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Ecology-Based Regulatory Model for Seagrass Ecosystem Protection in the Aru Islands

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Abstract: Seagrass ecosystems serve important ecological functions as habitats for marine life, coastal protection, and blue carbon sinks. However, seagrass ecosystem protection in the Aru Islands still faces various challenges due to weak coastal area management regulations that are not yet ecologically based. This study aims to analyze the legal regulations for seagrass protection, identify weaknesses in coastal management regulations, and formulate an ecologically based regulatory model for seagrass ecosystem protection in the Aru Islands. The study uses normative legal methods with a legislative and conceptual approach, supported by limited empirical data. The results indicate that seagrass protection regulations in Indonesia are still partial and sectoral, and do not provide specific protection for seagrass ecosystems. Furthermore, coastal area management regulations are still oriented towards natural resource utilization rather than ecological protection. This study proposes an ecologically based regulatory model through an ecoregional approach, strengthening coastal village regulations, community participation, integrated coastal management, and integrating blue carbon governance as an effort to realize sustainable seagrass ecosystem protection in the archipelago

Keywords: Ecologically Based Regulation; Seagrass Ecosystem; Archipelago; Aru Islands

1. Introduction

Seagrass ecosystems are one of the coastal ecosystems that play a crucial ecological role in maintaining the balance of the marine environment (Sari et al., 2023). Seagrass serves as a habitat for various marine organisms, a spawning and nursery ground for fish, a coastal protection against erosion, and a blue carbon sink that contributes to climate change mitigation. From a sustainable development perspective, the existence of seagrass holds strategic value because it not only supports coastal ecological sustainability but also underpins the social and economic livelihoods of coastal communities, particularly in archipelagic regions. Constitutionally, environmental protection in Indonesia is grounded in pasal 28H ayat (1) of the 1945 Constitution of the Republic of Indonesia, which guarantees every person's right to a good and healthy environment.

In addition, Pasal 33, ayat (3) and (4) of the 1945 Constitution stipulate that the management of natural resources must be carried out in a sustainable and environmentally sound manner. At the regulatory level, environmental protection is governed by Law No. 32 of 2009 on Environmental Protection and Management and Law No. 27 of 2007, as amended by Law No. 1 of 2014 on the Management of Coastal Areas and Small Islands. However, these various regulations have not yet specifically provided comprehensive provisions regarding the protection of seagrass ecosystems.

This situation poses a serious problem in archipelagic regions such as the Aru Islands, which have vulnerable coastal and marine ecological characteristics.

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Communities in this region are highly dependent on coastal and marine resources, including seagrass ecosystems that help maintain fisheries productivity and coastal environmental stability. However, seagrass in the Aru Islands faces various threats due to human activities, such as marine coral mining, unsustainable fishing practices, increased maritime transport, domestic waste disposal, sedimentation, and weak oversight of marine space utilization. These activities contribute to the degradation of seagrass beds, which has the potential to disrupt the balance of coastal ecosystems and the livelihoods of coastal communities.

