Community structure and spatial distribution of seagrass in Tulehu coastal waters, Central Maluku Regency, Indonesia

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Abstract. The surrounding waters of Tulehu Village are coastal areas with ecosystems such as seagrass, adjacent to marine natural resources (mangroves, macroalgae, fish, mollusks, etc.). Seagrass in the coastal waters of Tulehu has spread widely, but information about seagrass communities in these waters is limited. This research was conducted to describe the species composition, density, frequency of occurrence, percentage of coverage, importance value, biomass, and distribution of pattern of seagrass in the area. The method used is the quadratic linear transect method. The results of the study showed that there are four seagrass species *Cymodocea rotundata*, *Halodule pinifolia*, *Halophila ovalis*, and *Thalassia hemprichii*. The highest values of density, frequency of occurrence, percentage of coverage, importance value, and biomass were found for *H. pinifolia*. The lowest values for density, percentage of coverage, and biomass were found for *H. ovalis*, while *T. hemprichii* had the lowest values for frequency of occurrence and importance. Spatial distribution based on density, percentage of coverage and biomass have the values of >10 stands m^{-2}, >40% and >200 g m^{-2}, respectively.
Key Words: biodiversity, coastal ecosystem, management, productivity.

Introduction. Seagrass is a flowering plant (Angiospermae) that has seeds, roots, rhizomes, leaves, flowers, and fruit. Seagrasses represent an ecosystem with high organic productivity, and important functions in coastal aquatic ecosystems, including as habitat, rearing, spawning, foraging grounds for several organisms, shoreline stabilization, source of building materials, and carbon sequestration. Globally, seagrass plays a significant role in supporting biodiversity, food security, and mitigating climate change (Hoegh-Guldberg et al 2014; Oreska et al 2017; Unsworth et al 2019).

Seagrass growth, abundance, and survival are strongly influenced by biophysical factors, including underwater light, transparency, nutrients, and temperature. Seagrasses grow in salt and brackish waters around the world, usually along protected and gently sloping coastlines (Barillé et al 2010; Ondiviela et al 2014). Because of their dependence on light for photosynthesis, seagrasses are most commonly found in shallow water, where light levels are high with good water circulation to deliver nutrients and oxygen and regulate seagrass metabolic products outside the seagrass area. Many seagrass species live at depths of about 1 to 3 m, but there is also a species that grows in deep water, namely *Halophila decipiens*, which can be found at depths of 58 m (Ondiviela et al 2014 Reynolds 2018).

Substrate characteristics affect the structure and abundance of seagrass. Seagrasses live on various types of substrates ranging from mud to sediments consisting of 40% silt and fine sand. Each seagrass species has a favorite substrate characteristic. Seagrasses may like muddy, sandy, clay substrates, or substrates with coral fractures and rock crevices, so it is not surprising that seagrass can still be found in coral and mangrove ecosystems (De Silva & Amarasinghe 2007; Newmaster et al 2011).

The waters of Tulehu Village are a coastal area with a seagrass ecosystem side by side with other marine biological resources such as mangroves, macroalgae, and mollusks. Seagrass communities in the waters of Tulehu Village have a fairly wide distribution, but information about seagrass communities in these waters is limited. Early research on the composition of seagrass species in Tulehu waters had previously been carried out by Elly (2008) at locations around the sea transport crossing wharf, where six species of seagrass were found, namely *Enhalus acoroides, Cymodocea serrulata, Cymodocea rotundata, Halodule pinifolia, Halophila ovalis,* and *Thalassia hemprichii*. Another study was conducted by Sangadji (2011) in the vicinity of a hot spring location, where four species of seagrass were found, namely *C. rotundata, H. pinifolia, H. ovalis, and T. hemprichii*.

Seagrass studies in Tulehu State waters and Ambon Island waters, in general, have so far focused on species composition and community structure. Further and specific research focused on the spatial distribution and community structure of seagrass has not been carried out, to our knowledge. Information about the spatial distribution of seagrass is important because it determines its effectiveness as an ecosystem stabilizer. If there is a disturbance to the seagrass, especially if there is habitat fragmentation, it can affect the entire coastal ecosystem. Lack of information about spatial patterns makes it difficult to understand the dynamics of long-term change in the spatial distribution of seagrass communities (Frost et al 1999; Short & Coles 2001). In addition, information about the spatial distribution of seagrasses is very useful in supporting the management planning of seagrass ecosystems and coastal ecosystems in general.

Considering the importance of spatial distribution information in the management of seagrass ecosystems, it is necessary to conduct research that examines the community structure and spatial distribution of seagrass in the waters of Tulehu Village. This study aims to describe the species composition, species density, frequency of presence, percentage of cover, importance, biomass, abundance, distribution pattern, and spatial distribution of seagrass communities in the coastal waters of Tulehu, Indonesia.

