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Seagrass diversity in Pulau Banyak, Aceh Singkil District, Indonesia

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Abstract. *Erniati, Andika Y, Imanullah, Imamshadiqin, Erlangga, Rahmad, Tauladan TA, Siregar FR, Fitri A, Ritonga GH. 2023. Seagrass diversity in Pulau Banyak, Aceh Singkil District, Indonesia. Biodiversitas 24: 6621-6628.* Seagrass is a high-level plant where life activities are submerged in seawater. Currently, the seagrass ecosystem is threatened with destruction and disappearance. The extent of seagrass ecosystems globally was estimated to have declined by about 58%. The solution to this problem is to balance local communities' utilization of biological resources and biodiversity maintenance. The biodiversity aspect of seagrass is key to the sustainability of seagrass ecosystems. Banyak Island is one of the sub-districts in Aceh Singkil Regency, which consists of a cluster of small islands and has rich fisheries and marine potential, one of them is seagrass, where station 1 is Balong Island, Stasion 2 is Balong Island, Stasion 3 is Lamun Island and Stasion 4 is Rago-Rago Island. This study aimed to assess the diversity of seagrass beds, including seagrass species composition, density, percentage cover, and water quality that affect the existence of seagrass ecosystems. This study used a purposive sampling method with 3 transect lines spaced 50 m perpendicular from the shoreline to the sea. Each transect line has 5 plots with a distance of 10 meters measuring 50 x 50 cm^2, and the water quality parameters were measured in situ. This research found 5 seagrass species, namely *T. hemprichii, C. rotundata, E. acroides, S. isoetifolium,* and *H. ovalis. C. rotundata* is the species with the highest density on Matahari Island, but seagrass diversity is low, and no species were dominant in the groups. The results of PCA analysis showed that the environmental factors that most influenced the pattern of seagrass distribution and density were nitrate, phosphate, and substrate. The conclusion revealed that seagrass diversity on Banyak Islands is relatively low.

Keywords: Banyak Island, density, diversity, seagrass

INTRODUCTION

Seagrass is a high-level plant whose entire life activities are submerged in seawater (Kim et al. 2021). Seagrass grows-across the tidal zone to depths still accessible to sunlight (Kawaroe et al. 2016). Seagrass life is influenced by environmental conditions such as substrate, temperature, salinity, nutrients, brightness, and current speed (Fitrian et al. 2017). Seagrass plays a significant role in fisheries (Nugraha et al. 2021). Ecologically, seagrass provides habitat, spawning grounds, and shelter for fish and invertebrates (Unsworth et al. 2019). In addition, seagrasses also function as wave absorbers, sediment deposits, and water purifiers (Nordlund et al. 2016; Lamb et al. 2017; Wainwright et al. 2019; Moussa et al. 2020). Another role of seagrasses is climate change mitigation and ocean acidification, of which about 15% is absorbed by seagrasses globally (Kennedy and Bjork 2009; Fourqurean et al. 2012; UNEP 2020). Seagrasses contribute more economically than terrestrial forests (Dewsbury et al. 2016), about $28,916 ha-1 year-1, while tropical forests contribute only $5,382 ha-1 year-1 (Costanza et al. 2014).

Globally, seagrasses that were found consist of 4 families, 12 genera, and 60 species (Short et al. 2007) distributed in tropical and subtropical regions (Xu et al. 2021). Still, the Indo-Pacific region has the highest diversity (Kawaroe et al. 2016). So far, 24 seagrass species have been identified in the Indo-Pacific region, and 14 species are found in Indonesia (Short et al. 2007). Seagrass species that were found in Indonesia include *Cymodocea rotundata* Asch. & Schweinf., *C. serrulata* (R.Br.) Asch. & Magnus, *Enhalus acoroides* (L.f.) Royle, *Halodule pinifolia* (Miki) Hartog, *Halodule uninervis* (Forssk.) Boiss., *Halophila decipiens* Ostenf., *H. minor* (Zoll.) Hartog, *H. ovalis* (R.Br.) Hook.f., *H. spinulosa* (R.Br.) Asch., *H. sulawesii* J.Kuo, *H. major* (Zoll.) Miq., *Syringodium isoetifolium* (Asch.) Dandy, *Thalassia hemprichii* (Ehrenb. ex Solms) Asch., and *Thalassodendron ciliatum* (Forssk.) Hartog (Sjafrie et al. 2018; Kurniawan et al. 2020; Nugraha et al. 2021). The area of seagrass beds in Indonesia in 2017 was around 293,464 ha, with moderate conditions (Sjafrie et al. 2018; Hernawan et al. 2021).

