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IoT Based Catfish Farm Monitoring with ESP32 Microcontroller and DS18B20 Sensor

Agus Suwardono[1*], Fidya Eka Prahesti[2*], Elsanda Merita Indrawati[3], Moh. Abd Jalil Ashofa[4]

[1,2,3,4] Technical Electronics , Nusantara PGRI University , Kediri, Indonesia

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ABSTRAK

Kualitas dan suhu air merupakan parameter penting yang perlu diperhatikan dalam budidaya ikan. Parameter kualitas air dan suhu yang tidak tepat dapat menghambat pertumbuhan ikan, bahkan dapat menyebabkan kematian pada ikan sehingga petambak mengalami kerugian ekonomi bagi tambak. focus permasalahan dalam penelitian ini adalah parameter kualitas air dan suhu yang tidak sesuai dapat menghambat pertumbuhan ikan lele atau menyebabkan kematian, sehingga merugikan usaha budidaya secara ekonomi. Proses monitoring kualitas air pada kolam ikan lele yang dilakukan secara manual dinilai kurang efisien karena tidak memberikan kontrol suhu secara realtime. Penelitian ini bertujuan untuk merancang dan mengimplementasikan sistem monitoring kualitas air berbasis Internet of Things (IoT) pada kolam budidaya ikan lele, dengan fokus pada pengaturan suhu secara realtime. Penelitian ini merupakan penelitian eksperimen dengan subjek kolam budidaya ikan lele. Data dikumpulkan melalui pengujian sistem berbasis IoT, dan hasilnya dianalisis menggunakan metode deskriptif untuk mengevaluasi efektivitas sistem dalam menjaga suhu kolam pada rentang 28°C–32°C. Hasil penelitian menunjukkan bahwa sistem monitoring peternakan lele berbasis IoT dengan mikrokontroler ESP32 dan sensor DS18B20 berfungsi dengan baik dalam memantau suhu air secara real-time. Sistem ini mampu mengirimkan data secara nirkabel ke platform monitoring berbasis web atau aplikasi, memungkinkan pengguna untuk memantau kondisi peternakan kapan saja dan di mana saja.. Implikasi dari penelitian tentang monitoring peternakan lele berbasis IoT menggunakan mikrokontroler ESP32 dan sensor DS18B20 menunjukkan potensi transformasi dalam manajemen akuakultur, khususnya peternakan lele.

ABSTRACT

Water quality and temperature are important parameters that need to be considered in fish farming. Inappropriate water quality and temperature parameters can inhibit fish growth, and can even cause fish death so that farmers experience economic losses for the pond. The focus of the problem in this research is that inappropriate water quality and temperature parameters can inhibit the growth of catfish or cause death, thereby economically harming the cultivation business. The process of monitoring water quality in catfish ponds which is carried out manually is considered less efficient because it does not provide real-time temperature control. This research aims to design and implement an Internet of Things (IoT)-based water quality monitoring system in catfish cultivation ponds, with a focus on real-time temperature regulation. This research is experimental research with the subject of catfish cultivation ponds. Data was collected through IoT-based system testing, and the results were analyzed using descriptive methods to evaluate the system's effectiveness in maintaining pool temperature in the range of 28°C–32°C. The research results show that the IoT-based catfish farm monitoring system with the ESP32 microcontroller and DS18B20 sensor functions well in monitoring water temperature in real-time. This system is capable of sending data wirelessly to a web or application-based monitoring platform, allowing users to monitor farm conditions anytime and anywhere. The implications of research on IoT-based catfish farm monitoring using an ESP32 microcontroller and DS18B20 sensors show the *potential for transformation in aquaculture management , especially catfish farming.*

1. INTRODUCTION

Catfish cultivation is one of food security in Indonesia. Catfish is one of the freshwater fish that is most popular with the public, because of its ease of cultivation and affordable price, so many beginner catfish breeders choose this fish as their mainstay commodity (Akpasi, 2020; Ariffin, 2019). The need for catfish is increasing along with population growth and demand for consumption-sized catfish. As is known, catfish is often consumed as a daily food for Indonesian people, especially as a side dish with rice. Catfish is very popular among people, because it contains a lot of protein to complement good

