Design of Real-Time Aquarium Monitoring System for Endemic Fish on the Smartphone

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ABSTRACT

The high rate of decreasing population of endemic fish species is becoming more severe over time. Therefore, it needed an effort to bring back the stability of the number. One of the reasons for the decreasing population is the changing environment due to climate change and the difficulty of treatment for this species. This research aims to design an aquarium monitoring system for endemic fish. The main components for this system are microcontroller ESP32 DOIT, Temperature Sensors DS18B20, DF Robot Analog pH Sensors, ESP32 Cam, UV Lamp, and Blynk server. The experiment was conducted by monitoring the aquarium environment using sensors and comparing it with the reference sensors. With a monitoring system, we can find out whether the current condition of the aquarium is in accordance with the fish's living environment or not. The monitoring results show that the average error for temperature is 0.14% and for pH is 0.67%. These results indicate that the prototype sensors are linear with reference sensors. Besides that, a real-time monitoring system is easy to use and more attractive because of smartphone utilization to monitor fish with a camera and lamp.

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1. INTRODUCTION

Indonesia is an archipelagic country with a tropical climate rich in biodiversity or commonly called "Mega-biodiversity" [1][2]. As an archipelagic country, Indonesia covers around 5,193,250 million km^2 area, where two-thirds of Indonesia's territory is a water area of 3.25 million km^2 [3][4]. The area of water that is larger than the mainland makes Indonesia rich in fish species. There are 4,782 fish species recorded in Indonesia, and about 130 are endemic species [5]. Endemic species are species that grow naturally in only one geographic area. Naturally, The factors that cause the endemism of animals are temperature, humidity, and wind [6].

However, this diversity is not in line with public awareness to maintain and preserve the diversity of endemic fauna. It is characterized by being very rare and difficult to find in its natural habitat [7]. This problem has occurred for a long time but has not been resolved until now. Moreover, water temperature has an important role in fish development activities. Rapid temperature increases are known to cause acute stress responses and expose fish to disease. In addition, highly fluctuated temperatures can cause fish death [8][9]. In addition, a good pH content for fish waters generally ranges from 5-9. Inappropriate pH content can cause fish vulnerability to parasites, growth to slow down, cause physiological disturbances in fish, and decrease the survival of fish [10][11].

The Internet of Things (IoT) refers to a network to connect anything with the Internet. Internet of Things enables one device to control and monitor other devices in the same network [12][13]. Currently, the development of IoT is very rapid. It has allowed for various possibilities in technological advancements for different aspects of life [14][15]. With the condition of endemic fish habitat becoming concerning and overexploited increasingly, the application of IoT-based technology that is integrated with sensors and actuators makes Ex-Situ conservation more and more well-monitored and controlled. However, the current smart aquarium system can only monitor the quality of the water in the aquarium without displaying the visual state of the aquarium in real-time [16]. Table 1 shows a comparison of the features possessed by the related works. This study aims to design an aquarium system to monitor (temperature and pH) and display the aquarium's condition using a camera in real-time. The research contribution is to apply technology for monitoring in Ex-situ conservation.

Table 1. Comparison of features of related works.

References	pH	Temperature	TDS	Turbidity	Camera	Lamp
[17]	✓	✓	-	-	-	-
[18]	✓	-	✓	-	-	-
[19]	✓	✓	-	-	-	-
[20]	✓	✓	✓	✓	-	-
[21]	-	✓	-	-	-	-
This work	✓	✓	-	-	✓	✓

2. RESEARCH METHOD

Fig. 1 and Fig. 2 show the design and block diagram of the prototype. The main components for this system are microcontroller ESP32 DOIT, Temperature Sensors DS18B20, DF Robot Analog pH Sensors, ESP32 Cam, UV Lamp, and Blynk server.

