

THE ROLE OF NITRATE, PHOSPHATE AND SEDIMENT TYPE AS FACTORS CONTROLLING SEAGRASS DENSITY ON PANJANG ISLAND, CENTRAL BANGKA.

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ABSTRACT

Seagrass is an important ecosystem in coastal areas that plays a role in maintaining water stability, providing habitat for biota, and supporting primary productivity. Seagrass growth and density are influenced by environmental factors including the availability of nutrients in the substrate such as nitrate and phosphate, as well as the characteristics of sediment types. This study aims to analyze the relationship between nitrate and phosphate content in sediment and its types with seagrass density in Panjang Island Waters. Data collection was carried out using the quadrant transect method at three stations with nine observation substations extended 100 m towards the open sea. Substrate samples were analyzed in the laboratory to determine nitrate and phosphate content based on the applicable Indonesian National Standard (SNI). Sediment type analysis used dry sieving for the 4.75-0.038 mm fraction and wet sieving for the 0.0625-0.001 mm fraction, then classified using the Wentworth system and Shepard's triangle. Relationship analysis was carried out using Principal Component Analysis (PCA). The results showed that seagrass density ranged from 31-50 ind/m² with *Cymodocea rotundata* dominating. Analysis of the relationship between nitrate phosphate and sediment type to seagrass density using PCA showed that phosphate and clay sediment types clustered in the same main component and correlated with seagrass density.

Keywords : Phosphate, Sediment type, Seagrass density, Nitrate, Panjang Island

INTRODUCTION

Seagrasses are higher plants that grow submerged in marine waters. These plants possess complete structural components, including vascular tissues, leaves, rhizomes, and roots. Throughout their life cycle, seagrasses can reproduce through two mechanisms, namely generative reproduction through seeds and vegetative reproduction through shoot formation (Wasniatun, 2024). Seagrasses grow to form extensive beds consisting of either a single species or several seagrass species, commonly referred to as seagrass meadows (Hartini & Lestarini, 2019). Seagrass meadows are ecosystems formed by assemblages of seagrass plants and are generally located in transitional zones between mangrove ecosystems and coral reefs (Yunita et al., 2020). The condition of seagrass meadows is highly dependent on the environmental conditions of their habitat. According to Azzahra et al. (2022), one of the environmental factors influencing seagrass

conditions is the nutrient content of the substrate, particularly nitrate and phosphate, as both nutrients play important roles in seagrass growth and development. These nutrients are absorbed by seagrasses through their roots and support tissue formation (Riniatsih, 2016).

Substrate type is also an important factor influencing seagrass growth and density. Seagrasses are capable of growing on various substrate types, including sand, mud, clay, and coral fragments (Fahrudin et al., 2017). The substrate plays an important role as a medium for root attachment, while differences in substrate characteristics can influence the form and size of seagrasses growing within a particular habitat (Sermatang et al., 2021). The growth and development of seagrasses can be assessed based on their density. Density is a measure that describes the number of individuals of a particular species within a given area and reflects the level of seagrass growth and development

(Nulita et al., 2025). Nutrient availability in seagrass ecosystems is influenced by the condition and presence of seagrasses themselves, as seagrasses play a role as nutrient traps in aquatic environments (Tampubolon et al., 2020). Nutrient concentrations in sediments tend to be higher than those in the water column. This condition occurs because nutrients in the water column are present in dissolved form and are therefore more readily transported by currents and tidal dynamics. In contrast, nutrients in the bottom substrate tend to settle and accumulate, making them less readily transported by water movement (Arnando et al., 2022). As the substrate contains various nutrients that influence seagrass growth and development, further investigation of the factors affecting seagrass meadow conditions, particularly substrate quality, is warranted.

Panjang Island, Central Bangka Regency, Bangka Belitung Islands Province, has a seagrass meadow ecosystem that is utilized for fisheries and tourism activities. Septiani et al. (2022) reported the presence of several seagrass species on Panjang Island, with the existing seagrass cover still requiring attention. However, the study did not examine the relationship between nutrient concentrations in the substrate, particularly nitrate and phosphate, and seagrass density. Therefore, this study was conducted to complement the existing information and to determine the relationship between nitrate and phosphate concentrations in the substrate and seagrass density on Panjang Island.

METHODS

This study was conducted in November 2025 in the waters of Panjang Island, Central Bangka Regency. The research location is presented in Figure 1. The research site was determined using a purposive sampling technique. Three sampling stations were established at the study site, with each station consisting of three substations based on the respective nutrient sources. Station 1 was located in a mangrove area, Station 2 in a tourism area, and Station 3 in an area characterized by fishing boat activities.

