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Community-Led Coral Reef Farming: A Case Study from Pahawang Island, Indonesia

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Abstract: Coral reefs play a crucial role in Indonesia's coastal ecosystems, offering ecological and economic benefits. Pahawang Island, Lampung, presents a potential site for sustainable coral reef farming. However, destructive fishing practices, such as fish bombing in 2000, caused severe reef damage, prompting a cultivation initiative aimed at restoration and sustainable utilization. This study, conducted in 2024, explored the impacts and challenges of coral reef farming on Pahawang Island using surveys and focus group discussions. Data collection involved interviews with 100 residents, including coral farmers and village officials, and discussions with representatives from BUMDes, POKDARWIS, village officials, and coral reef traders. The Business Model Canvas and SWOT analysis were employed for evaluation. Hamlet had significantly stronger positive perceptions of coral reef farming (p-value = 0.037), while Pahawang Hamlet residents emphasized its challenges (p-value = 0.018). The findings also highlighted that many coral reef farmers had yet to fully implement all aspects of their business models. This study underscores the need for targeted interventions to address challenges and enhance sustainable coral reef farming practices.

Keywords: Conservation; Coral reef farming; Negative impact; Pahawang island; Positive impact

Introduction

Pahawang Island in Lampung, Indonesia, is an emerging hotspot for sustainable coral reef farming, offering a unique opportunity to balance local economic growth and environmental conservation (Sangaji, 2017). However, destructive fishing practices, such as fish bombing in 2000, caused severe reef damage, prompting a cultivation initiative aimed at restoration and sustainable utilization (Irawan et al., 2017). While coral reefs globally are known for their ecological significance, Pahawang Island faces challenges due to the previous destruction, and research specifically examining coral reef farming's role in local economic development while ensuring ecological preservation remains limited (Smith-Godfrey, 2016).

This study fills a critical gap by focusing on Pahawang Island's coral reef farming practices and how they contribute to the blue economy, which emphasizes the sustainable use of ocean resources to promote long-term economic benefits (Smith-Godfrey, 2016). Pahawang Island, with a population of 1,642 people and spanning 1,084 hectares, presents an ideal setting for this investigation due to its rich marine biodiversity and growing ecotourism sector (Novriadi et al., 2024). The island is home to active community organizations, including Tourism Awareness Groups (POKDARWIS) and Village-Owned Enterprises (BUMDes), both of which play essential roles in fostering coral reef conservation and sustainable practices (Irawan et al., 2017).

Unlike previous studies that either focus on the ecological or economic aspects of coral farming, this research integrates both dimensions. By analyzing how coral farming impacts local livelihoods and marine ecosystems, it aims to provide insights into how such practices can be effectively managed to support both the economy and the environment. Understanding the

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challenges and opportunities of coral farming on Pahawang Island is crucial for developing scalable models that can be applied to other regions in Indonesia, ensuring that sustainable coral reef farming contributes to local economic resilience while restoring and preserving marine ecosystems for future generations.

Method

This research was conducted in 2024 on Pahawang Island, which has a population of 1,642 individuals based on data from the Central Statistics Agency (BPS) in 2022. The study aimed to evaluate the positive impacts and challenges of coral reef farming on the island. A sample size of 100 participants was determined using the Slovin formula with a 5% margin of error to ensure statistical reliability. Stratified random sampling was employed to ensure proportional representation of key community groups, including coral farmers, village officials, and community members involved in coral reef cultivation.

Data collection involved structured interviews with 100 participants aged 17–60 years. This age range was chosen to ensure that participants could provide reliable answers while focusing on adults actively involved in or significantly affected by coral reef farming activities. The interviews focused on participants' involvement in coral reef farming, the benefits they experienced, and the challenges they faced. Structured interviews are a widely used method in social science research, providing a systematic approach to data collection and ensuring consistency across interviews (Bryman, 2016). The selection of participants within the 17–60 age range aligns with common practices in studies examining adult populations, as this group is typically considered to be in the workforce and actively engaged in community activities (Creswell & Creswell, 2017).

To analyze the data, a logistic regression model was employed to explore the relationship between socio-demographic and economic factors and the perceived benefits of coral reef farming. The dependent variable, positive impacts, represented participants' assessments of the benefits of coral reef farming. Several independent variables were included in the model, namely sex, domicile, years of residency, occupation, monthly salary, age, education level, and the ethnicity of the participant's father. These variables were chosen based on their potential influence on the participants' views on coral reef farming.

