Technological Adaptation of Aquaculture Practices in Sagñay, Camarines Sur: An Integrated Multi-Trophic Aquaculture (IMTA)-Based Assessment of Entrepreneurial Opportunities

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ABSTRACT

This study assessed the technological adaptation of aquaculture practices in Sagñay, Camarines Sur, with the objective of identifying entrepreneurial opportunities that enhance profitability and sustainability. It examined aquaculture practices in terms of hatchery and nursery management, feed and feeding systems, water quality monitoring, and production reporting systems. It also identified key environmental challenges, explored technological and entrepreneurial opportunities, and developed an Integrated Multi-Trophic Aquaculture (IMTA) adaptation manual.

The study involved 50 registered fisherfolk engaged in aquaculture operations, selected through purposive sampling to ensure relevant experience. Data were collected using structured questionnaires.

Findings revealed that technological adaptation was implemented to a great extent, particularly in feed and feeding systems, water quality monitoring, and production reporting systems, contributing to improved operational efficiency and cost management. However, hatchery and nursery practices were only moderately implemented, indicating gaps in early-stage production. Key challenges included water quality fluctuations, temperature variability, and limited adoption of advanced technologies, which affect production stability.

Based on the findings, entrepreneurial opportunities were identified in aquaculture diversification, IMTA adoption, seaweed integration, value-added processing, and cooperative-based marketing. The study concludes that strengthening technological adoption, enhancing environmental management, and promoting entrepreneurial innovation are essential to improving the competitiveness and sustainability of aquaculture enterprises. It recommends strengthening training programs, improving access to technology and financing, and supporting IMTA-based systems to promote resource efficiency and income diversification.

Keywords: technological adaptation; aquaculture entrepreneurship; Integrated Multi-Trophic Aquaculture (IMTA); profitability; sustainable aquaculture; fisher folks; Philippines; Sagñay, Camarines Sur.

Aquaculture has increasingly become a critical component of global food systems, particularly in response to the growing demand for sustainable and reliable sources of protein. As capture fisheries continue to decline due to overexploitation, environmental degradation, and climate-related pressures, aquaculture offers a viable pathway to support food security, economic growth, and livelihood development. The sector has evolved significantly through the adoption of improved production systems, technological innovations, and sustainability-oriented practices that aim to enhance efficiency while minimizing ecological impacts. In developing countries such as the Philippines, aquaculture plays a dual role in strengthening national food supply and providing income opportunities for rural and coastal communities. Consistent with these trends, aquaculture is now recognized as one of the fastest-growing food production industries globally, contributing to employment generation, rural development, and the stability of aquatic food systems (Garlock et al., 2024). In more developed contexts, such as the United States, the industry also supports domestic seafood production and regional economies, with over 1,500 aquatic species produced across freshwater and marine systems and approximately 22,000 jobs generated, particularly in coastal and rural areas.

Studies conducted in countries like Norway, China, and the United States have shown that the adoption of sustainable aquaculture technologies in terms of water recycling systems, eco-friendly feeds, and integrated multi-trophic aquaculture (IMTA) enhances production efficiency while reducing environmental impacts (Ahmed et al., 2021; FAO, 2022). These global developments serve as benchmarks for local fish farming initiatives, demonstrating the importance of integrating modern technologies with traditional practices to achieve long-term sustainability.

According to the Food and Agriculture Organization (FAO, 2020), sustainable aquaculture involves practices that maintain ecological integrity, promote social responsibility, and ensure economic viability. It emphasizes efficient resource utilization, responsible feed management, and the reduction of environmental impacts such as water pollution and habitat disturbance.

In the Philippines studies have underscored both the promise and the challenges of aquaculture development. (Briones et al. 2017) noted that aquaculture remains one of the fastest-growing food sectors in the country, contributing significantly to national fish production. However, the sustainability of this growth is often constrained by environmental degradation, poor waste management, and weak governance. Similarly, (Guerrero 2019) highlighted that small-scale fisher folks often struggle with limited access to credit and modern technology, making it difficult to adopt sustainable production systems.

