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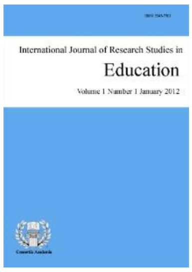

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Seagrass assessment on coastal barangays in San Antonio, Tinambac and San Ramon, Siruma Camarines Sur: An input to conservation mechanism policy

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Abstract

This study assessed the ecological status and physico-chemical conditions of seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. A quantitative research design using vegetation analysis was employed, wherein five line transects were established in each site and quadrat sampling was conducted to measure seagrass species diversity, relative dominance, relative density, and percent cover. Physico-chemical parameters, including temperature, salinity, pH, and dissolved oxygen (DO), were measured using calibrated equipment, while direct observation and opportunistic sampling documented associated marine organisms and potential bioindicators present within the seagrass beds. Results showed that Barangay San Antonio has very low seagrass diversity, dominated only by *Enhalus acoroides* (EA), and exhibited highly acidic pH levels and elevated temperatures, indicating ecological stress and unfavorable environmental conditions for seagrass growth and associated marine life. In contrast, Barangay San Ramon supported multiple seagrass species, stable water quality, and abundant biological components, including corals, macroalgae, fish, mollusks, and seahorses, reflecting a healthier and more resilient marine habitat. The comparison revealed significant differences between the two areas, highlighting the influence of physico-chemical conditions on seagrass ecosystem integrity and emphasized the importance of site-specific management approaches. Based on these findings, policy recommendations were proposed focusing on rehabilitation for San Antonio and conservation and monitoring for San Ramon.

Keywords: seagrass, species diversity, ecological status, physico-chemical parameters, bio-indicators, water quality, seagrass cover

Seagrass assessment on coastal barangays in San Antonio, Tinambac and San Ramon, Siruma Camarines Sur: An input to conservation mechanism policy

1. Introduction

Seagrasses are among the most important yet often overlooked coastal marine ecosystems in the world. These marine flowering plants play significant ecological, biological, and environmental roles in maintaining the productivity and stability of coastal waters. According to Zulkifli et al. (2021), seagrasses influence the physical, chemical, and biological processes of marine ecosystems by regulating nutrient cycling, stabilizing sediments, and improving water quality. They also provide critical habitat for many marine organisms and contribute greatly to biodiversity, food security, and climate regulation (Unsworth et al., 2022). As the only group of flowering plants capable of living entirely in marine environments, seagrasses occur across tropical, temperate, and sub-arctic coastal regions around the world (Zhang et al., 2023). Their ability to thrive in shallow marine habitats allows them to support highly productive ecosystems that serve as nursery grounds, feeding areas, and shelter for numerous marine species.

Seagrass beds are widely recognized as one of the most productive ecosystems on Earth because of their ability to support complex food webs and sustain marine biodiversity. These ecosystems provide habitat for commercially and ecologically important species such as fish, prawns, mollusks, sea turtles, dugongs, manatees, scallops, shrimps, and seahorses (Short et al., 2016). Many juvenile fish species depend on seagrass meadows during their early stages of development because the dense vegetation provides protection from predators and abundant food sources. In addition, seagrasses function as primary producers that contribute significantly to marine food chains and nutrient cycling processes. Through photosynthesis, seagrasses produce oxygen and organic matter that support surrounding marine organisms and adjacent ecosystems such as mangroves and coral reefs (McHenry et al., 2021). These ecological functions emphasize the importance of seagrass ecosystems in maintaining coastal productivity and environmental balance.

Globally, the distribution of seagrass ecosystems covers a wide range of coastal marine environments. McKenzie et al. (2020) estimated that seagrass ecosystems occupy approximately 160,387 square kilometers worldwide, with the tropical Indo-Pacific region having the largest known distribution. According to Widhah (2025), there are around 72 recognized seagrass species distributed across 159 countries and six continents, supporting more than one billion people living near seagrass habitats. Southeast Asia is considered one of the regions with the richest seagrass diversity and distribution due to its tropical marine conditions and extensive coastlines. Sudo et al. (2021) reported that seagrass ecosystems in Southeast Asia cover approximately 36,700 square kilometers. However, despite their ecological significance, seagrass habitats in the region continue to decline because of increasing anthropogenic pressures, habitat destruction, pollution, sedimentation, and climate-related disturbances.

In the Philippines, seagrass ecosystems are considered highly significant because the country possesses one of the highest seagrass diversities in the world. Lamit et al. (2017) reported that the Philippines contains 21 seagrass species belonging to nine genera and four families, representing approximately 29% of the world's seagrass species. These seagrass meadows support fisheries production, biodiversity conservation, coastal protection, and food security for many coastal communities. However, despite their ecological and economic importance, Philippine seagrass ecosystems continue to face increasing threats from coastal development, land reclamation, pollution, sedimentation, overfishing, and unregulated tourism activities (Abdulla, 2025). Fortes (2022) further explained that seagrass beds in the Philippines are declining at an estimated rate of 2.62% annually due to nutrient loading, industrial development, and sediment accumulation in coastal waters. Such threats negatively affect seagrass growth, productivity, and ecosystem stability, making conservation and monitoring efforts increasingly important.

The protection and conservation of seagrass ecosystems are supported by several environmental policies and conservation programs in the Philippines. Republic Act No. 8550, also known as the Philippine Fisheries Code of 1998, and its amended version under Republic Act No. 10654, mandate the protection, conservation, and management of coastal and marine ecosystems, including seagrass beds. Similarly, Republic Act No. 9275 or the Philippine Clean Water Act of 2004 aims to reduce water pollution and maintain water quality in coastal and marine environments, while Republic Act No. 9003 or the Ecological Solid Waste Management Act of 2000 addresses proper waste management practices that may help minimize land-based sources of pollution affecting marine habitats. Local government units also implement Coastal Resource Management (CRM) programs to strengthen environmental conservation and sustainable use of coastal resources. These programs are commonly supported by the Fisheries and Aquatic Resources Management Council (FARMC) and the Coastal Resource Management Office (CRMO), which assist in developing conservation strategies and promoting community participation in coastal management (Faustino & Madela, 2018).

