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Research Article

The estimation of carbon storage in the seagrass meadows of Badi Island

Nurazizah Pratiwi Baharudin [1], **Khusnul Yaqin** [1], **Supriadi Mashoreng** [2]

[1] Departemen of Marine Resources Management, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia.
[2] Marine Science Study Program, Marine Science Major, Hasanuddin University, Indonesia.

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Correspondence:
Nurazizah Pratiwi Baharudin
Center for Coastal and Small Islands Studies, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalanrea, Makassar, South Sulawesi, Indonesia 93618
diskan.kolut01@gmail.com

ABSTRACT. Global warming is becoming increasingly apprehensive day by day, marked by the continued increase in levels of carbon dioxide (CO_2) in nature. One of the efforts made to reduce the effects of global warming is biosequestration by empowering photosynthetic organisms, one of which is seagrass beds. This study aims to measure the density and percentage of seagrass cover, biomass value, and estimate carbon storage in seagrass biomass in the form of tissue at the top (leaves and upright stems) and tissue at the bottom (roots and rhizomes), as well as estimate carbon storage in sediments. Sampling was carried out using line transect and quadrant plot methods at each station. Calculation seagrass carbon storage using the Loss of Ignition (LOI) method at the Soil Chemistry Laboratory of the Pangkep State Agricultural Polytechnic, a total of 5 species of seagrass were found, namely *Enhalus accoroides*, *Thalassia hemprichii*, *Halodule uninervis*, *Halopila ovalis*, and *Cymodocea rotundata*. The average seagrass carbon storage on Badi Island is 18.92 gC/m^2, or 0.189 MgC/ha. The species that act as the largest contributor to carbon storage are Cymodocea rotundata, namely 35.44 gC/m^2, and *Halopila ovalis*, which acts as the lowest contributor to carbon storage, namely 1.92 gC/m^2. The average seagrass carbon storage at the bottom of the substrate was three times greater than that at the top of the substrate, namely 14.10 gC/m^2 at the bottom and 4.82 gC/m^2 at the top. The average carbon storage in sediments is 10.98 gC/m^2, or 0.109 MgC/ha.

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1. Introduction

Global warming is becoming increasingly apprehensive day by day, marked by the continued increase in levels of carbon dioxide (CO_2) in nature. Carbon dioxide (CO_2) has the highest content of greenhouse gases, namely 55% (IPCC, 2007). One of the efforts made to reduce the effects of global warming is **biosequestration** by empowering photosynthetic organisms. However, it should be noted that forest land cover in the world, especially in Indonesia, is decreasing due to forest fires and logging. It was recorded that the area of forest in Indonesia decreased from 128.72 million hectares in 1990 to 99.6 million hectares in 2005. The 2005 land cover map shows that 40% (38.5 million hectares) of existing forest is disturbed or logged-over forest. This shows the high level of forest damage due to logging and timber harvesting (Ekadinata *et al.*, 2012). Seagrass meadow ecosystems in coastal areas have been studied to have twice the ability to absorb carbon compared to existing vegetation in the forest (Forqurean *et al.*, 2012). This is one of the considerations for using *bio-sequestration*, not only to focus on land that is on land but also to start considering the potential of coastal and marine vegetation that can absorb carbon quite well, commonly referred to as *blue carbon* (Rustam *et al.*, 2015).

Seagrass has the ability to absorb CO_2 through the process of photosynthesis. Some of the carbon absorbed by seagrass is used as energy, and the other part is stored in the body's tissues in the form of biomass. Apart from storing it in its body tissues, the sediment beneath it also stores carbon content, so seagrass beds are considered effective carbon storage. The ability of seagrasses to store carbon varies from species to species. This difference can be caused by internal factors in the form of metabolic ability and seagrass morphology (Khairunnisa *et al.*, 2018).

According to Putra (2017), in the waters of Poncan Island, Sibolga, North Sumatra Province, the amount of seagrass carbon stored in the biomass section below the substrate was 24.17%. In the Bahoi coastal village, north Minahasa Regency, seagrass can absorb 11.56–29.13% carbon (Yunitha, 2015). In East Persisir, Bintan Regency also has a relatively high average carbon storage, namely 26.95–46.51% (Khairunnisa *et al.*, 2018). Meanwhile, the total carbon storage of seagrass tissue on Barrang Lompo Island reached 76.3% (Supriadi *et al.*, 2014). The data above shows that seagrass has a fairly good ability to store carbon because it can store more than 10% carbon (Runtuboi *et al.*, 2018). Unfortunately, for the range of islands in the Spermonde Archipelago, there is still very little information on the ability of seagrass communities to store carbon. It is on this basis that it is necessary to conduct research on estimating carbon stocks on one of the islands that has good water quality in the Spermonde Archipelago, namely Badi Island (Suraji *et al.*, 2015).