an the other hand, regulations governing coastal zone management in Indonesia still reflect a sectoral, administrative, and natural resource exploitation-oriented approach. Coastal ecosystem protection has so far been focused primarily on mangroves and coral reefs. Despite their equal ecological function as coastal buffers, seagrass ecosystems are often marginalized by regulation in marine conservation law compared to mangroves and coral reefs. This crucial policy balance lies in the disproportionate focus given to regulations. From a legal-ecological perspective, three key policy gaps distinguish and separate seagrass protection from these two other coastal ecosystems. Jurisdictional and Spatial Overlap Blindness: Mangroves enjoy clear statutory protection under both forestry and coastal management laws due to their terrestrial-marine interface. Coral reefs are highly protected through marine protected areas (MPAs) and fisheries regulations due to their direct link to commercial fish biomass. Conversely, seagrass ecosystems exist in an ambiguous sub-tidal zone that spans multiple jurisdictional boundaries (fisheries, coastal zoning, and land-based pollution runoff frameworks), resulting in fragmented enforcement where no single authority assumes primary trusteeship. Divergent Threat Matrices and "Invisible" Degradation: While mangrove destruction (e.g., aquaculture conversion) and coral degradation (e.g., blast fishing) are legally visible and localized, seagrass degradation is primarily driven by cumulative, diffuse, and cross-boundary impacts. These include land-based sedimentation, agricultural nutrient runoff, and benthic scarring from shallow-water destructive fishing. Existing legal frameworks are heavily designed for point-source pollution or localized physical destruction, failing to regulate the land-sea interactions (*source-to-sea connectivity*) that directly dictate seagrass survival. The Property Rights and Valuation Gap: Mangroves provide clear timber/blue carbon assets, and coral reefs generate immediate ecotourism and commercial fisheries revenue, making them easy to quantify within traditional cost-benefit legal frameworks. Seagrass meadows, despite being unparalleled carbon sinks and critical nurseries for endangered megafauna (e.g., *Dugong dugon*), suffer from "regulatory invisibility" because their ecosystem services are largely indirect and public-good in nature. Consequently, current marine zoning laws rarely trigger strict environmental impact assessments (EIAs) for activities affecting seagrass beds compared to the stringent prohibitions applied to coral reefs and mangroves.

The urgency of an ecoregional approach to seagrass ecosystem protection in archipelagic regions is rooted in the imperative to align legal jurisdictions with continuous ecological boundaries. Traditionally, coastal management laws are constrained by anthropocentric administrative boundaries—such as district or provincial

borders—that rigidly fragment marine governance. In contrast, seagrass meadows in archipelagic regions like the Aru Islands rely on dynamic, transboundary interactions, including hydrological currents, marine fauna migration, and sediment transport from surrounding islands. An ecoregional approach addresses this limitation by treating the entire island cluster and its adjacent waters as an indivisible legal management unit. By doing so, this regulatory model facilitates collaborative cross-jurisdictional governance, prevents fragmented law enforcement, and ensures comprehensive legal protection for the entire marine seascape that sustains the seagrass ecosystem.

This approach views the law not only as an administrative tool for natural resource management but also as a means of maintaining ecological balance and environmental sustainability. In the context of the Aru Islands, an ecological regulation model needs to be developed through an ecoregion approach, strengthening of coastal village regulations, community participation, integrated coastal management, and the integration of blue carbon governance. Therefore, this research is important to analyze the weaknesses in seagrass ecosystem protection regulations while formulating an ecological regulation model for seagrass ecosystem protection in the Aru Islands (Saputro & Surakarta, 2024).

2. Materials and Methods

This study employs a normative legal research design using conceptual and statutory approaches, supplemented by limited empirical data. The normative legal approach is used to examine legal norms, principles of environmental law and coastal zone management policies related to seagrass ecosystem protection (Zhang et al., 2024).

Meanwhile, empirical data is used to support the analysis of the actual conditions of seagrass ecosystem protection in the Aru Islands. The statutory approach involves examining various regulations related to the protection and management of the environment, coastal areas, and marine resources, including the 1945 Constitution of the Republic of Indonesia, Law No. 32 of 2009, Law No. 27 of 2007 as amended by Law No. 1 of 2014, as well as various other regulations concerning coastal and marine environmental management.

This approach is used to identify regulatory frameworks, regulatory gaps, and regulatory weaknesses in the protection of seagrass ecosystems. In addition, this study employs a conceptual approach to analyze the concepts of ecological regulation, sustainable development, green governance, and coastal ecosystem protection as a basis for formulating an ecology-based regulatory model (Law et al., 2026). The conceptual approach involves a review of doctrines, theories, and the perspectives of environmental law experts regarding the protection of coastal resources and ecology-based environmental governance. This study also employs a limited empirical approach to obtain factual insights into the condition of seagrass ecosystems and the implementation of coastal environmental protection policies in the Aru Islands. Empirical data was obtained through interviews with relevant parties, such as local governments, environmental agencies, marine and fisheries agencies, coastal village governments, and coastal communities involved in the utilization of seagrass areas.

