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Seagrass Community Structure and Ecosystem Carbon Stocks Along the Shoreline of Semujur Island, Bangka Belitung Province, Indonesia

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ABSTRACT

Seagrass meadows serve as vital blue carbon ecosystems, sequestering significant amounts of CO_2 and playing a crucial role in climate change mitigation. Semujur Island, located in the Bangka Belitung Province, exemplifies numerous small Indonesian islands boasting extensive seagrass meadows lining their shores. This research seeks to (1) describe the community structure of seagrass on Semujur Island, (2) assess the carbon storage within the seagrass ecosystem, and (3) analyze the relationship between seagrass community structure and carbon reserves across three distinct sites. According to the results of this study, there are eight species of seagrass on Semujur Island, i.e., *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila ovalis*, *Oceana serrulata*, *Syringodium isoetifolium*, *Thalassia hemprichii*, and *Thalassodendron ciliatum*. Diversity indices varied among sites, ranging from 1.48 to 1.72. Species evenness indices varied between 0.83 and 0.92, while dominance indices varied between 0.20 and 0.28. The highest estimated carbon stock was obtained at the site dominated by the species *H. uninervis* (75.11 MgC/ha); followed by the site dominated by *T. hemprichii* (50.55 MgC/ha). The correlation between seagrass community structure, including density and coverage, and carbon stocks demonstrated a moderate positive correlation, with coefficients of 0.430 and 0.528, respectively ($p<0.05$). This research highlights the significance of integrating ecological dynamics into the management of seagrass ecosystems to enhance climate change mitigation efforts. Additionally, it offers valuable data as a reference for the restoration and conservation of seagrass ecosystems.

1. INTRODUCTION

Climate change is a global threat and challenge affecting countries around the world (James et al., 2023; Losciale et al., 2023). The situation is exacerbated by the rising levels of greenhouse gases, including CO_2, CH_4, and N_2O in the atmosphere, primarily driven by increased human activities (Cassia et al., 2018). Climate change mitigation endeavors have primarily focused on terrestrial vegetation, such as forests and plantations, as carbon sinks, often neglecting the potential contribution of coastal ecosystems (Bandh et al., 2023). Coastal ecosystems are renowned for their remarkable capacity to sequester and store carbon. Among the 'blue carbon ecosystems' in the tropical region, mangroves, seagrass meadows, and tidal swamps play pivotal roles in this regard (Hilmi et al., 2021). In particular, seagrass ecosystems exhibit an impressive capability to store carbon, with an astonishing capacity of 830 MgC/ha, thereby surpassing the carbon absorption potential of terrestrial forests, which stands at 300 MgC/ha (Fourqurean et al., 2012). Seagrass meadows possess an outstanding capacity for carbon sequestration, accomplished through the daily removal of carbon from the atmosphere. This carbon is then stored within seagrass tissues (0-10% of total carbon) and sediments (90-99% of total carbon) (Tahir et al., 2023; Stankovic et al., 2021).

Indonesia is characterized by its extensive coastline which spans 81,290 km and ranks as the

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second longest globally, surpassed only by Canada (Lasabuda, 2013). The nation has emerged as a significant contributor, accounting for approximately 17% of the world's blue carbon reserves, which are crucial for climate change mitigation purposes (Alongi et al., 2015). Nevertheless, this portrayal is deemed incomplete in fully representing Indonesia's coastal ecosystems. Thus, there is an imperative for comprehensive exploration, particularly concerning coastal ecosystems such as seagrass meadows, to augment Indonesia's role in advancing climate change mitigation efforts.

Semujur Island, located within the administrative region of the Bangka Belitung Islands in Indonesia, is encircled by extensive and pristinely conserved seagrass ecosystems, thereby serving as a representative microcosm of the broader state of seagrass meadows in Indonesia. This unique ecological site remains relatively underexplored in scientific research, lacks formal protection status, and exists in proximity to human communities actively engaging in or near these seagrass habitats.

Different seagrass meadow locations are expected to exhibit differences in their community structure, potentially influencing their capacity to absorb and retain carbon. This hypothesis emphasizes the importance of examining the correlation between community structure and carbon storage, underscoring its significance for forthcoming management strategies of seagrass ecosystems. Consequently, this study aimed to achieve the following purposes: (1) describe the community structure of seagrass around Semujur Island; (2) estimate carbon stocks in the seagrass ecosystem; and (3) analyze the relationship between seagrass community structure and carbon stocks.

2. METHODOLOGY

2.1 Area of study

Field data collection was conducted from January to February 2023 in the waters around Semujur Island, Bangka Belitung Islands (2°09'00" South Latitude and 106°19'12" East Longitude) (Figure 1(a)). Sampling was carried out at three separate sites of seagrass meadows (designated as Mead-1, Mead-2, and Mead-3) which differed in general environmental conditions (Figure 1(b)). Mead-1 is situated furthest from the shoreline of Semujur Island, approximately 1.17 km away. It is characterized by clear water conditions, depths ranging from 90 to 135 cm, and a notable abundance of macroalgae. The sediment composition at this site comprises coarse sand interspersed with mixed corals, remnants of faunal shells, and rocks. In contrast, Mead-2 is positioned closer to the island's shoreline, characterized by turbid water conditions attributed to its proximity to human settlements. The water depth ranges from 40 to 60 cm, and the area exhibits a significant presence of plastic and other debris. Sediment composition predominantly consists of coarse sand, occasionally interspersed with fine sand, and remnants of faunal shells. Lastly, Mead-3 is located near a shallow area that emerges during low tide, revealing seagrass beds. It features clear water conditions and depths ranging from 60 to 90 cm, with some macroalgae present. The sediment composition comprises mainly fine sand mixed with remnants of faunal shells.

