*MUST Journal of Research and Development (MJRD) Volume 2 Issue 2, December 2022*
*e ISSN 2683-6467 & p ISSN 2683-6475*

# Development of Internet of Things-Based System for Monitoring and Controlling the Water Quality in Small-Scale Aquaculture

[1]Abbas Nyoni[*], [2]Lusajo Minga, [3]Sadiki Lameck Kusyama

[123]Mbeya University of Science and Technology

[123]P.O. Box 131 Mbeya, Tanzania

Email Addresses: [1]nyon1988@gmail.com, [2]lusajominga103@gmail.com, [3]sadikilameck@gmail.com

**ARTICLE INFORMATION**

**Article History**

*Received: 15th December 2021*
*Revised: 12th February 2022*
*Accepted: 25th March 2022*
*Published: 28th December 2022*

**Keywords**

Aquaculture
Water Quality
IoT
Temperature Sensor
NodeMCU ESP8266
Blynk
Water quality parameter

**ABSTRACT**

*Water quality is an essential factor for any successful aquaculture project. For high productivity from aquaculture, critical water quality parameters such as temperature, pH, dissolved oxygen, salinity, and turbidity must be kept in the optimum range. Temperature is the second-most critical water quality parameter after dissolved oxygen. Tropical fish prefer temperatures ranging from 25$^0$c to 32$^0$c. This study designed and implemented a system prototype for monitoring and controlling water temperature in an aquaculture environment based on the Internet of Things (IoT). The system comprises temperature sensors, a NodeMCU Esp8266 Microcontroller, a 2-channel relay switch, a liquid-crystal display, a cooling fan, a water heater, and a mobile application. The temperature sensor immersed in a fish pond collects the pond's temperature. The collected temperature data from fish ponds is sent to the microcontroller, a NodeMCU Esp8266, for processing and transmission to the cloud server. The Blynk Cloud IoT platform was used for data visualisation and controlling actuators. The system users could access data through the Blynk Mobile application installed on a smartphone. The system automatically switches ON the cooling fan to cool the water when the temperature is above 32$^o$c and switches ON the water heater when the temperature is below 25$^o$c. The system was tested both in the laboratory and in field to evaluate the system's performance in detecting pond temperature and data dissemination to the users. This study's findings have proved the system's capability in data acquisition with accuracy and efficiency. In addition, the results have shown that the system can effectively control pond temperature.*

*Corresponding author's e-mail address: nyon1988@gmail.com (Nyoni, A.)

## 1. Introduction

The insufficient supply of fish through natural sources, such as seas, lakes, and rivers, has prompted people to engage in aquaculture to meet the fish demand (Mzula et al., 2020). Aquaculture contributes to an increase in household income and food security (Mzula et al., 2020). Water quality is among the factors affecting aquaculture productivity (Summerfelt, 2015). Water quality is determined by several parameters, such as temperature, pH, dissolved oxygen, salinity, conductivity, and electrical conductivity (Sengupta et al., 2019). For better productivity from aquaculture ponds, water quality indicators must be monitored and kept within their ideal range (Ebeling, 2011). Excessive exposure to a high concentration of one or more water quality parameters, lower or greater than the ideal value, significantly negatively influences the development and well-being of fish in fish ponds (Huan et al., 2020).

Temperature is among the critical indicators of water quality that need to be regularly monitored and maintained (León et al., 2006). Fish metabolism, growth, swimming speed, feeding, reproduction, breathing, and survival are all impacted by the fluctuation of the water's temperature (León et al., 2006). Fish are cold-blooded (poikilothermic), implying that the environment's temperature affects their body temperature (Boyd, 2018). The growth rate of fish increases as the temperature rises within the acceptable temperature range until the maximum temperature is reached (Boyd, 2018). Fish from tropical regions require temperatures between 25 °C and 32 °C (Ebeling, 2011). If the temperature is not within this range, the fish may grow slowly or die at a certain point.

