Enhancing marine ecosystem resilience through strategic deployment of fish apartments: a case study of the Fuji Lestari Program in Karang Jeruk, Indonesia

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Abstract. Coral reefs are vital ecosystems that provide essential ecological, social, and economic benefits. However, they face increasing threats from destructive human activities and climate change. In Indonesia, the degradation of these ecosystems poses significant challenges. The Fuji Lestari Program introduces fish apartments (FAs) as artificial reefs to restore marine habitats and mitigate coastal erosion. Despite their potential, challenges such as limited stakeholder engagement and resource constraints hinder their effectiveness. This study evaluates the compliance of fish apartments in Karang Jeruk, Indonesia, with Indonesian standards (SNI 2021) and employs a SWOT analysis to assess internal and external factors influencing the program's implementation and sustainability. Data were collected through field observations, stakeholder interviews, and structured questionnaires. The compliance assessment revealed that FAs largely met technical specifications, although logistical constraints limited the deployment area. The SWOT analysis identified strengths such as robust community involvement and government support, alongside weaknesses like limited government prioritization and training opportunities. The findings demonstrate that the Fuji Lestari Program effectively enhances marine ecosystem health and provides socio-economic benefits to local communities. By integrating technical assessments with stakeholder insights, the program lays the groundwork for sustainable fisheries management. The study recommends strategies emphasizing community engagement, legal support, and marine tourism development to ensure long-term success. These initiatives are crucial for fostering sustainable practices and enhancing the program's impact within broader environmental and developmental objectives.
Key Words: marine habitat restoration, regulatory compliance, sustainable development.

Introduction. Coral reefs are among the most biologically diverse and ecologically valuable ecosystems on Earth, offering essential services such as habitat provision for marine species, coastal protection, and resources for fisheries and tourism. These ecosystems support approximately 25% of all marine biodiversity and contribute significantly to the socio-economic well-being of coastal communities worldwide (Paxton et al 2022). Indonesia, as the world's largest archipelagic country, harbors around 1.78 million hectares of coral reefs, representing a crucial component of global marine biodiversity. However, these ecosystems face increasing threats from destructive fishing practices, pollution, sedimentation, and the escalating effects of climate change, such as rising sea levels and increasing sea surface temperatures (Hoegh-Guldberg et al 2007). These stressors have accelerated coral reef degradation, leading to declines in fish populations, reduced habitat complexity, and diminished ecosystem services essential to the livelihoods of millions of Indonesians.

In response to the alarming degradation of coral reefs, artificial reef structures have been deployed globally as a conservation and restoration strategy. Artificial reefs mimic natural reef habitats by providing shelter, breeding grounds, and feeding areas for marine organisms, while simultaneously enhancing habitat complexity and increasing fish populations (Sherman et al 2002). Studies have shown that artificial reefs can enhance local biodiversity and fisheries productivity, as well as provide socio-economic benefits to coastal communities (Bohnsack & Sutherland 1985; Baine 2001). Countries such as Japan, the United States, and Australia have reported significant ecological and socio-economic benefits from artificial reef programs (Paxton et al 2022). In Indonesia, artificial reef initiatives have become an integral part of marine conservation efforts, supported by regulatory frameworks such as SNI 9016:2021 (SNI 2021), which outlines technical and spatial requirements for artificial reef placement.

Despite their potential, the success of artificial reef programs is not guaranteed and depends heavily on site-specific factors and stakeholder engagement (Pickering et al 1998). Most studies have focused on the technical or ecological performance of artificial reefs, with limited attention to socio-economic impacts and stakeholder perspectives (Seaman & Jensen 2000). This gap highlights the need for comprehensive evaluations that incorporate both technical assessments and stakeholder engagement to ensure long-term sustainability and effectiveness.

The Fuji Lestari Program, initiated by Indonesia’s Ministry of Marine Affairs and Fisheries (KKP), focuses on deploying artificial reef structures known as fish apartments (FAs) to restore degraded marine habitats and mitigate coastal erosion. These FAs are designed using environmentally friendly materials and are strategically placed in areas identified as ecologically degraded, but suitable for habitat restoration. Preliminary outcomes in pilot sites such as Banyuwangi (East Java) and Cirebon (West Java) have shown promising increases in fish abundance and socio-economic benefits for local fishing communities. However, systematic evaluations of the program remain limited, particularly concerning the integration of stakeholder perspectives and long-term sustainability.

To address these gaps, this study aims to evaluate the compliance of fish apartment installations in Karang Jeruk, Tegal Regency, Central Java, with the technical guidelines outlined in SNI 9016:2021 and Ministerial Decree No. 168 of 2023 (SNI 2021; KKP 2023a). Additionally, this study incorporates a quantitative SWOT analysis to assess internal and external factors influencing the program’s implementation and sustainability. Input from key stakeholders, including local communities, government representatives, and academics, was gathered through structured questionnaires to ensure a comprehensive understanding of the program’s strategic strengths, weaknesses, opportunities, and threats. By integrating technical compliance assessments with stakeholder-driven SWOT analysis, this research seeks to provide actionable recommendations to optimize the Fuji Lestari Program, enhance its ecological and socio-economic outcomes, and ensure its long-term sustainability for marine ecosystem restoration in Indonesia.

