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Current Status, Distribution, Threats, and Conservation of Mangrove Forests in the Bicol Region, Philippines: A Review

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Abstract:

Mangrove ecosystems are critical coastal habitats that provide ecological, economic, and climate resilience benefits. In the Bicol Region, Philippines, mangroves face multiple threats, including land-use conversion, pollution, sedimentation, climate change, and resource extraction, which collectively undermine forest health and ecosystem services. This literature review synthesizes current knowledge on the status, distribution, threats, and conservation initiatives of Bicol mangroves, drawing from peer-reviewed studies, government reports, and community-based programs. Findings indicate that while significant conservation and rehabilitation efforts, including community-based management and scientific restoration, have improved local mangrove conditions, gaps remain in longitudinal monitoring, species-specific ecology, socio-economic integration, climate adaptation modeling, and policy implementation. Addressing these gaps through coordinated management, adaptive restoration, and inclusive governance is essential to ensure the sustainability and resilience of mangrove ecosystems in the Bicol Region.

Keywords: mangrove, Bicol Region, coastal ecosystems, conservation, restoration, climate resilience

1. Introduction

Mangrove ecosystems are highly productive tropical coastal forests comprised of salt-tolerant plants adapted to intertidal environments, where they are periodically inundated by seawater and influenced by tidal dynamics. These ecosystems are characterized by specialized root structures (e.g., prop roots, pneumatophores) that facilitate survival in saline, anoxic sediments and support a unique assemblage of flora and fauna [4]. Mangroves provide essential ecosystem services such as coastal protection from storm surges and erosion, habitat and nursery grounds for fisheries, nutrient cycling, and carbon sequestration, making them critical for environmental stability and human well-being [6], [4].

In the Philippines, mangrove forests are recognized for their ecological richness and socio-economic value. The country is part of the Coral Triangle and is considered among the most biodiverse regions for mangrove species globally [4]. Historical assessments indicate that the Philippines once supported extensive mangrove cover, with estimates suggesting around 500,000 ha in the early 20th century; however, this has drastically declined due to conversion to aquaculture ponds, coastal development, settlements, and overexploitation [6]. Despite conservation and rehabilitation efforts, ongoing pressures such as land-use change and unsustainable exploitation continue to threaten mangrove integrity nationwide [6]. Mangrove ecosystem services—including shoreline stabilization, fishery support, and carbon storage—underpin both ecological health and local livelihoods in coastal communities, highlighting their integrative importance for sustainable development [4].

Within the Bicol Region (Region V) of the Philippines, mangrove forests occur along estuaries, coastal bays, and river deltas, where the interplay of marine and freshwater systems creates suitable environmental conditions for mangrove colonization [1]. A notable example is Bongsanglay Natural Park in Masbate, which preserves one of the few primary growth mangrove forests in the region and harbors a diversity of mangrove species, including century-old individuals and a documented tally of 34 true mangrove species and numerous associates [3], [1]. Historically, the Bicol Region's mangrove cover has experienced fluctuations, with documented increases in total mangrove area between 2003 and 2010 attributed to community and government rehabilitation initiatives, yet ongoing threats linked to climate change, fishery demands, land conversion, and governance challenges persist [1]. Mangroves in this region thus play a vital role in buffering coastal communities against frequent typhoons and storm surges, supporting fisheries, and maintaining biodiversity, but require continued attention in conservation planning.

Understanding the current status, distribution, threats, and conservation responses of mangrove ecosystems in the Bicol Region is fundamental for informing sustainable management, policy formulation, and community engagement strategies. While national-level reviews exist regarding the overall status and threats to Philippine mangrove forests [6], [4], there is a need for a region-specific synthesis that addresses local conditions, trends, and institutional responses in Bicol. This literature review aims to bridge that gap by critically examining the available evidence and highlighting priority areas for research and conservation action.

