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Quantifying Shoot Density and Biomass of Seagrass Beds in the Central Coast of Vietnam

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Abstract: This study was conducted to provide a comprehensive database of shoot density and biomass characteristics of seagrass beds in several coastal waters in Central Vietnam. The survey process of the characteristics related to shoot density and biomass of seagrass beds was carried out mainly in the dry season (from April to September) during the period from 2017-2019. The data were collected at six sampling locations in Lang Co lagoon, Thua Thien Hue Province; five sampling locations at Cua Dai estuary in Quang Nam Province and Van Phong bay, Khanh Hoa Province; and finally in Ly Son MPA (Marine Protected Area) with nine sampling locations. The characteristics of shoot density collected through the field surveys obtained the difference in the Central Coast region. DW (Dry Weight) biomass of seagrass in Lang Co lagoon and Cua Dai estuary reached 76.56 ± 52.38 (g DW)/m^2) and 53.21 ± 57.66 (g DW/m^2), respectively dominated by *Thalassia hemprichii* and *Halodule pinifolia* in Lang Co lagoon and Cua Dai Estuary, respectively. The rate of above- and below-ground biomass was different. Seagrass species tended to grow below-ground part compared to above-ground part. The study results would be a significant database on environmental informatics to promote the sustainable management of seagrass resources in the central coastal areas of Vietnam.

Key words: Seagrass beds, shoot density, biomass, environmental informatics, Central Vietnam.

1. Introduction

Seagrass beds are one of the coastal ecosystems that play an important role in estuaries environment as well as considered as an important marine resource for socio-economic in the coastal area [1]. Seagrass beds provide abundant food for marine species, contributing to stabilizing the bottom and preventing erosion [2]. Besides, seagrass beds are involved in the food chain, nutrition cycle, environmental stability and habitat for many species of high economic value [2, 3].

Since 2010, numerous studies on the status of seagrass beds have been conducted in the coastal areas of Vietnam. This also demonstrated the efforts of Vietnamese scientists in assessing the status and understanding the challenges of seagrass ecosystems, typically the research of Nguyen, et al. [4] about suggesting solutions for sustainable management of mangroves and seagrass beds at Thuy Trieu lagoon, Khanh Hoa Province. Initially, the study has proposed a number of solutions for management, corresponding to specific goals and orientation of community-based co-management. In 2014, Cao, et al. [5] studied the current state of seagrass in the western coast region of the Gulf of Tonkin. The results showed that the distribution and coverage of seagrass beds in the region tended to increase compared to those in ten years ago, from 2,210 ha to 2,858 ha but the total number of species decreased from six to five species. Besides, Cao and Do [6] conducted a study on the composition, distribution of seagrass species in Quang Ninh and Hai Phong—the status and the dynamic change, in which coastal areas of Quang Ninh and Hai Phong witnessed eight species of seagrass with a total of area of 2,000 ha and scattered distribution, little forming large seagrass beds.

The characteristics of Vietnam seagrass ecosystem were documented through case studies in the central

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coastal region of Vietnam, especially the study of Nguyen, et al. [7] on the current status and trends of mangroves and seagrasses in Nha Trang bay. Initially the results identified 10 species of seagrass. Seagrass beds in Nha Trang Bay tended to decline rapidly in area (losing about 28 hectares, accounting for 29% of the area). Besides, Vu and Pham [8] carried out a study related to application of a quantity assessment method for the conservation potential of the seagrass ecosystem in a pilot study at Ly Son Islands, Quang Ngai. The study recorded six species of seagrass, besides the analysed results indicated that seagrass in Ly Son was under threats from human activities as well as extreme natural conditions. Moreover, Nguyen and Luong [9] studied on the status of submerged aquatic vegetation in Con Chim aquatic resources protected area, Tam Giang-Cau Hai Lagoon. The study results showed that three species of seagrass were presented with the total area of 13.05 ha and the canopy coverage of 48%. At the same time, the fresh biomass weight was 385.7 g/m^2 and the shoot density was 5,559 shoots/m^2 on average. In 2018, Nguyen and Luong [9] conducted study on the characteristics of seagrass ecosystem in Ly Son Island-Quang Ngai Province. Seven seagrass species were found in the south-west and south-east of Ly Son Island. Besides, the recent years also witnessed many impacts of people and extreme natural conditions causing serious decline in seagrass beds.

Most of these studies focused on researching and presenting results of species diversity as well as distribution characteristics of seagrass beds in the study areas [5, 10]. In addition, a number of other studies were conducted on a wide range of studies, so the seagrass beds of each region were not simulated specifically, leading to the fact that there was not a synoptic study on seagrass beds in the coastal area of Vietnam.

To respond to increasing environmental informatic data requirements for research activities, conservation and protection of seagrass resources, the assessment on distribution characteristic of shoot density and biomass of seagrass beds is also considered as an important database for sustainable management and utilizations. Therefore, this study was carried out to provide a comprehensive database of shoot density and biomass characteristics of seagrass beds in several coastal waters in order to promote the sustainable management of seagrass resources in the central coastal areas of Vietnam.

2. Materials and Methods

2.1 Study Area

Four study areas including lagoon, coastal estuaries, bay and island in the central coast region, Lang Co lagoon, Thua Thien Hue, Cua Dai coastal estuary-Quang Nam, Ly Son MPA (Marine Protected Area), Quang Ngai and Van Phong bay, Khanh Hoa were selected for this study (Fig. 1).

Lang Co lagoon (also known as An Cu or Lap An lagoon) belongs to Lang Co Town, Phu Loc District, Thua Thien Hue Province, in which the total area of lagoon is 105.5 km^2 and the population of town is estimated at 11,550 people [11]. According to favorable geographical location and white sandy beaches, this lagoon has great potentials for tourism and aquaculture development. Besides, Lang Co lagoon is also an area with high biodiversity of seagrass beds. However, fishing and aquaculture activities of local people have been causing negative impacts on the environment and the benefits of the lagoon. In addition, Lang Co lagoon also has been in the situation of serious erosion, causing the erosion at seaport.