Material and Method

Description of the study area. The research was conducted in June 2021, in the coastal waters of Tulehu Village (Figure 1), Indonesia. The coastal waters of Tulehu Village are administrated by Salahutu District, Central Maluku Regency, Maluku Province, Indonesia. The study area is located at 03°35'39.6"-03°35'45.1"S and 128°20'52.8"-128°20'58.2"E. The area has sandy, rocky, and rocky sand substrates. In the form of coral fractures, the rocky sand substrate was also found, nearing the lowest tide at the study site. The sampling area of the seagrass community is 15000 m^2. During the rainy season, there is seepage of freshwater from land into coastal waters. In addition, there are activities carried out by local communities in the coastal ecosystem such as disposing of household waste, bathing, washing, dredging sand, bathing, fishing, and others.

Fish, gastropods, bivalves, crustaceans, echinoderms, sea snakes, and algae are organisms associated with seagrass communities in the area. These organisms use seagrasses as a place to live and shelter. Fish and crustaceans are usually found in between clumps of seagrass leaves, echinoderms are found living on the substrate, and gastropods live on the substrate by burrowing, and sometimes also on the surface of the substrate, or attached to the rhizomes, roots, and leaves of seagrass. Seagrasses also function as a food source for the organisms mentioned above.

Data collection method. The data collection method applied in the field is the linear-quadratic transect method (Loya 1978). Observations were conducted in June 2021 using 25 transects consisting of 380 quadrants, with a distance between transects of 10 m and a distance between quadrants of 3 m. The transect rope was drawn perpendicular to the shoreline from the highest tide to the lowest tide and placed in a square-shaped quadrant measuring 1x1 m. In each quadrant, the number of stands of seagrass species found was recorded, the seagrass being cut and placed in plastic bags that had been labeled for each species. The sample was then cleaned of adhering impurities and weighed per each quadrant. Measurements of seawater temperature and salinity were carried out for each quadrant of observations. Visual observation of the substrate was carried out in each quadrant of observation.

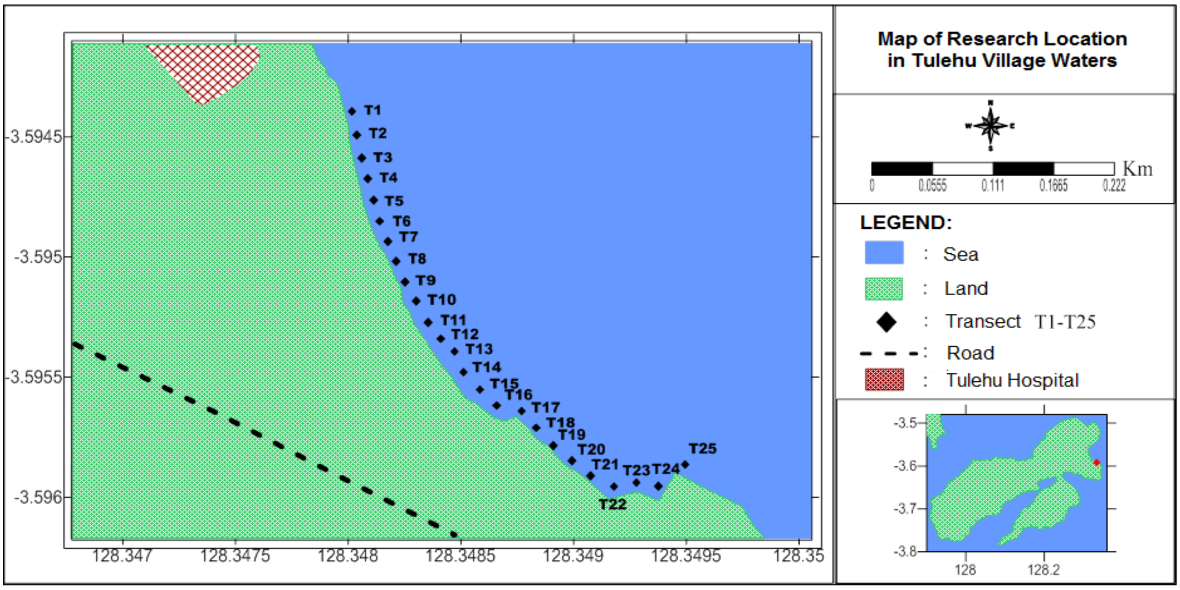

Figure 1. Map of the study area.

