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Utilizing Internet of Things (IoT) Technology in Recirculating Aquaculture Systems for Enhancing Water Quality and Health of Catfish (*Clarias* sp.) at Pokdakan Bintang Rosela Jaya, Pringsewu

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Abstract

This community service program is motivated by the necessity to enhance the productivity and efficiency of catfish farming in the Pringsewu Regency of Lampung, particularly in the face of challenges posed by water quality variability and climate change. Conventional fish farming systems frequently encounter obstacles such as temperature instability, pH fluctuations, and elevated ammonia levels, which can lead to stress and disease in fish. Consequently, this program aims to implement Internet of Things (IoT) technology based on a Recirculating Aquaculture System (RAS) as an innovative solution for real-time monitoring of pond water quality. The methods employed include technical assistance and training for the community partner, the Bintang Rosela Jaya group, through the installation of an IoT system that monitors temperature, pH, ammonia, and total dissolved solid (TDS) parameters. Program evaluation is conducted using pre-tests and post-tests to assess the improvement in participants' knowledge and skills. Evaluation results indicate a significant increase in the average scores of participants' understanding from 60 (pre-test) to 73 (post-test). Furthermore, the application of IoT technology has proven to enhance farming efficiency by reducing disease risks and facilitating water quality management. In conclusion, this program has successfully bolstered the capacity of partners in the adoption of innovative technologies in aquaculture, thereby supporting the sustainability of catfish farming operations and enhancing competitiveness in the national fisheries market.

Keywords: Catfish farming, Internet of Things (IoT), recirculating aquaculture system (RAS), water quality

Abstrak

Program pengabdian ini dilatarbelakangi oleh kebutuhan untuk meningkatkan produktivitas dan efisiensi budidaya ikan lele di wilayah Pringsewu, Lampung, terutama di tengah tantangan variabilitas kualitas air dan perubahan iklim. Sistem budidaya ikan konvensional sering kali menghadapi kendala seperti ketidakstabilan suhu, fluktuasi pH, serta tingginya kadar amonia yang dapat menyebabkan stres dan penyakit pada ikan. Oleh karena itu, tujuan dari program ini adalah untuk menerapkan teknologi Internet of Things (IoT) berbasis Recirculating Aquaculture System (RAS) sebagai solusi inovatif dalam pemantauan kualitas air kolam ikan secara real-time. Metode yang digunakan meliputi pendampingan teknis dan pelatihan kepada mitra kegiatan, Pokdakan Bintang Rosela Jaya, melalui pemasangan sistem sensor IoT yang memonitor parameter suhu, pH, amonia, dan kekeruhan air. Evaluasi program dilakukan dengan pre-test dan post-test untuk mengukur peningkatan pengetahuan dan keterampilan peserta. Hasil evaluasi menunjukkan peningkatan signifikan pada nilai rata-rata peserta dari 60 (pre-test) menjadi 73 (post-test). Selain itu, penggunaan teknologi IoT ini mampu meningkatkan efisiensi budidaya dengan mengurangi risiko penyakit dan mempermudah pengelolaan kualitas air. Kesimpulannya, program ini berhasil meningkatkan kapasitas mitra dalam penerapan teknologi inovatif di bidang akuakultur, sehingga diharapkan dapat mendukung keberlanjutan usaha budidaya ikan lele dan meningkatkan daya saing di pasar perikanan nasional.

Kata kunci: *Budidaya ikan lele, internet of Things (IoT), kualitas air, recirculating aquaculture system (RAS)*

Introduction

The potential of the fisheries sector in Pringsewu Regency presents a substantial opportunity for significant development. With the aquaculture area reaching 1,067 hectares and only about 50 percent of it currently utilized, there is substantial space for productivity increase (BPS, 2019). Besides that, geographic conditions that are supported by tens of reservoirs and eight river streams, particularly the biggest river, Way Sekampung, give rich potential for the growth of this sector. With an average freshwater fisheries yield reaching 8,000 tons per year, with main commodities, such as catfish, pangasius, common carp, tilapia, and gourami, demonstrate diversity and potential which can be harnessed furthermore (Shitu et al., 2023). Additionally, the existence of the Minapolitan area, especially in Pagelaran District, adds significant value to the development of this fisheries sector. Pagelaran District is noted for having the highest freshwater fish production among the nine districts in Pringsewu Regency. According to data from the Central Statistics Agency (BPS, 2019), the highest number of aquaculture households is found in Pagelaran, totaling 2,179, with catfish being the most widely cultivated commodity.

