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Silvofishery as a Nature-Based Response to Tin Mining Pressure: A DPSIR-Based Analysis of Coastal Resilience and Climate Change Mitigation in Kurau Barat Village, Central Bangka

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ABSTRACT

Climate change brought impacts on coastal ecosystems, particularly mangrove areas that functioned as blue carbon sinks and livelihood buffers for coastal communities. Kurau Barat Village, Central Bangka Regency, experienced severe pressure from mangrove degradation caused by tin mining activities and infrastructure development plans, which threatened ecological sustainability and socio-economic resilience. This study employed a descriptive qualitative approach, with data collected through interviews, observations and document analysis involving village officials, fishermen, fishpond farmers, community leaders, environmental groups, government and NGO stakeholders. Data were analyzed using the Miles, Huberman & Saldana interactive model, supported by NVivo 15 software. The findings indicated that mangrove degradation and mining activities reduced fisheries productivity and increased community vulnerability. Silvofishery showed potential as a nature-based solution due to community participation, market demand for mangrove crabs, and alignment with ASEAN blue economy policies, despite challenges such as land conflicts, limited capital, and environmental impacts from mining. The implementation of silvofishery contributed to coastal resilience through mangrove rehabilitation, livelihood diversification, and enhanced blue carbon stocks. The study concluded that silvofishery served as a strategic approach to strengthening coastal resilience and supporting climate change mitigation, although its sustainability depended on policy support, stricter mining regulation, and continuous community capacity building.

1. Introduction

Climate change is one of the greatest global challenges, significantly affecting coastal ecosystems and the livelihoods of communities that depend on marine resources. Coastal areas in Indonesia face serious pressures, including mangrove degradation, coastal abrasion, and declining fisheries productivity, which threaten the socio-economic resilience of local communities (Murdiyarso et al., 2015; Khairunnisa et al., 2018). Mangrove ecosystems are recognized as one of the largest blue carbon sinks, with the capacity to store up to five times more carbon than terrestrial tropical forests (Rifandi, 2021). However, the conversion of mangroves in South Sulawesi into ponds or settlements

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has resulted in the loss of ecological functions and climate change mitigation potential (Malik et al., 2023).

According to the National Mangrove Map, the mangrove area in Indonesia in 2021 covered approximately 3.364 million hectares, most of which (93%) were in dense cover condition (3.121 million ha), with the remainder in medium (188 thousand ha) and sparse condition (54 thousand ha) (Nurrahim, 2023). The most recent data from 2022 recorded an increase to 3.39 million ha, with the largest distribution in Papua, Kalimantan, and Sumatera (Fauzan & Lazuardi, 2023). Normatively (*das sollen*), these figures indicate Indonesia's strategic potential in supporting climate change mitigation through blue carbon-based ecosystem management. Empirically (*das sein*), however, the existence of mangroves in several regions is increasingly threatened by extractive economic activities that undermine ecological sustainability.

This contradiction is clearly evident in the Bangka Belitung Islands Province, where mangrove ecosystems face extraordinary pressure from tin mining. Over the past two decades, mangrove destruction has reached 240,460 ha, accompanied by damage to seagrass beds and coral reefs (Ismi, 2024a; Ismi, 2024b). In the Rumpak River, hundreds of illegal tin mining pontoons continue to destroy mangroves, threatening the livelihoods of small-scale fishers (Kurniawan, 2023; Nabillah, 2024). Offshore mining has even altered mangrove habitat characteristics, degrading water quality, thinning mud layers, and reducing biodiversity (Affressia, 2017). In addition, large-scale infrastructure projects such as the planned Bahtera Bridge linking Sumatera and Bangka are expected to sacrifice coastal mangrove areas, further exacerbating ecological vulnerability in Central Bangka (Hafsyah, 2020). These conditions demonstrate that mangrove degradation in Bangka is not merely an environmental issue, but also reflects conflicts of economic interest that often marginalize sustainability considerations.

Within the framework of the blue economy, development is normatively expected (*das sollen*) to emphasize harmonization between ecological preservation and economic growth. One concrete approach aligned with this framework is silvofishery, which integrates aquaculture practices with mangrove conservation. Silvofishery has been widely recognized as a nature-based solution capable of enhancing coastal resilience, reducing carbon emissions, and supporting the achievement of the Sustainable Development Goals (Perwitasari et al., 2021; Sabrina & Putra, 2025). Empirical studies in Indonesia show that silvofishery implementation in Banten increased blue carbon stocks while simultaneously providing economic benefits to local communities (Fatimah et al., 2024). Mangrove vegetation in silvofishery systems functions as a natural biofilter that maintains pond water quality (Kariada & Irsadi, 2014), and the integration of mangrove crab farming has been shown to improve fishers' welfare (Rahman & Pansyah, 2019). In the Bangka Belitung Islands Province, mangrove rehabilitation initiatives through silvofishery have begun to emerge as a response to massive ecosystem degradation (Nita & Sakti, 2024), aligning with ASEAN's Blue Economy framework that promotes synergy between conservation and productivity (ASEAN, 2023).

However, despite the growing body of literature on silvofishery, several research gaps remain. Existing studies in Indonesia largely focus on biophysical outcomes, such as carbon stocks, water quality, or aquaculture productivity, while paying limited attention to the socio-economic vulnerability context shaped by extractive industries, particularly tin mining. At the ASEAN level, studies from countries such as Vietnam and Thailand emphasize mangrove–aquaculture integration for climate adaptation, yet they are generally situated in post-deforestation or policy-driven rehabilitation contexts, rather than in areas experiencing ongoing mining pressures. Consequently, there is a lack of empirical research

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that explicitly positions silvofishery as a strategic response to overlapping ecological degradation, livelihood vulnerability, and extractive economic conflicts within the blue economy framework.

