BIODIVERSITAS
Volume 24, Number 4, April 2023
Pages: 2080-2087

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240418

Diversity, carbon stock and associated biota of seagrass beds in Central Tapanuli District, North Sumatra, Indonesia

MIRA MAULITA[1], ERICK NUGRAHA[1], RATNA SUHARTI[1], NANDA W. TANJUNG[1], MOHAMMAD SAYUTI[1,♥], MUGI MULYONO[1], SAYURI MANTANI[2], R. HARYO BIMO SETIARTO[3]

[1]Politeknik Ahli Usaha Perikanan. Jl. AUP No. 1, Pasar Minggu, South Jakarta 12520, Jakarta, Indonesia. Tel.: +62-21-7806874, ♥email: mohsayut@gmail.com

[2]Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College. Ashiya City 659-0026, Hyogo, Japan

[3]Research Center for Applied Microbiology, National Research and Innovation Agency. Cibinong Science Center, Jl. Raya Jakarta-Bogor Km 46, Cibinong, Bogor 16911, West Java, Indonesia

Manuscript received: 23 February 2023. Revision accepted: 9 April 2023.

Abstract. *Maulita M, Nugraha E, Suharti R, Tanjung NW, Sayuti M, Mulyono M, Mantani S, Setiarto RHB. 2023. Diversity, carbon stock and associated biota of seagrass beds in Central Tapanuli District, North Sumatra, Indonesia. Biodiversitas 24: 2080-2087.* Various human activities emit carbon dioxide which drives global warming and climate change. Seagrass ecosystems can absorb and store enormous quantities of carbon, hence reducing carbon emissions. This research aimed to assess the diversity, vegetation cover, carbon stock and associated biota of seagrass beds in Central Tapanuli District, North Sumatra, Indonesia. Purposive sampling method was employed with data collection used the line transect quadrant method. Carbon stock was measured using the loss of ignition method. There were four species of seagrass in the studied area, namely *Enhalus acoroides* (L.f.) Royle, *Thalassia hemprichii* (Ehrenb. ex Solms) Asch., *Cymodocea rotundata* Asch. & Schweinf. and *Halodule uninervis* (Forssk.) Boiss. with a density ranging from 23-164 stands/m^2. Seagrass cover ranged from 3.87%-34.37%. Associated biota (fish and crustaceans) at each observation station were *Siganus javus* Linnaeus 1766, *Siganus canaliculatus* Park 1797, *Siganus vermiculatus* Valenciennes 1835, *Colomesus psittacus* Bloch & Schneider 1801, *Epinephelus fuscoguttatus* Forsskål 1775, *Terapon jarbua* Forsskål 1775, *Ambassis dussumieri* Cuvier 1828, *Cryptocentrus leptocephalus* Bleeker 1876, *Leiognathus robustus* Sparks & Dunlap 2004, *Portunus armatus* A.Milne-Edwards 1861, *Rhinolambrus pelagicus* Rüppell 1830 and *Hippolyte obliquimanus* Dana 1852. The total carbon stock of the top substrate (leaves) was 12.8 tons, while carbon bottom substrate (rhizomes and roots) was 12.9 tons, resulting in a total carbon stock of 25.7 tons. The analysis of water quality parameters indicated that the studied area had suitable environmental conditions for seagrass growth. The results of this study add new information regarding seagrass ecology of the western region of Indonesia, especially Sumatra.

Keywords: Biomass, carbon stock, *Enhalus acoroides*, seagrass, water quality

INTRODUCTION

Climate change is among unprecedented global problems that is now faced by humankind and all living organisms on the earth. Climate change occurs due to increased emissions of greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NOx), chlorofluorocarbons (CFCs) and other gases in the atmosphere, are reflected by the earth as infrared radiation. Such greenhouse gases are then trapped in the atmosphere, thereby increasing the earth's temperature (Latuconsina 2010). One of the efforts to reduce carbon dioxide levels in the atmosphere and the oceans is by using vegetation on terrestrial and marine ecosystems to absorb and store carbon in the form of living biomass (Wahyudi and Yona 2017; Nur et al. 2022). In marine ecosystems, the vegetation consists of low-level and higher-level plants with habitats in the ocean and coast (Duarte et al. 2005).

There are various policies and efforts at a global scale to tackle climate change. In the context of marine realm, there is an initiative so called blue carbon which was released in 2009 as the collaboration between the United Nations Environment Program (UNEP), the Food and Agriculture Organization (FAO), and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Blue carbon is carbon stored in marine ecosystems, namely mangrove ecosystems (Tebaiy et al. 2014), seagrass ecosystems (Budiarto et al. 2021), algae ecosystems (Runtuboi et al. 2018) and saltmarshes. The blue carbon concept highlights the ability of these marine ecosystems in reducing carbon emissions and storing carbon as important as terrestrial ecosystems such as tropical rain forests (Harimbi et al. 2019).

Seagrass is a higher plant group and flowering Angiosperms that fully adapt to living in shallow waters (Runtuboi et al. 2018). As a higher plant group, seagrasses produce their food through photosynthesis (autotrophs). A variety of species and individuals of seagrass might form a vegetation community which is often called seagrass beds or seagrass meadows. Seagrass beds have immense ecological functions, from the habitat of marine biota, prevent coastal erosion and abrasion, to absorb and store carbon and recognized as an important component of blue carbon storage (Runtuboi et al. 2018). Seagrass ecosystems can store large amounts of carbon (Hertyastuti et al. 2020) because it is supported by substrates that are saturated with water and seagrass's ability to capture sediment. The substrates are constantly flooded with water which create anoxic conditions that avoid carbon releases (Gunawan et al. 2019) so that carbon can be stored in seagrass ecosystems for a long time (Duarte et al. 2005).

