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Seagrass diversity assessment in Libmanan, Camarines Sur: A basis for conservation and management initiatives

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Abstract

The study employed a Quantitative-Descriptive Research Design to quantify, analyze, and describe the seagrass diversity in three selected Coastal barangays in the Municipality of Libmanan, Camarines Sur. The Research aimed to assess the seagrass species diversity and recommend conservation and management initiatives within the study area. The data was gathered using the transect Quadrat Method (Saito and Atobe Method, 1970), species density, cover, frequency, and diversity indices using the Shannon-Weiner diversity indices and Simpson's (1-D) indices. The result showed that seven (7) species were identified in Libmanan, Camarines Sur, one (1) in Barangay Caima, four (4) in Barangay Bahao, and six (6) in Barangay Salvacion. These species are *Enhalus acoroides* (Tape grass), *Halophila minor* (Dwarf seagrass), *Halophila ovalis* (Spoon grass), *Thalassia hemprichii* (Dugong grass), *Cymodocea serrulata, Syringodium isoetifolium*, and, in the opportunistic sampling, *Cymodocea rotundata. Syringodium isoetifolium* shows higher shoot density, while *Enhalus acoroides* has the highest species cover and frequency where identified in Barangay Salvacion. Barangay Salvacion exhibits a higher number of species but low diversity; Bahao has fewer species but shows higher diversity due to the even distribution of seagrass species. Barangay Caima shows no diversity, or only one species is present. The study reveals that this coastal habitat is at high risk and threatens both human and natural threats. These findings suggested that seagrass species may be declining, especially in Barangay Caima. Conservation and Management are significant to this valuable ecosystem. The study provides essential baseline data that can guide future conservation and management in the Municipality.

Keywords: seagrass, species, diverse, physicochemical, threats

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1. Introduction

Seagrasses, which are marine flowering plants, offer a wide range of benefits to ecosystems (Nordlund et al., 2018). Seagrass/algae meadows are rated the 3rd most valuable ecosystem globally (on a per-hectare basis), only preceded by estuaries and wetlands (Seagrass-Watch, 2025), and among the most productive coastal habitats, consistently providing essential goods and services to fishing communities in many seaside countries. From an ecological standpoint, seagrass beds have high primary productivity, supporting various diverse food chains and ecosystems, such as mangrove forests and coral reefs, which are considered ecotones (Reyes et al., 2023, as cited in Fortes, 2013).

Seagrasses are often called the "lungs of the sea" because one square meter can produce 10 liters of oxygen daily through photosynthesis. Their leaves absorb nutrients and slow water flow, capturing sand, dirt, and silt particles. The roots stabilize sediment, enhancing water clarity and quality, reducing erosion, and protecting coastlines from storms. Additionally, seagrasses improve water quality by absorbing nutrients from land runoff. In nutrient-poor areas, they support nutrient cycling by absorbing nutrients from the soil and releasing them into the water via their leaves, functioning as a nutrient pump (Smithsonian Ocean, 2025). Seagrass covers only 0.1% of the ocean floor yet supports thousands of species as habitat and food, ranging from fish and shellfish to threatened, endangered, and charismatic animals such as dugongs, seahorses, and sea turtles. Although occupying just 0.1% of the ocean floor, the meadows are highly effective carbon sinks, holding up to 18% of the world's oceanic carbon (United Nations Environmental Programme, 2020). Additionally, the Bureau of Fisheries and Aquatic Resources (BFAR) notes that seagrass and seaweed beds retard water currents, reduce sediment loads, benefit nearby coral reefs, provide wave protection to coastal areas, and stabilize the seabed, thereby mitigating coastal erosion.

Despite their importance, Seagrass meadows have been declining worldwide at a rate of about 110 km² annually since 1980, losing 29% of global seagrasses. This decline is driven by both global factors—like ocean warming, marine heatwaves, and sea level rise—and local issues such as coastal development, eutrophication, dredging, and disease. These losses have caused substantial ecological and socioeconomic consequences (Climate Champions et al., 2025). Additionally, recent studies have revealed an alarming annual loss rate of 7%—equivalent to losing a football field-sized area every 30 minutes. These vital marine habitats are among the least safeguarded coastal ecosystems, with only 26% of seagrass meadows located within marine protected areas (United Nations Environmental Programme, 2020). During the last decades, losses in seagrass meadows have been documented worldwide, especially in quiet and poorly flushed estuaries where nutrient loads are intense and frequent (Viana et al, 2020, as cited in Burkholder et al, 2007).

In the Philippines, known for its remarkable seagrass diversity, it ranks second globally with 13 species spread across approximately 22,000 square kilometers, based on remote sensing data (Reyes et al., 2023, as cited in McKenzie, 2007). Additionally, seven of these species are found in the Bicol peninsula, particularly in the provinces of Albay and Sorsogon (Detecio L.R., 2009 & Magayanes G.L., 2007; as cited by Cocal, n.d). Furthermore, an assessment in 2011 in Buenavista, Legazpi City, Sta. Cruz documented seagrass populations using the transect line method across three sampling sites, resulting in 146 seagrasses collected in the area, indicating their presence within the sampled habitats. A significant portion of the Philippines' coastal habitat faces a high risk of being lost over the next decade (Periarce, 2018, as cited in Fortes, 2004).

A new study, 'The Planetary Role of Seagrass Conservation' by Unsworth, R. et al. (2022) shows the importance of seagrass for achieving UN Sustainable Development Goals. A new study by Project Seagrass and Swansea University shows seagrass conservation supports 16 of 17 UN Sustainable Development Goals, including no poverty, zero hunger, good health, quality education, gender equality, clean water, affordable energy, decent work, reduced inequalities, sustainable cities, life below water/on land, responsible consumption, climate action, and partnerships. Seagrass meadows bolster sustainable fisheries, food security, water quality, fish nutrition, women's empowerment via restoration, green jobs, biodiversity, carbon sequestration, and coastal protection—making them essential for resilient coastal communities and climate mitigation.