The samples obtained from the field were identified at the Laboratory of the Marine Science Study Program, Faculty of Fisheries and Marine Sciences, to describe the morphology of seagrasses including leaf shape, leaf color, leaf length, leaf width, rhizome, the distance between nodes, number of stands at each node and root shape using an identification book according to Waycott et al (2004). The seagrass samples were classified according to family, genus, and species. To determine the biomass, the seagrass samples were weighed using a digital scale "Ohaus Scout Pro 400 g".

Data analysis. Species density (Di), relative density (RDi), frequency (F), and relative frequency (RF) of seagrass were calculated based on the formula of Cox (2002). F of seagrass describes the probability of finding a particular seagrass species in all squares of observations, while RF is the ratio between the frequency of a particular seagrass species and the total frequency of all species. Di of seagrass is the ratio between the number of stands of a particular seagrass species and the area of the sample. RDi is the ratio between the number of certain seagrass species and the total number of all seagrass species.

The percentage value of species cover in each quadrant of observations was calculated according to Saito & Atobe (1970):

$$C = \frac{\Sigma\,(Mi\;x\;fi)}{\Sigma f}$$

Where: C - percentage of seagrass species cover; Mi - percentage of the midpoint of the i-th class; f - frequency (number of sectors in the same class); fi - frequency of class i.

Relative cover (RC) is the ratio between the individual cover of a particular species (ni) and the total cover of all species (n) (Brower 1990). The Importance Value Index (IVI) was used to calculate and estimate the role of each species of seagrass in the community. IVI was calculated using the formula:

IVI=RDi+RF+RC

Spatial distribution processing of seagrass data in the form of distribution of species, density, percent cover, biomass, and substrate was carried out using the SURFER 10 software. Coordinate data (x, y), species of seagrass, density, percent cover, and biomass were also processed with MS Excel 2003. The gridding process followed by selecting the grid on the menu and selecting the data that will be used to create a spatial distribution. The griding method applied is a natural neighbor. The next step was to produce a spatial distribution display using the contour map menu and enter the data to be distributed. After that, with the level edit function, the data has been divided into several classes as presented in Table 1. The final result is a map of the spatial distribution of seagrass based on the parameters of seagrass species, density, percent cover, and biomass.

Table 1

Class division range for density values, percent cover, and seagrass biomass

Class	*Density*	*Percent cover*	*Biomass*
1	Empty	Empty	Empty
2	<10 stands m^{-2}	<20%	<100 g m^{-2}
3	>10 stands/m^{-2}	20–40%	100–200 g m^{-2}
4	-	>40%	>200 g m^{-2}

Results and Discussion

Species composition of seagrass. The seagrasses found at the research site consisted of four species classified into two families, namely family Cymodoceaceae, with two genera and two species, and family Hydrocaritaceae, with two genera and two species (Table 2).

Table 2

The composition of seagrass species at the study site

Division	*Class*	*Family*	*Genus*	*Species*
Anthophyta	Angiospermae	Cymodoceaceae	*Cymodocea*	*C. rotundata*
			Halodule	*H. pinifolia*
		Hydrocaritaceae	*Halophila*	*H. ovalis*
			Thalassia	*T. hemprichii*

There are fewer species of seagrass found in this study area when compared to the results of research in different locations, which can be seen in Table 3. Based on Table 4, it can be seen that Indonesia has thirteen species of seagrass. Research by Hulopi (2000) and Latuheru (2011), in the waters of Suli Village, located not far from Tulehu Village, found six to seven species. This is because the waters of Suli Village have hydrological conditions and substrate conditions that support the growth and development of seagrass species. Meanwhile, according to Elly (2008), in the waters of Tulehu Village, six species were found. The results of Elly (2008) are different from the results of this study, because we found only 4 species. We believe this occurred because the substrate of the research location in this study is less diverse, and it is dominated by sand.

Figure 2 shows that the seagrass species that dominates the research location is *H. pinifolia*. On the other hand, the seagrass species that had the least distribution was *T. hemprichii*. *H. pinifolia* species spread from the northwest to the southeast of the study site, as well as *C. rotundata*. However, in the northeastern part, this species is rarely found. Generally, this species is found in abundance in the center of the site, where *H. ovalis* and *T. hemprichii* are also found.