Material and Method

Study area. The study was conducted in the coastal waters of Karang Jeruk, located in Tegal Regency, Central Java, as part of the Fuji Lestari program. This program focuses on ensuring compliance with established installation standards for artificial reefs. Karang Jeruk was chosen as the study area (Figure 1) due to its significant coral reef degradation and logistical suitability for the deployment of artificial reef structures. On July 17, 2024, 40 fish apartment (FA) modules were deployed, with subsequent monitoring planned to assess compliance with the technical standards outlined in SNI 9016:2021 and Ministerial Decree No. 168 of 2023 (SNI 2021; KKP 2023a). The initial deployment covered an area of 0.8 hectares, limited by the availability of 40 fish apartment (FA) modules, as stipulated by the Provincial Marine and Fisheries Service through Work Order No. 118.1/SP/APBN-TP/BPT/V/2024 (DKP 2024). This phase was executed with the intent to expand coverage in future phases, contingent on the availability of additional modules.

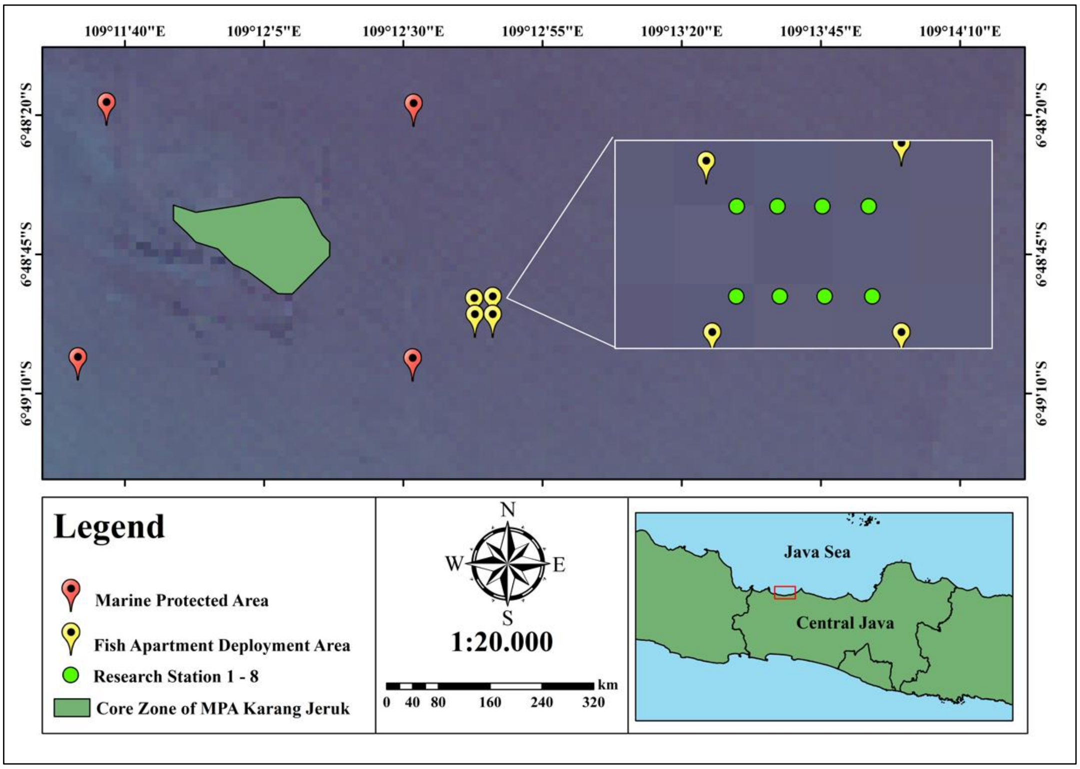

Figure 1. Study area map of Karang Jeruk, Tegal Regency, Indonesia (map generated using Sentinel-2A satellite imagery taken from the surface waters in Tegal Regency, Central Java Province, in December 2024).

Fish apartment description. Fish apartments are artificial structures or buildings deliberately placed on the seabed to mimic the natural functions of aquatic habitats, serving as fish shelters, feeding grounds, spawning grounds for adult fish, and nursery grounds for juvenile fish (KKP 2023a). The construction of fish apartments requires a specific set of tools and materials to ensure structural stability and functionality in an aquatic environment. The primary tools include a concrete mold, which serves as a container during the bottom casting process, and a sand trowel, used for thoroughly mixing sand and cement to create a stable base. A pair of scissors or a cutting knife is employed to trim excess materials and binding ropes, while a stitching and binding tool (locally referred to as "coban") assists in securely attaching the partitions. Additionally, a measuring tape is essential for ensuring precise measurements of all components, contributing to the structural integrity of the fish apartment.