Cua Dai estuary belongs to Hoi An City and Duy Xuyen District, Quang Nam Province, with a total area of 372.86 km^2 and a population of 221,086 people (in 2017) [12]. Based on the advantage for sea and island tourism, Cua Dai estuary was in top 50 of the most beautiful beaches worldwide. However, this is a highly sensitive coastal erosion area due to annual

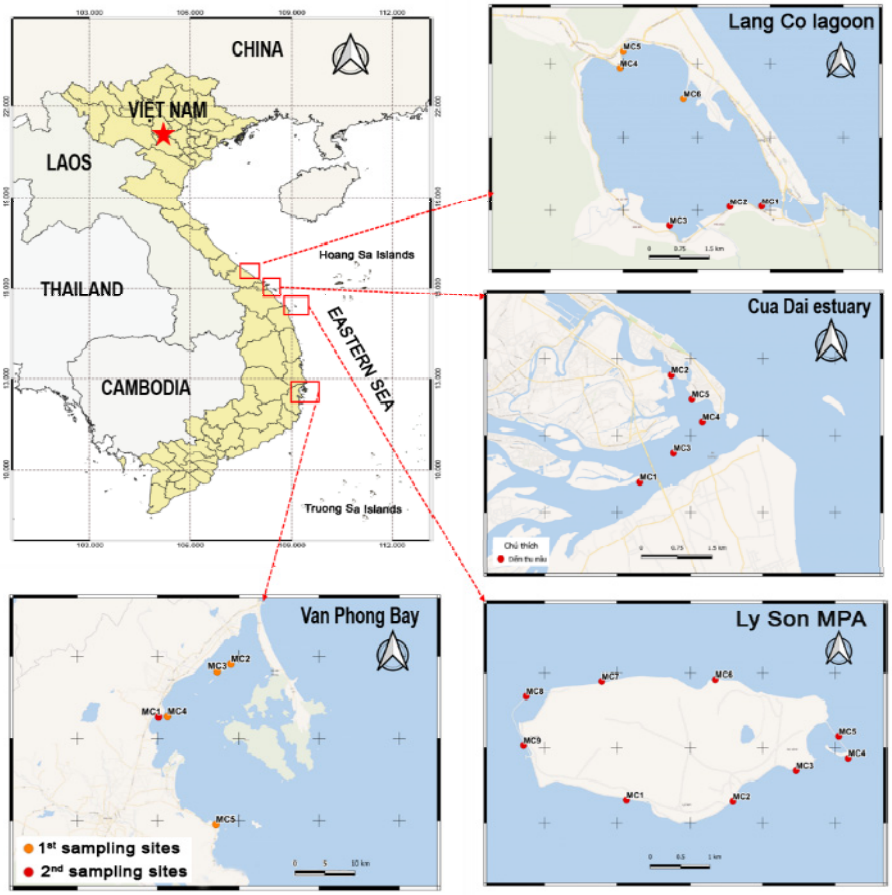

Fig. 1 Study areas of seagrass beds in the central coast region of Vietnam.

extreme weather events. The process of erosion has been happening very strongly in both spatial and temporal scales [13]. In particular, the short erosion section was about 400-500 m while the long one reached 3,000 m [14]. To solve that problem, the local authority must promptly come up with appropriate timely solutions.

Ly Son MPA is located northeast of Quang Ngai Province and lies 24 km of the main land with the total of area of 10 km^2 and population approximately 21,000 people [15]. Although this is one of the small islands, Ly Son MPA plays an important role in the socio-economic development and security defense in Quang Ngai Province. People here concentrate on agriculture development such as cultivating garlic, onion, and corn. Besides, Ly Son MPA was recognized as high biodiversity including coral reef, seagrass beds and valuable seafood, leading to favorable conditions for tourism and aquaculture development. Along with increasing investment in tourism development, the increasing of tourist visitors and service business activities could lead to over environment carrying capacity of the island area. Moreover, over fishing by destructive means could seriously destroy the habitat of coral ecosystems.

Van Phong bay is surrounded by eight communes of Van Ninh District and three communes of Ninh Hoa District, Khanh Hoa Province and lies about 30 km north of Nha Trang City, in which the total area was approximately 1,500 km^2 and the population of Van Ninh District was 128,000 people [16]. The advantage of topography and convenient location help Van Phong bay become the top potential area for ecotourism development and attract a large number of visitors around the world. In addition, Van Phong bay also has a high diversity of marine fauna and flora

[17]. However, the recent years have witnessed the impacts of socio-economic development activities, leading to the serious degradation of ecosystem as well as seafood resources, for example a decrease in the number of seafood and occurred diseases [7].

2.2 Study Period

The field studies were carried out mainly in the dry season (from April to September) during the period from 2017-2019. The data were collected at six sampling locations in Lang Co lagoon, Thua Thien Hue Province in June 2019; five sampling locations at Cua Dai estuary in Quang Nam Province on August 2017 and finally in Ly Son MPA with nine sampling locations in April 2019. Of those, Lang Co lagoon and Van Phong bay were conducted in two surveys. At Lang Co lagoon, the first survey was conducted in June and the second survey was in August 2019 with six sampling locations. Similarly, in Van Phong bay, the first survey was conducted in June and the second survey was in October 2018 with five sampling locations (Table 1).

2.3 Secondary Data

Secondary data related to seagrass beds were collected from several sources to support for this study such as statistics data on natural and socio-economic conditions of four provinces including Thua Thien Hue, Quang Nam, Quang Ngai and Khanh Hoa, and statistical yearbook of Quang Nam Province in 2017. In addition, the published studies related to seagrass beds were referred both in domestic and international reports.

2.4 Methodology

2.4.1 Field Study Methods

(1) Sampling Transects and Locations

The study used Landsat 8 OLI images and Google Earth Pro data to create a map of the seagrass sampling locations, ensuring the representative of the whole study area. Creating a map of sampling locations supports the evaluation of shoot density and biomass characteristics more convenient and simple.

