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Regular Research Article

Comparison of Mangrove and Coastal Ecosystem Management Strategies between Padang City (Indonesia) and Port Dickson (Malaysia) to Support Coastal Resilience

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Abstract: Mangrove and coastal ecosystems play a critical role in enhancing coastal resilience; however, their effectiveness strongly depends on governance arrangements and management strategies. This study applies a qualitative comparative case study approach integrating a Systematic Literature Review (SLR) and field observations to compare mangrove and coastal ecosystem management strategies in Padang City (Indonesia) and Port Dickson (Malaysia). A structured comparative framework was used to assess biophysical conditions, governance structures, monitoring capacity, community participation, and contributions to ecological, institutional, and social resilience. The results indicate that Padang City possesses larger mangrove extent and higher species diversity, supporting stronger ecological and social resilience, but is constrained by fragmented governance and weak enforcement. Port Dickson exhibits smaller and fragmented mangrove areas with clearer institutional authority and periodic monitoring, yet limited social–ecological integration. The findings highlight that effective coastal resilience requires integrating strong regulatory frameworks, community engagement, and consistent long-term monitoring.

Keywords: Mangrove management, Padang, Port Dickson

1. Introduction

Mangrove ecosystems and coastal areas play an important role in maintaining the stability of coastal regions [1]. These two ecosystems not only function as natural protectors against erosion, high waves, and seawater intrusion, but also serve as habitats for various types of biota and support the socio-economic activities of coastal communities [2]. However, pressure on coastal areas is increasing due to rapid development, land use changes, resource exploitation, and the tangible impacts of climate change [3]. This situation makes the management of coastal and mangrove ecosystems a strategic issue that requires more serious attention.

This challenge is compounded by global conditions showing that the total mangrove area worldwide is estimated at only around 17 million hectares, of which about 3.7 million hectares or 22% are in Indonesia. Although its contribution is significant, the rate of mangrove degradation continues in many developing countries because its utilization has not been entirely based on comprehensive scientific data. Poor management direction, lack of data, and weak policies have caused many mangrove

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areas to deteriorate in quality or even disappear completely.

The urgency of protecting this area becomes increasingly apparent when looking at global data that reinforces the fact that mangrove degradation is not merely a local phenomenon, but a crisis occurring almost worldwide. [4] notes that the world has lost about 20–35% of its mangrove area over the past 40 years. Southeast Asia, which has about 35% of the world's total mangroves, is the region facing the highest threat due to rapidly expanding coastal development activities. This is reinforced by a [5] report showing that around 60% of global mangrove degradation is caused by land conversion for tourism, aquaculture, settlements, and coastal infrastructure. These data indicate that mangroves are under significant pressure and require serious attention to maintain their sustainability.

Mangrove degradation is triggered by the complex interaction of four main factors. First, uncontrolled land conversion because coastal areas are considered strategic for economic development, leading to mangrove vegetation being cleared for recreational facilities, ponds, settlements, and ports [6]. Second, water pollution from industrial and domestic activities alters the physical-chemical characteristics of the substrate, which are crucial for mangrove growth [7]. Third, the lack of supervision and weak implementation of conservation policies make the degradation process continue without significant intervention [8]. Fourth, global climate change through rising sea levels and increasing surface temperatures puts additional pressure on mangrove ecological conditions [9].

This damage is left unmanaged without comprehensive treatment, its impact will be very serious for coastal ecosystems as well as community life [10]. Ecologically, mangrove damage will increase the rate of abrasion, reduce the quality of coastal biota habitats, and weaken the environment's ability to absorb carbon [11]. Socio-economically, the impact is seen in declining fisheries productivity, increased risk of tidal flooding, and reduced community income from the nature tourism sector [12]. In the long term, mangrove degradation will threaten the sustainability of coastal development as a whole due to the loss of ecosystem services that are very important for environmental balance [13].

The increasing vulnerability of mangrove ecosystems indicates that management efforts cannot be carried out partially or reactively [14]. Each coastal area requires a planned, adaptive management strategy that aligns with its ecological and social characteristics. In this context, Padang City in Indonesia and Port Dickson in Malaysia are two examples of coastal areas facing similar pressures but implementing different management approaches. Padang City still deals with erosion, mangrove conversion, and weak implementation of coastal management policies [15]. Meanwhile, Port Dickson develops its coastal areas by emphasizing tourism, mangrove rehabilitation, and a partnership-based management model [16]. The differences in conditions and approaches make these two regions relevant for comparative study. By comparing the strategies for managing mangrove and coastal ecosystems in Padang and Port Dickson, the research can identify strengths, weaknesses, and best practices that can serve as references for enhancing coastal resilience. This analysis is important not only for understanding the effectiveness of policies and management in each area but also for formulating more appropriate and sustainable recommendations for coastal ecosystem management in the future.

Despite the growing body of literature on mangrove degradation and coastal management, comparative studies that explicitly examine how different governance structures and management strategies contribute to coastal resilience across national contexts remain limited. This study addresses this gap by applying a structured comparative framework to assess mangrove and coastal ecosystem management in Padang City and Port Dickson, thereby providing empirical insights into how biophysical conditions, governance arrangements, and social participation jointly shape coastal resilience.