At the community level, the success of aquaculture projects often depends on the involvement of local stakeholders and the availability of institutional support. Pomeroy, Parks, and Balboa (2006) emphasized the role of participatory management and local governance in sustaining aquaculture and fisheries resources in the Philippines. Meanwhile, Tacio (2021) found that government-led interventions, such as training programs and livelihood assistance, contribute to improved productivity and environmental awareness among fisher folks.

Aquaculture in the Philippines is a mainstay of the country's fisheries industry, supported by depleting capture fisheries confronted with overfishing, loss of habitats, and climate-related stressors (Tolentino-Zondervan et al., 2022). The geographical location of the country, extensive coastlines, and abundant freshwater make it possible to have a wide range of aquaculture activities, including tilapia and milkfish culture and shrimp and seaweed farming. Nevertheless, given its potential, the industry still has to deal with sustainability issues, especially in smallholder systems like those found in Sagñay, Camarines Sur. It is thus important to understand local context of aquaculture practices, limitations, and innovations in order to determine viable opportunities for sustainable development.

Among the most immediate issues facing Philippine aquaculture is climate change, which exacerbates threats from temperature variation, excessive rainfall, and salinity intrusion. These changes in the environment have direct implications on growth performance, water quality, and farm productivity as a whole (Talbot et al., 2024; Macusi et al. 2021) highlighted that aquaculture societies are extremely susceptible to climate-related risks, especially in riverine and coastal municipalities based on small-scale production. Sagñay, which is located in Camarines Sur, is not spared from these threats since its geographical location subjects local fisher folks to recurring typhoons, flooding, and sea temperature increases that disrupt the aquatic ecosystem equilibrium. Climate adaptability is therefore one of the top priorities for sustainable aquaculture in the area.

Biosecurity and infectious diseases also pose serious threats to fish farming livelihoods. Shrimp farming in the Philippines, for instance, has been consistently plagued by viral and bacterial diseases, which result in tremendous economic losses and increased susceptibility on the part of small farmers (Macusi et al., 2022). Milkfish and tilapia farms also suffer from disease problems associated with hatchery management, stocking levels, and improper husbandry techniques (Salayo et al., 2021). Lack of proper biosecurity systems and better access to disease-resistant fry leaves smallholder farmers with limited ability to control losses, further decreasing profitability. This underscores the need to enhance hatchery regulation, community-level biosecurity practices, and technical training of farmers.

Yet another structural barrier is dependence on imported or unreliable quality of aquaculture inputs, especially feeds and fry. (Salayo et al. 2021) emphasized the importance of autonomous fry supply chains since reliance on external sources not only increases expenses but also compromises production stability. Feed cost continues to be the greatest operational cost for smallholders, tending to exceed half of total costs of production (Guerrero, 2019). The condition is particularly dire for towns such as Sagñay, where fisher folks might not have access to quality inputs and credit facilities, further limiting farm productivity and competitiveness. Without enhanced input availability, a significant number of small farmers continue to be exposed to market fluctuations.

In spite of these challenges, there are opportunities to develop sustainable aquaculture. At the global level, cutting-edge systems like integrated multi-trophic aquaculture (IMTA) have demonstrated the ability to increase ecological efficiency by reusing nutrients, minimizing waste, and varying income sources. In the Philippines, positive integrated multi-trophic aquaculture IMTA demonstrations in southern Cebu have established that co-cultivating species like seaweeds, mollusks, and finfish are capable of increasing water quality as well as farm profitability simultaneously (Largo et al., 2016). In addition, life-cycle analysis of integrated multi-trophic aquaculture (IMTA) systems underscores the ability of such systems to reduce environmental loads while ensuring food security (Hala et al., 2024). Implementing such sustainable approaches in Sagñay may contribute to better local production systems and less ecological pressure.

Seaweed farming also offers strong complementarity with finfish culture. Seaweed aquaculture has been a long-established practice in coastal rural communities of the Philippines, earning export income and generating livelihood opportunities for small-scale households (Tahiluddin et al., 2023). Incorporating seaweed culture into fish farming systems can enhance resilience in farms, diversify incomes, and generate ecological functions including nutrient uptake. For Sagñay fisher folks, such strategies of diversification can be game-changing, diminishing dependence on monoculture systems and opening doors to inclusive aquaculture development.