Moreover, in the Philippines, several policies and ordinances aim to conserve and manage seagrass ecosystems. The Philippine Biodiversity Strategy and Action Plan (PBSAP) 2015-2028 seeks to achieve no net loss of seagrasses by 2028 through species assessments. Republic Act No. 11038, known as the Expanded NIPAS Act of 2018, mandates protection in marine protected areas covering over 6,900 hectares. Additionally, Republic Act 8550 (the Philippine Fisheries Code, amended by RA 10654) prohibits destructive fishing practices in seagrass beds and establishes Fishery Management Areas. Fisheries Administrative Order No. 250, 2014, bans seagrass harvesting except for research authorized by permits. Republic Act 7586 (the NIPAS Act) designates seagrass within protected areas, and Republic Act 7611 enforces zoning regulations through Palawan's ECAN, all coordinated under Executive Order 533 for integrated coastal management.

Despite these efforts, significant challenges persist, including limited funding, weak enforcement against illegal fishing, coastal development, and poor community involvement. These issues worsen threats like pollution, sedimentation, and climate change, which threaten ecosystem health. Further research on seagrass is vital to address data gaps on species diversity in remote areas, develop adaptive restoration methods, assess policy effectiveness, and guide local regulations for sustainable use. Furthermore, globally, there seems to be little knowledge by the public of seagrasses and the benefits they provide (Nordlund et al., 2018). The municipality of Libmanan, Camarines Sur, is strengthening its efforts to protect and conserve coastal marine resources amid the challenges posed by climate change, including rising temperatures, flooding, and drought, which affect local communities and neighboring areas. Additionally, the MLGU actively promotes the documentation of existing marine resources such as mangroves, corals, and seagrasses within their jurisdiction, particularly in the selected coastal Barangay of the Municipality of Libmanan, Camarines Sur, which is Barangay Caima, Salvacion, and Bahao. However, there have been few records of these ecosystems over the years, largely due to shifting priorities and leadership changes.

Significance of the Study - This seagrass diversity study in Libmanan, Camarines Sur, benefits: Barangay Local Government Unit (BLGU) by informing coastal resource management and conservation; fisherfolk by supporting livelihoods and participation in protection efforts; the Municipality of Libmanan with data for management plans and policies; Department of Environment and Natural Resources (DENR) as baseline for ecosystem protection guidelines; Bureau of Fisheries and Aquatic Resources (BFAR) with species distribution info for sustainable fisheries and habitat conservation; and future researchers/educators as a foundation for deeper studies.

Scope and Limitations of the Study - The study is focused on identifying and assessing the Seagrass species, density, seagrass cover, evenness, richness, diversity indices, and determining the physicochemical parameters in Libmanan, Camarines Sur. It examines the level of Physical Parameters, such as color and temperature. Chemical Parameters include dissolved oxygen, Salinity, and pH. Additionally, the natural and human threats to the seagrass ecosystem and the condition of the seagrass ecosystem in the area were included. The Data collection involves field surveys, species identification, and sampling methods such as transect and Quadrat sampling. The participants in the study are the researchers, with data gathered directly from the natural environment. The study is limited to the three (3) barangays (Caima, Salvacion, and Bahao) in Libmanan, Camarines Sur, and the findings may not apply to other localities. Additionally, the study was focused on the specific objectives, and other variables were not covered.

Theoretical Framework - The study draws on three key theories to guide seagrass diversity assessment and conservation: Ecological Niche Theory introduced by Joseph Grinnell, 1917, which defines a species' niche by its habitat, resources, survival needs amid competition; Biodiversity-Ecosystem Function (BEF) Theory by David Tilman, 1994 and Michel Loreau, 2001 which are the primary proponents, linking higher biodiversity to enhanced ecosystem stability, productivity, nutrient cycling, and resilience; and Intermediate Disturbance Hypothesis (IDH) by Joseph H. Connell, 1979, positing peak biodiversity at moderate disturbance levels—avoiding low (dominance by few species) or high (species loss) extremes—to inform management by identifying optimal conditions for seagrass survival.

2. Methodology

The study was conducted in the Municipality of Libmanan, Camarines Sur. The municipality of Libmanan has 75 barangays, and five (5) of which are coastal barangays. From the five (5) coastal barangays, the three selected study areas were the barangays Bahao, Caima, and Salvacion. The study used the Quantitative-Descriptive Research Design in assessing the seagrass diversity in Barangay Bahao, Salvacion, and Caima, Libmanan, Camarines Sur. The seagrass diversity assessment used the transect-quadrat technique (Saito and Atobe, 1970), with a transect line laid perpendicular to the shoreline (Figure 1). At fixed intervals, .5 m x .5 m quadrats (Figure 2) were placed every 5 m. Density counts were made in the four corner cells and the middle cells, while species cover was counted in every 25 cells. Ocular inspection was conducted before the conduct of the study. The study was conducted during the spring tide, when the water level is at its lowest. Identification followed the Seagrass Watch Philippines and Bureau of Fisheries guides, with cover assessed per protocol. Physicochemical parameters—color, temperature, dissolved oxygen, salinity, pH—were recorded at each sampling point, following the guidelines given by the DENR-EMB in collecting water samples stapled at DAO2016-08. Data analysis included calculating density, cover, and diversity indices using the formulas of Shannon-Wiener and Simpson. Threats were observed, leading to conservation and management recommendations submitted to the Municipality of Libmanan.

