RIZAL TECHNOLOGICAL UNIVERSITY
Cities of Mandaluyong and Pasig
College of Engineering and Industrial Technology

Automated Aquaculture Management System (AutoAquaManS): Integrating AI for Fish Vitality Detection and Real-time Water Quality Monitoring in Aquaculture Ponds

A System Developmental Study presented to the

Faculty of Computer Department College of

Engineering Architecture and Technology

Rizal Technological University

Maybunga, Pasig City

In Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Computer Engineering

By:

BELISARIO, LEXUS JOHN H.

BATANG, ERNESTO JR. B.

CORPUZ, NICA BEATRICE G.

DURANA JERIC L.

FURAQUE, JOHN DANIEL G.

CHAPTER 1

1.1 INTRODUCTION

Fishkeeping is a popular trend nowadays. Commercial aquaculture and ornamental aquaculture have become very popular for decoration purposes, a hobby, or as a source of income. It is hard to check aquarium or pond conditions by manual means. Therefore, developing an automatic aquarium capable of monitoring and controlling it by remote means should be considered. On the other hand, the side of the fishing industry has a major impact on the country's food security. The fishery has played a role in providing food, income, and livelihoods to hundreds of millions of people since ancient times. Aquaculture accounts for a significant proportion of the total fish harvest of the Philippines. Fish farms are being marketed in the emerging countries. They're offering family farms with a source of food and a profit selling of fish, as well as providing animal irrigation needs and water. One of the major problems concerning fishpond aquaculture is insufficient fish harvest due to the impending heat which is caused by the drought season. Designers use different types of sensors in a recent paper, such as temperature, pH value, and level detectors. All the task is streamlined by using these sensors and it will also be useful to track fish production wirelessly from other places. Another paper established a set of mobile aquaculture surveillance systems that not only can track the dissolved oxygen, temperature, pH value, and level metrics of the ponds in real time but

also track the fish status in real time using a wireless camera. The DO, pH, temperature, and water levels are calculated in another project and incorporated with aerating and water system motors utilizing Arduino as its microcontroller. By addressing these concerns, this project aims to develop a system that monitors the status of the whole aquarium by injecting innovative and new technologies such as sensors. And by the help of NodeMcU, helps the design project to communicate to the internet which gives the user the power to monitor the fishpond and control it remotely with an Android phone. It also uses an alert system in case of internet interruption or if there is no possible internet connection.

1.2 BACKGROUND OF THE STUDY

These days, a method for keeping an eye on an automated aquarium is not new. The pH level, temperature, turbidity level, water level, and feeding the fish can all be controlled directly by the machine. A physical check of an aquarium, on the other hand, would be inconvenient. It requires a lot of time and dedication. Here, an Internet of Things (IoT)-connected system is suggested to keep an eye on and manage the aquarium's upkeep. This would be done with electronics and devices that are always talking to each other and sending real-time information to the user's smartphone. The new system will keep an eye on the changes in the water's physical state and keep it in perfect shape by using the system to decide what changes need to be made. Any changes you make to

the aquarium, like changing the water level, feeding the fish, and controlling the temperature and pH will be done immediately. It will cut down on the amount of work that needs to be done by hand to run the tank.

1.3 STATEMENT OF THE PROBLEM

1.3.1 General Problem

Most ponds are suffering from widespread fish kills from time to time. It is largely caused by lack of proper monitoring system that will monitor the status of the fish and its well-being. The researchers of this study aim to decrease the fish kill rate in the country and improve the overall condition of the fishes.

1.3.2 Specific Problem

1. How would the system be able to monitor and display accurate data gathered from the aquarium/pond?
2. How would it give positive impact to the aquarium/pond in the long run?
3. How can the system enhance overall condition of all the catfish in a pond or aquarium?

1.4 OBJECTIVE OF THE STUDY

The users of the proposed system are able to use the system remotely as if any conditions of the fishes or water may vary, the system will notify them remotely or on-site of the system, all without human intervention.

1.4.1 Specific Objectives

The specific objectives of the proposed system are as follows:

1. To develop a system that will include:
   1.1 Monitor fishes in the aquarium and their condition
   1.2 Detect any foreign objects that is inside the aquarium
   1.3 Listing down the possible causes of the death of a fish in accordance to the condition of the water or environment
   1.4 Listing down how many fishes have died.
2. To monitor the fish mortality rate as accurate and as concise as possible.
3. To help fish farmers monitor the condition of the fish and water in their ponds remotely.
4. To help improve the conditions of the fish and water by providing important data for the fish farmers to analyze into.

1.5 SYSTEM DESIGN PARADIGM

As being shown in Figure 1.1, is the Input-Process-Output Model, also known as the IPO Model, that will represent how the designed system the proponents have proposed, will work, and the flow of process in the system will be.

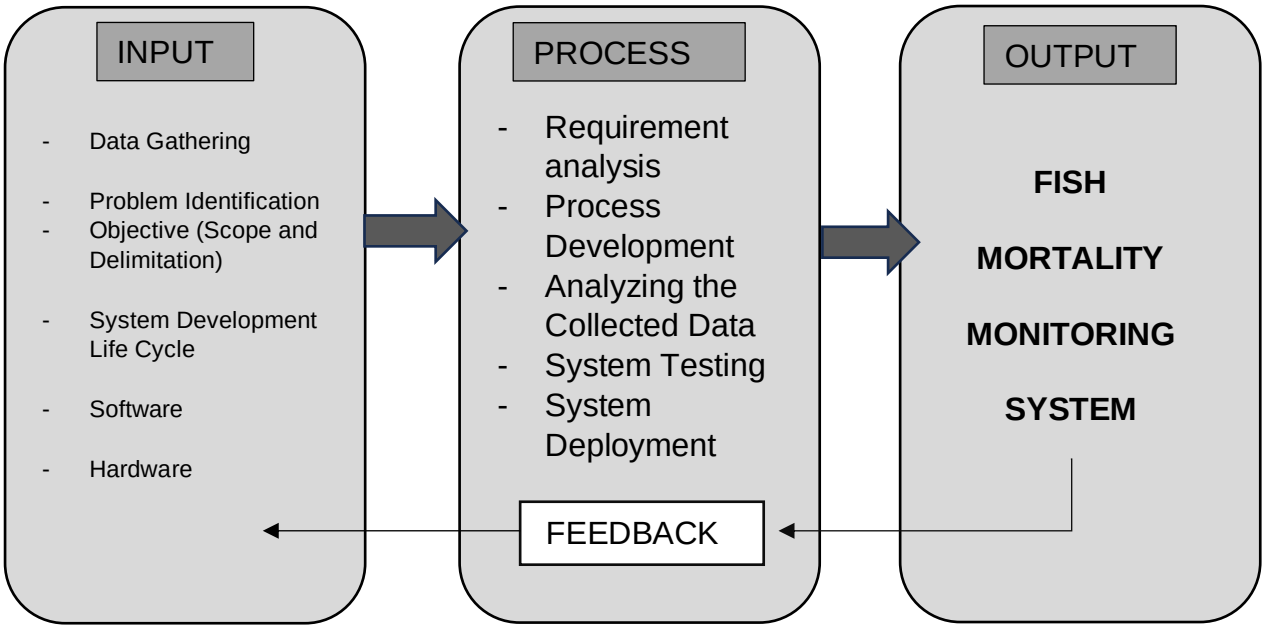

Figure 1.1: The System Design Paradigm

The following inputs listed in the figure will help the proponents who proposed the system to identify the different type of information such as Data Gathering, problem identification, System Development Life Cycle(SDLC), and as the development of the system moves on, the proponent concluded that requirement analysis, process development, analyzing

the collected data from the sensors, and system deployment are the processes to achieve the intended result as the system development progresses with SDLC's assistance in attaining the Automated Aquaculture Management System.

Input - The inputs represent the flow of data and materials into the process from the outside.

Data Gathering – The proponents conducted research and studied other related studies to find the data that is vital for developing the proposed system, Fish Mortality Monitoring System

Problem Identification – At this phase, the proponent conducts a brainstorming to evaluate and determine the inadequate and true problem of the current system.

Objective – Through the acquired information, the proponents create a goal on how to handle plausible suggested replies offered by the client and real statement.

Scope – Based on the proposed system, the proponent determined the system coverage. throughout the construction of this study's objective identification. At this stage, the proponent established a matrix to determine if the suggested remedy will directly address the stated problem.

Delimitation – Because all existing systems have limits that must be addressed, the proponent specified the system restriction to ensure that the intended aim is satisfied.

System Development Life Cycle – Given that this is developmental research and that the waterfall method is very relevant and dependable to achieve the project scope and delimitation, it was determined to be acceptable for creating the suggested system.

Process – The processing step includes all tasks required to effect a transformation of the inputs.

Requirement Analysis – To determine the needs or conditions to meet the requirements for the proposed idea, the proponent's system will use all necessary data.

Process Development – The proponents will conduct a last system test to all the units developed in the implementation phase are integrated into a system after testing of each unit.

Analyzing the Collected Data – The proponents will analyze the conducted data that is gathered from other related studies and literatures.

System Testing – Once every unit tested during the implementation phase has been integrated into the system, a final system test will be performed.

System Deployment – The proponent has completed the system-wide testing, and the system is prepared for implementation with the intended client.

Output – The output are the data and materials flowing out of the transformation process.

Automated Aquaculture Management System – The proposed system is designed and aims to develop an advanced AI controlled system that will be able to help fish farmers

monitor their fish's condition as well as count how many fishes have perish, gathering the possible causes of the death of their fishes, detecting if a fish in the aquarium is real or not, as well as helping the users monitor and be notified with the fish's status and well-being remotely.

1.6 SCOPE AND DELIMITATION

The proposed system titled "Automated Aquaculture Management System (AutoAquaManS): Integrating AI for Fish Vitality Detection and Real-time Water Quality Monitoring in Aquaculture Ponds" will be conducted with the scope to develop an easier and effective way of monitoring fishes and the possible health risks that they have, as well as giving users data that the system collected, that gives the possible causes of the fish's demise inside the pond, as well as the condition of the water the fishes are living in to. However, the system is not able to detect the exact reason why a fish perishes, as the proposed system is only able to give a data of possible reasons why a certain fish perishes. Moreover, the system is able to count how many fishes have died and users are able to monitor all of their fishes remotely as they can also be notified if a fish die.

