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Coastal and Island System Dynamics in the Philippines: A Review of Mangrove, Coral Reef and Seagrass Ecosystem Processes, Coastal Erosion and Habitat Restoration Approaches

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ABSTRACT: The Philippine archipelago lies at the centre of global marine shore fish biodiversity and supports extensive mangrove forests, coral reefs and seagrass meadows that sustain coastal livelihoods, food security and shoreline protection. These ecosystems are under mounting pressure from aquaculture conversion, siltation, destructive fishing, coastal development, land subsidence and increasingly intense tropical cyclones. This review synthesises peer-reviewed literature on (i) the ecological processes that govern mangrove, coral reef and seagrass dynamics in the Philippines, (ii) the drivers and consequences of coastal erosion and hazard exposure, and (iii) the effectiveness of habitat restoration approaches. Philippine mangrove cover has declined substantially over the past century, largely through conversion to brackishwater fishponds, and long-term survival of planted mangroves has often been low because of inappropriate species and site selection. Philippine coral reefs have lost about a third of their hard coral cover within a decade, while seagrass species richness declines sharply under siltation and aquaculture effluent. Healthy reefs and mangroves substantially attenuate wave energy, yet their protective role is undermined by degradation, subsidence and maladaptive hard engineering. Restoration has advanced from monospecific mangrove planting and coral gardening towards hydrology-based mangrove rehabilitation, larval enhancement of corals and seascape-scale planning. However, restoration remains constrained by scale, limited monitoring and weak institutional integration. We propose a research and management agenda that couples ecosystem process knowledge with nature-based coastal protection, long-term monitoring and governance reform.

KEYWORDS: Seascape connectivity; nature-based coastal defence; sediment dynamics; ecological rehabilitation; climate resilience; integrated coastal management.

1. Introduction

The Philippines is an archipelago of more than 7,000 islands with one of the longest coastlines in the world. It sits at the heart of the Coral Triangle and has been described as the “center of

the center" of marine shore fish biodiversity [1]. Its coastal and island systems are dominated by three interconnected tropical ecosystems: mangrove forests, coral reefs and seagrass meadows. Together they support fisheries, coastal livelihoods and food security [2], store large amounts of organic carbon [3, 4], and protect shorelines from waves and storm surges [5, 6].

These ecosystems have been heavily degraded. Philippine mangrove cover declined from an estimated 500,000 ha to about 120,000 ha over the last century, mainly through conversion to brackishwater fishponds [7, 8]. Satellite mapping has since provided national baselines of mangrove extent and change [9, 10]. Philippine coral reefs were already in mostly fair condition by the early 1990s and were threatened by sedimentation and destructive fishing [11]. More recent surveys indicate the loss of about a third of reef corals within a decade, with average hard coral cover of 22.8% [12]. Seagrass meadows in Southeast Asia are poorly documented compared with mangroves and reefs [13], and seagrasses are declining at accelerating rates worldwide [14].

Coastal hazards compound these pressures. The Philippines is among the countries most exposed to tropical cyclones, and while the annual number of landfalling cyclones has not increased, more extreme cyclones have affected the country in recent decades [15]. Super Typhoon Haiyan (Yolanda) in 2013 generated catastrophic storm surges that caused about 6,300 deaths [16] and left overwash deposits that extended up to about 1.7 km inland [17]. Haiyan also damaged mangrove forests extensively across the central Philippines [18]. Around northern Manila Bay, flooding is aggravated by land subsidence caused by human activity, which is a more immediate threat than global sea-level rise [19].

In response, a wide range of restoration and management approaches has been applied, from mangrove replanting and coral gardening to community-based marine protected areas (MPAs) [7, 20, 21]. This review aims to synthesise current knowledge of the ecological processes, coastal hazard dynamics, and restoration strategies associated with mangrove forests, coral reefs, and seagrass meadows in the Philippines. Specifically, the objectives are to: (1) examine the ecological functions and interactions among these three ecosystems; (2) evaluate the natural and anthropogenic drivers of coastal erosion, flooding, and habitat degradation; (3) assess existing restoration and management approaches, including their reported outcomes and limitations; and (4) identify knowledge gaps and priorities for future research and integrated coastal management. By examining these interconnected themes, the review seeks to provide a scientific basis for ecosystem-based coastal protection and restoration planning. Figure 1 illustrates the overall conceptual framework of the review.