Furthermore, dissolved oxygen, the most critical parameter, is influenced by the increase in water temperature (Simbeye and Yang, 2014). The temperature influences the dissolved oxygen in a fish pond in two ways. Dissolved oxygen decreases with increasing temperature since oxygen hardly dissolves in warm water. Second, the dissolved oxygen consumed during respiration increases as the temperature rises (Simbeye and Yang, 2014). Thus, temperature is an important water quality parameter in aquaculture because it affects metabolism, growth, and the concentration of dissolved oxygen in the water.

Lack of proper water quality monitoring and control can result in poor fish growth, diseases, and death, resulting in poor aquaculture productivity (Banrie, 2015). This study designed, implemented, and tested a system prototype based on the Internet of Things (IoT) for water temperature monitoring and control in small-scale aquaculture. Adopting the developed system will increase fish productivity in small-scale fish farmers' ponds.

In a similar study, Faustine et al. (2014) developed a prototype for water quality monitoring based on a wireless sensor network in the Lake Victoria Basin (LVB). The system was preceded by an assessment of the availability of a cellular network in the study area. The study used an Arduino board, water quality sensors, and a wireless communication module. The parameters considered by the study were water temperature, dissolved oxygen, and electrical conductivity. The sensors installed in the water collected data and sent it to the central station in real-time. The collected data were disseminated to the stakeholders through a web portal and mobile phones. However, the system in this study could not control the variation of parameters.

In another study, an Internet of Things-based system for monitoring temperature, pH, and TDS in aquaculture was developed and used by Susanti et al. (2022). The goal was to create a system that would be easy to implement. Hardware, including temperature sensor type ds18b20, pH sensor, and TDS, were used in the system's development. The microcontroller used in this system was the Arduino Mega, and the NodeMCU Esp8266 was used as a WIFI shield for data transmission to the cloud. The aquaculture pond data was accessed via the blynk mobile app, which was installed on the user's smartphone. The system was tested and could read the temperature, pH, and TDS from the fish ponds; however, it could not control the variation of water quality parameters to their optimum levels.

### *1.1 The Proposed System*

The proposed system comprises a microcontroller (NodeMCU Esp8266), waterproof temperature sensors (DS18B20), an LCD, a relay switch, a water heater, a cooling fan, and a mobile application. The temperature sensor collects temperature data and sends it to the microcontroller (NodeMCU Esp8266). The microcontroller processed and sent the collected data to the IoT cloud platform through WiFi. When the temperature is below the predefined threshold values, a microcontroller sends the signal to switch on the water heater. When the temperature exceeds the threshold value, a microcontroller switches off the heater and the fan. The users shall visualise the data by using a mobile application that is installed on the user's smartphone.

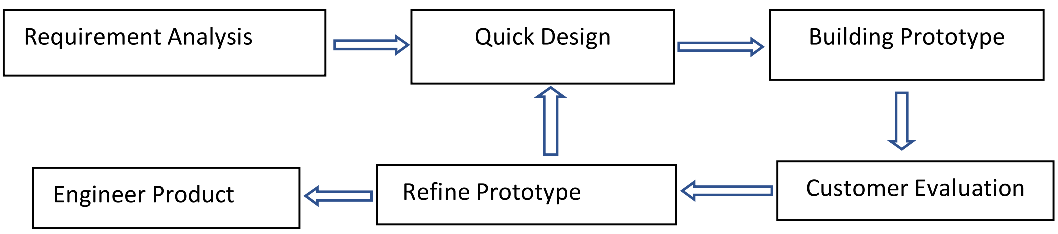
## 2. Materials and Methods

### *2.1 System Development Approach*

This study adopted the prototyping methodology. In this methodology, a prototype is built, tested, and reworked until an acceptable outcome is obtained from which the entire system or product can be developed (Martin, 2022). When the system's needs are not well known, this methodology works well. Customer input was gathered to help the prototype of a system, which was still in its early phases, be enhanced. The stages that were taken during the development are depicted in Figure 1.