In Camarines Sur, coastal municipalities such as Tinambac and Siruma possess extensive coastal areas that potentially support important seagrass ecosystems. In San Ramon, Siruma, conservation efforts are strengthened through local ordinances and environmental programs that support the sustainable management and protection of coastal resources. Castro et al. (2023) emphasized that local environmental policies and conservation initiatives are important in maintaining marine habitat stability and biodiversity. However, in some coastal areas such as Barangay San Antonio, Tinambac, limited localized policies and ecological information regarding seagrass ecosystems remain evident. Exeter et al. (2021) explained that insufficient ecological data often limits the effectiveness of environmental management strategies and conservation planning at the community level. In addition, Ward et al. (2022) highlighted that updated ecological and physicochemical information is necessary in designing science-based conservation programs and sustainable coastal management practices.

Although several studies have been conducted on seagrass ecosystems in the Philippines, limited research has focused specifically on the coastal barangays of Tinambac and Siruma, Camarines Sur. Existing studies commonly focus on mangrove ecosystems, fisheries, or general coastal resource utilization, leaving limited information regarding the ecological status and environmental conditions of seagrass habitats in these areas. Furthermore, many previous assessments concentrated mainly on species identification and distribution without integrating detailed analysis of physicochemical parameters that influence ecosystem stability and productivity. Sanchez-Delute et al. (2025) emphasized that environmental variables such as temperature, salinity, pH, and dissolved oxygen are important indicators of ecosystem health because they directly affect the growth, survival, and resilience of marine vegetation and associated organisms.

Considering the ecological importance of seagrass ecosystems and the increasing environmental pressures affecting coastal habitats, there is a need to strengthen ecological assessment and monitoring efforts in coastal communities. Comparative ecological studies between neighboring coastal areas are also important because differences in local management practices, environmental conditions, and conservation efforts may influence the condition of marine ecosystems. Understanding these ecological variations may help provide baseline information necessary for environmental planning, biodiversity conservation, coastal resource management, and sustainable policy development. Through proper assessment and continuous monitoring, seagrass ecosystems may be better protected and conserved for future generations while supporting the ecological stability and socioeconomic well-being of coastal communities.

1.1 Objectives of the Study

The main objective of this study was to assess the ecological status and physico-chemical condition of the seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur as basis for developing conservation mechanism policies. Specifically, the study aimed to determine the ecological status of the two study sites in terms of seagrass cover, relative density, relative dominance, and species diversity. It also aimed to assess the physico-chemical condition of the sites based on salinity, temperature, water pH, and dissolved oxygen. Furthermore, the study intended to compare the ecological status and physico-chemical condition of the two areas, identify possible bio-indicators present within the seagrass meadows, and formulate policy recommendations based on the findings of the study.

1.2 Significance of the Study

This study is important because it provides baseline information regarding the ecological status and physico-chemical condition of seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. The results of the study may contribute to a better understanding of the condition of seagrass meadows and the environmental factors affecting their growth and survival. The findings may benefit local government units by providing scientific data that can support the development of coastal conservation programs, environmental monitoring activities, and policy implementation. Environmental agencies such as the Department of Environment and Natural Resources and Bureau of Fisheries and Aquatic Resources may also use the results as reference for future marine resource management and habitat protection initiatives. For coastal communities, the study may increase awareness regarding the ecological importance of seagrass ecosystems and encourage participation in conservation activities. The research may also help students, researchers, and future scientists by serving as a reference for studies related to marine ecology, biodiversity, and coastal ecosystem management. Most importantly, the study may contribute to the protection and sustainability of seagrass ecosystems by identifying environmental issues affecting the study sites and recommending appropriate conservation mechanisms based on scientific findings.

1.3 Scope and Limitations of the Study

This study focused on assessing the ecological status and physicochemical condition of seagrass ecosystems located in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. Specifically, the study concentrated on evaluating seagrass cover, relative density, relative dominance, species diversity, temperature, salinity, water pH, and dissolved oxygen within the identified seagrass beds of the two selected coastal barangays. The research was limited only to the selected study sites and focused solely on seagrass ecosystems, excluding other coastal ecosystems such as mangrove forests and coral reef communities. The study was also limited to field observations, ecological assessment, and physicochemical measurements conducted during the sampling period. Furthermore, the research did not include historical analysis of seagrass distribution, seasonal variation monitoring, GIS-based spatial mapping, or detailed assessment of anthropogenic activities and socioeconomic factors affecting the coastal environment. The findings of the study were based only on the actual data gathered during the conduct of the research in the selected coastal areas of Tinambac and Siruma, Camarines Sur.

1.4 Theoretical Framework

This study was anchored on several ecological theories that explain the relationship between environmental conditions and ecosystem functioning. The primary foundation of the study was Eugene Odum's Ecosystem Theory (1969), which explains that ecosystems are composed of interacting biotic and abiotic components that influence ecological balance and productivity. This theory supports the idea that physicochemical parameters such as temperature, salinity, pH, and dissolved oxygen directly affect seagrass growth, distribution, and survival. The study was also supported by the Biodiversity and Ecosystem Functioning (BEF) Theory of Loreau et al. (2001), which states that ecosystems with higher biodiversity tend to be more stable, productive, and resilient to environmental stress. In addition, the Indicator Species Theory of Carignan and Villard (2002) explain that certain species can serve as bio-indicators that reflect the environmental condition and health of ecosystems. Lastly, the Ecosystem Services Theory of Costanza et al. (1997) emphasizes the ecological and socioeconomic importance of ecosystems by highlighting their roles in providing food, coastal protection, carbon sequestration, nutrient cycling, and habitat support. These theories collectively provided the conceptual foundation for assessing the ecological condition, biodiversity, physicochemical parameters, and conservation importance of seagrass ecosystems in the study areas.