2. Methodology of Review

This study employed a structured literature review approach to synthesize existing research on the current status, distribution, threats, and conservation of mangrove ecosystems in the Bicol Region, Philippines. The review followed established principles for narrative and semi-systematic literature reviews to ensure transparency, consistency, and methodological rigor in the selection and synthesis of sources [1]. This approach was deemed appropriate due to the interdisciplinary nature of mangrove research, which spans ecology, geography, policy, and community-based resource management, and the relatively limited number of region-specific studies available for the Bicol Region.

Relevant literature was obtained through a comprehensive search of international and national academic databases, including Google Scholar, Scopus, Web of Science, ScienceDirect, and FAO AGRIS. In addition, gray literature and institutional publications were sourced from the Department of Environment and Natural Resources (DENR), the Food and Agriculture Organization of the United Nations (FAO), and related government and research institutions [1], [2]. These sources were included to capture policy documents, technical reports, and regional assessments that provide critical contextual information not always available in peer-reviewed journals.

The literature search employed a combination of keywords and Boolean operators to ensure broad coverage of relevant studies. Search terms included variations of "mangrove ecosystems," "mangrove distribution," "threats to mangroves," "mangrove conservation," and "Bicol Region, Philippines." Reference lists of selected articles were also examined to identify additional relevant publications. Searches were conducted for literature published between 2000 and 2025 to reflect contemporary ecological conditions, management practices, and policy frameworks relevant to mangrove ecosystems.

Studies were screened and selected based on predefined inclusion and exclusion criteria. Included sources consisted of peer-reviewed journal articles, books, theses, and technical reports written in English that focused on mangrove ecosystems in the Philippines, with particular emphasis on studies addressing the Bicol Region. Publications that examined mangrove status, spatial distribution, drivers of degradation, conservation initiatives, or management strategies were prioritized. Studies unrelated to mangroves, those lacking scientific or institutional credibility, and publications focusing exclusively on non-Philippine contexts without relevance to the study objectives were excluded.

The selection process involved an initial screening of titles and abstracts to assess relevance, followed by a full-text review of eligible studies. This process was guided by the general principles of the PRISMA 2020 framework to enhance transparency and reduce selection bias [1]. Preference was given to authoritative and frequently cited sources, as well as government and institutional reports that provide official data on mangrove extent, management programs, and policy implementation.

Data were systematically extracted from each selected publication, including information on authorship, year of publication, study location, methodological approach, mangrove area estimates, species composition, identified threats, and documented conservation or management efforts. The extracted data were then organized thematically according to the four main focus areas of the review: current status of mangrove ecosystems, spatial distribution patterns, major threats, and conservation and management initiatives.

The synthesis of findings was conducted using thematic analysis, allowing for the identification of common patterns, trends, and knowledge gaps across studies [1]. Quantitative data, such as mangrove area estimates and temporal trends, were compared across different sources and time periods where possible, while qualitative findings from policy analyses and community-based studies were synthesized to assess governance structures and management effectiveness. This integrative approach facilitated a comprehensive understanding of mangrove ecosystem dynamics in the Bicol Region within the broader national context.

This review acknowledges certain limitations, including the limited availability of peer-reviewed studies focusing exclusively on the Bicol Region and the reliance on secondary data that may vary in methodological rigor. Nevertheless, the triangulation of multiple data sources, including peer-reviewed literature and official government reports, enhances the reliability and robustness of the synthesized findings [1], [3], [4].