Currently, seagrass ecosystems are threatened with damage and loss; it is estimated that the global seagrass ecosystem area has decreased by around 58% (Waycott et al. 2009), while in Indonesia, the area has decreased by around 40% (Vo et al. 2020). The decline in seagrass area is caused by anthropogenic activities such as tourism, port, capture fisheries and aquaculture, and coastal sand mining (Kawaroe et al. 2016); if this situation continues, the seagrass ecosystem area will decrease yearly (Zhou et al. 2015). In the last decade, the United Nations has mandated the development of solution-oriented science and sustainable environmental management (UN Environment 2018). One of the efforts that can be made is to balance local communities' utilization of biological resources and maintain biodiversity (Schuckmann et al. 2020). The biodiversity aspect of seagrass is the key to preserving seagrass ecosystems (Nordlund et al. 2018).

Banyak Island is one of the sub-districts in Aceh Singkil District, which consists of a cluster of small islands. The archipelago consists of 63 large and small islands located at coordinates 97°3'40" East-97°27'58" East and 1°58'25" LU-2°22'25" LU. Many islands have a lot of marine and fisheries potential, one of which is seagrass. The potential diversity of seagrasses in Aceh's waters, including on the island of Banyak, has not been found in scientific reports, so research on seagrass diversity on Banyak Island must be carried out thoroughly to evaluate the seagrass data. In addition, the need to maintain seagrass ecosystems begins with an in-depth study of their diversity (Kawaroe et al. 2016; Fortes et al. 2018). The study aims to assess seagrass diversity, including seagrass species composition, density, percentage cover, and water quality affecting the existence of seagrass ecosystems.

MATERIALS AND METHODS

Research location

This study was conducted in September 2023 on Balong Island, Matahari Island, Lamun Island, and Rago-Rago Island, where found in Banyak Island Sub-district, Aceh, Indonesia (Figure 1). The coordinates of the research stations are presented in Table 1.

Seagrass data collection methods

The method used was purposive sampling, determined based on seagrass ecosystems on each island. Sampling of seagrasses was conducted when the sea water was at low tide and then identified using a manual guidebook (Rahmawati et al. 2017). At each station, there are 3 transect lines with a distance of 50 m drawn perpendicularly as far as 50 m from the shoreline to the sea. Each transect line has 5 plots with a distance of 10 m measuring 50 x 50 cm (English et al. 1997; McKenzie and Yoshida 2009). Water quality parameters were measured in situ. Water quality parameters measured included DO, temperature, pH, salinity current velocity, nitrate, phosphate, and type of substrate.

Seagrass abundance

Seagrass abundance is quantified using the following formula (English et al. 1997):

$$D = \sum \frac{Ni}{A} \quad \text{(i)}$$

Where:
D : Seagrass abundance (ind/m^2)
N*i* : Number of shoots in its species (ind)
A : Total Area (m^2)

Index of diversity, uniformity, dominance, and Morisita dispersion

The diversity index is quantified using the formula (Odum 1993):

$$H' = -\sum Pi \ln Pi \quad \text{(ii)}$$

$$Pi = \frac{ni}{N} \quad \text{(iii)}$$

Where:
H' : Species diversity index
n*i* : Number of individuals of each species
N : Total number of individuals

The criteria for the diversity index are the value of H' < 1 = diversity index is categorized as low, 1 ≤ H' ≤ 3 = diversity index is in the medium category, and if the value of H' > 3 is classified as high.

