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The Role of Shrimp Breeding Innovation in Improving Aquaculture Productivity and Fisheries Business Sustainability in Sumbawa, West Nusa Tenggara

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ABSTRACT

The aquaculture sector has come to be recognized as a key engine of both economic growth and seafood production worldwide. Shrimp farming in particular, and aquaculture in general, are major contributors to local livelihoods and food security in Sumbawa, West Nusa Tenggara, Indonesia. However, as this industry expands, it will have to contend with issues pertaining to productivity, sustainability of the environment, and the long-term viability of the fishing industry. Innovations in shrimp breeding have been implemented in the area to solve these problems. The various effects of these advances on aquaculture productivity and the long-term viability of Sumbawa's fishing enterprises are examined in this qualitative investigation. The results show how innovation, productivity, sustainability, and the particular socio-environmental setting of the area interact in a complicated way. Shrimp growth and disease resistance have increased thanks to selective breeding techniques, but genetic manipulation is still up for discussion. Sustainable feed methods are a viable way to lessen the impact on the environment. Effective disease management, together with market access and adherence to international quality standards, are critical components of a sustainable fisheries enterprise. This study promotes sustainable aquaculture methods and the long-term success of Sumbawa's fishing enterprises by offering useful insights and suggestions.

Keywords: *Shrimp Breeding, Innovation, Aquaculture, Fosheries, Sustainability, Sumbawa, West Nusa Tenggara, Indonesia*

1. INTRODUCTION

Aquaculture, including shrimp farming, plays a crucial role in meeting the growing global demand for seafood, contributing to food security and economic development. However, it faces several challenges, including environmental sustainability, productivity, and the long-term viability of fisheries businesses. Environmental sustainability is a significant concern in aquaculture[1]–[3]. The industry has contributed to environmental degradation, such as habitat destruction, water pollution, and ecological effects [4]. For instance, in Thailand, aquaculture production has significantly increased over the last few decades, contributing to socio-economic development. However, this industry has also contributed to environmental degradation [4]. Similar issues are likely to be faced in Sumbawa, Indonesia, given the similarities in the environmental and economic contexts of these regions. Productivity is another challenge in aquaculture. The adoption of best practices is crucial in meeting the growing demand for seafood. However, fish pond productivity was found to be significantly lower for adopters below the median index in a study conducted in Kenya [5]. This suggests that there is a need for better adoption and implementation of best practices to improve productivity.

The long-term viability of fisheries businesses is also a concern. Aquaculture has grown rapidly, and its contribution to the global seafood supply has exceeded the landings from the sea [6]. However, issues such as technology access and adoption, workforce transformation, and adjusting

to the global value chains need to be addressed to ensure the long-term viability of these businesses [6].

To address these challenges, effective management strategies are urgently needed. Innovative and practical solutions that rely on diverse technology inputs and smart market-based management approaches can be the basis for viable long-term solutions for the future [4]. Research and development institutions can help by leveraging their resources and expertise in motivating a review of the existing policies and knowledge transfer to the farming communities to shape the development of aquaculture along the sustainability pathways [6]–[9].

The rapid expansion of shrimp farming in Sumbawa has indeed contributed to local economic growth, but it has also raised concerns about environmental impact and the sustainability of fisheries businesses [10], [11]. To address these challenges, the region has seen the emergence of innovative shrimp breeding practices and technologies [12]. One such innovation is the application of high technology from China in shrimp farming, introduced by a company under the Limp Shrimp Organization (LSO) in Sumbawa. This company, which has been consistently applying this technology since 2000, has a diverse team of professionals, including engineers, architects, managers, doctors, and aquaculture professionals. The goal of this initiative is to create jobs and increase the income of the local society [13].

Another example of innovation in shrimp farming comes from China, where systematic selective breeding and technological innovation have been introduced to improve the growth performance and disease resistance of shrimp. Two new varieties of shrimp, named "Huanghai No. 1" and "Huanghai No. 2", were developed after 7 and 10 years of selective breeding, respectively. The "Huanghai No. 1" variety is characterized by faster growth, with its average body length and body weight increasing by 8.40% and 26.86% respectively compared to the unselected population. The "Huanghai No. 2" variety, developed using combined individual/family selection methods and the multi-trait BLUP (Best Linear Unbiased Prediction) strategy, is tolerant to the white spot syndrome virus (WSSV), a common disease in shrimp [14]. These innovative practices aim to enhance aquaculture productivity while minimizing the negative ecological and economic consequences associated with traditional shrimp farming methods. They represent a shift towards more sustainable and environmentally friendly practices in the aquaculture industry.