3. Current Status of Mangrove Ecosystems in the Bicol Region

3.1 Mangrove Cover and Historical Trends

The current status of mangrove ecosystems in the Bicol Region reflects a combination of historical degradation and gradual recovery driven by conservation and rehabilitation initiatives. According to Dadea [1], mangrove cover in Region V increased substantially from approximately 13,499 hectares in 2003 to 24,953 hectares in 2010. This increase was attributed to intensified mangrove protection, rehabilitation programs, and community-based coastal resource management initiatives implemented by the Department of Environment and Natural Resources (DENR), local government units, and partner organizations. Dadea [1] emphasized, however, that increases in mangrove area do not necessarily equate to improvements in ecological condition, as many rehabilitated sites consist of young or monoculture plantations with limited structural complexity. The historical decline of mangroves in the region mirrors national trends documented by Primavera [5], [6], who identified large-scale conversion of mangrove areas into fishponds and coastal settlements as the primary drivers of mangrove loss in the Philippines. While the Bicol Region has shown measurable recovery in total mangrove area, legacy impacts of past land-use conversion continue to influence forest structure, hydrology, and species composition.

3.2 Species Composition and Forest Condition

Mangrove species composition and ecological condition vary considerably across the Bicol Region. The most ecologically intact mangrove ecosystem is found in Bongsanglay Natural Park in Masbate, which has been documented as the only remaining primary growth mangrove forest in the region. According to DENR-BMB [3], the park supports at least 34 true mangrove species, including dominant taxa such as Avicennia marina, Sonneratia alba, and Rhizophora apiculata. These species form structurally complex forest stands with large, mature trees that provide critical habitat for coastal

and marine fauna. In contrast, mangrove forests outside protected areas are predominantly secondary growth or rehabilitated plantations. Studies conducted in Masbate and nearby islands indicate that rehabilitated sites often exhibit lower species richness and simplified stand structure compared to natural forests, particularly where reforestation efforts relied heavily on single-species planting of Rhizophora spp. [7]. Such structural limitations may affect ecosystem functions, including biodiversity support and resilience to climatic disturbances.

3.3 Case Study: Prieto Diaz Mangrove Ecosystem, Sorsogon

One of the most well-documented examples of mangrove recovery in the Bicol Region is found in Prieto Diaz, Sorsogon. Research by Samson and Rollon [9] and later assessments by Primavera et al. [7] highlight how decades of community-based mangrove rehabilitation transformed previously degraded coastal areas into a contiguous mangrove landscape exceeding 1,000 hectares. The success of the Prieto Diaz mangrove ecosystem has been attributed to sustained community participation, enforcement of local ordinances, and integration of mangrove conservation with livelihood programs. A comparative ecological study by Salmo, Lovelock, and Duke [8] further demonstrated that mixed-species mangrove plantations in Prieto Diaz exhibited improved biomass accumulation and functional traits compared to monoculture plantations, although differences remained when compared to old-growth mangrove stands. These findings underscore the importance of species diversity and site suitability in restoration outcomes.

3.4 Contemporary Monitoring and Management Initiatives

Recent developments in mangrove assessment and management emphasize improved monitoring and science-based decision-making. The DENR [3] has initiated nationwide efforts to validate mangrove extent using ground surveys, participatory mapping, and remote sensing, including validation activities in the Bicol Region. According to DENR-BMB [3], these initiatives aim to refine mangrove spatial data, assess ecosystem condition, and identify priority areas for restoration, particularly abandoned fishponds suitable for mangrove reversion. Despite these advances, several challenges persist. Garcia, Malabrigo, and Gevaña [4] noted that uneven enforcement of coastal regulations, limited technical capacity at the local level, and inconsistencies in restoration approaches continue to constrain the long-term sustainability of mangrove ecosystems. These challenges highlight the need for site-specific management plans, long-term ecological monitoring, and stronger integration of local knowledge systems into formal governance structures.