2. Methodology

This study utilized a quantitative research design to assess the ecological status and physicochemical condition of seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. Vegetation analysis was employed to quantify seagrass cover, relative density, relative dominance, and species diversity, while physicochemical analysis was conducted to measure temperature, salinity, water pH, and dissolved oxygen. The study involved field surveys, direct observation, line transect methods, quadrat sampling, and opportunistic sampling to identify possible bio-indicators within the study areas. The selected study sites are coastal barangays located near San Miguel Bay and are characterized by shallow coastal waters, muddy to sandy substrates, and visible seagrass meadows that support various marine organisms and local fishing activities. Five transect lines with 20-meter intervals were established perpendicular to the shoreline during low tide, and sampling points were marked every five meters along each transect. A 0.5 m × 0.5 m quadrat was placed at every sampling point to assess and record seagrass species and percent cover. Species identification was based on the Field Guide on Seagrass by Mendez (2022), and samples were photographed using Geo Camera for documentation. Water quality parameters were measured on-site using calibrated probes and dissolved oxygen meters to ensure accurate readings. Statistical treatments such as dominance, relative dominance, population density, relative density, Shannon-Weiner Diversity Index, Simpson's Biodiversity Index, mean, standard deviation, and range were utilized to analyze and interpret the collected data comprehensively.

3. Results and Discussion

This section presents the results gathered from the ecological assessment and physicochemical analysis conducted in the seagrass ecosystems of Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. The discussion is organized according to the objectives of the study and includes the ecological status of the seagrass beds, physicochemical conditions of the study sites, comparison between the two areas, possible bio-indicators observed during sampling, and policy recommendations based on the findings of the study.

3.1 Ecological status of seagrass beds in San Antonio, Tinambac and San Ramon, Siruma Camarines Sur along: a. seagrass cover, b. relative density, c. relative dominance, and d. species diversity

The ecological status of the seagrass beds in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma was assessed through the analysis of seagrass cover, relative density, relative dominance, and species diversity. These ecological parameters were used to determine the condition, composition, and distribution of seagrass species present in the study areas and to evaluate the overall health and stability of the seagrass ecosystems.

3.1.1 Seagrass Cover

The percent cover assessment in Barangay San Antonio revealed that Enhalus acoroides (Figure 1) was the only recorded seagrass species in the area and exhibited generally low percent cover across all transects, ranging from 1% to 14% (Table 1). Transect 3 recorded the highest cover at 14%, while Transect 4 showed the lowest cover at only 1%, indicating uneven distribution and sparse vegetation within the meadow. The low seagrass cover observed in San Antonio may suggest environmental stress conditions that limit seagrass growth and expansion. According to Christianen et al. (2019), large-bladed species such as E. acoroides are highly affected by poor water clarity and sedimentation because their slower growth rates reduce their capacity to recover under stressful environmental conditions. Bertelli and Unsworth (2021) also explained that meadows dominated by a single large species often exhibit lower overall cover because these species invest more energy in structural strength rather than rapid horizontal spreading.

In contrast, Barangay San Ramon, Siruma exhibited relatively higher seagrass cover across all transects, with values ranging from 25.97% to 36.72%. Specifically, Transect 1 recorded 31%, Transect 2 had 30.55%, Transect

3 showed 26%, Transect 4 had 25.97%, and Transect 5 recorded the highest cover at 36.72%. These findings indicate that seagrass beds in San Ramon are more extensive and better distributed compared to those in San Antonio, although the meadow still appeared patchy rather than continuously dense. The relatively higher seagrass cover in San Ramon suggests that the site provides more suitable environmental conditions for seagrass growth and survival.

Table 1

Seagrass Cover in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

San Antonio, Tinambac		San Ramon, Siruma
Transect No.	Seagrass Cover (%)	Seagrass Cover (%)
1	6%	31%
2	7%	30.55%
3	14%	26%
4	1%	25.97%
5	3%	36.72%

Legend: 0 – 10% - Very Low Cover (Poor Condition), 11 – 25% - Low Cover (Fair Condition), 25 – 50% - Moderate Cover (Good Condition), 51 – 75% - High Cover (Very Good Condition), and 76 – 100% - Very High Cover (Excellent Condition)

Species-specific observations in San Ramon further supported the healthier condition of the meadow. Cymodocea rotundata (Figure 2) consistently exhibited high cover values ranging from 43% to 72%, making it the dominant contributor to the meadow structure. According to Phang et al. (2019), C. rotundata commonly thrives in sandy substrates and moderate wave conditions, allowing it to maintain stable and extensive cover in tropical coastal ecosystems. Other species such as Halodule uninervis (Figure 3) and Halophila ovalis (Figure 4) also recorded moderate cover values ranging from 17% to 48% and 21% to 43%, respectively, indicating their ability to coexist within the meadow and occupy available substrate spaces. Yaakub et al. (2020) explained that these fast-growing species commonly expand in areas experiencing periodic environmental disturbances. In addition, Thalassia hemprichii (Figure 5) and Cymodocea serrulata (Figure 6) were also observed in several transects, while Syringodium isoetifolium (Figure 7) was sighted outside the quadrats, suggesting a more diverse seagrass community in the area. Ruiz-Frau et al. (2019) noted that S. isoetifolium commonly occurs in slightly deeper and more stable substrates, supporting the observed habitat conditions in San Ramon.