The municipality of Sagñay, Camarines Sur, located along the eastern coast of the Bicol Region, is endowed with rich aquatic resources that are conducive to fish farming. Local fisher folks engage in aquaculture activities such as milkfish (Chanos chanos) and tilapia (Oreochromis niloticus) cultivation, which provide both subsistence and commercial value. Despite the industry's potential, many fisher folks in Sagñay face persistent challenges, including limited access to capital and technology, inadequate technical knowledge, environmental threats, and inconsistent institutional support. These constraints hinder the long-term sustainability and competitiveness of the local aquaculture sector.

The aquaculture in Sagñay portrays both challenges and opportunities in chasing sustainability. Climate threats, biosecurity issues, and input vulnerabilities challenge the resilience of smallholder farmers, but trends like integrated multi-trophic aquaculture (IMTA), seaweed inclusion, and more robust governance models provide avenues to sustainability. Local aquaculture practices in Sagñay, Camarines Sur, embody many of these national and international trends but also have specific dynamics that need localized examination. An organized analysis of the threats and opportunities in Sagñay's fish farming systems is hence crucial to guide policy, direct extension programs, and design interventions that advance resilient, inclusive, and sustainable aquaculture.

Research Objectives

This study aimed to assess the issues and challenges in realizing sustainable aquaculture in Sagñay, Camarines Sur, with a particular focus on local fish farming activities. It sought to determine the current status of aquaculture practices in terms of hatchery and nursery operations, feed and feeding systems, water quality monitoring, and production reporting systems. Additionally, the study aimed to identify the key environmental challenges affecting fishermen, including water quality fluctuations, temperature changes, and the application of new technologies in aquaculture production. It also explored technological opportunities available to fisherfolk, such as the adoption of Integrated Multi-Trophic Aquaculture (IMTA), seaweed integration, value-added processing, cooperative-based marketing, and sustainability technology adoption. Finally, the study proposed the technological adaptation of an Integrated Multi-Trophic Aquaculture (IMTA) manual to promote ecological balance and reduce waste.

Scope and Delimitation

This study examines the opportunities and challenges in promoting sustainable and innovative aquaculture in Sagñay, Camarines Sur, focusing on the application of innovative practices in local fish farming to support environmental, economic, and social sustainability. It seeks to understand the current practices, challenges, and opportunities experienced by fisher folks, as well as how these relate to their socio-demographic characteristics. The study is limited to aquaculture activities within the municipality and aims to provide insights that can enhance sustainability, improve livelihoods, and support local development initiatives.

Theoretical/Conceptual Framework

The present study is anchored on three complementary theories: Sustainability Theory, Tragedy of the Commons Theory, and Diffusion of Innovation Theory, which collectively guide the analysis of sustainable aquaculture practices in Sagñay, Camarines Sur. These theories provide a multidimensional understanding of how environmental balance, resource management, and technological adoption influence aquaculture development. Sustainability Theory emphasizes the integration of environmental protection, economic growth, and social equity; Tragedy of the Commons Theory highlights the risks of resource overuse and the need for collective management; while Diffusion of Innovation Theory explains how new technologies and practices are adopted within communities. Through their integration, the study offers a comprehensive framework for examining sustainable practices, community behavior, and technological advancement in aquaculture.

METHODOLOGY

The research methodology used in this study. It covered the research design, methods and procedures, respondents of the study, data analysis techniques, and ethical considerations.

Research Design

This study employed a descriptive research design using a quantitative approach. Data were gathered through structured questionnaires administered to fisher folks in Sagñay, Camarines Sur. Descriptive research is appropriate for documenting existing practices, perceptions, and socio-economic conditions of respondents (Creswell & Creswell, 2018). The use of structured questionnaires enabled the systematic collection of measurable data related to sustainable aquaculture practices, challenges, and opportunities, allowing for objective analysis and interpretation of the findings (McCombes, 2022).

Respondents/Participants of the Study

This study focuses on local fisher folks engaged in aquaculture in Sagñay, Camarines Sur, a coastal municipality with active fish farming practices. The respondents consist of 50 fisher folks who are directly involved in aquaculture production. Only those with at least two years of experience in freshwater or marine aquaculture are included to ensure sufficient knowledge of production processes, technological applications, and sustainability practices.