3.5 Synthesis of Current Status

Overall, the current status of mangrove ecosystems in the Bicol Region can be characterized as a mosaic of intact primary forests, recovering secondary forests, and rehabilitated plantations. Quantitative data indicate a net increase in mangrove area over the past two decades [1], while qualitative assessments reveal substantial variation in forest condition, species composition, and ecological functionality across sites. The presence of ecologically intact systems such as Bongsanglay Natural Park and successful community-managed landscapes like Prieto Diaz illustrates the potential for effective mangrove conservation, provided that restoration efforts are guided by sound ecological principles and sustained institutional support

4. Distribution of Mangrove Ecosystems in the Bicol Region

4.1 Spatial Distribution Across Provinces

Mangrove ecosystems in the Bicol Region are distributed along the coastlines of Camarines Norte, Camarines Sur, Albay, Sorsogon, and Masbate, primarily in estuarine, deltaic, and sheltered bay areas. According to Dadea [1], Masbate and Sorsogon host the largest contiguous mangrove stands, while Albay and Camarines Norte contain smaller, often fragmented forests. Masbate's Bongsanglay Natural Park remains the most extensive and ecologically intact area, serving as a critical reference site for species composition and forest structure. Similarly, Prieto Diaz in Sorsogon represents one of the largest restored mangrove landscapes, demonstrating the impact of community-led rehabilitation efforts [9], [7]. Dadea [1] also notes that fragmented mangrove patches are often located along river mouths, coastal lagoons, and bay shores where sediment deposition creates suitable conditions for colonization.

The spatial distribution of mangroves is strongly influenced by geomorphology, hydrology, and tidal dynamics. Areas with gentle slopes, fine sediments, and protected waters tend to support higher mangrove density and diversity, whereas exposed coastlines with strong wave action or intensive human use often have sparse or degraded mangrove cover [4]. These patterns indicate that natural factors, combined with anthropogenic pressures, dictate both the extent and quality of mangrove ecosystems in the region.

4.2 Species Distribution Patterns

The composition of mangrove species varies across the region depending on environmental gradients such as salinity, tidal inundation, and sediment type. Bongsanglay Natural Park in Masbate supports at least 34 true mangrove species, including dominant species such as Avicennia marina, Sonneratia alba, and Rhizophora apiculata, along with numerous associate species [3]. In contrast, restored mangrove areas, such as those in Prieto Diaz, Sorsogon, are often dominated by Rhizophora species, reflecting the preference for fast-growing and structurally resilient species in rehabilitation projects [8]. These differences highlight the heterogeneity of mangrove distribution at both the species and stand levels, influenced by both ecological conditions and restoration practices.

Studies in Masbate, Sorsogon, and Camarines Sur show that species richness tends to decline in smaller or isolated mangrove patches, emphasizing the importance of habitat connectivity for maintaining biodiversity and ecological functions [7]. Mangrove stands along river mouths often have higher species diversity due to freshwater influence, whereas coastal fringes exposed to strong tidal surges are typically dominated by a few pioneer species such as Avicennia and Sonneratia.

4.3 Mangrove Distribution by Coastal Type

Mangrove ecosystems in Bicol can be categorized according to coastal typology: estuarine, deltaic, lagoonal, and open coast. Estuarine mangroves, found in Camarines Sur and Masbate, are typically species-rich due to nutrient input from rivers and reduced wave energy. Deltaic mangroves, such as those at the mouth of the Bicol River, are influenced by sediment deposition patterns and often exhibit zonation with Rhizophora species dominating the seaward edge. Lagoonal mangroves, such as those in Sorsogon Bay, are relatively sheltered and provide important nursery habitats for fish and crustaceans [4], [1]. Open coast mangroves, while limited in extent, are generally less dense and structurally simplified due to exposure to strong winds and waves.

These coastal typologies also determine vulnerability to threats. Estuarine and lagoonal mangroves are particularly sensitive to water pollution, aquaculture expansion, and sedimentation, while open coast mangroves are more prone to physical damage from storms and erosion. Understanding the distribution of mangroves according to coastal type is critical for planning site-specific management and restoration strategies.

4.4 Distribution Trends and Conservation Hotspots

Recent mapping efforts by the DENR [3] and FAO [2] show that overall mangrove cover in Bicol has increased over the past two decades due to rehabilitation programs, yet the distribution remains uneven. Masbate and Sorsogon emerge as conservation hotspots with both natural and restored mangrove stands providing high ecological and socioeconomic value [7], [1]. Meanwhile, other provinces such as Albay and Camarines Norte have smaller, fragmented mangrove patches requiring targeted restoration and protection.