Table 3
Differences in seagrass species composition in several locations in Indonesia and Ambon Island

Family/Species	Location						
	1	2	3	4	5	6	7
Hydrocharitaceae							
Enhalus acoroides	√	√	√	√	√	-	-
Halophila ovalis	√	√	√	√	√	√	√
Halophila minor	√	-	-	-	-	-	-
Halophila spinulosa	√	-	-	-	-	-	-
Halophila decipiens	√	-	-	-	-	-	-
Halophila sulawesii	√	-	-	-	-	-	-
Thalassia hemprichii	√	√	√	√	√	√	√
Cymodoceaceae							
Cymodocea rotundata	√	√	√	√	√	√	√
Cymodocea serrulata	√	√	-	-	√	-	-
Halodule pinifolia	√	√	-	√	√	√	√
Halodule uninervis	√	-	√	-	-	-	-
Syringodium isoetifolium	√	√	√	-	-	-	-
Thalassodendrom ciliatum	√	-		-	-	-	-

Note: √ - presence; 1 - Indonesia, with reference to Kuriandewa & Supriyadi (2006) and Kuo (2007); 2 - Suli Village, with reference to Latuheru (2011); 3 - Suli Village, with reference to Hulopi (2000); 4 - Waai Village, with reference to Corputty (2010); 5) Tulehu Village, with reference to Elly (2008); 6 - Tulehu Village, with reference to Sangadji (2011); 7 - Tulehu Village, with reference to Sangadji (2011).

Table 4
Differences in species density values at three locations on Ambon Island

Species	Location		
	Suli Village[a]	Waai Village[b]	Tulehu Village[c]
H. pinifolia	45.23 stands m^{-2}	33.26 stands m^{-2}	944.85 stands m^{-2}
C. rotundata	87.41 stands m^{-2}	29.40 stands m^{-2}	127.86 stands m^{-2}
C. serrulata	66.88 stands m^{-2}	–	–
T. hemprichii	99.03 stands m^{-2}	65.68 stands m^{-2}	15.45 stands m^{-2}
E. acoroides	41.43 stands m^{-2}	136.35 stands m^{-2}	–
H. ovalis	52.00 stands m^{-2}	7.57 stands m^{-2}	3.79 stands m^{-2}
S. isoetifolium	87.14 stands m^{-2}	–	–

Note: a - Latuheru (2011); b - Corputty (2010); c - Sangadji (2011).

The density of seagrass species. *H. pinifolia* dominated the study site, so it had a higher density than the other three species, namely 944.85 stands m^{-2}. The reason is that this species has a higher number of stands. Another reason is because of the sandy substrate that supports the growth of this species. On the other hand, *H. ovalis* had the lowest density of 3.79 stands m^{-2}. This species has a distribution area that depends on the substrate (Mateu-Vicens et al 2012). The density of *C. rotundata* was 127.86 stands m^{-2}. *T. hemprichii* had a fairly low density of 15.45 stands m^{-2}. Based on Table 4, in the waters of Suli village, *T. hemprichii* had the highest species density of 99.03 stands m$^{-2,}$ and in, Waai village, *E. acoroides* had a density of 136.35 stands m^{-2}. This indicates that the density of each species is different in each location depending on the type of substrate. In Suli village, *T. hemprichii* had a high density due to the presence of a substrate that supports its growth, namely sandy and rocky substrate, mixed with dead coral debris (Tuahatu et al 2016). In the waters of Waai village, *E. acoroides* also has a favorable substrate, namely rocky sand, muddy sand, and sand mixed with dead coral debris (Corputty 2010).

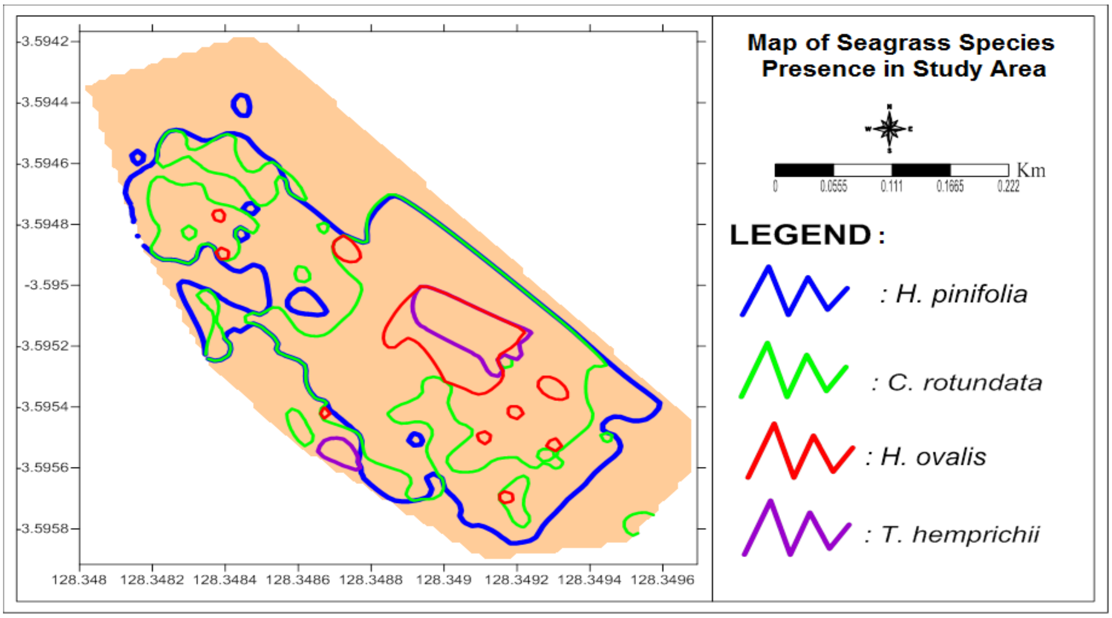

Figure 2. Spatial distribution of seagrass by species presence.