Figure 1

*A Prototyping Model*

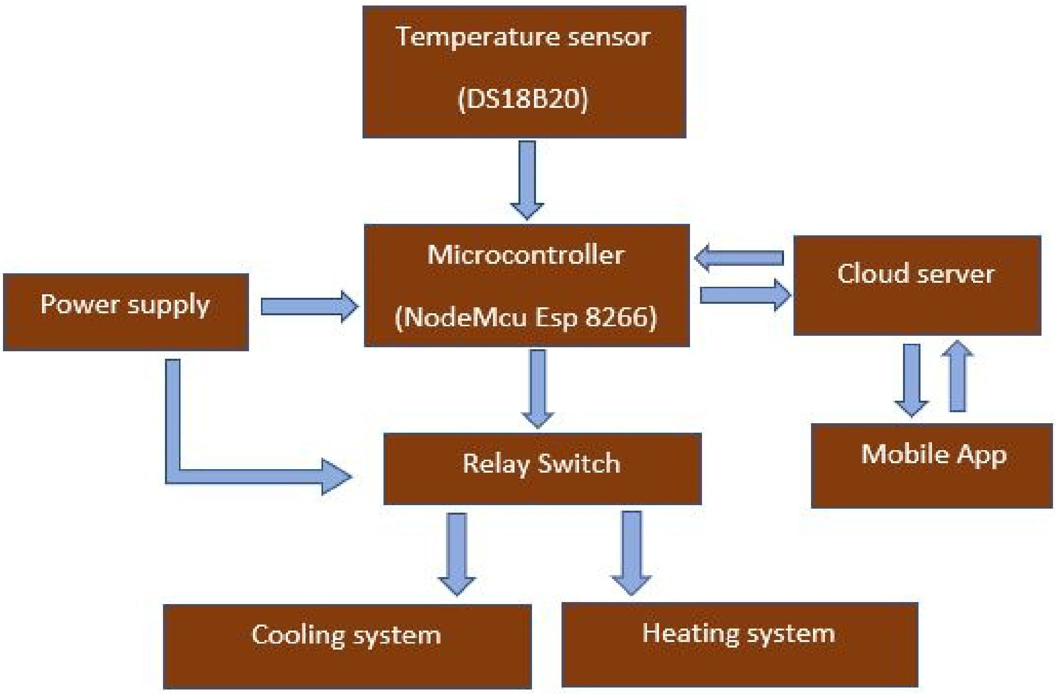


*2.2 System Design*

Figure 2 is a block diagram of the proposed system. The diagram shows how the system components interface with each other. The system's design is based on the fundamental architecture of the Internet of Things. The basic IoT architecture has three layers: the perception layer, the network layer, and the application layer (Lufyagila et al., 2022). The perception layer is for data collection from the environment. The network layer communicates the collected data, and the application layer provides an interface to the system user (Lufyagila et al., 2022).

Figure 2

*Block Diagram of the System*




*2.3 Hardware Components of the System*

*2.3.1 Temperature Sensor*

The water temperature indicates how much water is hot or cold. A DS18B20 sensor has been used in this study to detect the temperature of fish ponds. With an accuracy of -2/+2 co, the DS18B20 can detect temperatures ranging from -55 c to +125 c. This work used a waterproof DS18B20 temperature sensor.

*2.3.2 NodeMCU Esp8266*

NodeMCU is an open-source microcontroller board based on the Esp8266 with WiFi capability that can be used as a microcontroller. It can connect objects in the Internet of Things (IoT) network to exchange data using the WiFi protocol (Lufyagila et al., 2022). In this study, the NodeMCU Esp8266 was chosen as a microcontroller board since it has WiFi capability and is less expensive than other boards like Arduino and Raspberry Pi. NodeMCU Esp8266 is Arduino compatible, meaning that all code written for Arduino can run on NodeMCU Esp8266.

#### *2.3.3 A Two-Channel Relay Switch*

A relay switch is an electromagnetic switch that operates under a voltage of 3.3V–5V and allows a user to control devices with a high voltage by a microcontroller with a low voltage. A two-channel relay switch has four input pins: IN1, IN2, VCC, and GND; and the three output pins are Common (COM), Normally Open (NO), and Normally Closed (NC). A 2-channel relay switch was connected to the microcontroller to control the cooling fan and water heater.