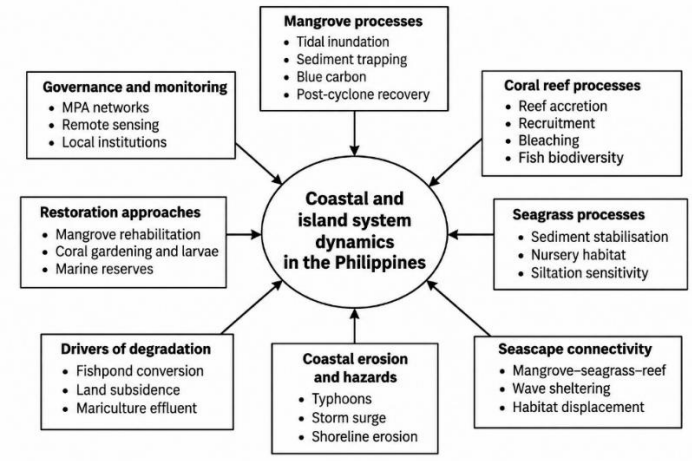


Figure 1. Conceptual Map of Coastal and Island System Dynamics in the Philippines.

2. Review Methodology

This study employed a narrative literature review approach to synthesise existing research on mangrove forests, coral reefs, seagrass meadows, coastal erosion, and habitat restoration in the Philippines. The review focused on ecological processes, environmental pressures, ecosystem connectivity, restoration outcomes, and management implications. Relevant publications were identified using combinations of keywords such as “mangrove”, “coral reef”, “seagrass”, “Philippines”, “coastal erosion”, “storm surge”, “sediment transport”, “ecosystem connectivity”, “habitat restoration”, and “coastal management”. The literature selection prioritised peer-reviewed research articles, review papers, and authoritative technical reports addressing Philippine coastal ecosystems. Relevant regional and international studies were also considered where they provided supporting evidence for ecological processes or management approaches applicable to the Philippine context.

Studies were considered relevant when they provided information on ecosystem functions, environmental disturbances, coastal protection, habitat degradation, restoration performance, or governance. Publications lacking sufficient relevance to these themes were excluded from the synthesis. The selected literature was examined thematically, with findings organised into ecosystem processes, coastal hazards, restoration approaches, and research and management priorities. Comparative tables were developed to summarise the main findings, reported outcomes, and limitations. The review adopted a qualitative synthesis rather than a statistical meta-analysis because the available studies differed in geographical coverage, research design, ecological indicators, and monitoring periods.

3. Ecosystem Processes in Philippine Coastal and Island Systems

3.1. Mangrove Forests.

Mangrove distribution and productivity depend on tidal inundation, sediment supply, salinity and disturbance regimes [22, 23]. Mangroves are among the most carbon-rich forests in the tropics, and most of their carbon is stored in organic-rich soils [3]. In the Philippines, the dominant historical driver of mangrove loss was conversion to aquaculture ponds, reinforced by institutional arrangements that favoured fishpond development over mangrove conservation [8]. Landsat-based mapping established a national mangrove baseline [9] and quantified changes in mangrove extent between 1990 and 2010 [10]. Tropical cyclones are a major natural disturbance for mangroves. Globally, roughly 45% of reported mangrove disturbances are attributed to cyclones, and tree mortality ranges from 0 to 100% depending on storm intensity, position relative to the track and pre-existing stress [24]. After Super Typhoon Haiyan, satellite assessments documented widespread mangrove damage followed by spatially variable recovery [18]. Time-series analyses have linked mangrove change across the Philippines to repeated cyclone impacts [25]. These findings show that mangroves are disturbance-adapted systems whose recovery depends on forest condition and setting [24].

3.2. Coral Reefs.

Philippine coral reefs support exceptional levels of marine biodiversity and provide essential ecosystem services to coastal communities [1]. Beyond their ecological importance, reefs sustain fisheries that contribute directly to food security, employment, and household

livelihoods, particularly among poorer coastal communities that have limited alternative sources of income and animal protein [2]. Healthy reef structures also provide nursery and feeding habitats for numerous marine species and dissipate wave energy, thereby contributing to the protection of adjacent coastlines and connected mangrove and seagrass ecosystems. Consequently, coral reef degradation in the Philippines represents not only a biodiversity concern but also a broader socioeconomic and coastal-resilience issue.