*Corresponding author.
E-mail addresses: fidya.prahesti@unpkdr.ac.id (Fidya Eka Prahesti)

nutritional intake (Anas, 2019; Asiva Noor Rachmayani, 2015). The nutritional composition of catfish includes protein (17.7%), fat (4.8%), minerals (1.2%) and water (76%). The advantage of catfish is that it is rich in Leucine and Lysine. Leucine (CHN) is an essential amino acid that is very necessary for children's growth and maintaining nitrogen balance. There are five types of catfish that are often cultivated. There is a type of local catfish, this local catfish is a species of Clarias Batrachus which is a catfish native to Indonesian waters. The advantages of this fish are its tasty meat and not much fat, but its disadvantages are This local catfish grows slowly so it wastes food. There is also a type of African catfish. This catfish comes from Taiwan and was introduced in 1985. The advantage of this type of African catfish is that it grows faster than local catfish so that feed requirements are more economical and can be spawned every year, but the texture of African catfish has soft meat. (Merinda Tasya Aulia, 2022; Setiawan et al., 2024). Sangkuriang catfish is the result of genetic improvement of African catfish carried out by the Freshwater Aquaculture Development Center in Sukabumi. The advantage of this fish is in its egg production process. More eggs are produced, which saves on feeding, but the quality of the seeds will decrease if this type of catfish is bred again. The fourth type of catfish is the phyton catfish. Phyton catfish is the result of a genetic cross between ex-Thai catfish parents and local catfish parents. The advantage of this catfish is that it is resistant to cold weather and has a low mortality rate. Meanwhile, the fifth type of catfish is pearl catfish, but this pearl catfish has incomparable quality. This catfish is the best catfish with superior quality compared to other types of catfish. This pearl catfish grows faster, namely 10%- 40%, and easily adapts to temperature and environment

The long drought that will occur in 2022-2023 will put many catfish farmers out of business. Farmed fish experience crop failure due to fish mortality rates reaching 80% (Dendy Denhero et al., 2022; Yazid et al., 2023). Extreme temperature changes between day and night make it difficult for catfish farmers to suffer from white snout due to the decrease in pond water discharge. Coupled with the relatively cheap price of fish, fish farmers have to rack their brains to survive and try to save fish from death due to erratic weather. Farmers must diligently regulate the water temperature during the day. Because during the day the pool water temperature is very hot, while at night it is very cold. Farmers must also be diligent in checking the temperature of their pond water at all times. However, due to the water crisis experienced by catfish farmers, water temperature is difficult to control(Aisyah et al., 2022; Kurniatuty & Widodo, 2015). As a result, farmers usually try to migrate to other pond areas where the water supply is safe. However, this step is not without risks. The dry season is also a warning for farmers, because they are very vulnerable to the threat of disease. One of them is a white snout. This disease is a disease experienced by catfish because there is fungus in the mouth of the catfish. This fungus thrives because the pH conditions of the water are not ideal (Damayanti et al., 2021; Qalit et al., 2017). The Director General of Aquaculture described the trend in demand for consumption fish as continuing to increase. FAO even noted that the growth in world demand for fish exceeds the growth of world population. This is an opportunity to encourage increased national catfish production. To seize this opportunity, entrepreneurs must begin to understand the importance of good and correct fish farming techniques. One way that can be done to increase production is to maintain water quality as a living medium for catfish. In catfish farming, water quality affects the growth and development of catfish (Pemantauan et al., 2024; Sujono & Wahyunugroho, 2023). Water is an interesting object of study considering that water has many characteristics such as temperature, salinity, pH, DO and turbidity. Water can be used both as water for consumption, cultivation activities and research. Generally, cultivating freshwater fish will be successful in water with a pH of 6.5-9 and optimal growth occurs at a pH of 7-8.5. Water for fish cultivation must be clean, not too cloudy and not contaminated with toxic chemicals and oil/factory waste. In previous research, monitoring of catfish ponds was carried out using only two temperature sensors and the age of the catfish was monitored instead of seeds. Monitoring and control were successfully carried out on adult catfish. Study focus on hatching but the object used is gourami fish. From the results of research using experimental methods, it was successful in monitoring and controlling the temperature in fish hatchery ponds (Irhamna et al., 2024; Kurniawan Ratnasari Nur Rohmah, 2020). The addition of IoT technology that has been carried out in previous research has been successful and also makes it easier for farmers to monitor the condition of fish in ponds. In obtaining production results, many catfish farmers experience losses such as less than optimal results. or lots of dead fish. This case was then investigated and the result was that one of the causes was the temperature and acidity or pH level of the water in the pool which often changed according to weather changes that occurred in the surrounding environment, so technology/tools were needed. It is necessary to be able to always monitor the temperature and pH levels in the water at any time as desired(Haqim et al., 2018; Prabowo et al., 2020). The development of research regarding Internet of Things (IoT)-based livestock monitoring has experienced significant progress in recent years. Various previous studies have examined the use of IoT technology to monitor various parameters in aquaculture, such as water temperature, pH, salinity and dissolved oxygen levels. One of the main focuses of previous research was the development of systems that can integrate environmental sensors with efficient microcontrollers to collect and transmit data in real-time. Several studies have used microcontrollers such as Arduino and Raspberry Pi, but the ESP32-based technology used in this research offers advantages, such as more stable wireless connectivity capabilities and faster data processing. Apart from that, previous research also shows that the use of an IoT-based monitoring system can help farmers manage environmental conditions more effectively, reduce the risk of fish death, and increase production efficiency. However, many of the systems being developed are still limited to the use of expensive or complex hardware, which makes adoption difficult for small farmers. This research focuses on developing a system that is simpler, more affordable and easy to implement, which can be applied by catfish farmers on a small to medium scale. Thus, this research complements previous research by offering solutions that are more practical and relevant in the local context, as well as opening up opportunities for the application of IoT in the wider field of aquaculture.