Table 1. Coordinate research location

Location	Coordinate
Balong Island	2°18'33" N - 97°14'40" E
Matahari Island	2°17'36" N - 97°14'50" E
Lamun Island	2°15'07" N - 97°12'29" E
Rago-Rago Island	2°15'07" N - 97°14'41" E

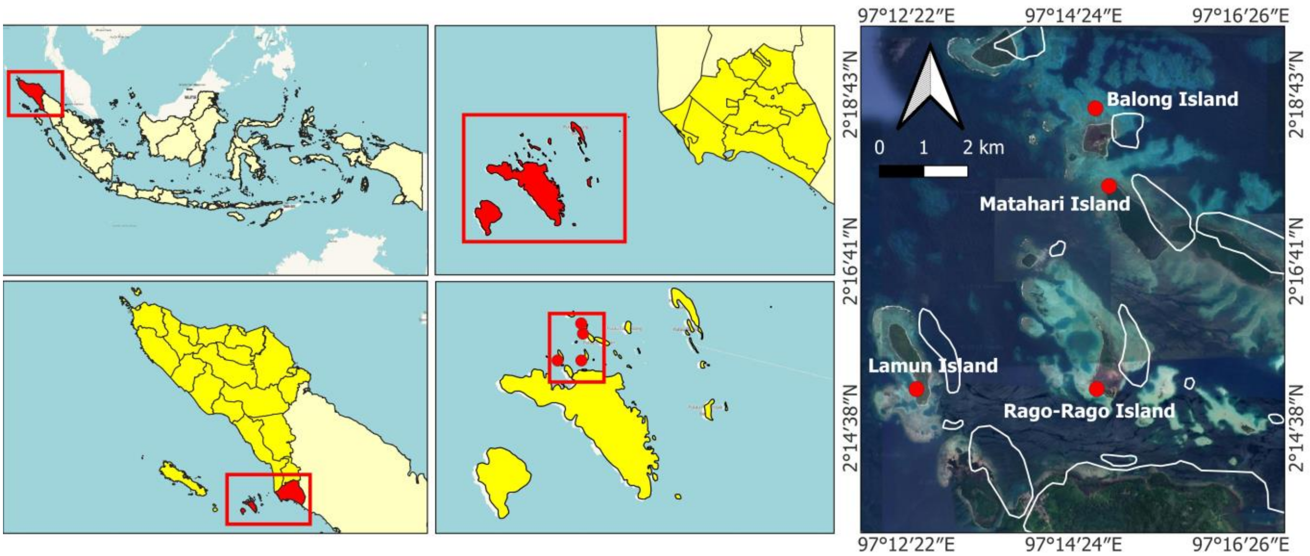

Figure 1. Research location in Pulau Banyak, Aceh Singkil District, Aceh Province, Indonesia

The uniformity index is quantified using the formula (Odum 1993):

$$E = \frac{H'}{Log\ S} \quad \text{(iv)}$$

Where:
E : Index of uniformity
H' : The diversity index
S : Total number of species

The criteria for the uniformity index are E<0.4, categorized as low; 0.4<E<0.6, categorized as medium; and the value of E>0.6, categorized as high.

The dominance index is quantified using the formula (Odum 1993):

$$C = \sum \left(\frac{ni}{N}\right)^2 \quad \text{(v)}$$

Where:
C : Dominance index
n*i* : The number of individuals of each species
N : The total number of individuals

Almost no one dominates if the C value is close to 0, while a C value close to 1 indicates an individual dominating the population.

The Morisita dispersion index is calculated using the formula (Krebs 1998):

$$Id = n\left[\frac{(\sum x^2 - N)}{N(N-1)}\right] \quad \text{(vi)}$$

Where:
I_d : The Morisita dispersion index
n : Number of samples
N : Total number of samples
x : Number of individuals found on each plot

The criteria for the uniformity index are Id = 1, then the seagrass random distribution, Id<1, then the seagrass uniform distribution, and Id>1, then the seagrass clustered distribution.

Data analysis

Data were analyzed using cluster analysis and Principal Component Analysis (PCA) (Mishra et al. 2017) using Past 4.03 software.

RESULTS AND DISCUSSION

Seagrass distribution

Seagrasses found in Banyak Island were 5 species from 2 families, namely *Thalasia hemprichii*, *Cymodocea rotundata*, *Enhalus acroides*, *Syringodium isoetifolium dan Halophila ovalis*. Seagrass distribution is presented in Table 2.