The map of the spatial distribution of seagrass based on density shows that the density values of *H. pinifolia* and *C. rotundata* are high. These two species have a density value of >10 stands m^{-2} and are classified into the third class of density value. Even though both species have high-density values, *H. pinifolia* is the most dominant. This species has a large number of stands. On the other side, *H. ovalis* and *T. hemprichii* each had a value of <10 stands m^{-2}, being classified into the second class (Figure 3).

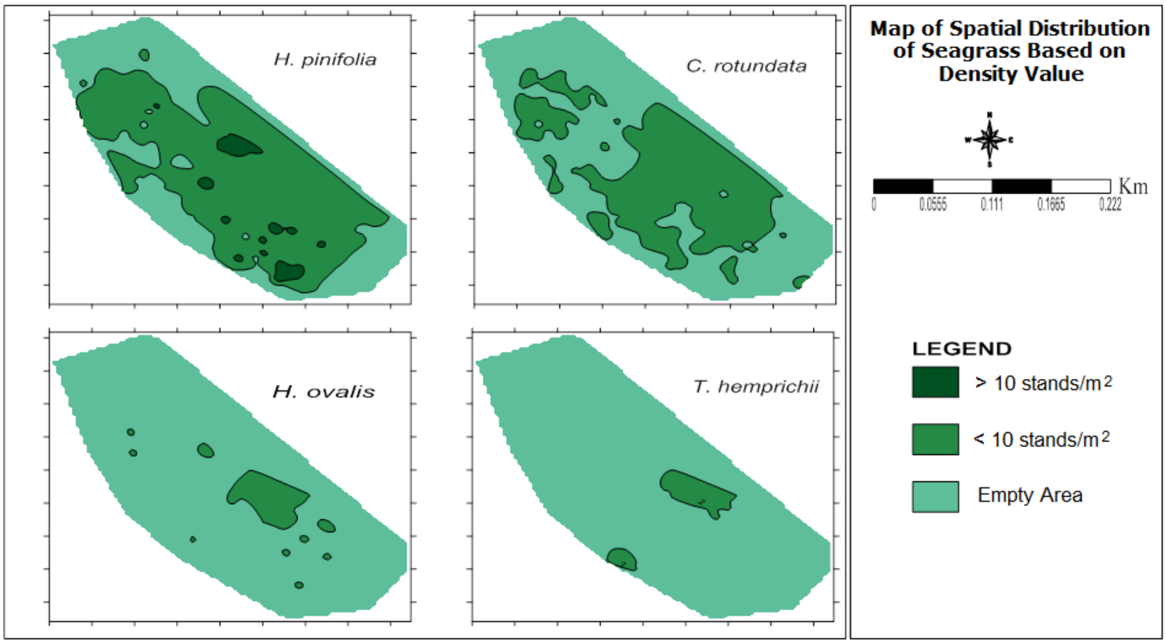

Figure 3. Spatial distribution of seagrass based on density.

Frequency of seagrass species presence. *H. pinifolia* was found in 239 quadrants out of 380 total quadrants on all transects (Figure 4). This species dominates the research location, having the highest frequency of all four found species, with a value of 0.81. The species that had the lowest presence of frequency, *T. hemprichii*, was found in 17 quadrants of the 380 total quadrants, with the value of 0.06. *C. rotundata* was found in

145 quadrants out of 380 total quadrants in all transects. From the measurement results obtained from all transects, this species has a presence frequency value of 0.49. *H. ovalis* was found in 26 quadrants out of 380 total quadrants on all transects. This species has a fairly low presence frequency value of 0.09. The research site has a predominantly sandy substrate, so *H. pinifolia* had a higher frequency.