(a)

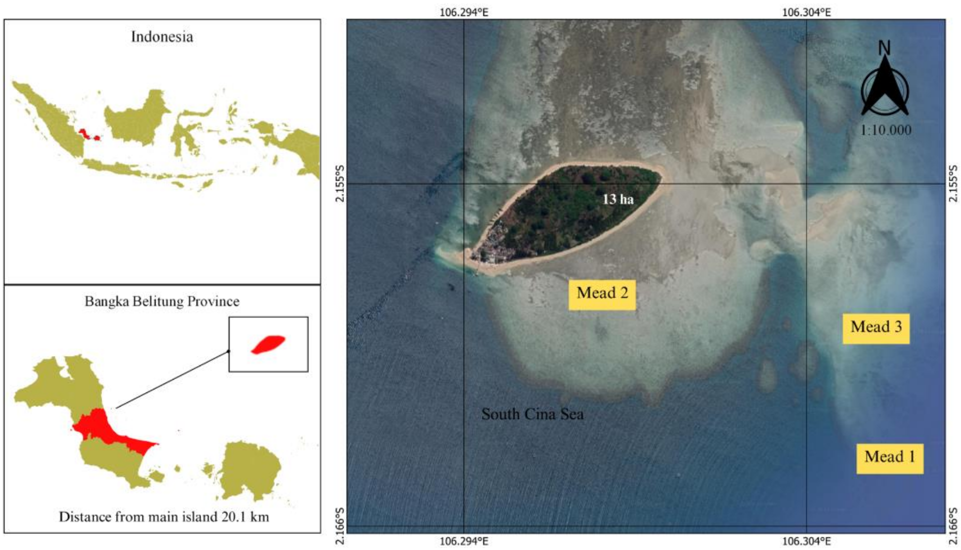

Figure 1. (a) Map of the study area in Semujur Island and (b) Conditions of seagrass and sediment at the three meadow sites

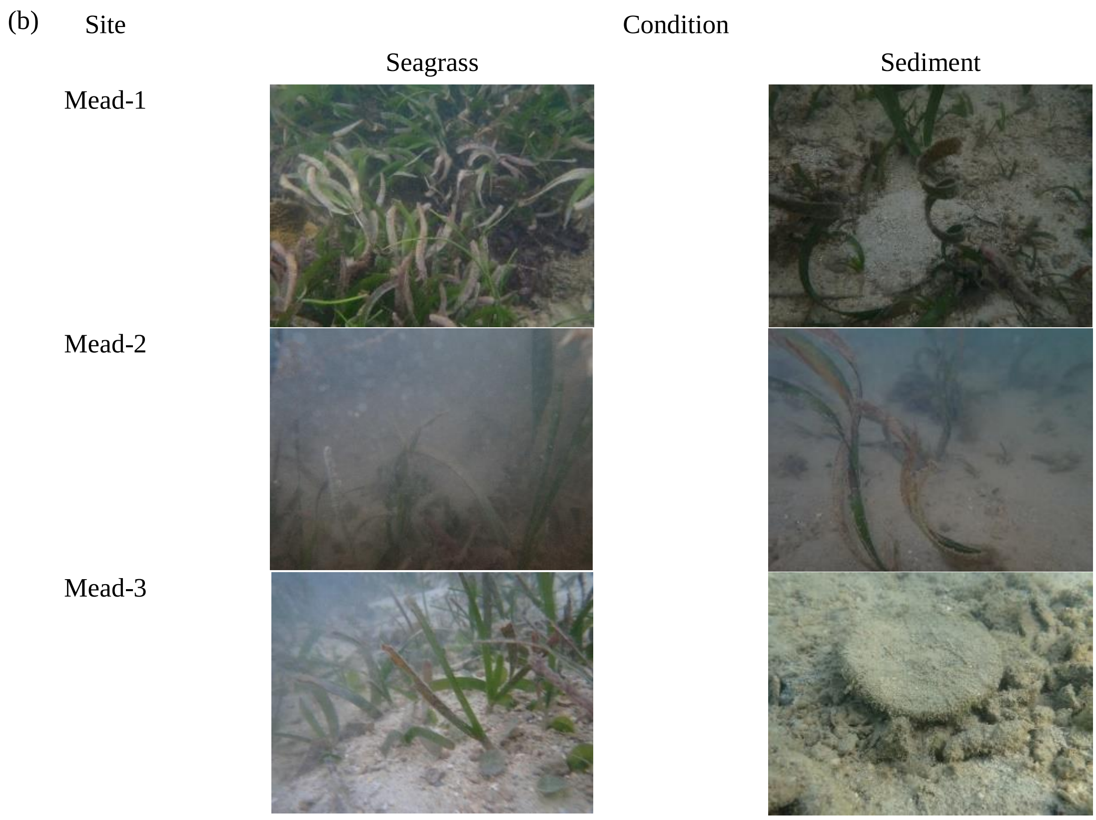

Figure 1. (a) Map of the study area in Semujur Island and (b) Conditions of seagrass and sediment at the three meadow sites (cont.)