Informants were selected through purposive sampling based on their legal capacity, regulatory authority, and ecological stakes in the seagrass ecosystems of the Aru Islands. Local government representatives were selected due to their jurisdictional authority in formulating macro-policies and coastal zoning frameworks; environmental agencies were involved for their technical functions in regulatory enforcement, environmental impact assessments (EIA), and legal sanctions; while coastal communities and customary leaders were chosen as primary stakeholders who possess indigenous knowledge and are directly affected economically. The combination of these three informant groups is crucial to achieve robust data triangulation, allowing the study to map the legal gaps between top-down regulatory frameworks and bottom-up legal compliance at the grassroots level.

The legal materials in this study consist of primary, secondary, and tertiary legal materials. Primary legal materials include legislation, government policiesand legal instruments related to the environment and coastal zone management. Secondary legal materials consist of books, scientific journals, research findings, and academic articles relevant to seagrass ecosystem protection and ecological regulation. Tertiary legal materials include legal dictionaries, encyclopedias, and other supporting sources (Budianto, 2020; Hamzani et al., 2023)

The rationale for utilizing limited empirical data in this study is to serve as a sociological illustration and a confirmatory instrument to assess the real-world efficacy and enforceability of the analyzed normative legal structures. Within legal research, restricted field data is not intended for quantitative statistical generalization, but rather to provide contextual depth regarding how statutory texts are interpreted and implemented by stakeholders at the grassroots level. Through this qualitative lens, empirical insights sourced from a specific locality like the Aru Islands function as a critical test case to identify the gap between "law in books" and "law in action." Therefore, the limited field data is methodologically sufficient to sharpen the practical relevance of the ecology-based regulatory model formulated from the overarching normative-theoretical analysis.

Legal materials were collected through library research, while empirical data was gathered through interviews and documentation. All data and legal materials obtained were analyzed qualitatively using a descriptive-analytical approach. The analysis was conducted through a process of regulatory inventory, identification of regulatory gaps, legal interpretation, and the construction of an ecology-based regulatory model for the protection of seagrass ecosystems in island regions. The results of the analysis were then used to formulate a regulatory model that prioritizes ecological aspects as the primary foundation for seagrass ecosystem protection, taking into account the characteristics of the archipelagic region, environmental sustainability, and the participation of coastal communities in the sustainable management of coastal resources.

3. Results and Discussion

3.1 Seagrass Conservation Policies in Indonesia

Legal provisions regarding the protection of seagrass ecosystems in Indonesia have not yet been specifically addressed in a single, standalone regulation; rather, they are scattered across various legal provisions related to the environment, coastal zone management, marine affairs, and natural resource conservation (Yustisiabel et al., 2025) This situation indicates that seagrass protection remains fragmented and has not yet been given a comprehensive legal framework as a coastal ecosystem with strategic ecological functions. Constitutionally, environmental protection—including that of coastal ecosystems—is grounded in the 1945 Constitution of the Republic of Indonesia.

Pasal 28 H ayat (1) affirms that every person has the right to a good and healthy environment, while Pasal 33 ayat (3) and (4) mandate that the utilization of natural resources must be carried out for the greatest possible prosperity of the people, based on the principles of sustainability and environmental awareness. These provisions indicate that the state has a constitutional obligation to protect all environmental ecosystems, including seagrass ecosystems as part of coastal and marine ecosystems. Regulations regarding environmental protection were subsequently strengthened through Law No. 32 of 2009. This law serves as the primary instrument of environmental law in Indonesia, governing various important principles, such as sustainability, precaution, participation, ecoregions, and local wisdom.