Listed here are the capabilities of the system:

1. The System is able to identify the possible causes a fish or fishes have died.
    - Acid Rain
    - Environmental Change
    - Lack of oxygen
2. The system is able to analyze and detect if a fish is authentic or fake. Whether it's a living or dead fish.
3. The users of the system will be able to monitor and analyze any given data remotely, as well as notifying them if a fish or fishes died in the pond.
4. The system is able to count how many fishes are inside the pond.

However, the proposed system also has its delimitations such as:

1. The system is not able to give the exact reason why a fish has died
2. The system is only limited to certain fishes such as saltwater fishes and not with crustaceans.

1.7 SIGNIFICANCE OF THE STUDY

The significance of the research the proponents proposed is significant in the context of fisheries management, namely monitoring the mortality rate of fishes in a pond. As well as finding out what the possible causes of the fish's health decline, and the

possible causes of how they perish. The people who will benefit upon conducting the study of the proposed system are:

To the fish farmers – They will be the one to manage the fishes, either remotely or on-site. The proposed system will make it easier for them to analyze and monitor all the fish's condition and the possible causes of the fishes if one or many perishes in their pond as it will be notified from them anywhere.

For future researchers – The proposed system research will help future researchers, with the concepts behind the system, when conducting similar research of their own. They can apply, and develop a more innovative system and add more features to the proposed system.

For the Proponents – The proponents of this research can benefit by gaining a deep understanding more about designing and developing an automated system, and have a deeper understanding in aquaculture environment and practices. This study will also help the proponents to develop and enhance their expertise and skills in both programming, automation and in aquaculture.

1.8 DEFINITION OF TERMS

Aquaculture- refers to the controlled cultivation and farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants, under controlled conditions. It

involves the breeding, rearing, and harvesting of aquatic species in various aquatic environments such as ponds, tanks, and ocean enclosures.

Fish- The fishes will be the one to be monitored in this system. They can either be pet fishes or fishes from aquaculture.

Fishkeeping - also known as aquaria, is the practice of keeping fish species in enclosed environments such as aquariums or ponds. It involves maintaining fish health, providing suitable habitats, and ensuring appropriate water quality. Fishkeeping is pursued both as a hobby and for educational or research purposes.

Fishpond- A fishpond is an artificially created or modified pond, pool, or enclosure designed for the purpose of raising and breeding fish.

Mortality - the quality or state of being a fish that is alive and therefore certain to die.

Proponents- are the people who proposed the idea and the research itself that will be used in developing the designed system.

CHAPTER 2

2.0 REVIEW OF RELATED LITERATURE AND STUDIES

In this chapter, the review of related literature and studies, which is a cornerstone in research, discovers knowledge gaps, develops research questions, and synthesizes data from several sources to determine the study's context and importance. This study also identifies theoretical frameworks and procedures from past research, which helps to create a strong research design.

2.1 FOREIGN LITERATURE AND STUDIES

This chapter introduces the concepts, generalizations or conclusions, techniques, and other concepts. This chapter's contents serve to familiarize the reader with knowledge pertinent to and similar to the subject

2.1.1 IMPLEMENTATION OF SMART AQUARIUM MONITORING SYSTEM

Fishkeeping is a popular fad; almost people from all the age groups like to keep fish in their homes, offices, etc., for decoration purposes or as a hobby. Fishkeeping is itself an industry that comes in agriculture. Fishkeeping is not an easy job; we always need an aquarium or a pond for that. It has always been a headache to take care of the fish and aquariums because, during periodic intervals, water needs to be changed, the fish needs to be fed on time, the temperature, pH level and water level of the aquarium needs to be maintained. The project, “SMART AQUARIUM MONITORING SYSTEM” has

been designed by keeping in mind, the problem of those who cannot take care of their aquarium every day. The aquarium will perform all the steps automatically like temperature control, light monitor, feeding, water level monitor and control, lightening control, etc., It will reduce the manual effort required in the maintenance of aquariums by automating the aquarium management process. Also, an automatic food feeding system operated by a servo motor mechanism which used to feed fishes on regular time intervals. To continuously check the aquarium's status, the Arduino Mega board is chosen as a central board to collect data from sensors, process the data and declare whether the values are safe or exceeded the limit range indicating danger situation. Our project aims to replace manual maintenance of a fish aquarium with an Automated system by using Arduino.

According to the researchers (Venkat et al., 2022) that fishkeeping has grown in popularity among individuals of all ages, with people incorporating fish into their living and working places for aesthetic and recreational purposes. They (Venkat et al., 2022) stated that as an agricultural sector, fishkeeping has problems in terms of continuous care, needing frequent attention to water changes, timely feeding, and tank temperature, pH levels, and water levels. In response to these issues, the "SMART AQUARIUM MONITORING SYSTEM" was created to solve the concerns of those who struggle to keep their aquariums in good condition on a regular basis. This ground-breaking initiative

automates crucial operations including temperature control, light monitoring, feeding, water level management, and lighting control, decreasing the human labor generally associated with aquarium upkeep.

2.1.2 Developing an AI-based, Low-cost Surveillance System for Experimental Fish Keeping

Observation of fish behavior is a cornerstone of health assessment in research facilities. However, presence of humans can interfere with the fish normal behavior in different ways. In order to reduce opportunities for direct interactions of animals with humans in the laboratory setting, and minimize such interferences, a remote non-invasive monitoring system was developed from low-cost components. The system was tested with zebrafish (Danyo rerio) in 50 L glass aquariums and one externally positioned webcam with visual field covering the entire aquarium volume. The series of images was recorded with RaspberryPi controlled webcams, and visual data evaluation was carried out via neural networks from the field of AI, based on Mask R-CNN framework. Positive fish detection of 95% was achieved, confirmed by human beings on a subset of over 3000 photographs. Furthermore, software was developed to automatically load images and display AI predictions. If the predictions are incorrect, the neural network detection can be further improved by means of a human correction.

According to the researchers (La Roche et al., 2021), they are developing a low-cost remote non-invasive monitoring device was designed to decrease direct animal-human contact in the lab. Their method was tested using Danyo rerio zebrafish in 50 L glass aquariums, using a camera with a wide vision field. Images from RaspberryPi-controlled webcams were analyzed using AI-based neural networks, specifically the Mask R-CNN framework. Fish detection was 95% accurate, confirmed by humans on over 3000 photos. Additionally, they created a software that will load photographs and present AI predictions. The amazing part is that, any incorrect predictions of the systems occur, it can be corrected by humans to enhance neural network detection.

2.1.3 The smart monitoring and automation control system for fish aquarium based on internet of things technology

Fish is an aquatic animal which has beautiful scales that people keep it either for hobby or breeding. Healthy fish is a dream for fishkeepers. It requires balanced of water temperature, turbidity, and the amount of feeding. But unfortunately, treating fish is not as easy as buying. Humans have limitations to observe something periodically. Based on that case, a smart monitoring and automation control system for a fish aquarium is created. The prototype applies Internet of Things technology, so the fishkeepers can adjust the fish needs (water and feed) remotely anywhere and anytime. The system has temperature and turbidity sensor, automatic water drain, and live stream features. The

data obtained will be processed in Raspberry Pi to take action and sending the report into the owner's device. The result shows that the system works well and helping fish keep health. The system can save human resource and time efficiently.

According to the researchers (Afifah et al., 2019), Fish live in water and have beautiful scales that make them popular pets or pets to breed. People who keep fish want their fish to be healthy. It needs the right amount of food, water temperature, and turbidity. But it's not as easy to treat fish as it is to buy them. People can only look at something for a certain amount of time. Because of this, a smart system for tracking and controlling an aquarium full of fish is made. Their sample design uses Internet of Things technology, which lets the fish keepers change the fish's water and food needs from anywhere at any time. The device has a live stream, a temperature and turbidity sensor, and an automatic water drain. The collected data will be used by Raspberry Pi to do something and send the report to the owner's device. The outcome proves that the method works well and helps fish stay healthy. The method is a good way to save both money and time.

2.1.4 IoT Based Automatic Aquarium Monitoring System for Freshwater Fish

A monitoring system for an automated aquarium is not a new system in today's world. The machine allows the user to automatically control the pH level, temperature level, turbidity level, water level and feeding the fish. But it will be inconvenienced to check for the conditions of an aquarium manually. It is time consuming and required

commitment. Here, Internet of Thing (IoT) connected system is proposed to monitor and control the whole aquarium maintenance using electronics and sensors which constantly communicate and transmitting real time status to user smartphone. The developed system will monitor the physical changes in the water and maintain it to the ideal conditions, with the required changes decide automatically by the system. The aquarium will perform all the operations automatically including the temperature control, pH control, turbidity control, feeding and water level control. It will reduce the manual effort required for the aquarium management process.

The researchers of this study (Tahir et al., 2021) have proposed an IoT-connected monitoring system for automated aquariums which is a huge step forward in aquarium care. While automated systems for managing pH, temperature, turbidity, water level, and fish feeding are currently available, manual inspection of aquarium conditions is difficult and time-consuming. The proposed system uses electronics and sensors to create real-time contact with a user's smartphone, providing continual status updates on the aquarium. This innovation intends to simplify management by automating processes including temperature and pH control, turbidity management, feeding, and water level adjustment. It not only decreases the physical work necessary for aquarium care, but it also ensures that the aquarium maintains perfect conditions on a continuous basis through autonomous decision-making based on real-time data.

2.1.5 IOT BASED AUTOMATED FISH TANK MONITORING SYSTEM

It's known that many people like to keep fish tank in their house as it can help them to relax, reduce stress and it also maintains a good atmosphere in the house. But for those with busy daily schedule it's difficult for them to spend time for fish maintenance. We've come with a solution to monitor and feed the fish even when one fails to take care of it when they're not at home with a handy app. We've used two ultrasonic sensors one for feedbox level and the other one for fish tank level. If the levels are low in either of the cases it'll be notified via app to the user to do the needful. This will save time for the users and let them have their fish tank without worrying about the proper maintenance. The app will display and intimate the user at the proper time.