Seagrass abundance and coverage

Seagrass abundance by species and stations is presented in Figure 2, and the Percentage of Seagrass species by stations is presented in Figure 3.

Table 2. Seagrass distribution in Banyak Island

Family	Species	Research location			
		Balong Island	Matahari Island	Lamun Island	Rago-rago Island
Hydrocharitaceae	*T. hemprichii*	+	+	+	+
	E. acroides	+	+	+	+
	H. ovalis	-	-	-	+
Potamogetonaceae	*C. rotundata*	+	+	+	+
	S. isoetifolium	+	+	+	-

Note: +: Found, -: Not found

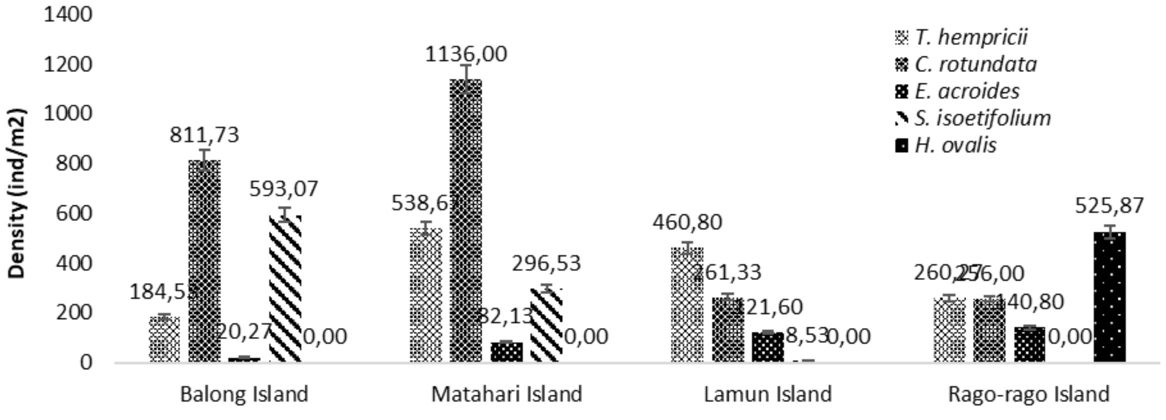

Figure 2. Seagrass species abundance at each study site

Table 3. Index of diversity, uniformity, dominancy, and dispersion of Morisita

Index	H'	Category	E	Category	C	Category	I_d	Category
Balong Island	1.02	Low	1.69	High	0.40	Low	1.61	Clumped
Matahari Island	1.09	Low	1.81	High	0.40	Low	1.59	Clumped
Lamun Island	1.02	Low	1.69	High	0.41	Low	1.62	Clumped
Rago-rago Island	1.28	Low	2.12	High	0.31	Low	1.23	Clumped

Table 4. The average value of water quality parameters

Water quality parameters	Research location				Quality standard
	Balong Island	Matahari Island	Lamun Island	Rago-rago Island	
DO (mg/L)	10.10±1.30	10.87±0.51	7.53±1.19	9.80±0.95	>5
Temperature (°C)	30.97±0.68	31.80±1.70	29.50±0.91	28.20±0.26	28-32
pH	7.90±0.43	7.33±0.41	8.22±0.35	7.87±0.13	7-8.5
Salinity (‰)	30.00±0.00	30.00±0.00	31.00±1.00	30.67±1.15	28-39
Current speed (m/s)	0.06±0.01	0.07±0.01	0.01±0.01	0.01±0.01	Natural
Nitrate (mg/L)	0.01±0.01	0.02±0.01	0.01±0.01	0.02±0.01	0.08
Phosphate (mg/L)	1.21±0.35	1.59±0.09	1.38±0.21	5.49±5.16	0.15

Note: Natural is the normal condition of an environment, varying over time (day, night, and season)