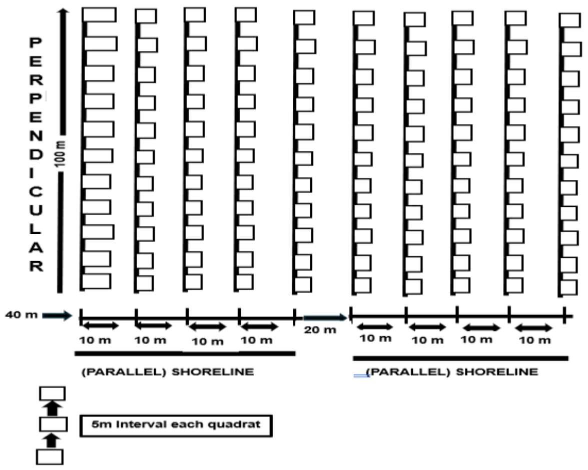

Figure 1. Sampling Layout

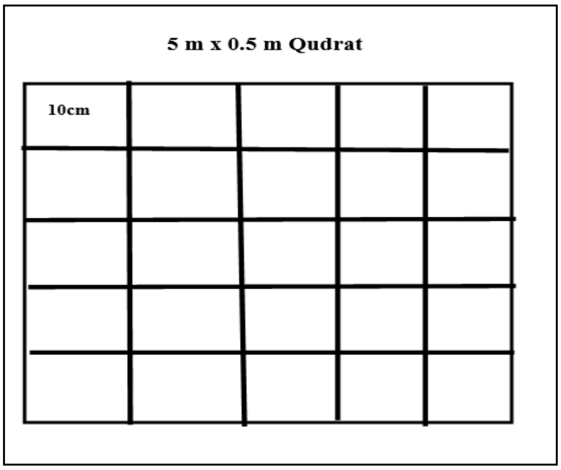

Figure 2. Quadrat with 25 cells

3. Results and Discussion

The areas selected for this study are Brgy. Caima, Salvacion, and Bahao, Libmanan, Camarines Sur, for seagrass diversity and conservation management initiatives. In this section, the results and discussions are presented aligned with the objectives.

3.1 The existing status of the seagrass ecosystem along the following biotic components: Species, Density, Species cover, Frequency, and Diversity Indices

The assessment of Seagrass Species, cover, Density, Frequency, and Diversity indices provides a measure of the distribution and overall health of the seagrass meadow. These components help to assess the diversity of the seagrass in the study area.

3.1.1 Identified Species in Selected Coastal Barangay of Libmanan, Camarines Sur

Table 1 shows seven seagrass species identified in Caima, Salvacion, and Bahao, Libmanan, Camarines Sur. These belong to two families: Cymodoceaceae (*Cymodocea serrulata*, *Syringodium isoetifolium*, and *Cymodocea rotundata*) and Hydrocharitaceae (*Enhalus acoroides*, *Halophila minor*, *Halophila ovalis*, and *Thalassia hemprichii*). Caima recorded only *Thalassia hemprichii*. Salvacion had six species: *Enhalus acoroides* (Figure 3), *Halophila ovalis* (Figure 4), *Halophila minor* (Figure 5), *Thalassia hemprichii* (Figure 6), *Cymodocea serrulata* (Figure 7), and *Syringodium isoetifolium* (Figure 8). Bahao had four species: *Enhalus acoroides, Cymodocea serrulata, Syringodium isoetifolium, and Thalassia hemprichii,* while *Cymodocea rotundata* (Figure 9) was an opportunistic species identified in Barangay Caima.

The identified species in the coastal barangay of Libmanan, Camarines Sur, is the common seagrass species found in the Philippines, as confirmed by other studies. According to Elsevier (2003, as cited by Lagriada, 2016), almost 18 common species of seagrass are found in the seagrass meadows, which are present at sites from low to high deposition. Additionally, Cocal (n.d) stated that seven (7) seagrass species were present in the Bicol Peninsula. The statement of Cocal (n.d) and Elsevier (2003) applies to the findings since six (7) species of Seagrass in Libmanan, Camarines Sur, were included in the list as common in the Philippines and found in the Bicol Peninsula.

Table 1

Identified Seagrass Species in Three Selected Coastal Barangays in Libmanan, Camarines Sur (September 11-13, 2025)

Family name	Scientific name	Common name	Barangays		
			Caima	Salvacion	Bahao
Cymodoceaceae	*Cymodocea serrulate (CR)*	Toothed grass	X	✓	✓
	Syringodium isoetifolium (SI)	Syringe grass	X	✓	✓
Hydrocharitaceae	*Enhalus accoroides (EA)*	Tape grass	X	✓	✓
	Halophila minor (HM)	Dwarf seagrass	X	✓	X
	Halophila ovalis (HO)	Spoon grass	X	✓	X
	Thalassia hemprichii (TH)	Dugong grass	✓	✓	✓
		Opportunistic			
Cymodoceaceae	*Cymodocea rotundata*	Round-tip grass	✓	X	X