(2) Field Survey Method

The survey process of the characteristics related to shoot density and biomass of seagrass beds was carried out based on the reference "Seagrass Research Methods" [18]. At each sampling location during the field surveys, three quadrats were located from the shore (shallow) to the outer edge of the seagrass beds so that each quadrat was at least 50 m apart [18]. The location of quadrat was determined by a handheld GPS device (Garmin *e*Trex-10, U.S.A). At the same time, the field survey data including sampling locations and coordinates must be fully noted during the survey process. The photos of representative species and canopy cover were captured at each quadrat by Nikon (Japan) underwater camera.

(3) Collecting and Preserving Samples

Iron trowel or shovel was used to collect all seagrasses in the selected quadrats. These seagrass samples were immediately pre-treated to remove Polychaeta, Crustacea, Mollusca, and large corals before storing them into labeled plastic bags. Then, seagrass samples were stored in cold containers at a temperature approximately 5-10 °C and transported to the laboratory of Faculty of Environment Science, University of Sciences, Hue University.

2.4.2 Laboratory Works

(1) Sample Preservation Method

Seagrass samples were stored in Alaska freezer at a temperature of -10 to 0 °C to ensure limit of the decomposition process during sample processing.

(2) Method of Determining the Average of Canopy Height and Shoot Density

It is necessary to estimate the number of shoots in each quadrat to calculate parameters such as biomass, yield, sediment type and nutrient concentration [18]. Seagrass samples were washed under running tap water to remove attached sands, rocks, corals, small sized organisms from the seagrass. After classifying

Table 1 The information of study areas, sampling periods and locations.

Study areas	Lang Co lagoon	Cua Dai estuary	Ly Son MPA	Van Phong bay
Sampling periods	6-8/2019	8/2017	4/2019	6-10/2018
Number of sampling locations	6	5	9	5
Sampling locations codes	MC1-6	MC1-5	MC1-9	MC1-5
Area of water body (km^2)	105.5	372.86	10	1.500
Population (2017) (individuals)	11,550	221,086	21,000	128,000

the species, the average canopy height of each seagrass species was determined by randomly measuring height of five shoots with ruler (in centimeter) and then counting the number of shoots corresponding with each species. The shoot density was the number of seagrass shoots in one quadrat converted to shoot/m^2 unit.

(3) Method of Determining Fresh Biomass

The seagrass samples were placed into a grid tray to air-dry and then the total fresh biomass of quadrat were weighed by standard scale (Electronic SF-400, unit: grams). Then, seagrass samples were separated into two parts according to species, including above-ground biomass (leaf shoots, flower shoots); below-ground biomass (stem, roots) and then weighed respectively. The result of FW (fresh weight) biomass in the quadrat (0.5 × 0.5 m) was converted into g FW/m^2 unit.

(4) Method of Determining Dry Biomass

The seagrass samples were dried in an oven (Memmert) at 65 °C for 1-2 days to obtain the constant weight [17]. Then, dry weight (DW)was weighted (Sartorius, unit: grams) with g DW/m^2 unit and stored in the storage containers at room temperature.

(5) Data Processing Methods

The data were statistically analyzed by IBM SPSS Statistic 20 for Windows (IBM Corporation, USA) and XLSTAT 2020.1.2 add-in of Microsoft Excel 2013. The data of shoot density and seagrass biomass did not have a normal distribution or homogeneity of variance. Non-parametric Kruskal-Wallis *H* test and one-way ANOVA (Analysis of Variance) were employed to assess response differences. The statistical significance level was set at 0.05, and all results are presented as mean ± SE (standard error).

3. Results

3.1 Characteristics of Seagrass Shoots Density

According to the survey results, seven seagrass species belonging to two different families were identified in the central coast region. In which, *Halodule pinifolia* and *Thalassia hemprichii* (*Tha. hemprichii*) were the two most dominant species in terms of species composition. Ly Son MPA has the highest species composition (five species) compared to the remaining three study areas.

For Lang Co lagoon area, the results showed an increase in shoot density from sampling locations MC1 to MC6 (Fig. 2a), the average shoot density was 3,577 ± 1,680 (shoots/m^2). The highest and lowest shoot densities were at MC5 and MC1 with the average values of 5,880 ± 988 (shoots/m^2) and 542 ± 230 (shoots/m^2), respectively. In particular, *Halodule uninervis* domitated shoot density in Lang Co area (46,340 shoots/m^2). However, according to the results of Kruskal-Wallis test, there was no statistically significant difference between the sampling locations (Fig. 2a). According to survey results in Cua Dai estuary of Quang Nam Province, the average shoot density was 108 ± 50 (shoots/m^2). In particular, MC5 had the highest shoot density in the area and reached an average of 203 ± 149 (shoots/m^2), whereas the figure for MC2 was relatively low, about 67 ± 33 (shoots/m^2) (Fig. 2b). For the results of Kruskal-Wallis test, there was also no statistically significant difference between the sampling locations (Fig. 2b).

The survey result at Ly Son MPA indicated that this area was the most diverse in species composition compared to the remaining three study areas (5 out of 7 species), the average shoot density reached 816 ±