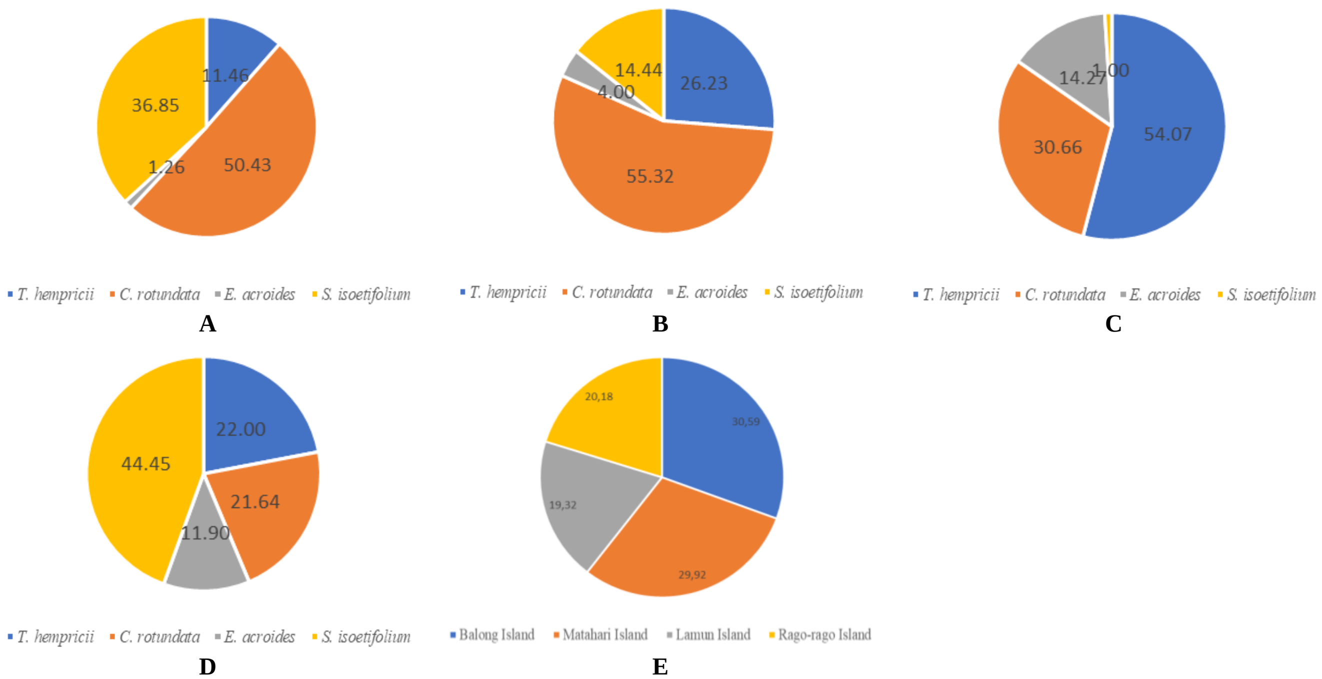

Figure 3. Seagrass coverage at each study site: A. Balong Island, B. Matahari Island, C. Lamun Island, D. Rago-rago Island, and E. Total coverage at each station

Index of diversity, uniformity, dominancy, and Morisita index of dispersion

The index of diversity, uniformity, dominancy, and dispersion index of Morisita are presented in Table 3.

Water quality parameters

The results of the average value of measured water quality parameters, including dissolved oxygen, temperature, pH, salinity, current velocity, nitrate, and phosphate, are presented in Table 4. The results of PCA analysis, the relationship between seagrass abundance and environmental parameters are presented in Figure 4, and cluster analysis in Figure 5.

Discussion

Based on Table 2, seagrass species *T. hemprichii*, *E. acroides*, and *C. rotundata* are distributed on all observation islands, while *H. ovalis* is only found on Rago-rago island. Banyak Island has many clusters of islands, where the distance between each island is not too far, so the seagrass habitat characteristics are not much different. Rago-rago Island has slightly unique characteristics, the seagrass habitat substrate consists of muddy sand, sand, crusted sand, and rocky sand. *Halophila ovalis* on Rago-rago Island was found on muddy sand substrates. The distribution of seagrass *H. ovalis* is quite wide in Indonesian waters (Kawaroe et al. 2016; Iswari et al. 2017; Nugraha et al.