Legend: ✓- Identified X- not identified

Figure 3. Enhalus accoroides

Figure 4. Halophila minor

Figure 5. Halophila ovalis

Figure 6. Thalassia hemprichii

Figure 7. Cymodocea serrulata

Figure 8. Syringodium isoetifolium

Figure 9. Cymodocea rotundata

Data also reveals that the Hydrocharitaceae family identified more species, which can be attributed to its adaptability and characteristics. According to Botanico Hub (2025), it's a widespread family of flowering aquatic plants, known as tape-grasses, with around 18 genera and over 100 species in freshwater habitats. Found globally in temperate and tropical regions, especially Asia, some tolerate brackish water, thriving from shallow marshes to deep lakes. Additionally, the identified species in this family were mostly found in sandy-muddy substrates. On the other hand, Cymodoceaceae have three (3) species identified. The Cymodoceaceae is a small family of five genera that are easily recognizable when reproductive organs are present (Petersen et al., 2014), commonly known as manatee grasses, and adapted to warm, shallow tropical and subtropical coastal waters. Plants are perennial, marine aquatic herbs rooted in the substrate; most of their leaves are submerged (BotanicaHub, 2025). Seagrass species across the hydrocharitaceae and cymodoceae families exhibit distinct habitats and adaptability to thrive in diverse marine environments. As defined by Ecological Niche Theory introduced by Grinnell (1917), A species' niche is shaped by its habitat and behavioral adaptations. Grinnell described this niche as a specific environment where a species lives, along with all the necessary conditions for its survival. Since niches are species- specific, each has unique requirements.

3.1.2 Density

Salvacion consistently has a higher density of seagrass species than Caima and Bahao. *Syringodium* *isoetifolium* (Syringe grass) exhibits the highest shoot density with 0.8 shoots. This species is widespread and has a stable population (Short, 2010, as cited by Tebaiy et al., 2024). Additionally, according to Khairunnissa et al. (2021), *Syringodium isoetifolium* has cylindrical leaves that allow it to grow densely and be more flexible when the current passes through it, and it can be found in shallow areas with bare reef. *Thalassia hemprichii* (Dugong grass) is the only species identified in Barangay Caima and Bahao, with 0.02 and 0.06 shoots per square meter and shows 0.36 shoots per square meter in Barangay Salvacion. Barangay Bahao and Caima have a fine sandy substrate, and Barangay Caima experiences sedimentation, while Barangay Salvacion has a sandy-muddy substrate. According to Tebaiy et al. (2024), *Thalassia hemprichii* had a significant negative relationship with the fine sand substrate type. This explains that *Thalassia hemprichii* prefers sandy-muddy substrates. Moreover, *Enhalus acoroides* (Tape grass) has 0.2 shoots per square meter, only in Barangay Salvacion. *E. acoroides* is more commonly found on muddy substrates (Tomascik et al., 1997; Tebaiy et al., 2024). It also has a long, strong root system, allowing it to absorb nutrients effectively and stand firmly (Wangkanusa et al., 2017). Furthermore, the lowest densities are observed in *Halophila ovalis* (Spoon grass) with 0.16 shoots, *Halophila minor* (Dwarf seagrass) with 0.08 shoots, and *Cymodocea serrulata* (Round-tip grass) with 0.04 shoots in Barangay Salvacion. As noted by Gosari & Haris (2012, cited by Tebaiy et al., 2024), these seagrasses are smaller compared to other types, with unstable growth often caused by intense competition for nutrients. This conforms with the study of Fajarwati et al. (2015, cited by Tebaiy et al., 2024), who pointed out that small-sized seagrass species are more vulnerable to environmental changes and are frequently covered by sediment, which affects their growth.

3.1.3 Species Cover

Enhalus acoroides has the highest species cover in Barangay Salvacion with 37.57%, compared to 0.64% in Barangay Bahao. This suggests a preference for the substrate in Barangay Salvacion. The dominance of this species is closely related to the habitat conditions, especially the sandy-muddy substrate present there. According to Wangkanusa et al. (2017), large beds of *E. acoroides* are typically found in thick sandy mud substrates, which offer stability against physical disturbances like waves and currents, and support nutrient cycling that promotes growth. While *Syringodium isoetifoleum* has a mean cover percentage of 2.26% in Barangay Salvacion and 0.56% in Barangay Bahao. This seagrass prefers clear waters with moderate wave action, but it thrives less in nutrient-rich muddy areas, possibly due to the competition from other species like *Enhalus acoroides* that dominate such environments (McKenzie, 2014). Moreover, *Thalassia hemprichii* has 1.80% in Barangay Salvacion, 1.20% in Barangay Caima, and 0.56% in Barangay Bahao. The dominance of *Thalassia hemprichii* in Barangay Salvacion reflects its adaptability to a variety of sediment types and environmental conditions, consistent with its wide distribution across the Philippines (Rollon, 2001). In addition, the presence of *T. hemprichii* in Bahao and Caima aligns with its ecological characteristics of slow growth but wide tolerance to environmental variability (Fortes, 2024).

Cymodeocea serrulata has a cover of 1.2% in Barangay Salvacion and 0.32% in Barangay Bahao. *C. serrulata* occurs in the lower intertidal zone, in sheltered localities, on coarse coral-sand, sand-mud, or mud with coral rubble substrates. The plant is reported to grow together with *Thalassia hemprichii, Enhalus acoroides, Halophila ovalis, and Syringodium isoetifolium. Cymodocea serrulata* is absent in places where there is a freshwater influence in the area that affects the presence of these species (Meñez et. al, 1997 as cited in SIPLAS Seagrass assessment and monitoring, 2018). Generally, this indicates their minor presence and possibly different substrate or environmental preferences in this site. While *Halophila ovalis and Halophila minor* have the lowest seagrass cover in Barangay Salvacion at 1.12% and 0.24%, respectively, possibly due to the competition from other species like *Enhalus acoroides* that dominate such environments.

3.1.4 Frequency (%)

Enhalus acoroides has the highest percentage of frequency in Barangay Salvacion, with 53.50% and 15% in Barangay Bahao. This dominance of *Enhalus acoroides* in Barangay Salvacion and Bahao may be particularly favorable conditions for this species or effective adaptations to environmental factors. According to McMillan

(1984) and Terrados et al. (1999, cited by Artika et al., 2020), *Enhalus acoroides* is a tropical seagrass with a high tolerance to environmental changes such as temperature and nutrients. While *Syringodium isoetifolium* shows a higher frequency of occurrence in Barangay Bahao at 15.00% compared to only 5.50% in Barangay Salvacion, which indicates that this seagrass species is more commonly found in Bahao. This difference in frequency indicates that environmental factors such as sediment type and water clarity conditions can likely influence the distribution and abundance of *Syringodium isoetifolium* between the two sites.

