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Baseline report of the identified seagrass beds and its relative abundance in Carmen, Cebu, Philippines

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Abstract

Seagrass beds are among the most productive coastal ecosystems, providing habitat, nursery grounds, and shoreline protection, while also playing a vital role in carbon sequestration. Despite their importance, they remain unprotected and understudied in many areas of the Philippines, including Carmen, northern Cebu. Therefore, study aimed to assess the species diversity, abundance, and distribution of seagrass beds in four coastal barangays of Carmen—Puente, Luyang, Dawis Sur, and Dawis Norte. Standard ecological methods were employed, including the use of 50-meter transects and 0.75 × 0.75 m quadrats placed at 5-meter intervals. A total of 140 quadrats were surveyed across 14 transects. Seagrass species were identified using established field guides, percent cover, relative abundance, and biodiversity indices were calculated. Physico-chemical parameters like temperature, pH, dissolved oxygen, and salinity were also recorded. 6 species composition were the most abundant; *Enhalus acoroides* (29.61%), followed by *Halodule uninervis* (29.52%), *Cymodocea rotundata* (20.43%), *Thalassia hemprichii* (13.68%), *Syringodium isoetifolium* (6.51%), and *Halophila minor (0.25%)*, respectively. The results will provide a baseline understanding of the seagrass ecosystem in Carmen. This research highlights the need for continued monitoring and protection of seagrass habitats, especially in the face of increasing coastal development and fishing activities, pollution, and climate change-related impacts.

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Introduction

Seagrasses are vital marine flowering plants ecosystems in both intertidal and subtidal zones of tropical and subtropical regions (Orth *et al.,* 2006; Aji and Widyastuti, 2020; Brazas and Lagat, 2022). In the Philippines, a tropical archipelago, an estimated 12 to 18 seagrass species have been identified (Fortes, 2013). These ecosystems serve crucial ecological functions, including carbon sequestration, shoreline stabilization, and serving as habitats and nursery grounds for numerous marine species (Duarte *et al.,* 2013). The actual use of seagrass resources was limited, implying either resource depletion or a gap between awareness and active resource use. To place the biological findings of this study within larger coastal management frameworks, it is critical to investigate how community attitudes influence seagrass conservation efforts in similar Philippine environments.

They are highly sensitive to changes in their environment, making them effective indicators for the occurrence of ecological disturbances that might not be immediately evident in coral reef or mangrove ecosystems. Recent studies in the Philippines have explored seagrass diversity, percent cover, and species distribution (Payo *et al.,* 2018; Mascariñas and Otadoy, 2022), highlighting the growing interest in understanding of these vital ecosystems. Although the complete mapping of these species has not been fully established in the Philippines and Indonesia (McKenzie *et al.,* 2020; Citra *et al.,* 2024). Seagrass communities are being challenged by pollution, coastal development, eutrophication, land reclamation, and unsustainable fishing practices. These stressors have led to significant degradation of seagrass habitats across the country. Another major challenge in addressing these issues is the limited knowledge and awareness of the ecological importance of seagrasses. Studies of Fortes (2012), mentioned of systemic obstacles that hinder effective seagrass conservation in the Philippines, including the lack of trained researchers, the predominance of descriptive over predictive research, poor implementation of environmental laws, and weak academic-industry linkages.

Carmen, northern Cebu, Philippines is recognized for its coastal biodiversity, including seagrass habitats, yet remains understudied in terms of species composition and abundance.

This lack of localized data impedes effective conservation planning and sustainable coastal management. Thus, there is a pressing need to conduct baseline assessments of seagrass beds in this area.

This study aims therefore to baseline seagrass species present in Carmen, Cebu and determine their relative abundance and population diversity. By providing a baseline report, this research intends to fill existing knowledge gaps and support informed decision-making for conservation strategies. Furthermore, the findings will contribute to the broader understanding of seagrass ecosystems in the Philippine context, offering insights into their ecological and potential economic value.

