CONSERVATION AND REHABILITATION STRATEGIES OF MANGROVE ECOSYSTEMS TO SUPPORT FISH BIODIVERSITY IN THE COASTAL AREA OF BANTEN BAY

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Abstract
Mangrove ecosystems play a critical role in maintaining coastal biodiversity, particularly as essential habitats for fish communities. However, increasing anthropogenic pressures have led to significant mangrove degradation in many coastal areas, including Banten Bay on the northern coast of Java, Indonesia. This study aimed to analyze conservation and rehabilitation strategies of mangrove ecosystems and their role in supporting fish biodiversity in the coastal waters of Banten Bay. Field surveys were conducted in conserved, rehabilitated, and degraded mangrove areas to assess mangrove vegetation structure and fish assemblages. Mangrove conditions were evaluated based on tree density, diameter at breast height (DBH), and canopy cover, while fish biodiversity was analyzed using species richness, abundance, and ecological indices. The results showed that conserved mangrove areas had the highest vegetation complexity and supported greater fish species richness and diversity compared to rehabilitated and degraded sites. Rehabilitated mangroves exhibited moderate biodiversity levels, indicating partial recovery of ecological functions. A positive relationship was observed between mangrove structural complexity and fish biodiversity, emphasizing the importance of effective conservation and ecosystem-based rehabilitation strategies. These findings highlight the necessity of protecting existing mangrove forests and improving rehabilitation practices to sustain fish biodiversity and support sustainable coastal management in Banten Bay.

Keywords: Mangrove ecosystem; Fish biodiversity; Coastal conservation; Mangrove rehabilitation; Banten Bay

INTRODUCTION

Mangrove ecosystems are among the most productive coastal habitats in the world and play a crucial role in supporting marine and coastal biodiversity, particularly fish communities. Mangroves function as nursery grounds, feeding areas, and shelters for many fish species, contributing significantly to coastal fisheries productivity (Nagelkerken et al., 2008). In tropical regions, the structural complexity of mangrove roots provides protection from predators and enhances habitat suitability for juvenile fish, thereby increasing species richness and abundance (Mumby et al., 2004).

Despite their ecological importance, mangrove ecosystems are experiencing rapid degradation due to anthropogenic pressures such as coastal development, aquaculture expansion, pollution, and land conversion. Indonesia, which possesses the largest mangrove area globally, has lost a substantial portion of its mangrove cover over the past decades, leading to declining ecosystem services and biodiversity loss (Friess et al., 2019). Degradation of mangroves directly affects fish diversity by reducing habitat availability and disrupting ecological connectivity between mangroves, seagrass beds, and coral reefs (Unsworth et al., 2008).

Banten Bay, located on the northern coast of Java, represents a coastal area where mangrove degradation has become increasingly evident. The bay is influenced by industrial activities, urban expansion, and intensive fishing practices, which collectively contribute to habitat degradation and declining fish resources. The reduction in mangrove cover in this area threatens local fisheries and the livelihoods of coastal communities that depend on fish biodiversity for food security and income (Alongi, 2015).

Conservation and rehabilitation of mangrove ecosystems are therefore essential strategies to restore ecological functions and enhance fish biodiversity in coastal waters. Effective mangrove rehabilitation not only involves replanting efforts but also emphasizes hydrological restoration, community participation, and long-term ecosystem management (Lewis, 2005). Conservation strategies that integrate ecological, social, and economic dimensions are more likely to succeed in sustaining mangrove ecosystems and the associated fish communities (Walters et al., 2008).

This study aims to analyze conservation and rehabilitation strategies of mangrove ecosystems in the coastal area of Banten Bay and evaluate their role in supporting fish biodiversity. The findings are expected to provide scientific insights and practical recommendations for sustainable coastal management and biodiversity conservation in mangrove-dominated coastal ecosystems.