According to the researchers of this study (Dinesh et al., 2022) the idea of creating a solution to ease the maintenance of fish tanks for busy individuals is both innovative and practical. They also stated that the recognition that many people find joy and relaxation in having a fish tank at home, but struggle to dedicate time to their upkeep, highlights a real-world problem. In their research design, they are developing the integration of two ultrasonic sensors to monitor the feedbox and fish tank levels, coupled with a user-friendly app to notify users of any necessary actions, adds a technological and convenient dimension to fishkeeping. Their solution not only addresses the challenge of maintaining a proper atmosphere in the house but also aligns with the modern lifestyle by

offering a time-saving and efficient approach to fish tank care. Overall, their proposed system demonstrates a thoughtful consideration of user needs and a creative use of technology to enhance the experience of having a fish tank at home.

2.1.6 Real time fish pond monitoring and automation using Arduino

Investment and operating costs are the biggest obstacles in modernizing fish ponds in an otherwise very lucrative industry i.e., food production, in this region. Small-scale farmers running on small ponds could not afford to hire workers to man daily operations which usually consists of monitoring water levels, temperature and feeding fish. Bigger scale enterprises usually have some kinds of automation for water monitoring and replacement. These entities have to consider employing pH and dissolved oxygen (DO) sensors to ensure the health and growth of fish, sooner or later as their farms grow. This project identifies one of the sites, located in Malacca. In this project, water, temperature, pH and DO levels are measured and integrated with aerating and water supply pumps using Arduino. User could receive information at predetermined intervals on preferred communication or display gadgets as long as they have internet. Since integrating devices are comparatively not expensive; it usually consists of Arduino board, internet and relay frames and display system, farmer could source these components easily. A sample of two days measurements of temperature, pH and DO levels show that this farm has a high-quality water. Oxygen levels increases in the day as sunshine supports photosynthesis in

the pond. With this integration system, farmer need not hire worker at their site, consequently drive down operating costs and improve efficiency.

The researcher's observation in this study emphasizes that the enormous obstacles that small-scale fish farmers in the region confront, particularly when it comes to the investment and running costs connected with renovating fish ponds. The difficulty of these farmers to afford manpower for everyday activities such as water monitoring is a stumbling block in an otherwise successful agricultural production industry. Larger organizations, on the other hand, benefit from automation and sensor technologies to properly regulate water quality. Their Malacca project intends to address these concerns by incorporating Arduino-based devices that detect and monitor water, temperature, pH, and dissolved oxygen levels before managing aerating and water supply pumps. These components that the researchers have are affordable to farmers, allowing them to improve efficiency and lower operational expenses without the need for on-site staff. The integrated system allows for remote monitoring, which provides farmers with timely information while also helping to the sustainability and growth of their fish farm.

2.1.7 Water monitoring IOT system for fish farming ponds

Fish like many living organisms have specific tolerant range of various environmental parameters, thus fish farming of specific types of fish species requires certain conditions that have to be reached. Moreover, the people that work in the fish

farming ponds have to be engaged in all day activities to maintain the living fish habitat. Therefore, monitoring and taking actions to maintain the habitat's sustainable environment for certain fish species inside of fishing ponds over distributed machine to machine communication, which will shorten the time needed for some basic actions, is the main motivation for this paper. In this paper we present an upgrade on a functional Internet of Things (IoT) system for monitoring fish farming ponds. The IoT system consists of various sensors that measure important factors of the water quality like temperature, light intensity or water level, as well as small board computer that processes the data and sends sound and visual notifications to the fish farming manager. The current system lacks the ability to process the data to the end-user via web or mobile platform. Due to remote distance of the fish farming ponds and their location dependence of clean fresh water, one solution of this problem is using expansion module like Wivity modem to enable the end users in real time to monitor and control certain aspects of the fish farming pond IoT system. Wivity modem allows user to communicate to the IoT system via WiFi connection, cellular, LoRaWAN or satellite communication; all in one product. Later on, this module can be integrated with IoT platforms including Japser, Microsoft Azure or Amazon Web Services. For future work, we plan to expand not only the applicable services on different platforms, but also add more control modules and sensors to the existing IoT system for specific fish species.

The significance of preserving particular environmental parameters in fish farming ponds for the welfare of fish species is emphasized in the paper. The authors suggest an improved Internet of Things (IoT) system that uses a variety of sensors to evaluate water quality indicators in order to satisfy the demand for ongoing monitoring and prompt reactions. The data is processed by a small board computer, which then uses visual and auditory cues to inform the fish farming management. Nevertheless, end users cannot directly access data through web or mobile platforms under the existing system. In order to enable real-time monitoring and control via WiFi, LTE, LoRaWAN, or satellite connections, the solution entails incorporating a Wivity modem. Future plans include for increasing control modules and sensors to accommodate the unique requirements of many fish species, as well as connecting this module with popular IoT platforms like Microsoft Azure, Amazon Web Services, or Japser. This suggested update not only increases accessibility but also establishes the framework for future extension and customization of IoT systems for fish farming.

2.1.8 Quality Maintenance of Fish Farm: Development of Real-time Water Quality Monitoring System

Fish farming is a challenging job for producing fish without any hazard. By maintaining the water quality of the pond can safely fish production. This paper will discuss the development of a real-time water quality system to monitor fish farm. The water quality

monitoring system consist of a dissolved oxygen sensor, pH sensor and water temperature sensor using CC3200 Launchpad as the microcontroller, integrated with Internet of Things (IOT) platform is set up to enable the real-time remote water monitoring system. The system is designed to efficiently monitor the water quality in fresh-water fish farm, specifically the water parameters suitable for the catfish habitat. Instead of testing the system in the real catfish farm, it is tested using a water that is simulated to the water quality for the catfish habitat.

According to the researchers (Billah et al., 2019), Fish farming poses inherent challenges in ensuring safe and hazard-free fish production, with water quality maintenance being paramount. This paper addresses this concern by presenting the development of a real-time water quality monitoring system for fish farms. The system incorporates a dissolved oxygen sensor, pH sensor, and water temperature sensor, with the CC3200 Launchpad serving as the microcontroller. Integrated with an Internet of Things (IoT) platform, this setup allows for remote real-time monitoring of water conditions. The focus is on monitoring water parameters suitable for catfish habitats in freshwater fish farms. Although their system's testing is conducted using simulated water conditions resembling those in a catfish habitat rather than in an actual catfish farm, its potential to enhance real-time monitoring in aquaculture settings is evident.

2.1.9 Design and Development of Wireless Sensor Network System to Monitor Parameters Influencing Freshwater Fishes

In this paper we have designed, developed and proposed a prototype Wireless Sensor Network (WSN) System to monitor the Fish Farm. Salinity of the fresh water is a prominent parameter and is responsible for the difference in environment from marine conditions. Salt is an effective ingredient for fishes in fighting disease, parasites and chemical poisoning. The pH is equally a key parameter which influences the environment where fishes live. Generally, the fishes can live in pH ranges from 6.0 to 9.0, but their quality of life is best between pH 7.0 to 8.0. The change in the value of pH even by a small amount will be more stressful for fish. The temperature is other parameter which decides the value of pH and in turn affects the fishes. The developed prototype WSN system monitors these three parameters affecting the fresh water fishes. The open-source technology-ARDUINO (open electronics prototype and open source) is used to develop the system.

According to the researchers (Nocheski, S. et al., 2018), in order to ensure safe and efficient fish production, the challenges and problems of fish farming need a thorough approach. They stated that recognizing the critical importance of pond water quality, this research investigates the development of a real-time water quality system customized for fish farms. The CC3200 Launchpad serves as the microcontroller for the system, which

includes a dissolved oxygen sensor, pH sensor, and water temperature sensor. This arrangement, when combined with an Internet of Things (IoT) platform, allows for remote real-time monitoring of water conditions. The technology the researchers of this study are developing is specifically built for freshwater fish farms and focuses on aspects that promote catfish habitat, just like our designed system. While the technology is initially evaluated using simulated water conditions similar to those found in a catfish habitat rather than in a catfish farm, the emphasis on real-time monitoring offers promise for improving the precision and efficiency of fish farming techniques.

2.1.10 Fish Tank Monitoring System Using IoT

Moving to a different home can be a shock for all creatures but for the fish it's stressful. As there will be a change in the water, the fish's lifestyle might be under stress. The water quality also might have subtle changes. The environment for them to live in should be made easier. With the ongoing day-to-day activities, it is difficult for people to give them attention all the time. Therefore, the fish keepers or aquarists can be relaxed as this is a system where it keeps an eye on the fish tank or aquarium. This project aims to create a prototype which will calculate as well as maintains the temperatures, pH and the water level automatically. When there is a water change, its parameters affecting might change like the pH or the temperature. These changes might stress the fish causing death of the fish. In this modern life, the maintenance of a fish tank is quite complex or

difficult. Methods for measuring pH, temperature, are restricted to physically utilizing a test kit of chemicals. The study used data collected from pH, temperature, and electronic sensors to enable the consumer to calculate amounts. It will help the fishes to live a healthy life. In the approach used, the temperature, pH, and the water level of the fish tank are all automatically calculated. Once the parameters change, the user will get a notification via a short message service (SMS) and letting them know what the condition of the tank is.

According to the researchers of this project (Deepa et al., 2021), their aim is to develop a prototype that automates the calculation and maintenance of crucial parameters like temperature, pH, and water level in aquariums, addressing the complexities of modern fish tank maintenance. This innovation uses electronic sensors and data analysis to ensure fish well-being and provide real-time notifications via SMS, allowing for timely intervention and informed decision-making in maintaining a healthy aquatic environment. It addresses the complexities of modern fish tank maintenance and offers a solution beyond traditional methods. All of these are necessary in solve the challenges fish face when transitioning to a new home and the difficulties that fish keepers encounter in maintaining optimal tank conditions amidst their daily routines.

2.1.11 Digital twin-based intelligent fish farming with Artificial Intelligence Internet of Things (AIoT)

This paper focuses on designing a Digital Twin infrastructure that supports an agile-based Artificial Intelligence Internet of Things (AIoT) system for intelligent fish farming in aquaculture. Our infrastructure includes the Internet of Things, cloud technology, and Artificial Intelligence (AI) as its building blocks. Our physical entity is equipped with smart devices such as sensors and actuators embedded in smart machines (fish feeding and sorting machines) that collect and transmits big data to the cloud using wireless communication networks for real-time and remote monitoring. We have four major digital twin services: fish feeding to automate the feeding process, metric estimation (fish count, size, and weight), environmental monitoring (water condition, net hole, and green algae), and health monitoring (vitality, mortality, and diseases). Each digital twin service is equipped with multiple AI services (or the digital twin objects) capable of performing complex and other functions such as optimizations, predictions, and analyses for intelligent decision-making to optimize farm profits and production. We integrated a prototype that represents the virtual entity accessible using the web and mobile devices where users can perform fish farm monitoring using the various digital twin services and their related AI services.