Seagrass flight in selected Philippine sites

Recent seagrass assessment studies in the Philippines have highlighted both ecological significance and emerging threats to these vital marine habitats. Dagalea (2024) conducted a seagrass assessment along the vicinity of Bangaan Island Marine Sanctuary in Tungawan, Zamboanga Sibugay, using the line intercept transect method combined with 1m² quadrats to determine species composition, percent cover, and diversity. The study identified four seagrass species in Site 1 and five in Site 2, with *Enhalus acoroides* and *Thalassia hemprichii* being dominant. Overall seagrass cover was low (11.5%), and species diversity indices were below the threshold for ecological stability (Shannon Index < 2), indicating a sparse and possibly stressed seagrass community. Both natural factors (such as wave action and sediment type) and anthropogenic activities (notably tourism) contribute to the low diversity and cover. Similarly, Mahilac *et al.* (2023) assessed macroinvertebrates associated with seagrass beds in Sinacaban, Misamis Occidental, and found 40 species, with gastropods being the most dominant. The study used a modified transect-quadrat approach alongside water quality analysis, revealing that while pH, salinity, and temperature remained within normal limits, dissolved oxygen and total suspended solids exceeded recommended values. The highest biodiversity and species evenness were recorded in less disturbed areas like Libertad, while more urbanized zones such as Poblacion showed lower diversity. And in a separate study by Zalsos *et al.* (2021), seagrass beds in Laguindingan, Misamis Oriental (an undisturbed site), and Rizal, Zamboanga del Norte (a disturbed site) were analyzed for gastropod and bivalve diversity. Using coring and transect methods, researchers found a greater diversity of gastropods (13 families) in the disturbed site, potentially due to higher levels of organic matter. In Maribojoc Bay, Bohol, Mascarinas and Otadoy (2022) documented seagrass species composition, density, and diversity, noting that *Thalassia hemprichii* was dominant across the study area. They used standard line transect and quadrat sampling methods to map species distribution and assess environmental influences such as water depth and sediment type. Their study emphasized spatial variability in seagrass cover and stressed the importance of localized environmental conditions in shaping these ecosystems. Both studies emphasize the pressing need for conservation, restoration, and sustainable management of seagrass ecosystems in the Philippines, especially in the face of increasing human activity and climate-related stressors.

Earlier studies across the Philippines have highlighted varying degrees of seagrass diversity and cover in different coastal areas. For instance, Alcala *et al.* (2008) reported that seagrass beds were more abundant in Davao del Sur compared to Davao de Oro. In 2009, surveys conducted across 13 sites around Lubang and Looc Islands, Occidental Mindoro, revealed that seagrass meadows were generally multispecific and ranged from continuous to patchy formations, with percent cover varying between 0.62% and 59.49%. Among the eight species observed, *Thalassia hemprichii* and *Cymodocea rotundata* were the most prevalent. But in 2015, in southwest portion of Davao Gulf, 7 species were monitored and *Enhalus acoroides* and *Thalassia hemprichii* were abundant in almost all sites (Capin *et al.,* 2020). The study also linked the decline of seagrass cover to upland "kaingin" (slash-and-burn farming) practices, which resulted in sedimentation along coastal areas. Similarly, Castillejos *et al.* (2018) assessed seagrass community structures in Cuatro Islas, Leyte, finding eight abundant species: *Enhalus acoroides*, *Syringodium isoetifolium*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodule uninervis*, *Halodule pinifolia*, *Halophila ovalis*, and *Thalassia hemprichii*. Using transect lines, they recorded seagrass cover ranging from 0–100%, with *Cymodocea rotundata* emerging as the dominant species in terms of cover, and *Halodule uninervis* having the highest density.

Challenges in protecting seagrass beds

Seagrass ecosystems, pivotal components of coastal marine environments (Brazas and Lagat, 2022), are globally recognized for their ecological and economic significance, providing crucial habitats for diverse marine species, supporting fisheries, and playing a vital role in nutrient cycling and carbon sequestration. Despite their importance, seagrass meadows are facing increasing threats from human activities, climate change, and ecological degradation, leading to habitat fragmentation and overall decline (Stockbridge *et al.,* 2020). It is crucial to monitor seagrass ecosystems and implement effective conservation strategies tailored to specific regional needs, as these habitats are essential for marine organisms, act as carbon sinks, and protect shorelines. Detailed investigation of seagrass populations is necessary to understand the present state of seagrass in Carmen, Cebu.

Seagrass ecosystems are increasingly vulnerable to anthropogenic pressures, particularly those originating from land-based activities. Increasing human settlement in coastal areas, agricultural and industrial wastes, and coastal reclamation projects have led to elevated nutrient loading and sedimentation in nearshore waters, significantly impacting seagrass health. Construction of ports, harbors, and tourism infrastructure disrupts coastal habitats, reducing sunlight penetration and fragmenting seagrass meadows (Spalding *et al.,* 2003).