Indonesia has a large extent of seagrass beds with a total area of 30,000 km^2, representing at least 5% of the world's total seagrass area (Green and Short 2003). Currently, 13 seagrass species have been recorded in Indonesia, namely *Cymodocea rotundata* Asch. & Schweinf., *Cymodocea serrrulata* (R.Br.) Asch. & Magnus, *Enhalus acoroides* (L.f.) Royle, *Halodule pinifolia* (Miki) Hartog, *Halodule uninervis* (Forssk.) Boiss., *Halophila decipiens* Ostenf., *Halophila minor* (Zoll.) Hartog, *Halophila ovalis* (R.Br.) Hook.f., *Halophila spinulosa* (R.Br.) Asch, *Halophila sulawesii* J.Kuo, *Syringodium isoetifolium* (Asch.) Dandy, *Thalassia hemprichii* (Ehrenb. ex Solms) Asch. and *Thalassodendron ciliatum* (Forssk.) Hartog. The seagrass species belong to 2 families and seven genera. These seven genera consist of 3 from the Hydrocharitaceae family, namely *Enhalus*, *Thalassia* and *Halophila*, and four from the Potamogetonaceae family, namely *Syringodium*, *Cymodocea*, *Halodule* and *Thalassodendron* (Philips and Menez 1988).

Indonesia likely has the largest extent of seagrass compared to any country (Unsworth et al. 2018). Indonesian seagrasses support high species richness of fish (Unsworth et al. 2014), sea turtles (Heithaus et al. 2014), and dugongs (Schipper et al. 2008), potentially storing at least 2% of the world's blue carbon (Alongi et al. 2016), and support seagrass resilience throughout the Indo-Pacific with high genetic diversity (Hernawan et al. 2017). Estimates show that as much as 40% of Indonesia's seagrasses are in danger of being lost (Tomascik et al. 1997; Nadiarti et al. 2012). One of the contributing factors is poor general knowledge about seagrass ecology (Ooi et al. 2011), and seagrasses are not a priority for large international NGOs and governments, as marine conservation funding focuses primarily on coral reefs and mangrove ecosystems (Unsworth et al. 2018).

Central Tapanuli District is located in North Sumatra Province, Indonesia. The western part of this district is marine area with some occurrences of seagrass. Up to date, there is no study to reveal the ecological information of seagrass in the coastal waters of Central Tapanuli despite the importance of this type of ecosystem. This study aims to examine the diversity, carbon stock, and associated biota of seagrass beds in the waters of Central Tapanuli District. We expected the results of this study might add a new information regarding seagrass ecology of the western region of Indonesia especially Sumatra.

MATERIALS AND METHODS

Study area and period

This study was conducted in the waters of Central Tapanuli District, North Sumatra Province, Indonesia. Data collection was carried out on March 8 to June 5, 2021 at three observation stations, namely station 1 (Hajoran), station 2 (Pandaratan) and station 3 (Pane Island) as presented in Figure 1. The observation stations were determined purposively based on the level of seagrass density, cover and water conditions which had clear conditions.

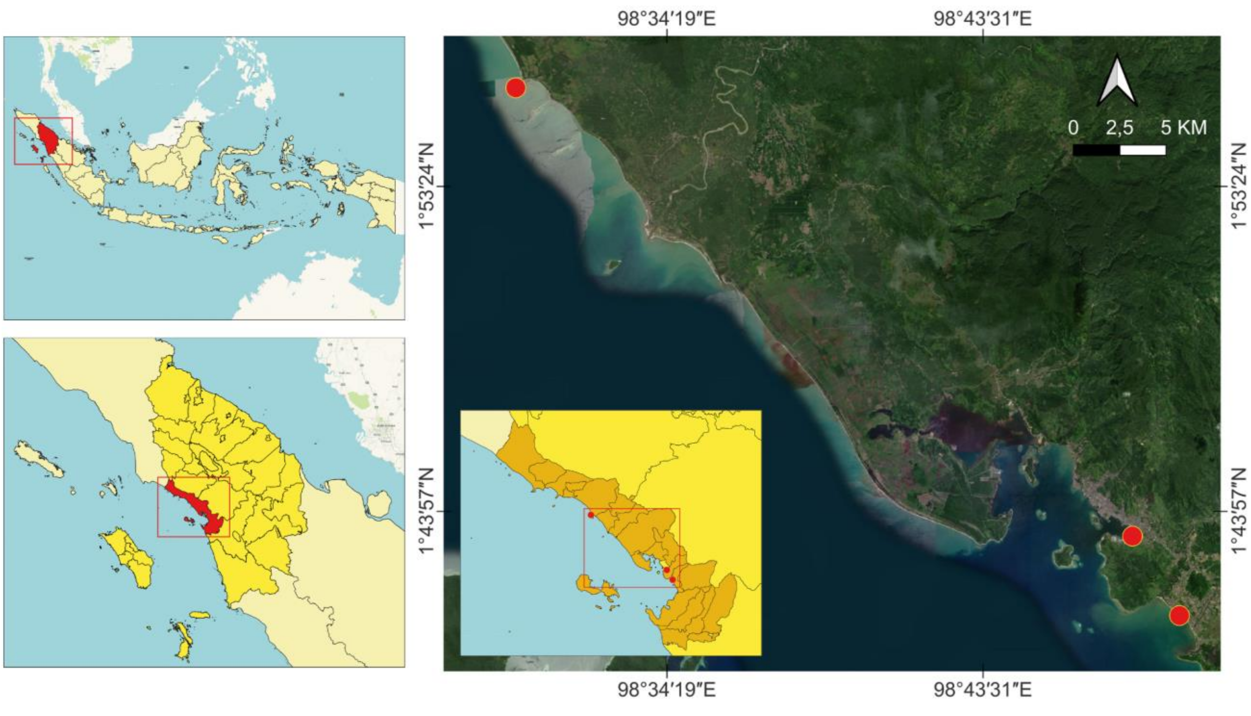

Figure 1. Map of three observation stations in Central Tapanuli District, North Sumatra Province, Indonesia

Research procedures

Seagrass vegetation analysis

Vegetation data were collected using the line transect quadrant method, and all observations made in this method were measured and visually observed in the field. This method followed the Seagrass Monitoring Guidebook (Rahmawati et al. 2014) published by LIPI (Indonesian Institute of Sciences). The line transect quadrant consisted of a line transect drawn over the seagrass ecosystem, and the quadrant (squared) is an equally quadrilateral frame measuring 50x50 cm, which is divided into four sub-quadrants measuring 25x25 cm which were placed on the line.

