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Revitalizing shrimp cultivation in Kolaka Regency, Southeast Sulawesi through IoT water quality monitoring to increase productivity

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ABSTRACT

This paper describes a community empowerment program by implementing Internet of Things (IoT) Water Quality Monitoring technology to encourage innovation and increase productivity in shrimp cultivation. Collaboration between Muhammadiyah University of Kendari, Ahmad Dahlan University, and local farmers has resulted in the latest solution to optimize shrimp pond management. This empowerment involves several stages, from identifying water quality problems to implementing IoT monitoring infrastructure in the field. First, through intensive discussions, critical issues faced by farmers were identified. The main problem in shrimp cultivation is the limited technology to monitor water quality, which causes shrimp seed mortality to be relatively high (10%). Based on these findings, the development team from Ahmad Dahlan University designed and implemented a solution in the form of IoT Water Quality Monitoring. Furthermore, the Muhammadiyah University of Kendari held intensive training and workshops to increase farmers' understanding of data interpretation and tool operation. The workshop lasted for three days, which successfully improved farmers' practical skills and increased optimism regarding increasing shrimp production. The final stage of this empowerment involves installing IoT Water Quality Monitoring infrastructure at identified shrimp farming locations. In conclusion, implementing this technology significantly positively impacts shrimp cultivation productivity and farmer welfare. Recommendations for further development and wider dissemination of information provide a basis for improving sustainability and efficiency in the local fisheries sector.

KEYWORDS
Community empowerment
Kosabangsa program
Internet of things
Shrimp production
Water quality monitoring

1. Introduction

Indonesia has earned a reputation as one of the world's leading shrimp producers, with shrimp exports being an essential contributor to the country's foreign exchange earnings [1], [2]. 2023, shrimp production will reach 1.097 million tons, while an ambitious target is set to reach 2 million tons by 2024 [3]. According to data, shrimp tops as the leading commodity in Indonesian fisheries exports, recording an export value of 2.16 billion US dollars in 2023 [4].

The government pays serious attention to the development of shrimp cultivation by implementing revitalization policies and opening up new land in various regions. To support the success of this government target, various programs to empower shrimp cultivation farmers are important. Examples of the success of this approach also occur in several other countries [5]–[7]. Southeast Sulawesi is one of the provinces that is the main focus for shrimp farming development, especially with Kolaka Regency designated as an area emphasized in shrimp cultivation. Therefore, efforts to increase shrimp productivity

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in this region significantly support and strengthen the fisheries sector. Collaboration between the government, farmers, and research institutions can help achieve shrimp production targets to support the sustainability of the fisheries sector and contribute to the national economy [8]–[10].

With the target of increasing shrimp production, it is essential to pay attention to sustainable cultivation practices and environmental balance, shrimp health, and farmer welfare. Apart from that, reasonable management efforts are also needed to overcome potential problems such as shrimp diseases, water quality, and other environmental impacts [2], [11], [12]. Most shrimp cultivation uses tarpaulin ponds. From discussions with shrimp cultivation farmers in Kolaka, it is known that the main problem is maintaining water quality. The main problem in shrimp cultivation is the limited technology to monitor water quality, which causes shrimp seed mortality to be relatively high (10%). Several times, it was found that shrimp deaths occurred due to delays in obtaining water quality information from the laboratory. This condition greatly influences production and business success. Given this problematic situation, adopting sustainable farming practices, monitoring shrimp health regularly, and maintaining pond water quality is essential [7], [13].

One technology that can be used to monitor water quality is IoT (Internet of Things), which can monitor parameters such as pH, salinity, dissolved oxygen, Total Dissolved Solids (TDS), and temperature [14], [15]. This technology is known as IoT Water Quality Monitoring. IoT technology enables real-time monitoring of water quality so that shrimp farmers can quickly detect changes in water parameters and take appropriate action. Real-time data on these parameters helps optimize feeding schedules, reduces the risk of overfeeding, and increases feed efficiency [14], [16]. Additionally, data collected from IoT systems can be used for long-term analysis. Farmers can make better decisions to improve shrimp farming overall by understanding trends and patterns in water quality data. Utilizing IoT Water Quality Monitoring is a valuable tool in increasing the efficiency and sustainability of shrimp farming by providing accurate and fast information regarding pond water quality.