Based on the study of Ubina et al. (2023), this paper presents a Digital Twin infrastructure for intelligent fish farming in aquaculture, utilizing AIoT, cloud technology, and AI. The infrastructure includes smart devices embedded in fish feeding and sorting machines, collecting and transmitting big data to the cloud for real-time monitoring. Four major digital twin services are provided: fish feeding, metric estimation, environmental monitoring, and health monitoring. Each service has multiple AI services capable of performing complex functions for intelligent decision-making. A prototype is integrated for web and mobile devices, allowing users to monitor fish farms using these services and their related AI services.

2.1.12 Monitoring of water quality in the catfish (Clarias sp.) farming in Tuban Regency

Fish need a decent environment for their lives and livelihoods. Types of fish that have different respiratory organs, such as catfish, can survive in extreme water conditions. However, in order to grow and develop naturally in a cultured environment, they need optimum water quality. This study aimed to determine the quality of water in catfish aquaculture ponds in three partner locations for community service activities in Tuban Regency, East Java. The method used in this research is descriptive, with 3 points of location for water sampling, namely, in Jenggolo Village (A), Tegalagung Village (B), and Campurejo Village (C), Tuban Regency.

The results of the study showed that the highest temperature in the pond in Campurejo Village was 30.2 ºC. The highest pH in the pond in Tegalagung Village is 7.59. The highest dissolved oxygen in the pond in Jenggolo Village was 13.4 mg/L. The highest nitrate level was in the pond in Tegalagung Village, namely, 25 mg/L. The pond in Tegalagung Village has the highest phosphate content. Furthermore, the highest Total Ammonia Nitrogen (TAN) levels are in the pond in Tegalagung Village, which is 16.6 mg/L. Based on the results, the water quality parameters were classified as great. However, some parameters are less than optimal at different locations. Water quality management needs to be developed to optimize the growth of catfish.

2.1.13 Temperature Monitoring System and pH Control of Catfish Breeding Pond Water Based on NodeMCU 8266 with Telegram Bot Notification

This research presents the design of a temperature monitoring and pH control device for catfish nurseries. The pH range of 6.5 to 8.5 with a temperature of 27℃ to 31℃ is the optimal condition for catfish farming. However, water quality can decrease due to unstable pH conditions and temperature changes. In this case, periodic monitoring is necessary to maintain stable pH and temperature conditions. This tool is constructed to monitor temperature and control water pH using DS18B20 temperature sensors, pH sensors, water pumps, Node MCU 8266, and a telegram application. This device is applied to maintain the stability of the pH of the water; pH control is carried out with a new

water replacement method when the pH value is over the normal limit or is in acid and alkaline state. The new water replacement method is carried out by utilizing a water pump for the circulation process. When all components are well integrated into a system, including the whole program, then testing is carried out. Testing on this tool begins with turning on and running the system and observing the system's performance, dipping the temperature sensor and pH sensor probe into the water, and then observing the temperature and pH data displayed on the LCD. Furthermore, if the pH is in an acid or alkaline state, the pump will be active to carry out the process of circulating water replacement. The output of water temperature and pH measurements is displayed on the LCD and with Telegram notifications by sending messages or statuses on Telegram.

Based on the study of Irfan and Ginting (2022), a temperature monitoring and pH control device designed for catfish nurseries, aiming to maintain stable water quality and pH levels. The device uses DS18B20 temperature sensors, pH sensors, water pumps, Node MCU 8266, and a telegram application to monitor and control water pH. A new water replacement method is used when the pH value is over the normal limit or in acid or alkaline states. The system is tested by observing the performance, dipping the temperature sensor and pH sensor probe into the water, and observing the temperature and pH data displayed on the LCD. If the pH is in an acid or alkaline state, the pump is activated for circulating water replacement. The other interesting part here is that, Irfan

and Ginting (2022) used a bot called Telegram Bot Notification, however we do believe that using SMS notification is a lot better than Bot Notification.

2.1.14 Design of a catfish feeding control system and water temperature monitoring based internet of things (IoT)

Catfish (Clarias gariepinus) is the main commodity and prima donna in the freshwater fish market which also generates significant sales in the market. Data from the Directorate General of Aquaculture from 2009 to 2013 shows an increase in consumption of catfish in Indonesia. From these data it can be seen that there is an economic potential from the needs of catfish in the market. To support meeting the needs of catfish, it is necessary to make efforts to increase catfish production, one of which is by increasing the work efficiency of catfish farming and monitoring water quality. Feeding automatically using a microcontroller is one way to increase work efficiency. This effort is realized in a design of an automatic catfish feeding device whose operating method uses the Internet of Things (IoT) concept to adjust the opening and closing of the feed door. The feeding algorithm or program is stored in the microcontroller (NodeMCU esp8266) as the control unit. The results of the application of the tool show that in terms of quality, automatic fish feeders can improve efficiency in feeding fish. In this case, the farmer's workload can be reduced for feeding activities. It is hoped that reducing the burden and working hours of farmers will provide opportunities for other productive activities for farmers.

Catfish, a major commodity and prima donna in the freshwater fish market, has seen a significant increase in consumption in Indonesia from 2009 to 2013. This indicates economic potential in the market. To meet catfish needs, efforts are needed to increase production and improve work efficiency in farming and water quality monitoring. An automatic catfish feeding device using the Internet of Things (IoT) concept has been designed to improve efficiency and reduce farmers' workload. The application of this tool has shown that automatic fish feeders can improve quality and reduce farmers' working hours, providing opportunities for other productive activities.

2.1.15 Design of Web-Based Information System on Monitoring the Water Quality of Catfish Pond

Water environmental factors that greatly affect the survival and growth of catfish include temperature and water pH with pH range of 6.5-8 and temperature of 25^0C-30^0C. The monitoring and measurement are still done manually by catfish farmers to get the temperature and pH parameter values without knowing the exact value of these measurements. According to those problems, this final project provides an information system on monitoring the water quality of catfish pond to facilitate monitoring, namely by using a device that is remotely controlled in real-time, and contains sensors needed for measurement so that it can measure the parameters from a different place. Each node in each pond contains a measurement system using a DS18B20 temperature sensor and a

SEN0161 pH sensor that can measure temperature and pH. The system is using a method with several stages, namely the stages of design, implementation and testing. The measurement results from the temperature sensor and pH sensor are displayed on the web page in the form of graphs and tables.

The survival and growth of catfish are significantly influenced by water environmental factors such as temperature and pH. Currently, these parameters are manually monitored by catfish farmers. This project aims to provide a remote-controlled information system for monitoring catfish pond water quality, utilizing sensors for temperature and pH measurements. Each node in the pond has a DS18B20 temperature sensor and a SEN0161 pH sensor, which are then tested and displayed on a web page in the form of graphs and tables.

2.2 LOCAL LITERATURE AND STUDIES

The literature and studies cited in this chapter tackle the different concept, understanding, and ideas, generalization or conclusions and different development related to study of the enrollment from the past up to the present and which serves as the researchers guide in developing the project. Those that were also included in this chapter helps in familiarizing information that are relevant and similar to the present study.

2.2.1 TILAPIA FISHPOND MONITORING SYSTEM WITH FISHKILL PREVENTION

Since the world is evolving and technology have become rampant, there are still improvements or reforms about the monitoring system in fish farms. This study titled “Tilapia Fishpond Monitoring System with Fishkill Prevention” will modernize the current system of fish farming. One of the major concerns in the fish farming industry is the fish kill problem. Fishkill refers to the die-off of fish populations which occurs when the water of the pond is in bad condition or if it lacks oxygen. That is why the researchers focus on this matter to improve the ways the old system is using to prevent this from happening. This paper includes the conceptualization of a microcontroller-based system for the prevention of fish kills. It uses sensors that will automatically detect the characteristics of water as to its water temperature, humidity, and ph. level. The pH meter sensor is used to trigger the probiotic dispenser. The water temperature sensor is used to turn on the water pump. If the water temperature is at the threshold level, the buzzer will turn on. It also includes a night light when sunlight is not available. It is embedded with an email notification feature to inform the owner or the caretaker of the fish farm about its status. At the end of the study, the researchers find out that the system works properly based on the evaluation of experimental testing conducted.

This study, named "Tilapia Fishpond Monitoring System with Fishkill Prevention," covers a critical component of fish farming in response to the ever-changing environment

and the ubiquitous impact of technology. Despite technological developments, enhanced monitoring methods in fish farms are still required. The research focuses on reducing fish kills, which are a major concern in the sector and are frequently connected to poor water quality and oxygen deficit. The researchers suggest a modernized system that detects water parameters such as temperature, humidity, and pH level using a microprocessor and sensors. These sensors activate numerous preventive measures, such as a probiotic dispenser and water pump, a buzzer in critical temperature circumstances, and night lighting. Their designed system also has an email notification option to keep the owner or caretaker of the fish farm updated. The researchers confirm the system's efficacy through experimental testing, which is a great step toward improving fish farm monitoring and preventative measures.

2.2.2 Fish Aquarium Monitoring System

This study aimed to design and develop a fish aquarium monitoring system which could display the water level and temperature inside the tank. It consisted of a visual alarm that would tell if the water is too saline or turbid. Experimental development and descriptive approaches were the methods used. Ten purposively chosen evaluators were requested to assess the fish aquarium monitoring system. Findings of the study indicated that the device could be useful for fish owners due to its functionality and reliability.

The study that the researchers, namely (Galemba, R. B., et al., 2012) aimed to create a fish aquarium monitoring system that provides real-time information on water level and temperature. The system features a visual alarm to alert users to potential unfavorable water conditions, such as excessive salinity or turbidity. The system was evaluated by ten evaluators using experimental development and descriptive approaches. The findings showed the system's practicality and reliability, making it a valuable tool for fish owners to maintain optimal aquatic environments. The successful integration of functionality and reliability makes the device a promising asset for enhancing the care and well-being of aquarium-dwelling fish.