2020), found living on various substrates ranging from muddy sand to craggy substrates (Nugraha et al. 2021). Seagrass habitat variation affects adapting and thriving in a changing environment (Kaewriskhaw and Prathep 2014).

The seagrass species with the highest density was *C. rotundata* (1,136.00 ind/m^2) found on Matahari Island. *Cymodocea rotundata* is widely distributed in Indonesia because it is adaptable and can live on various substrates. Besides *C. rotundata*, *T. hemprichii* also has high adaptability to its environment. Kawaroe et al. (2016) mentioned that seagrass species *C. rotundata* and *T. hemprichii* have a very wide distribution in Indo-Pacific waters, and both species could tolerate high environmental changes. In some research locations, the density of *E. acroides* was found to not too much, this is due to its large body size, which affects its density. The location of the highest density of E. acoroides is on Rago-rago Island, namely 140, 80 ind/m^2 and the lowest density of *E. acroides* is on Balong Island, namely 20, 27 ind/m^2. The seagrass structure itself can also influence density; the size of the seagrass body is very influential on its distribution (French et al. 2021).

The highest total seagrass abundance was found on Matahari Island, and the lowest was on Lamun Island, while the substrate in the four research locations has different characteristics and the low density of seagrass on Lamun Island because the expanse of Lamun Island borders directly on the Indian Ocean so that the seagrass beds are narrower than other locations. The high density on Matahari Island was because the substrate on Matahari Island was coarse sand, while the substrate on Lamun Island was fine sand with a little mud with a small seagrass bed area. Substrates influence seagrass abundance (Kaewriskhaw and Prathep 2014; Kawaroe et al. 2016; Short et al. 2016).

The results showed that the percentage cover of seagrass species ranges from 1.00% to 55.32%. The highest seagrass species cover value is *C. rotundata* on Matahari Island (52.32%), while the lowest seagrass species cover value is *S. isoetifolium* found on Lamun Island (1.00%). The total cover percentage value ranged from 19.32% - 30.59%. The highest percentage of total cover is found on Balong Island (30.59%), and the lowest is on Lamun Island (19.32%). The high percentage on Balong Island is due to the characteristics of a sloping and wide beach with sandy substrate conditions, making it very suitable for seagrass habitat. On Lamun Island, many small rocks are located very close to coral reefs, so rocks block the seagrass distribution pattern. The percentage value of seagrass indicates the level of resistance to its environment (Lincoln et al. 2021). Seagrass beds are usually overgrown by seagrass species that are uniform, thick, and clustered in an area (de Los Santos et al. 2019; Xu et al. 2021). Lohr et al. (2017) reported that several coral communities lived in seagrass meadow habitats.

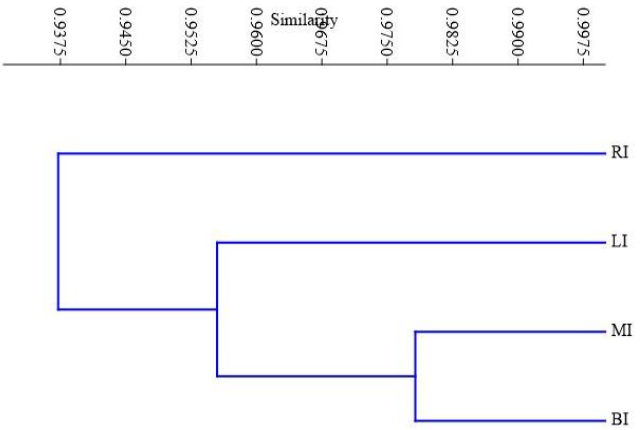

Figure 5. Cluster analysis of similarity among seagrass sites. Note: BI: Balong Island, MI: Matahari Island, LI: Lamun Island, and RI: Rago-rago Island