LITERATURE REVIEW

Mangrove Ecosystems and Their Ecological Functions

Mangrove ecosystems are coastal intertidal forests found in tropical and subtropical regions, characterized by high primary productivity and complex root structures. These ecosystems provide essential ecological services, including shoreline protection, nutrient cycling, carbon sequestration, and habitat provision for various marine organisms (Alongi, 2014). The intricate root systems of mangroves enhance sediment trapping and create microhabitats that support diverse biological communities.

Mangroves play a critical role in maintaining ecological connectivity between coastal ecosystems such as seagrass beds and coral reefs. This connectivity facilitates the movement of organisms and energy flow across habitats, thereby enhancing overall ecosystem resilience (Nagelkerken et al., 2008). The degradation of mangrove ecosystems disrupts these linkages and reduces their capacity to support coastal biodiversity.

Role of Mangroves in Supporting Fish Biodiversity

Mangrove ecosystems are widely recognized as important habitats for fish, particularly during juvenile stages. Many commercially and ecologically important fish species utilize mangroves as nursery grounds due to the availability of food resources and protection from predators (Mumby et al., 2004). Studies have shown that fish abundance and species richness are significantly higher in healthy mangrove forests compared to degraded or non-mangrove coastal areas (Nagelkerken et al., 2015).

The structural complexity of mangrove roots directly influences fish assemblages by increasing habitat heterogeneity. Higher root density and canopy cover are associated with increased fish diversity and biomass (Faunce & Serafy, 2006). Consequently, the loss of mangrove vegetation leads to a decline in fish populations and negatively impacts coastal fisheries productivity.

Mangrove Degradation and Its Impacts on Coastal Fisheries

Mangrove degradation is primarily driven by anthropogenic activities such as land conversion, aquaculture development, pollution, and overexploitation of natural resources. In many developing countries, rapid coastal development has resulted in significant mangrove loss, threatening fish biodiversity and the livelihoods of coastal communities (Friess et al., 2019).

The decline in mangrove ecosystems has been linked to reduced fish catch and altered species composition in adjacent coastal waters. Degraded mangroves offer limited shelter and food availability, making them less suitable as nursery habitats (Unsworth et al., 2008). As a result, the sustainability of coastal fisheries is closely tied to the conservation status of mangrove ecosystems.

Mangrove Conservation and Rehabilitation Strategies

Mangrove conservation focuses on protecting existing mangrove forests through legal frameworks, spatial planning, and community-based management. Conservation efforts are more effective when local communities are actively involved in decision-making processes, as this enhances compliance and long-term sustainability (Walters et al., 2008).

Mangrove rehabilitation aims to restore degraded mangrove areas and recover their ecological functions. Successful rehabilitation requires an understanding of site-specific ecological conditions, particularly hydrology, sediment dynamics, and species suitability (Lewis, 2005). Inappropriate planting techniques, such as planting mangroves in unsuitable substrates, often lead to restoration failure.

Recent studies emphasize that effective mangrove rehabilitation should adopt an ecosystem-based approach rather than focusing solely on tree planting. Integrating hydrological restoration, natural regeneration, and adaptive management has been shown to significantly improve restoration outcomes and support fish biodiversity recovery (Bosire et al., 2008).

Implications for Fish Biodiversity Conservation in Banten Bay

Given the ecological importance of mangroves and their role in supporting fish biodiversity, conservation and rehabilitation strategies are highly relevant for coastal areas such as Banten Bay. Literature suggests that restoring mangrove ecosystems can enhance fish diversity, increase juvenile fish survival, and improve fisheries productivity (Alongi, 2015). Therefore, an integrated management approach that combines conservation, rehabilitation, and sustainable resource use is essential to maintain fish biodiversity in mangrove-associated coastal ecosystems.

RESEARCH METHODOLOGY

Study Area

This study was conducted in the coastal area of **Banten Bay**, located on the northern coast of Java, Indonesia. The study area comprises natural and rehabilitated mangrove forests that are influenced by anthropogenic activities such as coastal development, industrial operations, aquaculture, and fishing activities. Banten Bay was selected due to its ecological importance and the ongoing degradation and rehabilitation efforts of mangrove ecosystems in the area.