2.2.3 Assessment of Tilapia Cage Farming Practices in Relation to the Occurrence of Fish Mortality along the Fish Cage Belt at Magat Reservoir, Philippines

The present study was conducted in Magat Reservoir, Philippines, to determine the profile and practices of tilapia cage farmers in relation to the occurrence of fish mortality. Eight stations were established: Station 1 (Baligatan), Station 2 (Namnama), Station 3 (Halag 1), Station 4 (Halag 2), Station 5 (Halag 3), Station 6 (Taliktik), Station 7 (Dallaw) and Station 8 (Isla Berde). A total of 80 households were interviewed from December 2016 to May 2017. Results showed that most incidents of fish mortality in cages occurred during the summer season (March to June). Farmers perceived the primary causes of fish mortality in Magat Reservoir to include fluctuating temperature

(91.25%), water quality (83.75%), pollution and predation by birds (each 76.25%), parasite infestation (56.25%) and diseases (50%). Reduced feeding, isolation of the infected fish and proper stocking are the major activities conducted by the fish farmers to prevent the occurrence of fish mortality at Magat Reservoir.

The present study conducted in Magat Reservoir, Philippines, aimed to delve into the profile and practices of tilapia cage farmers in connection with fish mortality incidents. Eight stations were strategically established across different areas, each serving as a representative sample: Baligatan, Namnama, Halag 1, Halag 2, Halag 3, Taliktik, Dallaw, and Isla Berde. Over the period from December 2016 to May 2017, 80 households were interviewed to gather insights. The findings unveiled a noteworthy pattern, indicating that the majority of fish mortality incidents in cages took place during the summer season, specifically from March to June. Farmers identified fluctuating temperature (91.25%), water quality (83.75%), pollution, and predation by birds (each 76.25%), parasite infestation (56.25%), and diseases (50%) as the primary perceived causes of fish mortality in Magat Reservoir. In response, fish farmers engaged in crucial activities such as reduced feeding, isolation of infected fish, and proper stocking to mitigate the occurrence of fish mortality in Magat Reservoir. This comprehensive examination sheds light on the multifaceted factors influencing fish mortality and the proactive measures taken by tilapia cage farmers in this specific geographic context.

2.2.4 Predicting fish kills and toxic blooms in an intensive mariculture site in the Philippines using a machine learning model

Harmful algal blooms (HABs) that produce toxins and those that lead to fish kills are global problems that appear to be increasing in frequency and expanding in area. One way to help mitigate their impacts on people's health and livelihoods is to develop early-warning systems. Models to predict and manage HABs typically make use of complex multi-model structures incorporating satellite imagery and frequent monitoring data with different levels of detail into hydrodynamic models. These relatively more sophisticated methods are not necessarily applicable in countries like the Philippines. Empirical statistical models can be simpler alternatives that have also been successful for HAB forecasting of toxic blooms. Here, we present the use of the random forest, a machine learning algorithm, to develop an early-warning system for the prediction of two different types of HABs: fish kill and toxic bloom occurrences in Bolinao-Anda, Philippines, using data that can be obtained from in situ sensors. This site features intensive and extensive mariculture activities, as well as a long history of HABs. Data on temperature, salinity, dissolved oxygen, pH and chlorophyll from 2015 to 2017 were analyzed together with shellfish ban and fish kill occurrences. The random forest algorithm performed well: the fish kill and toxic bloom models were 96.1% and 97.8% accurate in predicting fish kill and shellfish ban occurrences, respectively. For both models, the most important predictive

variable was a decrease in dissolved oxygen. Fish kills were more likely during higher salinity and temperature levels, whereas the toxic blooms occurred more at relatively lower salinity and higher chlorophyll conditions. This demonstrates a step towards integrating information from data that can be obtained through real-time sensors into a an early-warning system for two different types of HABs. Further testing of these models through times and different areas are recommended.

The research tackles the global problem of harmful algal blooms (HABs) and their negative consequences on human health and fisheries. Recognizing the rising frequency and geographic extent of HABs, the researchers offer a realistic method for nations such as the Philippines, where sophisticated multi-model systems may be difficult to implement. The work effectively creates an early-warning system for forecasting two forms of HABs—fish fatalities and toxic blooms—in Bolinao-Anda, Philippines, using the random forest machine learning algorithm. The models are highly accurate, with 96.1% accuracy for fish deaths and 97.8% accuracy for hazardous blooms, demonstrating the power of empirical statistical models. A reduction in dissolved oxygen is the major predictive predictor, emphasizing its importance in predicting HAB occurrences. The findings of the study represent an important step toward integrating real-time sensor data into effective early-warning systems for various HAB occurrences, prompting additional validation across varied times and locales.

2.2.5 AquaStat: An Arduino-based Water Quality Monitoring Device for Fish Kill Prevention in Tilapia Aquaculture using Fuzzy Logic

In the Philippines, Tilapia fish farming sector is vital to the economy in providing substantial employment, income and meeting local demand for protein sources of the Filipinos. However, the possible benefits that can be derived from this industry are at stake because of the sudden occurrences of fish kill events. This can be attributed to a wide variety of natural and unnatural causes such as old age, starvation, body injury, stress, suffocation, water pollution, diseases, parasites, predation, toxic algae, severe weather, and other reasons. With the identified severe effects of fish kill events to the fish farmers, consumers and the fisheries industry, advanced measures and methods must be established to alleviate the adverse effects of this phenomenon. To solve the underlying problem on water quality monitoring system to improve freshwater aquaculture, various studies were already conducted. However, these studies merely focused on the reading and gathering of water parameters. In this paper, fuzzy logic was used to come up with a model that can analyze and generate result regarding the overall quality of the water being used in Tilapia aquaculture. The water parameters considered in this paper were temperature, dissolved oxygen, and pH level. The results of the water parameter readings using the conventional method were compared to the data that were gathered by AquaStat to test its accuracy and showed no significant difference. Also, the overall water

quality obtained using the conventional method was compared to the overall water quality generated by AquaStat and obtained an accurate result.

In this research, their variable for their aquaculture monitoring system is tilapia. The researchers of the study (Molato, 2022) stated that the Tilapia fish farming business in the Philippines is critical to the economy, contributing considerably to employment, revenue creation, and satisfying local protein need. However, they also stated that the sector confronts hurdles as a result of recurrent fish death events caused by a variety of natural and manmade reasons. These occurrences can have serious ramifications for fish producers, consumers, and the fishing industry. Recognizing the significance of water quality monitoring in improving freshwater aquaculture, this work applies fuzzy logic to construct a model measuring overall water quality in Tilapia aquaculture. The study compares findings acquired using the conventional technique with those provided using AquaStat, focusing on critical factors like as temperature, dissolved oxygen, and pH level.

2.2.6 Machine Learning-Based Algorithm for Fish Kill Evaluation using Differential Changes of Input Parameters via Wireless Communication

The existing methods of monitoring and management of freshwater ponds to prevent fish kills cannot adapt fast enough to the frequently changing environment. Recent inventions monitor water quality and water level in fishponds in response to fish mortality related to the dissolved oxygen level, water salinity, pH levels, temperature, and many

more. With the additional use of machine learning algorithms, these methods can be further improved for more energy-efficient water quality detectors. This project is a buoy-type device that is designed to transmit data through an RF transceiver module outside the set threshold embedded in the microcontroller. The buoy transmits data when there are great differential changes in the measured parameters to save energy. Then the receiver hub is equipped with a microprocessor that utilizes K-means Clustering Machine Learning Algorithm that can reconstruct as much as possible the received data. The buoys were deployed in a fishpond and tested their functionality. The sensors were calibrated and the analysis of the gathered results for the deployment showed a significant amount of power reduction when compared with and without data transmission.

According to the researchers, Current methods for monitoring and maintaining freshwater ponds to minimize fish deaths are slow to respond to a constantly changing environment. Water quality and level monitoring innovations respond to fish mortality due to parameters such as dissolved oxygen, water salinity, pH levels, and temperature. By using machine learning algorithms, these approaches are improved, making water quality monitors more energy-efficient. The project presented here proposes a buoy-like device designed to broadcast data via an RF transceiver module when measured parameters differ considerably from the defined threshold, hence conserving energy. The received

data is reconstructed by the receiver hub, which is equipped with a CPU and employs the K-means Clustering Machine Learning Algorithm.

2.2.7 Development of an IoT-based Intensive Aquaculture Monitoring System with Automatic Water Correction

Due to the depleting stocks of fish in the market, there have been an increased interest in aquaculture. However, raising fishes in an Intensive Aquaculture System result on a low-quality fish or even fish kills as fishes are being cultured in artificial tanks and cage systems, not on their natural habit. This paper presents a water quality monitoring system with automatic correction to monitor and maintain vital water quality parameters essential for fish growth, such as temperature, potential hydrogen (pH) level, oxidationreduction potential, turbidity, salinity, and dissolved oxygen to achieve optimum yield using Arduino and Raspberry Pi 3B+ through LoRaWAN IoT Protocol. The system uses sensors, microcontrollers, and a web application for acquiring and monitoring data of six different water quality parameters and are maintained in a desired level optimal for fish growth using aquarium heater, motor for sodium bicarbonate distribution, solenoid valve and water pump that serves as correcting devices. The proponents measured the system's efficiency and reliability through monitoring two intensive aquaculture setups – controlled and conventional setup. From the data gathered, the controlled setup greatly

increased efficiency, reduced the work of fish farmers, avoided fish kills, and surpassed yield quality of the conventional setup.

This paper describes an innovative water quality monitoring system with automated correction that makes use of Arduino and the Raspberry Pi 3B+ via the LoRaWAN IoT Protocol. The sensor-equipped system focuses on critical factors like as temperature, pH level, oxidation-reduction potential, turbidity, salinity, and dissolved oxygen. The system's effectiveness is demonstrated by the results of monitoring two aquaculture settings - controlled and traditional. The controlled arrangement improves efficiency, decreases labor for fish farmers, minimizes fish fatalities, and excels the yield quality of the conventional setup, providing a viable answer to the issues of intensive aquaculture.