Purposive sampling is employed to select participants, with 50 respondents considered adequate for generating meaningful descriptive and exploratory insights. The inclusion criteria are as follows: (1) the respondent must be a local fisher folk in Sagñay, Camarines Sur; (2) must have at least two years of experience in aquaculture; (3) must be actively engaged in aquaculture operations; and (4) must be willing to participate in the study. These criteria ensure that respondents can provide reliable information on technological adaptation, farm management practices, and entrepreneurial opportunities in aquaculture.

Data Gathering Tools

The data gathered from the survey questionnaires will be organized, tabulated, and analyzed in accordance with the objectives of the study. Descriptive statistical tools such as frequency, percentage, mean, and standard deviation will be used to summarize the responses. These measures are appropriate for presenting patterns and trends related to aquaculture practices, environmental concerns, and the socio-economic profile of fisher folks in Sagñay, Camarines Sur. Frequency and percentage will describe the distribution of responses for categorical variables, while the mean and standard deviation will be used to interpret responses measured through Likert-scale items. These statistical treatments will help determine the level of practice, perception, and challenges experienced by the respondents.

Data Analysis Techniques

The results were presented in tabular form to ensure clarity and systematic organization of the data, with each table accompanied by a brief discussion of key findings in relation to the research objectives. These discussions highlighted patterns in aquaculture practices, sustainability challenges, and opportunities for technological adaptation among fisher folks in Sagñay, Camarines Sur. This structured presentation and interpretation of data provided both clear quantitative summaries and meaningful insights, forming a strong basis for drawing conclusions and recommending strategies, including the proposed technological adaptation of Integrated Multi-Trophic Aquaculture (IMTA) manual to promote ecological balance and reduce waste in aquaculture practices.

Ethical Considerations

This study was committed to upholding high ethical research standards in examining the technological adaptation of aquaculture practices among fisherfolks in Sagñay, Camarines Sur. Participation was entirely voluntary, and all respondents were provided with a clear explanation of the study's purpose, procedures, and their rights prior to data collection. Informed consent was obtained from all participants, ensuring that they understood their participation was optional and that they could withdraw at any time without penalty or negative consequences.

Confidentiality and anonymity were strictly maintained throughout the research process. Survey responses did not include personally identifiable information, and all data were securely stored and used solely for academic purposes related to the study. Only the researcher had access to the raw data, and findings were reported in aggregate form to protect the identities of the fisherfolk respondents.

Given that the study primarily utilized survey questionnaires related to aquaculture practices, special care was taken to respect participants' privacy and comfort, particularly when addressing production challenges, income-related concerns, and operational practices.

The researcher adhered to the principles of beneficence and non-maleficence, ensuring that the study posed minimal risk to participants, as it did not involve any invasive procedures and focused only on professional and livelihood-related information. The potential benefits of the study particularly in improving aquaculture practices, promoting sustainable technologies such as Integrated Multi-Trophic Aquaculture (IMTA), and identifying entrepreneurial opportunities were considered to outweigh any minimal risks involved.

The principle of justice was observed in the selection of respondents, as only registered and actively practicing aquaculture fisherfolks in Sagñay, Camarines Sur were included based on defined criteria, ensuring relevance and fairness in participation. The researcher further affirmed adherence to academic integrity by properly citing all sources using APA 7th edition guidelines. Plagiarism, data fabrication, and misrepresentation of findings were strictly avoided. Transparency was maintained throughout the research process, and no form of deception was employed.

Finally, while AI tools were occasionally utilized to assist in improving clarity and organization of the manuscript, all research decisions, data analysis, and interpretations remained the sole responsibility of the researcher.

RESULTS AND DISCUSSION

This chapter presents and discusses the results of the study on the technological adaptation of aquaculture practices among fisher folks in Sagñay, Camarines Sur. The findings are organized according to the specific objectives of the study and are presented in tabular form using mean scores and corresponding interpretations to describe the level of practice, challenges, and opportunities identified. The results are discussed thematically under three major themes: technological adaptation in aquaculture practices, environmental and climate-related challenges, and entrepreneurial and technological opportunities. Each table is followed by an in-depth narrative discussion written in PAILR form to provide analysis, implications, and recommendations supported by relevant and peer-reviewed literature.