Water quality measurements were found to vary among sites for certain parameters (Table 1). Water temperature, pH, and DO levels were assessed using a water quality meter (WQM, Combo Handeld AZ Instrument Model AZ 8603), while salinity was determined using a refractometer (ATC RZ 118). Total suspended solids (TSS) were quantified utilizing a TSS meter within the Padjajaran University Integrated Laboratory. All parameters met the seawater quality standards for seagrass growth and development (Republic of Indonesia Government Regulation Number 22, 2021), except for turbidity in Mead-2 which exceeded the specified quality standard (TSS>5).

Table 1. Physico-chemical parameters of water at each site. Different superscripts within the same row indicate significant differences at $p<0.05$

	Site		
	Mead-1	Mead-2	Mead-3
Temperature (°C)	24.63 ± 0.06^{a}	25.97 ± 0.12^{b}	26.80 ± 0.00^{c}
pH	8.35 ± 0.00^{a}	8.44 ± 0.05^{b}	8.41 ± 0.02^{ab}
Dissolved oxygen (mg/L)	8.37 ± 0.76^{a}	8.97 ± 0.12^{a}	8.03 ± 0.50^{a}
Salinity (‰)	30.33 ± 0.58^{b}	28.00 ± 0.00^{a}	28.33 ± 1.15^{a}
Turbidity (FNU)	2.68 ± 0.85^{a}	7.11 ± 2.65^{b}	4.38 ± 1.35^{ab}
Total suspended solid (mg/L)	12.33 ± 11.15^{a}	14.00 ± 9.00^{a}	19.00 ± 19.92^{a}

2.2 Seagrass vegetation analysis

Vegetation analysis was undertaken to characterize the seagrass community structure at each site. This methodology was executed in accordance with the seagrass-watch protocol, as outlined by Rahmawati et al. (2019). Three parallel transect lines were delineated at each designated site, positioned parallel to the shoreline and separated by 50 m. Seagrass species identification and assessment of coverage were conducted at intervals of 10 m along the transects, employing square quadrats measuring 50×50 cm. This process commenced from the 0-meter mark and continued to 100 m, encompassing a total of 11 quadrats per transect. Species abundance was estimated within subplots measuring 25×25 cm within the quadrats. With three transects and 33 quadrat plots, the cumulative sampling area represented 10,000 m^2 or 1 hectare. Analysis of the collected data to characterize the community structure at each site was performed utilizing the equations presented in Table 2 (Odum, 1993).

Table 2. Parameters and formula for seagrass vegetation analysis (Odum, 1993)

Parameter	Formula	Description
Species density	$D = \frac{\sum ni}{Ai}$	D=seagrass density (ind/m^2) ∑ni=number of individuals of seagrass species (ind) Ai=transect area (m^2)
Shannon-wiener diversity index	$H' = -\sum_{i=1}^{n} (pi \ln pi)$	H'=diversity Index pi=the proportion of individuals of each species belonging to the i^{th} species (ni) of the total number of individuals (N)
Simpson evenness index	$E = \frac{H'}{H_{max}}$	E=evenness Index H'=diversity Index H_{max}=log of number of seagrass species
Simpson dominance index	$D = \sum_{i=1}^{n} (pi)^2$	D=simpson Index pi=the proportion of individuals of each species belonging to the i^{th} species (ni) of the total number of individuals (N)

2.3 Carbon stock measurement

Seagrass biomass data were collected by extracting samples from each observed seagrass species within every transect. This involved carefully prying to obtain all parts of the plant. During the sampling process, 5-10 individuals of each identified seagrass species were collected, or an approximate weight of 200 grams per species was obtained. These samples were meticulously cleaned to remove any attached organisms or debris. Subsequently, each seagrass plant was separated into its above-ground biomass (AGB), comprising leaves and sheaths, and below-ground biomass (BGB), consisting of roots and rhizomes. This facilitated a detailed and robust analysis of carbon distribution within the seagrass ecosystem, obtaining robust data and providing insights into the contribution of different plant components to carbon sequestration and storage dynamics. Subsequently, the seagrass samples were subjected to drying in a laboratory oven at 60°C for a period of 48-72 h until a constant weight was achieved (Rahmawati et al., 2019).

Regarding sediment sampling, sediment cores were extracted using PVC pipes measuring 50 cm in length and 5 cm (2 inches) in diameter. Three sediment samples were retrieved from each transect, totaling nine samples from each study site. The collected sediment cores were then stratified based on depth intervals (0-5 cm, 5-20 cm, and 20-50 cm). Following this, the samples underwent drying at 60°C for 48-72 h until they reached a constant weight, rendering them ready for further analysis (Rahmawati et al., 2019).