2.2.8 IoT-BASED FISH POND WATER CONDITION MONITORING SYSTEM FOBANGUS FARMING

Water pollution and climate change are considered the two major factors affecting water quality for fish farming. Fish kill happens yearly and it is one of the major problems encountered by the Bangus growers in Pangasinan, a province in the Philippines. Surface level temperature, water acidity (pH level) and dissolved oxygen are the usual physical parameters used in determining the water quality for fish farming. The monitoring of these parameters is done manually and periodically by farmers with the assistance of the Bureau of Fisheries and Aquatic Resources (BFAR)by using the YSI Pro 1020, a handheld

instrument used for the measurement of dissolved oxygen, temperature and the pH level of water. As a means of innovating the existing practices of fish farmers, the researchers developed an IoT-Based system that would integrate the functionalities of the YSI Pro 1020 and at the same time provide a periodic recording of water quality for analysis and processing to generate information which can be easily understood by fish farmers. A short message service (SMS) is also integrated in the system to alert the stakeholder should there be degradations on water parameters.

2.2.9 Survivability of Aqua Marine Products in Fish Ponds Through Water Quality Evaluation Using Machine Learning Algorithm

Water quality is considered as the most important factor in aquaculture production systems affecting fish health and performance. Water quality can be considered good if it relates to what aquaculture wants and needs to survive and develop, which means that aquacultured farmers must be able to understand the water quality requirements of their cultured products to ensure their fast growth and survival. Different species of fish have different and particular aspects of water quality needs in which they can live, grow and reproduce.[1]–[5] It is, therefore, imperative for fish producers to make sure that the physical and chemical conditions of pond water remain, as much as possible, within the optimum or acceptable range of the fish under culture all the time. Fish may show poor development, erratic behavior, and signs of disease or parasite infestations outside of

these acceptable ranges. Fish kill can occur in extreme cases or where poor conditions persist for extended periods of time.[1], [4], [6]–[8] Using water sampling to monitor water quality takes up time, while laboratory results do not show the current state of water in fish ponds, which is critical information needed by fish farmers. Water quality monitoring in fish ponds should be in real-time, analysis of water parameters must be done as soon as possible to ensure water quality and its acceptability for aquacultured products. The purpose of this study is to develop a system that can monitor water parameters in fish ponds analyze and evaluate these parameters to determine the suitability and survivability rate of aquacultured products based on water quality using machine learning algorithms regression tree and decision tree in accordance with the water quality requirements of cultured products. With the help of Arduino microcontroller device that uses IoT (Internet of Things) technology. By implementing this study, it was found out that the system effectively helps the fish farmers to manage and help maintain the water quality of their fish ponds it minimizes losses due to untimely solutions to water quality problems and promotes a healthy environment which helps increase the growth and survival of aquacultured products. It also increases the fish farmer harvest and income, which creates a positive impact on agricultural productivity in terms of fish farming.

2.2.10 Real-Time Water Quality Monitoring System with Predictor for Tilapia Pond

Water quality is the first most important limiting factor in pond fish production. It is also one of the most difficult production factors to understand, predict and manage. It is not just where the fish live; its quality directly affects growth rates, the fish's health and survival. Most fish kills, disease outbreaks, poor growth, poor feed conversion efficiency and similar management problems are directly related to poor water quality. The study and prediction of water quality is necessary to prevent serious problem that may occur during production period. In this study, water level, temperature, pH and DO levels are measured using Arduino microcontroller. User could receive information at predetermined intervals on preferred communication through SMS. Since integrating devices are comparatively not expensive; it usually consists of Arduino board, access to internet and relay frames and display system. With this integration system, farmer need not hire worker at their site, consequently drive down operating costs and improve efficiency. Prediction interface was developed using msSQL. The system was evaluated and it performs its intended function. In this study, segmented moving average prediction model was found to be effective in predicting water quality parameters.

2.2.11 Monitoring of Coastal Aquaculture Sites in the Philippines through Automated Time Series Analysis of Sentinel-1 SAR Images

With the unprecedented expansion of aquaculture around the world, there is a critical need to monitor its progress. In Palawan, Philippines, coastal aquaculture is gaining momentum towards increasing fish production, a pressure that presents a challenge to the sustainability of these areas. In this paper, we explore the application of Earth observation methods to map coastal aquaculture development in Palawan and evaluate the extent of its change. The European Space Agency Sentinel-1 synthetic aperture radar and Sentinel-2 multispectral instrument sensor data were applied in fully automatic mode to build maps of Palawan coastal aquaculture. The maps were validated using Google Earth high-resolution optical images and in situ observations in Malampaya Sound, and demonstrated a successful detection rate of 72%, while the false alarm rate was less than 7.5%. Objects only 5 m across, four times smaller than the spatial resolution of the Sentinel-1 sensors, were successfully detected using the developed methodology, thus exceeding the capabilities of other published methods that are limited to detecting large groups of aquaculture structures. The maps revealed aquaculture structures in high quantities in Malampaya Sound, Taytay Bay, and other locations in the coastal waters of Palawan, Philippines. A significant change of aquaculture spatial distribution was identified by comparing aquaculture maps generated with an interval of three years. This

new automated methodology was validated as robust for mapping aquaculture objects in Palawan, Philippines, and can be applied to aquaculture studies in other regions worldwide.

According to Kurekin et al. (2022). Because of the unprecedented expansion of aquaculture around the world, there is a critical need to monitor its progress. In Palawan, Philippines, coastal aquaculture is gaining momentum towards increasing fish production, a pressure that presents a challenge to the sustainability of these areas. In this paper, we explore the application of Earth observation methods to map coastal aquaculture development in Palawan and evaluate the extent of its change. The European Space Agency Sentinel-1 synthetic aperture radar and Sentinel-2 multispectral instrument sensor data were applied in fully automatic mode to build maps of Palawan coastal aquaculture. The maps were validated using Google Earth high-resolution optical images and in situ observations in Malampaya Sound, and demonstrated a successful detection rate of 72%, while the false alarm rate was less than 7.5%. Objects only 5 m across, four times smaller than the spatial resolution of the Sentinel-1 sensors, were successfully detected using the developed methodology, thus exceeding the capabilities of other published methods that are limited to detecting large groups of aquaculture structures. The maps revealed aquaculture structures in high quantities in Malampaya Sound, Taytay Bay, and other locations in the coastal waters of Palawan, Philippines. A significant

change of aquaculture spatial distribution was identified by comparing aquaculture maps generated with an interval of three years. This new automated methodology was validated as robust for mapping aquaculture objects in Palawan, Philippines, and can be applied to aquaculture studies in other regions worldwide.

2.2.12 Development of IoT-based Fish Tank Monitoring System

The aquaculture management system will be significantly improved with the adoption of recent technological advances. This study introduces the development of a fish tank monitoring system using the Internet of Things (IoT) modules with four subsystems—water quality monitoring, video surveillance of the fish tank, on-demand feeding machine, and Cloud data storage. During the evaluation, the calibrated sensors for water quality monitoring were accurate for the monitoring purpose. In contrast, the simultaneous transmission of the sensors' gathered data from the IoT modules to the Cloud storage was 100% successful from 0.25 Mbps to 10 Mbps upload speed. The automated video surveillance was able to record 98.45% of the scheduled time.

The implementation of recent technological advancements in the aquaculture management system, specifically the integration of an Internet of Things (IoT)-based fish tank monitoring system, demonstrates a significant enhancement in efficiency. The four subsystems comprising water quality monitoring, video surveillance, on-demand feeding, and Cloud data storage contribute to a comprehensive and automated approach. The

study's evaluation highlights the precision of calibrated sensors for water quality monitoring and the flawless transmission of data from IoT modules to Cloud storage across varying upload speeds. Notably, the automated video surveillance system exhibits a high recording efficiency, capturing 98.45% of the scheduled time. This innovation showcases the potential for technology to revolutionize aquaculture management, offering precision, automation, and real-time data accessibility.

2.2.13 Design and Implementation of Real-Time Mobile-based Water Temperature Monitoring System

In this age of international trade and competition, the aquaculture industry needs to plan and implement a technology that will address issues concerning global food security. In modern aquaculture management, a remote water quality monitoring and computer-controlled intensive culture is the future trend in aquaculture. The objective of this research is to design and develop a real-time mobile-based water temperature monitoring system capable of decreasing the reliance on manpower at the monitoring site to reduce the cost and to assess fish production cycle and fish grow-out system. The system implementation resulted in a monitoring system that collects the current water temperature from the core-controller in real-time. Also, the system provides and displays information that includes normal range, maximum, minimum, average and findings of the collected temperatures. The results obtained in this study has shown the ability of data

acquisition in the remote and real-time detection of water temperature accurately and efficiently. It provides decision support to help and guide fisher folks in avoiding distress to fish and obtaining the optimum water temperature range.

The aquaculture industry needs to implement technology to address global food security issues. This research aims to design a real-time mobile-based water temperature monitoring system that reduces manpower reliance, costs, and assesses fish production and grow-out systems. The system collects real-time water temperature data from a core-controller and displays information like normal range, maximum, minimum, average, and findings. The results show accurate and efficient remote and real-time water temperature detection, providing decision support to fishers to avoid distress and achieve the optimal water temperature range.

2.2.14 Development of dissolved oxygen monitoring system for fish ponds

Dissolved oxygen is probably the single most important water quality factor that pond managers need to understand. The purpose of the present study is to create a program that helps fish pond owners and aqua culturist in producing high quality fishes by maintaining normal level of dissolved oxygen in fish ponds. Also through this system, it will solve the long-time problem of fish-kill in fishponds. The study was tested in ponds and rivers in Kawit and Noveleta, Cavite. The researchers joined the Bureau of Fisheries and Aquatic Resources during the actual rounds of monitoring water quality in the said

area. Of the 20 respondents, all gave excellent rating for the criteria included in the survey, the speed, user friendliness, reliability, and security. The user friendliness got the highest score, followed by reliability, security, and speed which got the lowest score. Based on the findings of this paper, the program's speed, reliability, user friendliness, and security are all ranked excellent by the respondents.

This study focuses on developing a program to aid fish pond owners and aqua culturists in producing high-quality fish by regulating dissolved oxygen levels. The program aims to address the persistent issue of fish kills in ponds. Field-tested in Kawit and Noveleta, Cavite, the study involved collaboration with the Bureau of Fisheries and Aquatic Resources for real-time water quality monitoring. The survey, conducted among 20 respondents, indicates unanimous excellent ratings for the program's speed, user-friendliness, reliability, and security. Notably, user-friendliness received the highest score, followed by reliability, security, and speed. The overall findings underscore the program's excellence in terms of speed, reliability, user-friendliness, and security, showcasing its potential to enhance fish farming practices and mitigate fish-kill incidents.