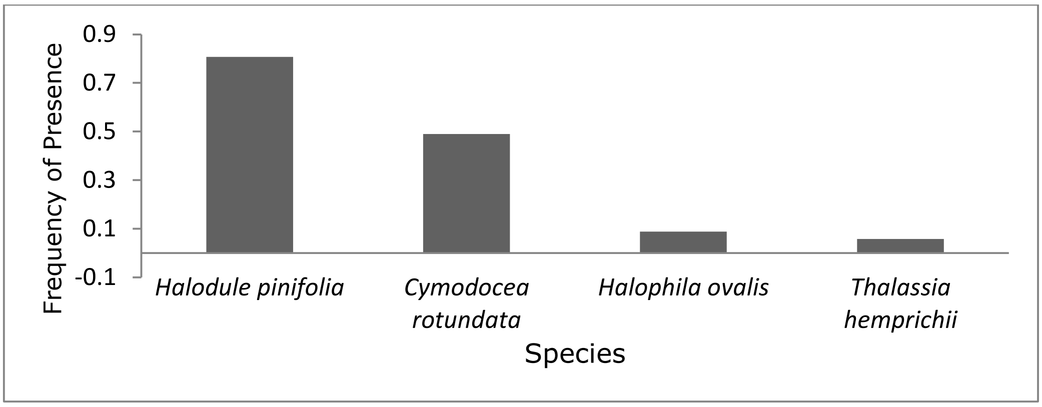

Figure 4. Frequency of presence of seagrass species.

Coverage percentage of seagrass species. *H. pinifolia* had the highest percentage of coverage, with a value of 28.95%. This species was found in almost all research locations where the substrate was dominated by sand. *H. ovalis* had a lower coverage percentage value of 0.16%. In addition, several factors that affect the percentage of cover of a species are the density value and the leaf width. At this location, *H. ovalis* was found growing on sandy substrates and coral fractures. The percent cover value of *C. rotundata* was 2.63%, while *T. hemprichii* had a percentage cover value of 0.49%.

Figure 5 shows that *H. pinifolia* has a high percentage cover value and is in the fourth class with a value of >40%, while *C. rotundata* has a value ranging from 20-40% and is in the third class. *H. ovalis* and *T. hemprichii* each had a value of <20%, being in the second class.

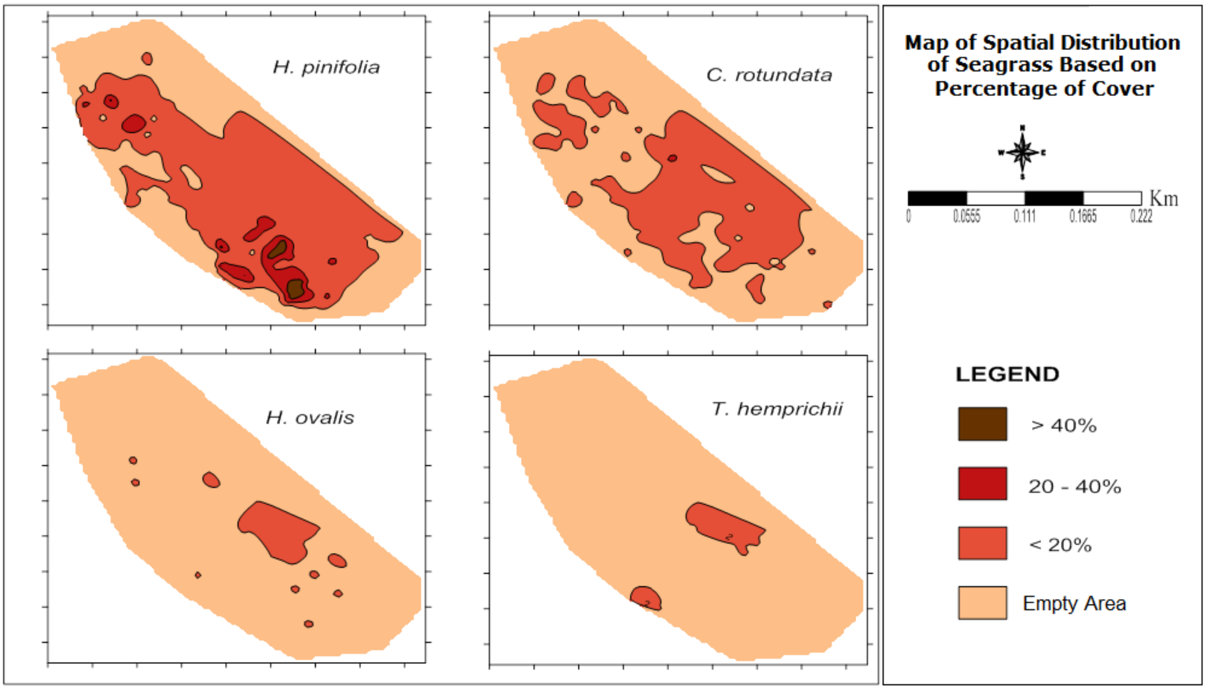

Figure 5. Spatial distribution of seagrass by the percentage of cover.