These developments often produce sediment plumes and marine pollution, exacerbating habitat degradation. Global studies, including those by Fortes (2022), emphasize the urgent need to address these impacts through integrated coastal management. While seagrass beds are widely recognized for their role in supporting marine biodiversity and climate regulation, conservation efforts in the Philippines remain fragmented. Key barriers include limited trained personnel, qualitative research outputs with low predictive value, poor law enforcement, and insufficient community engagement (Warguez *et al.,* 2023). Emerging research also highlights the effects of climate change—such as rising sea surface temperatures—on seagrass productivity and resilience. As such, a multidisciplinary and community-based approach to research, monitoring, and policy development is crucial to safeguard these ecosystems.

Materials and methods

Site description

Carmen is a third-class municipality situated on the northeastern coast of Cebu, Philippines, located at approximately N 10.353480° latitude and E 124.010480° E longitude, as identified via Google Map - GPS plots. Known for its scenic coastlines, Carmen features a mix of natural beaches, shallow nearshore ecosystems, and moderate community development. The municipality includes both popular recreational beaches and areas used for traditional fishing and gleaning practices. For this study (Fig. 1), four coastal barangays within Carmen were selected based on their ecological potential and representativeness of the area's coastal diversity. These were Puente (Station 1; N 10.611177°, E 124.027028°//N 10.611256° , E 124.027445°//N 10.611261°, E 124.02695°); Luyang (Station 2; N 10.598428°, E 124.030353° //N 10.598857-77°, E 124.030410°//N 10.598616°, E 124.030726°), Dawis Norte (Station 3; N 10.581557°, E 124.024988°//N 10.581665°, E 124.025165°//10.581251°, E 124.025843°//N 10.581467°, E 124.025696°//N 10.580843°, E 124.025327°), and Dawis Sur (Station 4; N 10.578339°, E 124.03037°//N 10.571371°, E 124.02272°//N 10.571266°, E 124.022742°). Brgy. Puente and Brgy. Luyang are moderately active fishing communities with visible seagrass patches, with Carmen Proper or Brgy. Poblacion that serves as the central municipal hub with more dynamic shoreline use including fishponds, school university, and docking pier site, followed directly with Dawis Norte and Dawis Sur which is relatively undeveloped coastal, providing contrast with minimal anthropogenic disturbance except for the freshwater intrusion coming from the river inlets of one of the populated channels and presence of both functional and nonfunctional fishponds.

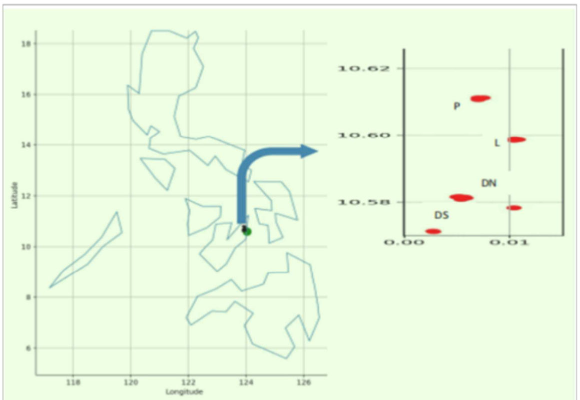

Fig. 1. Location map (lat and long) of the 12 + 2 surveyed transects of Carmen, Cebu, Philippines showing stations; P-Puente or S1; L-Luyang or S2; DN-Dawis Norte or S3; DS-Dawis Sur or S4

Sampling design

Prior to fieldwork, a formal letter and courtesy visit were made to the Municipal Agriculture Office (MAO) of Carmen to secure permissions and coordinate logistical needs. The actual field assessment was carried out from May to December 2024, and site revalidation in January 2025. At each of the four study stations, three replicate sampling sites were established, separated by replicates of a minimum from 20 meters interval at low tide reference. At each replicated seagrass site stations, a 50-meter transect line where transect/s were laid perpendicular to the shoreline. Ten quadrats, each measuring 0.75 m × 0.75 m, were placed at five-meter intervals along each 50 meter transect line. This produced a total of 30 quadrats per station or 120 quadrats across all sites with 2 extra plots for Brgy. Dawis Norte. This design allowed systematic data collection on seagrass species distribution, abundance, and community structure. Sediment type and color, organisms observed inside the quadrats were also recorded in every plotted stations.

Species identification and data collection

Seagrass species distribution and composition within each quadrat deployed to each sampling stations were identified through direct observation, following standard seagrass assessment guides, including those by Calumpong and Meñez (1997), and Philippine Seagrass field guide (BFAR - FishCORAL Project 2022) . Unfamiliar species were photographed in situ and later verified using reference monographs, including Fortes (2012-2013). Within each quadrat, data on seagrass species composition, percent cover, and relative abundance were recorded.