By paying attention to the problems of shrimp cultivation farmers in Kolaka and the potential of IoT to help manage water quality, this community empowerment program aims to explain the level of optimism of shrimp cultivation farmers in using IoT as a tool to help reduce shrimp mortality rates due to poor water quality. The long-term impact is increasing national shrimp productivity with the use of technology. Therefore, the primary objective of this research initiative is to revitalize shrimp cultivation in the Kolaka Regency, Southeast Sulawesi, by implementing IoT Water Quality Monitoring.

2. Conceptual Foundation

The conceptual foundation of the empowerment program is rooted in the belief that the synergy between technology, community empowerment, and sustainable collaboration can significantly enhance the productivity and resilience of shrimp farming, laying the groundwork for a more efficient and sustainable aquaculture industry. The empowerment program was grounded in the fundamental concept of empowering shrimp farmers through integrating IoT technology for water quality monitoring in aquaculture. The following conceptual pillars provide the foundation for the program. The primary concept revolves around integrating cutting-edge IoT technology into the traditional practices [14], [16] of shrimp farming. This app uses sensors to monitor crucial water quality parameters, such as pH, temperature, salinity, dissolved oxygen, and TDS [12], [17], [18]. This integration aims to enhance precision, efficiency, and real-time data accessibility in aquaculture management. The program was built upon empowering shrimp farmers by providing them with the knowledge, skills, and tools needed to effectively utilize IoT for water quality monitoring. Capacity-building activities, including training programs and workshops, are designed to enhance the farmers' understanding of technology, enabling them to make informed decisions and optimize their farming practices.

A key concept involves fostering collaboration within the shrimp farming community. The program acknowledges the importance of creating a network where farmers can share experiences, insights, and best practices [1], [19], [20]. Establishing online communities facilitates peer-to-peer learning, support, and the exchange of valuable information, contributing to a collective effort to improve aquaculture practices. The program recognizes the significance of aligning with governmental and institutional efforts to promote sustainability [8], [9]. Collaboration with local government, as seen in coordination with Towua village in the Kolaka Regency, seeks to integrate the empowerment program into existing

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community development initiatives. This alignment ensures financial and infrastructural support for the sustainability of the implementation of IoT technology.

The commitment to constant improvement and innovation is central to the conceptual foundation. The program acknowledges that technology evolves, and ongoing efforts are needed to stay current. Regular updates, feedback mechanisms, and partnerships with external entities, including technology companies and research institutions, contribute to continuously enhancing the IoT water quality monitoring system. The conceptual framework emphasizes integrating education and research activities [6], [7], [19]. By involving universities such as Muhammadiyah University Kendari, the research focuses on practical applications and contributes to academic knowledge. This integration supports the development of sustainable practices through student involvement, internships, and community service.

3. Method

3.1. Activity Context

This community empowerment program was implemented as an implementation of the Kosabangsa program from the Ministry of Education, Culture, Research and Technology of the Indonesian Republic. Muhammadiyah Kendari University and Ahmad Dahlan University carry out the performance of this program. The program is implemented in Kolaka Regency, one of the regencies the government prioritizes. Specifically, this activity was carried out in Towua Village, Kolaka Regency (https://www.google.co.id/maps/@-4.148828,121.483511,12z?entry=ttu) in Southeast Sulawesi, where 52.35% of the area is dedicated to shrimp and fish cultivation. The cultivation pond covers an expansive area of 585.69 hectares, predominantly utilized for cultivating milkfish and shrimp. Issues have been observed in the Koperasi Serba Usaha (KSU) Tambak Berkah Towua. Fig. 1 shows the community empowerment implementation team at the partner's shrimp pond location.