The update of this research with previous research is that this research uses a different communication protocol from previous research, namely ESP Now with a wireless system. It is hoped that this system will make it easier for farmers to control catfish ponds. Catfish farmers do not need to check manually all the time, because with an automatic monitoring system, farmers can control catfish ponds with their cell phones. This research adds a heater if the pool temperature turns out to be below a reasonable threshold, which happens at night or during the rainy season. This research will compare the temperature between controlled and uncontrolled water in catfish ponds. The aim of this research is to develop an Internet of Things (IoT) based catfish farming monitoring system using an ESP32 microcontroller and DS18B20 sensor to monitor water temperature in real-time. This system aims to provide an efficient and affordable technological solution for catfish farmers in managing the quality of the cultivation environment, especially water temperature, which affects fish health and growth. This research also aims to test the reliability of the system in sending data wirelessly and providing early warning if the water temperature is outside the optimal range. In addition, this research seeks to contribute to the development of IoT-based monitoring technology that is easy to access and implement by small to medium farmers, in order to increase the productivity and sustainability of catfish farming businesses.

2. METHOD

The research method used is development using a qualitative descriptive approach. Using quantitative data analysis methods. At this stage there are two design stages for the software system and then for the hardware system. At the design stage, several tools and materials are needed for assembling the hardware. This research software system will describe the monitoring program flow presented in Figure 1.

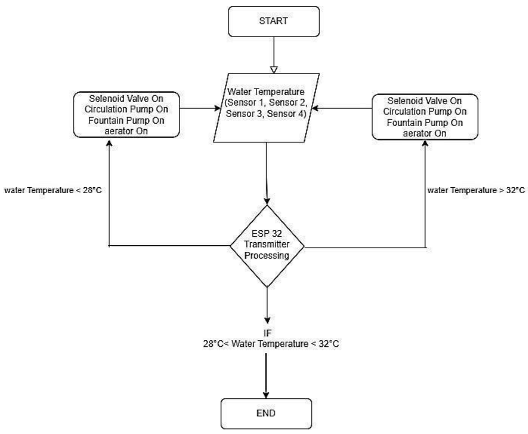

Figure 1. Flow Diagram of the Working Mechanism for Controlling Catfish Cultivation

The monitoring tool design process begins with four temperature sensors that are immersed in water and one sensor that is placed outside the pool. The sensor reading results will send a signal to the ESP32 microcontroller. If the water temperature reading is not within the normal threshold, the system will make the heater turn on and the circulation pump turn on when the water temperature is at the lower threshold, and when the water temperature is above the upper threshold, it will cause the solenoid valve to work. the circulation pump is on, the aerator and fountain pump are on (Kurniawan et al., 2020; Kustija & Andika, 2021). LoT-based water temperature data monitoring is presented in Figure 2.