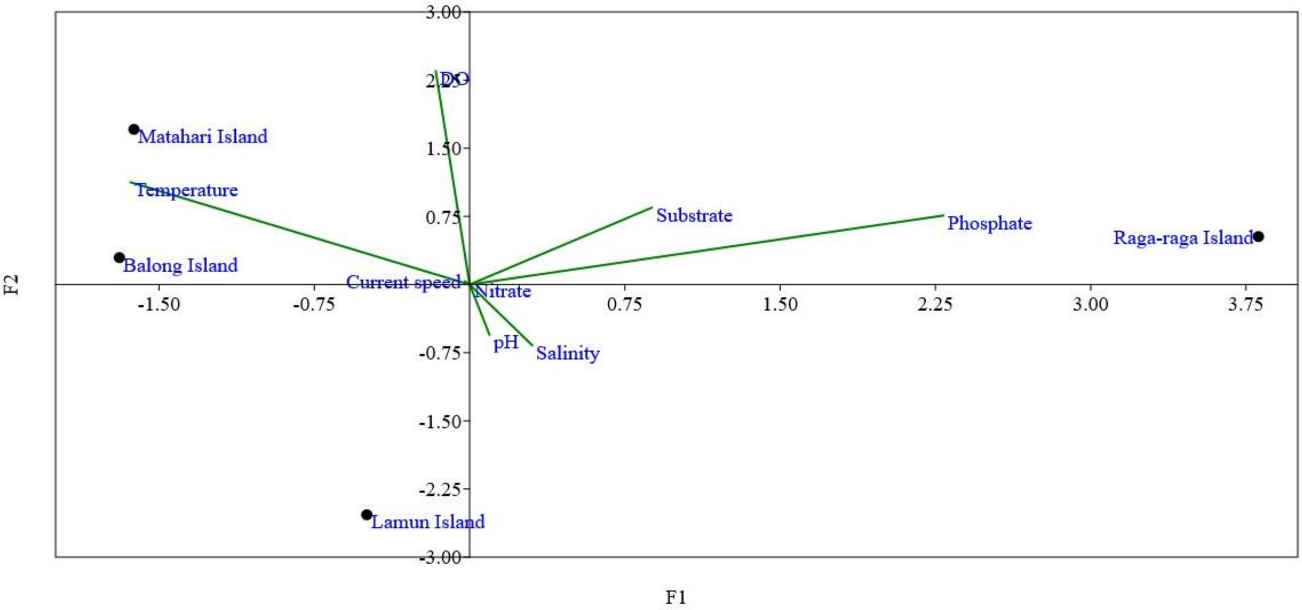

Figure 4. Analysis of the relationship between seagrass abundance and environmental parameters

Diversity index values ranged from 1.02-1.28, with all low categories at all stations. At all stations, only 4 seagrass species were found, so seagrasses on Banyak Island have low diversity. The greater the diversity index value, the more species found at the research location and the higher the stand of each species, so the more abundant the seagrass. Species diversity is described by the number of species found and the number of stands of each seagrass species (Erniati et al. 2023). Competition between species for nutrients also affects seagrass diversity (Fitrian et al. 2017).

Uniformity index values ranged from 1.69-2.12, with a high category at all stations. The results showed that the average number of species did not differ too much. Only in Pulau Matahari that shows seagrass species *C. rotundata* found quite widely spread. A high uniformity index indicates the number of individuals of each species is not much different (Fitrian et al. 2017). The uniformity index also indicates the ecological balance; the higher the uniformity value, the environment is suitable for seagrass life (Putri et al. 2021).

The dominance index value ranged from 0.31-0.41, with a low category at all stations. The low value of the dominance index is evidenced by the absence of dominating species at each station. The dominance index will be opposite to the uniformity index; when the number of seagrass species is evenly distributed, there is no dominating seagrass species. Moreover, the dominance index is caused by the uneven number of individuals in each species (Pramesti et al. 2016).

Morisita dispersion index values ranged from 1.23-1.62, with a group category at each station. The research results show that seagrasses live in groups, where each community is scattered with the same species. In addition, the grouped seagrass community is also influenced by vegetative seagrass reproduction, where new shoots will grow at the end of the rhizomes and external influences such as substrate and nutrients. Clumped distribution patterns in ecology can indicate the potential for nutrient concentration in a particular location (Metananda et al. 2015). Zhang et al. (2014) reported that water nutrients affect seagrasses' growth and physiology.