The main construction material is polypropylene (PP) plastic partitions, selected for its durability, resistance to seawater corrosion, and lightweight properties, which facilitate easy deployment underwater. To securely fasten the partitions, polyamide (PA) monofilament no. 500 and polyethylene (PE) rope with a diameter of 5 mm are used, both of which exhibit high tensile strength and resilience in marine conditions. A plastic strip attractor is incorporated into the design to encourage fish habitation, providing an artificial refuge that mimics natural marine environments. Furthermore, sand and cement are used in the bottom casting process to act as ballast, ensuring that the fish apartment remains stable and resistant to underwater currents and external disturbances.

Criteria for fish apartment placement (SNI 9016:2021). The placement of FAs follows specific environmental and spatial criteria established in the Indonesian National Standard SNI 9016:2021 (SNI 2021). These guidelines ensure that the deployment site is ecologically suitable for artificial reef structures, enhancing ecosystem recovery while maximizing ecological benefits. Figure 2 illustrates the spatial configuration of FA modules based on recommended deployment depths.

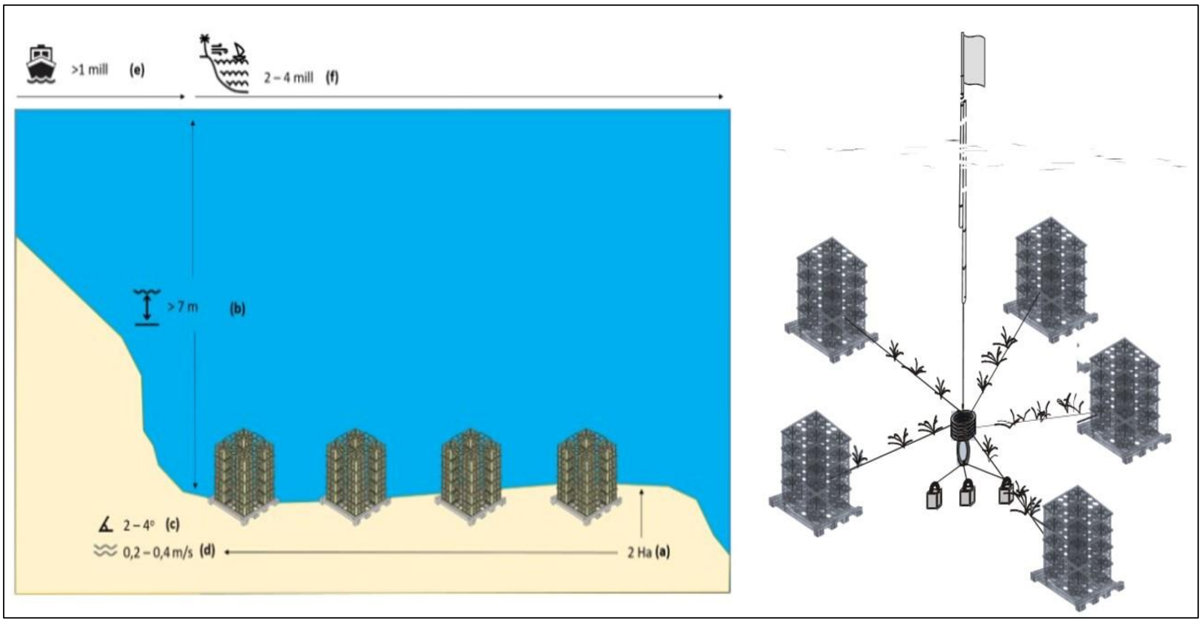

Figure 2. Fish apartment placement in Karang Jeruk, illustrating depth and positioning based on SNI 9016:2021 (SNI 2021) requirements.

Quantitative and qualitative criteria were applied to validate the Karang Jeruk site's suitability for FA placement. Quantitative criteria, such as area size, depth, and current speed, ensure that environmental conditions support FA stability and the formation of marine habitats (Table 1). For the placement area coordinates are determined and measured using the Garmin FF 250 GPS, in accordance with the Confirmation of Suitability for Marine Space Utilization Activities (KKPRL) Number B.1570/MEN-KP/VIII/2024 (KKP 2024). Distance from the shoreline was measured using Garmin FF 250 GPS. Water depth was measured using Garmin FF 250 GPS and the Chasing M2S ROV drone. The seabed slope was assessed using the Chasing M2S ROV drone. Current speed was obtained from secondary data sources, including real-time weather forecast websites (www.windy.com) and the Indonesian Nautical Chart Catalog (December 2024) (IHDC 2024). Distance from shipping lanes was obtained based on secondary data sources from the Indonesian Nautical Chart Catalog (December 2024) (IHDC 2024).

Table 1

Criteria for fish apartment (FA) placement based on SNI 9016:2021 (SNI 2021) standards, detailing environmental and spatial requirements.