It is impossible to overstate the importance of innovative shrimp breeding practices in Sumbawa's aquaculture industry. Our primary goal in conducting this research is to investigate the complex effects of these developments on the aquaculture industry as well as the long-term viability of fisheries enterprises. The fundamental idea is that improvements in shrimp breeding may help reduce the current conflicts between sustainability and production by offering a blueprint for balanced regional expansion.

This qualitative study uses Sumbawa as a case study to explore the subtleties and complexity of this problem. In order to understand the complex relationships, experiences, and local contextual elements that influence shrimp breeding innovation in aquaculture and its consequences for the long-term viability of fisheries enterprises, a qualitative approach was selected. Through the application of qualitative techniques like participant observation, in-depth interviews, and document analysis, our goal is to create a thorough understanding of the topic.

The final objective of this study is to offer information, analysis, and suggestions that help improve business plans, legislative initiatives, and aquaculture methods on the ground in Sumbawa

in order to promote sustainability in the fisheries industry. We hope to close the gap between innovation and its practical application by conducting this qualitative investigation, with a focus on sustainable practices and guaranteeing the long-term viability of Sumbawa's aquaculture and fisheries sector.

2. LITERATURE REVIEW

2.1 Aquaculture and Its Significance

Aquaculture, the farming of aquatic organisms such as fish, shrimp, and mollusks, has become a vital component of global food production and economic development. As the world's population continues to grow, there is increasing pressure on traditional fisheries and a need to find sustainable alternatives to meet the rising demand for seafood [15]–[18]. Aquaculture has emerged as a solution to this challenge, providing a means to produce seafood efficiently and mitigate the over-exploitation of wild fish stocks.

In Indonesia, and specifically in Sumbawa, aquaculture has gained immense importance, contributing significantly to both domestic consumption and exports. Indonesia ranks among the world's top aquaculture producers, with shrimp farming playing a central role in the country's aquaculture sector [19], [20]. The growth of aquaculture in Sumbawa has stimulated local economic development and employment opportunities, enhancing livelihoods for many within the region.

2.2 Shrimp Breeding Innovation

Innovative breeding practices in the aquaculture industry, particularly in shrimp farming, have indeed gained prominence in response to various challenges. These practices aim to enhance the growth and disease resistance of shrimp while reducing the negative environmental impact.

Selective breeding programs are one such innovation. These programs target specific traits in shrimp populations, such as growth rate and disease resistance, with the goal of developing broodstock that can produce offspring with desirable characteristics. Selective breeding has been shown to be effective in improving traits of commercial importance, such as growth and disease resistance, in shrimp farming [21]. However, there are significant obstacles to the large-scale adoption of genetic improvement strategies. For instance, the value of selectively bred shrimp cannot be fully realized if shrimp are grown in environments where virulent pathogens exist [21]. There are also concerns about viral mutations, whereby previously resistant shrimp strains may become susceptible to evolving viruses [22].

Genetic modification is another innovative breeding practice. Although this approach offers the potential to engineer shrimp with improved traits, it raises ethical and environmental concerns3. The use of genetic modification to produce new varieties suited for organic agriculture and crop improvement by genetic engineering still sparks hot debate among various scientific and social factions. The major concern is the possible existence of unintended effects both on human and world health [23]. Innovations in shrimp feed aim to reduce the reliance on wild-caught fish for feed and enhance the nutritional quality of the shrimp produced. For instance, farmers can produce stunted fish fingerlings by rearing fish at a higher stocking density and feeding them with natural food for a prolonged period. Farmers use a supplementary feed mixture of Soya Bean Cake, Ground Nut Oil Cake, Rice Bran, and Fish Meal to promote optimal growth [24].

2.3 Fisheries Business Sustainability

The sustainability of fisheries businesses, such as those in Sumbawa, is indeed closely linked to the sustainability of aquaculture practices. These businesses are vulnerable to various factors including market fluctuations, environmental challenges, and disease outbreaks. Therefore, achieving sustainability involves not only optimizing production but also ensuring long-term profitability and market access.

In the context of Sumbawa, the economy of West Sumbawa Regency was highly dependent on the mining sector, which is a non-renewable resource. To sustain the economic development of West Sumbawa, it was necessary to develop and diversify the economy to renewable non-mining based sectors, especially agriculture and its business and industrial chains [25]. This diversification could potentially include the development of sustainable fisheries businesses. In terms of aquaculture practices, consumer awareness and acceptance play a significant role in promoting sustainability. A study in Penang, Malaysia, found that while consumers were aware of the potential negative effects of uncontrolled aquaculture activities on human health and the environment, they still chose to buy aquaculture products due to their cheaper price compared to wild catch seafood products. However, the study also found that enhancing consumer awareness could lead to pressure on the aquaculture industry to become more environmentally-friendly and sustainable [26].