Fig. 1. Kosabangsa Program Implementation Team in Shrimp Farms

3.2. Empowerment Stages

Community empowerment programs are carried out in certain stages to ensure successful achievement of goals [8], [19]. The following are the stages of empowering shrimp farming farmers in utilizing IoT Water Quality Monitoring:

- Identification of Problems of Shrimp Cultivation Farmers: Identify the problems shrimp cultivation farmers face related to pond water quality. It includes such issues as shrimp disease, water temperature fluctuations, unstable salinity, or other water parameters that can affect shrimp growth and health.
- IoT Technology Development: Design and develop an IoT Water Quality Monitoring system that suits the needs of farmers and environmental conditions in shrimp ponds. This technology must be able to measure and convey real-time data related to water parameters such as pH, salinity, dissolved oxygen, Total Dissolved Solids (TDS), and temperature.

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- Training and Workshops Implementation: Conducting training and workshops for shrimp cultivation farmers to understand the use and benefits of IoT Water Quality Monitoring technology. It includes an understanding of data interpretation, IoT device operation, and actions that can be taken based on monitoring results.
- Establishment of Monitoring Infrastructure: Install IoT monitoring infrastructure at identified shrimp farming locations. This infrastructure includes installing sensors, IoT devices, and monitoring devices connected to a central system. Make sure this infrastructure can convey data in real time and can be easily accessed by farmers.

3.3. Tools and Instruments

IoT technology was developed in accordance with the characteristics of water quality parameters in shrimp cultivation ponds. Fig. 2 presents the schematic diagram of the IoT-based Smart Water Quality application. The chart shows the four sensors and their respective probes connected to the Arduino board.

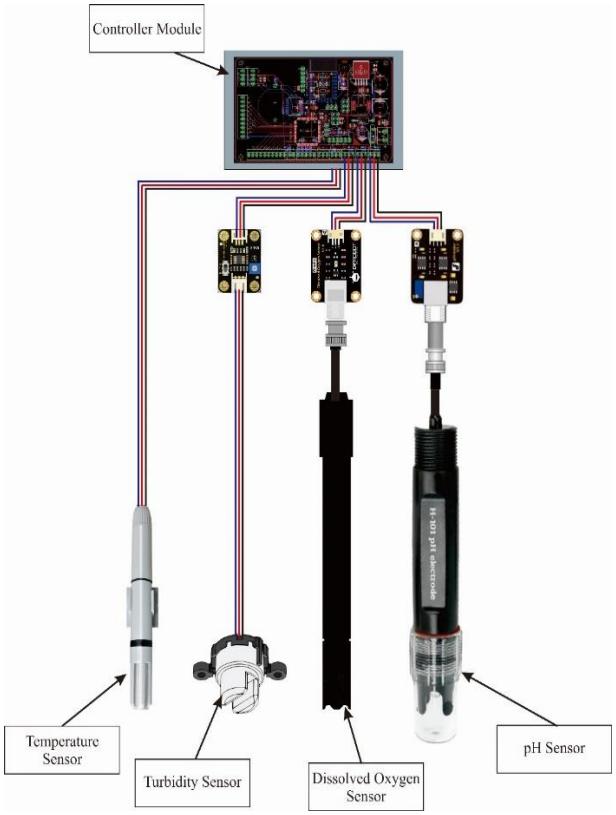

Fig. 2. Schematic of IoT-based Smart Water Quality Monitoring

IoT specifications contain sensors encompassing conductivity, pH, oxygen level, turbidity, and water temperature; contactor relays; 1 HP, 750W, 9A capacity aeration; an Android-based smartphone, Android application, and Arduino Uno processor.

4. Results and Discussion

4.1. Identifying Problems of Shrimp Cultivation Farmers

Shrimp farming farmers often face serious challenges related to water quality in their ponds. Problem identification includes critical issues, such as shrimp diseases that can spread quickly, uncontrolled water temperature fluctuations, salinity instability, and other water parameters that significantly impact shrimp growth and health.