Figure 1. Enhalus acoroides (EA)

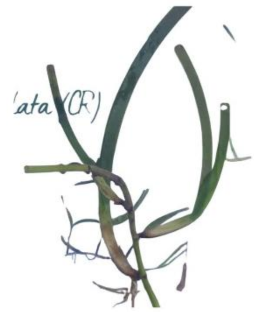

Figure 2. Cymodocea rotundata CR)

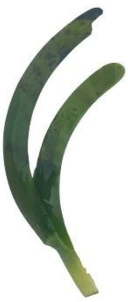

Figure 3. Thalassia hemprichii (TH)

Figure 4. Halodule uninervis (HU)

Figure 5. Halophila ovalis (HO)

Figure 6. Cymodocea serrulata (CR)

Figure 7. Syringodium isoetifolium (HU)

3.1.2 Relative Density

The results in Barangay San Antonio revealed that *Enhalus acoroides* (EA) recorded 100% relative density across all transects (Table 2), indicating that it was the only seagrass species present in the entire study area. Although the total density values varied from 1.14 to 13.75 individuals per m², all recorded individuals belonged solely to *E. acoroides*. The complete dominance of a single species suggests a monospecific seagrass meadow where environmental conditions favor the survival and persistence of *E. acoroides*. According to Lefcheck et al. (2018), *E. acoroides* possesses extensive rhizome networks and large leaf structures that enable it to survive in soft sediment environments with moderate turbidity and unstable substrates. Similar findings by McKenzie et al. (2019) showed that *E. acoroides* commonly dominates shallow coastal habitats exposed to sediment disturbance and reduced water clarity.

Table 2

Relative Density of Seagrass Beds in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

San Antonio, Tinambac			San Ramon, Siruma	
Transect No.	Relative Density (%)		Relative Density (%)	
1	EA	100%	CR	56%
			TH	0%
			HU	20%
			HO	12%
			CS	13%
2	EA	100%	CR	57%
			TH	0%
			HU	19%
			HO	24%
			CS	0%
3	EA	100%	CR	30%
			TH	20%
			HU	33%
			HO	16%
			CS	0%

4	EA	100%	CR	33%
			TH	15%
			HU	21%
			HO	31%
			CS	0%
5	EA	100%	CR	48%
			TH	9%
			HU	19%
			HO	24%
			CS	0%

Legend:
CR – *Cymodocea rotundata*
TH – *Thalassia hemprichii*
HU – *Halodule uninervis*
HO – *Halophila ovalis*
CS – *Cymodocea serrulata*
EA – Enhalus acoroides

Interpretation:
0% - Absent
1 – 25% - Low Density
26 – 50% - Moderate Density
51 – 75% - High Density
76 – 100% - Very High Density

In contrast, Barangay San Ramon, Siruma exhibited a more diverse seagrass community composed of *Cymodocea rotundata* (CR), *Thalassia hemprichii* (TH), *Halodule uninervis* (HU), *Halophila ovalis* (HO), and *Cymodocea serrulata* (CS). Among these species, *Cymodocea rotundata* consistently recorded the highest relative density values ranging from approximately 30% to 57% across the transects, indicating that it was the dominant species within the meadow. According to Aoki and McGlathery (2018), *C. rotundata* commonly thrives in sandy substrates with moderate hydrodynamic conditions and sufficient light penetration, allowing it to establish rapidly through clonal rhizome growth. Other species such as *Halodule uninervis* and *Halophila ovalis* also exhibited notable relative density values ranging from 12% to 33%, suggesting that the environmental conditions in San Ramon support the coexistence of multiple fast-growing seagrass species. Roca et al. (2016) noted that these opportunistic species usually flourish in habitats with stable substrates, favorable nutrient availability, and good water quality.

3.1.3 Relative Dominance

The results from Barangay San Antonio, Tinambac showed that *Enhalus acoroides* (EA) recorded 100% relative dominance in all five transects (Table 3). This indicates that *E. acoroides* was the only seagrass species occupying the sampled quadrats, forming a completely monospecific meadow throughout the study area. No other seagrass species were observed within the established transects. Such dominance reflects the ability of *E. acoroides* to survive under the existing environmental conditions in the area. According to Short and Coles (2002), *E. acoroides* is a large and robust species with long leaves and extensive rhizomes that enable it to tolerate shallow coastal environments with moderate disturbances and unstable substrates.

Table 3
Relative Dominance of Seagrass Beds in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

San Antonio, Tinambac			San Ramon, Siruma	
Transect No.	Relative Dominance (%)		Relative Dominance (%)	
1	EA	100%	CR	81.48%
			TH	0%
			HU	10.39%
			HO	3.74%
			CS	4.39%
2	EA	100%	CR	77.62%
			TH	0%
			HU	8.62%
			HO	13.76%
			CS	0%
3	EA	100%	CR	34.03%
			TH	15.12%
			HU	41.17%
			HO	9.68%
			CS	0%

4	EA	100%	CR	47.89%
			TH	9.89%
			HU	19.38%
			HO	42.24%
			CS	0%
5	EA	100%	CR	71.09%
			TH	2.5%
			HU	11%
			HO	14%
			CS	0%

Legend:
CR – *Cymodocea rotundata*
TH – *Thalassia hemprichii*
HU – *Halodule uninervis*
HO – *Halophila ovalis*
CS – *Cymodocea serrulata*
EA – Enhalus acoroides