Olive et al (2022) stated that in the Philippines, *Syringodium isoetifoleum* species typically thrives in shallow waters with sand-mud or coarse sandy substrates, often in sheltered bays, lagoons, or coral reef areas where hydrodynamic conditions are moderate, and sediments are stable. Therefore, the higher occurrence of *Syringodium isoetifoleum* species in Barangay Bahao was due to its environmental factors and conditions, which are favorable for this species. Other species*, Cymodoceae serrulata, Halophila minor, Halophila ovalis,* and *Thalassia hemprichii* have a lower frequency, generally ranging from 1% to 5% in the three barangays. In Barangay Salvacion, *Thalassia hemprichii, Halophila minor, and Halophila ovalis* have the lowest frequency; this is due to the species' competitive ability that affects their abundance and distribution. According to Sapotiri et al (2021), the competitive interactions in subtidal seagrass favor larger seagrass species and negatively affect smaller seagrass. Additionally, the nutrient competition among seagrasses can take place and is influenced by the traits of their rhizomes and roots (Fourqurean et al., 1996; Duarte et al., 2000; and Bando, 2006; as cited by Sapotiri et al., 2021).

3.1.5 Diversity Indices

Diversity refers to the variety or number of different species in an area and how evenly they are distributed. In this section, the diversity of seagrass species is discussed. Table 2 shows the comparison of diversity indices in three selected coastal barangays in Libmanan, Camarines Sur. The Shannon-Weiner and Simpson Indices provide quantitative measures of diversity and evenness. Data reveals that Barangay Bahao has the highest value in both Shannon-Weiner and Simpson Diversity Indices, followed by Barangay Salvacion, with Barangay Caima being the least diverse. This was based on both Shannon-Weiner and Simpson Diversity Index, which measure diversity and evenness. The standard ranges for Shannon-Weiner diversity Index typically range from <1.0 to >3.5 in ecological studies. >3.5 generally indicates higher diversity, while <1.0 indicates lower diversity, while Simpson's typically ranged from 0.4 to 0.6. The range 0.6 and above ranks 4 equivalents for higher Diversity, and 0.4 and below indicates rank 1 equivalent for lower diversity (BioLibreTexts,2024; Coastalwiki, 2025). Additionally, the value for Simpson's Diversity Index ranges between 0 and 1; the higher the value, the lower the diversity. Shannon-Weiner Diversity Index: The higher the value of H, the higher the diversity of species in a particular community. The lower the value of H, the lower the diversity. A value of H = 0 indicates a community that only has one species (Bobbitt, 2022).

Table 2

Shannon-Weiner Diversity Index and Simpson Diversity Index in Three Selected Barangay Libmanan, Camarines Sur (September 11-13, 2025)

Diversity Indices	Barangays		
	Caima	Salvacion	Bahao
Simpson-Diversity Indices	0	0.30	0.77
Shannon-Weiner Diversity Indices	0	0.66	1.36

Barangay Bahao has the highest value for both the Shannon-Wiener (1.36) and Simpson Diversity Index (0.77). It leads among the three barangays in these indices, the Shannon-Wiener value of 1.36 is classified as moderate diversity, and Simpson's (1-D) value of 0.77 indicates a high diversity based on the presented standard ranges of Simpson's. This means that Barangay Bahao has diverse seagrass species and is evenly distributed. However, Barangay Salvacion has the value of 0.66 in Shannon-Weiner and 0.30 in Simpson's Diversity Index, which indicates low diversity, confirming that the community is dominated by one species. While, Barangay Caima has a zero (0) value of both Shannon-Weiner and Simpson (1-D) Index, which is according to BioLibreTexts (2024), zero (0) diversity means only one species is identified in the area.

3.2 Diverse Barangay in terms of Seagrass species

The study showed that six species were identified in Barangay Salvacion, while Barangay Bahao had four species identified. This indicates that the Shannon-Weiner Diversity and Simpson's (1-D) Index measure not only species richness but also the evenness of species distribution in each area. The study of Bollarapu et al (2024) and the BioLibreText (2024) highlighted that the Simpson and Shannon-Weiner Diversity Index primarily focus on species richness, abundance, and how evenly the species are distributed. Therefore, Barangay Bahao is more diverse than Salvacion and Caima. According to the Biodiversity Ecosystem Function (BEF), Higher Biodiversity often leads to more stable, productive, and resilient ecosystems. It connects species, richness, composition, and interactions to ecological processes. These proved that Barangay Bahao and Salvacion have a good condition where a seagrass species can survive, even with different stressors and disturbances.

3.3 Physicochemical Parameters

Physicochemical parameters are crucial for the seagrass ecosystem, directly affecting its growth, distribution, survival, and habitat stability. Regarding environmental responses, different seagrass species display varying resilience to adverse conditions, while more delicate types may fail to survive under certain harsh environments (Benigno, 2017). It aligns with Ecological Niche Theory by zoologist Joseph Grinnell in 1917, that describe a species has a specific environment where a species lives, along with all necessary conditions for its survival. The Physicochemical Parameters of the three barangays: Caima, Salvacion, and Bahao are shown in Table 3.