The average DO value ranges from 7.53-10.87 mg/L, with the highest DO value found on Matahari Island and the lowest DO value found on Lamun Island. The average temperature ranges from 28.20-31.80°C, with the highest temperature on Matahari Island and the lowest on Rago-rago Island. The average pH ranges from 7.33-8.22, with the highest pH on Lamun Island and the lowest on Matahari Island. The average salinity value ranges from 30.00-31.00‰, with the highest salinity value found on Lamun Island. The average current velocity value ranges from 0.01-0.07 m/s, with Matahari Island's highest current velocity value; the average nitrate value ranges from 0.01-0.02 mg/L. The mean value of phosphate ranges from 1.21-5.49 mg/L; the highest phosphate value is found on Rago-Rago Island, and the lowest is found on Balong Island. All water quality parameter values at all research locations are good for seagrass survival except the phosphate parameter. The condition of quality parameters is strongly influenced by activities that occur in the vicinity (Allgeier et al. 2018). The phosphate value is greater than the quality standard; this is thought to be the input of phosphate sources from domestic waste around the island such as household and tourist activity wastes. Maslukah et al. (2020) reported that domestic waste contains high phosphate.

The PCA analysis showed that the key parameters affecting seagrass abundance were phosphate, substrate, and nitrate; these nutrient contents of seawater are very important for seagrass life. The elements needed by seagrasses for reproduction are nitrate, phosphate, and potassium. Phosphate that functions for seagrass rhizome growth will indirectly affect seagrass abundance. The more rapid the growth of seagrass rhizomes, the wider the seagrass distribution area. Phosphate functions for seagrass rhizome and root growth, while nitrate functions for seagrass leaf growth (Andika et al. 2023). In addition, a decrease in the nitrification or denitrification process in certain circumstances can remove nitrate elements from the ecosystem so that nitrate is reduced and an increase in phosphate occurs (Blackford and Gilbert 2007). Photiou et al. (2021) reported that seagrasses absorb phosphate at a higher rate than nitrate. Phosphate is the most significant limiting factor in seagrass life (Allgeier et al. 2018). Substrate is one of the main factors affecting seagrass diversity and density. Kawaroe et al. (2016) reported that substrate is very important in seagrass distribution patterns; some species, such as *E. acroides, C. rotundata, T. hemprichii,* and *H. ovalis,* could live and adapt to various substrates.

PCA analysis can also describe the characteristics of the water quality parameters at each study site. Rago-rago Island is characterized by high nitrate, high phosphate, and varied substrate parameters compared to other locations. Matahari Island and Balong Island are characterized by high DO and temperature parameters. In contrast, any water quality parameters do not characterize Lamun island. These water quality parameters will have an impact on seagrass abundance.

The cluster analysis shows that there is only one cluster group on Banyak Island. The display of cluster analysis is a dendrogram diagram that displays the similarity of seagrass communities on Banyak Island. The grouping of seagrass communities is based on the characteristics of the aquatic environment at each observation station. The similarity of species between observation stations depends on community similarity, the higher the value, the more similar the species among stations. Balong Island and Matahari Island show a similarity of 82%, indicating similarities in seagrass species based on the characteristics of the aquatic environment. The environmental characteristics of Balong Island and Matahari Island are very similar in almost all water quality parameters, so the seagrass species that grow on both islands are the same. In addition, the proximity of Balong Island and Matahari Island also affects the similarity of seagrass species and environmental characteristics. Lamun Island has a similarity level of 63% to Balong Island and Matahari Island. There are species similarities between these three islands, but the DO parameter on Lamun Island is lower than Balong Island and Matahari Island. Rago-rago Island has one distinct species and is also characterized by high phosphate parameters and low temperatures compared to the other three islands.

This research concludes that there are as many as 5 seagrass species, namely *T. hemprichii*, *C. rotundata, E. acroides*, *S. isoetifolium*, and *H. ovalis*. The highest density on Matahari Island and species abundance is the seagrass species *C. rotundata;* the Seagrass diversity is low, and no species dominate and live in groups. The PCA analysis showed that nitrate, phosphate, and substrate were the environmental factors that most influenced the pattern of seagrass distribution and density.

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