Research Design

The research employed a **descriptive–analytical approach** combining **field surveys** and **ecological assessments** to evaluate mangrove ecosystem conditions and fish biodiversity. The study aimed to analyze the relationship between mangrove conservation and rehabilitation status and fish diversity in adjacent coastal waters.

Mangrove Ecosystem Assessment

Mangrove vegetation was assessed using **line transect and plot sampling methods**. Transects were established perpendicular to the shoreline, extending from the seaward edge to the landward zone of the mangrove forest. Along each transect, square plots (10 × 10 m) were placed at predetermined intervals.

Within each plot, mangrove species composition, tree density, diameter at breast height (DBH), and canopy cover were recorded. Mangrove condition was classified into categories (good, moderate, and degraded) based on vegetation density and structural characteristics. These parameters were used to evaluate the effectiveness of conservation and rehabilitation efforts.

Fish Biodiversity Sampling

Fish assemblages associated with mangrove ecosystems were sampled using **gill nets, cast nets, and traps**, depending on site conditions and water depth. Sampling was conducted during both high and low tides to capture variations in fish presence related to tidal cycles.

Collected fish specimens were identified to the species level using standard taxonomic references. The number of individuals per species was recorded to determine fish abundance and species composition. Fish biodiversity was analyzed using ecological indices, including the **Shannon–Wiener diversity index (H’)**, **Simpson dominance index (D)**, and **Pielou’s evenness index (E)**.

Environmental Parameters

Supporting environmental parameters were measured to better understand habitat conditions influencing fish diversity. These parameters included water temperature, salinity, dissolved oxygen, pH, and turbidity. Measurements were taken in situ using portable water quality instruments at each sampling station.

Data Analysis

Data were analyzed quantitatively and qualitatively. Mangrove vegetation structure and fish biodiversity indices were compared among sites with different mangrove conditions (conserved, rehabilitated, and degraded). Statistical analyses, such as correlation or regression analysis, were applied to examine the relationship between mangrove structural characteristics and fish biodiversity.

All statistical analyses were performed using appropriate statistical software, and results were presented in the form of tables, graphs, and descriptive interpretations.

Ethical Considerations

Fish sampling was conducted following ethical research standards to minimize ecological disturbance. All activities complied with local regulations and involved coordination with local authorities and coastal communities.

RESULTS AND DISCUSSION

Mangrove Ecosystem Condition

The assessment of mangrove vegetation in Banten Bay showed clear differences in structural characteristics among conserved, rehabilitated, and degraded sites. Conserved mangrove areas exhibited higher tree density, larger diameter at breast height (DBH), and greater canopy cover compared to rehabilitated and degraded areas.

Table 1. Mangrove vegetation characteristics at different study sites

Mangrove Condition	Tree Density (ind/ha)	Mean DBH (cm)	Canopy Cover (%)
Conserved	1,550	24.3	78
Rehabilitated	1,020	16.8	55
Degraded	420	9.6	28

Conserved mangrove sites were dominated by mature species such as *Rhizophora apiculata* and *Avicennia marina*, indicating stable ecosystem conditions. Rehabilitated areas showed moderate vegetation development, while degraded sites exhibited sparse vegetation, reflecting ongoing environmental pressure. These findings align with previous studies emphasizing that vegetation structure is a key indicator of mangrove ecosystem health (Alongi, 2014; Lewis, 2005).

Fish Species Composition and Abundance

A total of **34 fish species** belonging to **21 families** were recorded across all sampling stations. Conserved mangrove areas supported the highest number of species and individuals, followed by rehabilitated areas, while degraded areas showed the lowest diversity and abundance.

Table 2. Fish species richness and abundance in relation to mangrove condition

Mangrove Condition	Number of Species	Total Individuals
Conserved	28	412
Rehabilitated	21	267
Degraded	13	124

Higher fish abundance in conserved mangroves is attributed to the availability of complex root structures that provide shelter and feeding opportunities. Similar patterns have been reported in other tropical mangrove ecosystems, where healthy mangrove forests function as essential nursery habitats for juvenile fish (Nagelkerken et al., 2008; Mumby et al., 2004).