2.2.15 Design and Implementation of AquoSense – a Water Quality Sensor System

Aquaculture has become an effective breeding and farming method for aquatic plants and animals, but is also rendered vulnerable by increasing weather fluctuations and unexpected environmental changes that affect water quality. Real-time detection of

fluctuations in water quality parameters is important for executing appropriate and timely operational responses to minimize losses, say, due to fish kills or a collapse of a harvest cycle. This necessitates continuous monitoring which, at present, is mostly done manually, aperiodically, inconsistently, haphazardly, and oftentimes reactively. To address these pain points, the proponents have designed and developed AquoSense - a low-cost and easy-to-use water quality sensor system. AquoSense can be automated or pre-programmed to regularly measure parameters such as pH, dissolved oxygen (DO), electrical conductivity (EC), and temperature; and monitor the derived parameters salinity, total dissolved solids (TDS), and specific gravity (SG). Tests done for pH and EC sensor probes revealed that it can be comparable to a commercial-grade water quality measuring device. AquoSense can store data locally, and/or transmit these to a local mobile device or to the internet cloud. AquoSense comes in two versions: handheld and submersible, and both have been tested in the laboratory and deployed in aqua field conditions.

According to researchers of this study, Aquaculture has proven to be an effective method for breeding aquatic plants and animals, yet its vulnerability to unpredictable environmental changes, especially in water quality, poses significant challenges. Timely detection of fluctuations in water parameters is crucial to mitigate losses, such as those from fish kills or disrupted harvest cycles. The current manual and sporadic monitoring methods lack consistency and are often reactive. In response, the proponents have

introduced AquoSense—a cost-effective and user-friendly water quality sensor system. Capable of automated or pre-programmed measurements for pH, dissolved oxygen, electrical conductivity, and temperature, AquoSense monitors derived parameters like salinity, total dissolved solids, and specific gravity. Tests indicate that the pH and electrical conductivity sensor probes compare favorably with commercial-grade devices. With options for data storage and transmission to local devices or the cloud, AquoSense, available in handheld and submersible versions, has undergone successful laboratory testing and real-world deployment in aquaculture settings. This innovation addresses the need for continuous, reliable monitoring in aquaculture operations.

2.3.1 Synthesis of Related Literature

Features	A	B	C	D	E	F	G	H	I	J
Able to Be Used Remotely	✓	X	X	✓	✓	✓	X	✓	✓	✓
Able to Monitor and Control Aquarium Temperature, Oxygen, pH Level.	✓	✓	X	✓	✓	✓	✓	✓	✓	✓
Able to Detect how many fishes are on the pond	✓	X	✓	X	X	X	X	X	✓	X
Able to identify the possible causes a fish have died	✓	X	X	X	X	X	✓	X	X	X
Able to Notify Users if a Fish Perishes	✓	X	X	X	X	X	✓	✓	X	X
AI-Integration	✓	✓	✓	✓	X	X	X	✓	✓	X
Automated Detection of Authentic or Unauthentic Fish	✓	X	X	X	X	X	X	X	X	X
Image Processing	✓	X	✓	✓	X	X	X	✓	✓	X
Uses Raspberry Pi and Python	✓	X	X	✓	X	X	X	X	✓	X
Uses Machine Learning	✓	X	✓	✓	X	X	X	✓	✓	X

Legend:

System A - Automated Aquaculture Management System (AutoAquaManS): Integrating AI for Fish Vitality Detection and Real-time Water Quality Monitoring in Aquaculture Ponds

System B - IMPLEMENTATION OF SMART AQUARIUM MONITORING SYSTEM

System C - Developing an AI-based, Low-cost Surveillance System for Experimental Fish Keeping

System D - The smart monitoring and automation control system for fish aquarium based on internet of things technology

System E - IOT BASED AUTOMATED FISH TANK MONITORING SYSTEM

System F - Quality Maintenance of Fish Farm: Development of Real-time Water Quality Monitoring System

System G - AquaStat: An Arduino-based Water Quality Monitoring Device for Fish Kill Prevention in Tilapia Aquaculture using Fuzzy Logic

System H - Machine Learning-Based Algorithm for Fish Kill Evaluation using Differential Changes of Input Parameters via Wireless Communication

System I - Development of an IoT-based Intensive Aquaculture Monitoring System with Automatic Water Correction

System J - IoT-BASED FISH POND WATER CONDITION MONITORING SYSTEMFORBANGUS FARMING

CHAPTER III

RESEARCH METHODOLOGY/DESIGN

This chapter introduces the process researchers created, including tools used throughout the data collection process to develop the study, the study site, and the developed process model. A software system is used to evaluate the planned system.

3.1 Research Instruments

This chapter introduces the process that researchers developed including tools used throughout the data collection process to develop the study and process model developed. The study aims to understand and counteract fishkeeping problems with the combination of data collected. Questionnaires were provided to fish keepers and non-fish keepers to learn more about their opinions and insights in this field.

3.2 Locale of the Study

The study was conducted at Rizal Technological University in Brgy, Maybunga Pasig City Metro Manila. This research aimed to observe, address, and counteract problems regarding fishkeeping monitoring.

3.3 Population of the Study

To select those who are available and willing to participate in this study, a convenience sample was used by the researcher. The Study will focus on people who were previously or currently fish farmers/hobbyists who reside in the Philippines.

3.4 Data Gathering

To ensure that the data gathered are valid and accurate, the researcher used the data gathering tools listed below:

Observation.

Observation is the collection of Primary Data through observing the proposed system by watching the subject's behavior, and events, or noting physical characteristics in their natural setting.

Survey Questionnaire.

The researchers will give out survey questionnaires to the fish farmers and hobbyists that gather statistical information about the attributes, attitudes, or actions of a population through a structured set of questions. The participants' answers were interpreted using a 5-point Likert scale. The Likert scale had a sequence of statements, each with a scale ranging from 1 to 5. A rating of 5 indicated the highest or positive response, while a rating of 1 indicated the lowest or negative response. The scale's middle point, 3, denoted a neutral response. The following is the five-level Likert scale which used to interpret the data gathered:

SCALE	INTERPRETATION
5	STRONGLY AGREE
4	AGREE
3	NEUTRAL
2	DISAGREE
1	STRONGLY DISAGREE

Figure 1.2: Scale Range

Results

The researchers divided the survey questionnaires into 3 different categories, the first set of questions is about Target Respondents (Fish Farmer/Hobbyists). The second set of questions tackles the efficiency and accuracy of the website, and the last set addresses the proficiency and reliability of the system in terms of data gathering and monitoring of the fish and its environment inside the aquarium/pond. The questions provided were answered by 35 respondents.

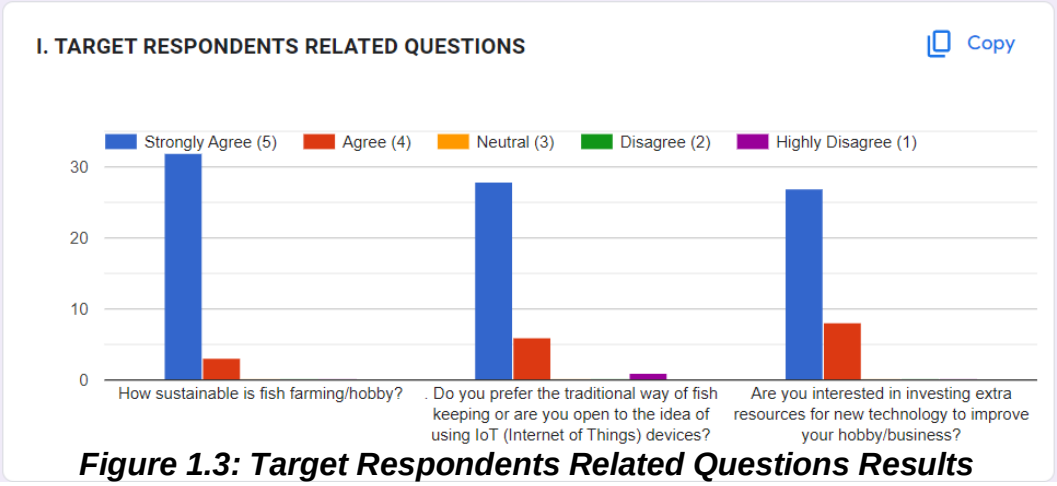

Figure 1.3: Target Respondents Related Questions Results

As shown in Figure 1.3, In question 1 category I, the researchers asked “Is fish farming/hobby sustainable?”, 32 (91.4%) of the respondents answered 5 (denoted as Strongly Agree) while 3 (8.5%) answered 4 (Agree). The second question “Do you prefer the traditional way of fish keeping or are you open to the idea of using IoT” provided 28 (80%) of the respondents answered 5 (Strongly agree), 7 (17.1%) selected 4 (Agree) and only one (2.8%) of the respondents answered 1 (Strongly disagree).

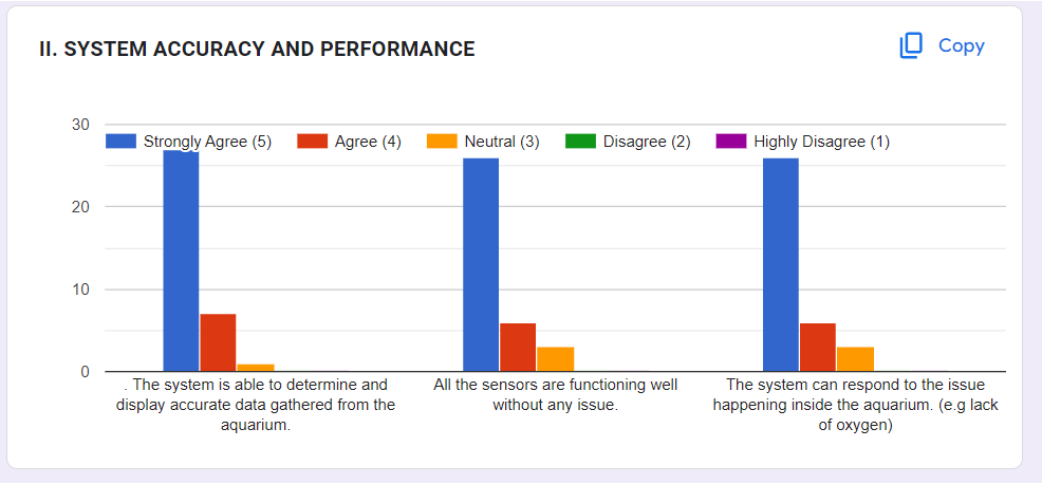

Figure 1.4: System Accuracy and Performance Results

The second set of survey questionnaires as shown in Figure 1.4, focuses on the accuracy and performance of the System. On the first question “The system is able to determine and display accurate data gathered from the aquarium” 27 (77.1%) of the respondents answered 5 (Strongly Agree), 7 (20.0%) respondents for Agree, and only 1 (2.8%) of the respondents chose 3 (Neutral).

