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Comparative analysis of morphological traits in *Cymodocea rotundata* Asch. & Schweinf. **From Yenkarwar Beach and Rawar Beach, Indonesia**

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Abstract. Intensive coastal development and human transport activities are increasingly threatening seagrass ecosystems, which can change seagrass morphometrics. This study compares the morphological characteristics of *Cymodocea rotundata* Asch. & Schweinf. at two sites: the traditional ports in Yenkarwar beach, Manokwari, West Papua (PY), and Rawar beach in Biak Numfor Regency, Papua (PR). Fieldwork conducted in mid-2023 used transect and quadrat sampling. The measured traits included leaf length and width, rhizome length and diameter, average maximum length of individual roots (root length), and number of leaves per individual, along with environmental parameters. The results showed that leaves in PY were longer and wider than those in PR, although not significantly different ($p>0.05$). In contrast, rhizome length, diameter, root length, and leaf number showed significantly differences ($p<0.05$) between the sites. Principal component analysis (PCA) indicated a clear separation of the two locations: temperature most strongly influenced morphometric traits at PY, while oxygen levels and pH were more influential at PB. The PCA model explained 53.3% of the total variance, suggesting the presences of additional unmeasured factors. Significant differences in below ground traits imply that seagrass root systems are more susceptible to human disturbance, highlighting the need for further research on below ground biomass.

1 Introduction

Seagrass is a flowering plant that can adapt to life in marine environments. Seagrass is one of the most productive and important marine ecosystems worldwide. Seagrass serves as food for fish, turtles, and dugongs and supports complex food webs because of its physical structure and primary productivity [1]. Fourteen seagrass species have been identified and confirmed in Indonesia. Seagrass species in Indonesia are evenly distributed in eastern and western Indonesian waters. One of the most common species is *Cymodocea rotundata* Asch. & Schweinf [2]. According to Namira [3], *C. rotundata* has a high tolerance and can grow in almost all habitat categories, from healthy habitats with seagrass cover >60% to less healthy habitats with seagrass cover ranging from 0% to 60%.

Percentage data on seagrass cover in eastern Indonesian waters shows that West Papua Province is categorized as having ‘unhealthy’ seagrass conditions with an average cover of 42%. Papua Province is categorized as having healthy seagrass conditions with an average cover of 64%. It is suspected that seagrass beds in eastern Indonesian waters will change because of environmental changes, particularly as a result of increasing human activity on the coast each year [4]. Changes in land use on the coast, including the construction of ports, fish-ponds, and settlements, can directly alter the distribution of seagrass. According to Kilmaskossu et al. [5], variations in seagrass morphology can be significantly influenced by changes in water conditions.

Yenkarwar beach is a coastal area in West Papua Province that functions as a sea transportation route and public port. It is located in West Manokwari District, Manokwari Regency. The beach is situated close to residential areas and restaurants, which has resulted in the accumulation of plastic debris and other waste materials along the shoreline. The seagrass beds in this area occur on a narrow reef flat, whereas offshore beds are bordered by a coral reef ecosystem that is in relatively poor condition. Rawar beach is located in Rawar Village, Orkeri District, Biak Numfor Regency, Papua Province, Numfor Island. The beach functions as a public port for sea transportation and as a docking area for boats. It also contains seagrass beds where local residents engage in various activities, including fishing and the collection of marine organisms, such as bivalves and gastropods. Because of the beach’s potential and its strategic characteristics in supporting human activities, research on seagrass ecology is necessary. Therefore, this study aimed to compare the morphometric structure

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of *C. rotundata* seagrass in the traditional port at Yenkarwar beach in Manokwari, West Papua Province, with that at Rawar beach in the Biak Numfor Regency, Papua Province.

1 Materials and Methods

1.1 Research location

This study was conducted at Yenkarwar beach, Manokwari Regency, West Papua Province (-0.8731° S; 134.0684° E) and Rawar beach, Biak Numfor Regency, Papua Province (1.1346° S; 134.9155° E). A map of the study site is shown in Fig 1.