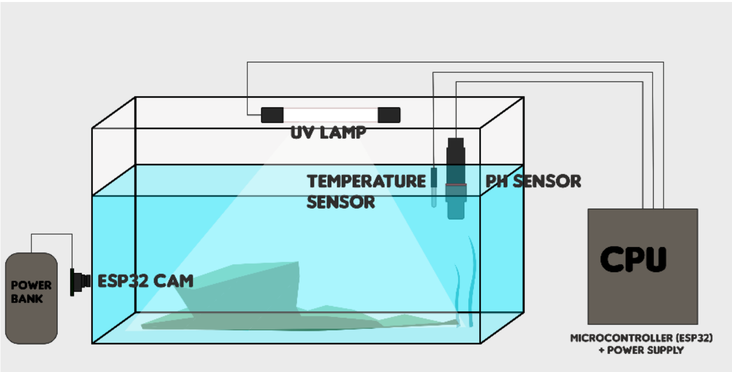


Fig. 1. Design of prototype.

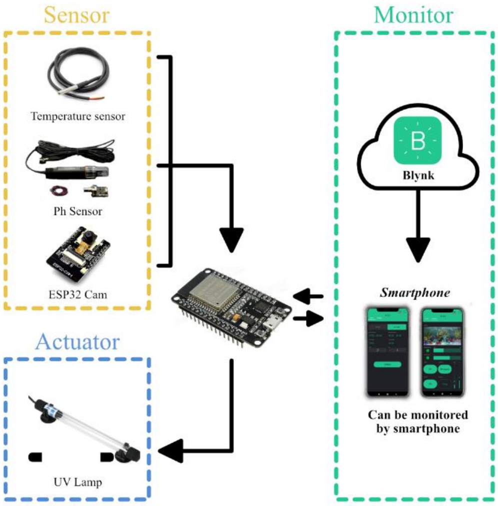


Fig. 2. Prototype block diagram.

PCB design and wiring tool are shown in Fig. 3. This prototype uses the ESP32 Development board as the main microcontroller, which is powered by a dual-core Tensilica Xtensa LX6 microprocessor [22][23].

Its minimalist design but equipped with a WiFi module makes the ESP32 a good microcontroller for IoT development. The DS18B20 is a waterproof temperature sensor used to measure liquids, soils, or solutions. The temperature sensor DS18B20 has a temperature measurement range from -55°C to 125°C and uses a 3.0–5.0 V supply for its operation [24][25]. In reading the aquarium water temperature, we use the DS18B20 sensor, changing the temperature value to voltage. The pH sensor used in this system is the DFRobot sensor kit which has a measuring range of 0-14 with accuracy ± 0.1 and response time ≤ 1 min [26]. This sensor works with a working voltage of 5V, so it is easy to integrate with a microcontroller [27]. The camera functions as a monitoring tool for fish and aquarium conditions. The camera will be connected to the IoT server so that users can see the condition of the aquarium from anywhere. In this prototype, we use the ESP32 Cam as a camera module which has a small size board with a footprint of 27x40.5x4.5 millimeters. The ESP32-Cam uses an OV2640 camera module. It can operate with a maximum resolution of 1600x1200 pixels at fifteen frames per second [28]. UV lamps are used to reduce the viability of the fish pathogenic bacterium [29].

The smartphone application for this prototype is utilized the Blynk platform. Blynk is an IoT platform that enables the development and implementation of smart IoT devices with ease and speed. With Blynk, all the sensor data can be observed in real-time easily from our smartphones, and the user can also give orders to the prototype [30][31]. This can be facilitated because Blynk provides cloud services to exchange information between tools and users. In addition, the application also has an additional feature that is a reminder that will notify users if the aquarium conditions are outside normal limits. Users can enter the limits for normal conditions of temperature and pH in the application. So, if the condition of the aquarium water is not between these normal limits, then the application in the smartphone will send a notification to the user's smartphone.