Table 3
Physicochemical Parameters in Barangay Caima, Salvacion, and Bahao, Libmanan, Camarines Sur (September 11-13, 2025)

Physicochemical parameter	Barangays		
	Caima	Salvacion	Bahao
Physical Parameters			
Temperature ℃	29.83℃	28.57℃	29.20℃
Color	murky	Slightly murky	Crystal clear
Chemical parameters			
Salinity	35.1ppt	32.3ppt	34.1ppt
pH	8.37	8.54	8.46
Dissolved Oxygen	4.2	6.5	5.3

3.3.1 Physical Parameters

Physical parameters of water quality refer to measurable characteristics of water related to its physical properties. These parameters provide valuable insights into the physical state and condition of water (Testbook, 2025).

- **Temperature (°C)**

Temperature is a factor that affects the seagrass. The seagrass meadows in Barangay Caima and Bahao have quite similar temperatures. Barangay Caima has a temperature of 29.83°C, and Bahao has a temperature of 29.20 °C. On the other hand, Salvacion has the lowest water temperature among the three barangays, with 28.57°C. Barangay Caima and Bahao had warmer temperatures than Barangay Salvacion due to environmental differences such as sunlight exposure, proximity to land and human activities, and the time differences of conducting the study. This supports the findings of Collier et al. (2014) and Campbell et al. (2006), indicating that direct or prolonged sunlight results in higher water temperatures, particularly in shallower regions where sunlight penetrates more deeply. Moreover, the water temperature in three barangays is generally within the range of optimum seagrass growth and can tolerate these temperatures. The optimal temperature range is between 23 °C and 32 °C for tropical/subtropical seagrass species (Lee et al., 2007, as cited by Jiang et al., 2022). Moreover, according to the Department of Environment and Natural Resources Administrative Order No. 2016-08, the temperature range for Marshy and/ or Mangrove areas declared as fish wildlife sanctuaries is 25 °C to 31 °C. Additionally, Arbilo et al (2020) stated that extended exposure to temperatures outside this range can stress seagrass and lead to its decline.

- **Color**

As per the study observations, the watercolor in the seagrass area of Barangay Caima is murky, and Barangay Salvacion is slightly murky, while crystal clear in Barangay Bahao (Figure 19). According to Florida Keys National Marine Sanctuaries (2025), Seagrasses grow in shallow, coastal waters where sunlight and nutrients are available for photosynthesis.

Water that is too murky attenuates or blocks sunlight from reaching seagrass blades, inhibiting seagrass photosynthesis. Poor water clarity can cause seagrass dieback, narrowing of spatial extent to shallower waters, and ultimately seagrass loss (Behesht, 2018). Additionally, the murky water in Barangay Caima is due to the study area being near the estuaries, which can also influence the color of the water in Barangay Caima. The National Oceanic and Atmospheric Administration (2016) stated that in an estuary, fresh water from rivers or streams mixes with salt water from the ocean triggers several natural processes that suspend sediment and organic material. The increased "muddiness" of estuarine waters reduces water clarity and has a number of adverse effects on estuarine and coastal ecosystems (National Institute of Water and Atmospheric Research, 2012). Moreover, the murky watercolor of the seagrass area in Barangay Caima must also be due to the presence of seaweeds. According to Thomsen et al. (2012), seaweeds have been suggested to outcompete the seagrasses, particularly when facilitated by eutrophication, causing regime shifts where green meadows and clear waters are replaced with unstable sediments and turbid waters. This confirms the number of species identified and the possibility of the loss of seagrass species in this study area.

Barangay Salvacion is slightly murky, and according to the Behest (2018), too murky water blocks the sunlight. This confirms that, in slightly murky water, light can penetrate the seagrass beds in Barangay Salvacion for photosynthesis. The slightly murky color of seawater in Barangay Salvacion is due to soil erosion, especially in rainy seasons, which creates siltation. Barangay Salvacion is highly prone to soil erosion that comes from the hillside near the study area. This erosion can carry heavy loads of sediment directly into the coastal zone. This can result in siltation, which is a primary cause for the slightly murky color of seawater, as fine particles remain suspended in the water and block the sunlight. According to the study of Payo et al. (2018), *Enhalus acoroides, Cymodocea serrulata*, and *Thalassia hemrichii* are the most tolerant of light reduction. This means that the species identified in the study area can tolerate the slightly murky color of water in Barangay Salvacion, even the limitation of sunlight. The crystal-clear color of water in Barangay Bahao shows a water clarity, according to Behesht (2018), water clarity is important for thriving seagrass beds, and improved water clarity can allow light to penetrate to the seagrass bed.

The crystal clear color of seawater in Barangay Bahao is due to the absence of suspended particles, and based on the observations, the seafloor in the study area is slightly white sand, not muddy. In Addition, the study area was surrounded by sea urchins, not just a few but a colony of them. According to Bangi and Meñez (2023), Sea urchins are usually found in seagrass beds and coral reefs. Sea urchins are considered grazers that have a key role in decomposition and recycling of nutrients, enhancing the seagrass productivity. This process of grazing of epiphytes, algae, and sediment increases light and nutrient uptake by seagrass. In addition, Sea urchins eat sediments and algae (Liu et al., 2024). However, when sea urchin populations become too large, their herbivory can change from being beneficial to damaging the stability of seagrass beds (Cahyana et al., 2025).

3.3.2 Chemical Parameters

Chemical parameters of water quality are measures of the various chemical substances present in water. These indicate the chemical composition of water, including the presence of natural and anthropogenic contaminants (Testbook, 2025).