In addition, percent cover estimates were made through ocular percent estimation using photo reference guides by McKenzie *et al.* (2003), and data were logged accordingly for each modified quadrat (75cm × 75cm) and transect length (50m) with 20m interval per transect line. Average percent cover per transect was calculated, and the overall seagrass cover for each station was derived by averaging values from all replicates.

Seagrass beds were categorized by cover based on the classification of Amran (2010); >75.4% was Very good, 50.5 -75.4% Good, 25.5 -50.4% Fair, 5.5 -25.4% Poor, and < 5.5% was very poor. All sites were geotagged using the Google Maps locator tool for mapping purposes. Species diversity and abundance were analyzed using ecological and statistical tools. The relative abundance was calculated using the formula (n/N) × 100, where *n* represents the number of individuals of a species and N is the total number of individuals across all species. Biodiversity indices such as the Shannon-Wiener Index (H′), Simpson's Dominance Index (D), and evenness (E) were computed to assess species richness and distribution.

Physico-chemical parameters

To supplement biological observations, environmental parameters were measured at each site. Dissolved oxygen (DO) using a Smart Sensor AR8406 digital meter, pH and temperature were measured using pH meter (Hanna Marine Monitor). Both the sensor probe was dipped just below the water surface to capture accurate readings. Salinity was measured using an ATAGO refractometer by applying a drop of seawater onto the device's sample plate. These parameters were taken in triplicate per sampling sites to ensure reliability and account for spatial variation within the 4 sampling barangays.

Data analysis

Derived data were processed into Excel free apps for graph and tables. Statistical differences in species cover among the four stations were analyzed using one-way ANOVA via the JAMOVI free software. When significant differences were found, Duncan's post-hoc test was applied to determine specific site differences contributing to the variation. One-way analysis of variance (ANOVA) was used to test for significant differences at the alpha (α=0.05) level of confidence. The post-hoc test was used in defining the subsets of variance that contribute to differences among sampling stations and between sampling sites. The data was further analyzed using SPSS.

Results and discussion

Status of seagrass per sampling site in terms of percent cover

Six seagrass species were being recorded, namely, *Halodule uninervis*, *Syringodium isoetifolium, Cymodocea rotundata*, *Halophila minor*, *Enhalus acoroides*, and *Thalassia hemprichii* inside the transects during the survey period in June - December 2024 among the 4 target sites (Fig. 1; Table 3). Patches of very few *Halophila ovalis* growths were observed outside the targeted plots in barangay Luyang and Dawis Norte. Survey results (Fig. 2) showed seagrass percentage cover was recorded as 31.17% (fair) in Barangay Puente, 23.90% (poor) in Barangay Luyang, 26.83% (fair) in Barangay Dawis Sur, and 16.50% (poor) in Dawis Norte. Overall, Carmen, Cebu had an average seagrass cover of 24.60%, which is classified as a "poor" seagrass condition. Of all the six species encountered (Fig. 3), site-specific distributions can be inferred were most of the *Th* were found only in two sites; Brgy. Puente and Brgy. Luyang, *Ea* on the other two sites; Brgy. Dawis Sur and in Brgy. Dawis Norte - a monospecific with *Ea* field only. The *Enhalus-Thalassia* association found in muddy substrates as described in Calumpong and Meñez (1997) were not observed in our study sites, *Th* prominent in Brgy Luyang, but *Ea* in Brgy Dawis areas. In this present study, *Cr* was found only in Brgy. Dawis Sur a dominant species inside the three 50m transects having extreme mud and turbid water as compared to Brgy. Dawis Norte. Whereas, *Si* were only present in Brgy Puente a clear water among the four sites. To compare with other studies, 8 seagrass species were observed in Looc Islands, Occidental Mindoro, Philippines with *T. hemprichii* and *C. rotundata* being the most ubiquitous (Genito *et al.*, 2009); Identified 4 species were *E. acoroides, T. hemprichii, C. serrulata,* and *Halodule uninervis* in 2017 by Payo *et al. (*2018); 7 seagrass species identified, with *T. hemprichii* being the most abundant in Maribojoc, Bohol, Philippines by Mascarinas and Otadoy (2022) and discovering a total of 8 species (*Enhalus acoroides, Syringodium isoetifolium, Cymodocea rotundata, Cymodocea serrulata, Haluodule uninervis, Halodule pinifolia, Halophila ovalis*, and *Thalassia hemprichi*i) in Cuatro Islas, Leyte, Philippines, where the research highlights how human activities impact their distribution and growth rates (Castillejos *et al.*, 2018). Both the graph and the ANOVA interpretation (Table 1) together help in understanding how the seagrass measurements vary with location and whether these variations are statistically meaningful. Based on the analysis conducted to determine the significant difference, One-way ANOVA analysis showed no significant difference ($p>0.05$) in seagrass percent cover among sampling sites ($F(3,36)=0.87$, $p=0.47$).