Six transect lines were laid out at observation station after observing the environment and seagrass conditions. The line transect was stretched perpendicular to the shoreline, starting from point 0 (zero) on the roll meter. The observation station consisted of six line transects as replicates, with a distance between lines to the side of 25 m. The distance between quadratic transects in one transect line was 10 m and replications were carried out until the end of the transect line reached 100 m, resulting in eleven quadratic transects along each line as can be seen in Figure 2.

The seagrass found between the line transects were taken by digging a 20x20 cm quadrat to obtain the roots, rhizomes, and leaves as the samples. Samples were taken outside the transect line to not disturb the monitoring area of the seagrass community structure. This method was done by digging the seagrass to the depth of the roots and cutting the rhizomes that spread to the side (outer boundary of the quadrant or transect). The seagrass taken was then cleaned with adhering substrate and put into a labeled sample bag to be brought to the laboratory. Repeated sampling was carried out randomly on the line transect as many as three points from six transect points at each observation station to represent the seagrass community.

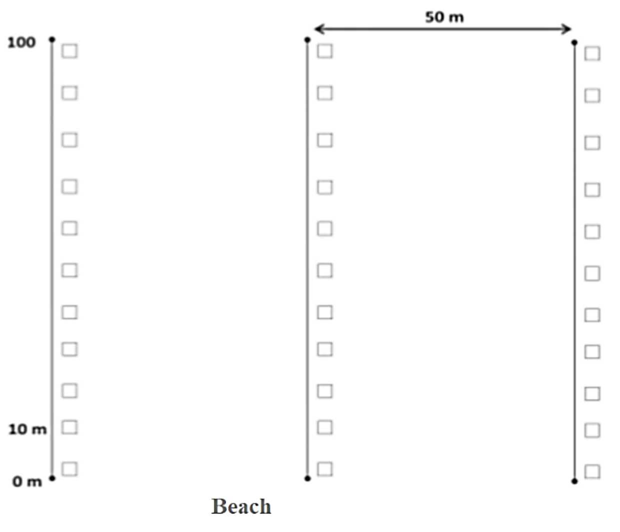

Figure 2. Diagrammatic of line transect quadrant method at each observation station following (Rahmawati et al. 2014)

Seagrass biomass measurement

The analysis of seagrass biomass was conducted in the laboratory and then calculated using a particular formula according to (Rustam et al. 2019). The biomass was then grouped into categories under substrate (roots, rhizomes) and upper substrate (leaves). Seagrass sample biomass was measured trough drying and weighing in the laboratory. Seagrass sample was placed in an oven at a temperature of 100°C for 16 to 24 hours or until the sample reached a constant weight. Measurement of biomass per stand of seagrass was be determined by dividing the total weight of each sample by the number of stands (density). The relationship between density and seagrass biomass was used to predict the value of seagrass biomass at all density sampling points (Duarte 1990).

The value of carbon content in seagrass tissue samples (leaves, rhizomes, and roots) was analyzed using the LOI (Loss on Ignition) method or referred to as the ash method (Helrich 1990). This method was carried out with the following procedure: the sample porcelain cup was put into an electric furnace for 16 hours to 24 hours at a temperature of 550°C, then a weighing process was carried out. Carbon content in seagrass was calculated following (Helrich 1990).

Data analysis

The density of each species at each station was calculated based on the formula according to (Hartati et al. 2017). Seagrasses' percent cover (% cover) was analyzed using the procedure according to (Rahmawati et al. 2014). Seagrass biomass was measured using dry weight value and seagrass density value (stand/m^2) following Duarte (1990). Calculation of the carbon content of seagrass tissue used the ashing method, which included the value of ash content, organic material content, and carbon content according to Helrich (1990). Calculation of the total carbon content of seagrass in the study area was analyzed by converting the biomass data into carbon content. The estimated carbon content value was averaged and used as the carbon content value of the seagrass tissue.

RESULTS AND DISCUSSION

This study observed the general condition of the study site in the waters of Central Tapanuli, seagrass species, individual density, percentage of cover, diversity index, uniformity index, dominance index, identification of associated fish biota, biomass, carbon measurement, total stock of carbon, and water quality. There were four species of seagrasses in the studied area that occurred on the substrate/sediment with sand, silty sand, and sandy mud, namely *E. acoroides, T. hemprichii, C. rotundata,* and *H. uninervis.*

Seagrass density and coverage

Observation of seagrass density at each observation station was based on the number of stands of each species. On the other hand, the percentage of seagrass cover was defined as how much seagrass covered the water and was usually expressed in percent (%) (Hidayat et al. 2019). The highest seagrass density was at station 2 (Pandaratan), followed by station 1 (Hajoran) and the lowest at station 3 (Pane Island). There were three types of seagrass at station 2: *H. uninervis*, *C. rotundata* and *E. acoroides*. The highest density at station 2 was *H. uninervis*, with density value of 164.5 stands/m^2 (Figure 3). Station 1 was identified having two seagrass species, namely *E. acoroides* and *T. hemprichii*. Stations 1 and 3 were dominated by *E. acoroides* with density values of 114.45 stands/m^2 and 78.35 stands/m^2, respectively. Meanwhile, the lowest density of seagrass across the three stations was *T. hemprichii* with 23 stands/m^2.