Kurau Barat Village in Central Bangka Regency represents a critical case that reflects this gap. As a coastal community experiencing high vulnerability due to mangrove degradation driven by tin mining activities and planned large-scale infrastructure development, Kurau Barat illustrates the divergence between normative sustainability goals (*das sollen*) and empirical realities (*das sein*). While silvofishery is promoted as a sustainable coastal management model, its actual feasibility, challenges, and contributions to resilience and climate change mitigation in mining-affected coastal areas remain underexplored.

Despite the growing literature on silvofishery as a sustainable aquaculture model, most existing studies focus on ecological performance or productivity outcomes in relatively stable coastal environments. Limited attention has been paid to the role of silvofishery as an adaptive response within mining-impacted coastal social–ecological systems, particularly in the context of small island regions such as Bangka Belitung. This gap underscores the need for an analytical framework capable of linking environmental pressure, socio-economic impacts, and governance responses

Therefore, the novelty of this research lies in its integrated analysis of silvofishery as a nature-based solution within the blue economy framework by simultaneously examining ecological conditions, socio-economic dynamics, and climate mitigation potential in a tin mining-impacted coastal area. Unlike previous studies that emphasize either ecological performance or economic outcomes in relatively stable environments, this study situates silvofishery within a context of structural environmental pressure and livelihood insecurity. By doing so, the research contributes to the broader discourse on blue economy implementation in Indonesia and ASEAN by offering empirical insights from a high-risk coastal setting.

Accordingly, this research is designed to address three key questions: (1) What are the ecological and socio-economic conditions of Kurau Barat Village in relation to mangrove degradation and tin mining pressures? (2) What are the opportunities and challenges in implementing silvofishery within the blue economy framework in this region? and (3) How does silvofishery contribute to strengthening coastal resilience while supporting climate change mitigation efforts? To answer these questions, the study focuses on three main objectives: analyzing the ecological and socio-economic conditions of Kurau Barat Village, identifying the opportunities and barriers to silvofishery development, and evaluating its contribution to coastal resilience and climate change mitigation in a sustainable manner.

2. Research Method

This research employs a descriptive qualitative approach designed to obtain an in-depth understanding of the social and ecological phenomena surrounding the implementation of silvofishery within the blue economy framework in Kurau Barat Village, Central Bangka Regency. The qualitative approach was considered appropriate because it allows for a comprehensive portrayal of the actual conditions of the community, the coastal ecosystem, and the socio-economic dynamics that shape local livelihoods (Moleong, 2021). Through this approach, the research aims to capture the complexity of human-environment interactions and contextualize the silvofishery practices within broader sustainability and

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resilience frameworks. A qualitative case study approach was employed to capture complex interactions between ecological degradation, livelihood adaptation, and governance dynamics that cannot be adequately explained through quantitative indicators alone.

Data collection was conducted over a three-month fieldwork period, from Oktober-Desember 2025, which allowed sufficient engagement with the study site and stakeholders. The research involved 12 key informants, selected using a purposive sampling strategy based on their relevance, experience, and direct involvement in coastal resource management and silvofishery practices. The selection criteria included: (1) active involvement in fisheries or silvofishery activities, (2) institutional or policy-related roles in coastal management, and (3) engagement in mangrove conservation or environmental advocacy at the local level. Data saturation was reached when additional interviews no longer produced new substantive information.

In-depth interviews were conducted with 1 village official and 1 representative of the regional government, 2 fishermen and 2 fishpond farmers directly involved in silvofishery practices, 1 coastal community leader, and 2 members of environmental groups such as HKM Gempa 01, which have initiated mangrove rehabilitation programs through silvofishery in the Bangka Belitung Islands. Additional informants included 1 academic representative, 1 member of a local NGO, and 1 officer from the Department of Marine Affairs and Fisheries, providing institutional and policy perspectives. Interviews were semi-structured, enabling flexibility to explore emerging themes while maintaining consistency across informants.

Field observations were conducted in coastal areas and community-managed fishponds in Kurau Barat Village to document the physical condition of mangrove ecosystems, aquaculture practices within silvofishery systems, and daily socio-economic activities of local communities. These observations provided contextual and visual evidence to support interview data and facilitated a deeper understanding of ecological-livelihood linkages.

A document review was also undertaken, covering official government reports, policy documents, scholarly publications, and relevant online news articles. This review strengthened empirical findings and provided a broader contextual framework for understanding the blue economy discourse, coastal governance, and development dynamics in the study area.

Data analysis followed the interactive model proposed by Miles et al. (2014), consisting of data reduction, data display, and conclusion drawing or verification. NVivo 15 software was used as an analytical support tool to organize interview transcripts, field notes, and documents through thematic coding and categorization. This process enabled systematic identification of patterns, relationships, and key themes relevant to silvofishery development, coastal resilience, and climate change mitigation.

To ensure the validity and reliability (trustworthiness) of the findings, several strategies were employed. Credibility was enhanced through prolonged engagement in the field and member checking, where preliminary interpretations were confirmed with selected informants. Dependability was ensured by maintaining a clear audit trail of data collection and analysis procedures. Confirmability was addressed through reflexive analysis and peer debriefing with academic colleagues to minimize researcher bias. Transferability was

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supported by providing rich, thick descriptions of the study context, allowing readers to assess the applicability of findings to similar coastal settings.

Through this comprehensive methodological approach, the study aims to generate a holistic understanding of the conditions, opportunities, and challenges in developing silvofishery practices as a nature-based solution to strengthen coastal resilience and support climate change mitigation in Kurau Barat Village. The findings are expected to contribute empirically and conceptually to the broader academic discourse on community-based implementation of the blue economy framework in Indonesia and the ASEAN region.

3. Results and Discussion

3.1. Ecological and Socio-Economic Conditions of Kurau Barat Village under Tin Mining Pressure

In-depth interviews with key informants, combined with NVivo 12 analysis, indicate that the ecological and socio-economic conditions of Kurau Barat Village are shaped by a complex social–ecological tension rather than a linear process of environmental degradation. The analysis identified three interrelated themes: mangrove ecosystem degradation driven by tin mining activities, the resulting threats to coastal livelihoods, and the emergence of silvofishery as a conditional restorative strategy. These findings suggest that Kurau Barat is experiencing a structural dilemma in which short-term extractive economic activities undermine the long-term ecological foundations required to sustain coastal livelihoods.