Primary criteria	*Reference value*	*Unit*
Placement area	2	ha
Distance from shoreline	2-4	nautical miles
Water depth	>7	meters
Seabed slope	2-4	degrees
Current speed	0.2-0.4	m/s
Distance from shipping lane	>1	nautical miles

In addition to quantitative parameters, SNI 9016:2021 (SNI 2021) outlines qualitative criteria to ensure ecological compatibility and long-term manageability by the local community. These qualitative requirements include aligning with designated zones in the Zoning Plan for Coastal Areas and Small Islands (RZWP3K) (BPK 2018), while avoiding conservation zones. It is essential to select areas experiencing ecosystem degradation, which allows artificial reefs to provide ecological benefits. The deployment sites must be free from significant pollution sources to ensure a healthy environment for marine organisms. Additionally, the substrate should consist of coral sand or muddy sand to stabilize the FA structures. It is crucial to avoid areas near river mouths to minimize sedimentation. Lastly, involving the local community in maintenance activities is vital to promote long-term sustainability.

Data collection. Data collection focused on verifying compliance by measuring technical parameters during deployment and at subsequent intervals (Creswell 2018). Observations were conducted directly in the field to monitor the deployment process, record technical measurements, and ensure accuracy over time. The observations included monitoring the environmental conditions, operational challenges, and the interaction of FA structures with the surrounding ecosystem. Depth and positioning were recorded using an echo sounder and GPS, while sediment samples were collected to assess substrate stability, ensuring long-term feasibility for FA placement.

In addition to technical observations, qualitative data was gathered through interviews and structured questionnaires. In-depth interviews were conducted only with key informants, namely the Chairman of the Rajungan Merah Munjungagung Fishermans Community (RMMFC) (1 person), the Head of the Fisheries Department of Tegal Regency (1 person), and an academic from Panca Sakti University Tegal (1 person). The interview questions focused on understanding the perceived strengths and weaknesses of the program, potential opportunities for growth, and the challenges stakeholders foresee in its long-term sustainability. Key themes explored included the effectiveness of the program's implementation, the socio-economic impacts on the local community, and the role of government support.

Furthermore, a structured questionnaire was distributed to 20 respondents, who were selected based on their direct involvement in the Fuji Lestari program. Respondents included representatives from local government, academic institutions, and the local community. Ten respondents were local fishermen who are the beneficiaries of the program. One representative from the following institutions answered the questionnaire: Ministry of Marine Affairs and Fisheries (MMAF), Central Java Province Marine and Fisheries Department, Tegal Regency Fisheries Department, Western Region Marine and Fisheries Branch Office (CDKWB), Academic from Panca Sakti University Tegal, National Disaster Management Agency (BNPB) of Tegal Regency, National Fishing Center Staff, Chairman of Village-Owned Enterprise (BUMDes), Manager of Larangan Fish Auction Site (TPI Larangan), Chairman of the Community Monitoring Group (Pokmaswas). The questionnaire utilized a Likert scale (1–5) to evaluate the significance of factors related to strengths, weaknesses, opportunities, and threats (SWOT). The use of a Likert scale allowed for quantification of stakeholder perceptions, while ensuring that responses were comprehensively captured across a range of factors critical to the success of the program (Creswell 2018).

Data analysis*.* The collected technical data were analyzed to assess conformity with regulatory standards. Parameters such as depth, substrate type, and FA positioning were compared against the benchmarks set in SNI 9016:2021 and Ministerial Decree No. 168 of 2023 (SNI 2021; KKP 2023a). Each FA was classified as "Compliant" or "Non-compliant" based on these criteria. Descriptive statistics were used to summarize adherence levels and identify any necessary modifications for future installations.

For the SWOT analysis, scores from the questionnaire were aggregated and averaged for each factor within the strengths, weaknesses, opportunities, and threats categories. Weighted scores were calculated by normalizing each factor's score relative to the total scores within its category. These weighted factors were then used to create a SWOT matrix, which mapped the most significant factors and provided a basis for strategic recommendations. The quantitative SWOT analysis facilitated the identification of dominant strengths and opportunities while highlighting critical weaknesses and threats that require mitigation. This integration of stakeholder input ensures a more robust evaluation of the program's implementation and long-term viability.

Results and Discussion

Evaluation of fish apartment technical compliance. The Fuji Lestari program was implemented in the coastal waters of Karang Jeruk, Tegal Regency, Central Java, with the aim of enhancing marine ecosystem health and supporting local fishing communities. In collaboration with the Rajungan Merah Munjungagung Fishermans Community (RMMFC), 40 FA modules were deployed to establish artificial habitats that support marine biodiversity and fish populations. Implementation involved three main stages: site survey, component construction, and FA deployment.