The distribution of seagrass in the studied area tended to be only a few species at each observation station which is thought to be related to the adaptability of the seagrass species to its environment and the different in substrate characteristics and environmental conditions between stations. According to Tishmawati et al. (2014), the density of seagrass shoots per area depends on the species. Seagrass distribution depends on several factors, namely water brightness (depth <10 m), temperature (28 to 30°C), salinity (10-40 ppt), substrate (40% coarse and fine silt) and current velocity (about 0.5 m/s) (Gosari and Haris 2012).

The percentage of cover indicated that the seagrass with the highest portion of coverage was *E. acoroides* with 34.37% (Table 1). Seagrass cover is influenced by seagrass density and morphology, especially leaf width. Because the broader the seagrass leaves, the more substrate area will be covered (Sarinawaty et al. 2020). This is in line with the result of our study that the highest percentage cover was *E. acoroides* which has an elongated and slightly wide leaf shape. Meanwhile, the smaller the size of seagrass will have a smaller coverage. The high percentage of seagrass cover at the observation site is likely because this species had the highest tolerance for growth in the waters of Central Tapanuli District.

Seagrass biomass

The result of analysis showed that the total biomass of bottom substrate was 734.87 gbk/m^2 at station 2 and 418.35 gbk/m^2 at station 3, which was greater than the total biomass of top substrate with 714.33 gbk/m^2 at station 2 and 324.29 gbk/m^2 at station 3 (Figure 4). This is because the rhizomes contain a lot of starch and nutrients in which these substances are produced from the photosynthetic results stored at the bottom of the substrate so that the biomass in the rhizomes is higher than other tissues. On the other hand, at station 1, the total biomass on the top of the substrate was 533.1 gbk/m^2, which is higher than at the bottom of the substrate with 532.4 gbk/m^2. This difference is because one of the adaptations of seagrass plants is to store biomass bottom substrate to grip the substrate firmly (Rahadiarta et al. 2019). Roots and rhizomes can absorb a lot of nutrients in the substrate, which is expected to affect the biomass in seagrass (Parnata et al. 2020). According to Bachmid et al. (2018), biomass is the total amount of living material of a plant, and in some plants, biomass can be calculated through the dry weight of the plant. The value of biomass can be influenced by density, where the higher the density of the seagrass, the higher the biomass of the seagrass (Wismar et al. 2021).

Station 2 had the highest biomass compared to other observation stations due to higher density of *H. uninervis* and *C. rotundata* (Figure 4). Biomass is affected by seagrass density. The greater the density of seagrass, the greater the biomass contained (Christon et al. 2014). Station 3 had the lowest total biomass compared to other observation stations because the seagrass type with a large morphology, namely the *E. acoroides*, had a relatively small density.

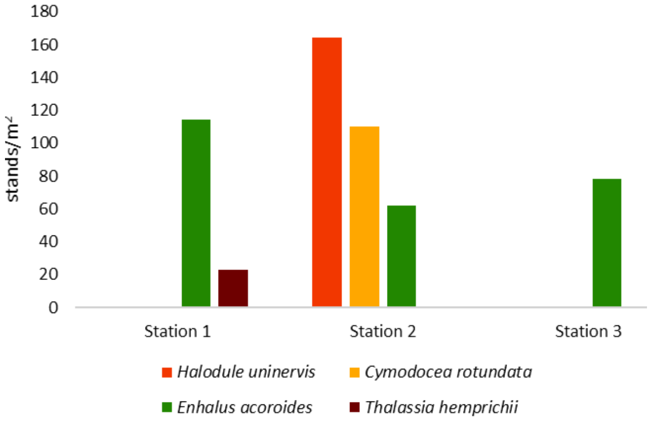

Figure 3. Seagrass density of each species at each observation station in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

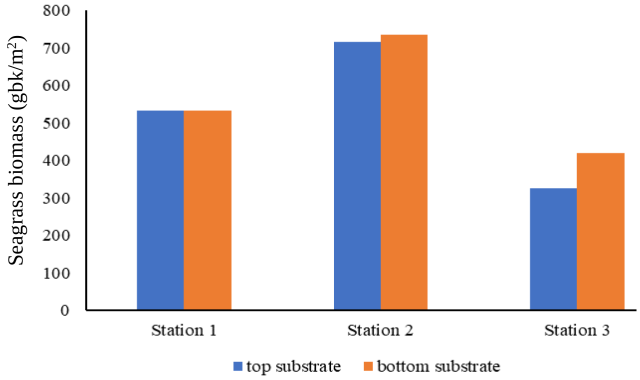

Figure 4. Total seagrass biomass of top substrate and bottom substrate at each observation station in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Table 1 Percentage of seagrass cover of each species at each observation station in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Family	Species name	Coverage (%)		
		Station 1	Station 2	Station 3
Potamogetonaceae	*Halodule uninervis* (Forssk.) Boiss	-	6.88	-
	Cymodocea rotundata Asch. & Schweinf	-	4.06	-
Hydrocharitaceae	*Enhalus acoroides* (L.f.) Royle	34.22	27.80	34.37
	Thalassia hemprichii (Ehrenb. ex Solms) Asch	3.87	-	-

Ash content and organic material

The analysis of organic material and ash content showed that the organic material bottom substrate had a higher value than that top substrate, it is reversed with the ash content where the top substrate is higher than the bottom (Table 2). Although different, the top and bottom substrates have the same proportion; both have a value of 6% ash content and 96% material organic. It is estimated that there was sample that undergoes evaporation during ashing. It is known that the mineral material contained in the sample is estimated to be more in the sample of the bottom substrate (Table 2). Usually, the rest of the dry weight in the sample occurs during the evaporation process in the form of organic minerals. The content of organic material is also influenced by density (Parnata et al. 2020). Organic material can also affect seagrass density, where the higher the density and morphology of the seagrass, the more organic material will be bound to the bottom of the water (Lestari et al. 2020).