2. Materials and Methods

2.1 Research Design and Article Type

This study is designed as a qualitative comparative case study integrating a Systematic Literature Review (SLR) with field observations**.** The research aims to compare mangrove and coastal ecosystem management strategies in Padang City (Indonesia) and Port Dickson (Malaysia) in relation to their contributions to coastal resilience. The study is analytical in nature and applies a structured comparative framework rather than a purely descriptive narrative approach.

2.2 Study Areas

The study areas include mangrove and coastal ecosystems in Padang City, West Sumatra Province, Indonesia, and Port Dickson, Negeri Sembilan, Malaysia. These sites were selected due to their contrasting ecological scales, governance arrangements, and levels of community involvement, which provide a suitable basis for cross-national comparison.

2.3 Systematic Literature Review (SLR)

The SLR was conducted to identify existing knowledge on mangrove management, coastal governance, and coastal resilience in both study areas. Literature searches were performed using Scopus and Google Scholar databases, covering publications from 2010 to 2025**.** The search employed keywords such as *mangrove management*, *coastal governance*, *coastal resilience*, *Padang City*, and *Port Dickson*.

Inclusion criteria comprised: (1) peer-reviewed journal articles, research reports, and official policy documents; (2) studies explicitly addressing ecological, institutional, social, or policy aspects of mangrove and coastal management; and (3) publications in English or Indonesian.

Documents lacking direct relevance to coastal ecosystem management or comparative analysis were excluded. Selected literature was thematically synthesized to support the comparative framework and interpretation of results.

2.4 Field Observations

Primary data were collected through direct field observations conducted in mangrove areas of Padang City and Port Dickson. Observations focused on biophysical conditions (mangrove extent, vegetation structure, and landscape context), visible degradation patterns, rehabilitation activities, and management practices. Data were recorded using structured field notes and photographic documentation and were integrated into the analysis to corroborate and contextualize findings from the literature review.

2.5 Comparative Analytical Framework

A structured comparative analytical framework was applied to systematically assess differences and similarities between the two study areas. The framework consisted of several key dimensions:

- biophysical characteristics and species composition;
- governance structure and institutional clarity;
- monitoring and rehabilitation capacity;
- community participation and social–ecological integration; and
- contributions to coastal resilience, including ecological, institutional, and social dimensions.

These indicators formed the basis for the comparative table and analytical synthesis presented in the Results section.

2.6 Data Analysis

Data were analyzed using a descriptive–comparative analytical approach, emphasizing structured interpretation rather than narrative description. Differences and similarities between Padang City and Port Dickson were evaluated against the defined indicators to assess how each management system contributes to coastal resilience. The results of this analysis directly inform the discussion and conclusions of the study.

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3. Results

A structured comparative summary of biophysical conditions, governance arrangements, and resilience indicators between Padang City and Port Dickson is presented in Table 1

Table 1. Comparative Summary of Coastal Resilience Indicators in Padang City and Port Dickson

Analytical Dimension	Indicator	Padang City (Indonesia)	Port Dickson (Malaysia)
Biophysical Characteristics	Mangrove extent	±120 ha; relatively continuous distribution [17].	±5–6 ha; small and fragmented patches
	Landscape context	Mangroves adjacent to residential and livelihood areas [21].	Mangroves isolated from settlements
	Ecological gradient	Complex zonation from seaward fringe to landward assemblages [19].	Narrow ecological gradient with limited spatial variation
Species Composition	Species richness	7 mangrove species [18].	6 mangrove species
	Dominant species	*Rhizophora apiculata*, *Sonneratia caseolaris* [19].	*Rhizophora apiculata*, *R. mucronata*
Governance Structure	Management authority	Fragmented, involving multiple agencies [20].	Centralized under a single lead agency (Forestry Department)
	Institutional clarity	Overlapping mandates and administrative gaps [20].	Clear institutional roles and coordination
Monitoring Capacity	Monitoring continuity	Irregular; approximately 8-year data gap in some areas [23].	Periodic monitoring supported by institutions and volunteers
	Data management	Limited long-term ecological records [23].	More structured but not fully standardized
Community Participation	Local involvement	High; resident communities actively engaged [20].	Low; no resident communities within mangrove areas
	Social–ecological integration	Strong integration with livelihoods and daily practices [21].	Limited integration; mangroves mainly used for education and research

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Analytical Dimension	Indicator	Padang City (Indonesia)	Port Dickson (Malaysia)
Degradation Patterns	Main disturbance drivers	Aquaculture expansion, wastewater pollution [22].	Acute oil spill event (2020)
	Degradation type	Chronic and gradual degradation [22].	Sudden, event-driven disturbance
Rehabilitation Strategy	Rehabilitation approach	Community-based replanting and protection [23].	Phased rehabilitation (natural recovery followed by replanting)
	Long-term effectiveness	Constrained by weak governance and monitoring [23].	Moderately effective but lacking long-term evaluation framework
Policy and Regulation	Legal framework	Strong formal regulations (RTRW, RZWP3K) [24].	Less comprehensive zoning but clear authority
	Enforcement effectiveness	Weak and inconsistent implementation [24].	More consistent but still limited enforcement
Contribution to Coastal Resilience	Ecological resilience	Moderate to high due to ecological diversity [21].	Moderate, constrained by limited spatial extent
	Institutional resilience	Weak due to fragmented governance [20].	Stronger due to centralized authority
	Social resilience	Strong community-based stewardship [21].	Weak social integration

Overall, the comparative indicators demonstrate that differences in mangrove extent, governance clarity, and social integration substantially influence the resilience outcomes of each coastal management system.