#### *2.3.4 Cooling Fan*

A cooling fan was used to cool the pond's water and reduce the pond's temperature to its optimum level. It is done when the temperature is above 32 degrees. The cooling fan was interfaced with a relay switch connected to and controlled by a microcontroller. The system should trigger a relay switch to allow electrical current to the cooling fan.

#### *2.3.5 Water Heater*

In the prototype system, an immersion water heater was used for heating pond water to raise the pond's temperature to the optimum range. It is done when the temperature is below the predefined threshold value. The heater is interfaced with a relay switch, which is connected to and controlled by a microcontroller. The system should trigger a relay switch to allow electrical current to reach the heater.

### *2.4 Software Components of the System*

#### *2.4.1 Blynk Mobile App*

Blynk is an IoT platform that allows building interfaces to visualise sensor data from monitoring systems and control hardware from iOS and Android devices (Bunker, 2015).

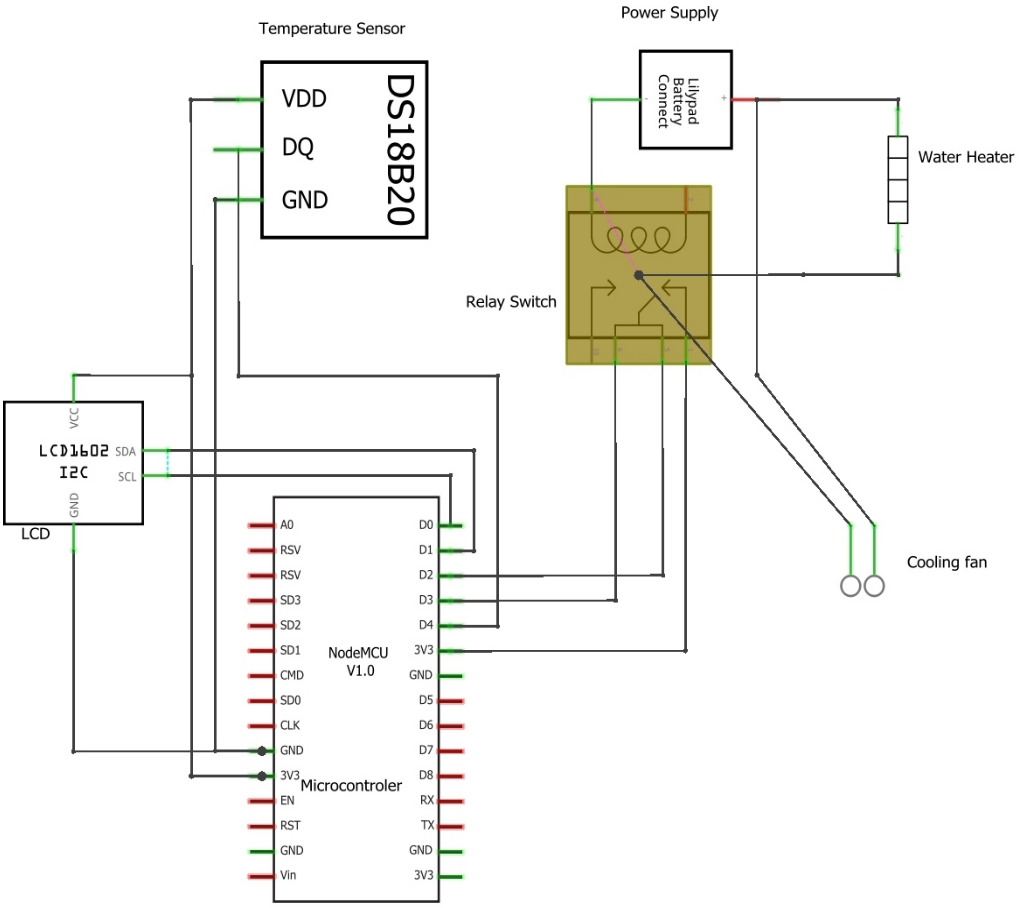
The Blynk mobile app was used to build a dashboard where buttons, graphs, sliders, and other widgets were arranged. Using those widgets and buttons, we could visualise sensor data and control the connected hardware, such as the cooling fan and water heater.