Interpretation:
0% - No Dominance
1 – 25% - Low Dominance
26 – 50% - Moderate Dominance
51 – 75% - High Dominance
76 – 100% - Very High Dominance

In contrast, Barangay San Ramon, Siruma exhibited a more diverse and structurally balanced seagrass community. Results showed that *Cymodocea rotundata* (CR) had the highest relative dominance across most transects, ranging from 34.03% to 81.48% (Table 3). Other species such as *Halodule uninervis* (HU), *Halophila ovalis* (HO), *Thalassia hemprichii* (TH), and *Cymodocea serrulata* (CS) also contributed to the meadow structure. The dominance of *C. rotundata* agrees with findings of Aoki and McGlathery (2018), who explained that this species commonly dominates sandy tropical substrates with favorable light conditions and moderate hydrodynamic activity. The coexistence of several species within the meadow suggests that San Ramon provides more suitable environmental conditions that support species interactions, habitat complexity, and ecological stability.

3.1.4 Species Diversity

The results in Barangay San Antonio, Tinambac revealed extremely low species diversity. The Shannon-Wiener Diversity Index recorded a value of 0 across all transects (Table 4), indicating the absence of species variation within the study area. All quadrats contained only one seagrass species, *Enhalus acoroides* (EA), which completely dominated the meadow. Similarly, the Simpson's Reciprocal Index recorded a value of D = 1 in all transects, further confirming complete dominance by a single species. According to Reynolds et al. (2013), *E. acoroides* commonly dominates shallow and disturbed coastal habitats because of its strong rhizome system and tolerance to unstable environmental conditions. However, Unsworth et al. (2018) explained that monospecific meadows generally have lower ecological resilience because ecosystem functions depend heavily on one species alone, making them more vulnerable to environmental disturbances and habitat degradation.

In contrast, Barangay San Ramon, Siruma showed higher species diversity and a more complex seagrass community structure. The Shannon-Wiener Diversity Index values ranged from 0.82 to 1.50, indicating low to moderate diversity across the transects. Five seagrass species were identified in the area, namely *Cymodocea rotundata* (CR), *Thalassia hemprichii* (TH), *Halodule uninervis* (HU), *Halophila ovalis* (HO), *and Cymodocea serrulata* (CS). Among these species, *Cymodocea rotundata* consistently recorded the highest relative abundance, followed by *Halodule uninervis* and *Halophila ovalis*. The Simpson's Reciprocal Index values ranged from 0.29 to 3.72, with Transects 3, 4, and 5 recording the highest values, indicating more balanced species distribution and greater ecological stability within those parts of the meadow. According to Roswell et al. (2021), Shannon-Wiener values between 1.0 and 3.0 generally indicate moderate species diversity and a relatively stable ecosystem. Mixed-species meadows are considered more resilient because different species contribute complementary ecological roles that improve ecosystem functioning and resistance to disturbances (Cardinale et al., 2012).

The findings of this study support the Biodiversity and Ecosystem Functioning Theory of Loreau et al. (2001), which explains that ecosystems with higher biodiversity tend to have greater productivity, stability, and resilience. The higher diversity observed in San Ramon suggests a healthier and more ecologically balanced seagrass ecosystem capable of supporting diverse marine organisms and maintaining ecosystem functions. On the other hand, the monospecific condition observed in San Antonio reflects limited ecological interactions and reduced ecosystem resilience. Therefore, the results indicate that species diversity plays a significant role in maintaining the ecological stability and overall condition of seagrass ecosystems in coastal environments.

Table 4

Seagrass Species Diversity in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

Shannon-Wiener Diversity Index Transect No.	San Antonio, Tinambac	San Ramon, Siruma
1	0	1.5
2	0	0.82
3	0	1.32
4	0	1.23
5	0	1.23
Simpson's Reciprocal Index Transect No.		
1	1	0.29
2	1	2.04
3	1	3.72
4	1	3.69
5	1	3.01

Legend: Shannon-Wiener Diversity Index (H'), H' < 1.0 – No/Low Diversity (Poor Condition), H' = 1.0 – 3.0 - Moderate Diversity (Good Condition), H' > 3.0 - High Diversity (Very Good Condition), Simpson's Reciprocal Index, Ranges from 1 – *S* (maximum value): Higher is more diverse.

3.2 Physico-chemical condition of the study sites along: a. temperature, b. salinity, c. water pH, and d. dissolved oxygen

Physico-chemical parameters are essential in maintaining the health, stability, and distribution of seagrass ecosystems because factors such as temperature, salinity, dissolved oxygen (DO), and pH directly influence photosynthesis, respiration, nutrient absorption, and overall seagrass productivity. Variations in these environmental conditions may affect species composition, seagrass cover, and ecosystem stability (Costa et al., 2021). This concept aligns with Eugene Odum's Ecosystem Theory (1969), which explains that ecosystems function through the continuous interaction of biotic and abiotic components, where environmental conditions strongly influence the survival and distribution of organisms. The Physicochemical Parameters of the two study areas: San Antonio, Tinambac and San Ramon, Siruma are shown in Table 5.