Sediment compression factor was determined following the methods of Rahmawati et al. (2019), based on measurements of the total length of the PVC pipe used for sampling (A), the PVC length that penetrated the sediment/core length (E), the remaining PVC length which did not penetrate (B), the length of the sediment sample (D), and the part of the PVC pipe that was not filled with sediment (C). The formula used to determine the compaction correction factor is as follows:

$$\text{Compaction Correction Factor} = \frac{\text{Length of sediment sample (D)}}{\text{Depth of core (E)}}$$

The corrected sample (H') was calculated by multiplying the previously calculated correction factor by the length of the sediment sample without compaction (H). The results obtained were used to calculate bulk density.

$$\text{Corrected Sample (H')} = \text{Correction factor} \times \text{Length of sediment sample (H)}$$

Where; H'=length of sample collected; H=length of original sample (the length of sample without compaction).

Total biomass was calculated using the following equation:

$$B = W \times D$$

Where; B=total seagrass biomass (g/m^2); W=individual biomass of seagrass species (g/ind); D=seagrass species density (ind/m^2) (Rahmawati et al., 2019).

After obtaining the value of seagrass biomass, organic carbon was then measured using the dry ashing method (loss on ignition). The loss of sedimentary organic matter in the combustion process was determined using the following equation:

$$LOI = (\frac{W_o - W_t}{W_o} \times 100)$$

Where; LOI=loss on ignition percentage (%); W_o=seagrass/sediment initial weight (g); W_t= seagrass/sediment final weight (g) (Rahmawati et al., 2019).

Organic content was analyzed using the following equation:

$$C_{org} = 0.43 \times LOI - 0.33$$

Where; C_{org}=organic carbon content percentage (%) (Rahmawati et al., 2019).

Carbon stocks in sediments were calculated using the following equation:

$$\text{Carbon storage in sediment}\ (g\ C_{org}/cm^3) = \text{DBD(dry bulk density)} \times C_{org}\ (\%)$$

Where; DBD=dry bulk density (g/cm^3) (Rahmawati et al., 2019).

The total carbon stock in sediments was calculated per sample using the following equation (Rahmawati et al., 2019):

$$\text{Total of carbon storage in sediment}\ (g\ C_{org}/cm^2) = \text{carbon storage in sediment}\ (g\ C_{org}/cm^3) \times \text{sediment thickness (cm)}$$

2.4 Correlation analysis

A correlation analysis was performed using SPSS software to investigate the relationship between the community structure and carbon stock within the seagrass ecosystem. The Pearson correlation test, with a significance level set at 0.05, was employed to calculate the coefficient and assess the significance of the correlation. The correlation coefficient (r) has a value between -1≥ r ≤1. A correlation coefficient between 0 and +1 indicates positive correlation, while a coefficient between -1 and 0 indicates a negative correlation and is interpreted as outlined in Table 3 (Schober et al., 2018).

Table 3. Interpretation of r-value in Pearson Test (Schober et al., 2018)

No.	r Value	Interpretation
1	0.00-0.10	Negligible correlation
2	0.10-0.39	Weak correlation
3	0.40-0.69	Moderate correlation
4	0.70-0.89	Strong correlation
5	0.90-1.00	Very strong correlation

3. RESULTS AND DISCUSSION

3.1 Seagrass community structure

3.1.1 Species richness

Eight seagrass species were observed along the shorelines of Semujur Island. However, the composition of species varied slightly among the three surveyed sites (Table 4); this, in turn, indicated that not all species were uniformly distributed across the sites. A total of six to seven seagrass species were documented in each site. Notably, the presence of *T. ciliatum* and *O. serrulata* was exclusive to Mead-1, suggesting a more constrained spatial range for these species, with their distribution influenced by substrate and abiotic factors. Notably, *T. ciliatum* and *O. serrulata* are recognized for their preference for hard substrate habitats, particularly comprising dead coral fragments and exposure to strong wave actions and currents (Verheij, 1993; Short and Coles, 2001; Priosambodo, 2007). Mead-1 is located farthest from the shoreline and is therefore more exposed to waves and currents. The suitability between the ecological preferences of these two species and the prevailing environmental conditions and substrate type at Mead-1 explains their limited presence at this particular site.

Cymodocea rotundata was recorded in both Mead-2 and Mead-3, which are characterized by substrate that is ideally suited for the growth and development of this species, i.e., composed of a mixture of sand particles intermingled with the remnants of faunal shells. A study conducted by Rawung et al. (2018) found that this species can grow and develop well in such substrate conditions. Additionally, these sites were relatively shallow, and become exposed during low tide, producing conditions that favor the growth of *C. rotundata*. According to Bchir et al. (2019), *C. rotundata* thrives in sunlit waters and falls within the category of cosmopolitan seagrass species, capable of thriving in a wide range of habitats. This adaptation is consistent with the environmental conditions found in Mead-2 and Mead-3, where *C. rotundata* was observed. These sites offer an optimal depth range, approximately 40 to 110 cm, which is shallower compared to Mead-1. The adequate depth in Mead-2 and Mead-3 provides the requisite conditions for the growth and development of *C. rotundata*, as it ensures effective light penetration.