The importance value of seagrass species. The importance value of seagrass species is used to calculate and estimate the overall role of one species in a community (Brower 1990). *H. pinifolia* has the highest value, of 232.33%. *T. hemprichii* has a lower value than the other three species, which is 6.92%. *C. rotundata* has a value of 53.83%, while *H. ovalis* has a value of 6.93%.

H. pinifolia had a higher density, percent cover, and frequency of presence. This was due to a higher number of stands of this species and was found in almost all observation transects. *T. hemprichii* has a low value because it has the lowest presence in the observation transects (Figure 6).

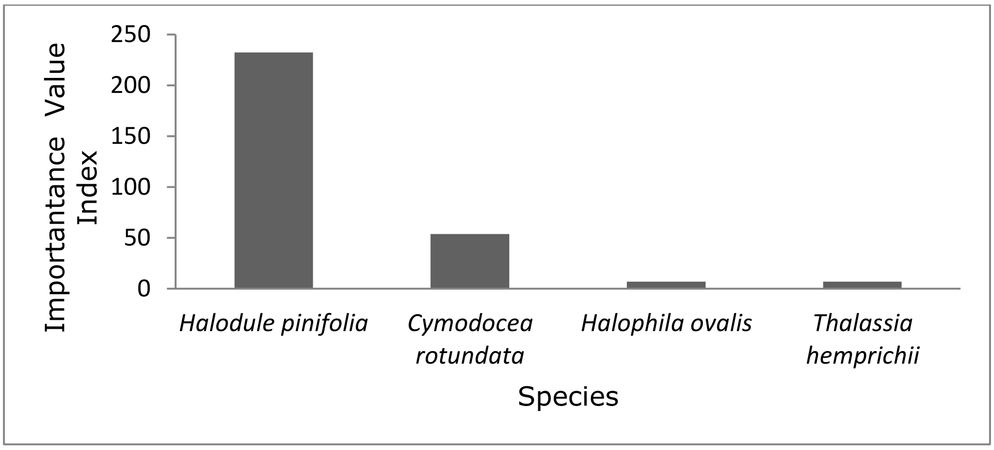

Figure 6. The importance value index of the seagrass species.

Biomass of seagrass species. Based on the results of the analysis, each seagrass species has different biomass values. The seagrass species with the highest biomass value is *H. pinifolia*, with 7695.8 g m^{-2}. The lowest seagrass biomass value was found for *H. ovalis*, which was 142.1 g m^{-2}. Meanwhile, *C. rotundata* and *T. hemprichii* have biomass values of 3922.5 g m^{-2} and 537.6 g m^{-2}, respectively (Figure 7).

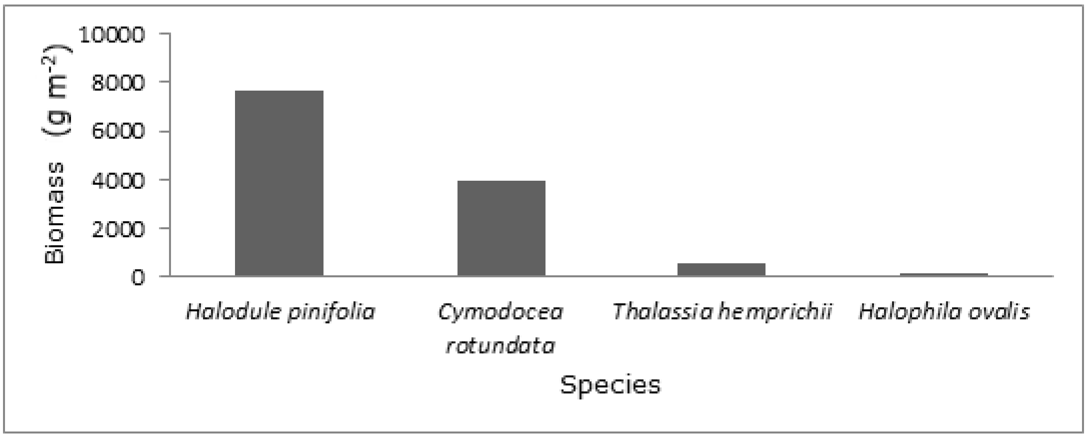

Figure 7. Biomass of seagrass species.

Figure 8 shows that *H. pinifolia* has a high biomass value and belongs to the fourth class, with a value of >200 g m^{-2}. Meanwhile, *C. rotundata* is included in the third class, and has values ranging from 100-200 g m^{-2}. *H. ovalis* and *T. hemprichii* each have a value of <100 g m^{-2}, being in the second class. One of the factors that play a role in the growth and existence of seagrass is the substrate. Gladstone-Gallagher et al (2018) explained that the factor that controls seagrass biomass is the size of the seagrass leaves. Seagrass species *T. hemprichii* and *H. ovalis* had low biomass due to the small number of stands and *H. ovalis* had small leaf sizes.