Early national assessments identified sedimentation, siltation, and destructive fishing practices as major pressures on Philippine coral reefs [11]. These stressors can affect reefs through different but interacting mechanisms. Elevated sediment loads can reduce light availability, interfere with coral feeding, cover suitable settlement surfaces, and inhibit the recruitment of juvenile corals. Destructive and excessive fishing can further alter reef ecological processes by removing functionally important species, including herbivorous fishes that help regulate algal growth. When these local pressures occur simultaneously, they can reduce the capacity of reefs to recover from episodic disturbances and gradually shift reef communities toward less structurally complex ecological states.

Changes in live coral cover provide one of the clearest indicators of this deterioration. Benchmarks based on relatively undisturbed reefs have been proposed to provide a more appropriate basis for evaluating reef condition within the Philippines, where naturally high biodiversity and considerable spatial variation make universal reef-condition thresholds difficult to apply [26, 27]. National-scale evidence nevertheless indicates substantial degradation. A national survey reported an average hard coral cover of only 22.8%, corresponding to an estimated loss of approximately one-third of reef corals over the preceding decade [12]. As summarized in Table 1, coral reef dynamics should also be considered within the broader Philippine coastal seascape. Mangroves, coral reefs, and seagrass meadows are linked through the movement of organisms, sediments, nutrients, and energy. Reef degradation can therefore have consequences beyond the reef itself, while changes in adjacent landward ecosystems can influence reef water quality and sediment exposure. This interconnectedness supports an ecosystem-based approach in which reef conservation, watershed management, fisheries regulation, habitat restoration, and climate adaptation are treated as complementary components of coastal management rather than as separate interventions.

Table 1. Key Ecological Processes and Drivers of Change in Philippine Coastal Ecosystems.

Ecosystem	Key processes	Main drivers of change	Philippine evidence	Ref.
Mangrove forests	Tidal inundation, sediment trapping, soil carbon accumulation, post-cyclone regeneration	Fishpond conversion, cyclones, coastal development	Decline from ~500,000 ha to ~120,000 ha; extensive Haiyan damage with variable recovery	[3, 7, 18, 24]
Coral reefs	Reef accretion, coral recruitment, herbivory, wave dissipation	Sedimentation, destructive fishing, thermal stress	Average hard coral cover 22.8%, about one-third of corals lost in a decade	[11, 12, 28, 29]
Seagrass meadows	Sediment stabilisation, nutrient cycling, nursery habitat, carbon burial	Siltation, nutrient loading, mariculture	Species richness declines above ~15% silt–clay; species loss near milkfish farms	[4, 30, 31]
Seascape connectivity	Exchange of sediment, nutrients and organisms; reef sheltering of landward habitats	Habitat conversion and fragmentation	Mangrove afforestation reduced seagrass cover	[1, 32, 33]

As summarised in Table 1, the three ecosystems are interconnected through physical and biological processes. Figure 2 conceptually illustrates these relationships, highlighting the movement of sediments and nutrients from landward environments towards coastal waters, wave attenuation by coral reefs, sediment stabilisation by seagrass meadows and mangroves, and the movement of marine organisms among habitats. These interactions influence ecosystem productivity, habitat quality, and shoreline stability. Consequently, effective restoration and coastal protection require consideration of the entire coastal seascape rather than individual habitats in isolation.

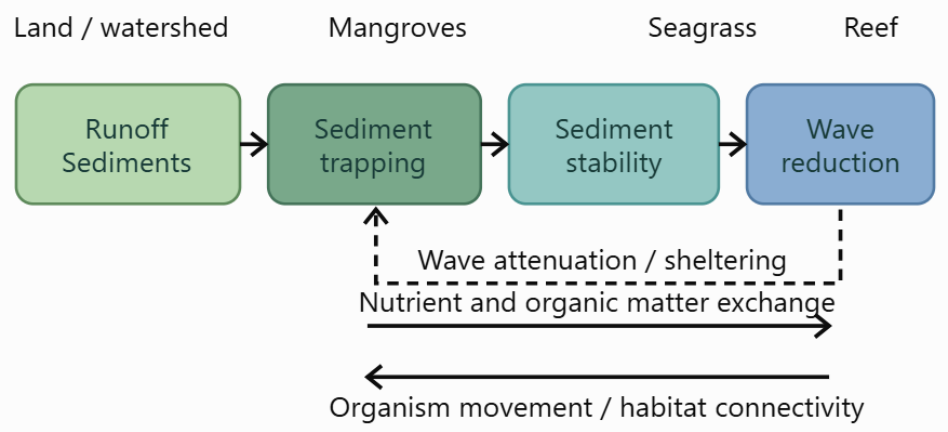


Figure 2. Conceptual Schematic of Ecological and Physical Interactions Among Mangrove Forests, Seagrass Meadows, and Coral Reefs.