Seagrass carbon content

Based on the calculation of the carbon content of the dominant seagrass species using the LOI (Loss of Ignition) ashing method, it was found that the highest carbon content was found in *H. uninervis* with a carbon content of 55.59 gC/m^2, followed by *C. rotundata* with carbon content of 55.38 gC/m^2, and the lowest carbon content was *T. hemprichii* with 52.52 gC/m^2 (Figure 5). The high carbon content of the *H. uninervis* is due to the higher biomass compared to other species in the study site as stated by (Lestari et al. 2020). This result is in line with the statement of (Yuniwati and Suhartana 2014) that the greater the biomass, the greater the carbon. Carbon content can be interpreted as the amount of carbon absorbed by seagrass in the form of biomass. The carbon content in seagrass illustrates how much the seagrass can bind CO_2 from the air (Maramis et al. 2020). In seagrass, carbon is stored in leaves, rhizomes, and roots. Some of the carbon in the seagrass forms a substance called carbohydrate. Seagrass carbon in the form of biomass is stored as long as the seagrass is still alive (Lestari et al. 2020).

The average carbon content of bottom substrate (rhizome and roots) was 54.41 gC/m^2, while that of top substrate (leaves) had an average of 54.29 gC/m^2, suggesting that carbon content is not too much different between above and bottom substrate (Figure 6). This is because the carbon content of bottom substrate is not too affected by physical environmental factors compared to the carbon content of top substrate, which is more influenced by water factors such as temperature and others. Lestari et al. (2020) stated that the carbon content of bottom substrate will be stored in the sediment even though the shoots on the seagrass have died, while the carbon top substrate will only be stored if the seagrass shoots are still alive. The result of this study is similar to the research of Rahadiarta et al. (2019), which showed that bottom substrate, the carbon content is higher than top substrate. High carbon content in bottom substrate is essential because carbon will be accumulated by sediments (Parnata et al. 2020).

The total carbon stock of seagrass in each observation station was estimated from the average calculation of the carbon stock multiplied by the seagrass area at the time of data collection. Based on the analysis, the highest total carbon stock was at station 2 (Pandaratan Beach) with most of the carbon stored in bottom substrate (Table 3). The estimated total carbon stock of top substrate (leaves) was 12.8 tons while that if bottom substrate (rhizomes and roots) was 12.9 tons, resulting a total carbon stock of seagrass beds in Central Tapanuli being 25.7 tons. *E. acroides* contributed the most significant carbon stock which can be seen from the relationship between seagrass density, occurrence frequency value, biomass value, and carbon content value, where almost all transects occurred *E. acroides*, either singly (only *E. acroides*) or multiple species dominated by *E. acroides*.

Table 2. Ash content and organic material top substrate and bottom substrate of seagrass in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Material	Top substrate		Bottom substrate	
	Content	(%)	Content	(%)
Ash content	6.4	6	6.19	6
Organic material	92.32	94	93.81	94

Note: %: Percentage

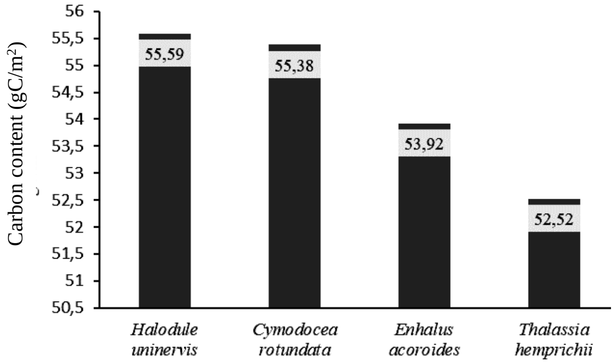

Figure 5. Carbon content in each species of seagrass in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

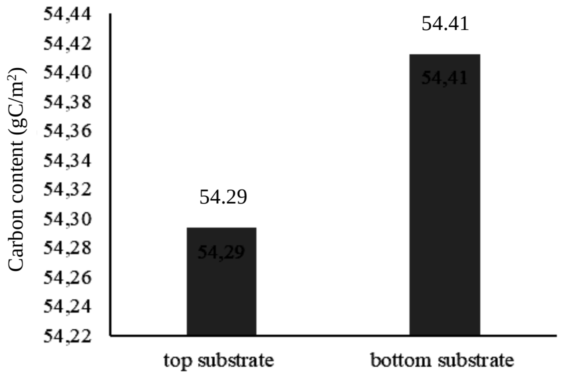

Figure 6. Average carbon content top substrate and bottom substrate in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Table 3. Estimated total carbon stock at each observation station substrate in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Observation station	Top substrate (tons)	Bottom the substrate (tons)	Total carbon stock (tons)
Station 1	5.338	5.296	10.634
Station 2	6.608	6.699	13.307
Station 3	0.854	0.905	1.759

Associated biota

Based on the observation, station 2 (Pandaratan Beach) had the highest number of marine biota with eight fish species and three associated crustacean species (Table 4). In contrast, station 3 (Pane Island Beach) had the lowest number of marine biota with only five fish and three crustacean species. This is because the diversity of fish communities is related to the variety of habitat types and ecological processes in which species and genetic diversity exist.

Water quality parameters

Stations 1 and 2 both had a temperature of 30°C, while at station 3 had a temperature of 32°C (Table 5). The optimum temperature for seagrass growth is 28-30°C (Collier et al. 2017). This means that the temperature range at station 1 (Hajoran Beach) and station 2 (Pandaratan Beach) was categorized as still optimum for seagrass growth, while on station 3 (Pane Island), it exceeded the optimal temperature. High temperature results in the increase in sediment temperature, resulting in the loss of leaves. Temperature dramatically affects physiological processes including photosynthesis, respiration rate, development, and reproduction.