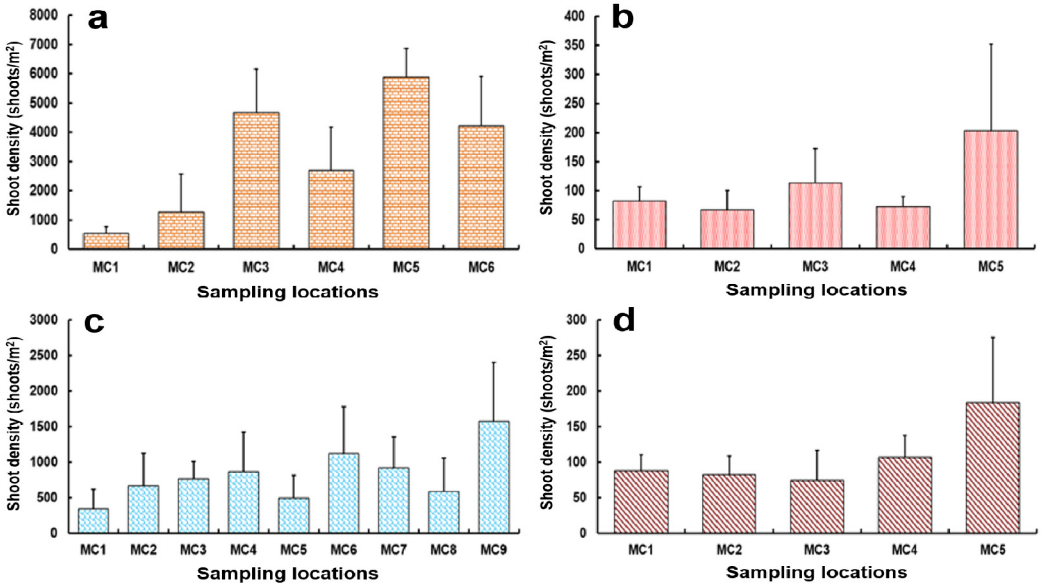

Fig. 2 Spatial dynamic in shoot density of seagrass beds among sampling locations in each study areas: (a) Lang Co lagoon, (b) Cua Dai estuary, (c) Ly Son MPA, and (d) Van Phong bay.

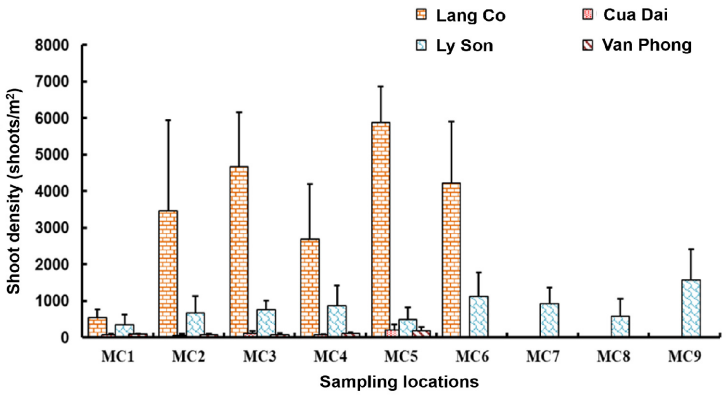

Fig. 3 Spatial changes in shoot density of seagrass beds between study areas.

346 (shoots/m^2). Among the survey areas, the highest shoot density at MC9 was 1,576 ± 825 (shoots/m^2), MC1 had the lowest shoot density and reached a value of 348 ± 273 (shoots/m^2) (Fig. 2c). The average shoot density based on the Kruskal-Wallis test showed that there was no difference between the sampling locations. The shoot density was dominant by *Tha. hemprichii* in Ly Son MPA (16,929 shoots/m^2) (Fig. 2c).

The field survey at Van Phong bay resulted in an average shoot density of 107 ± 40 (shoots/m^2). In particular, MC5 had the highest shoot density in five sampling locations, with averaged value of 184 ± 92 (shoots/m^2). In contrast, the lowest shoot density was observed at MC3 with 75 ± 42 (shoots/m^2) (Fig. 2d). The shoot density between sampling locations in Van Phong bay has not statistically difference based on the Kruskal-Wallis test (Fig. 2d). *Enhalus acoroides* was found in many sampling locations (four out of five sampling locations) and dominated in the shoot density in the study area (1,056 shoots/m^2).

In general, the shoot density between study areas was highly different, especially between Lang Co lagoon (3,577 ± 1,680 shoots/m^2) and Van Phong bay

(107 ± 40 shoots/m^2) (Fig. 3). When analyzing and comparing shoot density among species in the study areas, *Halodule uninervis* had the highest average shoot density, reached 4,634 ± 1,906 (shoots/m^2), and accounted for 41% of the total shoot density which was collected from four areas and mostly found in study areas whereas the lowest species of shoot density was 22 ± 8 (shoots/m^2) *Enhalus acoroides* (*E. acoroides*), which accounted for only 5% of the shoot density. One-way ANOVA analysis revealed that the shoot density among the study areas had statistically significant differences (one-way ANOVA, $F = 30.445$, $p = 0.0001<0.05$) (Fig. 4), in which, there was a statistically significant difference in shoot density between Lang Co lagoon and the remaining study areas (Fig. 4).

3.2 Characteristics of Total Dry Biomass of Seagrass in the Central Coastal of Vietnam

Quantifying dry biomass of seagrass beds plays an important role in assessment of the quality of ecosystems and seagrass beds' health. The higher the biomass is greater the role of providing habitat services and feeding sources for aquatic organisms.

Through surveys in Lang Co lagoon, the average dry biomass was 76.56 ± 52.38 (g DW/m^2). Among the sampling locations, the highest and lowest dry biomass were obtained at MC2 and MC6 with averaged values of 147.4 ± 131.8 (g DW/m^2) and 13.99 ± 4.69 (g DW/m^2) respectively (Fig. 5a). Besides, there was no significant difference in dry biomass of seagrass between sampling locations (Kruskal-Wallis test, $p = 0.062>0.05$) (Fig. 5a). Although *Tha. hemprichii* was not found in many sampling locations, they dominated the dry biomass (760 g DW/m^2) in the lagoon.

In Cua Dai estuary, the percentage of biomass was lower than remaining three study areas, in which the coverage was about 5%-75% and the average dry biomass reached 53.21 ± 57.66 (g DW/m^2). The highest dry biomass was obtained at MC4 with the average value of 158.4 ± 47.7 (g DW/m^2), while MC3 witnessed the lowest dry biomass in transects at Cua Dai estuary, with only 1 ± 0.8 (g DW/m^2) (Fig. 5b). According to analysis results, there was a difference in dry biomass between sampling locations (Kruskal-Wallis test, $H = 11.396$, $p = 0.022<0.05$) (Fig. 5b). The post-hoc test showed that MC5 had no statistically significant difference compared to the other sampling locations (Fig. 5b). There was a statistically significant difference in dry biomass between MC1 and MC4 ($p = 0.013<0.05$) and between MC3 and MC4 ($p = 0.002 <0.05$) (Fig. 5b). Although *Halophila beccarii* appeared at most sampling locations, *Halodule pinifolia* was dominant in dry biomass in Cua Dai area (783.2 g DW/m^2).