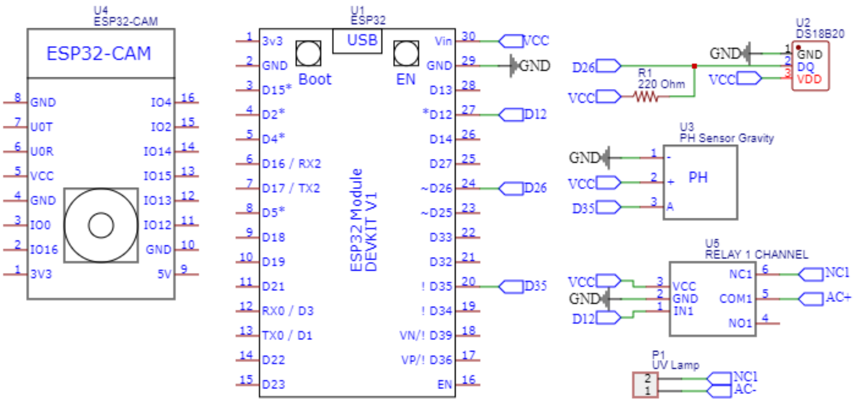


Fig. 3. Schematic circuit of the prototype.

3. RESULTS AND DISCUSSION

Data collection using the prototype is shown in Table 2 for temperature measurement and Table 3 for pH measurement. The prototype was tested in an aquarium with dimensions of 90x40x40 cm^3 filled with 77 liters of water, as shown in Fig. 4. The fish used as the subject for this prototype is the Sepat Mutiara (*Trichopodus leeri*).

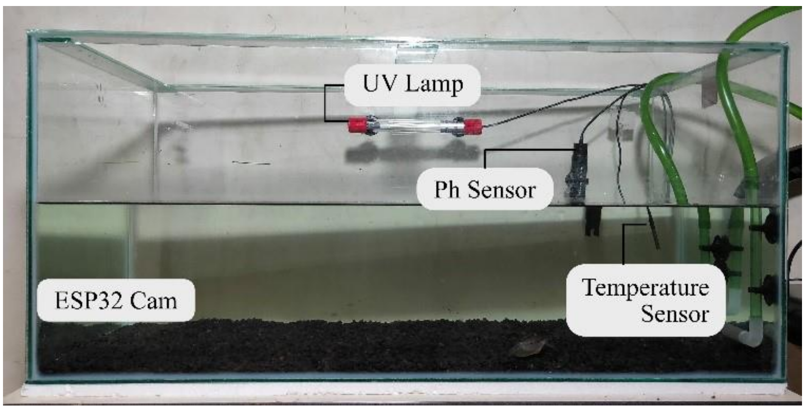


Fig. 4. View of the prototype.

Table 2 shows the average error data from the temperature test. Error data is obtained by comparing the temperature read by the DS18B20 sensor and the reference temperature every 5 minutes, five times each day, for three days. From the test, the average error for temperature is 0.14%. The linear temperature relationship of the prototype with the reference is shown in Fig. 5.

Table 2. Data accuracy measurements of temperature.

Day	**Time Sampling**	**Prototype temperature (°C)**	**Reference Temperature (°C)**	**Error rate**
1	1	29.94	29.9	0.13%
	2	29.94	29.9	0.13%
	3	29.94	29.9	0.13%
	4	29.94	29.9	0.13%
	5	29.94	29.9	0.13%
Mean 1				0.13%
2	1	29.95	29.9	0.17%
	2	29.95	29.9	0.17%
	3	29.95	29.9	0.17%
	4	29.95	29.9	0.17%
	5	29.95	29.9	0.17%
Mean 2				0.17%
3	1	30.04	30.0	0.13%
	2	30.04	30.0	0.13%
	3	30.04	30.0	0.13%
	4	30.04	30.0	0.13%
	5	30.04	30.0	0.13%
Mean 3				0.13%
Average				0.14%