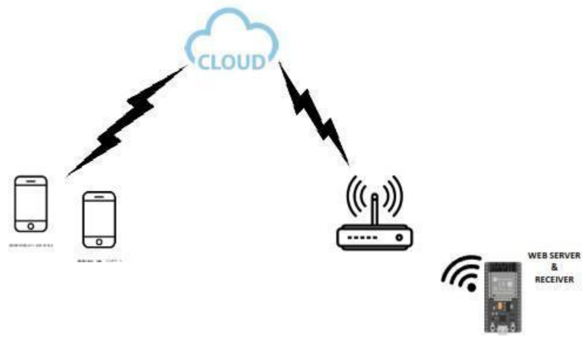

Figure 2. IoT-Based Water Temperature Data Monitoring

In Figure 2 you can see the process of receiving water temperature data in an IoT-based catfish pond. This research is planned to be used in two catfish cultivation ponds. In designing this tool, supporting equipment is needed which consists of software and hardware. The software used is Thonny IDE. (Integrated Development Environment). This application is useful for creating, opening, and editing Micropython source code. Meanwhile, the hardware used includes an ESP32 microcontroller, DS18B20 temperature sensor, 16 x 2 LCD LCD, two-channel relay, submersible water pump, water heater, GSM router, power supply and other consumable components. In this research, three ESP32 microcontrollers are needed which act as transmitters and receivers (web servers). The number of ESP32 transmitters corresponds to the number of pools. The process of designing a water temperature controller is divided into several stages, namely literature study, tool design and measurement procedures. At the literature study stage, a research study was carried out that was close to this research, but the previous research only involved one pool. This design stage includes creating a block diagram of the entire system which includes hardware design and software design. In Figure 4 below is a scheme for combining catfish pond monitoring. From the results of temperature sensor readings on water and air, all components will work according to the flowchart in Figure 1, and all data will be sent in real time to a cloud system that can be accessed via the web or smartphone. A schematic diagram of IoT-based water temperature measurement and regulation is presented in Figure 3.

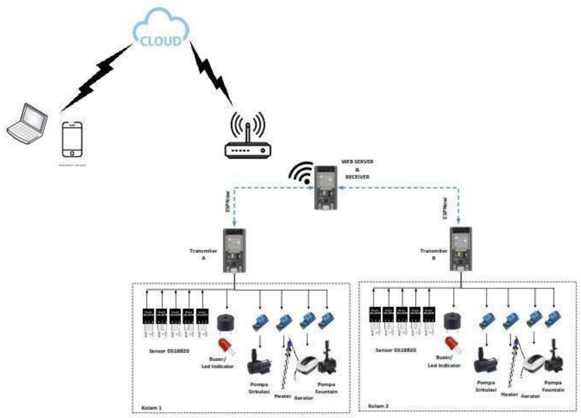

Figure 3. Schematic Diagram of IoT-based Water Temperature Measurement and Regulation

The procedure for setting the pool water temperature consists of several steps as shown in Figures 2 and 3. The step is that calibration is carried out on the sensor so that the intended temperature value matches the actual one. Second, the water temperature is measured by placing four sensors in the pool. Apart from the water temperature, the air temperature is also measured. This is done to see how much influence temperature control has on the water. Third, the temperature measurement results obtained from the sensor input are sent to the ESP32 transmitter to be processed into water and air temperature values; Fourth, the ESP32 transmitter controls the start of the heater or pump according to the temperature in the pool. If the measured water temperature is below the threshold then the circulation pump and heater will work. If the measured water temperature is above the threshold then the circulation pump, fountain pump and air aerator will work. To obtain even temperature measurements, a circulation pump is used in the water cooling/heating process. Fifth, the temperature data on the ESP32 transmitter is transferred to the ESP32 receiver. Finally, the ESP32 receiver acts as a data receiver and web server to forward temperature data to the database server