2. Materials and Methods

2.1. Study Area

The research was conducted on Badi Island, Mattiro Deceng Village, Liukang Tupabbiring District, Pangkajene, and Islands Regency, South Sulawesi Province. Location of the observation and sampling performed at four stations (Figure 1). Seagrass samples were analyzed at the Soil Chemistry Laboratory of the Pangkajene and Islands State Agricultural Polytechnic. Research was carried out for one month, namely, in August 2019.

2.2. Tools and materials

The tools used in this study were tape measure rolls measuring 50x50 m, quadrant transects measuring 50x50 m and 20x20 m, paralon pipes measuring 2.54x10 cm, seagrass identification sheets, slates, cameras, GPS, masks, snorkels, plastic samples, sieves, labels, machetes and knives, furnaces, ovens, and

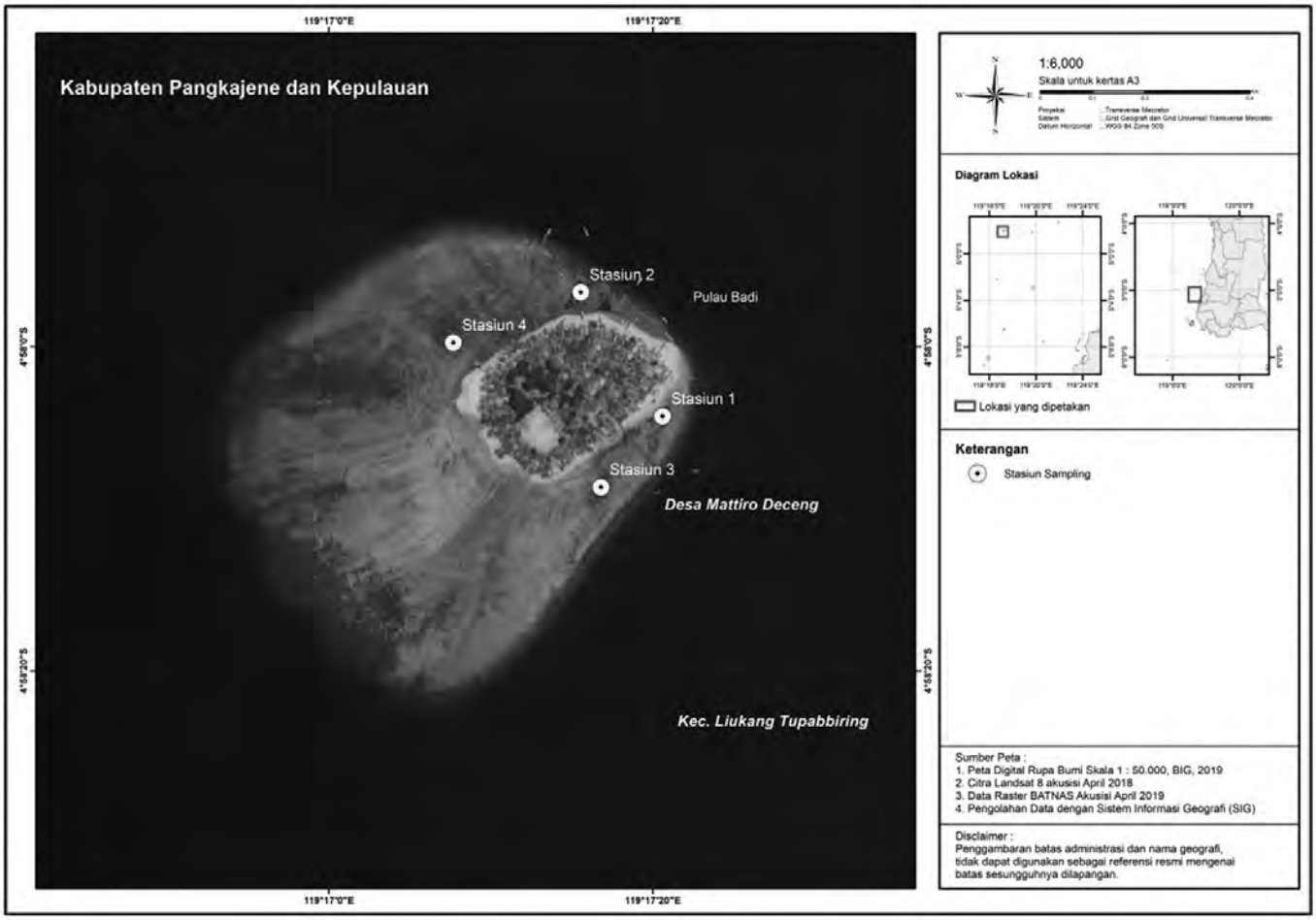

Figure 1. Research location map.

porcelain dishes.