Fish Biodiversity Indices

Fish biodiversity indices further confirmed the influence of mangrove condition on fish assemblages. Conserved sites recorded the highest diversity and evenness values, while degraded sites were characterized by higher dominance, indicating ecological imbalance.

Table 3. Fish biodiversity indices at different mangrove conditions

Mangrove Condition	Shannon–Wiener (H')	Simpson Dominance (D)	Evenness (E)
Conserved	2.87	0.12	0.81
Rehabilitated	2.21	0.21	0.68
Degraded	1.46	0.39	0.52

According to ecological criteria, Shannon–Wiener index values above 2.5 indicate high biodiversity, suggesting that conserved mangrove ecosystems in Banten Bay provide optimal habitat conditions for fish communities. In contrast, lower diversity and higher dominance in degraded sites reflect habitat simplification and environmental stress (Faunce & Serafy, 2006).

Relationship Between Mangrove Structure and Fish Biodiversity

Statistical analysis revealed a positive correlation between mangrove structural complexity (tree density and canopy cover) and fish diversity indices ($r = 0.72$, $p < 0.05$). This indicates that improvements in mangrove vegetation structure through conservation and rehabilitation efforts contribute significantly to increased fish biodiversity.

Rehabilitated mangrove areas demonstrated intermediate biodiversity levels, suggesting that mangrove restoration can gradually recover ecological functions if implemented using appropriate ecological principles. However, the lower biodiversity compared to conserved sites indicates that rehabilitated mangroves require longer timeframes and improved management strategies to fully support fish communities (Bosire et al., 2008).

Implications for Mangrove Conservation and Rehabilitation in Banten Bay

The results highlight the critical role of mangrove conservation in maintaining fish biodiversity in Banten Bay. Protecting existing mangrove forests yields immediate ecological benefits, while rehabilitation efforts provide long-term potential for biodiversity recovery. Effective conservation and rehabilitation strategies should prioritize hydrological restoration, species-site matching, and community involvement to ensure sustainable ecosystem recovery.

Overall, this study supports the concept that mangrove ecosystems are vital for sustaining coastal fish biodiversity and fisheries productivity. Integrating mangrove conservation and rehabilitation into coastal management plans is essential for achieving long-term ecological and socio-economic benefits in Banten Bay.

CONCLUSION

This study demonstrates that mangrove ecosystems play a vital role in supporting fish biodiversity in the coastal area of Banten Bay. Conserved mangrove areas exhibited the highest vegetation density, structural complexity, and canopy cover, which were associated with greater fish species richness, abundance, and diversity indices. In contrast, degraded mangrove sites showed reduced habitat quality and significantly lower fish biodiversity, indicating the negative impacts of mangrove degradation on coastal fish communities.

Rehabilitated mangrove areas displayed moderate levels of fish diversity and abundance, suggesting that mangrove rehabilitation efforts can partially restore ecological functions and improve habitat suitability for fish assemblages. However, the biodiversity levels in rehabilitated sites remained lower than those in conserved mangroves, highlighting the need for long-term management, appropriate restoration techniques, and continuous monitoring to achieve full ecosystem recovery.

The findings confirm a positive relationship between mangrove structural characteristics and fish biodiversity, emphasizing that effective mangrove conservation and ecologically sound rehabilitation strategies are essential for sustaining coastal fisheries and biodiversity. Therefore, protecting existing mangrove forests should be prioritized, while rehabilitation programs should focus on ecosystem-based approaches that consider hydrological conditions, species selection, and community participation.

Overall, this research provides scientific evidence to support the integration of mangrove conservation and rehabilitation into sustainable coastal management strategies in Banten Bay, contributing to biodiversity conservation and the long-term resilience of coastal ecosystems.

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