Mr. ZKR, a farmer, expressed his experience, stating that he once faced a situation where shrimp suddenly died and floated. To overcome this problem, the pond water was taken to a laboratory for analysis, but the results took two days. It causes many shrimp to die before the laboratory results are

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received. Another farmer, Mr. WAN, added his perspective by stating that farmers often need more adequate tools to monitor water quality directly. Therefore, they can only rely on guesses regarding the water quality in the pond. In tarpaulin ponds, monitoring salinity and temperature is crucial, and the need for tools that can provide information quickly and accurately is increasingly urgent. Intensive discussions between shrimp cultivation experts from the Muhammadiyah University of Kendari and shrimp farmers resulted in an in-depth understanding of water quality parameters crucial to controlling shrimp cultivation. Some main parameters agreed to be the main focus include dissolved oxygen, temperature, pH (acidity level), and Total Dissolved Solids (TDS).

The emphasis on these parameters is based on the understanding that dissolved oxygen plays an essential role in shrimp respiration and optimal growth. Stable water temperature is the key to preventing fluctuations that can cause stress to shrimp. pH balance is needed to support biochemical processes in the shrimp body, and TDS reflects the amount of dissolved solids that can affect water conditions. The results of this discussion are also clearly conveyed to farmers as concrete and implementable solutions. Providing a better understanding of controlling and monitoring these parameters has helped farmers optimize water conditions in their shrimp ponds. Alignment between experts and farmers in determining these critical parameters is the basis for providing more effective and targeted solutions [7], [8] to increase the success of shrimp cultivation.

4.2. IoT Technology Development

The next step after discussions with shrimp cultivation farmers was the development of IoT Water Quality Monitoring by a team from Ahmad Dahlan University (See Fig. 3). This product was designed based on specifications obtained from these discussions. The sensors used in this tool are selected from industrial quality to ensure accuracy and robustness in diverse fishing environments. To ensure the quality and accuracy of the equipment, the team involved a testing institution, namely PT. ADI Multi Calibration (http://lku.uad.ac.id/tentang-pt-amk) [7], in carrying out calibration tests. The aim was to ensure that the sensors installed in the tool provide accurate and consistent measurement results.

Fig. 3. IoT-based Smart Water Quality Monitoring

The tool that has been successfully developed allows farmers to monitor water quality parameters in real time. The information obtained can be accessed easily via the site http://www.watermonitor.iotmu.id, which can be accessed via smartphone (See Fig. 4 for the display). Thus, farmers have direct access to critical data parameters, enabling them to take quick and appropriate action in managing their shrimp farms. This technology has similarities to similar IoT developed by other researchers [14], [15]. It's just that this product is focused on being able to monitor water quality in shrimp ponds which has threshold values for each specific parameter. In addition, this site also provides the option to download data in Excel format and allows farmers to carry out time series analysis. With this feature, farmers can track changes in water quality parameters over time, helping them make better decisions to improve their shrimp farming conditions.

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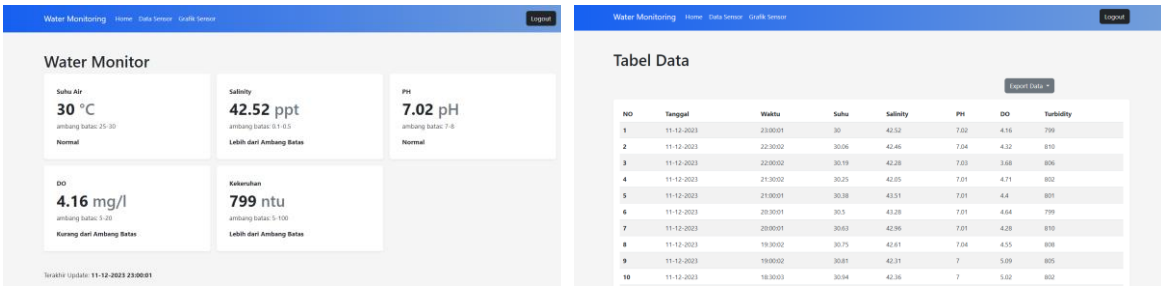