Conservation efforts, particularly in priority areas like Bongsanglay Natural Park, integrate habitat protection, biodiversity monitoring, and community engagement to safeguard critical mangrove ecosystems. The spatial distribution data also highlight gaps where future rehabilitation could improve connectivity between isolated stands, enhancing resilience against climate-related disturbances and supporting biodiversity conservation at a landscape scale [4], [3].

5. Threats to Mangrove Ecosystems in the Bicol Region

5.1 Land-Use Conversion and Coastal Development

Land-use conversion remains the most significant anthropogenic threat to mangroves in the Bicol Region. Large areas of mangrove forests were historically cleared to establish aquaculture ponds, particularly for milkfish (Chanos chanos) and shrimp farming. Primavera [5], [6] explains that such conversions result in permanent loss of mangrove habitats, altering coastal hydrology and reducing sediment stabilization capacity. In the Bicol Region, provinces like Masbate and Camarines Sur have experienced significant mangrove fragmentation due to this trend, where remaining patches are often isolated, reducing ecological connectivity and limiting dispersal of flora and fauna. Furthermore, urban expansion along coastal towns, such as in Daraga (Albay) and Naga City (Camarines Sur), has encroached on mangrove areas for housing and infrastructure, adding pressure to already stressed ecosystems. The impact of land-use conversion is not only ecological but also socio-economic: communities lose natural shoreline protection, fisheries productivity declines, and vulnerability to coastal hazards increases, highlighting the cascading consequences of mangrove destruction [4].

5.2 Pollution and Sedimentation

Mangroves in Bicol are also threatened by pollution and sedimentation, which significantly impair regeneration and growth. Agricultural runoff from upland farms introduces fertilizers and pesticides into river systems that drain into mangrove areas, leading to eutrophication and toxic conditions for seedlings [4]. Industrial and domestic effluents contribute additional chemical and biological pollutants, while solid waste, including plastics, physically smothers roots and reduces tidal flushing. Sedimentation from deforested upstream watersheds and poorly managed construction sites further alters the geomorphology of coastal flats, potentially burying propagules before they can establish. Estuarine mangroves, such as those in the Bicol River delta and Sorsogon Bay, are particularly sensitive because they rely on periodic sediment deposition to maintain soil elevation relative to tidal levels. Excessive sedimentation can therefore suffocate pneumatophores, reduce aeration, and hinder nutrient exchange, ultimately limiting species richness and forest resilience.

5.3 Climate-Related Threats

The Bicol Region is one of the most typhoon-prone areas in the Philippines, making mangrove ecosystems highly susceptible to climate-driven disturbances. Strong tropical cyclones can uproot trees, break branches, strip leaves, and erode coastal soils, leaving young mangrove plantations particularly vulnerable. Rodríguez, Smith, and Lopez [10] demonstrate that repeated storm events can reduce canopy cover and biomass accumulation, slowing natural regeneration and altering forest structure. Beyond immediate physical damage, climate change amplifies threats through sea-level rise, which can submerge low-lying mangrove areas beyond the tolerance limits of certain species such as

Rhizophora and Sonneratia. Saltwater intrusion from rising seas also shifts soil salinity, potentially favoring more tolerant pioneer species over sensitive ones, thus altering species composition and zonation. In combination, these climatic factors reduce mangrove resilience and increase the likelihood of long-term degradation if adaptive management measures are not implemented.