The materials used in this study were distilled water and sea grass.

2.3. Research procedure

This research was carried out in several stages, namely field surveys, seagrass biomass, sediment collection, observation of seagrass cover area and density, laboratory analysis, and statistical analysis.

2.3.1. Collection of Seagrass Biomass

The above-ground biomass, which consists of upright stems, strands, and leaf sheaths, and the below-ground biomass**,** which consists of roots and rhizomes, Biomass sampling using a transect size of 20 cm x 20 cm Sampling of seagrass biomass was done by hand to determine the depth of root penetration, which was carried out at points of 0 m, 25 m, and 50 m (Short & Coles, 2001). To facilitate sampling of seagrass biomass, cutting the rhizome outside the quadrant transect was carried out using a machete or knife (Supriadi, 2012). The biomass that has been obtained is separated from the attached substrate using a sieve, then separated according to the parts (leaves, rhizomes, and roots) of each type. Furthermore, the sample is stored in a sample plastic bag that has been labeled. Each part of the seagrass is placed in the oven at a temperature of 60-800 °C to dry for 2 to 3 days (until it reaches a constant weight). Biomass (g/m^2) can be calculated using the formula (Azkab, 1999):

$$\text{Biomass (g/m2)} = \frac{\text{Dry Weight (g)}}{Area\ (m2)} \quad \text{.....(1)}$$

2.3.2. Sediment Collection

The dry bulk density was first measured. Sampling of sediment for measurement of dry bulk density using a pipe measuring 1 inch in diameter and 10 cm in height by pressing the PVC pipe vertically into the sediment. After the paralon pipe is fully filled, the pipe is rotated and then lifted slowly so that no sediment falls. Sediment sampling was carried out at points 0 m, 25 m, and 50 m. The sediment samples that have been obtained are then put into the oven at a temperature of 60–800 °C to dry for 2–3 days (until constant weight). The dry bulk density value is obtained using the formula (Kauffman & Donato, 2012):

$$\text{dry bulk density} = \frac{\text{Dry Weight (g)}}{Volume\ (m3)} \quad \text{.....(2)}$$

Sediment samples will be taken on the surface. The sediment sampling method is the same as the **dry bulk density** sampling method and the same as the dry bulk density sampling method. The dried samples were analyzed using the **Loss of Ignition** (LOI) method to obtain the sediment organic C concentration of the sediment (% C).

2.3.3. Observation of Seagrass Cover Area and Percentage Cover

Seagrass cover density and percentage data were collected using three line transects at each station with a length of 50 m each and a distance of 10 m between one transect and another. Squared plots (50 cm x 50 cm) were placed on the right side of the transect at a distance of 5 m from each other, so that the total plots on each transect were 11 transect and another. Squared plots (50 cm x 50 cm) were placed on the right side of the transect at a distance of 5 m from each other, so that the total plots on each transect were 11. The starting point of the plot is placed at a distance of 0 to 5 m from the first time that seagrass is encountered (from the shoreline).

The type of seagrass is determined by matching the type of seagrass obtained with the seagrass identification sheet. The density

of each type at each station is calculated using the Azkab formula (h the seagrass identification sheet. The density of each type at each station is calculated using the Azkab (1999) formula, which is:

$$D = \frac{N}{A} \quad \text{.....(3)}$$

Information:
D = Density of seagrass species (individu/m^2);
N = Number of stands (individu);
A = Area (m^2).

Estimating the percentage of seagrass cover is done by assessing the percentage cover of each box in the plot according to seagrass cover standards. The percentage value of seagrass cover is obtained using the formula (Rahmawati *et al.*, 2014) :

$$\text{seagrass cover (\%)} = \frac{\text{Percent cover}}{4} \text{ x } 100\% \quad \text{.....(4)}$$

The percentage cover obtained in each plot will be averaged to obtain the percentage value of seagrass cover at each station.

2.3.4. Carbon Loss of Ignigation (LOI) Analysis

The C-organic content of seagrass and sediment was analyzed using the *Loss of Ignition* (LOI) method in the soil chemistry laboratory of the Pangkajene and Islands State Agricultural Polytechnic. The stages of LOI analysis are as follows (Rustam *et al.*, 2019) :

Before being burned in the furnace, the samples were air-dried, weighed (A gram), then heated in an oven at 60 - 80 ºC for 2-3 days (to constant weight to remove water content in the sample). Furthermore, the sample is cooled in a desiccator and then weighed (B grams). Samples in this condition can be called raw samples that can be used for carbon concentration analysis.