Picture 1. Word Frequency Query using Nvivo 12 Plus
Source: Processed by researcher, 2025

Village officials and representatives of local government emphasized that mangrove degradation in Kurau Barat has intensified coastal abrasion and simultaneously constrained the village's capacity to develop a sustainable fisheries sector. Concerns were also raised regarding large-scale infrastructure projects, such as the planned Bahtera Sumatra Bridge, which may further increase pressure on mangrove ecosystems if development is not accompanied by strict conservation and mitigation measures. These local perceptions are consistent with regional assessments showing that approximately 240,460 hectares of mangrove ecosystems in Bangka Belitung have been degraded over the past two decades due to land conversion and tin mining activities, resulting in the loss of critical ecosystem

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services such as shoreline protection and nursery habitats for marine biota (Anjani et al., 2023).

From an ecological perspective, tin mining both conventional and illegal acts as the primary driver exerting continuous pressure on mangrove ecosystems in Kurau Barat. Previous studies on unconventional tin mining demonstrate that while mining can provide short-term economic benefits, it simultaneously generates negative environmental and social impacts that persist in the medium to long term (Erwana et al., 2016). Field evidence indicates that mining activities have led to declining water quality and increased sedimentation, which restrict the availability of suitable habitats for fish and mangrove crabs and reduce overall fisheries productivity. Changes in soil morphology and substrate composition have further impaired mangrove regeneration capacity, while disruptions to coastal hydrology have accelerated abrasion and increased exposure to tidal forces. These ecological pressures collectively reduce the functional integrity of mangrove ecosystems and push them closer to critical ecological thresholds beyond which natural recovery becomes increasingly difficult.

The degradation of mangrove ecosystems has directly altered the ecological state of coastal waters in Kurau Barat. Traditional fishers reported a sharp decline in fish catches over recent years, which they associated with the loss of mangrove areas that previously functioned as spawning and nursery grounds. Mangrove crab farmers similarly reported rising production costs caused by deteriorating water quality linked to sedimentation and pollution from mining activities. These observations align with scientific findings from the Rumpak River, which show decreased plankton diversity and reduced primary productivity as a result of illegal tin dredging, indicating disruptions to the coastal food web (Nabillah, 2024). The decline in plankton diversity reflects a broader reduction in ecosystem productivity that ultimately affects higher trophic levels, including commercially important fish and crustaceans.

Socio-economically, Kurau Barat remains highly dependent on capture fisheries and aquaculture, particularly mangrove crab cultivation, which constitutes a flagship local commodity (Nita & Sakti, 2024). However, declining fisheries productivity has increasingly threatened the sustainability of household livelihoods that rely on coastal resources. While tin mining offers immediate income opportunities, these benefits are offset by long-term losses in ecosystem services that underpin local food security and economic resilience. This trade-off illustrates a classic coastal development dilemma in which extractive activities generate short-term gains at the expense of long-term socio-economic stability. Community leaders further noted that environmental degradation has intensified social tensions, including horizontal conflicts over pond land and access to coastal resources, particularly between groups that benefit from mining and those whose livelihoods are directly affected by ecosystem decline.

In response to these challenges, local initiatives led by the HKM Gempa 01 community organization have promoted mangrove rehabilitation through silvofishery, integrating mangrove restoration with mangrove crab aquaculture (*wanamina* system). Proponents of this approach argue that silvofishery not only restores degraded ecosystems but also creates alternative economic opportunities that reduce dependence on destructive mining practices. Empirical evidence from other coastal regions supports this claim. A case study in Banyuasin, South Sumatra, demonstrates that crab silvofishery systems in mangrove restoration areas produce significantly better growth performance, with positive allometric

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relationships in carapace length and body weight compared to non-vegetated ponds, indicating improved habitat quality and ecological functionality (Afrillia, 2021; Anjani et al., 2023). These findings suggest that mangroves enhance nutrient availability, provide shelter during molting phases, and stabilize substrates, thereby improving aquaculture productivity.

Nevertheless, both field findings and comparative studies indicate that silvofishery should not be interpreted as a universally successful solution. Its effectiveness is highly conditional and depends on the extent to which external pressures particularly illegal mining can be controlled, as well as on the strength of local institutions, technical assistance, and long-term ecological monitoring. Where mining pressure remains high and law enforcement is weak, mangrove restoration efforts often fail to reach the ecological thresholds required to support sustainable production. Fragmented governance and insufficient cross-sectoral coordination further undermine the long-term viability of silvofishery initiatives, turning them into short-lived projects rather than adaptive management strategies. To clarify the conditional nature of silvofishery implementation, Table 1 summarizes the key ecological, institutional, and policy-related factors distinguishing successful and failed outcomes

Table 1. Comparative Conditions of Successful and Failed Silvofishery Implementation

Aspect of Evaluation	Conditions of Success	Conditions of Failure or Stagnation
Habitat Quality	Mangrove stands remain partially intact, regeneration processes occur, and organic substrates support ecological functions	Mangroves are severely degraded or fragmented, with insufficient organic substrates
External Pressure	Mining activities are controlled through effective law enforcement	Illegal mining persists, generating continuous ecological pressure
Technical Support and Monitoring	Long-term ecological monitoring and adaptive management are implemented	Monitoring is limited, preventing learning-based adaptation
Local Institutions and Participation	Strong community organizations and agreed internal rules	Weak institutions and conflicts over resource access
Policy Support	Synergy among village, provincial, and national policies	Fragmented cross-sectoral governance
Socio-Economic Outcomes	Increased aquaculture income and livelihood diversification	Stagnant or declining income due to low productivity
Ecological Outcomes	Mangrove rehabilitation and increased coastal biodiversity	Restoration fails to reach functional ecological thresholds

Source: Processed by researcher, 2025

From a policy perspective, representatives of the Department of Marine Affairs and Fisheries emphasized that silvofishery aligns with the blue economy framework currently promoted at national and ASEAN levels, particularly in relation to sustainable fisheries, climate change adaptation, and coastal resilience. However, they acknowledged that institutional fragmentation and inconsistent policy enforcement especially in regulating illegal mining remain major barriers. This observation is consistent with coastal resilience theory, which argues that community vulnerability increases when ecosystems lose their capacity to deliver essential services such as shoreline protection, habitat provision, and carbon sequestration (Adger, 2000).