Table 5

Physicochemical Parameters in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

Physicochemical Parameters	San Antonio, Tinambac (Mean)	San Ramon, Siruma (Mean)
Temperature	33.67°C	31.33°C
Salinity	30ppt	29ppt
Water pH	3.95	8.42
Dissolved Oxygen (DO)	7.50mg/L	8.9mg/L

Legend:

Temperature
10°C – 26°C - Optimal (Temperate)
23°C – 32°C – Optimal (Subtropical/Tropical)
30°C – 35°C - Thermal Stress/Limit

Salinity
20 – 35 ppt - Optimal/Healthy
10 – 35 ppt - Tolerant/Stable
>40 ppt - Hypersaline (Stressed)

Water pH
> 8.2 - High alkalinity
8.0 – 8.2 - Typically Healthy
7.8 – 8.0 - Normal
7.5 – 7.8 - Low pH
< 7.5 - Critically Acidic

Dissolved Oxygen (DO)
> 7.0 mg/L - Excellent/Healthy
5.0 – 7.0mg/L - Good
3.0 – 5.0 mg/L - Moderate
1.0 – 3.0 mg/L - Low/Hypoxic
< 1.0 mg/L – Very Low/Severe
0 mg/L – Anoxic (No DO)

3.2.1 Temperature

Water temperature is an important physico-chemical parameter that influences seagrass growth, metabolism, and survival because it directly affects photosynthesis and respiration (Jorda et al., 2017). Barangay San Antonio, Tinambac recorded higher temperature values of 32°C, 34°C, and 35°C, with a mean of 33.67°C, while Barangay San Ramon, Siruma recorded lower and more stable temperatures of 30°C, 32°C, and 32°C, with a mean of 31.33°C. The relatively higher temperature in San Antonio may indicate greater thermal stress, as studies have shown that prolonged exposure above 32°C can reduce seagrass productivity and photosynthetic efficiency (Beca-Carretero et al., 2020). This condition may explain the dominance of only *Enhalus acoroides* (EA) in the area, a species known for its tolerance to warmer environments. In contrast, the lower and more stable temperature in San Ramon may have provided more favorable conditions for the growth and coexistence of multiple species such as *Cymodocea rotundata* (CR), *Halodule uninervis* (HU), *Halophila ovalis* (HO), and *Thalassia hemprichii* (TH). Moderate temperatures between 28°C and 32°C are generally considered optimal for tropical seagrass development and ecosystem stability (Ruperez et al., 2019).

3.2.2 Salinity

Salinity is an important physico-chemical parameter that influences seagrass growth, nutrient absorption, and species distribution (Cambridge et al., 2017). Barangay San Antonio, Tinambac recorded consistent salinity values of 30 ppt across all sampling points, resulting in a mean of 30 ppt with no variation, indicating highly stable marine conditions favorable for *Enhalus acoroides* (EA), a species adapted to fully marine environments (Kiani et al., 2021). In contrast, Barangay San Ramon, Siruma recorded slight salinity variation of 27 ppt, 30 ppt, and 30 ppt, with a mean of 29 ppt. Although minimal fluctuations were observed, the values remain within the optimal range for tropical seagrass ecosystems. Studies suggest that moderate salinity variation may support higher species diversity by allowing species with different salinity tolerances to coexist (Ramesh et al., 2019). This may explain the presence of multiple seagrass species in San Ramon, compared to the monospecific meadow dominated by *Enhalus acoroides* in San Antonio.

3.2.3 Water pH

Water pH is an important physico-chemical parameter that affects nutrient availability, photosynthesis, and the overall physiological functioning of seagrass species (Song et al., 2025). Barangay San Antonio, Tinambac recorded highly acidic pH values of 4.3, 4.01, and 3.55, resulting in a mean pH of 3.95, which is far below the normal seawater range of 7.5–8.4. Such acidic conditions may impair photosynthesis and nutrient absorption, limiting the survival of sensitive seagrass species (Jiang et al., 2020). This condition may explain why only *Enhalus acoroides* (EA), a stress-tolerant species, was observed in the area. In contrast, Barangay San Ramon, Siruma recorded stable and slightly alkaline pH values of 8.53, 8.55, and 8.3, with a mean of 8.42, which falls within the optimal range for marine ecosystems and seagrass growth (Santos et al., 2019). The stable alkaline condition in San Ramon may have contributed to the presence of multiple seagrass species, indicating a healthier and more suitable marine environment compared to San Antonio.

3.2.4 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is an important physico-chemical parameter that supports respiration, photosynthesis, and other ecological processes in marine ecosystems (Tu et al., 2025). Barangay San Antonio, Tinambac recorded DO values of 8 mg/L, 8.2 mg/L, and 6.3 mg/L, with a mean of 7.50 mg/L, indicating generally suitable oxygen conditions for seagrass survival. However, fluctuations in DO may affect root and rhizome respiration, particularly in shallow and disturbed environments (Brodersen et al., 2018), which may explain the dominance of only *Enhalus acoroides* (EA) in the area. In contrast, Barangay San Ramon, Siruma recorded higher DO values of 5.7 mg/L, 10.5 mg/L, and 10.5 mg/L, with a mean of 8.9 mg/L, suggesting stronger photosynthetic activity and better oxygen production commonly associated with productive seagrass meadows (Koch et al., 2021). The higher dissolved oxygen condition in San Ramon may have supported the presence of multiple seagrass, indicating a healthier and more stable seagrass ecosystem compared to San Antonio.

3.3 Difference between the two study sites in terms of ecological status and physicochemical condition

The findings revealed clear differences between the ecological status of the seagrass meadows in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma. San Antonio exhibited a monospecific meadow dominated entirely by *Enhalus acoroides* (EA), with 100% relative density and relative dominance across all transects, indicating low species diversity and poor seagrass condition. In contrast, San Ramon showed a more diverse and stable seagrass ecosystem, with the presence of *Cymodocea rotundata* (CR), *Halodule uninervis* (HU), *Halophila ovalis* (HO), *Thalassia hemprichii* (TH), *Cymodocea serrulata* (CS) and the observed occurrence of *Syringodium isoetifolium* (SI). The meadow in San Ramon also exhibited higher percent cover and more balanced dominance patterns, with *Cymodocea rotundata* identified as the dominant species. Diverse seagrass meadows are commonly associated with healthier coastal ecosystems because they provide greater ecological stability, productivity, and resistance to disturbance (de los Santos et al., 2019).