### *2.5 Schematic Diagram of the System*

Figure 3 illustrates the schematic diagram of the developed system. The schematic diagram shows how system hardware components are interfaced to form a working system. The temperature sensor, DS18B20, is interfaced with the microcontroller (NodeMCU Esp8266) at pin 4. The microcontroller is connected to a 12V power supply. A two-channel relay switch is connected to a microcontroller at pins 2 and 3. The water heater and cooling fan are connected to the relay switch in channels one and two, respectively. An LCD is connected to a microcontroller at pins 0, 1, and 4.

Figure 3

*The Schematic Diagram of the System Showing the Interconnection of System Components*




## 3. Results and Discussion

### *3.1 Laboratory Testing and Results*

The system shown in Fig. 5 was successfully developed following the proposed design and architecture. The prototype was tested in the laboratory on different water samples to evaluate its performance. The values recorded on the system's LCD were compared with the values from the handheld thermometer, and the values were almost the same. Table 1 summarises the results obtained during the testing of the developed system in different water samples and compares the sensor readings with a handheld thermometer. When the sensor was placed in water samples with a temperature above 32$^{o}$C, the system switched ON the cooling fan to cool the water. When the sensor was placed in water samples with a temperature below 25$^{o}$C, the system turned ON the water heater to increase the water's temperature. However, in water samples with temperatures between 25°C and 32°C, both the heater and fan remained OFF.

### *3.2 Field Testing and Results*

The prototype was taken to the field for field testing. Field testing was done after laboratory testing to verify the system's performance in data transmission from the fish pond to the user's smartphone. The prototype was installed in a fish pond for 12 hours, from 7:00

a.m. to 6:00 p.m. The temperature readings displayed on the LCD were recorded after each hour. Data from the field was transmitted to the cloud and monitored in real-time through the Blynk mobile application. Data recorded from LCDs and remote mobile applications were compared to find the variation. There was no variation in temperature readings between the two parts; therefore, the system effectively transmitted data to the remote mobile application. Fig. 4 is a flowchart representing a working algorithm of the system prototype. Table 2 summarises the results of field testing.

Figure 4

*The Flowchart Illustrating a Working Algorithm of the System*

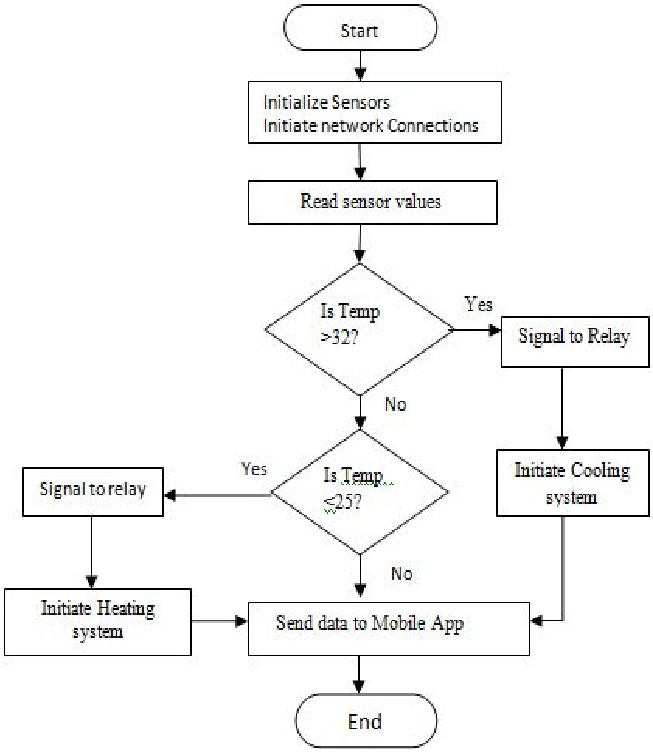



Table 1
*Laboratory Test Results*

| Water sample | TempValue, C⁰ (Sensor) | TempValue, C⁰ (Thermometer) | Variation |
|---|---|---|---|
| Sample 1 | 41.1c⁰ | 41.3c⁰ | -0.2 |
| Sample 2 | 24.2c⁰ | 24.1c⁰ | +0.1 |
| Sample 3 | 12.4c⁰ | 12.2c⁰ | +0.2 |
| Sample 4 | 13.5c⁰ | 13.5c⁰ | 0 |
| Sample 5 | 17.3c⁰ | 17.6c⁰ | -3 |
| Sample 6 | 31.4c⁰ | 31.6c⁰ | -2 |
| Sample 7 | 9.7c⁰ | 9.6c⁰ | +1 |
| Sample 8 | 25.1c⁰ | 24.9c⁰ | +2 |