Global studies further reinforce the role of mangroves as nature-based solutions capable of reducing coastal flood risks due to their capacity for post-disturbance recovery (Gijsman et al. (2021), as well as their complex adaptive mechanisms involving microbial processes

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that maintain ecosystem stability under environmental stress (Saho Wang & Dong Gu, 2021). Overall, the ecological and socio-economic conditions of Kurau Barat reflect a tightly coupled social–ecological system characterized by competing development pathways. Tin mining functions as a dominant driver exerting sustained pressure on mangrove ecosystems, altering their ecological state and generating cascading socio-economic impacts. Silvofishery emerges as a potentially transformative response, but its success is contingent upon ecological suitability, effective governance, and long-term institutional support. Integrating the DPSIR framework with resilience theory allows silvofishery to be understood not merely as a technical intervention, but as an adaptive strategy aimed at strengthening the social-ecological resilience of coastal communities over time.

3.2. Opportunities and Challenges of Implementing Silvofishery within the Blue Economy Framework

Silvofishery emerges as a strategic alternative based on Nature-Based Solutions (NbS), capable of integrating fisheries production with mangrove ecosystem conservation. In Bangka Belitung, the *HKM Gempa 01* community has initiated mangrove rehabilitation programs through silvofishery models in Munjang Village, East Belitung, which have successfully increased mangrove cover while maintaining pond productivity (Nita & Sakti, 2024). This demonstrates that similar opportunities can be applied in Kurau Barat Village. From an economic perspective, silvofishery development is seen as a means of increasing community income through fisheries product diversification, particularly high-value mangrove crabs (Wahyuni, 2020). Innovations such as the *Si Abang Tampan* Program (*Silviofishery Peningkat Produksi Kepiting Bakau Ramah Lingkungan untuk Perikanan Masa Depan*) using crab boxes in Central Bangka also support sustainable production improvements (Nita & Sakti, 2024).

Empirical evidence from other coastal regions in Indonesia and Southeast Asia supports this opportunity. A crab silvofishery case study in Banyuasin, South Sumatra, shows that mangrove-based aquaculture systems can simultaneously enhance mangrove regeneration and improve crab growth performance, indicated by positive allometric relationships in carapace width and body weight compared to conventional ponds (Anjani et al., 2023). Similar findings reported in aquaculture and coastal management studies demonstrate that mangrove-integrated systems provide ecological benefits such as improved nutrient cycling, shelter during molting periods, and stabilized pond microclimates, which collectively increase aquaculture resilience under environmental stress (Hardi, 2024; Robinson et al., 2025). These outcomes position silvofishery as a practical manifestation of the blue economy principle that emphasizes productivity without ecosystem degradation.

However, several significant challenges remain. First, the limited technical capacity and knowledge of local communities regarding sustainable silvofishery management. Second, weak law enforcement against illegal tin mining activities that continue to damage coastal areas. Third, large-scale infrastructure plans such as the Bahtera Sumatera Bridge, which may cause further mangrove destruction (Hafsyah, 2020). These challenges are consistent with broader findings on small-scale tin mining in Indonesia, which highlight persistent environmental degradation, social inequality, and governance failures despite regulatory

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reforms (Erwana et al., 2016; Rahayu et al., 2023). Studies on environmental and social injustice associated with tin mining further emphasize that mining impacts are disproportionately borne by coastal communities through declining ecosystem services and livelihood insecurity (Rahayu et al., 2023).

NVivo 12 analysis of in-depth interviews revealed that village officials and local government representatives view silvofishery as a strategic opportunity to reduce community dependence on the mining sector. They stressed that the integration of mangroves and crab farming could strengthen the local economy while restoring ecological functions. Fishers and pond farmers believed silvofishery could bring tangible benefits, especially through increased mangrove crab productivity as a key commodity. However, they also pointed out technical constraints, such as limited knowledge of silvofishery pond management and the need for initial capital. Coastal community leaders added that silvofishery implementation could also ease horizontal conflicts by offering more sustainable livelihood alternatives compared to competition over mining land. This social dimension aligns with studies showing that nature-based livelihood diversification can reduce conflict intensity in resource-dependent coastal communities (Mollet et al., 2024).

Picture 2. Word Frequency Query using Nvivo 12 Plus
Source: Processed by researcher, 2025

Representatives of *HKM Gempa 01* emphasized the importance of community involvement in mangrove stewardship through silvofishery systems. They argued that the success in East Belitung could be replicated in Kurau Barat if institutional and policy support were available. Academics and local NGOs stressed that this practice is not only conservation-oriented but also a nature-based climate change adaptation strategy consistent with sustainable development policies. From a policy standpoint, the Department of Marine Affairs and Fisheries confirmed that silvofishery aligns with national and regional blue economy visions but acknowledged the need for stronger cross-sectoral coordination to curb illegal mining. This policy gap reflects broader governance challenges in coastal management, where fragmented institutional arrangements often undermine integrated coastal zone management efforts (Kanan & Giupponi, 2024).