Catfish is a freshwater commodity that is highly promising because this fish can be cultivated in high stocking densities (Engle et al., 2022), has a high level of protein 15-18% (Abdel-Tawwab et al., 2020), and a relatively stable market demand. However, the obstacles in catfish cultivation are the problem of the deteriorating water quality (ph 4-5, often very

alkaline 10-11, and ammonia > 1 mg/L) as the cultivation period progresses (Fregene et al., 2024; Hemal et al., 2024), followed by the deteriorating fish health condition, growth disturbance, and ended with death (Yen & Liuhuang, 2021). To overcome this problem, modern technologies such as Recirculating Aquaculture Systems (RAS) combined with the Internet of Things (IoT) offer innovative solutions (Lai et al., 2024; Nayoun et al., 2024). This technology enables water quality monitoring in real-time, such as temperature, pH, ammonia, and turbidity, which are important to maintain fish health and optimize its growth (Zainurin et al., 2022; Mandal & Ghosh, 2024). With more efficient monitoring, farmers can decide quickly and accurately in managing water quality, so it increases cultivation yield and lowers the risk of fish disease (Islam et al., 2024).

One organization that becomes a partner in this technology implementation is Pokdakan Bintang Rosela Jaya in Patoman Village, Pagelaran District, Pringsewu Regency, Lampung, which commits to incorporating technological innovation to boost productivity and promote sustainable catfish farming. This Pokdakan has been a deed of establishment since 2021, led by Mr. Puji Purwanto, and has ten active members who are productive economically and aspiring entrepreneurs in fish hatchery and grow-out operations.

Implementing technology based on IoT in the RAS system is expected to help farmers in managing ponds more efficiently and increase their competitiveness in the national fisheries market(Puccinelli et al., 2023). With that background, this research and technical assistance aim to increase farmers understanding and skills in implementing IoT-based technology in RAS, which can increase efficiency and sustainability in the aquaculture sector in Indonesia, particularly in Pringsewu Regency.

Methods

Activity Partner

This community service program is conducted in collaboration with partner Pokdakan Bintang Rosela Jaya, which is a fish farmer group (Pokdakan) in Patoman Village, Pagelaran District, Pringsewu Regency, Lampung Province.

Implementation of Internet of Things (IoT) Technology for Monitoring Pond Water Quality

Implementation of IoT technology for monitoring water quality in a pond of catfish farming, covering four main parameters: turbidity, temperature, ammonia, and pH in water, and giving the fish pond condition. This system monitors data in real-time and sends information regarding water quality to farmers through an application on a smartphone. The team, consisting of academic staff and students, is responsible for building the IoT system and ensuring the system works as planned.

Technical Assistance for the Implementation of Internet-of-Things-Based Technology (IoT)

This technical assistance programme was carried out by the team focusing on direct guidance to the partner in implementing Internet of Things (IoT), which is integrated into a *recirculating aquaculture system* (RAS) in catfish farming ponds. This assistance aims to deliver technical consultation, a deeper understanding, and interactive discussion about the usage and benefits of IoT technology in water quality monitoring. The assistance is provided through technical guidance, monitoring water quality, and consultation services. In technical guidance, the team delivered direct training to the Pokdakan members regarding how to operate the IoT system, including an explanation about the application used to monitor water quality in real-time. Monitoring water quality was conducted by the team and partner through monitoring important water quality parameters: temperature, pH, ammonia, and total dissolved solids (TDS). Consultation service was carried out by the team through providing regular consultation sessions to help the partner understand water quality and recommending corrective steps if problems in water parameters were found.

Evaluation

The evaluation stage was carried out to analyze program achievement. First, the evaluation of the implementation of PKM activity was carried out through an internal evaluation. Then, the impact of PKM activity on the improvement of knowledge and skills of Pokdakan members on the material and practices of this program was evaluated through the results of pre-test and post-test. Moreover, evaluation every two months during PKM was conducted to evaluate the dynamics of water quality and fish condition, and in the end, calculate fish production efficiency in one cycle.

Results and Discussion

Implementation of Internet of Things (IoT)-based Technology on Water Quality Monitoring of Farming Ponds

Implementation has been completed in the ponds of Pokdakan Bintang Rosela Jaya, at Pringsewu Regency, Lampung. The IoT equipment for water quality monitoring developed in this activity can be seen in Figure 1. This system uses Microkontroler ESP32 S3 DevKitC-1 N16R8, which is connected to four sensors, i.e., temperature sensor DS18B20, analog pH Meter DFRobot V1, ammonia gas sensor MQ-135, and TDS sensor DFRobot. Measurement results can be seen on the LCD and can be monitored via smartphone via the Blynk application through an internet connection (Figure 2).