To explore the relationships between positive and challenge in coral reef farming, Pearson correlation tests were conducted using the cortest function in R. The tests were performed to assess the strength and direction of linear relationships between the following pairs of variables: economic productivity and promote cooperation, long duration and capital investment, and also economic productivity and capital investment data.

Additionally, three focus group discussions (FGDs) were conducted, each consisting of 6–8 participants. The FGDs included representatives from Village-Owned Enterprises (BUMDes), Tourism Awareness Groups (POKDARWIS), village officials, and coral reef trade participants. Participants were selected based on their roles and relevance to coral reef farming activities. This FGD employed the Business Model Canvas and SWOT analysis to assess opportunities, challenges, and sustainability. This approach provided a comprehensive understanding of the socioeconomic and environmental aspects of coral reef farming, ensuring relevant findings and actionable recommendations.

Result and Discussion

The research involved 100 respondents from six hamlets in Pahawang Island Village: Jelarangan, Penggetahan, Pahawang, Suak Buah, Cukuh Nyai, and Kalangan. The average age of respondents was 42.97 years (SD ± 13.4). The sample included 33 male respondents and 67 female respondents. This sex disparity represents a significant number of housewives who do not fully engage in coral reef activity.

The community on Pahawang Island is particularly familiar with branching coral (*Acropora* sp.), recognized for its rapid growth rate and resilience in various marine conditions. *Acropora* sp. is often favored in coral farming due to its ability to regenerate quickly, supporting both ecological restoration and economic activities. While (Nybakken, 1992) highlights the ecological advantages of *Acropora* sp., such as its fast growth rate compared to other coral species, its selection for coral farming on Pahawang Island is further justified by its proven economic viability. This species has been successfully utilized in prior coral transplantation and farming projects, demonstrating its potential for sustainable income generation (Putri et al., 2023). However, further research specific to Pahawang Island is necessary to quantify the economic benefits derived from farming *Acropora* sp. and its contribution to local livelihoods.

The individual questionnaire included two questions aligned with the research objectives: whether coral reefs enhance the economic productivity of Pahawang Island Village and whether they foster community cooperation. Kalangan Hamlet demonstrated the strongest agreement with these positive impacts, with 100% of respondents affirming their benefits (Table 1). This indicates that coral reef farming activities not only contribute to economic growth but also strengthen social cohesion within the

community, promoting collaborative efforts in managing and sustaining coral reef resources.

Table 1. Percentage of individuals agreeing on positive impacts of coral reefs trade based on hamlet

Hamlet	Percentage (%)
Kalangan (11)	100
Jelarangan (22)	81.82
Pahawang (16)	75.00
Penggetahan (7)	71.43
Suak Buah (27)	55.56
Cukuh Nyai (17)	52.94

However, the community of Pahawang Island Village perceived several challenges associated with coral reef farming, including the time required and the financial investment involved. Pahawang Hamlet expressed the highest agreement with these challenges, with 66.67% of respondents acknowledging their existence (Table 2).

Table 2. Percentage of individuals agreeing on challenge of coral reefs trade based on hamlet

Hamlet	Percentage (%)
Kalangan (11)	63.63
Jelarangan (22)	45.45
Pahawang (16)	66.67
Penggetahan (7)	57.14
Suak Buah (27)	33.33
Cukuh Nyai (17)	35.29

This study employed a Linear Model in R to analyze the influence of demographic data on the community's perspectives regarding both the positive impacts and challenges of coral reef farming in Pahawang Island Village. The results indicate that residence in Kalangan Hamlet significantly influences perspectives on the positive impacts compared to other hamlets (estimate = 1.349; p-value = 0.037). Additionally, Pahawang Hamlet demonstrates a significantly stronger perspective on the challenges of coral reef farming (estimate = 1.293; p-value = 0.018).

In the analysis of the relationships between variables related to the positive impacts and challenges of coral reef farming on Pahawang Island, several correlation tests were conducted. Correlation Test 1 revealed a strong positive correlation between the perceived positive impacts of coral reefs on economic productivity and community cooperation, with a p-value of 2.49×10^{-4}. This indicates a statistically significant relationship, suggesting that as the perceived economic productivity of coral reefs increases, so does the level of community cooperation. The strength of this correlation highlights the close link between economic benefits and social cohesion within the community, supporting the idea that successful coral reef farming not only fosters economic growth but also strengthens social ties.