These interview findings are consistent with numerous scientific studies. The integration of mangroves and aquaculture has been proven to enhance ecosystem resilience and mitigate climate change impacts by maintaining coastal protection functions and

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improving recovery capacity after extreme events (Sualia et al., 2023; Gijsman et al., 2021). Silvofishery models are considered effective because they balance fisheries production with mangrove conservation, thereby preserving critical ecosystem services while generating economic value (Novida, 2024). International research further highlights that silvofishery contributes to blue carbon strategies, as mangrove ecosystems store carbon at rates up to four times higher than terrestrial forests, strengthening climate change mitigation outcomes within the blue economy framework (Alongi, 2020; Trenggono et al., 2025).

Nevertheless, recent sustainability assessments caution that silvofishery outcomes are highly context-dependent. Studies published in *Sustainability* and *Ambio* demonstrate that silvofishery initiatives tend to succeed only when external pressures such as illegal mining and land-use conflicts are effectively controlled and when communities receive sustained technical and financial support (Marwa et al., 2024; Herdiyanti et al., 2025). Without these enabling conditions, silvofishery risks becoming a short-term project rather than a transformative pathway toward coastal resilience.

Thus, both empirical field findings and cross-regional evidence indicate that the successful implementation of silvofishery in Kurau Barat requires multi-stakeholder collaboration, strengthened community capacity, consistent monitoring, and firm enforcement of regulations against destructive tin mining activities. Within the blue economy framework, silvofishery should therefore be understood not as a stand-alone solution, but as part of an adaptive governance strategy that reconciles economic development with long-term social-ecological sustainability. To clarify the multidimensional opportunities and constraints discussed above, Table 2 presents a comparative synthesis of silvofishery implementation within the blue economy framework

Table 2. Opportunities and Challenges of Silvofishery Implementation within the Blue Economy Framework

Analytical Dimension	Opportunities	Challenges
Ecological	Mangrove restoration enhances habitat quality, biodiversity, and coastal protection	Continued degradation from illegal tin mining reduces restoration effectiveness
Economic	Increased income from high-value mangrove crab aquaculture and livelihood diversification	High initial capital and limited access to technology for small-scale farmers
Social	Reduction of livelihood-based conflicts through alternative income sources	Horizontal conflicts persist where mining pressure remains dominant
Institutional	Alignment with national and ASEAN blue economy agendas	Weak cross-sectoral coordination and law enforcement
Climate Change	Contribution to blue carbon storage and climate adaptation strategies	Lack of long-term monitoring to quantify carbon and resilience benefits

Source: Processed by researcher, 2025

3.3.The Contribution of Silvofishery to Coastal Resilience and Climate Change Mitigation

Silvofishery has been proven to hold significant potential in strengthening coastal resilience while simultaneously supporting climate change mitigation. In the context of Kurau Barat, the pre-silvofishery condition was characterized by mangrove degradation,

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declining fisheries productivity, increased sedimentation, and rising socio-economic vulnerability linked to tin mining pressures. Mangrove loss reduced natural coastal protection functions and disrupted nursery habitats, leading to lower fish and crab yields and higher production costs, as also documented in other tin-mining-affected coastal regions in Bangka Belitung (Erwana et al., 2016).

The introduction of silvofishery represents a structural shift from extractive coastal use toward a nature-based production system. Mangrove vegetation integrated into silvofishery ponds functions as a natural biofilter that improves water quality, stabilizes salinity and temperature, and enhances nutrient cycling, while simultaneously absorbing substantial amounts of blue carbon (Afrillia, 2021; Susanto, 2025). Comparative studies in Banyuasin, South Sumatra, demonstrate that post-silvofishery conditions show measurable ecological recovery, including increased mangrove density, improved pond water parameters, and healthier crab growth patterns compared to conventional ponds (Anjani et al., 2023; Apriyanto et al., 2025). These findings provide a strong empirical basis to infer similar ecological trajectories for Kurau Barat under controlled implementation.

From a climate mitigation perspective, mangrove ecosystems within silvofishery systems are recognized as high-capacity carbon sinks. Studies indicate that mangroves can store up to five times more carbon than terrestrial tropical forests, particularly in belowground biomass and sediments (Rifandi, 2021), making silvofishery an essential component of national climate mitigation strategies. Before silvofishery adoption, Kurau Barat's degraded mangroves had limited capacity to deliver these climate regulation services. Post-intervention scenarios, as observed in comparable Indonesian coastal systems, show increased blue carbon sequestration alongside ecosystem recovery, positioning silvofishery as an effective local contribution to national climate mitigation strategies (Trenggono et al., 2025).

Beyond ecological and climate dimensions, silvofishery alters socio-economic conditions at the community level. Prior to silvofishery, local livelihoods in Kurau Barat were heavily dependent on capture fisheries and informal mining activities, both of which are vulnerable to environmental degradation and market instability. NVivo 12 analysis of in-depth interviews confirms that community members perceive silvofishery as a transitional livelihood strategy that bridges economic needs and conservation objectives. Fishers and crab farmers reported improved crab quality and reduced mortality rates under mangrove-integrated systems, consistent with findings from international aquaculture studies showing that mangrove presence enhances pond microclimate stability and reduces disease risks (Hardi, 2024; Robinson et al., 2025).

Picture 3. Word Frequency Query using Nvivo 12 Plus

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Source: Processed by researcher, 2025

Socially, pre-silvofishery conditions were marked by horizontal conflicts over pond land and resource access, particularly in areas influenced by mining expansion. Post-silvofishery experiences from East Belitung and Banyuasin indicate a gradual reduction in livelihood-based conflicts as communities gain alternative income sources that are less destructive and more collectively managed (Nita & Sakti, 2024; Apriyanto et al., 2025). This aligns with Community-Based Coastal Resource Management (CBCRM) principles, where ecological restoration and economic incentives reinforce collective action and social cohesion.