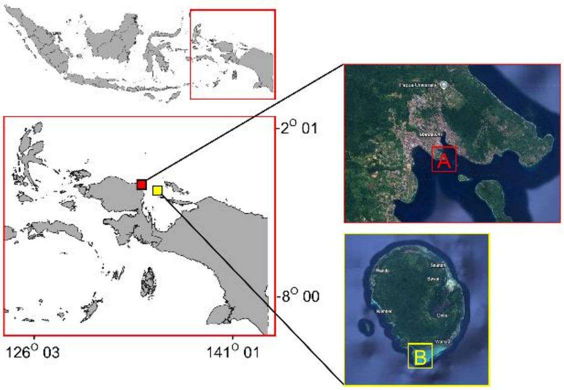

Fig 1. Map of study site. A= Yenkarwar beach and B= Rawar beach.

The sampling of *C. rotundata* was conducted using a combination of square transects and purposive sampling marked with ropes tied to wooden stakes. Two transects were created perpendicular to the coastline towards the sea. Three squares, each measuring 30 cm × 30 cm, were then placed on each transect (Fig 2). The placement of the squares represents different habitats where *C. rotundata* was found.

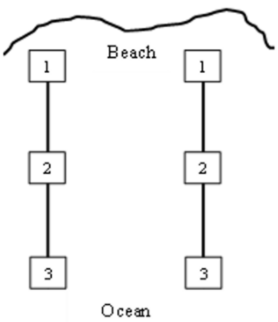

Fig 2. Transect and quadrat methods.

1.2 Research procedures

The first step was to measure the environmental parameters for each square. Environmental parameters consisted of (1) measuring water acidity and alkalinity using a pH meter, (2) measuring dissolved oxygen and temperature using a DO meter, (3) measuring seawater salinity using a refractometer, and (4) analyzing sediment samples using a graded sieve at the Aquatic Resources Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Papua.

The second step was to harvest the *C. rotundata* seagrass samples. Five seagrass samples were collected from each quadrat; consequently, 30 samples were used for morphometric measurements from the Rawar beach and 30 samples from the Yenkarwar beach. The samples were collected at low tide by digging the seagrass with a shovel. The seagrass samples were observed morphologically at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Papua. Morphological observations of *C. rotundata* samples included the average maximum length of individual roots (root length), rhizome length, rhizome diameter, leaf length, leaf width, and the number of leaves.

1.3 Data analysis

Morphological data of *C. rotundata* between the two locations were analyzed using a single-factor analysis of variance (ANOVA) using SPSS version 27. If there were significant differences, Tukey's test with 95% confidence interval was used. Furthermore, non-multidimensional scaling (NMDS) analysis combined with principal component analysis was also carried out to determine the morphology of *C. rotundata* based on its habitat conditions using PAST v. 4.3 program.

2 Result and Discussion

2.1 Morphological characteristics of *C. rotundata* on Yenkarwar Beach and Rawar Beach

Comparative morphological analysis of *C. rotundata* between populations on Yenkarwar beach and Rawar beach showed significant differences ($p<0.05$) in the four morphological characteristics (Table 1). The morphological characteristics that showed significant differences were root length, rhizome length, rhizome diameter, and the number of leaves. In contrast, leaf characteristics, including of leaf length and width, did not show significant differences between locations.

Our analysis showed significant morphological plasticity in *C. rotundata* in response to environmental heterogeneity between the Yenkarwar beach and Rawar beach (Fig 3). Morphological plasticity is the ability of an organism to produce different phenotypes when exposed to different abiotic and biotic environmental conditions [6]. This plasticity was particularly evident in organs below the sediment surface (roots and rhizomes) and in the number of leaves, reflecting different adaptation strategies. As a pioneer species, *C. rotundata* exhibits morphological variation on a broader spatial scale that is resistant to disturbed environmental conditions [7].

Significant differences in the roots and rhizomes indicated different resource allocations for stability and energy storage. The population on Rawar beach had a greater average root length. Longer roots are an important morphological adaptation for anchoring to less stable substrates, such as coarse sand, and for increasing the range of nutrient uptake from sediments. These conditions indicate that Rawar may have substrates with lower stability and/or greater difficulty accessing interstitial nutrients. Sandy substrates tended to contain low nitrate levels [8].