- Salinity (ppt)

Seawater salinity is an important factor influencing the growth of seagrasses. However, most seagrass species are adapted to grow at salinities. Barangay Caima has the highest salinity at 35.1 ppt, followed by Barangay Bahao with the salinity at 34.1ppt, while Barangay Salvacion has a lower salinity of 32.2ppt. On the other hand, Salvacion's lower, brackish salinity arises from mangroves and freshwater mixing, leading to variable conditions that certain seagrasses can tolerate. Barangay Caima and Bahao have higher salinity levels than Salvacion. This is from stronger evaporation that concentrates salts due to intense sunlight. The study by Kottuparambil et al. (2024) shows that high temperatures combined with strong sunlight increase seawater temperature, which increases salt concentration (salinity) in coastal waters. This indicates that areas exposed to more sunlight and higher temperatures undergo greater evaporation, leading to increased salinity levels. However, the salinity level of each barangay is generally within the salinity range for seagrass growth and survival. Touchette (2007), as cited by Zhang et al (2022), stated that most seagrass species are adapted to grow at salinities ranging from 20 to 40 PSU/ppt.

- Hydrogen Ion Concentration (pH)

Hydrogen ions (pH) are another factor that affects the seagrass growth. Barangay Salvacion, with 8.54 pH, while Barangay Bahao and Caima have 8.46 and 8.37 (see Table 2). The seagrass levels in each Barangay were in the normal range for seagrass. Daniel Fredrick et al (2019) stated that the pH range of seagrass growth was from 7.3 to 8.4. Additionally, based on DENR Administrative Order No. 2016-08, the pH level range is 6.5-8.5. This confirms that the pH level of each barangay is slightly alkaline. Moreover, as observed in three coastal barangays, Barangay Salvacion had the highest seawater pH, followed by Barangay Bahao. This resulted from lower freshwater runoff and organic pollution from human activities, such as waste products discharged directly into the sea. In contrast, Barangay Caima showed slightly lower pH levels due to its proximity to a river, which increased freshwater dilution and reduced alkalinity. However, according to Arbilo et al. (2023), sudden changes in pH can disrupt the balance of chemical reactions within the water and affect the growth and survival of seagrass.

- Dissolved Oxygen (mg/L)

Data reveals that the dissolved oxygen in Salvacion has a result of 6.5, Bahao has a dissolved oxygen level of 5.3, and Caima has 4.2. Dissolved oxygen levels differed across the three locations. Salvacion achieved the highest at 6.5 mg/L, due to conditions that favor increased oxygen saturation, such as greater light exposure and cooler temperatures, which boost photosynthetic activity. Bahao’s level was moderate at 5.3 mg/L, affected by warmer water that reduces oxygen solubility and makes the organism use up its energy faster. On the other hand, Caima had the lowest value at 4.2 mg/L, likely due to limited light penetration due to seaweeds, which affects photosynthesis and oxygen production by aquatic plants and algae. However, according to the Department of Environment and Natural Resources (DENR), the standards of Dissolved Oxygen level for Seagrass, including mangroves, were 5mg/L and above. This was based on DENR Administrative Order (DAO 2016-08).

3.4 The Human and Natural threats that affect the seagrass ecosystem in Libmanan, Camarines Sur.

Natural and human threats are significantly increasing, and challenges to the sustainability and health of the seagrass ecosystem, affecting biodiversity and habitat stability these align with the Intermediate Disturbance Hypothesis (IDH) by American ecologists Joseph H. Connell 11979; which suggests that biodiversity in ecosystems peaks under conditions of moderate disturbance. It also states that both too few and too many disturbances can hinder the diversity of plants in an area. IDH proved that understanding the disturbances leads to and how they influence the species survival.

3.4.1 Human Threats

The human threats observed by the researchers during the conduct in the Coastal Barangay of Libmanan, Camarines Sur, were boat anchoring, which was a threat that was observed due to its physical disturbance in the seagrass ecosystem. According to the study of Unsworth et al. (2017), they demonstrated how swinging moorings can cause greater damage than the immediate scar area, leading to seagrass thinning at distances beyond the anchor point. This thinning reduces essential ecosystem services provided by seagrass meadows, such as nursery habitats and carbon storage. The damage also allows colonization by macro-algae, which can inhibit seagrass recovery through competition. According to Smithsonian Ocean 2025, boat anchors and propellers can leave "scars" in the seagrass bed, killing sections of the seagrass and fragmenting the habitat. This fragmentation of seagrass beds can increase erosion around the edges, as well as influence the use and movement within the seagrass bed. Shellfishing affects the occurrence and growth of seagrasses mainly through physical disturbance to the seagrass beds. According to the study of Garmendia et al. (2017), shellfishing activities such as trampling and digging damage the seagrass beds by reducing shoot density and biomass, leading to fragmentation and degradation of the habitat. Such disturbances can slow or prevent recovery of seagrass meadows, resulting in lower seagrass abundance and possibly causing bare areas where seagrass once thrived.

3.4.2 Natural Threats

Flooding is considered a natural threat that affects the occurrence and growth of seagrasses. Flood events can cause sedimentation and increased turbidity, which also reduces the light availability and physically smothers the seagrass beds. Flood plumes transport sediments and nutrients that can bury or physically damage seagrasses, decrease light penetration due to suspended sediments (turbidity), and cause mortality if sediment deposition surpasses the growth tolerance of the plants (Seagrass-Watch, 2025). Climate change has contributed to the alarming decline of seagrass globally (Orth et al. 2006, as cited by Campbell, M. 2025). Temperature affects how enzymes and metabolism work, influencing how organisms grow. Rising water temperatures tend to increase rates of seagrass respiration (using up oxygen) faster than rates of photosynthesis (producing oxygen), which makes them more susceptible to grazing by herbivores. Increased temperature also increases seagrass light requirements, influences how quickly seagrasses can take up nutrients in their environment, and can make seagrasses more susceptible to disease (Smithsonian Ocean, 2025).