5.4 Resource Extraction and Local Pressures

Local resource use continues to threaten mangroves, even in areas that have undergone rehabilitation. Communities often rely on mangroves for fuelwood, charcoal, and construction materials, particularly during periods of economic stress. This selective harvesting disproportionately affects young and edge trees, reducing forest density and structural complexity, which in turn compromises ecological functions such as sediment stabilization, carbon sequestration, and nursery habitat for fish [7]. Furthermore, fishing practices, including the use of nets and traps near mangrove fringes, can damage root systems and disturb soil surfaces. Even seemingly minor disturbances accumulate over time, particularly in small or isolated patches, making restoration efforts more difficult to sustain. The interplay of subsistence resource use with weak enforcement of regulations underscores the need to integrate community-based management with formal governance to maintain ecosystem services while supporting local livelihoods.

5.5 Governance and Policy Challenges

Inadequate governance and policy enforcement exacerbate the vulnerability of Bicol mangroves. Primavera [5] notes that overlapping institutional mandates, unclear land tenure, and weak monitoring hinder effective protection. In Bicol, illegal clearing persists despite protected areas and rehabilitation programs, partly because regulatory oversight is limited, and local enforcement mechanisms are inconsistent. Policies for mangrove restoration often fail to fully incorporate community engagement or account for socio-economic dependencies, reducing the effectiveness of interventions. Successful management requires coordination between national agencies like DENR, local government units, and community stakeholders, with clear delineation of responsibilities, consistent enforcement of regulations, and long-term monitoring to ensure rehabilitation and protection objectives are achieved.

5.6 Summary of Threats

Overall, mangrove ecosystems in the Bicol Region face multiple, interrelated threats that affect both extent and ecological function. Land-use conversion, pollution, sedimentation, climate-related disturbances, resource extraction, and governance gaps collectively undermine resilience. Even though community-based rehabilitation and protected areas have mitigated some losses, the continued presence of these pressures highlights the urgent need for integrated, adaptive management strategies, combining restoration science, policy enforcement, and stakeholder participation to safeguard mangrove ecosystems and the services they provide to coastal communities.

6. Conservation and Management Initiatives for Mangrove Ecosystems in the Bicol Region

6.1 Policy and Regulatory Framework

The conservation of mangroves in the Bicol Region is anchored in national environmental policies, laws, and local ordinances that aim to protect coastal ecosystems while balancing socioeconomic needs. The Philippine Fisheries Code (RA 8550, 1998) explicitly recognizes mangroves as critical fishery habitats and prohibits unauthorized cutting, reclamation, and conversion, providing a legal basis for conservation programs. Additionally, Executive Order 533 (2006)

establishes critical habitat zones for protection, while the National Integrated Protected Areas System (NIPAS) Act of 1992 and its amendments enable the designation of protected areas such as Bongsanglay Natural Park in Masbate, which serves as a biodiversity hotspot and reference site for mangrove health [5], [3].

Despite these frameworks, implementation challenges persist. Garcia, Malabrigo, and Gevaña [4] highlight that overlapping mandates between national and local agencies, insufficient enforcement resources, and unclear land tenure sometimes allow illegal cutting and unregulated development to continue. Moreover, some policies fail to integrate adaptive management approaches, leaving mangroves vulnerable to climate change impacts. Recent efforts by the DENR-BMB involve GIS mapping, satellite imagery, and community monitoring to strengthen enforcement and ensure compliance with protective regulations [3]. These initiatives underscore the importance of legal and institutional mechanisms, which provide the structural foundation for mangrove protection and sustainable management.

6.2 Community-Based Management Approaches

Community participation is critical to sustaining mangrove ecosystems in the Bicol Region. Community-Based Management (CBM) programs involve local stakeholders in the protection, monitoring, and rehabilitation of mangroves, ensuring that conservation measures align with community needs and capacities. Samson and Rollon [9] document successful CBM in Prieto Diaz, Sorsogon, where residents actively participate in planting seedlings, enforcing local ordinances, and monitoring forest health. CBM programs often integrate livelihood alternatives, such as sustainable harvesting of non-timber products, eco-tourism, and handicraft production from mangrove resources, creating incentives for long-term protection.