Table 1. Summary of the results of the analysis of morphological characters of *C. rotundata* between Yenkarwar beach and Rawar beach locations.

No	Morphological characters	Location	
		Yenkarwar beach	Rawar beach
1	Average root length (mm)	34.47 b	61.08 a
2	Average rhizome length (mm)	28.05 a	22.20 b
3	Average rhizome diameter (mm)	2.92 a	2.38 b
4	Average leaf length (mm)	127.97 a	122.25 a
5	Average leaf width (mm)	4.20 a	3.97 a
6	Average number of leaves	2 b	3 a

Note: The same letters in the same column behind the numbers indicate significant differences based on Tukey's test ($p<0.05$).

The *C. rotundata* population at Yenkarwar beach had a larger average rhizome length and diameter. Rhizomes serve as storage sites for carbohydrates and oxygen to maintain the aerobic metabolism in anoxic sediments. The larger and thicker rhizomes at Yenkarwar beach indicate that this species allocates more resources to energy storage and aggressive vegetative clonal growth [9]. We suspect that *C. rotundata* exhibits two energy-allocation patterns. The first pattern is that *C. rotundata* on the Rawar beach allocates energy to prioritize anchoring and absorption (roots). The second pattern is that *C. rotundata* on Yenkarwar beach prioritizes energy storage and clonal expansion (rhizomes).

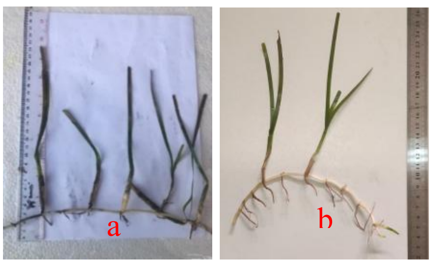

Fig 3. Morphological of *C. rotundata* found on the beach (a), Yenkarwar beach (b), Rawar beach.

2.2 Relationship between morphological characteristics and environmental factors

The results of the environmental parameter measurements, including salinity, temperature, dissolved oxygen, pH, and substrate type at Yenkarwar and Rawar beaches, are presented in Table 2. The results of the principal component analysis showed that the two research locations were separated based on morphological characteristics and environmental parameters. This analysis explained 53.3% of the total variance of the data-set, with axis 1 explaining 39.80% and axis 2 explaining 13.50% (Fig 4). The morphological characteristics of *C. rotundata* seagrass at Yenkarwar beach were more influenced by temperature parameters. At Rawar beach, it is influenced by dissolved oxygen (DO) levels and water pH.

Table 2. Environmental parameter of Yenkarwar beach and Rawar beach.

No	Parameter	Location	
		Yenkarwar beach	Rawar beach
1	Temperatures (°C)	29.3-29.6	28.5-29.0
2	Salinity (%)	31.0–32.0	30.0–33.0
3	Dissolved oxygen gas (mg/L)	6.8–7.2	7.3–8.5
4	pH	6.6–6.8	7.7–7.9
5	Sediment type	Medium sand-coarse sand	Coarse sand

Water temperatures within the optimal range of 25-31 °C for tropical seagrasses, such as *C. rotundata* support high rates of photosynthesis. Warmer temperatures tend to increase metabolic rate and growth. Abundant energy allows for a greater accumulation of carbohydrates and nutrients in rhizomes, resulting in larger rhizome diameters. When water temperatures exceed the optimal tolerance limit, which can reach 35-40°C for *C. rotundata* [10], seagrasses experience heat stress. Heat stress causes a drastic decrease in photosynthetic and respiratory efficiencies. To survive, seagrass reduces energy allocation for growth, as seen by a decrease in the number of leaves per shoot and a decrease in overall biomass [11].