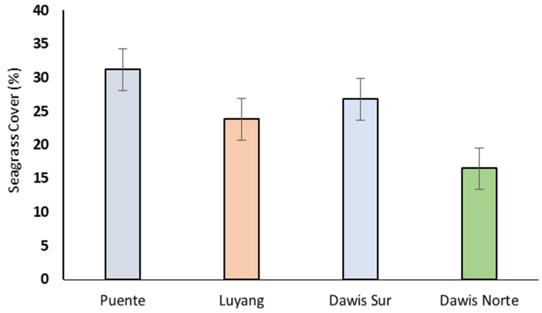

Fig. 2. Seagrass cover of the 4 barangays in Carmen, Cebu, Philippines

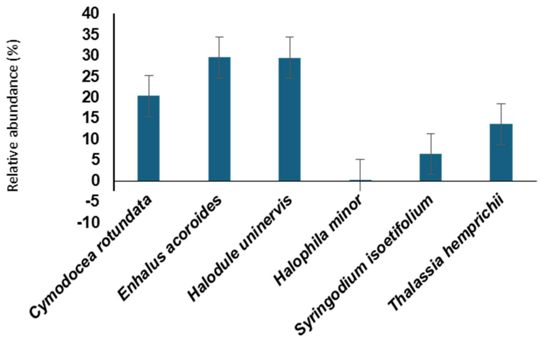

Fig. 3. Relative abundance (%) of the 6 seagrass species observed in 14 sampling sites in Carmen, Cebu, Philippines

Relative abundance of seagrass per sampling site in Carmen, cebu

During the present study, the spatial variation of seagrass species along the Carmen, Cebu coastline was observed (Table 3). In Brgy. Puente, the most abundant species seagrass was *Hu* (65.00%), followed by *Si* (26.00%), *Th* (8.00%) and *Hm* (1.00%) respectively.

Meanwhile, in Brgy. Luyang, only two species were found, composed of Hu (53.33%) and *Th* (46.47%).

Also, in Brgy. Dawis Sur, seagrass species recorded were *Cr* (81.67%) and *Ea* (18.33%). Meanwhile, in Brgy. Dawis Norte only *Ea* (100%) was collected in the sampling area. In this study, we estimated the seagrass abundance using the shoot density for *Ea* and percentage cover as extracted from transect-quadrat technique as practicable in very muddy and turbid water. It is highly likely that this homogeneous species is a result of, or at least promoted by a high muddy sediments in the area, caused by allochthonous inputs from the adjacent mangrove community as well as from the river mouth opening directed to the patchy seagrass bed. Canopy height measurements for monospecific *Ea* beds in Brgy. Dawis Norte was suggested for any future follow-up studies and local restorations.

Table 1. Summary of statistical analysis for one-way ANOVA of seagrass percent cover among 4 sampling sites($p<0.05$)

		Sum of squares	Df	Mean square	F	P-value
Percentage cover	Between groups	1141.855	3	380.618	0.869	0.47
	Within groups	15772.645	36	438.129		
	Total	16914.500	39			

Table 2. Summary of statistical analysis for one-way ANOVA of the relative abundance between seagrass species ($p<0.05$) among the 4 stations

		Sum of squares	Df	Mean square	F	P-value
Relative abundance	Between groups	2918.277	5	583.655	0.603	0.70
	Within groups	17409.212	18	967.178		
	Total	20327.489	23			

+ = Present; - = Absent

Table 3. Seagrass composition of the 4 coastal barangays of Carmen, Cebu, Philippines

Species	Brgy Puente (sandy-rocky)	Brgy Luyang (sandy-rocky-muddy)	Brgy Dawis Norte (sandy-muddy)	Brgy Dawis Sur (extremely muddy)
C. rodundata	–	–	–	+
E. acoroides	–	–	+	+
Halodule universis	+	+	–	–
Halophila minor	+	–	–	–
S. isoetifolium	+	–	–	–
T. Hemprichii	+	+	–	–

Table 4. Physicochemical parameters of 4 coastal barangays of Carmen, Cebu, Philippines