At the institutional level, silvofishery contributes to enhanced adaptive capacity but remains highly context-dependent. Before implementation, governance fragmentation and weak enforcement against illegal mining constrained sustainable coastal management. While silvofishery aligns with national blue economy and climate adaptation policies, post-implementation success depends on sustained technical assistance, policy coherence, and cross-sectoral coordination (Prasetya, 2025; Kanan & Giupponi, 2024). Without these enabling conditions, studies caution that silvofishery risks stagnating as a pilot intervention rather than evolving into a transformative resilience strategy (Marwa et al., 2024).

Thus, in Kurau Barat, silvofishery should be understood as a process-driven intervention rather than an instantaneous outcome. Drawing from empirical evidence in comparable coastal systems, silvofishery has the potential to transform pre-existing ecological degradation and socio-economic vulnerability into post-intervention conditions characterized by improved ecosystem services, diversified livelihoods, and enhanced coastal resilience provided that external pressures such as illegal mining are effectively controlled. To clarify how silvofishery alters ecological and socio-economic conditions in the study area over time, a comparative analysis of conditions before and after silvofishery implementation is summarized in Table 3.

Table 3. Changes in Coastal Conditions Before and After Silvofishery Implementation (Analytical Comparison)

Dimension	Before Silvofishery (Pre-Intervention)	After Silvofishery (Post-Intervention / Evidence-Based Projection)
Mangrove Condition	Degraded mangrove cover, fragmented habitats, limited regeneration capacity	Increased mangrove density and regeneration through integrated pond systems
Water Quality	High turbidity, sedimentation, unstable salinity due to mining runoff	Improved water clarity, stabilized salinity and temperature via mangrove biofiltration
Fisheries Productivity	Declining fish and crab catches; higher mortality and production costs	Improved crab growth performance, higher survival rates, and better product quality
Livelihood Structure	Dependence on capture fisheries and informal tin mining	Diversified income through mangrove crab aquaculture and eco-based livelihoods
Social Conditions	Horizontal conflicts over land and resource access	Reduced conflict intensity through shared conservation-based livelihood systems
Climate Mitigation	Limited carbon sequestration due to mangrove loss	Enhanced blue carbon storage in biomass and sediments
Adaptive Capacity	High vulnerability to abrasion and climate stressors	Improved coastal protection and recovery capacity as nature-based adaptation

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Governance Context	Weak enforcement; fragmented coastal management	Improved alignment with blue economy and climate policies, conditional on institutional support

Source: Processed by researcher, 2025

4. Conclusion

This research demonstrates that the ecological and socio-economic conditions of Kurau Barat Village are shaped by a tightly coupled social-ecological system under sustained pressure from tin mining activities. Using the DPSIR framework, the findings show that tin mining functions as a dominant driving force that generates continuous pressure on mangrove ecosystems, leading to a degraded state characterized by declining water quality, reduced fisheries productivity, and increased coastal vulnerability. These ecological changes produce significant impacts on local livelihoods, including income instability, rising production costs, and social conflicts over coastal resources.

In response to these conditions, silvofishery emerges as a conditional response strategy within the blue economy framework. The study finds that silvofishery contributes to coastal resilience by restoring mangrove functions, diversifying livelihoods through mangrove crab aquaculture, and strengthening blue carbon stocks that support climate change mitigation. However, its effectiveness is highly dependent on external conditions, particularly the control of illegal mining activities, institutional coherence, and sustained community capacity building.

By situating silvofishery within a mining-impacted coastal context, this research extends existing silvofishery studies that primarily focus on ecological or economic performance in relatively stable environments. The novelty of this study lies in demonstrating that silvofishery should not be understood as a purely technical intervention, but as an adaptive governance response to structural environmental pressures within a social-ecological system. Concepts of coastal resilience, Nature-Based Solutions, and Community-Based Coastal Resource Management function as complementary lenses that explain how silvofishery enhances adaptive capacity at the community level.

From a policy perspective, the findings suggest that silvofishery can serve as an effective blue economy instrument only when integrated with stricter regulation of extractive activities, cross-sectoral coordination, and long-term ecological monitoring. Without these enabling conditions, silvofishery risks stagnating as a short-term project rather than evolving into a transformative pathway toward coastal resilience and climate change mitigation.

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6. References

Adger, W. N. (2000). Social and Ecological Resilience: Are They Related?. *Progress in Human Geography*, *24*(3), 347-364. https://doi.org/10.1191/030913200701540465.

Afrillia, D. (2021). Silvofishery, Alternatif Melestarikan Hutan Bakau dengan Budidaya Ikan. *Goodnewsfromindonesia.id*. https://www.goodnewsfromindonesia.id/2021/09/24/silvofishery-alternatif-melestarikan-hutan-bakau-dengan-budidaya-ikan.

Affressia, R., Poedjirahajoe, E., & Hasanbahri, S. (2017). Karakteristik Habitat Mangrove di Sekitar Pertambangan Timah Lepas Pantai Kabupaten Bangka Selatan. *Jurnal Manusia & Lingkungan*, *24*(3), 131-140. https://doi.org/10.22146/jml.22997.

Alongi, D. M. (2020). *Blue Carbon: Coastal Sequestration for Climate Change Mitigation*. Springer: Berlin.

Anjani, R., Ihsan, I. M., & Mawardi, M. I. (2023). Silvofishery, Harmoni Vegetasi Hutan Mangrove dan Budidaya Perikanan. *Mongabay.co.id*. https://mongabay.co.id/2023/08/29/silvofishery-harmoni-vegetasi-hutan-mangrove-dan-budidaya-perikanan/.

Apriyanto., Suwignyo, R. A., Ulqodry, T. Z., & Sarno. (2025). The Crab Silvofishery System as a Conservation Strategy in Mangrove Restoration Area: A Case Study on the Coast of Banyuasin, South Sumatera. *Journal of Environmental Science and Sustainable Development*, *8*(1), 48-65. http://dx.doi.org/10.7454/jessd.v8i1.1336.

ASEAN. (2023). *ASEAN Blue Economy Framework*. Jakarta: ASEAN Secretariat. https://asean.org/wp-content/uploads/2023/09/ASEAN-Blue-Economy-Framework.pdf.