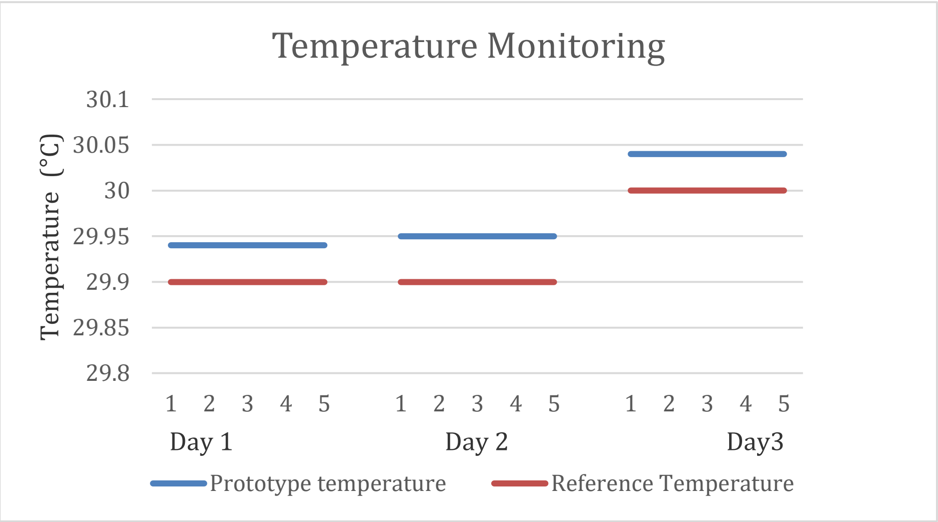


Fig. 5. Comparison temperature between prototype and reference.

Table 3 shows the average error data from the pH test. The error data is obtained by comparing the temperature read by the pH analog sensor and the reference pH in 5-minute intervals, five times each day, for three days. From the test, the average error for pH is 0.67%. The pH linear relationship of the prototype with the reference is shown in Fig. 6.

Table 3. Data accuracy measurements of pH.

Day	Time Sampling	Prototype pH	Reference pH	Error rate
1	1	7.89	7.8	1.15%
	2	7.93	7.9	0.38%
	3	8.02	7.9	1.52%
	4	7.83	7.9	0.89%
	5	7.87	7.9	0.38%
Mean 1				0.86%
2	1	7.92	7.9	0.25%
	2	7.90	7.9	0%
	3	7.97	7.9	0.89%
	4	7.94	7.9	0.51%
	5	7.87	7.8	0.9%
Mean 2				0.51%
3	1	7.98	8.0	0.25%
	2	8.12	8.0	1.5%
	3	8.05	8.0	0.625%
	4	7.97	8.0	0.375%
	5	8.03	8.0	0.375%
Mean 3				0.63%
Average				0.67%