In Quang Ngai, the survey was conducted at Ly Son MPA, the average dry biomass reached 506.67 ± 256.7 (g DW/m^2).

The analysis results indicated the difference in a dry biomass between sampling locations, which was the most recognized at MC6 and MC4 with 1,170.3 ± 41.1 (g DW/m^2) and 280.7 ± 335.3 (g DW/m^2) for the highest and lowest dry biomass respectively (Fig. 6). This proved that the seagrass beds on Ly Son Island were scattered around the island unevenly and *Tha. hemprichii* was dominant in the total dry biomass (16,595 g DW/m^2). There was no difference between the dry biomass of the sampling locations (Kruskal-Wallis test, $p> 0.05$).

According to the surveys at Van Phong bay, the averaged dry biomass reached 473.88 ± 213.28 (g DW/m^2). In general, seagrass beds were quite evenly distributed. The highest biomass was obtained at MC4 compared to the lowest at MC5, with 709.3 ± 379.7 (g DW/m^2) and 115.5 ± 35.3 (g DW/m^2) respectively (Fig. 6). There was no difference between the dry biomass of the sampling locations (Kruskal-Wallis test, $p> 0.05$). It can be seen that seagrass beds were quite evenly distributed at the survey areas and *Enhalus acoroides* was dominated in the dry biomass in Van Phong bay (7,511 g DW/m^2).

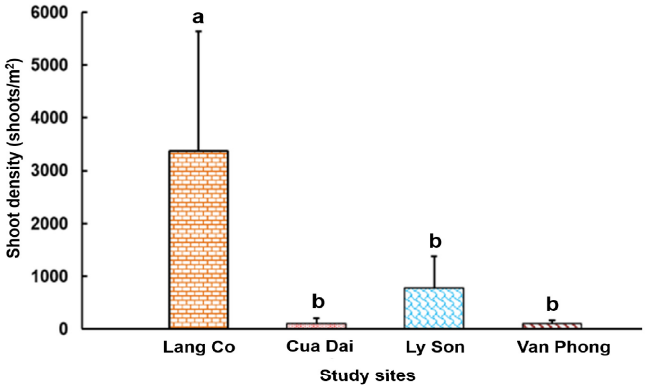

Fig. 4 Changes in shoot density according to one-way ANOVA analysis results between study areas. Same alphabetical superscript letters (a, b) in the same column were used to reveal there are no differences between the study areas according to ANOVA analysis results at $p = 0.05$ using the Least Significant Difference (LSD) test.

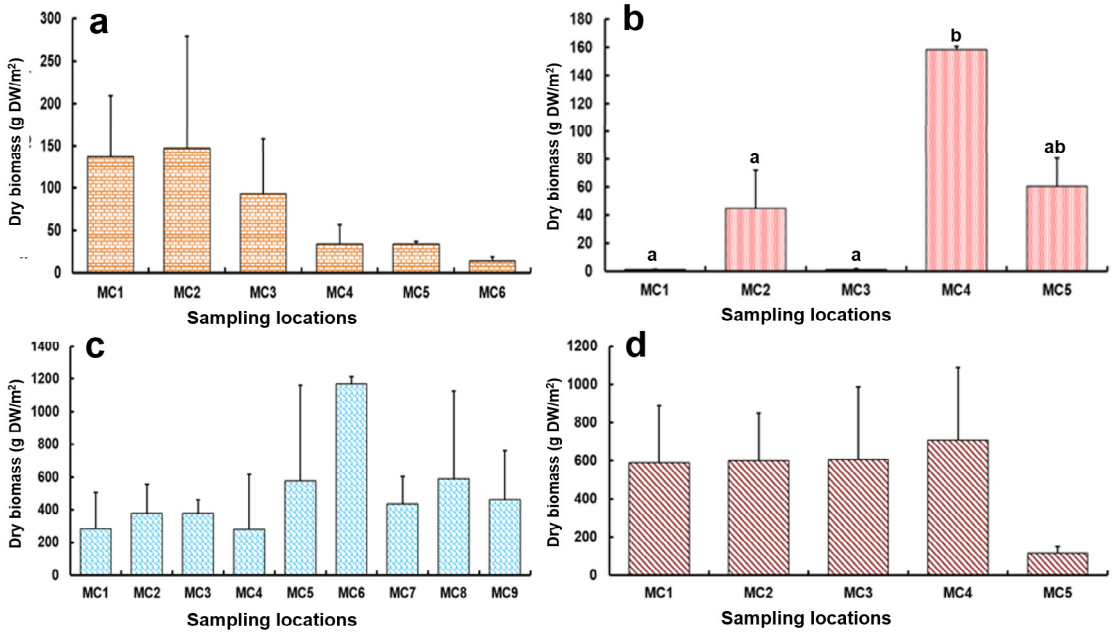

Fig. 5 The variation in dry biomass of seagrass beds according to one-way ANOVA analysis results in the study areas: (a) Lang Co lagoon, (b) Cua Dai estuary, (c) Ly Son MPA, and (d) Van Phong bay. Same alphabetical superscript letters (a, b) in the same column were used to reveal there are no differences between the study areas according to Kruskal-Wallis test results at $p = 0.05$.

The result of comparative analysis showed that Ly Son MPA witnessed the highest dry biomass, followed by Van Phong bay and the lowest dry biomass at Cua Dai estuary. The results of one-way ANOVA analysis illustrated differences in dry biomass between the study areas (one-way ANOVA, $F = 7.307$, $p < 0.05$) (Fig. 7). According to the post-test results, there was no statistically significant difference in biomass between Lang Co and Cua Dai (one-way ANOVA, $F = 2.632$, $p = 0.969 > 0.05$). The biomass of Lang Co was different from that of Ly Son MPA (one-way ANOVA, $F = 2.632$, $p = 0.041 < 0.05$) and of Van Phong bay (one-way ANOVA, $F = 2.632$, $p = 0.042 < 0.05$) respectively (Fig. 7), similarly, Cua Dai and Van Phong (one-way ANOVA, $F = 2.632$, $p = 0.004$) (Fig. 7).