- The sample is homogenized by grinding it in a mortar or blender until it is smooth and the particle size is the same.
- The porcelain cup is heated in a furnace at 900ºC for 15 minutes.
- The porcelain cup that had been ignited was then cooled, weighed and the weight (C gram) was recorded.
- ± 1 gram of sample that has been dried and homogenized is put into a porcelain cup, then its weight (D gram) is recorded.
- Samples in a porcelain cup were put into the furnace, and ignited at 450 - 550ºC for ± 4 hours.
- The sample in the porcelain dish is cooled in a desiccator and then weighed (E gram).

Calculation:

$$\text{\% LOI of organic matter} = ((D - E)/(D - C)) \text{ x } 100 \quad \text{.....(5)}$$

Information:
C is the weight of the empty porcelain cup
D is the weight of the porcelain cup + sample
E is the weight of the porcelain cup + sample after annealing (residue)

- Because in the LOI method it is not only carbon that is measured but also other organic matter excluding carbon such as nitrogen, sulfur and others, a correction is made (Fourqurean *et al.*, 2014) using the following formula:

$$\%C_{org} = 0.40\% \text{ x } \%LOI - 0.21 \quad \text{.....(6)}$$

- Next, an estimate of carbon storage in seagrass will be obtained using the formula (Fourqurean *et al.*, 2014):

$$\text{Seagrass carbon} = \frac{\text{Berat kering (g)}}{Luas\ Area\ (m2)} \text{x } \%C \quad \text{.....(7)}$$

Calculations to obtain estimates of carbon storage in sediments in each depth interval use the formula (Kauffman & Donato, 2012):

Sedimentary Carbon = *dry bulk density* (g/m^3) x interval (cm) x %C

2.4. Data analysis

The data obtained were analyzed using the one-way analysis of variance (ANOVA) test method to determine differences in estimated carbon storage of sediments and seagrass beds at each station and seagrass species on Badi Island. Prior to the ANOVA test, the data were tested for normality and homogeneity. Data with a normal and homogeneous distribution were tested with parametric ANOVA. Data that are not normally distributed are transformed with a log transformation and tested again for normality and homogeneity again. If the data is normal and homogeneous after being transformed, then proceed with the parametric ANOVA test. However, if the distribution is not normal and homogeneous, then the data are tested with a nonparametric ANOVA.

The Pearson correlation test was conducted to analyze the relationship between the estimated carbon stock and the percentage of seagrass cover and density on Badi Island. To measure the significance value, a 95% confidence level was used. The Pearson correlation test was carried out using the GraphPad Prism application.

3. Results and Discussion

Seagrass is one of the coastal vegetations capable of bio-sequestration through photosynthesis. The results of photosynthesis involve the absorption of CO_2 in the water column, which will then accumulate in carbohydrates and stored in the form of biomass. The biomass consists of two parts: the biomass at the top (upright stems, leaves, and fruit) and the biomass at the bottom (roots and rhizomes). Thus, measuring the amount of carbon stored in living plant bodies (biomass) in a land can describe the amount of CO_2 in the atmosphere or in waters absorbed by vegetation (Hairiah *et al.*, 2007).

In this study, five species of seagrass were found, namely *C. rotundata, E. acoroides, T. hemprichii, H. uninervis,* and *H. ovalis* (Figure 2). Referring to the criteria put forward by Rahmawati *et al.* (2014), the average density of seagrass is classified as moderate, ie 34 individu/m^2, and the average percentage of seagrass cover on Badi Island is classified as rare, namely 19.78% (Figures 3 and 4). The low density and percentage of seagrass cover are thought to be due to the uneven distribution of seagrass on Badi Island, which tends to be spotty, so the average density and percentage of seagrass cover are low. This is because the substrate on Badi Island is a type of sandy substrate, and many dead coral fragments and molluscs are found (Appendix I). This type of substrate stores very few nutrients. The availability of nutrients is closely related to the particle size and thickness of the sediment. The smaller the size of the sediment, the greater the availability of nutrients in the substrate (Steven, 2013).