The physico-chemical conditions of the two study sites also showed notable differences that may explain the variation in ecological status. San Antonio recorded more stressful environmental conditions, particularly its highly acidic pH ranging from 3.55–4.3 (mean = 3.95), which is far below the normal seawater pH range and may negatively affect photosynthesis, nutrient absorption, and seagrass productivity (Raven et al., 2020). The site also recorded higher temperatures ranging from 32°C–35°C (mean = 33.67°C), which may induce thermal stress and reduce seagrass growth (Kletou et al., 2021). Although salinity remained stable at 30 ppt and dissolved oxygen averaged 7.5 mg/L, these conditions may only favor stress-tolerant species such as Enhalus acoroides. In contrast, San Ramon exhibited more favorable environmental conditions, including stable alkaline pH values of 8.3–8.53 (mean = 8.42), lower temperatures of 30°C–32°C (mean = 31.33°C), slightly variable salinity of 27–30 ppt, and higher dissolved oxygen levels averaging 8.9 mg/L. These conditions are considered suitable for tropical seagrass growth and may support higher species diversity and meadow stability.

The differences observed between the two study sites support the Ecosystem Services Theory of Costanza et al. (1997), which explains that healthier ecosystems are more capable of providing essential ecological services such as habitat provision, nutrient cycling, water quality regulation, and coastal protection. The higher species diversity, better water quality, and more stable environmental conditions observed in San Ramon suggest a healthier and more functional seagrass ecosystem capable of sustaining greater ecological productivity and resilience. In contrast, the lower diversity and more stressful environmental conditions in San Antonio may reduce the ecosystem's ability to maintain ecological balance and provide ecosystem services effectively.

3.4 Possible bio-indicators in the two study sites

The biological components observed in the two study sites served as possible bio-indicators of the ecological condition of the seagrass ecosystems. In Barangay San Antonio, Tinambac, the organisms observed were mainly green algae, seaweeds, and Padina sp., with green algae recording the highest frequency of 10 occurrences, followed by seaweeds with 9 occurrences and Padina sp. with 3 occurrences (Table 6). Several quadrats in Transect 1 also showed no observed organisms, indicating low biological presence within portions of the meadow. In contrast, Barangay San Ramon, Siruma exhibited higher biological diversity, with the presence of mollusks, fish, corals, green algae, Padina sp., Sargassum, and seahorses. Mollusks recorded the highest frequency with 16 occurrences, followed by Padina sp. and green algae with 11 occurrences each, fish with 8 occurrences, Sargassum with 4 occurrences, and corals and seahorses with 2 occurrences each.

The greater diversity of organisms observed in San Ramon suggests a healthier and more stable seagrass ecosystem compared to San Antonio. The presence of mollusks indicates good sediment quality and oxygenation because these organisms are sensitive to pollution and excessive siltation (Oehlmann & Oehlmann, 2003). Fish and seahorses are also important ecological indicators because they depend on seagrass beds for shelter, feeding, and nursery habitats, reflecting functional and productive ecosystems (Unsworth et al., 2018). The occurrence of corals further supports the suitability of the physico-chemical conditions in San Ramon, particularly its stable alkaline pH and higher dissolved oxygen levels. In contrast, the dominance of algae and seaweeds in San Antonio may indicate a simpler ecosystem structure and possible environmental stress. Although algae and seaweeds contribute to primary productivity, excessive dominance of these organisms may also suggest nutrient enrichment or reduced habitat complexity (D'Archino & Piazzi, 2021).

Table 6
Biological Components in San Antonio, Tinambac and San Ramon, Siruma Camarine Sur

Transect No.	San Antonio, Tinambac	San Ramon, Siruma
1	None	Mollusk, Padina sp., and Green Algae
2	Seaweeds and Green Algae	Green Algae, Fish, Mollusk, and Corals
3	Seaweeds and Green Algae	Fish, Padina sp., Sargassum, Seahorse, and Mollusk
4	Padina and Green Algae	Seahorse, Mollusk, Sargassum, Padina sp., and Fish
5	Green Algae and Seaweeds	Green Algae, Mollusk, Padina sp., Fish, and Corals

The findings support the Indicator Species Theory of Carignan and Villard (2002), which explains that the presence or absence of certain organisms reflects the ecological condition of an environment. The higher diversity and occurrence of sensitive organisms such as fish, mollusks, corals, and seahorses in San Ramon indicate a more balanced and ecologically stable habitat. Meanwhile, the limited biological diversity observed in San Antonio suggests less favorable environmental conditions that may only support more tolerant organisms such as algae and seaweeds.

3.4 Policy recommendations based on the study results

The researchers aim to propose policy recommendations that promote the protection, conservation, and sustainable management of seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma. These recommendations include strengthening environmental policies, enhancing community awareness and participation, encouraging regular monitoring of seagrass meadows, and implementing coastal management strategies that help maintain water quality, biodiversity, and overall ecosystem health.

3.5.1 Policy Recommendations for San Antonio, Tinambac, Camarines Sur

The researchers recommend strengthening community-based coastal monitoring through regular assessment of water quality parameters and seagrass cover in coordination with the LGU, BFAR, DENR-CENRO, and trained community volunteers. Water quality improvement and pollution control measures should also be implemented by identifying possible sources of acidification such as improper waste disposal, runoff, and shoreline contamination, while promoting proper waste management and vegetative buffer zones. In addition, seagrass rehabilitation zones should be established in areas with critically low seagrass cover and minimal biological presence through transplantation and habitat restoration activities supported by local environmental agencies. Environmental awareness campaigns and educational programs should also be conducted within the barangay and schools to increase community participation in coastal conservation and promote sustainable coastal resource management practices.