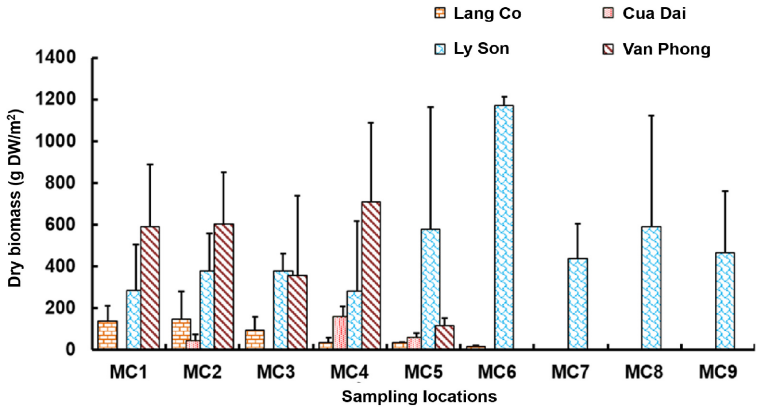

Fig. 6 The variation in dry biomass of seagrass beds between the study areas.

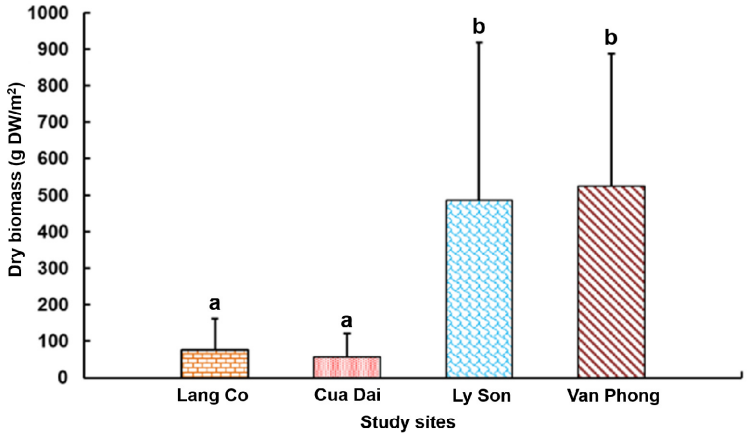

Fig. 7 Variation of dry biomass between the study areas. Same alphabetical superscript letters (a, b) in the same column were used to reveal there are no differences between the study areas according to ANOVA analysis results at $p = 0.05$ using the Least Significant Difference (LSD) test.

Besides, the difference between these two areas also illustrated in averaged dry biomass. However, when comparing the dry biomass of Ly Son and Van Phong bay, it is clear that there was no statistically significant difference between study areas (one-way ANOVA, $F = 2.632$, $p = 0.966$). Thus, the dry biomass between Lang Co and Cua Dai was statistically different from that in Ly Son and Van Phong (Fig. 7). While *Halodule pinifolia* was distributed mostly in the study areas, *Tha. hemprichii* presented the highest biomass (17,702 g DW/m^2) among all species found in the study areas.

3.3 The Ratio of Above- and Below-Ground Dry Biomass of Seagrass Beds

The analysis results showed that the rate of above-ground dry biomass was higher than below-ground dry biomass in all studied areas Lang Co lagoon, Ly Son MPA and Van Phong bay (Fig. 8). In particular, in Cua Dai estuary, the dry biomass of the seagrass collected was valuable, so only evaluated on the total dry biomass. The total dry biomass in Ly Son MPA was higher than the other study areas. The averaged above-ground dry biomass was 98.4 ± 38.6 (g DW/m^2) while the value for below-ground reached 545.1 ± 325.2 (g DW/m^2). In the remaining two areas, below-ground dry biomass also accounted for a higher proportion than above-ground dry biomass. *Tha. hemprichii* had higher dry biomass compared to the other species. In addition, above- and below-ground dry biomass account for 18% and 82% of the total dry biomass, respectively. It can be said that seagrasses

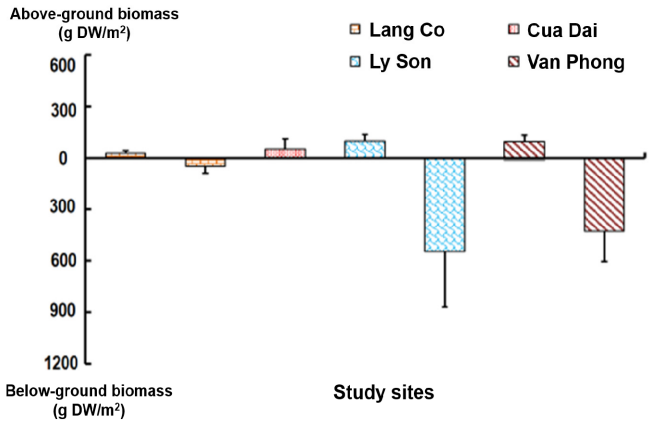

Fig. 8 The ratio between above- and below-ground dry biomass of seagrass beds in the study areas.

achieved high dry biomass in dry season but tended to develop below-ground parts.

4. Discussion

The results of shoot density and dry biomass of seagrass beds in the Central Coast region were reviewed. First of all, for the characteristics of shoot density, Lang Co lagoon had the highest value; then Ly Son MPA and Cua Dai estuary; the lowest shoot density value was Van Phong Bay. As for characteristic of dry biomass, the highest value was obtained in Ly Son MPA; followed by Van Phong bay and Lang Co lagoon; finally, Cua Dai estuary had the lowest dry biomass value.