3.3. Seagrass Meadows.

Seagrass meadows in the Philippines are typically mixed-species stands that stabilise sediments, support fisheries and store carbon [4, 13]. Experimental and survey work in Southeast Asia, including the Philippines, has shown that seagrass species richness and community leaf biomass decline sharply when the silt and clay content of the sediment exceeds about 15%. Enhalus acoroides is the most tolerant species and Syringodium isoetifolium the most sensitive [30]. Around Santiago Island, Bolinao, intensive milkfish mariculture was associated with a decline in seagrass species richness over 17 years, with two species disappearing at sites where siltation and nutrient loading were heaviest [31]. These local declines mirror the accelerating global loss of seagrasses [14], and regional reviews highlight major knowledge gaps on seagrass distribution, condition and trends in Southeast Asia [13].

3.4. Spatial Distribution and Ecological Connectivity.

Mangrove forests, seagrass meadows, and coral reefs occupy different but interconnected coastal environments in the Philippines. Mangroves commonly occur along sheltered intertidal shorelines and estuaries, seagrass meadows occupy shallow coastal waters, and coral reefs develop in suitable marine environments. Their spatial arrangement influences sediment movement, nutrient exchange, habitat connectivity, and coastal protection. Mangroves can retain land-derived sediments, seagrass meadows contribute to sediment stabilisation, and coral reefs dissipate incoming wave energy, thereby influencing conditions in adjacent coastal habitats [3–6, 22, 33]. These ecological connections demonstrate that habitat degradation or restoration within one ecosystem can influence neighbouring habitats. For example, inappropriate mangrove afforestation on existing seagrass beds can reduce seagrass cover [32],

while the protection of reef structures can help maintain wave-sheltered conditions in landward habitats [33].

4. Coastal Erosion and Hazard Dynamics

4.1. Tropical Cyclones and Storm Surges.

Tropical cyclones are the main episodic driver of coastal change in the Philippines. Analysis of cyclone records from 1951 to 2013 found no significant trend in the annual number of cyclones within the Philippine Area of Responsibility and a slight decrease in landfalling events. However, more extreme cyclones with winds above 150 km/h have affected the country, and economic damages have increased [15]. Super Typhoon Haiyan illustrated the destructive potential of storm surges. Forecast surge heights reached up to 5.3 m, and despite early warnings, storm surge was the predominant cause of death [16]. Haiyan overwash deposits extended about 1.7 km inland and contained sediments from intertidal, subtidal, deeper-water and terrestrial sources. They provide a modern analogue for reconstructing past cyclones [17].

4.2. Drivers of Shoreline Erosion and Flooding.

Shoreline erosion and coastal flooding in the Philippines result from the interaction of natural forcing with human modification of coastal systems. Around northern Manila Bay, groundwater extraction has caused land subsidence at rates that greatly exceed global sea-level rise, yet policy attention has focused largely on the latter [19]. The loss of mangroves to fishponds has removed natural buffers along sheltered coasts [7, 8]. Coral reef degradation reduces the capacity of reef flats and crests to dissipate incoming waves [5, 33]. Hard engineering responses, particularly seawalls, can be maladaptive on island coasts because they may accelerate erosion of adjacent beaches, degrade habitats and create a false sense of security [34]. Table 2 summarises the main hazard drivers and the role of coastal ecosystems in mitigating them.

Table 2. Coastal Hazard Drivers and the Mitigating Role of Ecosystems in the Philippines.