Fig. 4. Display of water quality parameter information on the web

4.3. Training and Workshop Implementation

Increasing the skills and knowledge of shrimp cultivation farmers is an important key to the success and sustainability of community empowerment. This issue is relevant to other studies in various community ones [1], [8], [9]. With IoT Water Quality Monitoring having been developed, the team from Muhammadiyah Kendari University and Ahmad Dahlan University continued with training and workshop activities for shrimp pond management partners. This activity was carried out over three days, from 10 to 12 December 2023. The workshop was designed to increase farmers' understanding of data interpretation, operation of IoT devices, and actions that can be taken based on monitoring results. During this training activity, farmers gain in-depth knowledge about reading and interpreting data produced by IoT Water Quality Monitoring. They also had the operational skills necessary to use these IoT devices effectively. Additionally, training includes an understanding of steps that can be taken to address potential problems identified through monitoring. Fig. 5 shows the training and workshop situation for using IoT Water quality monitoring at a location with 12 participants.

Fig. 5. Training and workshop atmosphere for using IoT

The results of this training and workshop were very positive. Shrimp farmers have improved their practical skills in using technology and feel more confident about increasing shrimp production. This training provides a strong foundation for implementing more innovative and more effective farming practices, which can help optimize shrimp pond conditions and reduce risks related to water quality. By increasing understanding and skills, the shrimp farming industry in the region can grow more sustainably.

Statements from Mr. ZKR, Mr. WAN, and Mr. BUD reflect the positive impact that has been felt and the optimism that has grown after implementing IoT Water Quality Monitoring. Mr. ZKR admitted that this tool was very helpful in increasing the productivity of shrimp ponds. He highlighted the importance of water quality in shrimp cultivation and believes that the successful implementation of this technology can attract the interest of other shrimp farmers. Mr. WAN emphasized that with this tool, farmers no longer need to worry about regulating water quality. This finding shows that this technology provides confidence and comfort for farmers in managing their shrimp ponds. Mr. BUD, while showing optimism regarding the effectiveness of the equipment, also asked whether similar technology could be applied to cultivating milkfish ponds in his family. Such demand reflects the potential for further development of this technology for application in producing various fisheries.

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Overall, the positive responses from these farmers indicate that IoT Water Quality Monitoring is not only an effective technological tool but can also be a catalyst for increasing sustainability and efficiency in shrimp farming and has potential applications in other aquaculture.

4.4. Establishment of Monitoring Infrastructure

The final stage of this community empowerment activity involves installing the equipment and ensuring optimal functionality. The team installed IoT monitoring infrastructure at previously identified shrimp farming locations (See Fig. 6).