Current Status of Aquaculture Practices in Sagnay Camarines Sur

The study examined the current status of aquaculture practices in Sagñay, Camarines Sur, focusing on hatchery and nursery management, feed and feeding systems, water quality monitoring, and production reporting. Findings revealed that hatchery and nursery practices are implemented at a moderate level, with operators relying heavily on traditional methods such as natural spawning and conventional fry sourcing, while advanced practices like disease screening are less frequently applied. In contrast, feed and feeding systems are practiced to a great extent, particularly through the use of commercial feeds, although monitoring feed consumption remains limited, indicating opportunities to reduce waste and improve efficiency.

Water quality monitoring practices are also carried out to a great extent, primarily through traditional observation methods such as assessing water color, odor, and clarity, while the use of scientific monitoring instruments remains minimal. Similarly, production reporting systems are widely practiced through manual recording; however, the lack of standardized logbooks or structured templates highlights gaps in data management. Overall, aquaculture in Sagñay demonstrates a high level of technological readiness, with stronger adoption in water quality monitoring and production reporting, but comparatively lower integration in hatchery and nursery management.

Based on these findings, the study concludes that while aquaculture operators show progress in adopting certain practices, there is still a need for more balanced and comprehensive technological integration. Recommendations include strengthening hatchery and nursery management through training, improving feeding efficiency and monitoring, enhancing water quality assessment using basic instruments, and promoting standardized or digital production reporting systems. Through coordinated efforts among local government units, the Municipal Agriculture Office, the Bureau of Fisheries and Aquatic Resources, and aquaculture extension workers, these interventions can improve productivity, sustainability, and overall farm management. Ultimately, these improvements support the development of more resilient and sustainable aquaculture systems in Sagñay, Camarines Sur.

Key Environmental challenges affecting fishermen in Sagnay Camarines Sur

The study identified key environmental challenges affecting aquaculture operators in Sagñay, Camarines Sur, particularly in terms of water quality fluctuations, temperature variability, fish stress and mortality, and pollution. Findings revealed that water quality fluctuations are highly challenging, with fish stress and mortality due to poor water conditions emerging as the most significant concern. Temperature changes, especially sudden increases during the dry season, are also experienced to a great extent, highlighting the vulnerability of aquaculture systems to climate variability. Similarly, fish stress and mortality remain major challenges, largely driven by poor water quality and limited access to preventive and treatment measures.

Pollution-related challenges further intensify these issues, with waste accumulation and declining water quality identified as critical factors affecting aquaculture production. Overall, these environmental challenges are experienced to a great extent, emphasizing the need for improved environmental management and adaptive strategies.

Based on these findings, the study concludes that aquaculture operators face significant environmental constraints that directly impact productivity and sustainability. To address these issues, it is recommended that practical and cost-effective interventions be implemented, including improved water quality monitoring, adoption of simple temperature management strategies, strengthening of fish health management practices, and implementation of basic waste management techniques. Through coordinated efforts among the Municipal Agriculture Office (MAO), the Bureau of Fisheries and Aquatic Resources (BFAR), and local aquaculture extension workers, these measures can enhance resilience, reduce risks, and promote more sustainable aquaculture practices in Sagñay, Camarines Sur.

Entrepreneurial Opportunities for fisher folks in Sagnay Camarines Sur

The study examined entrepreneurial opportunities for fisher folks in Sagñay, Camarines Sur, focusing on Integrated Multi-Trophic Aquaculture (IMTA), seaweed integration, value-added processing, cooperative-based marketing, and sustainable technology adoption. Findings revealed that IMTA offers significant opportunities, particularly in increasing income through multi-species production, while also contributing to environmental sustainability. Seaweed integration was identified as a viable complementary livelihood, especially in providing additional income during off-season periods, while value-added processing enhances the market value of aquaculture products despite limitations in access to facilities and equipment.

Cooperative-based marketing was also perceived as beneficial, particularly in improving bargaining power and market access through collective action. Meanwhile, the adoption of sustainable and eco-friendly technologies was recognized for its potential to improve long-term productivity and overall farm performance. Overall, entrepreneurial opportunities in aquaculture were perceived to a great extent, indicating that fisher folks are open to innovation and enterprise development as strategies for income stability and sustainability.