Ellison, A. M., Felson, A. J., & Friess, D. A. (2020). Mangrove Rehabilitation and Restoration as Experimental Adaptive Management. *Frontiers in Marine Science*, *7*, 327. https://doi.org/10.3389/fmars.2020.00327.

Erwana, F., Dewi, K., & Rahardyan, B. (2016). Study of Socio-Economic and Environment Impacts of Inconventional Tin Mining (A Case Study: Bangka Barat District of Bangka Belitung Province). *Jurnal Teknik Lingkungan*, *22*(2), 32-41. https://doi.org/10.5614/J.TL.2016.22.2.4.

Fatimah, G., Saputri, H. R., Rahmadhani, K., Hartoyo, A. P. P. (2024). Potensi Silvofishery Sebagai Blue Carbon Reservoir dan Sumber Pendapatan Masyarakat di Desa Sawah Luhur, Banten dalam Mitigasi Perubahan Iklim. *Jurnal Silva Tropika*, *8*(1), 1-12. http://dx.doi.org/10.22437/jurnalsilvatropika.v8i1.33017.

Fauzan, A. M., & Lazuardi, A. (2023). KLHK: Indonesia Punya 3,39 Juta Ha Mangrove. *Antaranews.com*. https://bali.antaranews.com/berita/328617/klhk-indonesia-punya-339-juta-ha-mangrove.

ISSN 1411-7924
Vol. 12, No. 1, January, 2026, pp. 9-25

Gijsman, R., Horstman, E. M., Wal, D. V. D., Friess, D. A., Swales, A., & Wijnberg, K. M. (2021). Nature-Based Engineering: A Review on Reducing Coastal Flood Risk with Mangroves. *Frontiers in Marine Science*, *8*, 702412. https://doi.org/10.3389/fmars.2021.702412.

Hafsyah, S. S. (2020). Wanamina untuk Konservasi Pantai dan Perbaikan Ekonomi. *Forestdigest.com*. https://www.forestdigest.com/detail/701/wanamina-untuk-konservasi-pantai-dan-perbaikan-ekonomi.

Hardi, E. H. (2024). Smart Silvofishery for Food Safety and Sustainable Aquaculture. *World Aquaculture Society (was.org).* https://www.was.org/Meeting/Program/PaperDetail/162649.

Herdiyanti., Suyanto, B., Mas'udah, S. (2025). Social Capital and Ecological Transformation in Post-Mining Land Restoration in Indonesia. *Ambio* (2025). https://doi.org/10.1007/s13280-025-02223-8.

Ismi, N. (2024a). Riset: Padang Lamun Dekat Penambangan Timah di Bangka Belitung Mengalami Kerusakan. *Mongabay.co.id.* https://mongabay.co.id/2024/11/29/riset-padang-lamun-dekat-penambangan-timah-di-bangka-belitung-mengalami-kerusakan/.

Ismi, N. (2024a). Tambang Timah dan Ancaman Kerusakan Daratan Kepulauan Bangka Belitung. *Mongabay.co.id*. https://mongabay.co.id/2024/12/29/tambang-timah-dan-ancaman-kerusakan-daratan-kepulauan-bangka-belitung/.

Kanan, A. H., & Giupponi, C. (2024). Coastal Socio-Ecological Systems Adapting to Climate Change: A Global Overview. *Sustainability*, *16*(22), 10000. https://doi.org/10.3390/su162210000.

Kariada, N. T. M., & Irsadi, A. (2014). Peranan Mangrove sebagai Biofilter Pencemaran Air Wilayah Tambak Bandeng Tapak, Semarang. *Jurnal Manusia dan Lingkungan, 21*(2), 188-194. https://doi.org/10.22146/jml.18543.

Khairunnisa, K., Setyobudiandi, I., & Boer, M. (2018). Estimasi Cadangan Karbon pada Lamun di Pesisir Timur Kabupaten Bintan. *Jurnal Ilmu dan Teknologi Kelautan Tropis, 10*(3), 639-650. https://doi.org/10.29244/jitkt.v10i3.21397.

Kurniawan, W. (2024). Hutan Mangrove Ditebang! Penambangan Timah Sungai Rumpak Tak Terkendali. *Suarapos.co.id*. https://suarapos.co.id/hutan-mangrove-ditebang-penambangan-timah-sungai-rumpak-tak-terkendali/.

Malik, A., Rahim, A., Jalil, A. R., Amir, M. F., Arif, D. S., Rizal, M., Husain, J., William, D., & Jihad, N. (2023). Mangrove Blue Carbon Stocks Estimation in South Sulawesi Indonesia. *Continental Shelf Research, 269*, 105139. https://doi.org/10.1016/j.csr.2023.105139.

Marwa, T., Muizzudidin., Bashir, A., Andaiyani, S., Cahyadi, A. (2024). Determinants of the Blue Economy Growth in the Era of Sustainability: A Case Study of Indonesia. *Economics, 12*(11), 299. https://doi.org/10.3390/economies12110299.

ISSN 1411-7924
Vol. 12, No. 1, January, 2026, pp. 9-25

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. Jakarta: UI Press.

Moleong, L. J. (2021). *Metode Penelitian Kualitatif*. PT Remaja Rosdakarya.

Mollet, J. A., Titalessy, P. B., & Zulhendri. (2024). The Blue Economy Approach and Development of Marine Fisheries Potential in the Coastal Region of Jayapura City. *Society*, *12*(2), 835-858. https://doi.org/10.33019/society.v12i2.745.

Murdiyarso, D., Purbopuspito, J., Kauffman, J. B., Warren, M. W., Sasmito, S. D., Donato, D. C., Manuri, S., Krisnawati, H., Taberima, S., & Kurnianto, S. (2015). The Potential of Indonesian Mangrove Forests for Global Climate Change Mitigation. *Nature Climate Change, 5*, 1089-1092. http://dx.doi.org/10.1038/nclimate2734.