The initial survey on May 22, 2024, confirmed the suitability of the deployment site based on SNI 9016:2021 (SNI 2021) standards. Located within the designated fishing zone (Zona Perikanan Tangkap/PT) and outside conservation zones, the site met zoning regulations under the Zoning Plan for Coastal Areas and Small Islands (RZWP3K) (BPK 2018). A follow-up survey on July 4, 2024, using an underwater drone remote operated vehicle (ROV), verified that the site conditions were appropriate for FA placement, with a depth range of 15–16 meters, seabed slope of 2–4 degrees, and a substrate of muddy sand containing visible marine burrows. The measured current speed of 0.2 m/s further supported site stability. Although the deployment area covered only 0.8 hectares—below the recommended 2 hectares due to module availability—the site was classified as "Suitable" based on compliance with environmental and spatial requirements. The FA modules were constructed in accordance with Ministerial Decree No. 168 of 2023 (KKP 2023a) technical specifications. Each module consisted of corrosion-resistant polypropylene (PP) partitions, PA monofilament (No. 500), and 4 mm PE rope, with frond-like structures added to simulate natural marine vegetation and provide microhabitats. Concrete weights (box, beam, sliding, and base types) were used to anchor the modules securely. The FA components, including the PP frame and concrete weights, met the regulatory standards for durability and suitability for marine deployment, ensuring long-term stability in underwater conditions.

Table 2

Compliance of fish apartment technical specifications in Ministerial Decree No. 168 of 2023 (KKP 2023a)

Component	*Specification*	*Compliance*
Fish apartment frame	PP Partitions, PA monofilament No. 500, PE Ø 4 mm	Compliant
Shelter	60 cm plastic tape, PA monofilament No. 500	Compliant
Concrete weight (box)	4 vertical partitions, 1 horizontal partition, PA monofilament No. 500, iron frame Ø 6 mm, dimensions 33 x 33 x 15 cm	Compliant
Concrete weight (beam)	Iron frame Ø 6 mm, dimensions 15 x 15 x 100 cm	Compliant
Sliding concrete weight	Iron frame Ø 6 mm, dimensions 25 x 25 x 40 cm	Compliant
Base weight for marker buoys	Dimensions 20 x 20 x 100 cm	Compliant

The technical suitability of the fish apartment (FA) modules was thoroughly assessed according to Ministerial Decree No. 168 of 2023 (KKP 2023a). Each component underwent rigorous testing to ensure compliance with marine deployment standards. The polypropylene (PP) partitions were checked for corrosion resistance, while the PA monofilament and PE rope were evaluated for tensile strength. Concrete weights were tested for their anchoring capability, and the frond-like structures were assessed for their effectiveness in providing natural habitats (Figure 3). All components met the required standards for durability and functionality in the marine environment. Detailed evaluation results can be found in Table 2.

Figure 3. Completed fish apartment modules prior to deployment and position under the sea (original images).

The compliance assessment yielded a total score of 22 out of 24, meeting most of the criteria outlined in SNI 9016:2021 (SNI 2021). Despite this limitation, the site was classified as "Suitable" for artificial reef deployment, supporting the FA modules' intended function. However, under the primary criteria, non-compliance was noted in the area of placement, which was only 0.8 hectares, falling short of the 2 hectare minimum required by the standard. This discrepancy was due to the limited number of modules deployed, totalling 40 units, as mandated by the Provincial Marine and Fisheries Service of Central Java through Work Order No. 118.1/SP/APBN-TP/BPT/V/2024 (DKP 2024), issued on May 27, 2024. According to SNI 9016:2021 (SNI 2021), achieving the 2-hectare area requires a minimum of 100 FA modules. Nevertheless, the total score obtained was 22, classifying this site as a "Suitable Location."

Table 3

Analysis of fish apartment placement compliance in Karang Jeruk Based on SNI 9016:2021 (SNI 2021)

Compliance criteria			*Yes / No*	*Score*
Alignment with RZWP3K			Yes	2
Ecosystem degradation			Yes	2
Free from pollution impact			Yes	2
Sandy or muddy-sand substrate			Yes	2
Not placed near river mouths or sediment areas			Yes	2
Community group willing to manage			Yes	2
Primary Criteria	*Reference Value*	*Unit*	*Value*	*Score*
Placement area	2	ha	0.8	0
Distance from shoreline	2-4	nautical miles	3.2	2
Water depth	>7	meters	15	2
Seabed slope	2-4	degrees	2	2
Current speed	0.2-0.4	m/s	0.2	2
Distance from shipping lane	>1	nautical miles	>1	2
Total score				22

The successful implementation of the Fuji Lestari program in Karang Jeruk highlights the feasibility of deploying FA modules as artificial habitats to support marine biodiversity and local fishing communities. The compliance score of 22 out of 24 based on SNI 9016:2021 (SNI 2021) standards reinforce the suitability of the site and the stability of the FA modules under marine conditions (Table 3). The initial deployment of FA modules demonstrated structural and environmental compliance, establishing a foundation for potentially enhancing habitat complexity in the region. The frond-like attachments on each module are expected to contribute to habitat complexity, potentially attracting marine species by providing shelter and breeding spaces, as shown in studies on similar artificial reef structures (Sherman et al 2002; Perkol-Finkel & Benayahu 2007). However, further studies are needed to assess the actual ecological impact of the FAs on local biodiversity, as this deployment did not include direct ecological monitoring.