In the context of seagrass ecosystem conservation, the ecoregion principle is of significant relevance because it prioritizes the ecological characteristics of a region as the foundation for environmental management. Legal provisions are established through Law No. 27 of 2007, as amended by Law No. 1 of 2014. This regulation serves as the primary legal basis for the management of coastal areas and small islands in Indonesia. The law states that coastal area management is carried out to protect, conserve, rehabilitate, utilize, and enrich coastal resources in a sustainable manner. However, provisions regarding seagrass ecosystems in the law remain very limited. Regulatory attention is primarily directed toward the general management of coastal resources, while specific protection for seagrass beds has not yet been comprehensively formulated. Consequently, seagrass has not yet secured a strategic position in coastal conservation policies, unlike mangroves and coral reefs.

In the context of the conservation of biological resources, Minister of Marine Affairs and Fisheries Regulation (PERMEN KP) No. 16 of 2016 on procedures for the rehabilitation of coastal areas and small islands—which includes provisions on the protection of seagrass ecosystems—and Presidential Regulation No. 73 of 2012, which designates seagrass as a critical component of coastal ecosystem management. These regulations demonstrate the government's recognition of the importance of seagrass ecosystems, particularly in supporting fisheries productivity and marine environmental protection. However, their implementation at the local level remains suboptimal and has not been accompanied by the establishment of specific local regulations. Additionally, seagrass protection is increasingly linked to climate change and blue carbon issues within various environmental and marine policies. Seagrass ecosystems are considered to have a high capacity to absorb and store carbon, thereby playing a crucial role in climate

change mitigation. However, the integration of seagrass blue carbon functions into local regulatory systems and coastal zone management policies remains relatively weak.

The implication of the paradigm shift from resource exploitation toward ecological sustainability for coastal policies manifests in the reconstruction of legal instruments from extractive to restorative and preventive frameworks. Historically, exploitation-driven coastal policies focused heavily on the legality of fiscal catch quotas and spatial conversion for short-term economic gains, which routinely sacrificed seagrass meadows for port developments or aquaculture. Shifting toward ecological sustainability forces modern coastal policies to strictly adopt the precautionary principle and internalize environmental costs through ecological-economic instruments. In practice, this redefines the function of coastal zoning: seagrass meadows are no longer viewed as vacant underwater spaces, but as critical natural infrastructure that triggers a legal obligation for layered environmental impact assessments, alongside the full recognition of the rights of nature and the customary rights of the indigenous communities managing them.

3.2 Regulatory Framework for the Protection of Seagrass Ecosystems in the Aru Islands

The development of a regulatory framework for seagrass ecosystem protection in the Aru Islands must fundamentally be based on the ecological characteristics of the archipelago and the need for sustainable coastal environmental protection (Salma et al., 2025). To date, coastal management regulations in Indonesia have remained general, sectoral, and focused on the exploitation of marine resources, and thus have not been able to provide effective protection for seagrass ecosystems. Consequently, seagrass protection relies heavily on administrative policies that are not integrated with the local ecological conditions of island communities (Amone-mabuto et al., 2023).

From an ecological regulation perspective, a regulatory model for seagrass protection cannot rely solely on formal conservation approaches through national regulations (Strachan et al., 2022). Island regions such as the Aru Islands require an adaptive, participatory, and ecosystem-based regulatory model. This is because seagrass ecosystems in island regions are directly linked to the socioeconomic lives of coastal communities, particularly in the sectors of traditional fisheries, coastal protection, and the ecological resilience of marine areas.

From the perspective of ecological regulation, seagrass protection should be established through an integrated coastal ecosystem governance approach—a management model that integrates ecosystem protection, marine spatial planning, community participation, and coastal economic sustainability (Kusbiarsi et al., 2025). This approach views seagrass ecosystems as an integral part of the coastal ecological system that cannot be separated from mangroves, coral reefs, and the lives of island communities.

Thus, regulation serves not only to govern the use of marine space but also to maintain ecological connectivity among coastal ecosystems (Popova et al., 2019). Conceptually, the regulatory model for seagrass protection in the Aru Islands must be developed through an integrated ecological governance approach—that is, a

management system that integrates ecosystem protection, coastal zone management, community participation, and the sustainable use of marine resources.