Correlation Test 2 found a significant positive correlation between the perceived challenges of coral reef farming, specifically the time required and the financial investment, with a p-value of 2.22×10^{-7}. The small p-value indicates a highly significant relationship, suggesting that as the time commitment for coral reef farming increases, so does the financial investment require. This positive correlation implies that participants perceive the time and financial challenges as interconnected, underscoring the potential barriers to scaling up coral reef farming activities.

However, Correlation Test 3 showed no statistically significant correlation between the perceived positive impact of coral reefs on economic productivity and the challenges associated with high capital investment, with a p-value of 0.629. This large p-value indicates that there is no meaningful relationship between these two variables, meaning that the perceived economic benefits of coral reefs are not significantly linked to the challenges of high capital investment. This finding suggests that, in this case, financial concerns may not directly influence the perceived economic benefits of coral reef farming.

The results of this study on Pahawang Island Village reveal that coral reef farming has significant socio-economic benefits, particularly in fostering community cooperation and enhancing economic productivity. The strong positive correlation between these two aspects, especially in Kalangan Hamlet, highlights the critical role that coral reef farming plays in both economic development and social cohesion. These findings are consistent with (Bruno & Côté, 2018), which demonstrates that coral reef restoration not only contributes to biodiversity but also enhances local livelihoods and strengthens community bonds. Similarly, Tobias & Lang (2020) emphasize the importance of coral reef ecosystem services, which are integral to improving local livelihoods and providing economic opportunities, mirroring the positive perceptions observed in Pahawang Village.

Despite the perceived benefits, the study reveals notable challenges, particularly the time investment and financial costs associated with coral reef farming. Pahawang Hamlet reported the highest agreement with these challenges, aligning with studies by Chaves et al. (2021); Pomeroy et al. (2006), who identified similar barriers, including high initial investments and the need for technical knowledge. These challenges complicate the implementation of coral reef farming on a larger scale, as financial and time constraints can limit adoption. Naylor et al. (2020) also emphasize that such barriers hinder widespread adoption, despite clear long-

term benefits. Additionally, the absence of a significant correlation between financial investment and perceived economic benefits in this study suggests that while challenges exist, the long-term economic advantages, such as biodiversity and eco-tourism potential, may outweigh initial concerns, as suggested by Mora et al. (2021). The community's perception that coral reef farming requires substantial time is consistent with Soong & Chen (2003), who note that coral reefs naturally require long periods for growth and recovery. The need for significant capital is also supported by Suharsono et al. (2013), who highlight the expensive materials and intensive labor required for successful coral farming. Thus, while these challenges are acknowledged, the potential for long-term ecological and economic benefits remains significant.

Furthermore, the study highlights the importance of community engagement in overcoming these challenges. Strong community involvement is essential for the success of coral reef farming initiatives, as it fosters a sense of collective responsibility for resource management and sustainability. This finding is consistent with the conclusions of Chaves et al. (2021), who argue that successful coral farming depends not only on financial and technical resources but also on the active participation of local communities. The choice of species, such as *Acropora* sp., known for its resilience and rapid growth, further supports the sustainable economic and ecological benefits of coral reef farming. Overall, this study adds to the growing body of literature on coral reef farming, emphasizing the need for integrated approaches that consider both the ecological and socio-economic dimensions, as well as the need for capacity-building and financial support to ensure the long-term success of these initiatives.

In addition to benefiting marine ecosystems, coral reefs also provide numerous advantages to coastal communities. The beauty of coral reefs presents an opportunity to boost the economy by developing the tourism sector. This type of tourism is known as ecotourism (Syaifuddin, 2023). The positive impacts of ecotourism include preserving natural integrity and beauty, as well as improving the standard of living for local communities through cooperative efforts due to tourist visits to areas with well-maintained natural conservation, which can foster business activities (Fandeli, 2000). If coral reef farming projects are widely implemented in Indonesia, coral reef restoration through transplantation, such as in Sanur, Bali, can contribute to the recovery of Indonesia's economy (Putri et al., 2023).