Strategic management formulation based on SWOT analysis. The integrated analysis of internal and external factors provides a comprehensive understanding of the strategic position of the Fuji Lestari Program at KKP Karang Jeruk, Tegal. The internal analysis (IFAS), as shown in Table 4, reveals significant strengths, with a total score of 4.25. Key strengths include the strategic location within a designated fishing zone, robust legal protection, and the availability of technical guidelines from the Fuji Lestari Program. Additionally, the active local community, support for coral reef ecosystems, and guidance from competent advisors contribute to the program's strong internal foundation. These strengths align with findings by Aceves-Bueno et al (2023), who emphasize the importance of strategic location and legal frameworks in enhancing the effectiveness of fisheries management programs.

Table 4

Internal factor analysis summary (IFAS)

Code	*Strenght*	*Weight*	*Rating*	*Score*
S1	Easy access to the fish apartment area	0.1	4	0.4
S2	Legal protection for the fish apartment location	0.15	4	0.6
S3	Active and enthusiastic local community	0.125	4	0.5
S4	Local community possesses environmentally friendly boats and gear	0.1	4	0.4
S5	Fish Apartment is located in a designated fishing zone	0.15	5	0.75
S6	Supports coral reef ecosystem growth	0.125	4	0.5
S7	Fuji Lestari Program has technical guidelines	0.15	4	0.6
S8	Local community is supported by competent advisors	0.1	5	0.5
	Total	1		4.25
Code	*Weakness*	*Weight*	*Rating*	*Score*
W1	Not yet a priority for the local government	0.175	4	0.7
W2	Presence of destructive fishing gear (arad) in the area	0.1	4	0.4
W3	Limited road access to the fish landing site, hindering mobility	0.15	3	0.45
W4	Community productivity is weather-dependent	0.075	3	0.225
W5	Lack of promotional media	0.1	4	0.4
W6	Low community involvement	0.075	4	0.3
W7	Absence of marine tourism locations	0.175	4	0.7
W8	Lack of training and competency enhancement	0.15	4	0.6
	Total	1		3.78
	Internal factor position (S-W)			0.48

However, the internal analysis also identifies several weaknesses, scoring a total of 3.78. Challenges such as the program not being prioritized by the local government, the absence of marine tourism locations, and limited training opportunities for the local community require targeted interventions. These issues resonate with research by Meng and Shaikh (2023), which highlight the critical role of government prioritization and community capacity-building in the success of environmental programs. Furthermore, restricted road access and low community involvement are additional hurdles that need addressing to optimize the program's potential.

Table 5

External factor analysis summary (EFAS)

Code	*Opportunity*	*Weight*	*Rating*	*Score*
O1	Central government attention to KKP Karang Jeruk	0.15	4	0.6
O2	Port facilities facilitate fishermen's catch distribution	0.1	4	0.4
O3	Increased fish resources (SDI) after the Fuji Lestari Program	0.15	4	0.6
O4	Potential to increase fishermen's income	0.125	4	0.5
O5	Potential to develop marine tourism	0.1	4	0.4
O6	Alignment with the Blue Economy program	0.125	4	0.5
O7	Potential to involve various stakeholders	0.1	4	0.4
O8	Joint commitment among stakeholders in managing the fish apartment	0.15	4	0.6
	Total	1		4
Code	*Threats*	*Weight*	*Rating*	*Score*
T1	Location near the core zone of Karang Jeruk Conservation Area	0.075	3	0.225
T2	Open area location subject to adverse weather (monsoon)	0.15	4	0.6
T3	Non-recipient fishermen using destructive gear	0.175	4	0.7
T4	Irresponsible parties damaging area markers	0.175	4	0.7
T5	Threats from global warming and climate change	0.075	3	0.225
T6	Cultural acculturation affecting community image	0.1	4	0.4
T7	Lack of socialization and supervision of the fish apartment area	0.1	4	0.4
T8	Tourists are not yet familiar with fish apartment tourism	0.15	4	0.6
	Total	1		3.85
	External factor position (O-T)			0.15

The external analysis (EFAS), detailed in Table 5, reveals promising opportunities with a total score of 4.00. Key opportunities include the central government's attention to the KKP Karang Jeruk location, increased fish resources following the program's implementation, and strong stakeholder commitment to managing the fish apartments. The alignment with the Blue Economy program (KKP 2023b) and potential to increase fishermen's income further underscore the program's promising external landscape. These opportunities are consistent with the findings of Pinheiro et al (2021), who note that government support and stakeholder collaboration are crucial for the success of fisheries initiatives. However, the external analysis also highlights significant threats, with a total score of 3.85.

Major threats include the use of destructive fishing gear by fishermen involved in IUU (illegal, unreported, and unregulated) fishing and damage to area markers by irresponsible parties. Adverse weather conditions in open areas and insufficient socialization and supervision pose additional risks. These threats align with concerns raised by Parlee and Wiber (2018), who emphasize the need for effective risk management and community engagement to mitigate environmental and operational risks in marine conservation efforts.