Based on these findings, the study concludes that aquaculture in Sagñay presents strong potential for entrepreneurship, supported by interconnected strategies that enhance productivity, market access, and environmental sustainability. To maximize these opportunities, it is recommended that local development programs promote IMTA adoption, support seaweed integration, improve access to value-added processing facilities, strengthen cooperative-based marketing systems, and encourage the use of sustainable technologies. Through coordinated efforts among local government units, fisheries agencies, and aquaculture stakeholders, these initiatives can transform opportunities into practical enterprise activities, ultimately improving livelihoods and fostering sustainable aquaculture development in Sagñay, Camarines Sur.

Technological adaptation of Intergrated Multi-Trophic Aquaculture (IMTA) based Manual to promote ecological balance and reduce waste.

The output of the study is the development of an Aquaculture Technology Adaptation Manual as a research-based and context-specific intervention designed to address the technological gaps, environmental challenges, and entrepreneurial opportunities identified among fisher folks in Sagñay, Camarines Sur. The manual is structured as an Integrated Multi-Trophic Aquaculture (IMTA)-based, step-by-step guide that translates the findings of the study into simple, practical, and actionable strategies suitable for small-scale aquaculture operators, emphasizing low-cost and easily adoptable technologies that can be integrated into existing systems without requiring advanced equipment or large capital investment. It aims to improve aquaculture productivity, promote environmental sustainability, enhance climate resilience, support livelihood diversification, and strengthen the technical knowledge and capacity of fishpond operators, fish cage operators, backyard aquaculture farmers, and fisher folk associations.

The manual specifically addresses identified gaps in hatchery and nursery management, environmental monitoring, and waste management by reinforcing existing practices such as water quality monitoring and record-keeping while introducing structured guidance on daily observation, temperature monitoring, regular water exchange, and natural filtration techniques. It incorporates IMTA principles through the integration of seaweeds and shellfish to absorb excess nutrients, reduce waste accumulation, improve water quality, and maintain ecological balance, while simultaneously creating additional income opportunities. Furthermore, the manual supports entrepreneurial development by presenting strategies such as IMTA adoption, seaweed integration, value-added processing, cooperative-based marketing, and sustainable aquaculture practices in a simplified and accessible format. Overall, it serves as both an independent guide for fisher folks and a training resource for local fisheries offices, agricultural extension workers, and aquaculture programs, thereby enhancing the practical application and community impact of the study.

Limitations of the Study

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As for the delimitations of this study, the focus is limited to aquaculture practices within Sagñay, Camarines Sur, excluding operations from neighboring municipalities to maintain consistency in local conditions and governance. The research includes only registered fisher folks engaged in fishpond, fish cage, and small-scale inland aquaculture, and does not cover other stakeholders such as traders, consumers, or policymakers, as their roles fall outside the scope of this study. Furthermore, the study does not involve technical or scientific measurements of environmental parameters, but instead emphasizes the experiences, practices, and perspectives of local fisher folks, recognizing that these insights are essential in understanding the practical challenges and opportunities in promoting sustainable and innovative aquaculture within the municipality.

CONCLUSIONS

This section summarizes the conclusions of the findings from the data gathered.

1. Aquaculture operators in Sagnay, Camarines Sur demonstrate varying levels of adoption across key operational practices, with stronger implementation in feed and feeding systems, water quality monitoring, and production reporting than in hatchery and nursery management. Hatchery and nursery practices are only moderately implemented, with operators continuing to rely on traditional methods such as natural spawning and conventional fry sourcing, while more advanced practices like disease screening remain less consistently applied, indicating gaps in biosecurity and quality control that may affect productivity and sustainability. Feed and feeding systems are practiced to a great extent, largely through the use of commercial feeds; however, limited attention to efficient feed management, particularly in monitoring feed consumption, suggests opportunities to improve utilization and reduce waste. Water quality monitoring is also highly practiced but remains primarily dependent on traditional and sensory-based methods, such as observing water color, odor, and clarity, with minimal use of monitoring instruments, highlighting the need for more accurate and scientific approaches. Production reporting systems are widely practiced through manual recording of daily activities, yet the absence of structured logbooks or standardized templates reflects weaknesses in data organization and management, limiting efficiency and informed decision-making. Overall, aquaculture practices in the area reflect a generally high level of technological readiness, with stronger adoption in monitoring and reporting functions, while hatchery and nursery management lag behind, indicating the need for a more balanced and comprehensive integration of technology across all aspects of operations.