Driver	Documented effect	Ecosystem role or response	Ref.
Tropical cyclones	More extreme cyclones since 1951; rising economic damage	Reefs and mangroves attenuate waves; mangroves themselves damaged by extreme events	[15, 18, 24]
Storm surge	Haiyan surges up to 5.3 m; overwash ~1.7 km inland	Early warning combined with protection of natural buffers	[16, 17]
Land subsidence	Groundwater extraction drives flooding around Manila Bay	Regulate groundwater use; account for subsidence in planning	[19]
Reef degradation	Reduced wave dissipation on reef flats and crests	Reefs reduce wave energy by ~97% when healthy	[5, 33]
Mangrove loss	Removal of natural buffers along sheltered coasts	Rehabilitate mangroves in suitable intertidal zones	[6, 7]
Hard engineering	Seawalls can accelerate adjacent erosion	Prefer nature-based or hybrid defences	[6, 34]

4.3. Ecosystems as Natural Coastal Defences.

A growing body of evidence shows that coastal ecosystems provide cost-effective shoreline protection. A global meta-analysis found that coral reefs reduce wave energy by about 97% on average, with the reef crest alone accounting for most of this reduction [5]. Wave modelling for Philippine reefs showed that reefs significantly reduce wave energy under both current and

climate change scenarios. These scenarios included stronger winds and sea-level rise of 0.3 m and 1 m, but the protective function depends on sustainable reef management [33]. Across habitats, coral reefs and salt marshes have the highest wave-attenuation potential, and mangroves and salt marshes can be two to five times cheaper than submerged breakwaters under certain wave conditions [6]. Mangroves also attenuate waves and trap sediment, although their protective capacity can be compromised when forests are damaged by extreme cyclones [18, 24].

5. Habitat Restoration Approaches

5.1. Mangrove Rehabilitation.

Mangrove planting has been promoted in the Philippines since the 1930s, but long-term survival of planted mangroves is generally low, at 10–20%. The two main causes of failure are planting the wrong species, typically Rhizophora on sandy coasts naturally occupied by Avicennia and Sonneratia, and planting in the lower intertidal zone rather than in the middle to upper intertidal zone where mangroves naturally grow. Ideal restoration sites have been converted to fishponds, so planting has shifted to open-access tidal flats, and reversion of abandoned ponds has been recommended [7]. Ecological engineering principles emphasise that the depth, duration and frequency of tidal flooding are critical for mangrove survival. Hydrology should therefore be restored to enable natural regeneration before planting is considered [23]. Afforestation on former seagrass beds in Mindanao produced fast-growing mangrove stands, but seagrass cover declined under the closing canopy. Such projects replace one valuable ecosystem with another rather than restoring degraded habitat [32]. Table 3 compares restoration approaches across the three ecosystems.

Table 3. Habitat Restoration Approaches in the Philippines.

Approach	Ecosystem	Reported outcome	Key limitation	Ref.
Monospecific mangrove planting	Mangrove	Long-term survival generally 10–20%	Wrong species and low intertidal sites	[7]
Hydrology-based rehabilitation and pond reversion	Mangrove	Supports natural regeneration	Tenure conflicts over fishponds	[7, 8, 23]
Afforestation of tidal flats	Mangrove / seagrass	Fast mangrove growth	Loss of existing seagrass beds	[32]
Coral nurseries and gardening	Coral reef	Production of transplantable fragments	~280,000 fragments needed per hectare	[20, 35]
Coral larval enhancement	Coral reef	Increased recruitment on degraded reefs	Requires spawning and larval-culture capacity	[36]
No-take marine reserves	Coral reef	Fish biomass increase and spillover	Small total coverage; governance gaps	[21, 37, 38]
Stressor reduction (siltation, effluent)	Seagrass	Prevents species loss	Requires watershed and aquaculture management	[13, 30, 31]

5.2. Coral Reef Restoration.

Coral restoration in the Philippines has used several techniques. Asexual approaches include fixed and suspended coral nurseries, which established the first step of the “gardening concept” of reef restoration [20]. Sexual approaches include mass larval enhancement, which increased

coral recruitment on degraded reefs in the Bolinao-Anda Reef Complex [36]. Scaling remains a fundamental challenge. One analysis estimated that about 280,000 coral fragments of 5-cm radius would need to be transplanted to raise hard coral cover in a single hectare from 0% to 22% [35]. A national review of 412 restoration projects implemented in 228 municipalities between 1977 and 2023 found that projects often achieved ecological objectives. However, existing guidelines were poorly implemented and not widely understood, and socio-economic benefits were limited [39]. Passive restoration through protection remains central to reef recovery. Long-term studies at Apo Island showed that a no-take marine reserve built up fish biomass and benefited adjacent fisheries through spillover [37]. These results helped inspire the rapid spread of community-based no-take reserves across the Philippines [21]. However, the national MPA system covers only a small fraction of reef habitat and falls short of biodiversity conservation targets [38]. Networks of MPAs managed by alliances of local governments have emerged, but they face governance and sustainability challenges [40].