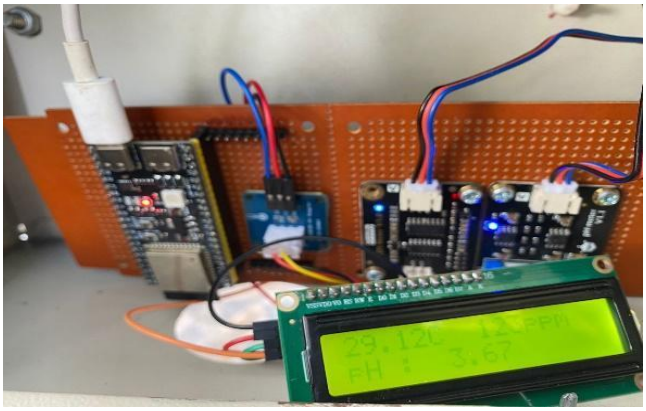

Figure 1. IoT equipment with four sensor measurements displayed on LCD

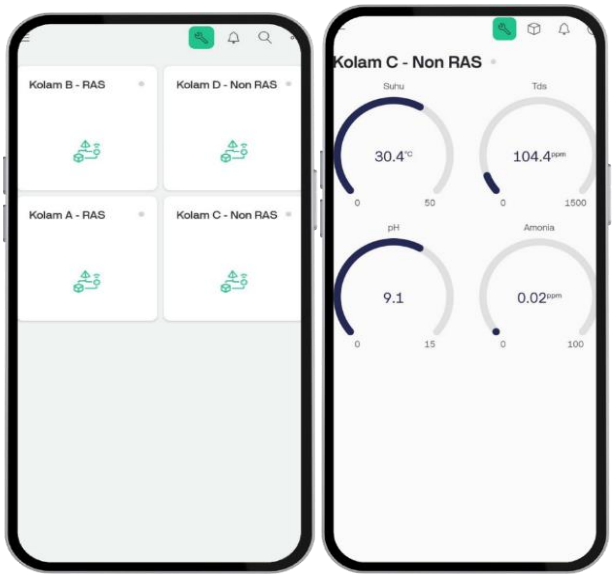

Figure 2. *Monitoring view* on a *smartphone*

The testing of water quality monitoring was conducted through reading 2 types of ponds, i.e. fish ponds without a recirculation system and fish ponds with a recirculation system. Testing results of IoT system sensors and manual water quality monitoring equipment were compared. The parameters measured were water pH, water temperature, water total dissolved solution, and ammonia in the ponds. The comparison result of water quality monitoring between the manual and IoT systems can be seen in Table 1.

Table 1 Comparison of measurement results of the manual and IoT systems

Pond	Parameter	Manual	IoT
Non recirculation	Temperature (℃)	28,9	29
	pH	7,5	7
	Ammonia (ppm)	0	0,01
	TDS (ppm)	106	102
With recirculation	Temperature (℃)	29,4	28,87
	pH	6,6	6,40
	Ammonia (ppm)	0	0,01
	TDS (ppm)	109	107

Based on Table 1, the community service team successfully created an IoT system and received data from sensors. As can be seen in Table 1, the results of manual measurement and IoT-based measurement do not show a significant difference. The water quality shown was safe. According to SNI (2014), good water quality for catfish farming is with a temperature of 25°C-30°C, pH 6,5-8, and ammonia <0,01

Testing the accuracy of water quality sensor equipment based on IoT applied to catfish farming ponds shows a satisfying result for every measured parameter. The accuracy of the measurement result of the equipment can be seen in Table 2. A temperature sensor having the highest accuracy of 99% shows that this sensor can measure water temperature precisely and consistently. pH sensor results in 97% accuracy, showing high accuracy in measuring water acidity. The ammonia sensor has an accuracy of 80%, which is still within the tolerance limit for detecting ammonia but needs more calibration for increasing accuracy. TDS (Total Dissolved Solids) sensor achieves 93% accuracy, showing the sensor ability to measure dissolved substances with good accuracy. In general, the measurement result shows that IoT based sensor system is reliable for monitoring the water quality of the catfish pond in real time, delivering accurate data to farmers for better water quality management.