3.5 Conservation management initiatives that preserve seagrass diversity in Libmanan, Camarines Sur.

The Researchers aim to propose recommendations, including enhancing community awareness, implementing environmental policies, encouraging local engagement, and creating barangay ordinances that promote the sustainable management of seagrass habitats.

3.5.1 Community, Education, and Public Awareness (CEPA) program

The Community, Education, and Public Awareness (CEPA) program helps raise awareness about the importance and overall benefits of seagrass species. Through continuous education and information campaigns, Community seminars, and school activities, residents can learn and be aware of how seagrass contributes to marine biodiversity, shoreline protection, and food security. CEPA is the effective first step of educating the community/public, especially the Municipality of Libmanan, Camarines Sur, about the importance and benefits of seagrass. According to the Convention on Biological Diversity (2025) stated that CEPA is a tool to effectively engage and manage multi-stakeholder dialogue to plan and implement policy. Margaret J. Wheatley's inspirational quote, *“There is no power for change greater than a community discovering what it cares about."*

3.5.2 Festivities regarding Seagrass

Organizing seagrass-centered festivities and community events helps raise public awareness and encourage local participation. Art contests, coastal clean-ups, and environmental exhibits can communicate the ecological and economic value of seagrasses while building community pride and motivating long-term stewardship. Events like the “Super Seagrass Festival” in Hull, UK, celebrate seagrass benefits and strengthen local commitment to protection and restoration (McKenna, BBC News, 2024). In areas with healthy seagrass meadows, annual festivals could include seagrass-meadow tours, cultural performances linked to indigenous fishing traditions, educational workshops, art exhibits, and community clean-up drives, all reinforcing the importance of conserving these habitats.

3.5.3 Policy Enforcement and Barangay Ordinances

Local governments in the Philippines, under RA 7160 (Local Government Code) and RA 8550 (Fisheries Code), should enact municipal and barangay ordinances to regulate boat anchoring, fishpond development, and waste disposal in seagrass areas, designating protected zones and Marine Protected Areas (MPAs) while banning destructive practices like fine-mesh nets. The Bureau of Fisheries and Aquatic Resources (BFAR) must enforce fishpond standards to reduce sedimentation and nutrient runoff, alongside strengthening RA 9003 for solid waste management in marine waters. In Libmanan, Camarines Sur, the Bantay Dagat Program should be strictly implemented with enhanced training for volunteers and enforcers, partnering with groups like Bantay Bakawan for patrols, penalties, monitoring, and cleanups. Additional measures—annual training, public awareness campaigns, and LGU collaboration—will boost compliance and balance human activities with seagrass conservation.

4. Conclusions and Recommendations

This chapter presents the conclusions and recommendations corresponding to each research problem. The conclusions explain the significance of the findings and the recommendations offer practical actions or steps for stakeholders such as policy makers, future researchers, and especially the Municipality of Libmanan, Camarines Sur, to protect the seagrass ecosystem.

Conclusion - The results show that Barangay Salvacion consistently has higher seagrass density, coverage, and frequency, suggesting a more supportive environment for seagrass growth, with Barangay Bahao following. Barangays Caima, Salvacion, and Bahao differ in substrate types and stability. Both Barangays Salvacion and Bahao offer better substrates for seagrass thriving and survival compared to Barangay Caima. Moreover, the findings reveal that the Shannon-Weiner and Simpson Diversity Indices consider not only species richness but also how evenly the species are distributed. Overall, the presence of seven species in the area indicates that the coastal waters still sustain a moderately healthy seagrass ecosystem. Despite this condition, the seagrass ecosystem is under increasing threats, especially in Barangay Caima, which requires effective management efforts. Without proper management and conservation efforts, the seagrass beds may continue to decline, affecting biodiversity and local coastal resources that depend on them. In conclusion, the proposed conservation and management initiatives for protecting these valuable ecosystems are the stepping stones to effectively managing the ecosystem. The results and findings helped improve and monitor the seagrass meadows in the study area, especially in Barangay Caima, which needs effective conservation efforts.

Recommendations - Seagrasses are among the most significant ecosystems. It provides habitats for fisheries. Balancing the seagrass ecosystem is essential. The Researchers recommend the following:

- The Local Government Unit of Libmanan, Camarines Sur should conduct regular study and monitoring of seagrass species, especially in Barangay Caima. The Municipality of Libmanan should focus on conservation and management to protect the seagrass beds in Barangay Caima.
- Collaboration and Community Involvement Local Government Units (LGUs) like Libmanan should collaborate with researchers, NGOs, academic institutions, and stakeholders to develop joint conservation and research programs.
- Regular physico-chemical monitoring of seagrass meadows is essential for effective management and conservation of these ecosystems (such as watercolor, temperature, dissolved oxygen, salinity, pH, and total dissolved solids).
- Community, Education, and Public Awareness (CEPA) and Information, Education, and Communication (IEC) should prioritize site-specific awareness on threats together with monitoring programs for the seagrass ecosystem.

- Festivities regarding seagrass. The Local Government Units (LGUs) should establish annual festivities regarding seagrass awareness.
- Enforce and strengthen the barangay ordinance to conserve and manage seagrass.
- Conservation management initiatives can be recommended to preserve seagrass diversity in Libmanan, Camarines Sur.

Implications for Schools and Educators. This study provides a local basis for environmental education by focusing on a specific ecosystem rather than general global concepts. The diversity assessment can be used in science classes to help students understand the ecological importance of seagrass meadows and turn local coastal areas into living laboratories.

Implications for Students. For students, the study connects theory with environmental stewardship. It helps students appreciate the role of seagrass as a nursery for marine life and a protector of coastal areas, while also building skills in field research, species identification, and ecological monitoring.

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