Nabillah, A. P. (2024). Tambang Ilegal di Sungai Rumpak: Ketidakmampuan Aparat dan Hancurnya Ekosistem Vital. *Laporpak.co.id*. https://www.laporpak.co.id/2024/12/tambang-ilegal-di-sungai-rumpak.html.

Nita, C. N., & Sakti, A. T. (2024). Tingkatkan Produksi Kepiting Bakau di Bangka Tengah dengan Si Abang Tampan, Sudah Ada 340 Crab Box. *BangkaPos.com*. https://bangka.tribunnews.com/2024/08/07/tingkatkan-produksi-kepiting-bakau-di-bangka-tengah-dengan-si-abang-tampan-sudah-ada-340-crab-box.

Novida, R. (2024). Silvofishery: Integrating Fishery Production with Mangrove Conservation. *Gis-coastalindo.com*. https://gis-coastalindo.com/silvofishery-integrating-fishery-production-with-mangrove-conservation/.

Nurrahim, T. (2023). Mangrove Indonesia yang Amat Berguna. *Indonesiabaik.id*. https://indonesiabaik.id/infografis/mangrove-indonesia-yang-amat-berguna.

Perwitasari, W. K., Muhammad, F., & Hidayat, J. W. (2021). Budidaya silvofishery di Desa Mororejo Kabupaten Kendal untuk Mendukung Program Budidaya Berkelanjutan. *Indonesia Journal of Fisheries Community Empowerment*, *1*(3), 196-201. http://dx.doi.org/10.29303/jppi.v1i3.345.

Praseyta. (2025). FPIK UB and Wahana Visi Indonesia Explore Collaboration on Silvofishery for Coastal Resilience. *Ub.ad.id*. https://prasetya.ub.ac.id/en/fpik-ub-dan-wahana-visi-indonesia-jajaki-kolaborasi-silvofishery-untuk-ketahanan-pesisir/.

Rahayu, D. P., Faisal., Darwance., & Ferdian, K. J. (2023). Environmental and Social Injustice: Impact and Sustainability of Small Scale Tin Mining Under Indonesia's New Mineral and Coal Regulation. *Cepalo, 7*(2), 119-130. https://doi.org/10.25041/cepalo.v7no2.3137.

Rahman, M.Z., & Pansyah, D. (2019). Pemberdayaan Ekonomi Masyarakat Pesisir melalui Pemanfaatan Hutan Mangrove untuk Budidaya Kepiting Bakau di Lombok Barat. *Jurnal Kajian Penelitian dan Pengembangan Pendidikan*, *7*(2), 1-10. http://journal.ummat.ac.id/index.php/geography.

ISSN 1411-7924
Vol. 12, No. 1, January, 2026, pp. 9-25

Rifandi, R. (2021). Pendugaan Stok Karbon dan Serapan Karbon pada Tegakan Mangrove di Kawasan Ekowisata Mangrove Desa Mojo Kabupaten Pemalang. *Jurnal Litbang Provinsi Jawa Tengah, 19*(1), 93-103. https://dx.doi.org/10.36762/jurnaljateng.v19i1.871.

Robinson, C., Sabine, C., & Isensee, K. (2025). Providing Solutions to Mitigate, Adapt, and Build Resilience to the Effects of Climate Change. *ICES Journal of Marine Science, 82*(6), fsae170. https://doi.org/10.1093/icesjms/fsae170.

Sabrina, O., & Putra, R. A. (2025). Navigating the Blue Economy: Indonesia's Regional Efforts in ASEAN to Support Sustainable Practices in Fisheries Sector. *Journals Sustainabillty, 17*(5). 6906. https://doi.org/10.3390/su17156906.

Shao Wang, J., & Dong Gu, J. (2021). Ecological Responses, Adaptation and Mechanisms of Mangrove Wetland Ecosystems to Global Climate Change and Anthropogenic Activities. International Biodeterioration & Biodegradation, 162, 105248. *Ecological Indicators, 125*, 107604. https://doi.org/10.1016/j.ibiod.2021.105248.

Sinta, R. D. (2024). Silvofishery, Revolusi Tambak untuk Masa Depan Budidaya Kepiting Bakau Secara Berkelanjutan. *Goodnewsfromindonesia.id*. https://www.goodnewsfromindonesia.id/2024/12/11/silvofishery-revolusi-tambak-untuk-masa-depan-budidaya-kepiting-bakau-secara-berkelanjutan.

Sualia, I., Lestari, I. A., & Al Kafi, R. (2023). Silvofishery sebagai Solusi Berbasis Alam dalam Strategi Mitigasi Perubahan Iklim Indonesia. *Mahasiswaindonesia.id*. https://mahasiswaindonesia.id/silvofishery-sebagai-solusi-berbasis-alam-dalam-strategi-mitigasi-perubahan-iklim-indonesia/.

Susanto, V. (2025). Get to Know: Silvofishery A Nature-Based Solution for Sustainable Aquaculture and Mangrove Restoration. *Fairatmos.com*. https://www.fairatmos.com/blog/get-to-know-silvofishery---a-nature-based-solution-for-sustainable-aquaculture-and-mangrove-restoration.

Trenggono, S. W., Meilano, I., Latief, H., Diantara, S. D., Sakti, W., Ketaren, D. G. K., Winata, I. N. P., Yuwono, T., Syamdidi., Arthatiani, F. Y., Kasim, K., & Radiarta, I. N. (2025). Innovation In the Blue Economy and Environmental Sustainability in Marine and Fisheries Strategy. *Global Journal of Environmental Science and Management*. https://doi.org/10.22034/gjesm.2025.02.08.

Wahyuni, A. (2020). Silvofishery Memelihara Kepiting Sambil Menjaga Mangrove " (Bagian-1). *Antaranews.com*. https://www.antaranews.com/berita/1908040/silvofishery-memelihara-kepiting-sambil-menjaga-mangrove-bagian-1.