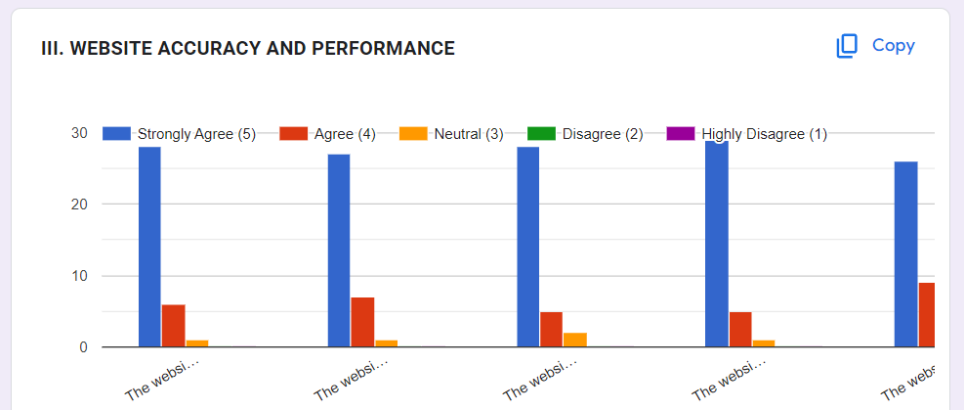

Figure 1.5: Website Accuracy and Performance Results

The graph above provides the result of Website Accuracy and Performance that belongs to category III. The first poll is about the website being user-friendly, 28 (80.0%) out of 35 respondents answered 5 (Strongly Agree), 6 (17.1%) picked 4 (Agree), and only 1 (2.8%) of them chose 3 (Neutral).

The second poll's "The website can give more knowledge about fish and about behaviors." option 5 (Strongly Agree) was picked by 27 (77.1%) of the respondents, and 7 (20%) answered 4 (Agree), while option 3 was only answered by 1 (2.88) respondent.

In poll number 3 "The website can identify how many fish are dead." Option 5 was answered by 28 (80.0%) of the respondents, option 4 (Agree) gathered 5 (14.2%) respondents, and option 3 was picked by 2 respondents.

The 4th poll “The website can counteract the problems that can be encountered by the system.” Gathered 30 respondents for option 5 (Strongly Agree), and 5 respondents for option 4 (Agree).

In the last poll, “The website displays real-time data gathered from the system.” Option 5 (Strongly Agree) was answered by 25 respondents, 9 of them picked 4 (Agree), and only 1 of them chose 3 (Neutral).

Interview.

The researchers will interview key men to gather data needed for the study. This method enables researchers to capture these topics’ nuances, contradictions, and subtleties, contributing to a more comprehensive understanding. The participants will answer 5 questions regarding the researcher’s study.

3.4 Research Design

The systems development life cycle (SDLC) is a conceptual model used in project management that describes the stages involved in an information system development project, from an initial feasibility study through maintenance of the completed application. Software development is an organized process that thrives to deliver products in faster, better and cheaper ways. Agile methods strive to deliver small sets of software features to customers as quickly as possible in short iterations. As part of this paper scope most commonly used methods will be examined from the angle of their applicability, strengths

and weaknesses and their adoption in industry. This will lead us to find benefits, limitations and difficulties in agile software development

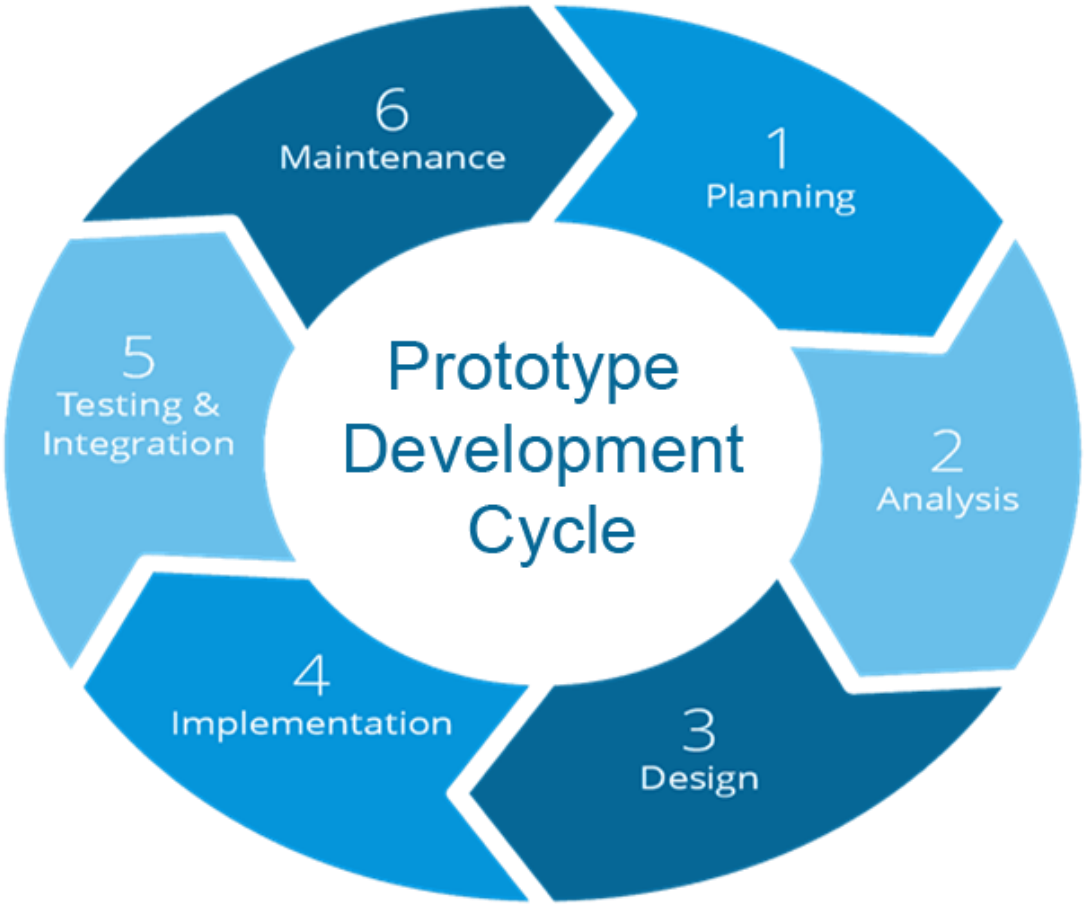

Figure 1.6: Agile software development life cycle model

This model is known as the Agile SDLC model. It combines iterative and incremental process models, focusing on process adaptability and user satisfaction by

rapidly delivering working software products. An iterative approach is taken and a working software build is delivered after each iteration. Each build is incremental in terms of features; the final build holds all the features required by the customer. The Agile thought process started early in software development and started becoming popular with time due to its flexibility and adaptability.

Table 3.1 – Table Results 1

WEBSITE FOR MONITORING	STATUS	REMARKS
View Homepage content	The website opens the content successfully	**Successful**
View About Us content	The website shows the about us content	**Successful**
View FAQS page content	The website shows FAQS page content	**Successful**
System Monitoring Parameter	The website shows System Monitoring Parameter	**Successful**
Water Temperature Chart	The website shows Water Temperature Chart	**Successful**
Water pH level Chart	The website shows Water pH level Chart	**Successful**
Water Turbidity Chart	The website shows Water Turbidity Chart	**Successful**
Data Logger Page	The website shows Data Logger Page	**Successful**

Fish Mortality Monitoring Website	REMARKS
Water pH Level chart	**Present**
Monitor the pH level of the water	**Present**
Water Turbidity chart	**Present**
Monitor the Turbidity of the water	**Present**
Data Logger	**Present**
Logs the Data gathered from the aquarium	**Present**
Monitors the count of fish alive	**Present**
Analyze and monitor the overall status of the fish	**Present**

About us	**Present**
Displays the information about the researchers	**Present**
FAQs	**Present**
Displays the user guide and manual	**Present**

Table 3.1 shows the result of Fish Mortality Monitoring website testing wherein, the page content of the Homepage, About Us, FAQs, and functions for monitoring are already working.

Table 3.2 – Table Result 2

Log In	**Status**	**Remarks**
Verifies username and password	The system verifies the username and password	**Successful**
Verifies the admin's access	The system verifies when the admin access	**Successful**
Forgot password function	The system opens a form for forgot password	**Successful**
System Monitoring Parameter		
View Water Temperature	The system shows the water temperature	**Successful**
View Water pH level	The system shows the water pH level	**Successful**
View Water Turbidity	The system shows the water turbidity	**Successful**
Water Temperature Chart		
Monitor the temperature of the water	The system monitors the temperature of water	**Successful**

Table 3.2 shows that the Fish Mortality Monitoring website is fully functional and can generate a report.

Data Analysis

Content analysis will be used to analyze the data gathered categorizing verbal or behavioral data to classify, summarize, and tabulate the data. Researchers quantify and

analyze the presence, meanings, and relationships of such words and concepts, then make inferences about the messages.

Operation and Testing Procedure

A consolidated requirement should meet the client's specifications. Operating and testing procedures were performed to verify the intended output met the desired outcome before implementation.

Operation Procedure

Website Administrator

1. Read and follow the manual before using the system
2. Redirect to the website.
3. The system should take necessary precautions.
4. Create and enter the password.
5. Navigate at your discretion.

Evaluation Procedure

Evaluation is a critical process that examines software. It involves collecting and eliminating biases in the evaluation and providing realistic results.

The researcher respondent was also given questionnaires for them to answer and made as the basis for their evaluation.