Table 2
*The Results from Field Testing*

| **Time** | **Temp Value C⁰ (**LCD readings) | **Temp Value C⁰ (**Mobile App readings**)** | **Variation** |
|---|---|---|---|
| 7:00 AM | 12.2 | 12.2 | 0 |
| 8:00 AM | 12.4 | 12.4 | 0 |
| 9:00 AM | 13.4 | 13.4 | 0 |
| 10:00 AM | 13.7 | 13.7 | 0 |
| 11:00 AM | 14.5 | 14.5 | 0 |
| 12:00 AM | 14.7 | 14.7 | 0 |
| 01:00 PM | 15.5 | 15.5 | 0 |
| 02:00 PM | 15.4 | 15.4 | 0 |
| 03:00 PM | 15.4 | 15.4 | 0 |
| 04:00 PM | 15.2 | 15.2 | 0 |
| 05:00 PM | 14:1 | 14:1 | 0 |
| 06:00 PM | 13:2 | 13:2 | 0 |

### *3.3 Data Visualization*

The temperature readings from sensors are visualised by two means. Data is displayed on the user's smartphone through the Blynk Mobile application and a liquid crystal display (LCD). The mobile application contains cooling and heating buttons to control the fan and heater manually. Figure 5 shows how the temperature readings from fish ponds are displayed on the user's smartphone.

Figure 5
*Temperature Visualization on Blynk Mobile App*

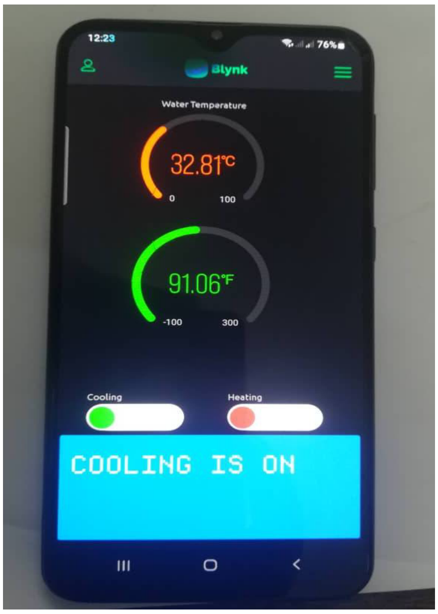
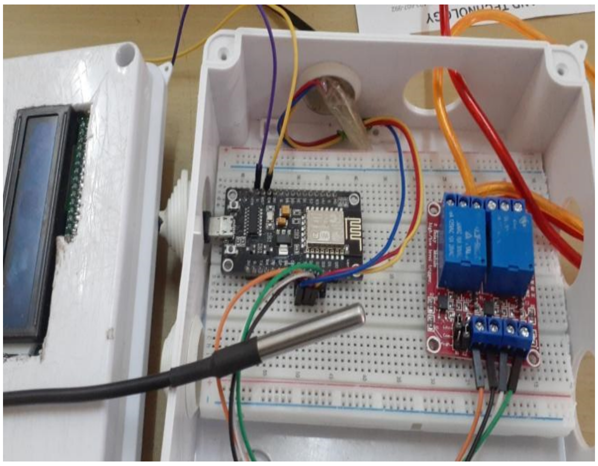


Figure 6
*Hardware Setup of the System*



## 4. Conclusion

This study aimed to develop a prototype system based on IoT for monitoring and controlling water quality in aquaculture environments. The prototype was successfully designed, developed, and tested. Field and lab testing of the system were done to evaluate the system's performance in gathering temperature data from the fish pond and transmitting that data to the remote mobile application. The results summarised in tables 1 and 2 concluded that the system could monitor and control temperature data remotely using the blynk mobile app. However, the developed prototype does not guarantee 100% the availability of quality water in aquaculture since it monitors and controls only one parameter. Temperature is the only parameter for water quality considered in this study.