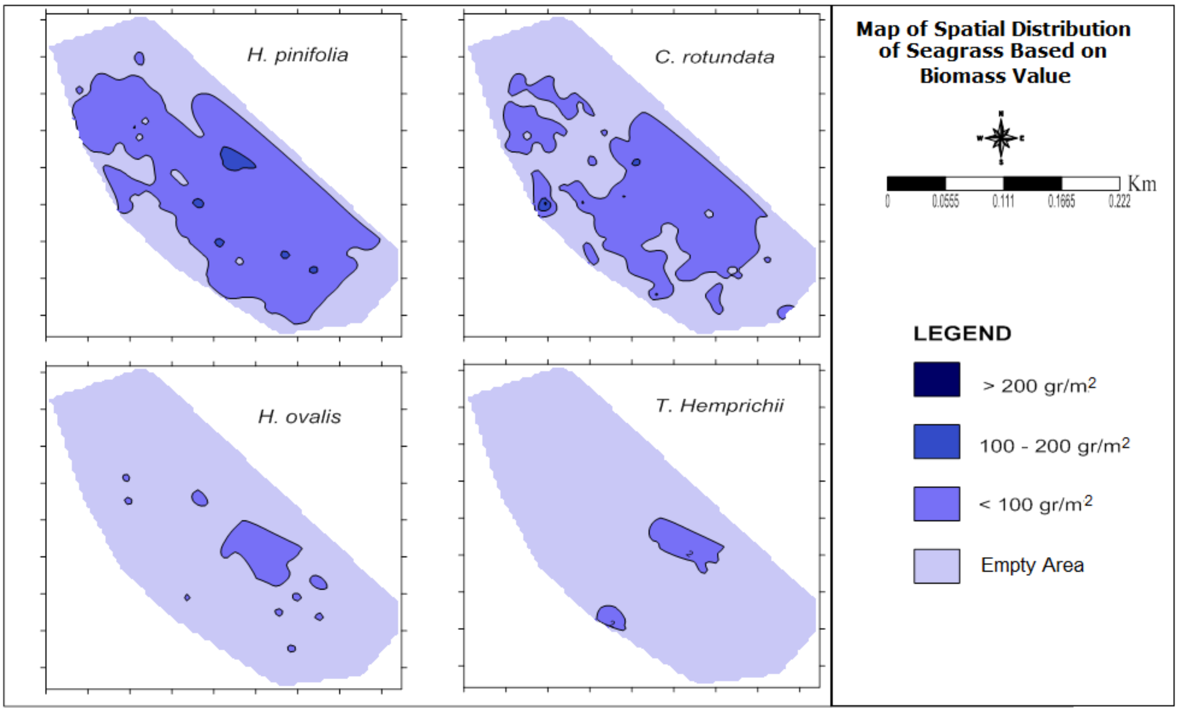

Figure 8. Spatial distribution of seagrass based on biomass value.

Based on Table 5, the seagrass biomass in Kotania Bay and Bintan Island had the highest percentage of around 50% and 58%, respectively, lower than 309 g m^{-2}. Meanwhile, in Tulehu coastal waters, the percentage of 100% is at the level lower than 309 g m^{-2}. This indicates that the Tulehu coastal waters have a low seagrass species biomass value, different when compared to Kotania Bay and Bintan Island. Seagrass biomass varies greatly depending on species and habitat conditions, especially according to water brightness, circulation, water depth, substrate, and available nutrients (Waycott et al 2007).

Table 5

Comparison of biomass values at three locations in Indonesia

Biomass (g m^{-2})	*Location and percentage (%)*		
	Kotania Bay	*Bintan Island*	*Tulehu Waters*
540-1000	10	9	0
310-539	40	33	0
<309	50	58	100

Note: source: Supriyadi (2010).

Conclusions. There are two families of seagrass and four species found in the waters of Tulehu Village: the Cymodoceaceae family with two species, *Cymodocea rotundata* and *Halodule pinifolia*, and Hydrocaritaceae family with two species, *Halophila ovalis* and *Thalassia hemprichii*. *H. pinifolia* has the highest values of density, frequency of occurrence, percentage of coverage, importance value, and biomass. The lowest values for density, percentage of coverage, and biomass were found for *H. ovalis*, while *T. hemprichii* had the lowest values for the frequency of occurrence and importance. Density, percentage of coverage and biomass, according to spatial distribution, had the values of >10 stands m^{-2}, >40% and >200 g, respectively.

Conflict of Interest. The authors declare that there is no conflict of interest.

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