The Lang Co lagoon area has the highest shoot density (3,577 ± 1,680 shoots/m^2) compared to the remaining studied areas, in which the shoot density at MC5 reached a peak of 5,880 ± 988 (shoots/m^2), *Halodule uninervis* was dominant in the shoot density in the area (46,340 shoots/m^2). However, the dry biomass in this area was low, averaging 76.56 ± 52.38 (g DW/m^2), the dominant species in dry biomass was *Tha. hemprichii*. Thus, the difference between shoot density and dry biomass could be seen in this area. The difference in the shoot density was high but low in dry biomass, which can be explained through four factors as follows: (i) The seagrass species found in Lang Co lagoon were small in size but large in shoot density such as *Halodule uninervis*, *Halophila beccarii*, *Halodule ovalis*; (ii) Lang Co lagoon was a closed water body and received directly from sea water, leading to high salinity; and (iii) several parts of the lagoon are really shallow when the tide was low (e.g. MC5 and MC6). This condition made many large sizes species such as *Enhalus acoroides* or *Tha. hemprichii* unsuitable for development; (iv) In addition, in Lang Co lagoon area, aquaculture and fishing activities of local people take place regularly, resulting in seriously affecting the growth and development of seagrass beds in the lagoon. Besides, Lang Co lagoon witnessed 669.11 ± 665.3 (g DW/m^2) of average fresh biomass, accounting for 1/9 dry biomass (76.56 ± 85.63 g DW/m^2) (Table 2).

There were several studies on seagrass beds in Thua Thien Hue Province such as Ha, et al. [20] with the study of seagrass mapping using ALOS AVNIR-2 data in Lap An lagoon, Thua Thien Hue, Vietnam. The study results indicated a new approach to map seagrass beds using remote sensing data. Besides, seagrass beds were distributed mainly in the southwest, south and east of the lagoon. In another study, Nguyen, et al. [21] studied characteristics of aquatic vegetations distribution in the fisheries protection area, Tam Giang, Cau Hai lagoon, Thua Thien Hue Province. The results identified two SAV (Submerged Aquatic Vegetation) species (*Halophila beccarii* and

Table 2 Ratio of fresh and dry biomass of seagrass species in the study areas.

Sites	Speciescomposition	Fresh biomass (g FW/m^2)	Dry biomass (g DW/m^2)	Rate
Lang Co lagoon	*Thalassia hemprichii*	964.7	126.7	1/8
	Halodule uninervis	494.8	53.6	1/9
	Halophila beccarii	229.3	14.0	1/16
	Halophila ovalis	312.0	22.7	1/14
	Total	669.1	76.6	1/9
Cua Dai estuary	*Halophila beccarii*	32.7	2.3	1/14
	Halodule pinifolia	507.0	97.9	1/5
	Total	303.7	56.9	1/5
Ly Son MPA	*Thalassia hemprichii*	3,769.7	452.7	1/8
	Halodule pinifolia	687.7	86.8	1/8
	Cymodocea rotundata	989.0	122.4	1/9
	Total	4,345.8	486.7	1/9
Van Phong bay	*Enhalus acoroides*	1,022.0	625.9	1/2
	Thalassia hemprichii	1,086.7	115.5	1/9
	Total	1,034.9	523.9	1/2

Halodule pinifolia). The SAV in Vung Bun aquatic resources protection area was distributed at the appropriated depth of 0.5-1.3 m and the average salinity of 18.9 ± 0.9 ppt. Besides, SAV species was found with the following characteristics: average vertical stem length of 6.63 ± 2.18 cm, total average shoot density of 445.9 ± 374.7 shoots/m^2, average fresh biomass of 18.2 ± 9.1 g FW/m^2, average coverage of 43.6 ± 13.1%.

Compared to the study of Ha, et al. [20] in Lang Co lagoon (Lap An), this study showed the results related to the shoot density, creating database to support other studies. This means that the study on shoot density could provide the data about distribution and the quality of seagrass beds in the lagoon. Besides, the study of Nguyen, et al. [21] which studied into seagrass beds in the area of Tam Giang, Cau Hai lagoon has provided a better overview of the seagrass characteristics. When comparing these two research papers, it is clear that Lang Co lagoon had a more diverse species composition (four species) than the Tam Giang, Cau Hai lagoon area. Shoot density and biomass obtained in the Lang Co lagoon area also reached higher values than in the Tam Giang, Cau Hai lagoon area.

Cua Dai estuary had a low shoot density, average reached 107.53 ± 50.47 (shoots/m^2). At MC5, the maximum shoot density in the area reached an average of 203.3 ± 149.1 (shoots/m^2). The area biomass obtained averaged 56.9 ± 63.9 (g DW/m^2). It can be seen that, the survey results on shoot density as well as dry biomass in this area were low value. This may be due to the following reasons: (i) In the Cua Dai estuary, there were only two seagrass species. In addition, seagrass species found in this study area had small size, such as *Halophila beccarii* and *Halodule pinifolia*; (ii) The study area was a coastal estuarine area where there are an interaction between sea currents and river flows, low salinity levels (5.75 ± 1.60 ppt); and (iii) Besides, local people's livelihood activities such as aquaculture and fishing which have significant impact on water quality, might lead to the seagrass ecosystem degeneration. In addition, seagrass biomass obtained at Cua Dai estuary had a significant difference between dry and fresh biomass. Averaged fresh biomass (303.7 ± 289.8 g FW/m^2) accounted for 1/5 dry biomass (56.9 ± 63.9 g DW/m^2), meaning that every 1g of fresh biomass would obtain 0.2 g dry biomass.

When studying the characteristics of seagrass in Cua Dai estuary, we could refer to the study of Cao [22], who studied the status of seagrass in Cua Dai (Hoi An, Quang Nam). This result has recorded three seagrass

species including *Zostera japonica*, *Halophila beccarii* and *Halodule uninervis*. The study carried out a comparison of shoot density, dry biomass, and leaf size between wet and dry seasons of *Zostera japonica* species [22].

According to Cao [22], there was a variation in species composition in Cua Dai estuary. In 2009, Cao [22] recorded three seagrass species, however, only two seagrass species had been recorded in 2017. Japanese eelgrass (*Zostera japonica*) was not found in 2017. Therefore, there was no comparison of shoot density and dry biomass between the period of 2009 and 2017 in this estuary.