In addition to consumer awareness, the management of fisheries businesses also plays a crucial role in their sustainability. For instance, a study on a seafood export-import firm in Vietnam found that the company managed to increase its net profit while reducing revenue, indicating better cost management. The study also highlighted the importance of considering both internal and external macroeconomic elements and their impacts on the business [27]. Moreover, the sustainability of fisheries businesses can also be influenced by factors such as employee turnover. A study on small construction businesses found that reducing voluntary employee turnover was critical to reducing business costs and increasing the performance of key business processes [28]. This finding could potentially be applicable to fisheries businesses as well, as retaining skilled employees could contribute to the long-term productivity and sustainability of these businesses.

2.4 Research Gap

Despite the growing body of research on aquaculture and shrimp farming, there is a need for in-depth qualitative analysis that examines the practical impact of shrimp breeding innovation on aquaculture productivity and its consequences for the sustainability of fisheries businesses in Sumbawa. This research seeks to fill this gap by investigating the complex interactions between innovation, productivity, sustainability, and the unique socio-environmental context of the region.

3. METHODS

Qualitative research was chosen as the main approach in this study due to its suitability for exploring the multi-dimensional, context-specific and complex nature of the research topic. Qualitative methods allow researchers to capture the richness of local experiences, perceptions and contextual factors that influence the subject matter, which is crucial in investigating the interactions between innovation, productivity and sustainability in aquaculture and fisheries.

3.1 Case Study Design

A case study design was chosen as it allows for an in-depth investigation of a specific geographical area, namely Sumbawa, and its shrimp breeding innovations and aquaculture practices. This approach provides a holistic view of the contextual factors that impact the research topic, thus allowing us to gain a nuanced understanding of the subject in a real-world setting.

3.2 Data Collection Techniques

In-depth Interviews

Semi-structured in-depth interviews were conducted with key informants, including shrimp farmers, aquaculture experts, government officials, and fisheries business representatives in Sumbawa using the Penta-Helix method. These interviews explored their experiences, perceptions and knowledge related to shrimp breeding innovations, aquaculture practices and sustainability in the region. The semi-structured interview format allowed flexibility to explore emerging topics and insights.

Participant Observation

Participant observation involves researchers actively engaging in the day-to-day activities of shrimp farming and fisheries in Sumbawa. This method provides a first-hand understanding of the practical aspects of shrimp farming and its impact on business sustainability. Field notes and observations documented the nuances of day-to-day operations.

Document Analysis

Existing documents, such as government reports, academic publications, industry literature, and policy documents, were reviewed to provide background information on shrimp breeding innovations, farming practices, and fisheries business sustainability in the region. This document analysis helped contextualize the current state of aquaculture in Sumbawa and understand the historical and regulatory aspects of the research context.

Participant Selection

Purposeful sampling was used to select participants with relevant knowledge and experience in shrimp breeding, aquaculture and fisheries businesses in Sumbawa. The selection criteria were designed to capture diverse perspectives and experiences, to ensure a holistic view of the subject matter. Inclusion criteria for participant selection included:

1. Shrimp farmers with varying levels of experience and success.
2. Government officials involved in aquaculture regulation and policy.
3. Experts in aquaculture and fisheries management.
4. Representatives from fisheries businesses operating in Sumbawa.

The sample size was determined by the principle of data saturation, i.e. the point at which no new information emerges from additional interviews or observations, a total of 10 research informants were involved.

3.3 Data Analysis

Thematic analysis was used to analyze qualitative data collected through interviews, participant observation and document analysis. The analysis process consisted of several main steps:

1. Data Introduction: The researchers immersed themselves in the data to become familiar with its content.
2. Generating Initial Codes: Researchers systematically code the data to identify patterns, themes, and key findings.
3. Theme Development: Codes are grouped into themes that reflect the research objectives.
4. Review and Refinement: The themes were reviewed, refined and cross-verified with the data to ensure accuracy and consistency.
5. Report Writing: Findings were reported in a coherent narrative, supported by relevant quotes and examples, to provide a comprehensive explanation of the research results.

4. RESULTS AND DISCUSSION

4.1 Sample Characteristics

In this section, we present the results of our qualitative analysis on the role of shrimp breeding innovation in improving aquaculture productivity and its impact on the sustainability of fisheries businesses in Sumbawa, West Nusa Tenggara. The findings are organized around the research objectives, offering insights into the diverse experiences, perspectives, and challenges faced by local stakeholders in the region.

4.2 Shrimp Breeding Innovation and Aquaculture Productivity

Our research revealed that selective breeding programs have gained significant traction in Sumbawa's aquaculture sector. Shrimp farmers participating in these programs reported notable improvements in growth rates and disease resistance. They also emphasized the importance of collaboration with local research institutions and universities in the development of selective breeding initiatives.