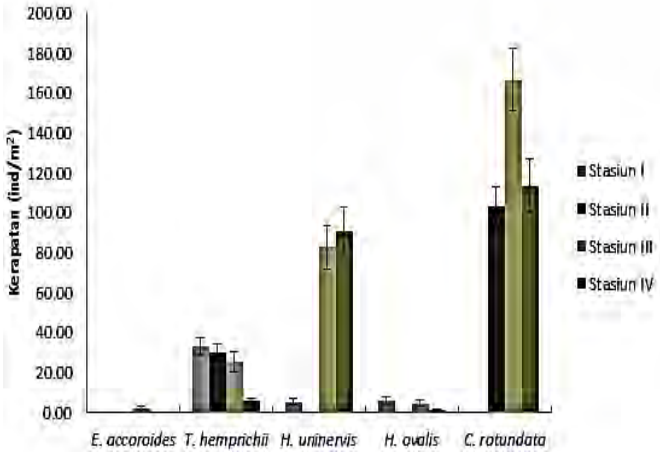

Figure 2. Density of seagrass species per station (Mean ± SE, n=33; different letters indicate significant differences).

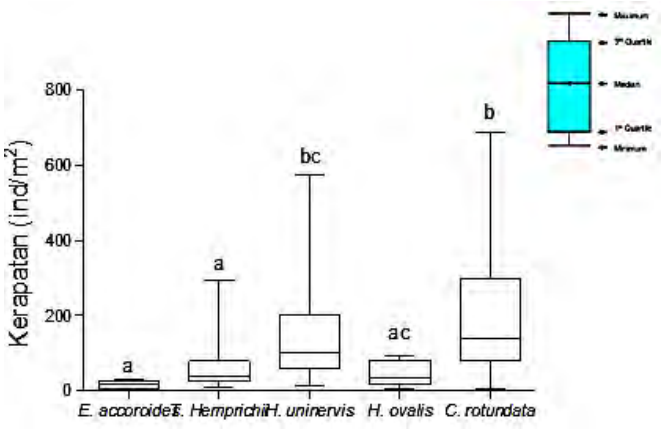

Figure 3. Average seagrass species density (Box Whiskers: min to max; different letters indicate significant differences).

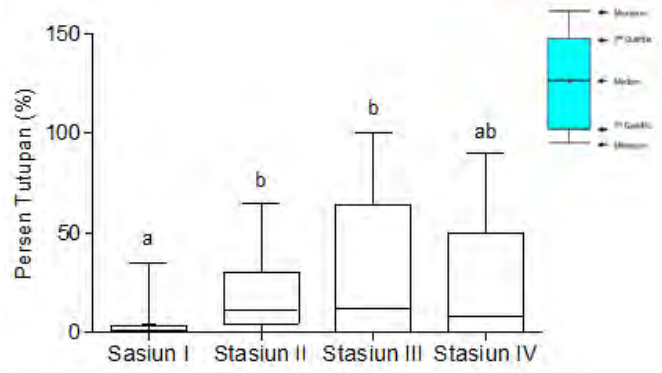

Figure 4. Seagrass cover percentage (Box Whiskers: min to max; different letters indicate significant differences).

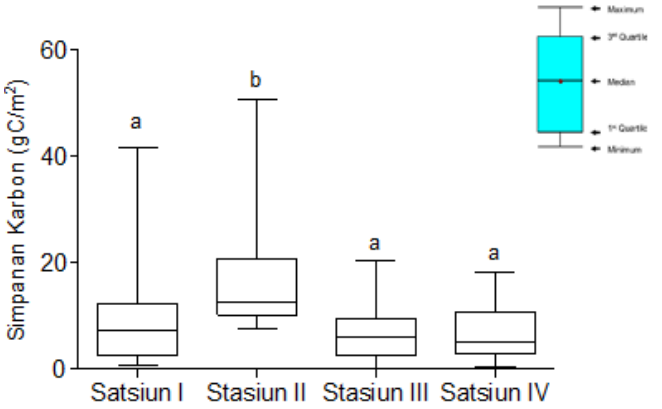

Figure 5. Seagrass carbon storage per station (Box Whiskers: min to max; different letters indicate significant differences)

Total carbon storage on Badi Island ranges from 1.92 to 35.44 gC/m^2, with an average of 18.92 gC/m^2 or 0.189 MgC/ha (Figure 5). This amount is smaller than a study conducted by Irawan (2017), with total carbon storage in the northern and eastern parts of Bintan Island being 133.24 gC/m^2 and 133.71 gC/m^2, respectively. Likewise, according to research conducted by Rahmawati (2011), the total carbon storage on Pari Island was 200.5 gC/m^2. However, in a study conducted by Putra (2017), the total carbon stock of seagrass on Poncan Sibolga Island was 8.68 gC/m^2, less than the total carbon stock of seagrass on Badi Island. The low estimated value of carbon storage on Badi Island is believed to be caused by the fact that very little seagrass with large biomass, namely *E. acoroides*, is found on this island, so it is not included in the plot for biomass extraction and carbon storage. According to Irawan (2017), large seagrasses have a large biomass for one canopy, so even though the density is low, the biomass content is high. On the other hand, smaller seagrasses have low biomass for one canopy, so even though the density is high, the biomass content is low. Thus, seagrass beds dominated by seagrass species with large biomass tend to have greater carbon storage potential than seagrass beds dominated by small seagrass species.