Table 2. Accuracy of water quality sensors based on IoT on catfish farming ponds of Pokdakan Bintang Rosela Jaya

No	Sensor Type	Sensor Accuracy
1	Temperature	99%
2	pH	97%
3	Ammonia	80%
4	TDS	93%

Technical assistance for Internet of Things (IoT) based Technology Implementation

Technical assistance was carried out by the community service team, which consists of academic staff and students, regarding the use and maintenance of IoT IoT-based system, including sensor calibration, so they can measure accurately, including water quality monitoring in real-time, and controlling water circulation. IoT technology is expected to ease the fish farming process by increasing efficiency, reducing disease risk, and optimizing fish growth. Students, along with academic staff, assisted the community partner in installing IoT equipment in ponds, integrating the system with the Internet, and connecting to a smartphone application that is used to monitor water quality in real time.

The assistance session continued with a simulation of water quality monitoring using IoT equipment. Farmers were taught how to read measuring results through application, and to understand what action needs to be carried out based on received data (Figure 3a). In this activity, the team also conducted scheduled monitoring for evaluating system effectiveness and giving technical support if a problem exists in operation. Besides that, the partner was also given knowledge about practical disease detection for catfish and its treatment (Figure 3b).

Figure 3. a) Assistance on usage and maintenance of IoT; b) Practice detecting diseases in catfish

Evaluation

Evaluation of the assistance program of IoT technology implementation on Recirculating Aquaculture System (RAS) on water quality monitoring was conducted by pre-test and post-test (Figure 4). Based on the evaluation result, there is a significant increase in participant understanding. The pre-test average was 60, which then increased to 73 on the post-test.

This increase showed that participants understood the basic concept and implementation of IoT technology in catfish farming, especially in the water quality monitoring aspect. IoT technology implemented in the RAS system enables critical parameters monitoring, such as temperature, pH, ammonia, and *Total Dissolved Solids* (TDS) in real-time. This is very important because good water quality will affect fish health, reduce fish risk, and optimize fish growth. RAS-based farming provides several benefits, such as the increase of pond management efficiency, the reduction of chemical substance usage, and early detection of changes in environmental conditions that can endanger the fish. With this assistance, the aquaculture sector in Pringsewu regency is expected to be more competitive and adopt the latest technology innovation to increase productivity and competitiveness in the national fish market.

The use of sensor technology has proven to increase monitoring effectiveness, help farmers in faster decision making, and minimize harvest failure risk (Ubina & Cheng, 2022; Gladju et al., 2022). Other research by Ahmed &Tuchini (2021) has also shown that IoT integration in the RAS system can reduce the operational cost and increase harvest results significantly.

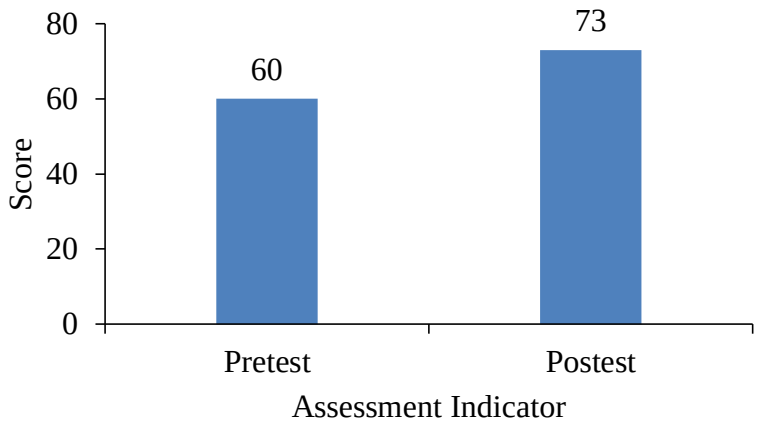

Figure 4. Evaluation of technical assistance using *pre-test* and *post-test*

Conclusion

From the result of the assistance of Internet of Things (IoT) technology implementation based on Recirculating Aquaculture System (RAS) on catfish farming in partner Pokdakan Bintang Rosela Jaya, it can be concluded that this program has a positive impact on the increase of knowledge and skill of farmers in managing pond water quality. The increase of pre-test score from 60 to post-test score of 73 shows an increase in partner understanding of IoT technology. This program successfully educates partners in using sensor-based technology; thus, they can adopt farming methods that are more efficient and environmentally friendly. With the success of this program, the aquaculture sector in Pringsewu Regency is expected to grow and innovate continuously, and be able to contribute to the increase of competitiveness of fish products at the national level.

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