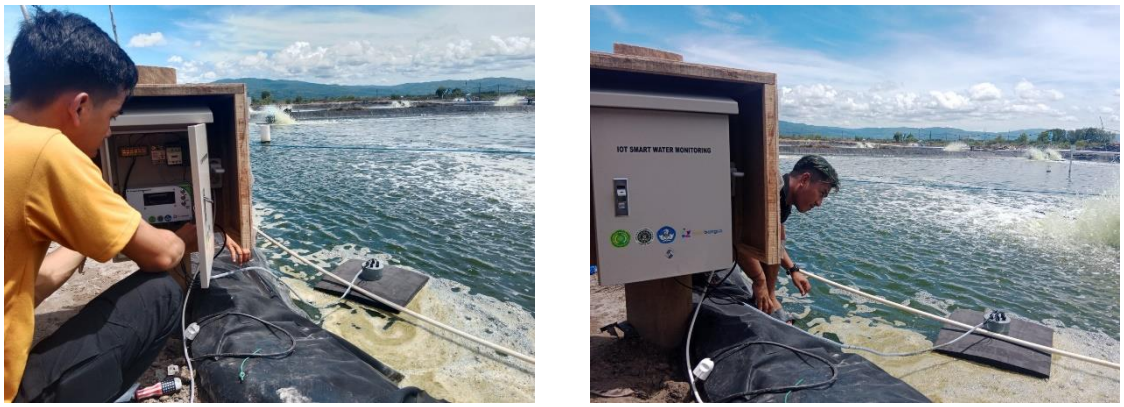

Fig. 6. Installation of IoT-based Smart Water Quality Monitoring in shrimp ponds

This process includes the installation of sensors, IoT devices, and monitoring devices connected to a central system. This infrastructure was designed to provide real-time monitoring of water quality parameters in shrimp farms. Installing sensors and IoT devices aims to collect accurate and up-to-date data while monitoring devices ensure that farmers can easily access this information. The success of this stage is highly dependent on the reliability and effectiveness of the infrastructure implemented. Ensure all components function as they should and can transmit data efficiently to the central system. Ease of access for farmers is also an essential factor, ensuring that they can utilize the information provided by IoT Water Quality Monitoring in the day-to-day management of their shrimp farms. This activity has been carried out successfully, and farmers can monitor all water quality parameters. The success of equipment installation and subsequent use also depends on farmers' acceptance of the technology. In many cases, the level of technology acceptance is an important variable in the successful implementation of technology [20]–[22] including IoT Water Quality Monitoring.

The results of implementing smart water monitoring align with the findings of previous research conducted by Ref. [23], who developed a similar device focusing on pH and temperature sensors. This research indicated that using only these two types of sensors could enhance the results of freshwater fish farming. This alignment establishes a foundation to validate the effectiveness of the smart water monitoring concept in aquaculture. Another study by Ref. [17], focusing on shrimp cultivation using salinity and temperature sensors, also demonstrated increased shrimp productivity. By combining the outcomes of both studies and implementing smart water monitoring technology equipped with a more comprehensive set of sensors, it is anticipated that shrimp farming productivity can experience a more significant improvement. The integration of additional sensors, such as dissolved oxygen and TDS, from the findings of this research can provide a more holistic understanding of water conditions, enabling farmers to take more precise and effective actions in shrimp pond management. Thus, this technology has the potential to be a comprehensive solution for enhancing productivity and efficiency in shrimp farming.

4.5. Program Sustainability

Several steps and strategies can be implemented to ensure the empowerment program's sustainability and that shrimp farmers continue to use IoT in water quality monitoring. In the initial implementation of this empowerment program, Muhammadiyah University Kendari has coordinated with the Towua village government in the Kolaka Regency to incorporate ongoing training for shrimp cultivators into the village fund program. The Secretary of the Village Head conveyed the commitment from the village government during the mentoring program. Continuing education and training for shrimp farmers may include updates on the latest technology, maintenance of IoT devices, and optimal strategies for utilizing the tools.

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Furthermore, online monitoring of pond water quality data allows all members of the shrimp farming community to learn from each other by sharing data and information online. The high level of information technology proficiency, especially with smartphones, among pond managers facilitates the formation of an online community (e.g., WhatsApp Group) where farmers can share experiences, ask questions, and provide solutions related to IoT use. Through continuous communication, they can continue to receive support and inspiration from fellow farmers. The current community has also received guidance in feed management from a national feed company. Existing relationships with the pond community allow for collaboration with other external entities such as technology companies, research institutions, or non-profit organizations that can provide technical support, maintenance assistance, or additional resources to ensure the sustainability and development of technology.

Muhammadiyah University Kendari has supported the sustainability of this partnership by incorporating pond manager mentoring activities into student internship programs and sustainable community service managed by the Research and Community Service Institution. By implementing these strategies, it is expected that this empowerment program will evolve into a sustainable initiative that supports the sustainability of shrimp farming and the utilization of IoT technology in water quality monitoring.