Table 4. Seagrass species richness at each site

Species	Mead-1	Mead-2	Mead-3
Cymodocea rotundata Asch. and Schweinf	-	+	+
Enhalus acoroides (Linnaeus F.) Royle, 1839	+	+	+
Halodule uninervis (Forssk) Asch	+	+	+
Halophila ovalis (R. Brown) Hooker f., 1858	+	+	+
Oceana serrulata (R. Brown) Byng and Christenh	+	-	-
Syringodium isoetifolium (Asch.) Dandy	+	+	+
Thalassia hemprichii (Ehrenberg) Ascherson, 1871	+	+	+
Thalassodendron ciliatum (Forssk.) Hartog	+	-	-
Total number of species	7	6	6
Description: (+)=species present, (-)=species absent			

3.1.2 Species density

Seagrass species density is affected by a variety of site-specific factors, including water depth, turbidity, current velocity, and substrate type. The mean seagrass densities observed at Mead-1, Mead-2, and Mead-3 were 560 individuals/m², 241.34 individuals/m², and 602.67 individuals/m², respectively. The higher seagrass densities at Mead-1 and Mead-3 can be attributed to *H. uninervis* and *E. acoroides*, whereas *T. hemprichii* exhibited the highest density at Mead-2. The variation in species density observed across the data collection sites (Figure 2) is likely attributable to differences in environmental and sediment conditions among these sites.

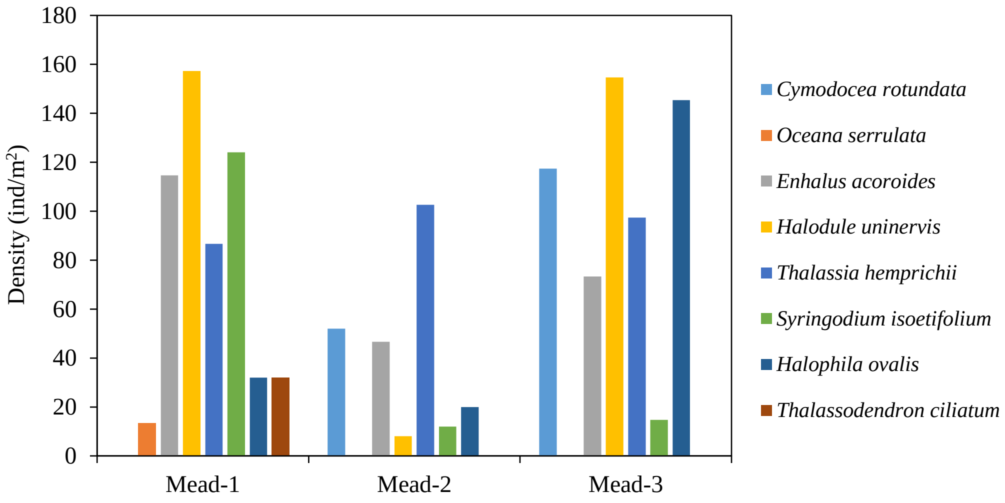

Figure 2. Species density at each site

Compared to the other seagrass species, *H. uninervis* exhibited notably higher densities at both Mead-1 and Mead-3. *H. uninervis*, a species widely distributed in the Indo-Pacific Region, thrives in intertidal and subtidal zones and demonstrates a robust capacity to flourish in high-salinity environments while maintaining resilience in the face of various disturbances (Ravilla et al., 2020). Its ability to coexist with other seagrass species contributes to its abundance at the two sites. Meanwhile, Mead-2 exhibited the highest species density of *T. hemprichii*, a species which is typically found in muddy sediments, sensitive to turbidity and thrives in fine sandy substrates enriched with coral remains (Vermaat et al., 1997; Terrados et al., 1998; Lefaan, 2012). The prevalence of *T. hemprichii* at Mead-2 can be ascribed to the specific environmental conditions present at this site. Previous studies (Waycott, 2011; Kilminster et al., 2015) have suggested that this species struggles to endure prolonged sun exposure and is susceptible to the impacts of rainwater. The discrepancies in species abundance observed among the sites have led to the development of distinct community structures, consequently influencing the potential for carbon sequestration and storage within the seagrass meadows. This variability in seagrass community structure across Semujur Island's waters is also mirrored in the diversity, evenness, and dominance indices calculated for each site (Table 5). These indices offer valuable insights into the degree of diversity in seagrass community structure as well as its concomitant effect on the sequestration and storage of carbon stocks in the seagrass ecosystem.

Table 5. Diversity, evenness, and dominance indices of seagrass at three sites

Site	Diversity (H')	Evenness (J)	Dominance (C)
Mead-1	1.72	0.88	0.20
Mead-2	1.48	0.83	0.28
Mead-3	1.65	0.92	0.20

The diversity, evenness, and dominance indices provide insights into the composition and structure of seagrass communities at the different sites. Mead-1 exhibits the highest diversity, attributed partly to its greater species richness compared to the other sites, likely influenced by more favorable environmental conditions for seagrass growth. Mead-2 shows the highest dominance index, mainly due to the prevalence of *T. hemprichii*, yet it maintains a moderately balanced level, suggesting diverse seagrass communities coexist. Mead-3 demonstrates the highest evenness index, indicating a more equitable distribution of species abundance. This equitable distribution at Mead-3 can benefit the ecological community by enhancing resilience against disturbances. Higher evenness may promote the establishment of a more resilient community less susceptible to environmental disruptions (Fitrian et al., 2017). These differences in community structure, as reflected by the indices, are anticipated to impact the carbon sequestration and storage capabilities of the respective seagrass meadows.