Physicochemical parameters	Puente	Luyang	Dawis Norte	Dawis Sur	Standard as per DAO 2016-08
Temperature	27.80 - 30.40°C	28.60 - 32.30°C	28.20 - 30.50°C	27.7 - 32.1°C	26-30°C
Salinity	31.80 - 32.3ppt	32.20 - 33.30ppt	31.9 - 32.4ppt	31.8 - 32.7ppt	>30
pH	6.7	3.1 - 4.7	6.7	6.7	7.8-8.5
DO	15.43 - 15.54ppm	20.62 - 21.13ppm	5.66 - 6.68ppm	5.47 - 6.20ppm	>5

Overall relative abundance (Fig. 3) of the seagrass community; the most abundant was *Ea* (29.61%), followed by *Hu* (29.52%), *Cr* (20.43%), *Th* (13.68%), *Si* (6.51%), and *Hm* (0.25%), respectively. Based on the analysis conducted to determine the significant difference, One-way ANOVA analysis (Table 2) showed no significant difference ($p>0.05$) in seagrass species relative abundance ($F(5,18)=0.60$, $p=0.70$).

Species diversity (h') of seagrass per sampling site in carmen, Cebu

The diversity of seagrass species (expressed as Shannon - Weiner index, H) among four sampling sites, Brgy. Puente showed a highest seagrass diversity value (H'=0.88), followed by Brgy. Luyang (H'=0.70), Brgy. Dawis Sur (H'=0.48), and Brgy Dawis Norte (H"=0.00) respectively. As observed in Table 3, Brgy. Puente had the higher seagrass diversity among the four sampling sites as four species were recorded: *Hu, Si, Hm,* and *Th*. On the other hand,

Bgry. Luyang and Brgy. Dawis Sur have lower diversity since these sites are dominated by two seagrass species. Meanwhile, Brgy. Dawis Norte has only *Ea* species, resulting to no diversity comparison within this site. The overall diversity index of seagrass community in Carmen, Cebu has the value of H'=1.51. The Shannon diversity index implies low diversity as the value is less than 2 (H'<2.0) based on the biodiversity index category by Odum (1983). This indicates a low level of species diversity across the entire sampling area. Therefore it is important to note that although Puente had higher diversity, the site had low evenness while, Dawis Norte with low diversity had highest evenness of *Ea* in the area. The seagrass community structure along the study sites occurs in patches. As a result there was no uniform pattern in the distribution along transect areas. This patchy distribution is either due to deterioration of once untouched aggregates or might be an environmental limitation, or due to the variations in the physicochemical parameters, affecting the occurrence and distribution of seagrass species. The low species diversity may be attributed to the human disturbance such as gleaning activities during lowest tides days into these surveyed barangays of Carmen municipality. On one end, surveyed plots in Brgy. Puente were adjacent to the Brgy. hall vicinity and other fishing activities aside from gleaning can be directly observed by the local government personnel. During transect samplings, there were abundant aggregates noticed which were not included because it was away from the assigned plots and could not been easily disturbed by specific gleaning activities because of depths during lowest tides. More were being observed outside the plots but in deeper portion. Same scenario where more seagrass species found in the deeper areas of the sea as compared to the shallow areas (Dagalea, 2024).

As to the physico-chemical parameters (Table 4) within the study period between August to December 2024 of the four barangays, all have normal range of temperatures where they can be tolerated for growth of the existing seagrasses. The salinity and pH is also within the normal range where the waters are mostly marine (Melendres and Largo, 2021). The pH and DO is still favorable except in Barangay Luyang which is below normal for pH (3.1 - 4.7) according to the standards of Department of Natural Resources Philippines (DENR, DAO 2016-08) and above normal range for DO (20.62 - 21.13ppm) during the sampling dates.

Based on my previous studies on integrated aquaculture in 2021, the low pH values could be attributed to land-based organic effluents, and relatively high pH could be due to organic pollutants from human settlements, from the outlet of the river. A presence of river water intrusions from its shorelines in Brgy. Luyang, Carmen can affect the values obtained. Other reason was before the sampling dates heavy and successive rains occurred and thus affecting some variables like pH and DO. The water depth for each Brgy. is usually shallow where penetration of sunlight is possible for the photosynthetic process of the plant. And in terms of substrate conditions, rocky-sandy were observed in Puente-Luyang stations (Table 3) with some sandy-muddy portions in particular near the river inlet were these are favorable for certain seagrasses to anchor and extreme mud-silty substrates throughout the Dawis stations which as reflected in Table 3 of the species to thrive on. Important to note that physical elements like temperature, salinity, waves, depth, and substrate are factors that influence seagrass physiological activity (Clarito *et al.,* 2020). On the other end, silt limits light availability among seagrasses but clear water can be seen in Brgy Puente sites among the four barangays. Among them were *Enhalus acoroides* as the most silt tolerant species for the two surveyed sites - Brgy. Dawis Sur and Dawis Norte. A whole suite of environmental factors (e.g. irradiance, rainfall, and physical disturbance) have been identified to influence the temporal dynamics of seagrasses (Qiu *et al.,* 2017). Such that a long-term monitoring is necessary to understand the temporal dynamics and progressions to fully capture the diversity of these seagrasses in the area. Carmen's seagrass beds could have been driven by historical climatic and oceanographic processes, and may host special characteristics representative of local substrate condition of the sampling area.