3.5.2 Policy Recommendations for San Ramon, Siruma, Camarines Sur

The researchers recommend establishing marine habitat protection zones, particularly in areas with high biological diversity, to regulate destructive fishing practices, anchoring, and overharvesting of marine resources through the implementation of local ordinances and active monitoring by bantay-dagat personnel in coordination with the LGU, BFAR, and DENR. Sustainable eco-tourism activities such as guided seagrass tours and marine awareness programs may also be promoted to support local livelihoods while encouraging environmental conservation. In addition, citizen science and biodiversity documentation programs should be strengthened by encouraging residents, fisherfolks, and youth to record sightings of marine organisms using simple monitoring tools and community-based reporting systems. Regular monitoring of water quality parameters, seagrass cover, and habitat condition should likewise be continuously conducted to ensure early detection of environmental changes and maintain the ecological stability and resilience of the seagrass meadow.

4. Conclusions and Recommendations

This section presents the conclusions and recommendations based on the findings of the study. The conclusions summarize the significant results regarding the ecological status, physico-chemical condition, and possible bio-indicators observed in the seagrass ecosystems of Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. Meanwhile, the recommendations provide practical strategies and management actions for local government units, environmental agencies, community stakeholders, and future researchers to support the conservation, protection, and sustainable management of seagrass habitats.

4.1 Conclusion

The study revealed significant differences in the ecological status and physico-chemical conditions of the seagrass ecosystems in Barangay San Antonio, Tinambac and Barangay San Ramon, Siruma, Camarines Sur. Barangay San Ramon exhibited a healthier and more ecologically stable seagrass meadow characterized by higher seagrass cover, greater species diversity, balanced relative density and dominance, favorable water quality conditions, and the presence of diverse biological components such as fish, mollusks, corals, and seahorses. In contrast, Barangay San Antonio showed low seagrass cover, monospecific dominance of Enhalus acoroides (EA), very low species diversity, highly acidic pH conditions, and limited biological components, indicating environmental stress and reduced ecosystem complexity. The findings suggest that physico-chemical factors such as temperature, salinity, pH, and dissolved oxygen strongly influence the composition, distribution, and overall health of seagrass meadows. Furthermore, the observed biological components served as effective bio-indicators of ecosystem condition, confirming that San Ramon possesses a more productive and resilient coastal habitat compared to San Antonio. In conclusion, the study emphasizes the importance of continuous monitoring, habitat protection, and science-based management strategies to conserve and sustain seagrass ecosystems in both coastal barangays.

4.2 Recommendations

Seagrass ecosystems are among the most important coastal habitats because they provide ecological functions such as habitat provision, shoreline protection, nutrient cycling, and support for marine biodiversity and fisheries. Maintaining healthy and balanced seagrass meadows is essential for sustaining coastal productivity and environmental stability. Based on the findings of the study, the researchers recommend the following:

4.2.1 Policy Recommendations for San Antonio, Tinambac, Camarines Sur

- Strengthen Community-Based Coastal Monitoring – Establish a barangay-level monitoring program to regularly assess water pH, temperature, salinity, dissolved oxygen, and seagrass cover through coordinated efforts of the LGU, BFAR, DENR-CENRO, and community volunteers.
- Implement Water Quality Improvement and Pollution Control – Investigate possible sources of acidification and strengthen waste management, regulate shoreline dumping, and establish vegetative buffer zones to reduce pollutants entering coastal waters.
- Establish Seagrass Rehabilitation Zones – Designate degraded areas as rehabilitation zones and implement seagrass transplantation, habitat protection, and regular monitoring in coordination with the LGU, BFAR, and DENR.

- Conduct Environmental Awareness Campaigns – Organize information drives and coastal education programs to increase community awareness on the importance of seagrass ecosystems, water quality protection, and responsible coastal resource use.

4.2.2 Policy Recommendations for San Ramon, Siruma, Camarines Sur

- Establish Marine Habitat Protection Zones – Designate marine protected areas in ecologically important seagrass habitats to regulate destructive fishing, anchoring, and overharvesting of marine resources through local ordinances and community-based enforcement.
- Promote Sustainable Eco-Tourism Programs – Develop eco-friendly tourism activities such as guided snorkeling, seagrass meadow tours, and marine awareness programs to support conservation and sustainable livelihoods.
- Strengthen Citizen Science and Biodiversity Documentation – Encourage residents, fisherfolks, and youth to document marine organisms through simple monitoring tools and community-based biodiversity recording programs.
- Maintain Regular Water Quality and Habitat Monitoring – Conduct continuous monitoring of pH, salinity, dissolved oxygen, temperature, and seagrass cover to detect environmental changes and preserve the ecological stability of the seagrass ecosystem.

Implications for Schools and Educators. This study provides a local and science-based reference for environmental education by highlighting the ecological status, physico-chemical conditions, and biodiversity of seagrass ecosystems in coastal communities. The findings may help schools and educators integrate local marine conservation issues into science and environmental lessons, allowing students to better understand the importance of seagrass meadows in maintaining biodiversity, water quality, and coastal protection. The study may also encourage schools to conduct community-based environmental activities, field studies, and coastal awareness programs that promote ecological conservation and sustainable resource management.

Implications for Students. For students, the study strengthens environmental awareness and appreciation for the ecological importance of seagrass ecosystems. It helps learners understand how environmental factors such as temperature, salinity, pH, and dissolved oxygen influence marine biodiversity and ecosystem stability. In addition, the study enhances students' knowledge and skills in ecological assessment, field sampling, species identification, and environmental monitoring, while encouraging active participation in marine conservation and coastal protection efforts.

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