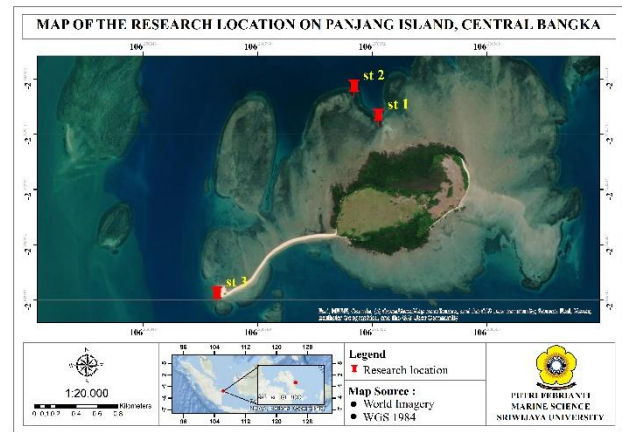


Figure 1. Map of the research location in the waters of Panjang Island, Central Bangka Regency.

Sediment samples were collected using a sediment core with a radius of 5 cm and a length of 30 cm. The sediment sampling procedure followed Hasmiati et al. (2021), in which the corer was inserted into the seagrass substrate to collect sediment samples. The collected samples were placed in labeled zip-lock plastic bags according to the sampling station and stored in a coolbox containing ice during transportation to the laboratory. Three sediment samples were collected at each station based on transect positions at 0, 50, and 100 m to represent sediment conditions. Nitrate and phosphate analyses were subsequently conducted at the Oceanography and Marine Instrumentation Laboratory, Universitas Sriwijaya. Nitrate concentrations were determined according to SNI 6989.79:2011, while phosphate concentrations were determined according to SNI 4819:2013 using spectrophotometric methods.

Seagrass observations included species identification and density measurements. Transect lines were established perpendicular to the shoreline toward the sea over a distance of 100 m, beginning at the 0 m point or the first location where seagrasses were encountered. Each station consisted of three substations spaced 50 m apart and arranged parallel to the shoreline.

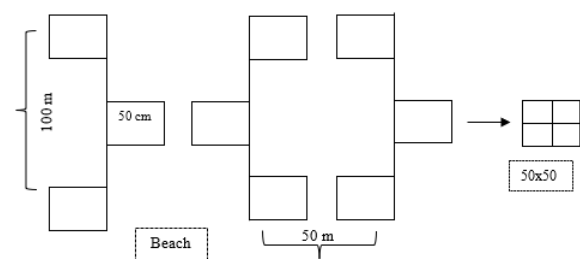


Figure 2. Data collection scheme.

Kuadran yang digunakan berukuran Quadrats measuring 50 × 50 cm were used for seagrass observations. Seagrass species and the number of individuals were recorded to determine seagrass density. Species identification was conducted with reference to the *Status Padang Lamun* guide published by COREMAP-CTI and P2O-LIPI in 2017. In addition, water quality parameters, including temperature, pH, dissolved oxygen (DO), and salinity, were measured *in situ* at each station with three replicates.

Sediment grain-size analysis was conducted to determine sediment type. Grain-size analysis was performed using the *dry sieving* method for fractions ranging from 4.75 to 0.038 mm and the *wet sieving* method for finer fractions ranging from 0.0625 to 0.001 mm (Buchanan, 1984). The resulting grain-size distribution was then classified according to the Wentworth scale and the Shepard sediment classification triangle, originally developed based on the Wentworth classification system in 1922.

DATA ANALYSIS

Water Quality Parameters

The water quality parameters obtained from measurements at the study site were subsequently compared with the seawater quality standards stipulated in Appendix VIII of Government Regulation of the Republic of Indonesia No. 22 of 2021.

Seagrass Density

The number of seagrass shoots was counted within each quadrat to determine seagrass density using the following formula (Brower et al., 1990):

$$Di = \frac{n_i}{A}$$

Description:

D: Species density (ind./m²)

Ni: Number of seagrass shoots

A: Sampled area (m²)

Density Criteria:

Ni > 300 : High Density

151 ≤ Ni ≤ 300 : Moderate Density

Ni ≤ 150 : Low Density

Source: (Putra, 2006).

Statistical Analysis

The data were analyzed using Principal Component Analysis (PCA) to examine the relationship between sediment nutrient concentrations, sediment types, and seagrass density.

RESULTS AND DISCUSSION

Water Quality Parameters

The water conditions in Panjang Island were assessed based on several water quality parameters measured during the study, as presented in Table 1. The parameters measured included water temperature, dissolved oxygen (DO), pH, and salinity. The results of the water quality measurements generally remained within the seawater quality standards stipulated in Government Regulation of the Republic of Indonesia No. 22 of 2021.