The combined analysis positions the Fuji Lestari Program in a favorable strategic context, with internal strengths and external opportunities slightly outweighing weaknesses and threats. With an internal factor position (S-W) of 0.48 and an external factor position (O-T) of 0.15, the program is well-positioned to leverage its strengths and capitalize on external opportunities. To achieve optimal outcomes, it is crucial to address identified weaknesses and threats through strategic interventions, such as enhancing promotion, actively involving the community, and securing government support. By doing so, the program can fully exploit its potential, ensuring long-term sustainability and positive impacts for both the fisheries sector and the local community.

A key strength of the program is its alignment with national and regional development agendas, particularly the Blue Economy initiative (KKP 2023b), which emphasizes sustainable resource use and environmental stewardship. This alignment not only enhances the program's credibility and attractiveness to potential investors and partners but also ensures that its objectives are in harmony with broader policy frameworks. Such strategic alignment has been shown to facilitate access to funding and technical support, as evidenced by similar programs globally (Wicaksono et al 2024). By integrating these broader objectives, the Fuji Lestari Program can enhance its impact and contribute meaningfully to sustainable development goals.

This analysis paves the way for a strategic discussion using the SWOT matrix, which will guide the development of targeted management strategies. By systematically aligning the program's strengths with external opportunities and addressing weaknesses and threats, the Fuji Lestari Program can formulate effective strategies that enhance its resilience and adaptability. The forthcoming SWOT matrix will serve as a critical tool in recommending strategic actions that align with both local and broader environmental and socio-economic objectives, ensuring the program's continued success and sustainability.

Following the IFAS and EFAS results, the next step is to determine the quadrant position and SWOT matrix to generate management strategy recommendations for the Fuji Lestari Program at KKP Karang Jeruk, Tegal. The analysis places the program in quadrant I, indicating significant internal strengths and promising external opportunities, as can be seen in Figure 4.

Positioned in Quadrant I, the Fuji Lestari Program is best suited for a growth-oriented strategy to fully harness its potential. This approach should focus on strengthening partnerships with government authorities and key stakeholders to secure regulatory backing and financial support, enhancing fisher competencies through continuous training, and utilizing technology for improved monitoring and management of fish apartments. Additionally, expanding public outreach initiatives to raise awareness about marine conservation and sustainable fishing practices can help address the risks associated with destructive fishing activities. By adopting these strategic measures, the program can enhance its resilience to challenges while maximizing its contributions to marine ecosystem sustainability and the economic well-being of the local fishing community.

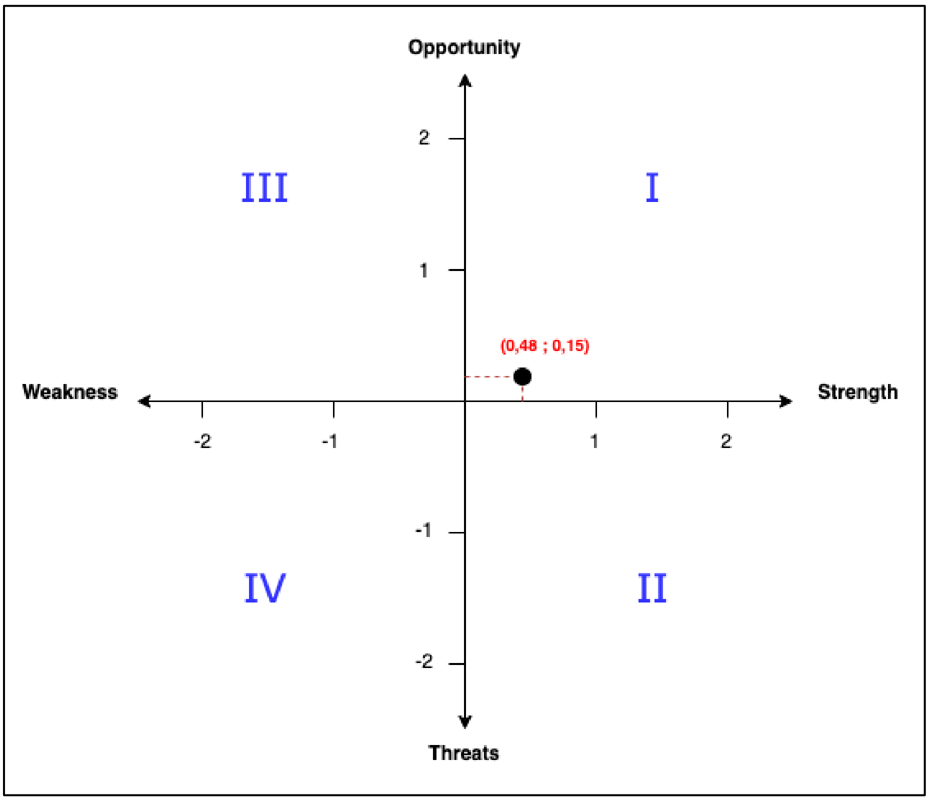

Figure 4. SWOT quadrants.