The data collection method in this research was carried out in three ways, namely Direct Observation, observing the temperature and quality of pool water in real-time using an Internet of Things (IoT) based monitoring system. Sensor Data Recording: The system automatically records temperature data every 10 seconds during the research period. Visual Documentation: Document pond conditions and monitoring tools throughout the research process. From the data obtained, an analysis will be carried out on how the experiments in ESIA research are running with the ultimate goal of working according to the monitoring system workflow. In the Data Analysis Method in this research, there are three methods, namely: Descriptive Analysis: Analyzing temperature data obtained from sensors to ensure the stability and effectiveness of the system in maintaining the temperature in the optimal range (28°C–32°C) (Daud et al. 2023).

3. RESULT AND DISCUSSION

Result

The results of the design that have been made can be seen in Figure 5 below. Control devices are installed in catfish ponds for monitoring. There are 2 pools under control, 1 pool which will later be installed with a control device and 1 pool without a monitoring device as a comparison. The results of making a monitoring tool installed in the pond are presented in Figure 4. And the web display of the monitoring system for water temperature regulation in catfish breeding ponds is presented in Figure 5.

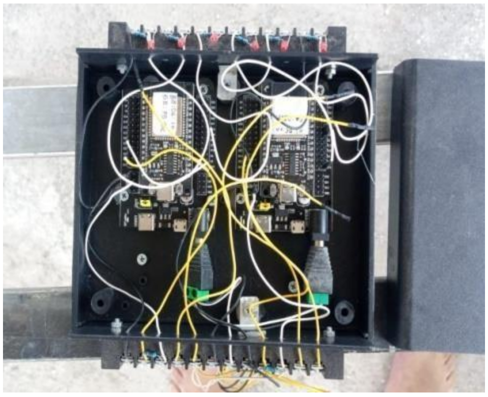

Figure 4. Catfish Temperature Monitoring Control Tool

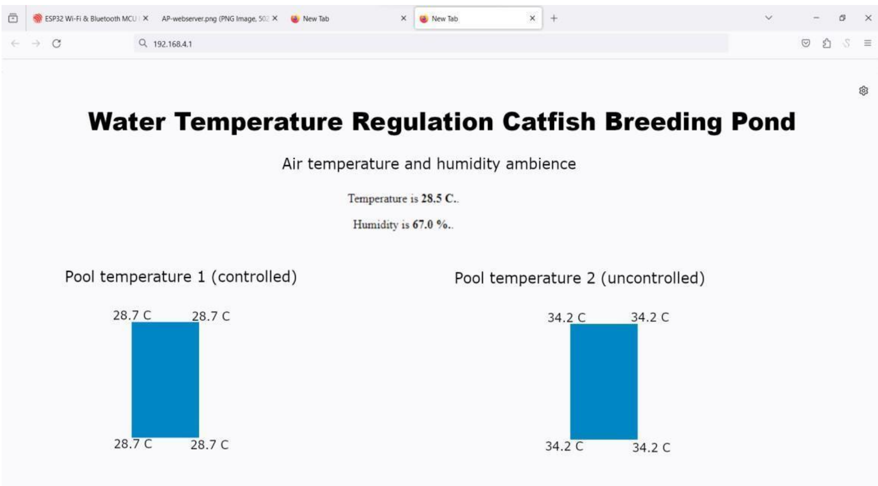

Figure 5. Web View of the Monitoring System for Water Temperature Regulation in Catfish Breeding Ponds