The measured depth at the three observation stations ranged from 0.3 to 1.6 meters. Shallow water conditions affect seagrass life because changes in water depth can affect several other aquatic environmental factors, namely temperature, light intensity, and water hydrodynamics. In natural waters, brightness is essential because it is closely related to the photosynthetic activity (Muarif et al. 2017). The brightness of the waters at the three measured observation stations was 100%, meaning that sunlight reached the bottom of the sea.

The pH condition of the waters at the observation station was 7 while the salinity ranged from 33-34 ppt (‰) which are suitable conditions for seagrass life and its biota. According to Rosalina et al. (2018), the optimum salinity for marine organisms is between 27-34‰. The substrate is a growth medium for seagrass that plays a role in seagrass distribution starting from the shoreline and at the lowest tide. The type of substrate at station 1 (Hajoran Beach) was dominated by the coarse-grained sand substrate with other part of the transect near the edge, the substrate found was gravel (stone grains and coral fragments). On the other hand, the substrate at station 2 (Pandaratan Beach) and station 3 (Pane Island Beach) was mud substrate and a small portion of the fine black sand substrate. The role of substrate depth in sediment stability includes two things, namely protecting plants from ocean currents and processing sites and nutrient suppliers. This condition allows the seagrass to grow and develop well because the type of sandy substrate will make it easier to stick its roots into the substrate.

Table 4. Associated biota (fish and crustaceans) at each observation station in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Biota		Observation station		
Species name	**Scientific name**	**Station 1**	**Station 2**	**Station 3**
Streaked spine foot	*Siganus javus* Linnaeus 1766	6	15	3
Pinspotted spinefoot	*Siganus canaliculatus* Park 1797	1	13	4
Vermiculated spinefoot	*Siganus vermiculatus* Valenciennes 1835	-	6	-
Banded puffer	*Colomesus psittacus* Bloch & Schneider 1801	1	1	-
Brown-marbled grouper	*Epinephelus fuscoguttatus* Forsskål 1775	-	1	-
Thornfish	*Terapon jarbua* Forsskål 1775	20	30	11
Barehead Glassfish	*Ambassis dussumieri* Cuvier 1828	-	9	1
Pink-speckled shrimpgoby	*Cryptocentrus leptocephalus* Bleeker 1876	2	7	4
Ray-finned Fish	*Leiognathus robustus* Sparks & Dunlap 2004	1	-	-
Blue swimmer crab	*Portunus armatus* A.Milne-Edwards 1861	1	4	2
Elbow Crab	*Rhinolambrus pelagicus* Rüppell 1830	2	2	2
Shrimp	*Hippolyte obliquimanus* Dana 1852	2	10	1
Total		36	98	28

Table 2. Water quality parameters at each observation station in the waters of Central Tapanuli District, North Sumatra Province, Indonesia

Parameter	Observation station			BM
	Station 1	Station 2	Station 3	
Substrate	Muddy sand and coral fragments	Muddy sand and coral fragments	Dirty sand and coral fragments	-
Physical parameters				
Temperature (°C)	30	30	32	28-30
Depth (cm)	40-140	30-160	50-150	-
Brightness (%)	100	100	100	-
Chemical parameter				
Salinity (‰)	33	33	34	33-34
pH	7	7	7	7-8.5

Based on observations of seagrasses in the waters of Central Tapanuli District, four species of seagrass were found across three observation stations, namely *E. acoroides*, *T. hemprichii*, *C. rotundata* and *H.uninervis* with a density of seagrass species ranging from 23 stands/m^2 –164 stands/m^2. Seagrass cover ranged from 3.87%-34.37%. The most dominant seagrass species was *E. acoroides*. Marine biota found at the observation site included: *S. javus*, *Siganus canaliculatus, S. vermiculatus*, *E. fuscoguttatus, T. jarbua*, *C. psittacus, A. dussumieri*, *C. leptocephalus, L. robustus, P. armatus, R. pelagicus*, and *H. variance*. The estimated total carbon of top substrate (leaves) was 12.8 tons while that of carbon bottom substrate (rhizomes and roots) was 12.9 tons, resulting an estimated total carbon storage in seagrass beds in the waters of Central Tapanuli District being 25.7 tons. The water quality parameters were suitable to support seagrass life and associated marine biota.

REFERENCES

Alongi DM, Murdiyarso D, Fourqurean JW, Kauffman JB, Hutahaean A, Crooks S, Lovelock CE, Howard J, Herr D, Fortes M, Pidgeon E, Wagey T. 2016. Indonesia's blue carbon: A globally significant and vulnerable sink for seagrass and mangrove carbon. Wetl Ecol Manag 24: 3-13. DOI: 10.1007/s11273-015-9446-y.

Bachmid F, Sondak C, Kusen J. 2018. Estimation of carbon absorption in the Bahowo mangrove forest, Tongkaina Village, Bunaken District. J Coast Trop Seas 6 (1): 8. DOI: 10.35800/jplt.6.1.2018.19463.

Budiarto MARR, Iskandar J, Pribadi TDK. 2021. Carbon stocks in seagrass ecosystems in Siantan Tengah, Anambas Archipelago Marine Tourism Park. J Trop Oceanol 24 (1): 45-54. DOI: 10.14710/jkt.v24i1.9348.

Christon C, Djunaedi OS, Purba NP. 2014. Effect of tidal height on growth and leaf biomass of *Enhalus acoroides* seagrass on Pari Island, Seribu Islands, Jakarta. Mar Fish J 3 (3): 287-294.

Collier CJ, Ow YX, Langlois L, Uthicke S, Johansson CL, O'Brien KR, Hrebien V, Adams MP. 2017. Optimum Temperatures for Net Primary Productivity of Three Tropical Seagrass Species. Front Plant Sci 8 (1446): 1-14. DOI: 10.3389/fpls.2017.01446.