3.2 Seagrass ecosystem carbon stock

3.2.1 Biomass carbon stock

The assessment of seagrass dry weight and organic carbon content per species revealed that *E. acoroides* exhibited the highest dry weight at 2.99 grams dry weight per individual (Figure 3). This could be attributable to the large size of *E. acoroides*, which should enhance its carbon sequestration and storage capacity in comparison to other seagrass species, as noted by Citra et al. (2020). The significantly higher dry weight recorded for *E. acoroides* is indicative of its potential to contribute significantly to the total community biomass and, consequently, augment carbon storage within a seagrass meadow, as shown by the findings of Nugraha et al. (2019).

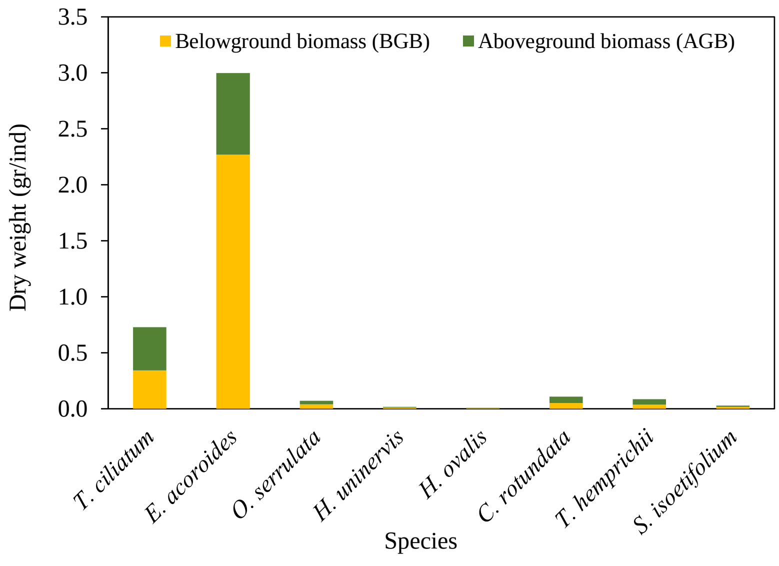

Figure 3. Dry weight of each seagrass species

Additionally, the comparison of dry weight results between aboveground biomass (AGB) and belowground biomass (BGB) reveals a significantly higher dry weight in BGB compared to AGB (Figure 3). This discrepancy is likely attributed to the inclusion of roots and rhizomes in BGB, which possess a higher capacity for carbon storage due to the accumulation of carbon resulting from the photosynthesis process. Furthermore, the positioning of roots and rhizomes beneath the sediment provides them with greater protection against environmental factors, thereby reducing the risk of disturbance and damage (Wahyudi et al., 2016).

Seagrass acts as an energy source for both the seagrass itself and the surrounding ecosystem by playing a pivotal role in the absorption of carbon dioxide (CO_2) and the production of glucose ($C_6H_{12}O_6$). The mechanism of carbon sequestration, facilitated by seagrass, is intricately tied to the growth and proliferation of seagrass biomass. An examination of the organic carbon content across various seagrass species yielded consistent outcomes, indicating a homogeneous distribution of carbon within seagrass tissues (Kumala, 2020). The findings of the current study further validate that numerous seagrass species, irrespective of their size, present on Semujur Island possess comparable abilities to store organic carbon ($\%C_{org}$) (Figure 4). This suggests that seagrass species, regardless of their size, exhibit efficient capabilities for storing organic carbon. Consequently, regions with thriving seagrass populations assume a crucial role in the sequestration and retention of carbon, surpassing areas lacking seagrass growth for this critical ecological function.