5.3. Seagrass Restoration and Integrated Seascape Approaches.

Active seagrass restoration is much less developed in the Philippines than mangrove or coral restoration, and regional reviews identify restoration and monitoring as key gaps [13]. Because seagrass decline is strongly linked to siltation and nutrient loading [30, 31], the most effective strategies address watershed sediment loads, aquaculture effluent and coastal development rather than planting alone. The mangrove–seagrass–reef continuum also means that restoration of one habitat can affect the others. Planting mangroves on seagrass beds reduces seagrass cover [32], whereas protecting reef crests helps shelter landward seagrass and mangrove habitats from wave energy [33]. Seascape-scale planning that prioritises protection of intact habitats, restoration of degraded areas in their original ecosystem type and management of land-based stressors is therefore essential [13, 22].

6. Challenges, Future Directions and Conclusions

6.1. Monitoring and Knowledge Gaps.

Satellite mapping has substantially improved understanding of mangrove distribution, extent, and spatial changes in the Philippines, providing essential information for identifying degradation hotspots and prioritising restoration areas [9, 10, 25]. Similarly, national coral reef surveys have established important benchmarks for assessing reef conditions, detecting ecological changes, and evaluating conservation effectiveness [12, 26]. However, comparable national datasets for seagrass meadows remain limited, restricting assessments of their distribution, degradation trends, and contributions to coastal ecosystem services [13]. Furthermore, many restoration initiatives lack systematic long-term monitoring of vegetation survival, ecological recovery, ecosystem functionality, and socio-economic benefits, making it difficult to determine whether restoration investments produce sustainable outcomes [7, 39].

As summarised in Table 4, research and management priorities differ across coastal ecosystems but share the common objective of improving ecological resilience and strengthening coastal protection. For mangroves, future research should evaluate long-term survival, natural recruitment, sediment accretion, and resistance to cyclone disturbances. Management interventions should prioritise hydrological restoration, site-appropriate species selection, and the rehabilitation of abandoned aquaculture ponds rather than relying exclusively

on planting activities [7, 18, 23, 24]. For coral reefs, research should identify thermal refugia, assess the effectiveness of restoration techniques under increasing ocean temperatures, and examine the socio-economic benefits of reef rehabilitation. These efforts should be supported by effective marine protected areas (MPAs), improved enforcement, and scientifically informed restoration guidelines [28, 35, 38, 39].

Table 4. Priority Research and Management Actions for Philippine Coastal Systems.

Domain	Research priority	Management priority	Ref.
Mangroves	Long-term survival and functional recovery of rehabilitated stands; cyclone resilience	Restore hydrology; plant site-appropriate species; revert abandoned ponds	[7, 18, 23, 24]
Coral reefs	Thermal refugia; scalable restoration methods; socio-economic outcomes	Expand effective MPAs; implement restoration guidelines	[28, 35, 38, 39]
Seagrass meadows	National mapping and trend monitoring	Control siltation and mariculture effluent	[13, 30, 31]
Coastal hazards	Quantify ecosystem wave attenuation under sea-level rise and subsidence	Integrate nature-based defences in risk reduction; avoid maladaptive seawalls	[5, 19, 33, 34]
Governance	Institutional capacity and financing for restoration	Strengthen MPA networks and local government roles	[2, 21, 40]

6.2. Governance and Social Dimensions.

The success of coastal restoration in the Philippines depends as much on institutions as on ecology. Community-based MPAs demonstrate that local governance can deliver ecological and fisheries benefits [21, 37]. However, MPA networks [40] and coral restoration programmes [39] face limited local government capacity, weak implementation of guidelines and uncertain financing. Mangrove rehabilitation is constrained by tenure conflicts over abandoned fishponds [7, 8]. Coastal protection policies often favour seawalls over nature-based solutions despite the latter's cost-effectiveness [6, 34]. Aligning restoration with food security, livelihoods and disaster risk reduction is essential for long-term success [2, 16]. Coastal habitat restoration in the Philippines faces interconnected ecological, socioeconomic, and institutional challenges. Anthropogenic pressures, including aquaculture expansion, coastal development, destructive fishing, sedimentation, and nutrient enrichment, continue to affect the recovery of mangrove forests, coral reefs, and seagrass meadows [7, 8, 11, 30, 31]. These pressures can reduce restoration success when the underlying causes of habitat degradation remain unresolved.