The total carbon storage value on Badi Island shows a comparison that is not significantly different at each station except

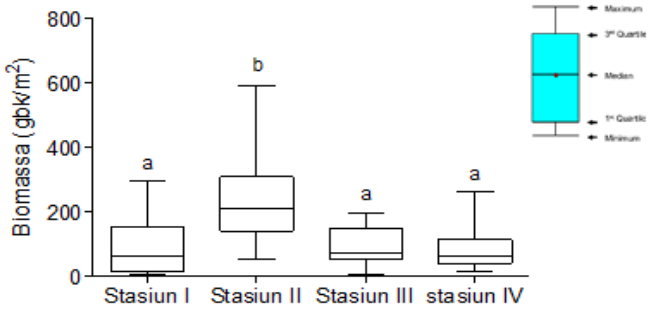

Figure 6. Seagrass biomass for each station (Box Whiskers: min to max; different letters indicate significant differences).

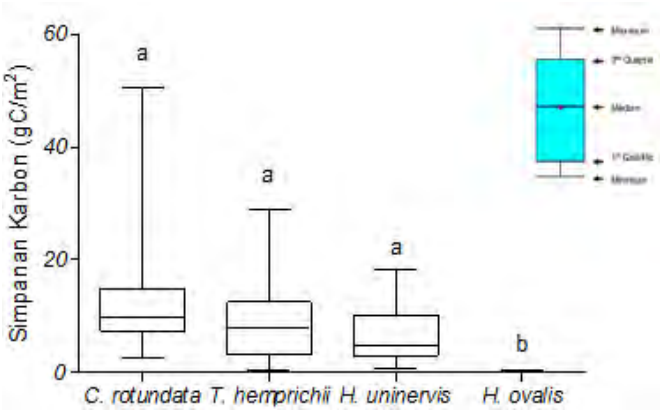

Figure 7. Seagrass carbon storage by species (Box Whiskers: min to max; different letters indicate significant differences).

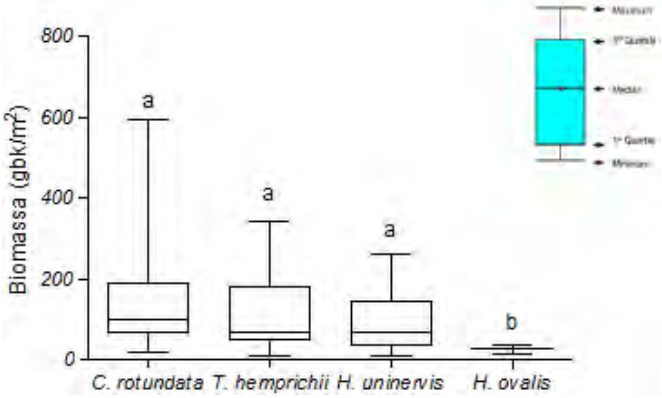

Figure 8. Seagrass biomass for each species (Box Whiskers: min to max; different letters indicate significant differences).

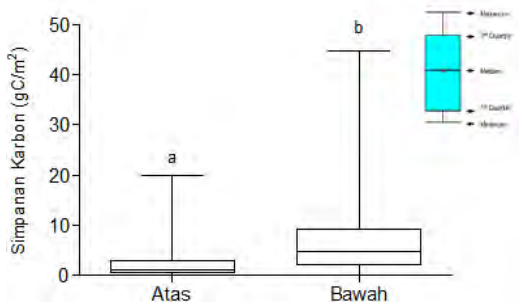

Figure 9. Top and bottom carbon storage (Box Whiskers: min to max; different letters indicate a significant difference).

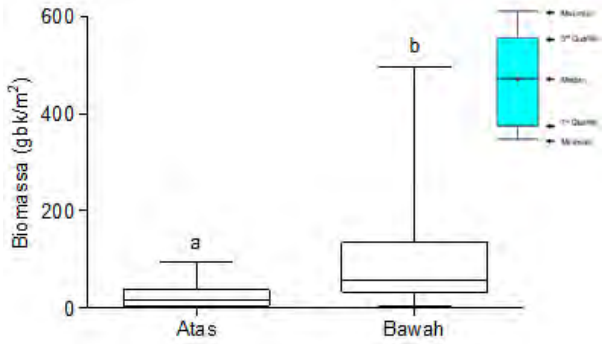

Figure 10. Upper and lower biomass (Box Whiskers: min to max; different letters indicate significant differences).