Education and capacity-building are central to CBM success. Awareness campaigns, workshops, and participatory mapping help communities understand the ecological functions of mangroves, including carbon sequestration, coastal protection, and nursery habitats for fish and crustaceans. Studies by Primavera et al. [7] indicate that CBM programs increase compliance with protective measures and enhance seedling survival rates, especially when paired with technical guidance from government agencies and NGOs. By fostering local stewardship, these approaches transform mangroves from a mere natural resource into a shared community asset, ensuring ecological sustainability and socioeconomic benefits.

6.3 Mangrove Rehabilitation and Restoration Science

Scientific approaches underpin most mangrove restoration efforts in Bicol. Effective rehabilitation involves site assessment, species selection, planting techniques, and post-planting maintenance. Salmo, Lovelock, and Duke [8] emphasize that planting mixed-species assemblages rather than monocultures improves structural diversity, resilience to storms, and ecological function. For instance, in Prieto Diaz and Bongsanglay Natural Park, combinations of Rhizophora, Avicennia, and Sonneratia species enhance biodiversity, stabilize sediment, and accelerate canopy formation.

Rehabilitation strategies also consider hydrological conditions, tidal inundation, and sediment dynamics to ensure seedlings establish in favorable conditions. The DENR and partner organizations conduct baseline assessments to identify degraded or abandoned areas suitable for restoration, while adaptive management allows modifications to planting density, species composition, and protective measures based on ongoing monitoring outcomes [3]. Restoration projects not only focus on replanting but also on ecosystem function recovery, including carbon sequestration, water filtration, and provision of fisheries habitat, ensuring that restored mangroves deliver tangible ecological and community benefits.

6.4 Monitoring and Evaluation Programs

Systematic monitoring and evaluation (M&E) are essential to measure restoration success, detect threats, and inform adaptive management. In Bicol, DENR-BMB employs satellite imagery, aerial drone surveys, and field inventories to quantify mangrove extent, canopy density, species composition, and soil characteristics [3]. Indicators such as seedling survival, tree height, basal area, and biodiversity indices are measured periodically to evaluate forest recovery and ecological function.

Monitoring is increasingly integrated with community participation, where local stakeholders report changes in mangrove health, illegal activities, or environmental hazards. According to Dadea [1], combining scientific M&E with community-based reporting improves both data accuracy and local engagement, providing feedback loops that enhance management interventions. The results from these programs inform adaptive restoration strategies, enabling managers to modify planting approaches, protective measures, or community engagement tactics, ensuring the long-term resilience and sustainability of mangrove ecosystems.

6.5 Integration with Climate Adaptation and Coastal Resilience

Mangrove conservation in the Bicol Region is closely linked to climate adaptation and disaster risk reduction. Mangroves act as natural buffers against storm surges, tidal flooding, and coastal erosion, reducing risks to human settlements and infrastructure. Conservation and restoration initiatives are increasingly integrated into Integrated Coastal Zone Management (ICZM) programs, which optimize ecological and social benefits. Primavera et al. [7] note that prioritizing restoration in vulnerable coastal zones enhances resilience, protects fisheries productivity, and contributes to carbon sequestration goals.

Climate-focused initiatives often involve site prioritization based on vulnerability assessments, combining ecological data, historical storm records, and community exposure. By aligning mangrove management with adaptation strategies, these programs enhance the dual role of mangroves as ecosystem services providers and climate buffers, ensuring that restoration investments deliver long-term benefits for both nature and local communities.

7. Gaps in Literature

Despite numerous studies on mangrove ecosystems in the Philippines and the Bicol Region in particular, there remain critical gaps in knowledge, methodology, and implementation that hinder a complete understanding of mangrove ecology and effective conservation strategies.