The implication of an ecology-based regulatory model for sustainable development in island regions lies in its capacity to dismantle fragmented, sector-specific legal frameworks and replace them with integrated land-sea connectivity governance. In small island regions like the Aru Islands, environmental carrying capacities are highly constrained, and terrestrial and marine ecosystems are instantly interconnected; hence, destructive upstream land activities directly jeopardize downstream seagrass meadows. This regulatory model ensures that economic policies, terrestrial spatial planning, and marine zoning are no longer isolated but synchronized to preserve the ecological stability of seagrass beds as vital fisheries nurseries and blue carbon sinks. By securing this natural capital, an ecology-based legal framework not only prevents coastal biodiversity loss but also guarantees the long-term economic resilience of traditional fishers, operationalizing ecological justice within vulnerable small-island dynamics.

The Seagrass Ecosystem Protection Regulation Model in the Aru Islands can be explained as follows:

a. An Ecoregion-Based Regulatory Model for Archipelagic Areas

The first model that needs to be developed is an ecoregion-based regulatory framework (Alisa & Sohl, 2004). Under this approach, seagrass protection must be tailored to the ecological characteristics of the archipelagic regions in the Aru Islands. To date, national regulations have continued to employ a generalized regional approach that tends to treat coastal management in mainland and archipelagic areas as identical. In reality, island regions have a high dependence on marine ecosystems, significant ecological vulnerability, and limited environmental carrying capacity. According to (Gri et al., 2020), seagrass protection regulations must be based on: Local Ecological Conditions, Coastal Carrying Capacity, Ocean Current Patterns, Fish Spawning Grounds, and The Presence Of Coastal Indigenous Communities.

This approach aligns with the ecoregion principle in Law No. 32 of 2009, which establishes ecological characteristics as the foundation for environmental management.

b. An Ecology-Based Coastal Village Regulation Model

Another key finding is the need to strengthen regulations at the coastal village level (Handoko et al., 2023). In the context of the Aru Islands, village governments hold a strategic position because they are closest to the communities and coastal areas where seagrass ecosystems are located. Until now, environmental protection has largely been top-down and dependent on the central and regional governments. As a result, oversight of activities damaging seagrass beds has been weak. An ecology-based village regulation model can be implemented through: Village Regulations On Seagrass Protection, Zoning Of Coastal Protection Areas, Prohibitions On Activities Damaging Seagrass Beds, Community-Participatory Monitoring and Strengthening Of Customary-Based Social Sanctions.

This approach is important because local communities actually possess ecological knowledge regarding their marine areas. Thus, regulations are not merely legal-formal in nature but are also grounded in the ecological culture of coastal communities. From the perspective of modern environmental law, such a model is referred to as community-based ecological governance—that is, environmental governance that involves the community as the primary agents of environmental protection (Chalil, 2025).

c. Blue Carbon Governance Integration Model

Seagrass ecosystems play a strategic role as blue carbon sinks. However, to date, this function has not been optimally integrated into local coastal management policies (Huxham et al., 2018). Yet, recognizing seagrass as a blue carbon ecosystem can strengthen its legal standing within the environmental policy framework. Therefore, the regulatory model for seagrass protection in the Aru Islands needs to integrate the concept of blue carbon governance through: protection of coastal carbon storage areas, inventory of seagrass beds, control of activities that cause coastal carbon degradation, and integration of seagrass protection into regional climate change mitigation policies.