Duarte C, Middelburg JJ, Caraco N. 2005. Major role of marine vegetation on the oceanic carbon cycle. Biogeosciences 2 (1): 1-8. DOI: 10.5194/bg-2-1-2005.

Duarte C. 1990. Seagrass nutrient content. Mar Ecol Prog Ser 67: 201-207. DOI: 10.3354/meps067201.

Gosari BAJ, Haris A. 2012. Study of seagrass density and coverage at Spermonde Archipelago. Torani 22 (3): 156-162.

Green EP, Short FT. 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley.

Gunawan JV, Parengkuan M, Wahyudi AJ, Zulpikar F. 2019. Estimation of carbon stocks in seagrass biomass on Semak Daun Island, Seribu Islands. Oceanol Limnol Indones 4 (2): 89-99. DOI: 10.14203/oldi.2019.v4i2.229. [Indonesian]

Harimbi KA, Taufiq-Spj N, Riniatsih I. 2019. Potential for carbon storage in seagrass species *Enhalus acoroides* and *Cymodocea serrulata* in Jepara Waters. Mar Oceanog Bull 8 (2): 109-115. DOI: 10.14710/buloma.v8i2.23657.

Hartati R, Widianingsih W, Santoso A, Santoso A, Endrawati H, Zainuri M, Riniatsih I, Saputra W, Mahendrajaya RT. 2017. Variations in composition and density of seagrass species in Ujung Piring Waters, Jepara District. J Trop Ocean 20 (2): 96-105. DOI: 10.14710/jkt.v20i2.1702.

Heithaus MR, Alcoverro T, Arthur R, Burkholder DA, Coates KA, Christianen MJA, Kelkar N, Manuel SA, Wirsing AJ, Kenworthy WJ, Fourqurean JW. 2014. Seagrasses in the age of sea turtle conservation and shark overfishing. Front Mar Sci 1 (28): 1-6. DOI: 10.3389/fmars.2014.00028.

Helrich. 1990. Official methods of analysis of the association of official analytical chemists. association of official analytical chemists. Official Method Anal 1 (1): 771.

Hernawan UE, van Dijk KJ, Kendrick GA, Feng M, Biffin E, Lavery PS, McMahon K. 2017. Historical processes and contemporary ocean currents drive genetic structure in the seagrass *Thalassia hemprichii* in the Indo-Australian Archipelago. Mol Ecol 26 (4): 1008-1021. DOI: 10.1111/mec.13966.

Hertyastuti PR, Putra RD, Apriadi T, Suhana MP, Idris F, Nugraha AH. 2020. Estimation of carbon storage in the seagrass meadows ecosystem of Dompak and Berakit waters, Riau Islands. Jurnal Ilmu dan Teknologi Kelautan Tropis 12 (3): 849-862. DOI: 10.29244/jitkt.v12i3.32199. [Indonesian]

Hidayat W, Warpala WS, Dewi SR. 2019. Composition of seagrass species and biophysical characteristics of waters in the port area of Celukanbawang Village, Gerokgak District, Buleleng District, Bali. J Biol Educ Undiksha 5 (3): 133-145. DOI: 10.23887/jjpb.v5i3.21966. [Indonesian]

Latuconsina H. 2010. The impact of global warming on coastal and marine ecosystems. Agrikan: J Agro Fish 3 (1): 30. DOI: 10.29239/j.agrikan.3.1.30-37. [Indonesian]

Lestari KIV, Hendrawan IG, Faiqoh E. 2020. Estimation of carbon storage in seagrass beds in the karang sewu beach area, Gilimanuk, Bali. J Mar Res Technol 3 (1): 40-46. DOI: 10.24843/JMRT.2020.v03.i01.p07.

Maramis MA, Th Wagey B, Rumengan AP, Sondakh CF, Opa ET, Kondoy KF. 2020. Carbon in seagrass beds in old Manado Island waters. Jurnal Pesisir dan Laut Tropis 8 (2): 79-91. DOI: 10.35800/jplt.8.2.2020.29950. [Indonesian]

Muarif, Zakirah RY, Rusaini. 2017. The effect of thallus density on the growth o in vitro culture of *Eucheuma cottonii*. Proceedings of the IV National Symposium on Maritime Affairs and Fisheries at Hasanuddin University, Makassar.

Nadiarti A, Riani E, Djuwita I, Budiharsono S, Purbayanto A, Asmus H. 2012. Challenging for seagrass management in Indonesia. J Coast Dev 15: 234-242.

Nur AAI, Arifiani KN, Ramadhandi AR, Sabrina AD, Nugroho GD, Kusumaningrum L, Ramdhun D, Bao TQ, Yap CK, Budiharta S, Setyawan AD. 2022. Estimation of aboveground biomass and carbon stock in Damas Beach, Trenggalek District, East Java, Indonesia. Indo Pac J Ocean Life 6: 103-109. DOI: 10.13057/oceanlife/o060203.

Ooi JLS, Kendrick GA, Van Niel KP, Affendi YA. 2011. Knowledge gaps in tropical Southeast Asian seagrass systems. Estuar Coast Shelf Sci 92: 118-131. DOI: 10.1016/j.ecss.2010.12.021.

Parnata IKA, Putra IDNN, Indrawan GS. 2020. Carbon storage in seagrass beds in Tanjung Benoa Waters, Bali. J Mar Aquat Sci 6 (1): 13-21. DOI: 10.24843/jmas.2020.v06.i01.p02.

Philips CR, Menez EG.1988. Seagrass. Smithsonian Contribusion to the Marine Science no.34. Smithsonian Institutions Press, Washington DC.

Rahadiarta IKVS, Putra IDNN, Suteja Y. 2019. Carbon storage in seagrass beds in the Mengiat Beach Area, Nusa Dua Bali. J Mar Aquat Sci 5 (1): 1-10. DOI: 10.24843/jmas.2019.v05.i01.p01.