Figure 6. Monitoring System in Catfish Ponds

Table 1. Controlled Catfish Pond Temperature Data

NO.	O'CLOCK	TEMPERATURE(C˚) 1	TEMPERATURE(C˚)2	TEMPERATURE(C˚) 3	TEMPERATURE(C˚) 4
1	05.00	28,38	28,31	28,44	28,56
2	06.00	28,44	28,38	28,5	28,56
3	07.00	28,44	28,38	28,44	28,56
4	08.00	28,44	28,31	28,5	28,56
5	09.00	28,38	28,31	28,44	28,56
6	10.00	28,38	28,25	28,44	28,56
7	11.00	28,38	28,31	28,44	28,5
8	12.00	28,31	28,25	28,38	28,5
9	13.00	28,38	28,31	28,38	28,5
10	14.00	28,38	28,31	28,44	28,5
11	15.00	28,38	28,31	28,44	28,5
12	16.00	28,38	28,31	28,44	28,5
13	17.00	28,38	28,31	28,44	28,56
14	18.00	28,38	28,31	28,44	28,5
15	19.00	28,38	28,31	28,44	28,5
16	20.00	28,38	28,31	28,44	28,5
17	21.00	28,38	28,31	28,38	28,5
18	22.00	28,31	28,31	28,38	28,5
19	23.00	28,38	28,31	28,44	28,56
20	24.00	28,44	28,38	28,5	28,56

The temperature monitoring tool has succeeded in measuring and recording temperature data accurately in accordance with the minimum and maximum limits that have been set. Measurements are taken every second to ensure the precision and accuracy of the data. However, to facilitate analysis and monitoring purposes, the data displayed has been aggregated into hourly time intervals. Based on the data presented, it can be seen that the temperature remains within the desired range throughout the monitoring time. This shows good system stability in maintaining the temperature within the specified limits. Temperature trends over the monitoring period can be observed to evaluate patterns of temperature change over time. This can help in identifying patterns associated with certain processes or environmental conditions. By monitoring hourly data, we can evaluate the achievement of the desired temperature target within a certain time period. If there is a deviation from the minimum or maximum limits, corrective action can be taken immediately to maintain the temperature within a safe and optimal range. The results of temperature monitoring in uncontrolled catfish ponds are presented in Table 2.

Table 2. Catfish pond temperature data is not controlled

NO.	O'CLOCK	TEMPERATURE(C˚) 1	TEMPERATURE(C˚)2	TEMPERATURE(C˚) 3	TEMPERATURE(C˚) 4
1	05.00	24.20	24.19	24.25	24.29
2	06.00	25,44	25,42	25,42	25,44
3	07.00	25,44	25,6	25,47	25,44

NO.	O'CLOCK	TEMPERATURE(C˚) 1	TEMPERATURE(C˚)2	TEMPERATURE(C˚) 3	TEMPERATURE(C˚) 4
4	08.00	26,44	26,4	26,43	26,44
5	09.00	288	28,8	28.3	28,8
6	10.00	28,38	28,38	28,8	28,38
7	11.00	29,38	29,38	29,78	29,38
8	12.00	32,31	32,31	32,81	32,31
9	13.00	35,38	34,38	35,78	35,38
10	14.00	36,38	36,38	36,38	36,38
11	15.00	30,38	30,38	30,98	30,38
12	16.00	30,38	30,38	30,78	30,38
13	17.00	28,38	28,38	28,8	28,38
14	18.00	26,38	26,38	26,53	26,38
15	19.00	25,38	25,38	25,58	25,38
16	20.00	24,38	24,38	24,58	24,38
17	21.00	22,38	22,38	22,48	22,38
18	22.00	23,31	23,31	23,61	23,31
19	23.00	23,38	23,38	23,88	23,38
20	24.00	22,44	22,44	22,44	22,44