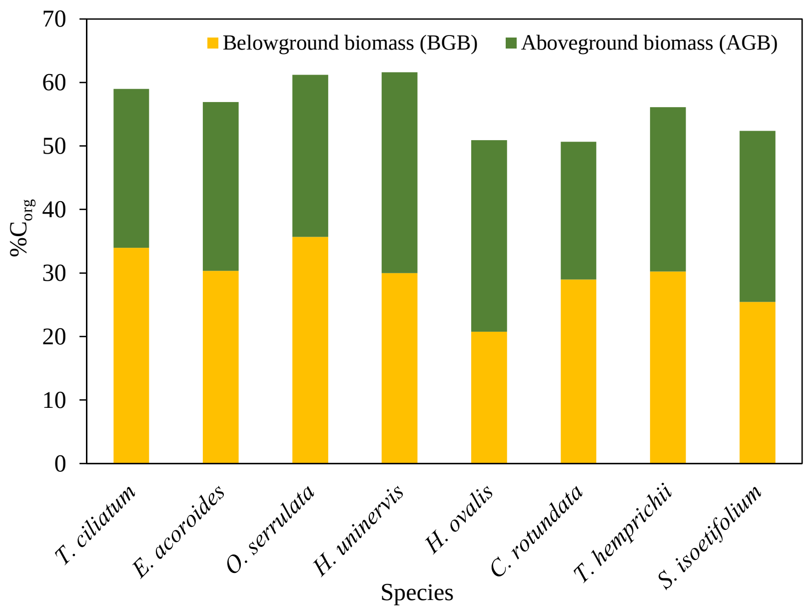

Figure 4. Carbon organic content ($\%C_{org}$) of each seagrass species

3.2.2 Sediment carbon stock

Seagrass ecosystems, pivotal for their carbon sequestration and retention functions, are intimately linked with sediment deposition, acting as primary carbon reservoirs crucial for long-term carbon storage. These sediments, integral to seagrass habitats, serve as optimal sites for carbon storage, effectively sequestering carbon reserves within the substrate, even amidst seagrass degradation and decomposition (Kennedy and Bjork, 2009). As highlighted by Faust et al. (2021), carbon retention within these sediments can endure for extensive periods, potentially spanning millennia. The containment of carbon within sediments presents a significant opportunity for prolonged preservation and ongoing accumulation, contingent upon the sustainability and upkeep of existing seagrass ecosystems (Kiswara and Ulumudin, 2009). Dry bulk density (DBD) and sediment organic carbon content ($\%C_{orgs}$) stand as crucial parameters employed to assess sediment carbon within seagrass ecosystems. Table 6 presents the measurements of these two parameters for the three sites on Semujur Island wherein the sediment organic carbon content is data averaged from the whole core.

Table 6. Sediment dry bulk density and organic carbon content in each site

Site	Sediment	Dry bulk density (g/cm^3)	Sediment organic carbon content (%C_{orgs})
Mead-1	Coarse sand	0.74±0.21	0.62±0.11
Mead-2	Coarse and fine sand	0.63±0.25	0.83±0.37
Mead-3	Fine sand	1.04±0.35	0.72±0.12

According to these findings following sediment analysis, Mead-3 exhibited the highest dry bulk density (DBD) at 1.04±0.35 g/cm^3, whereas Mead-2 recorded the highest sediment carbon organic content (C_{orgs}) at 0.83±0.37 %C_{orgs}. Differences in measurements can be ascribed to varying sediment conditions at each site. Sites characterized by fine sand sediment demonstrate an augmented ability for nutrient absorption compared to those with coarse sand sediment. The particle size of the underlying substrate plays a pivotal role in the organic matter binding process, with sediments containing smaller (finer) particle sizes exhibiting a heightened affinity for organic matter binding (Cyle et al., 2016). As a result, the distinct sediment conditions across the three sites can profoundly influence their respective capacities for carbon storage.

3.2.3 Total carbon stocks

Quantifying the total carbon stock in a particular location entails summing up the organic carbon within the entire seagrass biomass and the underlying sediment. The total carbon sequestered by seagrass and subsequently stored in sediment exhibited variations among sites. It is noteworthy that the site with the highest biomass carbon stocks does not necessarily correspond to the highest total carbon stocks (Figure 5). This observation can be linked to the specific characteristics of seagrass, sediment properties, and the overall environmental conditions unique to each site. Notably, Mead-3 emerges as the site with the highest total carbon stocks among the three sites under investigation, totaling 75.11 MgC/ha. This outcome may be attributed to a combination of factors, including significant seagrass biomass (due to the highest density), the presence of fine sand sediments with heightened carbon-absorbing capabilities, and the prevalence of optimal environmental conditions at Mead-3.

The data pertaining to carbon stocks within the seagrass ecosystem underscore the significant role of sedimentary carbon in the overall carbon stocks on Semujur Island. Sediment's capacity for carbon storage contributes approximately 90% of the total ecosystem carbon stocks in line with the findings of Stankovic et al. (2021). This outcome compellingly illustrates the crucial role played by seagrass ecosystems in carbon sequestration and subsequent storage within sediments. Consequently, areas or sites surrounded by seagrass meadows surpass those devoid of such vegetation in terms of their carbon storage potential. This attribute becomes particularly valuable when considering its utility in climate change mitigation, emphasizing the importance of preserving and maintaining these ecosystems.

In comparison with global and regional data (Indonesia) (Table 7), carbon stock values on Semujur Island fall within the range of the global average but exhibit lower values when contrasted with the regional average. The lower carbon stock measurements on the island may be attributed to specific contextual factors. Semujur Island, being a small landmass situated at a considerable distance from the main island, lacks vital carbon-contributing ecosystems such as mangrove habitats and tidal swamps. As highlighted by Ricart et al. (2020), a significant proportion of the most substantial carbon inputs, ranging from 70% to 90%, originate from allochthonous sources (external to the ecosystem), with autochthonous sources (internal to the ecosystem) accounting for only 10% to 30%. Field observations suggest that the carbon source within the seagrass ecosystem of Semujur Island is primarily internal, in stark contrast to other locations benefiting from external carbon sources. It is for this reason that the observed carbon stocks here are not as pronounced when compared with areas where additional external carbon sources enhance the ecosystem's carbon accumulation and storage.