Rahmawati S, Irawan A, Supriyadi IH, Azkab MH. 2014. Guidelines for Seagrass Monitoring (Issue 1). COREMAP CTI LIPI. Sarana Komunikasi Utama Co.Ltd, Jakarta.

Rosalina D, Herawati EY, Risjani Y, Musa M. 2018. Lamun diversity in District of South Bangka Province Bangka Belitung Islands. EnviroSci 14 (1): 21-28. DOI: 10.20527/es.v14i1.4889. [Indonesian]

Runtuboi F, Nugroho J, Rahakratat Y. 2018. Biomassa and accumulation carbon on seagrass *Enhalus acroides* in Gunung Botak Bay Coastal, West Papua. Sumberdaya Akuatik Indopasifik 2 (2): 91-102. DOI: 10.30862/jsai-fpik-unipa.2018.Vol.2.No.2.47. [Indonesian]

Rustam A, Adi NS, Daulat A, Kiswara W, Yusup DS, Rappe RA. 2019. Guidelines for Measuring Carbon in Seagrass Ecosystems. ITB Press, Bandung.

Sarinawaty P, Idris F, Nugraha AH. 2020. Morphometric characteristics of seagrass *Enhalus acoroides* and *Thalassia hemprichii* on the coast of Bintan Island. J Mar Res 9 (4): 474-484. DOI: 10.14710/jmr.v9i4.28432.

Schipper J, Chanson J.S, Chiozza F, Cox NA, Hoffmann M, Katariya V, Lamoreux J, Rodrigues ASL, Stuart SN, Temple HJ, Baillie J, Boitani L, Lacher Jr TE, Mittermeier RA, Smith AT, Absolon D, Aguiar JM, Amori G, Bakkour N, Baldi R, Berridge RJ, Bielby J, Black PA, Blanc JJ, Brooks TM, Burton JA, Butynski TM, Catullo G, Chapman R, Cokeliss Z, Collen B, Conroy J, Cooke JG, da Fonseca GAB, Derocher AE, Dublin HT, Duckworth JW, Emmons L, Emslie RH,Festa-Bianchet M, Foster M, Foster S, Garshelis DL, Gates C, Gimenez-Dixon M, Gonzalez S, Gonzalez-Maya JF, Good TC, Hammerson G, Hammond PS, Happold D, Happold M, Hare J, Harris RB, Hawkins CE, Haywood M, Heaney LR, Hedges S, Helgen KM, Hilton-Taylor C, Hussain SA, Ishii N, Jefferson TA, Jenkins RKB, Johnston CH, Keith M, Kingdon J, Knox DH, Kovacs KM, Langhammer P, Leus P, Lewison R, Lichtenstein G, Lowry LF, Macavoy Z, Mace GM, Mallon DP, Masi M, McKnight MW, Medellín RA, Medici P, Mills G, Moehlman PD, Molur S, Mora A, Nowell K, Oates JF, Olech W, Oliver WRL, Oprea M, Patterson BD, Perrin WF, Polidoro BA, Pollock C, Powel A, Protas Y, Racey P, Ragle J, Ramani P, Rathbun G, Reeves RR, Reilly SB, Reynolds III JE, Rondinini C, Rosell-Ambal RG, Rulli M, Rylands AB, Savini S, Schank CJ, Sechrest W, Self-Sullivan C, Shoemaker A, Sillero-Zubiri C, De Silva N, Smith DE, Srinivasulu C, Stephenson PJ, van Strien N,92 Talukdar BK, Taylor BL, Timmins R, Tirira DG, Tognelli MF, Tsytsulina K, Veiga LM, Vié J, Williamson EA, Wyatt SA, Xie Y, Young BE. 2008. The status of the world's land and marine mammals: Diversity, threat, and knowledge. Science 322 (5899): 225-230. DOI: 10.1126/science.1165115.

Tebaiy S, Yulianda F, Muchsin I. 2014. Fish community structure at seagrass beds habitat in Youtefa Bay Jayapura Papua. Ichtiol Indonesia J 14 (1): 49-65. DOI: 10.32491/jii.v14i1.95.

Tishmawati RNC, Suryanti, Ain C. 2014. Relationship between seagrass density and Syngnathidae abundance on Panggang Island, Seribu Islands. Manag Aquat Res J 3 (4): 147-153. DOI: 10.14710/marj.v3i4.7049.

Tomascik T, Mah JA, Nontji A, Moosa KM. 1997. The Ecology of the Indonesian Seas (Part II). University of Oxford Press, Oxford.

Unsworth RK, Ambo-Rappe R, Jones BL, La Nafie YA, Irawan A, Hernawan UE, Moore AM, Cullen-Unsworth LC. 2018. Indonesia's globally significant seagrass meadows are under widespread threat. Sci Total Environ 634: 279-286. DOI: 10.1016/j.scitotenv.2018.03.315.

Unsworth RK, Hinder SL, Bodger OG, Cullen-Unsworth LC. 2014. Food supply depends on seagrass meadows in the coral triangle. Environ Res Lett 9 (9): 1-9. DOI: 10.1088/1748-9326/9/9/094005.

Wahyudi I, Yona AJ. 2017. Carbon stock in seagrass meadows of Bintan Island, Riau Archipelago abstract introduction methodology. Oceanol Limnol Indones 2 (3): 1-11. DOI: 10.14203/oldi.2017.v2i3.99.

Wismar JE, Setyati WA, Riniatsih I. 2021. Potential for carbon storage in seagrass vegetation in North Pulau Besar Waters, Sikka, Maumere, East Nusa Tenggara. Mar Oceanog Bull 10 (1): 51-60. DOI: 10.14710/buloma.v10i1.27223.

Yuniwati Y, Suhartana S. 2014. Carbon potential of waste timber harvesting *Acacia crassicarpa*. Undip J Environ Sci 12 (1): 21-31. DOI: 10.14710/jil.12.1.21-31.