2. Aquaculture operators in Sagnay, Camarines Sur face multiple environmental and operational challenges, with water quality fluctuations, temperature changes, fish stress and mortality, and pollution-related issues all experienced to a great extent. Water quality fluctuations emerge as a major constraint, with frequent occurrences of fish stress and mortality due to poor water conditions, while indicators such as changes in water color and turbidity are perceived as moderately challenging, highlighting the need for improved monitoring and management strategies. Temperature variability also presents a significant challenge, particularly with sudden increases during the dry season that expose the vulnerability of aquaculture systems to climatic conditions; although fish mortality due to temperature changes is less frequent, it remains a considerable concern, underscoring the need for adaptive and responsive environmental management. Fish stress and mortality are largely driven by poor water quality, and despite the relatively limited access to treatment and preventive measures, these issues continue to affect productivity, emphasizing the importance of strengthening fish health management and expanding access to preventive interventions. Pollution-related challenges further compound these issues, with waste accumulation and declining water quality identified as the most critical concerns; although disease risks linked to pollution are less emphasized, they remain significant, reinforcing the need for stricter environmental practices, improved waste management, and more sustainable aquaculture production strategies.

3. Aquaculture operators in Sagnay, Camarines Sur perceive strong entrepreneurial opportunities across various innovation and sustainability-driven strategies, with Integrated Multi-Trophic Aquaculture (IMTA), seaweed integration, value-added processing, cooperative-based marketing, and sustainable technology adoption all rated to a great extent. IMTA adoption stands out as a highly viable opportunity, particularly in increasing income through multi-species cultivation, while also offering ecological

benefits despite environmental sustainability being rated relatively lower. Seaweed integration further supports income diversification, especially during off-season periods, although market stability remains a moderate concern, indicating the need for stronger market linkages. Value-added processing provides significant potential to enhance product market value; however, limited access to processing facilities and equipment constrains its full utilization, highlighting an area for development support. Cooperative-based marketing strengthens bargaining power and improves market access through collective efforts, with resource sharing contributing to operational efficiency despite receiving less emphasis. The adoption of sustainable and eco-friendly technologies also presents strong opportunities, particularly in improving long-term productivity, while compliance with sustainability standards remains an important but less prioritized factor. Overall, entrepreneurial opportunities in aquaculture are widely recognized, with the relatively consistent perceptions across these areas indicating that they are interconnected and mutually reinforcing, reflecting operators' openness to innovation, enterprise development, and strategies that support income stability, environmental sustainability, and long-term livelihood growth.

4. The adoption of Integrated Multi-Trophic Aquaculture (IMTA) presents a highly favorable and viable strategy for aquaculture operators in Sagnay, Camarines Sur, as it is perceived to a great extent. The strong emphasis on income diversification and nutrient recycling highlights its potential to enhance profitability and improve resource efficiency. Although environmental sustainability is relatively less emphasized, it remains a significant benefit. Overall, the findings suggest that IMTA is an attractive and practical approach that can support increased productivity and sustainable aquaculture development.

RECOMMENDATIONS

The researcher recommended the following:

1. Aquaculture operators in Sagnay, Camarines Sur are encouraged to strengthen overall aquaculture practices by improving hatchery and nursery management through better fry health management, simple disease screening, acclimatization, and access to quality fingerlings with support from the Municipal Agriculture Office (MAO) and the Bureau of Fisheries and Aquatic Resources (BFAR). They should also enhance feeding management by adopting basic feed monitoring, feed budgeting, and the use of locally available supplemental feeds to reduce costs and improve efficiency. In addition, operators are encouraged to strengthen water quality monitoring by using basic test kits, following routine monitoring schedules, and maximizing shared resources and technical assistance from local agencies. Production reporting systems should likewise be improved through the use of simple and standardized logbooks or digital tools to support accurate record-keeping and informed decision-making. Overall, through continuous training, technical support, and collaboration with MAO, BFAR, LGUs, and extension workers, these practical and low-cost interventions can enhance technological readiness, improve farm management practices, increase productivity, and promote sustainable aquaculture development in the municipality