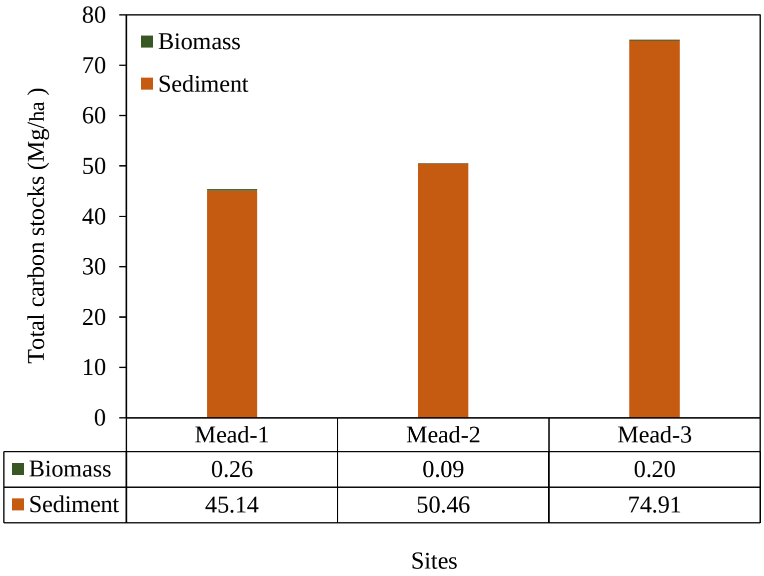

Figure 5. Total carbon stocks in the seagrass ecosystem of Semujur Island

Table 7. Comparison of carbon stock results with other studies

	Carbon stock (MgC/ha)		
	AGB	BGB	Sediment
Present study			
1. Mead-1	0.06	0.20	45.14
2. Mead-2	0.02	0.07	50.46
3. Mead-3	0.05	0.15	74.91
Global data (Fourqurean et al., 2012)	0.75 (0.001-5.548)	1.76 (0.001-17.835)	139.70 (9.10-628.10)
Regional data			
1. Java (Alongi et al., 2015)	0.66	1.75	62.40
2. South Sulawesi (Alongi et al., 2015)	0.26	0.55	148.40
3. East Kalimantan (Alongi et al., 2015)	0.01	0.02	243.30
4. Bali (Graha et al., 2016)	0.18	0.29	21.00
5. Lombok (Rahman et al., 2023)	0.14	0.30	48.40

3.3 Correlation between seagrass community structure and carbon stock

Notably, a correlation analysis was undertaken to explore the association between seagrass density and coverage with the acquired measurements of total carbon stock (sediment and biomass). According to Citra et al. (2020), elevated density and coverage have the potential to augment biomass within seagrass meadows, consequently influencing carbon storage. As it is clear that ecosystem carbon stocks are made up of primarily sediment carbon, further analysis in this study focused on the correlation between seagrass community structure and sediment carbon stock as a proxy for ecosystem carbon stocks. Sediment at different depths were used in the correlation analysis to see the relationship between community structure aboveground and the amount of carbon stored in sediment of varying depths.

The outcomes of this analysis unveiled a moderate correlation (0.430) between density and carbon stock, as well as between seagrass cover and carbon stock (0.528) (Table 8). These correlation findings suggest that the relationship between density and coverage with carbon stock is not notably robust. Initially anticipated to provide deeper insights into the link between community structure and total carbon stocks, this analysis reveals that multiple factors influence this relationship, and the findings of this study do not align with initial expectations. The portrayal of seagrass community structure through density and coverage in this investigation does not seem to serve as a robust predictive tool. The moderate correlations observed between community structure and carbon stock may partly stem from the limited dataset available for analysis. However, it is logical to infer that elevated density and coverage should bolster a seagrass meadow's ability for carbon absorption and storage. This logical inference can guide management strategies aimed at preserving, enhancing, or restoring existing seagrass meadows to optimize their carbon sequestration potential. For a more comprehensive understanding of the relationship between community structure and carbon stocks, future research endeavours should encompass a broader array of potential influencing factors.

Table 8. Correlation between seagrass community structure and carbon stocks for each stratification

Carbon stock at each water depth (MgC/ha)	Community structure	
	Seagrass density	Seagrass coverage
Depth 0-5 cm	0.426	0.528
Depth 5-20 cm	0.430	0.480
Depth 20-50 cm	0.377	0.308
Depth 50-100 cm	0.341	0.261

4. CONCLUSION

This research, focusing on the community structure of seagrass meadows surrounding Semujur Island, revealed notable variations among the different sites, influenced by factors such as seagrass size, density, species composition, and environmental conditions. Mead-3 particularly stands out, exhibiting the highest ecosystem carbon stock (75.11 MgC/ha), attributed to its distinctive community structure dominated by large species like *E. acoroides* and *T. hemprichii*, alongside sediment comprising partly fine sand. This study emphasizes the significance of considering ecological relationships in the management of seagrass ecosystems for effective climate change mitigation. Additionally, the findings offer valuable data as a reference for the restoration and conservation endeavors of seagrass ecosystems, indicating a correlation between higher seagrass density and coverage with increased carbon storage capacity within the ecosystem.

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