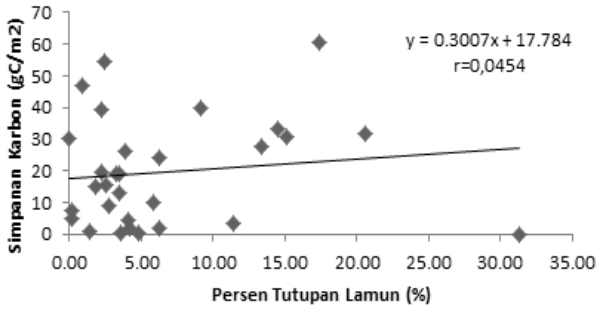

Figure 11. Correlation of carbon stock and percent seagrass cover.

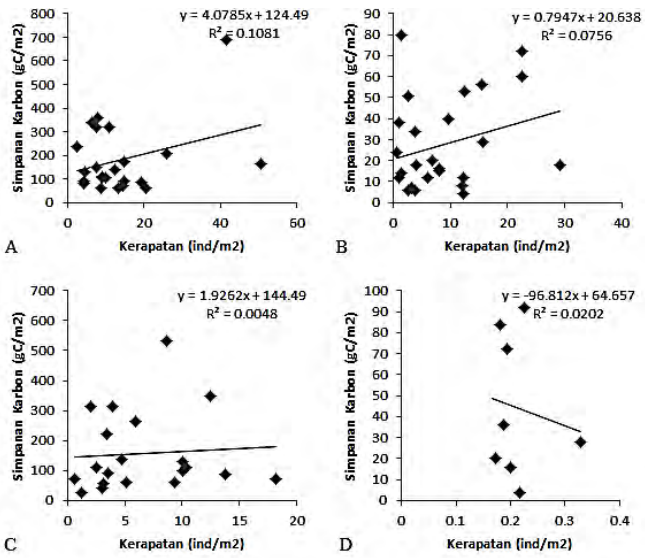

Figure 12. Relationship of carbon storage and species density of *C. rotundata* (A), *T. hemprichii* (B), *H. uninervis* (C), and *H. ovalis* (D).

at station II (Figure 5). This is consistent with the total seagrass biomass values on Badi Island that were not significantly different except for station II (P>0.05) (Figure 6). This difference occurs due to differences in the composition of seagrass species. At station II, only two species were found, namely *C. rotundata* and *T. hemprichii,* while at other stations four species were found, namely *C. rotundata, T. hemprichii, H. uninervis,* and *H. ovalis.*

The total carbon storage value of the seagrass on Badi Island for each species showed a comparison that was not significantly different except for the *H. ovalis* species (Figure 7). This is consistent with the total seagrass biomass value of each species showing a comparison that was not significantly different except for *H. ovalis* (P > 0.05) (Figure 8). This difference occurs because *H. ovalis* has the lowest density compared to other species and is also smaller in size than other species.

The average carbon storage of seagrass on Badi Island at the bottom (below ground) is 14.10 gC/m^2, which is more than three times the average carbon storage at the top (above ground), which is 4.82 gC/m^2 (Figure 1). This amount is in line with the ratio of seagrass biomass, which is 45.02 gbk/m^2 at the top of the substrate and 12.07 gbk/m^2 at the bottom of the substrate (Figure 9). In general, seagrasses develop larger biomass at the bottom compared to the biomass at the top. According to research conducted by Hartati *et al*. (2017), the amount of biomass at the bottom, which is 3.38–554.4 gbk/m^2, is greater than the biomass at the top, which is 2.79–342.72 gbk/m^2. The high bottom biomass indicates that most of the photosynthetic results of seagrasses are stored beneath the sediments. One of the functions of these conditions is to strengthen seagrass embedding (Mashoreng *et al.*, 2018). Related to the function of seagrass as carbon storage, the high carbon storage in the bottom seagrass network is very important because it can supply carbon in the sediment if the bottom biomass is dead. Besides that, the proportion of carbon stored at the bottom increases the rate of burial of organic carbon in sediments (Kennedy & Bjork, 2009).

The results of the total percent correlation test of seagrass cover on carbon storage did not show anything significant and weak, as can be seen from the value of r = 0.0454 and the value of P> 0.05 (Figure 11). The cause of the weak relationship between percent cover and carbon storage is the inconsistent composition of seagrass species in all plots. Some plots with high cover have seagrass species with small morphological sizes, such as *H. uninervis*, with a significant contribution at Station III and Station IV (Figure 2). The small morphological size of seagrass causes a small carbon stock (Laffoley & Grimsditch, 2009).