2. Aquaculture operators in Sagnay, Camarines Sur are encouraged to mitigate production challenges by strengthening water quality management through regular training, early detection of issues, and the use of simple monitoring tools and practical interventions such as aeration and water exchange. They should also adopt feasible temperature management strategies, including increasing pond depth, installing shade structures, adjusting feeding schedules, and monitoring temperature to reduce heat stress. In addressing fish stress and mortality, operators are encouraged to enhance fish health management by regularly monitoring key parameters, recognizing early signs of disease, applying basic biosecurity measures, and coordinating with local fisheries and veterinary services for timely intervention. Furthermore, pollution-related challenges should be minimized by improving waste management practices through proper feed rationing, use of feeding trays, regular waste removal, and simple treatment methods such as sedimentation or composting. Through continuous training and strong collaboration with the Municipal Agriculture Office (MAO), the Bureau of Fisheries and Aquatic Resources (BFAR), and extension workers, these practical and cost-effective strategies can reduce risks, improve fish survival, and promote sustainable aquaculture production

3. Aquaculture operators in Sagnay, Camarines Sur are encouraged to maximize entrepreneurial opportunities

by promoting the adoption of integrated multi-trophic aquaculture (IMTA) through pilot projects, training on simple system designs, and provision of financial and technical support to reduce risks and enhance income diversification. They should also explore seaweed integration as a complementary livelihood by participating in community-based production, improving post-harvest handling, and strengthening market linkages through cooperatives. In addition, value-added processing should be enhanced through the establishment of shared facilities, training on processing and food safety, and improved access to equipment and markets to increase product value and reduce losses. Strengthening cooperative-based marketing is also recommended to improve bargaining power, reduce costs, and ensure consistent product quality through collective action and institutional support. Furthermore, the adoption of sustainable and eco-friendly technologies should be promoted through training, demonstration projects, financial incentives, and easier access to certification to improve both productivity and environmental performance. Overall, through coordinated efforts in capacity-building, enterprise development, and market linkage support, these practical and accessible strategies can help transform aquaculture opportunities into sustainable and profitable ventures for small-scale operators.

4. It is It is recommended that local aquaculture development programs in Sagnay, Camarines Sur promote the adoption of integrated multi-trophic aquaculture (IMTA) through pilot demonstration farms that showcase its potential for income diversification and nutrient recycling, allowing aquaculture operators to better understand its practical benefits. These demonstration sites may serve as learning hubs where farmers can observe real-time applications of IMTA systems, particularly simple and cost-effective designs suitable for small-scale operators, such as integrating fish with seaweeds or filter feeders using existing farm structures. Training programs facilitated by the Municipal Agriculture Office (MAO), the Bureau of Fisheries and Aquatic Resources (BFAR), and aquaculture extension workers may focus on step-by-step implementation, system management, and maintenance to ensure that operators can gradually adopt IMTA practices with confidence. Additionally, financial and technical assistance may be provided through start-up support packages, subsidies, or cooperative-based schemes to help reduce initial investment risks and encourage wider participation among fisher folks with limited resources.

Furthermore, it is recommended that strong market linkages for IMTA products be developed through collaboration among local government units, fisheries agencies, cooperatives, and private sector partners to ensure stable demand and fair pricing for diversified aquaculture products. Establishing partnerships with local buyers, processors, and institutional markets may enhance product distribution and increase profitability, while cooperative-based marketing arrangements can help consolidate supply and improve bargaining power among small-scale operators. Regular coordination meetings, stakeholder consultations, and aquaculture trade events may also serve as platforms for strengthening networks, sharing best practices, and identifying emerging market opportunities related to IMTA production.

Finally, aquaculture operators are encouraged to adopt IMTA not merely as an alternative production method but as a sustainable operational framework that integrates economic, environmental, and social benefits into daily aquaculture practices. By incorporating IMTA principles into farm planning, resource utilization, and long-term business strategies, operators can reduce production risks, improve resource efficiency, and enhance ecological balance within their farming systems. Through continuous learning, collaboration, and gradual adoption of IMTA technologies, aquaculture stakeholders in Sagnay can strengthen their resilience, increase income opportunities, and contribute to the sustainable development of the local aquaculture industry.

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