Seagrass status and comparison

The results from Nakajima *et al.* (2023) highlight the genetic isolation and restricted connectivity of *T. hemprichii* populations throughout the Philippine archipelago. This is consistent with the current research conducted in Carmen, Cebu, where the presence of *T. hemprichii* (13.68%) may indicate a locally sustained and genetically unique population.

Considering the species' limited ability to disperse and unpredictable gene flow, conservation efforts in Carmen should focus on in situ protection and the reduction of local stressors, such as sedimentation and coastal development, to promote the long-term survival of the meadow and maintain genetic diversity. The study identified potential threats to adjacent seagrass beds outside the target barangay areas. Humans and seagrasses were in conflict for spaces (Castillejos *et al.,* 2018). Still, there are no seagrass meadows that can be considered pristine as the entire areas is either inhabited or disturbed by human activities in southern part of Philippines (Arriesgado *et al.,* 2024). Most of these threats observed can cause the deterioration of water quality. The current proliferation of fish corrals in Dawis Sur and fishcages for milkfish culture in Luyang area, if unregulated, can lead to further decline of surrounding coastal waters (Melendres and Largo, 2021) and can also be a potential threats towards the seagrass ecosystems in the area. Siltation (possibly due to nearby land development and beach economy) observed between Brgy. Luyang and Brgy Dawis waters may also bring a similar outcome. Some human activities can cause direct physical harm or scars on seagrass beds like; destructive gleaning of gastropods and bivalves by shoveling; fishing (such as; siganids) in seagrass environment. The state of seagrass ecosystem in Maribojoc Bay were due to rampant disturbances and degradations (Mascariñas and Otadoy, 2022), as in the cases of the eastern part of Bohol (Libres, 2015). Considering these threats, we propose a few actions to ensure conservation of these seagrass ecosystems in the the entire barangays of Carmen, Cebu. First, conduct regular monitoring of the growth pattern of the seagrasses in the area. Second, explore the creation of seagrass protected areas for *Enhalus acoroides* between Dawis Sur and Dawis Norte. Finally, explore the possibility of seagrass transplantation or revegetation, particularly with *Enhalus acoroides*, in stations of Puente and Luyang boundary so that the coverage of this species can penetrate the said areas as part of the conservation program. Seagrass transplantation is not new to the Philippines that it will be possible in Carmen areas (personal communication). Titioatchasai *et al.* (2023) offers valuable insights that could enhance current research on seagrass beds in Carmen, Cebu. They successfully used environmental DNA (eDNA) to assess microbial and faunal diversity in both natural and transplanted seagrass meadows. The transplanted seagrass site had no significant differences in species richness or evenness compared to natural meadows, indicating successful habitat functionality restoration. This supports the potential of seagrass restoration in Carmen using similar transplantation methods. If rehabilitation is required, this method can be both ecologically sound and practical in shallow coastal environments. The most important seagrass species that showed strong association with the environmental variables is *Enhalus acoroides*. Abundance of *E. acoroides* can be due to the effect of muddy substrate in both Dawis areas. *Enhalus acoroides* was observed to be the most tolerant to siltation during rainy season (Khogkhao *et al.,* 2017) and even thrived in diminished physical conditions (Quiros *et al.,* 2017).

Seagrass condition were poor-fair in four stations, with overall poor condition (24.60%) or sparse coverage. Based on previous studies that seagrass species population declines due to both directly or indirect anthropogenic impacts by Short *et al.,* 2011. Because of its proximity to shoreline, seagrasses are vulnerable to a sudden shifts of abundance in most sites of Carmen (personal communication). Presence of eutrophication caused by the increased of nutrients such as nitrates and phosphates in the water directly and indirectly from fishcage operation and river inputs (Melendres and Largo, 2021) can dramatically increase siltation and pollution. The reason for the low percentage of cover, density, and biomass of seagrass was the presence of water influx from the river carrying silted sediment (Reyes, 2023).