This analysis is important because, to date, coastal regulations have viewed seagrass primarily as part of marine habitats, rather than as a strategic ecological asset within global climate policy.

d. Integrated Coastal Management Model

The main weakness of current coastal management is the fragmentation of authority across sectors. Therefore, a regulatory model for seagrass protection must be developed through integrated coastal management, which brings together local governments, village governments, coastal communities, customary institutions, and environmental agencies. This model is necessary to address policy overlaps, weak oversight, conflicts over marine space utilization, and the exploitation of coastal resources (Bellanger et al., 2020). In this model, seagrass protection must be an integral part of: Marine Spatial Planning, Coastal Conservation Policies And Development Planning For Island Regions. Thus, regulations serve not only as administrative instruments but also as instruments of ecological sustainability.

e. Reconstructing the Coastal Regulation Paradigm

The most fundamental analysis of this regulatory model actually lies in the shift in the coastal environmental law paradigm. Until now, coastal regulations have been based on a resource exploitation paradigm, wherein the law is used to regulate the utilization of marine resources for economic interests (Basri, 2020; Wang, 2026). However, in the context of the ecological crisis and climate change, this paradigm is no longer adequate. Seagrass protection regulations must be established through the paradigm of ecological sustainability—that is, placing ecosystems at the center of protection, maintaining ecological balance, and ensuring the sustainability of the archipelago for future generations (Unsworth et al., 2019). Thus, the seagrass protection regulatory model in the Arubukan Islands is not merely the creation of new legal norms, but a reconstruction of

coastal environmental governance based on: Ecology, Sustainability, Community Participation and The Protection Of The Archipelagic Region.

This model is important because island regions have a high level of ecological vulnerability, thus requiring a more adaptive regulatory system compared to conventional coastal regulatory approaches, which have historically been centralized and exploitative (Li et al., 2024; Penghua et al., 2007; Qin et al., 2021)

4. Conclusions

This study shows that legal regulations for the protection of seagrass ecosystems in Indonesia remain fragmented and have not yet provided specific protection for seagrass ecosystems as a vital component of coastal areas. Existing regulations are still oriented toward sectoral and administrative approaches, and thus have not been able to integrate ecological principles into coastal zone management, particularly in archipelagic regions such as the Aru Islands. These shortcomings are evident in the fragmentation of authority, weak oversight of marine space utilization, low effectiveness of environmental law enforcement, and the suboptimal integration of the blue carbon concept into coastal policies. This study contributes to the development of environmental law, particularly through the concept of an ecological regulation model for the protection of seagrass ecosystems in archipelagic regions. The proposed model includes an ecoregion-based approach, strengthening of coastal village regulations, community participation, integrated coastal management, and the integration of blue carbon governance into coastal management. It is hoped that these contributions will serve as a conceptual foundation for the formulation of coastal ecosystem protection policies that are more adaptive, sustainable, and grounded in the ecological characteristics of island regions.

The implication of an ecology-based regulatory model for sustainable development in island regions lies in its capacity to dismantle fragmented, sector-specific legal frameworks and replace them with integrated land-sea connectivity governance. In small island regions like the Aru Islands, environmental carrying capacities are highly constrained, and terrestrial and marine ecosystems are instantly interconnected; hence, destructive upstream land activities directly jeopardize downstream seagrass meadows. This regulatory model ensures that economic policies, terrestrial spatial planning, and marine zoning are no longer isolated but synchronized to preserve the ecological stability of seagrass beds as vital fisheries nurseries and blue carbon sinks. By securing this natural capital, an ecology-based legal framework not only prevents coastal biodiversity loss but also guarantees the long-term economic resilience of traditional fishers, operationalizing ecological justice within vulnerable small-island dynamics.

To enrich the development of seagrass ecosystem protection regulations in Indonesia, further research should be directed toward two primary areas: comparative codification of customary marine law and the formulation of blue carbon regulatory instruments. First, macro-level comparative studies are needed to assess the effectiveness of diverse indigenous marine governance systems across Indonesia—such as Sasi in Maluku, Panglima Laot in Aceh, and Awig-Awig in Bali—to establish a standardized framework for integrating community-based law into national legislation. Second, given

the massive potential of seagrass meadows as carbon sinks, future legal research must explore the nuances of climate governance law, specifically regarding sub-tidal property rights within international carbon trade schemes. Interdisciplinary studies merging ecological economic valuation with local fiscal policy formulation are also urgently required to design institutional financial incentives for island regions that successfully preserve their seagrass ecosystems.

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