First, while the current status and distribution of mangroves have been mapped using remote sensing and field surveys [4], [3], there is limited longitudinal data tracking changes in mangrove coverage over time at fine spatial scales. Many studies rely on broad provincial or regional assessments, which may overlook local variability in species composition, stand structure, and degradation patterns. This limits the ability of policymakers and practitioners to identify priority areas for restoration or protection and to assess the success of community-based or government-led rehabilitation programs over the long term.

Second, research on species-specific ecology and functional diversity of mangroves in Bicol remains limited. While dominant species such as Rhizophora, Avicennia, and Sonneratia are well-documented, there is a lack of detailed studies on less common or pioneer species, their ecological roles, tolerance to environmental stressors, and contribution to overall ecosystem resilience. Understanding these dynamics is critical for designing restoration programs that enhance biodiversity, structural complexity, and ecosystem services, yet most rehabilitation projects prioritize fast-growing species or monocultures for practical reasons [8].

Third, the literature reveals insufficient integration of socio-economic and cultural dimensions in mangrove conservation research. While studies highlight threats from aquaculture, wood extraction, and pollution [5], [4], there is limited quantitative analysis of how livelihood dependence, local

governance, and social norms shape mangrove management outcomes. Similarly, few studies have assessed the long-term effectiveness of community-based management (CBM) programs in balancing ecological restoration with sustainable livelihoods, especially in areas experiencing rapid coastal population growth or economic pressures [9].

Fourth, although climate change and extreme weather events are recognized as major threats to mangroves [10], there is a scarcity of regional-scale predictive models assessing how typhoon frequency, sea-level rise, and storm surge specifically affect mangrove survival, regeneration, and ecosystem services in Bicol. Most existing climate-related studies are extrapolated from broader Philippine or Southeast Asian data, which may not accurately reflect the local hydrology, sediment dynamics, or species composition of Bicol mangroves. Without location-specific projections, restoration efforts risk selecting unsuitable sites or species, potentially reducing long-term resilience.

Fifth, there is a noticeable gap in monitoring and evaluation frameworks for restoration and conservation programs. While DENR-BMB and NGOs conduct periodic assessments [3], [1], these are often snapshot surveys rather than continuous, standardized monitoring protocols. There is also limited integration of modern technology, such as drone imagery, remote sensing time-series analysis, and citizen-science reporting, which could improve spatial resolution and data accuracy for adaptive management.

Finally, policy and governance research remains fragmented. Despite strong legal frameworks and protected areas, studies on policy implementation effectiveness, enforcement gaps, and inter-agency coordination are limited. Little is known about how national laws interact with municipal ordinances, customary practices, or community-led conservation efforts in practice, leaving uncertainty about which strategies yield the highest ecological and social outcomes [5], [4].

8. Conclusion

Mangrove ecosystems in the Bicol Region remain ecologically and socio-economically significant, providing critical services such as coastal protection, nursery habitats for fisheries, and carbon sequestration. Despite historical degradation due to aquaculture, urban expansion, pollution, and unsustainable resource use, ongoing conservation initiatives—including protected areas, community-based management, and scientifically guided restoration—have contributed to local recovery and enhanced ecosystem resilience. However, multiple knowledge and implementation gaps persist, particularly in longitudinal monitoring, species-specific ecological studies, socio-economic integration, climate impact modeling, and enforcement of policies. Addressing these gaps requires multi-level, adaptive, and inclusive strategies that integrate scientific evidence, community participation, and effective governance. Ensuring the long-term sustainability of Bicol mangroves will not only protect biodiversity but also support coastal livelihoods and strengthen resilience against climate-related hazards, highlighting the critical need for continued research, monitoring, and proactive management.

Disclosure Statement

The author declares that this literature review was conducted independently and without any financial or personal conflicts of interest that could influence the content or conclusions of the study. The author affirms that the views, interpretations, and conclusions presented in this review reflect a scholarly synthesis of existing literature on mangrove ecosystems in the Bicol Region, Philippines, and do not represent the official position of any organization, institution, or funding body.

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