## 5. Recommendation

In this study, we suggest other sensors be considered in future research for monitoring and control of other water quality parameters. Second, we suggest that the GSM module be used to send short text messages when the temperature is not good enough for fish to live.

## 6. References

Banrie (2015). *How to achieve good water quality management in aquaculture* [WWW Document]. URL https://thefishsite.com/articles/how-to-achieve-good-water-quality-management-in-aquaculture (accessed 12.27.21).

Boyd, C.E. (2018). *Water temperature in aquaculture*. Glob. Aquac. Advocate 1–5.

Bunker, J. (2015). *Control an Arduino with your Smartphone via Blynk* [WWW Document]. URL https://makezine.com/2015/07/06/control-arduino-your-smartphone-via-blynk (accessed 11.7.22).

Claude, E. B. (2018). W*ater Temperature in Aquaculture [WWW Document]*. URL https://www.globalseafood.org/advocate/water-temperature-in-aquaculture/ (accessed 6.11.22).

Ebeling, J.M. (2011). *Water Quality: Recirculating Aquaculture Systems Short Course*.

Faustine, A., Mvuma, A.N., Mongi, H.J., Gabriel, M.C., Tenge, A.J., Kucel, S.B., (2014). Wireless Sensor Networks for Water Quality Monitoring and Control within Lake Victoria Basin : *Prototype Development* 281–290.

Huan, J., Li, H., Wu, F., Cao, W. (2020). Design of water quality monitoring system for aquaculture ponds based on NB-IoT. *Aquac*. Eng. 90, 102088. https://doi.org/10.1016/j.aquaeng.2020.102088

León, C.J., Hernández, J.M., León-Santana, M. (2006). The effects of water temperature in aquaculture management. *Appl*. Econ. 38, 2159–2168. https://doi.org/10.1080/00036840500427379

Lufyagila, B., Machuve, D., Clemen, T. (2022). IoT-powered system for environmental conditions monitoring in poultry house: A case of Tanzania. *African J. Sci. Technol. Innov*. Dev. 14, 1020–1031. https://doi.org/10.1080/20421338.2021.1924

Lufyagila, B., Machuve, D., Clemen, T. (2022). IoT-powered system for environmental conditions monitoring in poultry house: A case of Tanzania. *African J. Sci. Technol. Innov. Dev.* 14, 1020–1031. https://doi.org/10.1080/20421338.2021.1924348

Martin, M. (2022). *Prototype Model in Software Engineering [WWW Document]*. URL https://www.guru99.com/software-engineering-prototyping-model.html (accessed 6.11.22).

Mzula, A., Wambura, P.N., Mdegela, R.H., Shirima, G.M. (2020). Present status of aquaculture and the challenge of bacterial diseases in freshwater farmed fish in Tanzania; A call for sustainable strategies. *Aquac*. Fish. 6, 247–253. https://doi.org/10.1016/j.aaf.2020.05.003

Sengupta, B., Sawant, S., Dhanawade, M., Bhosale, S. (2019). Water Quality Monitoring using IoT 2, 695–701.

Simbeye, D.S., Yang, S.F. (2014). Water quality monitoring and control for aquaculture based on wireless sensor networks. *J. Networks* 9, 840–849. https://doi.org/10.4304/jnw.9.4.840-849

summerfelt, R.C. (2015). water quality considerations for aquaculture.

Susanti, N.D., Sagita, D., Apriyanto, I.F., Anggara, C.E.W., Darmajana, D.A., Rahayuningtyas, A. (2022). Design and Implementation of Water Quality Monitoring System (Temperature, pH, TDS) in Aquaculture Using IoT at Low Cost. Proc. 6th Int. Conf. Food, Agric. Nat. Resour. (IC-FANRES 2021) 16, 7–11. https://doi.org/10.2991/absr.k.220101.002