4. Discussion

The comparison of mangrove and coastal ecosystem management strategies between Padang City and Port Dickson highlights how differences in biophysical conditions, environmental pressures, and regulatory strength shape distinct management approaches in each region based on the comparative indicators applied in this study [10]. As shown in Table 1, the larger mangrove cover and higher species diversity found in Padang provide stronger ecological functions, including shoreline stabilization, protection against seawater intrusion, and habitat provision for coastal biota [6]. In contrast, the narrower and more fragmented mangrove stands in Port Dickson limit their ecological contribution, making the coastline more vulnerable to degradation. This finding confirms the ecological resilience dimension, where ecosystem extent and diversity directly influence adaptive capacity and management priorities (Table 1).

The management strategies observed in both regions further reflect their dominant pressures and institutional frameworks. Padang relies heavily on national and regional spatial planning policies such as the PWP3K Act, the Padang City Spatial Plan (RTRW), and the RZWP3K of West Sumatra [24], which guide conservation zoning, rehabilitation efforts, and

land use control. As indicated in Table 1, this policy-driven approach corresponds to the city's major challenges, particularly abrasion, aquaculture expansion, and land conversion [25]. Community involvement plays a central role due to strong local dependence on coastal resources; however, weak enforcement and limited monitoring continue to hinder effective protection [26]. This condition reflects a paradox within the institutional resilience dimension, where formal regulatory strength is not consistently translated into effective field implementation. These findings echo earlier studies that emphasize the gap between policy formulation and field-level implementation in many Indonesian coastal regions.

In Port Dickson, management strategies are more strongly shaped by tourism-related demands, leading to community- and volunteer-based initiatives such as planting programs, coastal cleanups, and simple monitoring activities. Based on the comparative indicators presented in Table 1, this approach demonstrates relatively stronger social engagement but weaker institutional coordination. Although this model encourages community participation, regulatory measures remain less stringent compared to Indonesia, with the absence of dedicated core conservation zones and overlapping institutional mandates. Environmental pressures, particularly tourism activities and recurring oil spills, further constrain mangrove recovery and slow natural regeneration processes. This finding highlights a limitation in institutional and ecological resilience, despite the presence of active social initiatives.

The differing responses to ecosystem damage further underline contrasting management philosophies. Padang implements coordinated, long-term, community-based rehabilitation to reduce land conversion and strengthen ecological resilience [27]. Meanwhile, Port Dickson tends to rely on natural attenuation and volunteer-driven rehabilitation following oil spill incidents, which has shown effectiveness on small scales but lacks long-term structure due to the absence of formal monitoring systems and strong zoning regulations [28]. As summarized in Table 1, these contrasts suggest that coastal resilience outcomes depend not only on ecosystem capacity but also on how governance frameworks are institutionalized into sustained management actions.

Overall, Padang demonstrates stronger regulatory foundations and ecological potential, while Port Dickson excels in community engagement and tourism-supported initiatives. From a coastal resilience framework perspective, Padang shows relatively higher ecological resilience but weaker institutional effectiveness, whereas Port Dickson exhibits stronger social resilience with constrained ecological and institutional capacity (Table 1).

An integrated management model that combines Padang's regulatory strength with Port Dickson's community-based stewardship could therefore offer a more robust pathway to coastal resilience.

Future research should explore how hybrid governance models, cross-border knowledge exchange, and ecosystem-based approaches can enhance mangrove conservation effectiveness in both regions. Strengthening collaboration, enforcement mechanisms, and long-term monitoring will be essential for achieving sustainable coastal and mangrove management across diverse socio-ecological contexts.

5. Conclusions

This study concludes that the differences in biophysical conditions, ecological capacity, and governance systems strongly shape the contrasting mangrove and coastal management strategies in Padang City (Indonesia) and Port Dickson (Malaysia). Padang, with its wider mangrove extent, richer species diversity, and stronger regulatory foundation, demonstrates higher ecological potential to support coastal resilience, although its effectiveness is limited by weak enforcement and inconsistent long-term monitoring. In contrast, Port Dickson exhibits narrower mangrove distribution and greater vulnerability to tourism pressure and oil spill disturbances, yet benefits from clearer institutional authority and strong volunteer participation. The comparison highlights that

sustainable mangrove management requires integrating regulatory strength, community engagement, and consistent monitoring. Developing hybrid governance models and fostering cross-regional learning are essential pathways for improving coastal resilience and advancing effective ecosystem-based management in both regions.

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