Based on the results of interviews with the residents of Pahawang Island Village, most people obtain information about coral reef farming from their neighbors or those living nearby. This indicates a weakness in that village leaders have not evenly distributed information regarding the potential of coral reef farming to all hamlets. It is important to note that equal dissemination of information can enhance community involvement, which is crucial. Community involvement is essential at every stage of an activity, including planning, implementation, utilization of results, and evaluation (Hakim, n.d.; Suwarsito et al., 2019). Community involvement is particularly necessary because coastal communities are the primary stakeholders who experience the direct impact of coral reefs. Several studies have emphasized the significance of community engagement in coral reef restoration and sustainable management. For example, Hammen et al. (2017) highlight that local knowledge and involvement are critical for effective coral reef restoration projects, particularly in small-scale farming and conservation initiatives. Additionally, Smith et al. (2019) argue that the active participation of local communities fosters long-term sustainability in coral reef conservation efforts, as it increases awareness and promotes collective responsibility. Similarly, Naylor et al. (2020) underscore that involving communities in the decision-making process not only improves the success of restoration efforts but also ensures the equitable distribution of benefits from coral reef farming, ultimately contributing to both ecological and socio-economic resilience.

The community's knowledge regarding coral reef farming dates to around the 1700s when migrants from the Banten area of West Java began to settle on Pahawang Island (Mustika et al., 2017). Therefore, most of the Pahawang Island's population is originally from Java. Based on discussions with the leaders of Pahawang Island, although these migrants came from the Banten area near the coast, most of them did not bring knowledge about coral reef utilization to Pahawang Island. Before receiving adequate education about coral reefs, the Pahawang Island community referred to coral reefs as "mushrooms." At that time, they only knew that coral reefs existed in the sea without any in-depth understanding.

Based on interview results, in 1999, a company named PT. Golden Marindo Persada came to Pahawang Island to propose a collaboration in coral reef utilization. Through this collaboration, the community was educated on how to manage coral reefs, including trading coral reefs to be used as aquarium decorations. They learned about coral reef planting, packaging processes, and the distribution of coral reef sales both domestically and internationally. During this period, the community also began using local names for different types of coral reefs, such as staghorn coral, plate coral, table coral, and brain coral (Nurhayu et al., 2024).

After the collaboration with PT. Golden Marindo Persada ended in 2010, a new company, CV. Vivaria Marine, invited the community to collaborate in 2011 for one year. Although the collaborations with these companies have ended, since 2012 until now, the Pahawang Island community has continued coral reef farming activities for conservation purposes at least once every two months. With the education and hands-on experience that some members of the Pahawang Island community have gained regarding the trade of coral reefs, coral reef farming activities on Pahawang Island have certainly become easier.

This study conducted a SWOT analysis to assess the strengths, weaknesses, opportunities, and threats associated with coral reef farming in Pahawang Island. There are several key findings: Strengths: The island's marine beauty, potential for tourism, and the community's involvement in conservation efforts are significant strengths (Ban et al., 2019; Mora et al., 2021). Weaknesses: Lack of human resources, insufficient government support, and inadequate infrastructure are identified as weaknesses (Bruno & Côté, 2018; Chaves et al., 2021). Opportunities: Leveraging marine beauty for tourism, collaborating with experts, and attracting more tourists through partnerships with travel agents are potential opportunities (Hughes & Jackson, 2019; Manfredo et al., 2020). Threats: Coral reef damage from tourism and unstable funding cycles are key threats (Naylor et al., 2020; Smith et al., 2019). Thus, there are some recommendations: Address weaknesses: Focus on training and education to develop human resources, seek government support, and invest in infrastructure (Gorib & Pradnyana, 2017; Hammen et al., 2017). Maximize opportunities: Promote Pahawang Island as a marine tourism destination, collaborate with experts, and leverage partnerships to attract more tourists (Rincon & Castillo, 2018; Sutton & Henson, 2021). Mitigate threats: Implement measures to prevent coral reef damage from tourism and diversify funding sources to reduce reliance on BUMDes (Boström-Einarsson et al., 2020; Waycott & McKinnon, 2020). By addressing these factors, Pahawang Island can effectively manage coral reef farming activities and achieve a balance between economic development and environmental conservation.

This study used the Business Model Canvas (BMC) approach to develop strategies for coral reef farming in Pahawang Island. By analyzing key aspects of the business, such as partnerships, activities, value propositions, customer relationships, channels, customer segments, resources, and costs, the study aimed to identify opportunities for success.

Coral reef farming requires the collaboration of various stakeholders to succeed. Key partners include POKDARWIS (a local tourism awareness group), travel agents, academics, communities, social media influencers, companies, and the government. POKDARWIS: Plays a crucial role in implementing coral reef farming activities, from preparing materials to maintaining the reefs. Academics and Communities: Provide valuable mentorship, guidance, and scientific perspectives. Travel Agents: Serve as channels of information about coral reef farming to tourists. Social Media Influencers: Promote coral reef farming through engaging content. Companies and Government: Can assist with infrastructure, facilities, and policy support.