Ly Son MPA had a high number of shoot density, averaged 816 ± 346 (shoots/m^2). The highest shoot density at MC9 was reached 1,576 ± 825 (shoots/m^2). Among four study areas, Ly Son MPA obtained the highest biomass compared to the other study areas, the average value reached 506.67 ± 256.7 (g DW/m^2). MC6 had the highest biomass which reached 1,170.3 ± 41.1 (g DW/m^2). This area also had the most diversity seagrass species (5 out of 8 species found). The species found in the area were diverse, there are both large (e.g. *E. acoroides* and *C. rotundata*) and small sized species (e.g. *Halodule pinifolia* and *Th. hemprichii*). This area is an MPA under the strict management and conservation strategy. In addition, Ly Son MPA is an offshore island that was less affected by the anthropogenic activities from the mainland such as aquaculture, water quality, land use and land cover changes. Therefore, this study area also has the highest shoot density as well as biomass than the other study areas. The proportion of fresh and dry biomass in MPAs was highly different. Fresh biomass (4,345.83 ± 3,416.94 g DW/m^2) accounted for 1/9 of the dry biomass obtained (486.57 ± 431.96 g DW/m^2).

Ly Son MPA is recognized as one of highest biodiversity areas. Therefore, numerous of marine scientists have conducted many studies on the seagrass ecosystems. In particular, Nguyen, et al. [9] had studied the characteristics of seagrass ecosystem around the Ly Son Island. The study results revealed there were seven seagrass species mainly distributed in the Southwest and Southeast sides of the island. In addition, the study showed that the average shoot density of seagrasses reached 247 to 786 (shoots/m^2) and the average dry biomass ranged from 38.25 to 104 (g DW/m^2) [9]. According to Nguyen, et al. [9] study, it is shown that the shoot density and dry biomass in 2019 are on the trend of increasing. Based on our study, the averaged shoot density of seagrasses reached 816 ± 346 (shoots/m^2). In addition, the dry biomass obtained in this study was also increasing, average reached 506.67 ± 256.7 (g DW/m^2). This may be a positive sign that seagrass beds were gradually being recovered, reflecting the affective management strategy of Ly Son MPA management board.

In Van Phong bay, the average shoot density reached 107 ± 40 (shoots/m^2), which was the lowest value compared with other study areas. MC5 was one of the highest shoot density sections in the five investigated sampling locations (184 ± 92 shoots/m^2), whereas the lowest shoot density was found at MC3 section (75 ± 42 shoots/m^2). The dry biomass collected at Van Phong bay averaged 473.88 ± 213.28 (g DW/m^2). The results of shoot density and dry biomass in Van Phong bay were different, it can be explained as follows:(i) In Van Phong bay, seagrass species were mainly dominated with large-sized species (*Th. hemprichii*, *E. acoroides*). The under-ground shoots are strongly grown (428.1 ± 177.06 g DW/m^2); (ii) The study area is a bay which is surrounded by terrestrial land. The proportion of fresh biomass (1,034.93 g FW/m^2) accounts for two times of the dry biomass (523.85 g DW/m^2). The study carried out in Van Phong bay could be mentioned as the study of Nguyen, et al. [19], the current status and fluctuation trend of mangroves and seagrass beds in Van Phong bay, Khanh Hoa Province. The composition of seagrass species in Van Phong bay was quite diverse with nine seagrass species identified. The total area of

seagrass beds in Van Phong bay was about 600 ha [23]. According to Nguyen's [17] study, the diversity of species composition in 2018 was significantly lower as seven species were not found in this study. The degeneration in species composition may be affected by human activities such as over-exploitation and aquaculture of aquatic products, build up seaports, digging up mollusks harvesting. These activities have partly caused water pollution, causing many seagrasses to gradually disappear in the last five years (2013-2019) [24-26].

5. Conclusions

The characteristics of shoot density collected through the field surveys were obtained with difference in the Central Coast region. The average shoot density reached 3,576.78 ± 1,679.94 (shoots/m^2) in Lang Co lagoon and 107.53 ± 50.47 (shoots/m^2) in Cua Dai estuary, in which *Halodule uninervis* and *Halodule pinifolia* were dominated species in shoot density compared to the other species in Lang Co lagoon and Cu Dai estuary, respectively. The study results in Ly Son MPA showed that 816.29 ± 346,498 (shoots/m^2) belonged to the average shoot density dominated by *Th. hemprichii*. In Van Phong Bay, the average shoot density on average is 107.20 ± 39.82 (shoots/m^2) dominated by *E. acoroides*.

Seagrass biomass in Lang Co lagoon and Cua Dai estuary reached 76.56 ± 52.38 (g DW/m^2) and 53.21 ± 57.66 (g DW/m^2), respectively which are dominated by *Th. hemprichii* and *Halodule pinifolia* in Lang Co lagoon and Cua Dai Estuary, respectively. Ly Son MPA had an average shoot density of 506.67 ± 256.7 (g DW/m^2), with the highest value presented by *Th. hemprichii*. The averaged seagrass biomass results in Van Phong bay reached 473.88 ± 213.28 (g DW/m^2) where *E. acoroides* was dominant in the seagrass biomass in this area.

The rate of above- and below-ground biomass was different. Seagrass species tended to grow below-ground part compared to above-ground part. In Lang Co lagoon, the above-biomass and below-biomass were 28.54 ± 14.4 (g DW/m^2) and 48.29 ± 38.82 (g DW/m^2) respectively. The total biomass in Cua Dai estuary was 53.21 ± 57.66 (g DW/m^2). The results in Ly Son MPA showed that the average value of above-ground biomass was 98.36 ± 38.59 (g DW/m^2) compared to that of below-ground biomass which was 545.08 ± 325.19 (g DW/m^2). In Van Phong bay, while above-ground biomass was 95.75 ± 36.57 (g DW/m^2), below-ground biomass was 428.1 ± 177.06 (g DW/m^2).

Finally, the decline in seagrass beds is currently affected by economic development activities. Therefore, it is necessary to promote the management strategies for biodiversity conservation in the coastal areas. Besides, it is necessary to introduce several community-based management models in coastal resources management where the rights and responsibilities of related stakeholders must be clarified to respond to the purposes of biodiversity conservation and sustainable development.

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