Restoration effectiveness is also constrained by inappropriate site selection and technical limitations. Mangrove planting programmes have frequently experienced low survival rates because of unsuitable species selection and planting locations [7]. Coral restoration requires substantial resources and technical expertise, particularly when implemented at larger scales [35, 36]. Seagrass restoration remains comparatively underdeveloped, with limited evidence on long-term recovery and effectiveness [13]. These differences highlight the importance of ecosystem-specific restoration strategies. Climate-related disturbances further complicate restoration efforts. Tropical cyclones can cause extensive damage to mangrove forests, while thermal stress and other environmental pressures threaten coral reef recovery [18, 24, 28, 29]. Consequently, restoration programmes should incorporate climate resilience and adaptive management into their planning. Institutional and financial constraints represent additional

barriers. Limited local government capacity, inconsistent implementation of restoration guidelines, uncertain funding, and competing coastal land uses can restrict project effectiveness [7, 8, 39, 40]. Furthermore, insufficient long-term monitoring makes it difficult to determine whether restoration programmes achieve sustained ecological and socioeconomic benefits. Addressing these challenges requires stronger coordination among government agencies, research institutions, local communities, and other stakeholders, supported by sustainable financing and measurable restoration objectives.

6.3. Limitations and Future Research Recommendations.

This review has several limitations. First, the available literature differs considerably in spatial coverage, research methodology, monitoring duration, and ecological indicators, limiting direct comparisons among studies. Second, the evidence base is uneven across ecosystems. Mangrove mapping and coral reef assessments are relatively well developed, whereas comprehensive information on seagrass distribution, condition, and long-term trends remains limited [9, 10, 12, 13]. Third, many restoration studies emphasise short-term survival or habitat condition rather than long-term ecological functions, resilience, and socioeconomic outcomes [7, 39]. Finally, the narrative synthesis does not provide a quantitative assessment of effect sizes or causal relationships.

Future research should prioritise integrated monitoring of mangrove, seagrass, and coral reef ecosystems using consistent indicators and comparable assessment methods. Long-term studies are needed to evaluate restoration effectiveness, sediment dynamics, habitat connectivity, biodiversity recovery, and coastal protection under changing climatic conditions. Further investigation should also examine the combined effects of coastal development, pollution, cyclones, and sea-level rise on ecosystem resilience. From a management perspective, restoration programmes should prioritise protection of intact habitats, rehabilitation of degraded ecosystems in ecologically suitable locations, reduction of land-based stressors, and community participation. Sustainable financing, improved governance, and coordinated monitoring are also essential to support long-term restoration outcomes. These recommendations complement the priorities summarised in Table 4 and provide a basis for more integrated and adaptive coastal management.

7. Conclusions

Mangrove forests, coral reefs, and seagrass meadows form interconnected coastal ecosystems that support biodiversity, fisheries, carbon storage, and shoreline protection in the Philippines. However, these ecosystems face increasing pressures from coastal development, aquaculture conversion, sedimentation, destructive fishing, and climate-related disturbances. The reviewed evidence highlights the importance of ecological connectivity in regulating sediment transport, nutrient exchange, wave attenuation, and habitat functions. Although restoration approaches have progressed towards hydrology-based mangrove rehabilitation, coral larval enhancement, and ecosystem-based management, their effectiveness remains constrained by unsuitable site selection, limited financing, governance challenges, and insufficient long-term monitoring. Significant knowledge gaps also remain, particularly regarding seagrass distribution, restoration outcomes, and interactions among coastal ecosystems under changing environmental conditions. Future research should prioritise integrated monitoring, comparative restoration assessments, and the quantification of ecosystem connectivity and coastal

protection functions. Effective management requires protecting intact habitats, restoring degraded ecosystems in suitable locations, reducing anthropogenic pressures, and strengthening institutional coordination. These measures are essential for improving the resilience and sustainability of Philippine coastal ecosystems.

Author Contributions

Both authors contributed equally to this work, including conceptualisation, literature search and analysis, writing of the original draft, and review and editing of the manuscript. Both authors have read and agreed to the published version of the manuscript.

Competing Interests

The authors declare no competing interests.

Data Availability

No new data were created or analysed in this study. Data sharing is not applicable to this article. All sources reviewed are published, peer-reviewed journal articles cited in the reference list.

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