Coral reef farming activities often involve offering tourists a range of experiences, including open and private trips. These trips typically include activities like coral farming, island exploration, sea walking, parasailing, and snorkeling. This approach makes coral reef farming an attractive option for tourists seeking a vacation that combines enjoyment with environmental conservation.

To develop a successful business model for coral reef farming, it is essential to identify its unique value propositions. Coral reef farming offers several advantages, including economic benefits for the local community and positive contributions to coral reef conservation. By increasing tourism and supporting related industries, coral reef farming can boost the economy of Pulau Pahawang Village while also helping to preserve the marine environment.

Building strong relationships with customers is crucial for successful coral reef farming. To enhance customer relations, consider using social media platforms like Instagram and Facebook to promote your business. You can also attract loyal customers by offering personalized promotions or reaching out to those who have previously supported coral reef conservation efforts.

To promote coral reef farming activities, consider the following strategies: 1) Social Media Marketing: Create engaging content on platforms like Instagram and Facebook to educate potential tourists about coral reefs and attract their interest. 2) Targeted Campaigns: Launch social media campaigns using flyers and other materials to promote activities that combine tourism and conservation. 3)Partnerships: Collaborate with government agencies, academic institutions, local communities, and businesses to address challenges and find solutions for coral reef conservation. To effectively market coral reef farming activities, it is important to identify the target audience. Potential customers include both domestic and international tourists who are planning vacations or conducting research on Pulau Pahawang.

Currently, the primary source of funding for coral reef farming activities on Pahawang Island is the Village-Owned Enterprise. The main revenue stream comes from open trips that include coral planting, with a fee of Rp 150,000 per tourist. Future plans will involve forming partnerships with companies to improve infrastructure and facilities necessary for coral reef farming.

The successful implementation of coral reef farming projects requires addressing several key challenges, including the establishment of clear and achievable goals, standardized monitoring and reporting, and effective project design. Boström-Einarsson et al. (2020) highlight that clear goals are essential for ensuring coral restoration projects meet their ecological and socio-economic objectives. Similarly, Edwards et al. (2021) emphasize the importance of standardized monitoring protocols, noting that inconsistent or insufficient monitoring can undermine the success of such programs. Furthermore, Ban et al. (2019) argue that poor project design, which fails to align with local environmental and community needs, is a significant barrier to successful coral restoration efforts. In this context, utilizing tools like the Business Model Canvas and SWOT analysis could enhance the strategic planning and design of coral reef farming projects. These tools can help identify strengths, weaknesses, opportunities, and threats, as well as provide a clear framework for aligning the project's goals with community and environmental needs, ultimately fostering the long-term success of coral reef farming in Pulau Pahawang Village. Furthermore, it is important to integrate local wisdom into conservation strategies to address environmental challenges and promote sustainable practices (Efi et al., 2023; Irrubai & Subki, 2024; Snahan et al., 2024; Susilo et al., 2024).

The limitations of this study include the relatively small sample size of 100 respondents, which may not fully capture the diversity of perspectives within the entire community of Pahawang Island Village, potentially affecting the generalizability of the findings. Additionally, the study's cross-sectional design limits the ability to assess long-term trends or changes in community perspectives over time. The analysis, which focused on logistic regression and correlation tests, may not fully capture the complexity of community dynamics, and other factors such as climate change or government policies were not considered. These limitations suggest that future research should include a larger, more diverse sample, longitudinal data, and a broader set of variables to provide a more comprehensive understanding of the challenges and benefits of coral reef farming in the community.

Conclusion

In conclusion, the research highlights both the potential and challenges of coral reef farming in Pulau Pahawang Village. While there is significant community involvement in coral reef farming, with many participants recognizing its economic and social benefits, the study also reveals key barriers that must be addressed for its success. These include the lack of clear and achievable goals, insufficient and unstandardized monitoring, and the complexities of project design that may not align with local needs. The findings suggest that many coral reef farmers have not fully implemented all aspects of their business models, which limits the effectiveness and sustainability of their efforts. To overcome these challenges, targeted interventions are necessary, focusing on improving goal setting, standardizing monitoring practices, and refining project designs to align with both community and ecological objectives.

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Conflicts of interest
The authors declare that there are no conflicts of interest related to this study.

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