1. Participant Quote (Farmer A): *"The selective breeding programs have transformed our farms. Our shrimps are healthier, grow faster, and the mortality rate is lower. It's a game-changer."*
2. While genetic modification was discussed as a potential innovation, it was met with mixed reactions. Farmers expressed concerns about the environmental consequences and public perception of genetically modified shrimp. Regulatory challenges were also cited as impediments to adopting this technology.
3. Participant Quote (Farmer B): *"Genetic modification might work, but we must be cautious. It's not just about science; it's about ethics and sustainability too."*

4.3 Environmental Sustainability

Participants highlighted the importance of sustainable feed practices as a means to reduce the ecological footprint of shrimp farming. Using alternative feeds, such as plant-based and insect-based options, was discussed as a promising strategy. Nevertheless, there were challenges in terms of sourcing these feeds at scale.

Participant Quote (Researcher A): *"Shrimp feed innovation is vital. We need to reduce our reliance on wild-caught fish as feed. The switch to alternative, sustainable feeds is a step in the right direction."*

4.4 Fisheries Business Sustainability

The sustainability of fisheries businesses in Sumbawa is closely linked to market access. Participants emphasized the importance of building strong market connections and complying with international standards to ensure consistent sales and revenue.

Participant Quote (Business Owner A): *"Market access is crucial. We need to meet quality standards and connect with markets that appreciate sustainable aquaculture."*

Disease Management

Effective disease management was a key theme in discussions about fisheries business sustainability. The implementation of innovative disease management practices was seen as essential to reducing economic losses and ensuring business continuity.

Participant Quote (Business Owner B): *"Disease management is a constant battle. Innovations in this area can make or break our business."*

Discussion

The qualitative data indicates a complex relationship between aquaculture production, innovation in shrimp breeding, and the long-term viability of Sumbawa's fishing industry. Shrimp aquaculture has benefited from selective breeding initiatives that have improved growth and disease resistance. However, due to ethical and legal problems, genetic alteration is still up for discussion. Sustainable feed techniques present a viable way to lessen shrimp farming's environmental impact. However, there are still difficulties with large-scale alternative feed supply. For the fishing industry to be sustainable, market access and adherence to international quality standards are essential. A persistent concern, effective disease management depends on new methods and tools. The results highlight how crucial it is to take local context into account when implementing improvements in shrimp breeding. The unique ecological, cultural, and economic features of Sumbawa influence the applicability and viability of different inventions. With a thorough grasp of these subtleties, our research offers stakeholders useful guidance for advancing sustainable aquaculture methods and the long-term sustainability of the fisheries industry in the area.

Policy Implications and Recommendations

Based on the research findings, we propose several policy implications and recommendations:

1. Support for Selective Breeding: Government and industry stakeholders should support and expand selective breeding programs that have shown positive results. Collaboration with research institutions can further advance these initiatives.
2. Regulation and Oversight: Regulators should exercise caution in considering genetic modification in aquaculture, taking into account ethical, environmental, and public perception factors. Robust oversight and regulation are necessary.

3. Promotion of Sustainable Feeds: Efforts should be made to promote and incentivize the use of sustainable feed practices. Government incentives or partnerships with feed producers may help in sourcing alternative feeds.
4. Quality Standards and Market Access: Fisheries businesses should focus on meeting international quality standards to ensure market access and consistent revenue. Government support in this area can facilitate compliance.
5. Disease Management Research: Investments in disease management research and innovation are critical. Collaboration between farmers, researchers, and industry experts can yield effective strategies to combat diseases.

5. CONCLUSION

The relationship between aquaculture production, innovative shrimp breeding, and the sustainability of the fishing industry in Sumbawa, West Nusa Tenggara, is intricate and multifaceted. Our qualitative study has illuminated the critical role that innovation in shrimp breeding plays and provided a comprehensive picture of its effects on the aquaculture industry in the area as well as the livelihoods of local stakeholders. By improving shrimp growth and disease resistance, selective breeding programs have shown real benefits. Farmers and research institutions working together has been credited with the effectiveness of these initiatives. On the other hand, the use of genetic alteration is still controversial due to ethical, legal, and environmental concerns. Even though they seem promising, sustainable feed techniques have difficulties finding substitute feeds on a large scale. Still, they are a start in the right direction toward lessening the impact of shrimp farming on the environment. The viability of Sumbawa's fishing enterprises is contingent upon market accessibility and adherence to global quality benchmarks. The management of diseases effectively is still a task that requires creativity and cooperation from a variety of parties.

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