4. Conclusion

Community empowerment activities through developing and implementing IoT Water Quality Monitoring in shrimp cultivation have had a significant positive impact. Shrimp farmers now have better access to water quality information on their farms, enabling them to make more timely and effective decisions. With the results of training and workshops, farmers' skills in using this technology have also increased significantly. In addition, the collaborative approach between Muhammadiyah Kendari University, Ahmad Dahlan University, and farmers has brought innovative solutions that suit the real needs of the fisheries sector. Implementing IoT Water Quality Monitoring increases the productivity of shrimp cultivation and creates the potential for further development in other aquaculture contexts. However, this community empowerment program has several limitations. Industrial-scale quality equipment still needs to be lowered. This condition will be an obstacle for farmers. The duration of the program has yet to effectively reach the successful application of technology. The results achieved are only at the level of technology acceptance. Some recommendations for program sustainability are as follows: 1) The University of Muhammadiyah Kendari needs to follow up on the commitment from the local village government by establishing a collaborative initiative program. The village fund can integrate a two-month internship program involving marine aquaculture students into the village development program. 2) The village government can advocate for the shrimp farming community regarding shrimp cultivation governance through collaboration with shrimp feed entrepreneurs who participate in community service responsibility programs. 3) Best practices gained from this community empowerment program can be expanded with the support of the local marine affairs office. The University of Muhammadiyah Kendari needs to initiate communication of these results with the department to support broader marine productivity.

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Declarations

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References

[1] Khairawati, W. Fuadi, E. Ayuzar, Nurainun, and Rahmaniar, "Empowerment Of Tambak Farmers Groups In Community Economic Development In The Village Padang Sakti," *International Review of Practical Innovation, Technology and Green Energy (IRPITAGE)*,, vol. 03, no. 03, pp. 99-106, Nov. 19, 2023. [Online]. Available at: https://radjapublika.com/index.php/IRPITAGE/article/view/1294.

[2] C. Venkatrayulu, "Studies On Socio-Economic Profile, Problems And Constraints Of Shrimp Farmers In Nellore District Of Andhra Pradesh, India," *ASIAN J. Sci. Technol.*, vol. 10, no. 06, pp. 9371–9735, 2019. [Online]. Available at: http://www.journalajst.com.

[3] D. Margianto, "KKP is Ready to Collaborate with Other Ministries/Institutions to Boost Shrimp Production in 2024," *Kementerian Kelautan Dan Perikanan Republik Indonesia*, 2023. [Online]. Available at: https://kkp.go.id/artikel/58639-kkp-siap-berkolaborasi-dengan-k-l-lain-genjot-produksi-udang-di-2024.

[4] B. L. Rahadyarini, "Measuring Shrimp Production Achievements," *Seafood Media Group - Worldnews*, 2023. [Online]. Available at: https://seafood.media/Fis/Worldnews/worldnews.asp?.

[5] E. D. Macusi, D. E. P. Estor, E. Q. Borazon, M. B. Clapano, and M. D. Santos, "Environmental and Socioeconomic Impacts of Shrimp Farming in the Philippines: A Critical Analysis Using PRISMA," *Sustainability*, vol. 14, no. 5, p. 2977, Mar. 2022, doi: 10.3390/su14052977.

[6] R. Ilham, S. Sudarmiatin, and L. W. Wardana, "Social Entrepreunership In Fish Farming," *Int. J. Sci. Technol. Manag.*, vol. 4, no. 6, pp. 1699–1702, Nov. 2023. [Online]. Available at: https://www.ijstm.inarah.co.id/index.php/ijstm/article/view/996.

[7] I. Sivaraman, M. Krishnan, and K. Radhakrishnan, "Better Management Practices for sustainable small-scale shrimp farming," *J. Clean. Prod.*, vol. 214, pp. 559–572, Mar. 2019, doi: 10.1016/j.jclepro.2018.12.172.

[8] J. Lucena, J. Schneider, and J. A. Leydens, "Engineering and Sustainable Community Development",. Cham: Springer International Publishing, p. 218, 2010, doi: 10.1007/978-3-031-79961-7.

[9] A. Gilchrist, "The Well-Connected Community",. Bristol University Press, p. 282, 2019, doi: 10.46692/9781447347880.

[10] M. Ledwith, "Community development (second edition): A critical approach",. Bristol University Press, p. 248, 2011, doi: 10.2307/j.ctt1t892fd.

[11] C. E. Boyd and A. A. McNevin, "Aerator energy use in shrimp farming and means for improvement," *J. World Aquac. Soc.*, vol. 52, no. 1, pp. 6–29, Feb. 2021, doi: 10.1111/jwas.12753.