The dissolved oxygen levels on the water surface at the Yenkarwar and Rawar beaches can be categorized as high and stable (>5 mg/L) according to the quality standards for supporting optimal photosynthesis in seagrass (Minister of Environment Decree No. 51 of 2004). Seagrass, a flowering plant, produces oxygen via photosynthesis in its leaves. This oxygen is not only released into the water column but is also transferred through special tissues (aerenchyma) to the rhizomes and roots under the sediment. If the dissolved oxygen gas in the water column is sufficiently high, the seagrass can maintain adequate internal oxygen production. This ensures that rhizomes and roots remain healthy and can store energy reserves. Therefore, good dissolved oxygen conditions in the water indirectly support thick and healthy rhizome diameter.

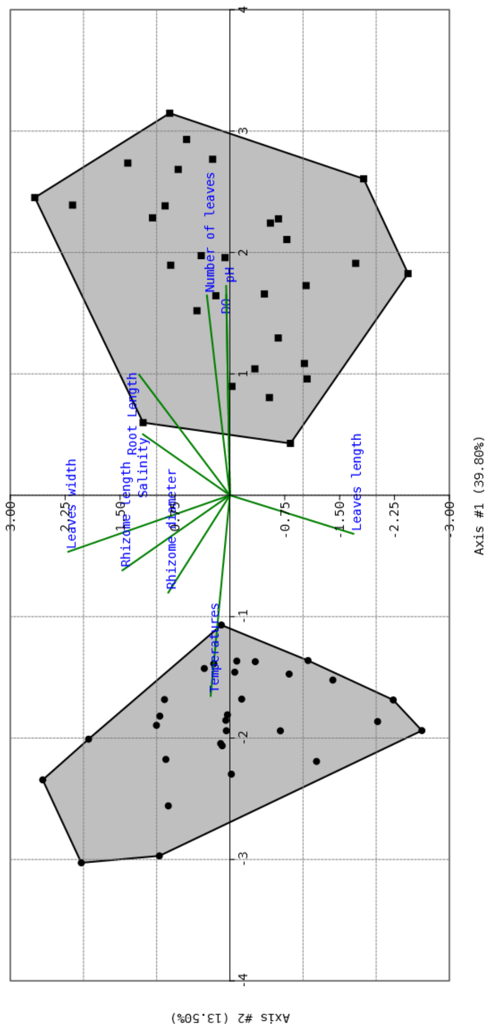

Fig 4. Principal component analysis that separates the two research locations based on environmental parameters and morphological characteristics. Note: ● is a location on Yenkarwar beach ■ is a location on Rawar beach.

If the dissolved oxygen in the water is low, the rate of photosynthesis is disrupted. A lack of internal oxygen makes seagrass more susceptible to sulfides in the sediment. To overcome this threat, seagrasses may allocate resources differently. Seagrasses tend to develop longer roots to anchor to unstable substrates. A prolonged decrease in dissolved oxygen gas reduces the efficiency of photosynthesis, which is the main source of energy. As a result, leaf growth decreased [12].

Tropical seagrass usually grows best in waters with a pH between 7.8 and 8.5. The pH of water is intricately linked to the ocean carbonate system, encompassing the concentrations of carbon dioxide and bicarbonate, which serve as carbon sources for photosynthesis. Water pH is intricately linked to the carbonate system in the ocean, encompassing the concentrations of carbon dioxide and bicarbonate, which serve as carbon sources for photosynthesis. Reduced pH (approaching 7.5), resulting from elevated CO_2 levels (ocean acidification), can impede the photosynthetic function of *C. rotundata* leaves. Impaired photosynthesis diminishes the energy available for structural growth, leading to a decreased leaf growth rate under adverse environmental conditions, which further inhibits photosynthesis. To increase the colony (horizontal rhizome growth) or improve anchoring (root growth), the remaining energy or nutrients are distributed to rhizomes and roots more vigorously, if possible [13].

3 Conclusions

Our study concluded that there are distinct morphometric differences in *Cymodocea rotundata* between the Yenkarwar beach, Manokwari and Rawar beach, Biak Numfor ($p<0.05$). These differences are likely attributable to human-induced changes in the coastal environment, including sedimentation and pollutant influx. Further research comparing morphological parameters across the Indonesian islands may validate these findings.

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