Correlation test results of seagrass density and carbon storage of *C. rotundata, T. hemprichii,* and *H. uninervis* showed a positive relationship with a determination index value of 20.77%, 13.32%, and 6.94% (r = 0.2077, 0.1332, and 0.0694). The value of the correlation coefficient indicates a weak relationship between the density of *C. rotundata* and carbon storage and a very weak relationship between the density of *T. hemprichii* and *H. uninervis* and carbon storage. The effect of seagrass density on carbon storage did not show a significant effect. This can be seen from the value of P> 0.05. Whereas in *H. ovalis* species, the results of the correlation test showed a negative relationship with r = -0.1422 and did not show a significant relationship (P > 0.05). This is due to the dissimilarity of the type and size of seagrass at each station. At stations I and III, most of the seagrasses found had small morphological sizes, while at station IV, the seagrasses found were intact individuals and large in size.

According to Wahyudi *et al.* (2018), the process of carbon absorption and storage is closely related to natural processes such as photosynthesis, food webs, and other processes in water and carbon storage in sediments. Seagrass beds store carbon in the form of biomass, both at the top (carbon **a**bove ground) and below (carbon below ground). Meanwhile, the fall of organic material, such as litter and dead leaves, on the substrate contributes organic carbon. In addition, dead roots and rhizomes with a greater biomass compared to leaf biomass also contribute organic carbon to sediments. The seagrass root system with dense rhizomes allows carbon to be trapped in the seagrass ecosystem and minimizes the release of CO_2 back into the atmosphere. In this study, the sediment

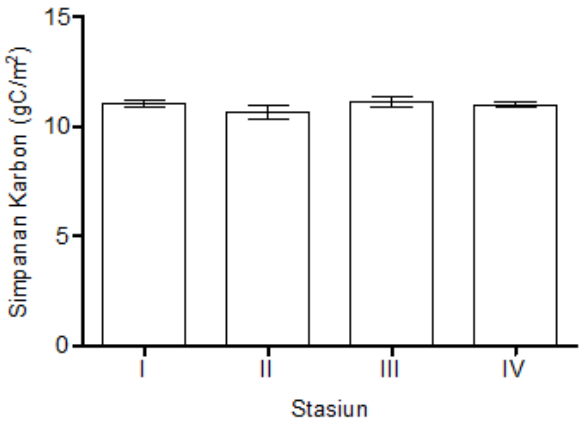

Figure 13. Density of seagrass species per station (Mean ± SE, n=33; different letters indicate significant differences).

carbon stocks did not differ significantly between the stations, with an average of 10.98 gC/m^2 or 0.109 MgC/ha (Figure 13). This is presumably because the characteristics of the substrate at each station are almost the same, namely a sandy substrate and many coral fragments and mollusk shells. These results are in line with the statement put forward by Putra (2017) that one of the factors that influence differences in sediment carbon stores is differences in substrate characteristics and anthropogenic influences from the surrounding seagrass bed ecosystems.

4. Conclusion

The average density of seagrass on Badi Island is moderate, that is, 34 ind/m^2. The average percentage of seagrass cover on Badi Island is rare, namely 19.78%. Seagrass biomass at the bottom is 45.02 gbk/m^2. This amount is three times greater than the carbon stock at the top, which is 12.07 gbk/m^2. The average carbon that seagrass beds can store on Badi Island is 18.92 gC/m^2. With the composition of each part at the bottom (below ground), which is 14.10 gC/m^2, this amount is three times greater than the carbon deposits at the top of the substrate (above ground), namely 4.82 gC/m^2, and carbon storage in sediments is 10.98 gC/m^2.

It is recommended for further research to provide information on differences in the ability of seagrass species to store carbon in the form of percent carbon to see differences in the ability of seagrass species to store carbon apart from being influenced by biomass.

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Supplementary files

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study, and/or contains supplementary material, which is available to authorized users.

Competing interest

All author(s) declare no competing interest.

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Nurazizah Pratiwi Baharudin, Departemen of Marine Resources Management, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia.
Center for Coastal and Small Islands Studies, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalanrea, Makassar, South Sulawesi, Indonesia 93618
Email: diskan.kolut01@gmail.com

Khusnul Yaqin, Departemen of Marine Resources Management, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia.
Email: khusnul@unhas.ac.id
URL Orcid: http://orcid.org/0000-0002-6050-8725
URL Google Scholar: https://scholar.google.co.id/citations?user=21lUj3wAAAAJ&hl=en

Supriadi Mashoreng, Marine Science Study Program, Marine Science Major, Hasanuddin University, Indonesia.
Email: supriadi112@yahoo.com

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