Similarly, continuous coastal development is also affecting water quality and leading to the degradation of seagrass beds (Supriyadi *et al.,* 2023). On other hand, seagrass species diversity and cover were negatively influenced by turbidity, sedimentation, and local disturbances such as bivalve gleaning, anchoring, and tourism (Clarito *et al.,* 2020).

There were prominent aggregates of brown and green algae in Brgy Luyang stations that according to Fortes (2013), anoxia in water occurs due to rise of temperatures and low tidal conditions resulting to green algae proliferation. This implies that higher DO showed the greatest effect on the occurrence and distribution of seagrass species *H. uninervis*. Likewise, *S. isoetifolium* was also strongly associated with higher DO and clear waters. This species together with the prominent presence of brown algaes like *Sargassum* sp. and *Padina* sp. combination was only observed along sampling transects of Brgy. Puente, of which clear water had higher horizontal visibility and the substrate type is generally a combination of both sand and rock. Moreover, *S. isoetifolium* can be found in sandy substrates that could be visible of slope limit up to 5m deep (Gole *et al.,* 2023). Notably, DO is one of the most important indicators for growth and survival of seagrasses. In addition to the importance of oxygen inside seagrass tissues, maintenance of oxic conditions around root system may provide efficient protection against invasion of reduced toxic compounds and metal ions from the surrounding sediments (Borum *et al.,* 2006).

Fishing activities like gleaning, fishcages and fish corrals, and land-use related to human settlement and development had the important impact on seagrass biological variables in the present study. These patterns may be indicative of the effect of human presence on seagrass health and species distribution. These findings underscore the importance of protecting both disturbed and undisturbed seagrass areas to ensure continued ecological function of the seagrass ecosystem and food resource sustainability. Understanding the population diversity and abundance of seagrass beds provides essential information for managing and preserving these critical habitats. Through the application of diversity indices and evaluations of species composition, it has become clear that the seagrass ecosystems in Carmen, Cebu are ecologically similar to other valuable coastal ecosystems in the Philippines, highlighting the necessity for focused conservation efforts.

The present study in Carmen, Cebu, identified six prominent seagrass species: *Ea, Hu, Cr, Th, Si,* and *Hm*. These species are similar to those found within the tropical Indo-Pacific region, along the Java Island coast in Indonesia, where Dewi *et al.* (2024) described eleven species, including all identified in our study. Establishing marine protected areas alongside frequent monitoring programs could be key steps in sustaining the health and resilience of Carmen's seagrass ecosystems, replicating lessons acquired from Java's coastal management. This present baseline field-based data could serve as a calibration set for future remote sensing applications. Further, participatory mapping and GIS of target sites for restoration program (Amone-Mabuto, 2023) for awareness of seagrass sites in Carmen, Cebu to different stakeholders and participants was also possible. Recent study by Clemente *et al.,* in 2023 offers insightful lessons that can enhance future seagrass assessment research in Carmen, Cebu. Remote sensing excels in covering larger areas with less time if baseline maps are already calibrated. Calibrating visual estimates with actual biomass measurements improved the accuracy of either remote and field data. In some instance biomass mapping can showed limitations in seagrass environments dominated by atypical species and different substrates.

Despite moderate awareness on seagrass management strategies on seagrass ecosystem, utilization of seagrass resources was low, suggesting potential resource depletion or weak engagement with seagrass conservation (Quevedo *et al.,* 2020). In Carmen, similar patterns may be anticipated, given the observed lack of historical data and active management interventions. These insights emphasize the need for subsequent activities in Carmen to incorporate socio-ecological frameworks, combining ongoing ecological monitoring with targeted community awareness programs.

Conclusion

Six seagrass species were recorded in Carmen, northern Cebu, Philippines, with *Enhalus acoroides* exhibiting the highest relative abundance across all sites. Among the four surveyed barangays, Puente demonstrated the greatest species richness and diversity, followed sequentially by Brgy. Luyang, Dawis Sur, and Dawis Norte. Overall, the seagrass community structure in Carmen was characterized by sparse distribution and low diversity, with the mean percent cover indicating a "poor" seagrass condition based on standard ecological thresholds.

The seagrass ecosystem, being one of the most important coastal ecosystems, demands increased monitoring, management, and conservation. Thus, more research into seagrass ecosystems is necessary in order to develop holistic rehabilitation approach and initiatives or improve present management in Carmen, northern Cebu, Philippines.

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