[12] E. G. Bull, C. de L. da N. Cunha, and A. C. Scudelari, "Water quality impact from shrimp farming effluents in a tropical estuary," *Water Sci. Technol.*, vol. 83, no. 1, pp. 123–136, Jan. 2021, doi: 10.2166/wst.2020.559.

[13] F. Amelia, A. Yustiati, and Y. Andriani, "Review of Shrimp (*Litopenaeus vannamei* (Boone, 1931)) Farming in Indonesia: Management Operating and Development," *Int. Sci. J.*, vol. 158, no. May, pp. 145–158, 2021, [Online]. Available at: www.worldscientificnews.com.

[14] S. Pasika and S. T. Gandla, "Smart water quality monitoring system with cost-effective using IoT," *Heliyon*, vol. 6, no. 7, p. e04096, Jul. 2020, doi: 10.1016/j.heliyon.2020.e04096.

[15] A. J. Ramadhan, "Smart Water-Quality Monitoring System Based On Enabled Real-Time Internet Of Things," *J. Eng. Sci. Technol.*, vol. 15, no. 6, pp. 3514–3527, 2020. [Online]. Available at: https://alkafeel.edu.iq/public/ar/save_file/files/d25a3e83daeeede6c48fbc5c188972c5_.pdf.

[16] B. VeerasekharReddy, S. Sarath, J. Philip, U. S. Reddy, L. Naresh, and K. Tejaswini, "Water Quality Monitoring System using IoT and Cloud," in *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, Jun. 2023, pp. 1036–1042, doi: 10.1109/ICSCSS57650.2023.10169212.

[17] A. G. Orozco-Lugo *et al.*, "Monitoring of water quality in a shrimp farm using a FANET," *Internet of Things*, vol. 18, p. 100170, May 2022, doi: 10.1016/j.iot.2020.100170.

[18] V. Hukom, R. Nielsen, M. Asmild, and M. Nielsen, "Do Aquaculture Farmers Have an Incentive to Maintain Good Water Quality? The Case of Small-Scale Shrimp Farming in Indonesia," *Ecol. Econ.*, vol. 176, p. 106717, Oct. 2020, doi: 10.1016/j.ecolecon.2020.106717.

ISSN 1978-0524 (print) | 2528-6374 (online) Vol. 7., No. 3, December 2023, pp. 77-86

[19] M. R. Hasan, "Strengthening, empowering and sustaining small-scale aquaculture farmers' associations," no. February. FAO, p. 195, 2020, doi: 10.4060/ca7741en.

[20] I. Ulhaq, N. T. A. Pham, V. Le, H.-C. Pham, and T. C. Le, "Factors influencing intention to adopt ICT among intensive shrimp farmers," *Aquaculture*, vol. 547, p. 737407, Jan. 2022, doi: 10.1016/j.aquaculture.2021.737407.

[21] O. M. Joffre, J. R. De Vries, L. Klerkx, and P. M. Poortvliet, "Why are cluster farmers adopting more aquaculture technologies and practices? The role of trust and interaction within shrimp farmers' networks in the Mekong Delta, Vietnam," *Aquaculture*, vol. 523, p. 735181, Jun. 2020, doi: 10.1016/j.aquaculture.2020.735181.

[22] Q. T. K. Ngoc, B. B. Xuan, E. D. Sandorf, T. N. Phong, L. C. Trung, and T. T. Hien, "Willingness to adopt improved shrimp aquaculture practices in Vietnam," *Aquac. Econ. Manag.*, vol. 25, no. 4, pp. 430–449, Oct. 2021, doi: 10.1080/13657305.2021.1880492.

[23] N. Ya'acob, N. N. S. N. Dzulkefli, A. L. Yusof, M. Kassim, N. F. Naim, and S. S. M. Aris, "Water Quality Monitoring System for Fisheries using Internet of Things (IoT)," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1176, no. 1, p. 012016, Aug. 2021, doi: 10.1088/1757-899X/1176/1/012016.