Temperature Fluctuations: The data obtained shows temperature fluctuations that may be caused by external factors such as weather changes, human activities, or natural changes in the environment. Due to the absence of a temperature controller, no temperature stability is observed. Temperatures can change drastically depending on environmental conditions and other variables. Without temperature control, there is a potential risk to goods or processes that are sensitive to temperature fluctuations. This may cause damage or loss in some situations. Compared to previous research, this system shows increased monitoring efficiency compared to manual methods that rely on timer or thermometer measurements (HS 1185 October 2020 2020). Other studies that use IoT for fish farming tend to only monitor without temperature control features. This system integrates these two functions so that it is more practical and can be applied by farmers. The advantage and contribution of research is that this system provides automatic temperature control, thereby reducing the risk of human error. Then, with a web-based platform, monitoring becomes flexible, increasing time and energy efficiency and the contribution of this research is a technology-based solution to overcome the economic problems of cultivators due to losses due to inappropriate water temperatures. This monitoring system can increase the productivity of catfish farming, reduce fish mortality rates, and support operational efficiency. Implementing this kind of system also has the potential to accelerate digital transformation in the fisheries sector. A limitation in this research is that other parameters such as pH and dissolved oxygen have not been integrated into the system. Recommendations for Further Research Develop a system that can monitor other water quality parameters, such as pH and dissolved oxygen, Integrate the system with a mobile application to increase user accessibility, and Test the system in various types of pools with different environments to measure its durability. devices and system effectiveness.

Discussion

The research results show that the pond water monitoring system in the IoT-based catfish cultivation hatchery process is successful in maintaining the pond temperature in the optimal range, namely 28°C–32°C. This is important because stable water temperatures contribute directly to the growth and health of catfish. With data updates every 10 seconds via the web platform, cultivators can carry out real-time monitoring without having to monitor manually. This system is superior to the manual method which only uses a timer for setting time without accurate temperature control. Previous research shows that IoT-based monitoring systems are effective in measuring water quality parameters, but do not include temperature control (Asiva Noor Rachmayani, 2015; Prabowo et al., 2020). Comparison of the results of this study with previous research shows several similarities and significant differences. Previous research has studied the use of IoT technology in fish farming, especially for monitoring environmental parameters such as temperature, pH and dissolved oxygen, and using microcontrollers such as Arduino or Raspberry Pi. However, systems developed in previous research tend to be more complex and expensive, making them less accessible to small or medium farmers (Gunarjati, 2019; Kurniawan Ratnasari Nur Rohmah, 2020). In contrast, this research uses an ESP32 microcontroller which is more affordable and offers better wireless connectivity capabilities, making this system more practical and efficient to implement on small-scale farms. In addition, although many previous studies have shown success in using sensors for monitoring water temperature, this research stands out because it tested and implemented the system directly in the field, namely on a catfish farm, by providing early warning if the water temperature was not within the optimal range. The results of this study show a high level of accuracy of the DS18B20 sensor in measuring water temperature, with small deviations compared to manual measurements, which strengthens the findings of previous studies. Overall, this research makes a contribution by developing a monitoring system that is simpler, cheaper and easier for farmers to use, and is more relevant to practical needs in the field, especially in the context of catfish farming. The innovation in this research is the integration of automatic temperature monitoring and control, providing a complete solution for cultivators. The advantage of this system also lies in the ease of data access via the website which allows farmers to monitor pond conditions from any location. However, the main limitation of this research is that it only focuses on temperature control, while other important parameters such as pH or dissolved oxygen levels have not been included in the system. The implication of the results of this research is that there is the potential to increase the productivity of catfish cultivation with a smaller risk of loss. Apart from that, IoT technology can encourage digital transformation in the fisheries sector so that it becomes more efficient and competitive. However, for large-scale applications, further research is needed to ensure system performance in different types of pools and different environmental conditions. As a recommendation, future research should include the integration of additional parameters and system testing on various types of ponds with larger sizes. In addition, mobile application development can increase user accessibility and comfort in managing their cultivation ponds.

4. CONCLUSION

The research results show that the implementation of an IoT-based monitoring system in real time is able to monitor and control catfish farmers' farms. More accurate, real-time temperature monitoring allows cultivators to manage cultivation environments efficiently and respond quickly to changing conditions. This system proves high operational efficiency with the ability to automatically monitor temperatures. Cultivators can save time and resources by obtaining the necessary information without needing to be physically at the cultivation location with more effective monitoring cultivators can optimize cultivation conditions, reduce possible disease risks, and manage water resources effectively. This leads to more sustainable cultivation practices and has a positive impact on the environment. Data obtained from controlled ponds between 28-32 degrees Celsius makes catfish more viable and healthy.

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