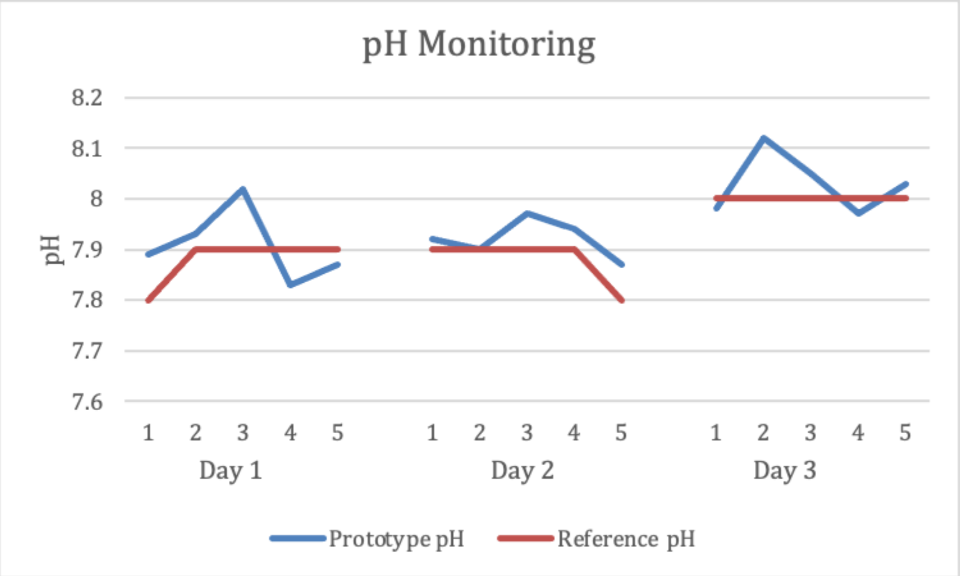


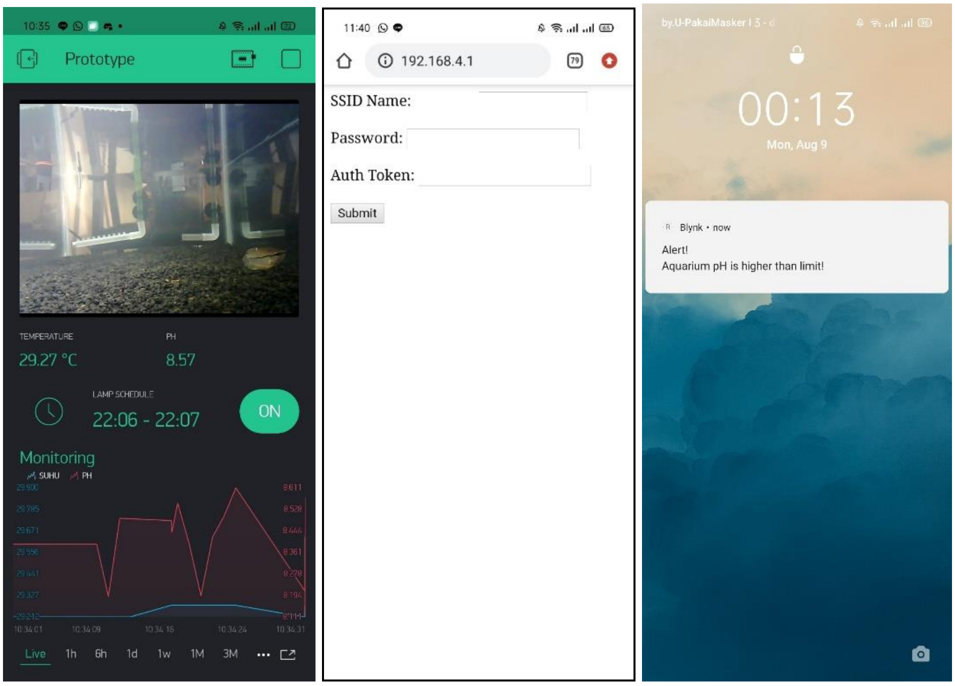
Fig. 6. Comparison pH between prototype and reference.

In addition to obtaining the pH and temperature data, we also tested other features of the prototype, such as a camera, UV lamp, and the use of a web server for setting Wi-Fi credentials. Based on the experiment, we found that the best resolution of the ESP32-Cam for monitoring the aquarium of 90x40x40 cm^3 is 640x480 pixels. This resolution will have a good image quality with a short rendering time. At the same time, the use of UV lamps in our aquarium is very useful for lighting and monitoring the aquarium, as shown in Fig. 7. Besides that, UV lamps also can inhibit the growth of bacteria.

(a) (b)

Fig. 7. Without lamp (a) and with lamp (b) view in the aquarium.

Fig. 8(a) shows the Blynk Graphical User Interface, which displays a real-time visual view of the aquarium, the value of temperature and pH level, time scheduler for lighting, and a graphic of temperature and pH level that stores data up to 3 months. Fig. 8(b) displays a webserver display to change the WiFi network so that users do not need to reprogram the hardcode of the ESP32 to switch networks. Fig. 8(c) shows a warning system that will notify if the monitored temperature or pH exceeds the limit set in the blynk application.



(a) (b) (c)

Fig. 8. Graphical user interface (a), web server displays (b), and (c) the notification of the prototype.

4. CONCLUSION

A real-time aquarium monitoring that can monitor fish photos, temperature and pH conditions on the smartphone has been successfully designed. The monitoring results on this prototype were tested in 5-minute intervals with five sampling times. The average error for temperature is 0.14% and for pH is 0.67%. These results indicate that the measurements made by the prototype are linear with reference data. In addition, this prototype can be further developed by adding features for temperature and pH control.

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