The recommended strategy based on this quadrant is the S-O (Strength-Opportunity) strategy, which is summarized in Table 6. The management strategy proposed based on the SWOT analysis for developing the fish apartment area presents significant potential to enhance sustainability and competitiveness in the fisheries sector. By leveraging central government attention, the program can secure funding and facilities that accelerate infrastructure development. Research by Meng and Shaikh (2023) indicates that policies supporting infrastructure investment can significantly boost fisheries sector productivity. This strategy, therefore, emphasizes not only physical development but also the enhancement of sustainable production capacity.

Furthermore, existing legal protection is crucial for attracting investors to support fisheries infrastructure. Research by Savage et al (2010) shows that legal certainty and investment protection are key factors in drawing investor interest to the fisheries sector. By involving the local community in managing the fish apartment, this strategy fosters synergy between investor and community interests, enhancing trust and participation. This approach aligns with stakeholder theory, emphasizing the importance of involving all relevant parties to achieve common goals (Mahajan et al 2023). Utilizing local fishermen's fleets as part of this strategy also has positive implications. Research by Mulyadi (2019) shows that utilizing local resources can increase operational efficiency and reduce production costs. By involving local fishermen, not only is their income increased, but social and economic networks around the fish apartments are strengthened. This creates a mutually beneficial ecosystem where local fishermen play an active role in developing a sustainable fisheries area. Additionally, promoting research and innovation in sustainable fisheries management can further support the long-term success of the program. Strengthening institutional collaboration and capacity-building initiatives will enhance the effectiveness of policy implementation and resource management. By integrating these elements, the Fuji Lestari Program can create a more resilient and adaptive fisheries sector, ensuring both economic benefits and ecological sustainability.

Table 6

Swot strategy (S-O)

Recommended actions	*Strategic basis*
Leverage central government attention to secure funding and facilities for fish apartments development	S2, S7, O1
Utilize existing legal protection to attract investors for developing fisheries infrastructure	S2, O1, O3
Engage the local community in managing and developing the fish apartments, capitalizing on local human resources	S3, S8, O4
Use the local fishermen's fleet to support fishing activities around the fish apartments	S4, O2
Develop marine tourism based on coral reef conservation and marine ecosystems around the fish apartments	S6, O5
Integrate the Fuji Lestari Program with the broader Blue Economy program to enhance the added value of fishery products	S7, O6
Conduct socialization and training for various stakeholders on the importance of the Fuji Lestari Program and how to participate	S3, S8, O7
Establish a joint coordination forum among stakeholders to ensure the sustainability of the Fuji Lestari Program	S3, S8, O8

Developing marine tourism based on coral reef conservation and marine ecosystems around the Fish Apartment can also become an additional attraction supporting the sustainability of the Fuji Lestari Program. Research by Hamka et al (2022) shows that ecotourism can provide significant economic benefits while preserving the environment. By integrating the Fuji Lestari Program with the broader Blue Economy program, this strategy enhances the added value of fishery products and raises awareness of marine conservation among the community and tourists. Through socialization and training for various stakeholders, the sustainability of this program can be maintained, providing long-term positive impacts for the fisheries sector and the local community.

The findings from this SWOT analysis have several critical implications for the Fuji Lestari Program and similar initiatives. First, the emphasis on leveraging governmental support and legal frameworks highlights the importance of policy alignment in achieving program objectives. This alignment can facilitate access to resources and support, which are essential for scaling and sustaining program activities. Second, the integration of local communities into program management not only enhances social capital but also ensures that development is inclusive and equitable. This approach can lead to more resilient and adaptable community structures that can withstand economic and environmental changes. Lastly, the focus on ecotourism and the Blue Economy underscores the potential for fisheries programs to contribute to broader sustainable development goals, demonstrating that environmental conservation and economic growth can be mutually reinforcing. These implications provide a roadmap for policymakers, practitioners, and researchers aiming to optimize the impact of fisheries management programs in diverse contexts.

Conclusions. The study of the Fuji Lestari Program, which employs fish apartments as artificial reefs, provides valuable insights into the restoration of marine ecosystems in Indonesia. This initiative addresses the critical need for conservation strategies amid the alarming degradation of coral reefs due to destructive fishing practices, pollution, and climate change. The deployment of fish apartments has shown promising outcomes in enhancing marine biodiversity and supporting local fishing communities, thus underscoring their potential as a viable tool for ecological restoration.

The compliance evaluation demonstrated that Fish Apartments largely met the technical standards set by Indonesian guidelines, although certain spatial coverage requirements were not fully achieved due to logistical constraints. Despite these limitations, the program's implementation has led to increased fish abundance and socio-economic benefits for local communities, indicating a positive trend toward ecosystem recovery and community resilience.

The SWOT analysis revealed significant strengths, such as robust stakeholder engagement and government support, which are crucial for the program's sustainability. Opportunities for further development, such as integrating marine tourism and broader sustainability initiatives, were identified as potential avenues to enhance the program's impact. However, challenges such as resource limitations and the need for comprehensive stakeholder assessments remain areas for improvement.

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