Table 1. Water quality parameters in the waters of Panjang Island

Station	Temperature (°C)	DO (mg/L)	pH	Salinity (‰)
1	30	5.9	7.3	30.3
2	31	5.7	8	29
3	34.3	5.1	7.5	30.7
Mean	31.8	5.6	7.6	30
Quality Standard *	28-32	>5	7-8.5	33-34

* Seawater quality standards based on Government Regulation of the Republic of Indonesia No. 22 of 2021.

The mean water temperature was 31.8 °C, with values ranging from 30 to 34.3 °C, indicating variation in temperature among stations. The lowest temperature was recorded at Station 1 (30 °C), whereas the highest temperature was observed at Station 3 (34.3 °C), exceeding the seawater quality standard of 28–32 °C. This condition was presumably related to the measurement at Station 3 being conducted during the daytime. However, Sutadi et al. (2021) reported that seagrass productivity increases with increasing temperature, suggesting that the recorded temperature may still support seagrass growth. High temperatures can also affect dissolved oxygen solubility in water, as oxygen solubility decreases with increasing temperature (Patty & Huwae, 2023).

The lowest dissolved oxygen (DO) concentration was recorded at Station 3 (5.1 mg/L), while the highest was observed at Station 1 (5.9 mg/L). According to Government Regulation of the Republic of Indonesia No. 22 of 2021, the seawater quality standard for dissolved oxygen (DO) in waters designated for marine biota is >5 mg/L. Thus, the DO concentrations at all observation stations remained within the established

quality standard, although the DO concentration at Station 3 was close to the minimum threshold. Differences in DO concentrations among stations were presumably associated with environmental conditions and biological activities at each station. The lower DO concentration at Station 3 may have been influenced by oxygen consumption by seagrasses during respiration, particularly in the roots and rhizomes (Rugebregt & Matuanakotta, 2020). In addition, aquatic activities, such as boat movement at Station 3, may influence water conditions and dissolved oxygen dynamics.

The pH values at all stations ranged from 7.3 to 8.0, with a mean value of 7.6, remaining within the seawater quality standard range of 7.0–8.5. Based on the measurements, pH values did not show significant differences among the observation stations and remained within conditions that support seagrass growth. James et al. (2020) stated that the optimal pH range for seagrass meadow growth is 6.5–8.5. Therefore, the pH values recorded at the three stations remained within the optimal range, with relatively small differences among stations. According to Andika et al. (2020), pH plays an important role in influencing seagrass growth and productivity, particularly through its effects on chlorophyll-a and chlorophyll-b concentrations, which function in the photosynthetic process.

The salinity measurements at the observation stations ranged from 29 to 30.7 ppm, with a mean value of 30 ppm. The highest salinity was recorded at Station 3 (30.7 ppm), whereas the lowest was observed at Station 2 (29 ppm). Based on Government Regulation of the Republic of Indonesia No. 22 of 2021, the salinity values at all study stations were considered suitable for seagrass growth, with a specified quality standard range of 33–34 ppm. Globally, normal seawater salinity generally ranges from 33 to 37 ppm (Kinne, 1964). Meanwhile, Indonesian marine waters generally exhibit salinity values ranging from 28 to 33 ppm (Nontji, 2002).

Sediment Type

The results showed that sediments at all observation stations were dominated by the sand fraction, as presented in Table 2. The highest percentage of sand was recorded at Station 3 (95.20%), followed by Station 2 (93.28%) and Station 1 (92.03%). Meanwhile, silt and clay fractions were present in relatively small proportions at all stations. The silt content ranged from 0.34 to 1.71%, whereas the clay fraction ranged from 3.09 to 7.63%.

Based on these compositions, the substrate type at all three stations was classified as sand. The dominance of sand was presumably related to the hydrodynamic conditions of the waters. Bayhaqi and Dunga (2015) explained that currents and tidal processes play a role in sediment transport and grain-size sorting, whereby fine particles are more readily resuspended and transported, whereas sand tends to settle. This condition is consistent with Septiani et al. (2022), who reported sand dominance ranging from 92.50 to 97.46% in the waters of Panjang Island.

Table 2. Sediment Types in the waters of Panjang Island

Station	Sediment Fraction Percentage (%)			Sediment Type
	Sand	Silt	Clay	
1	92.03	0.34	7.63	Sand
2	93.28	0.68	6.04	Sand
3	95.20	1.71	3.09	Sand

The sandy characteristics of the substrate result in a lower capacity of sandy sediments to retain organic matter and nutrients such as nitrate and phosphate compared with fine-textured sediments (Mustofa et al., 2023). This is because sediment particle size influences nutrient content, with smaller sediment particles generally associated with higher nutrient concentrations (Auliyah, 2018). Nevertheless, sandy substrates are still considered suitable as a growth medium for seagrass ecosystems, particularly for seagrass species with well-developed root systems (Rahmawati & Hernawan, 2022).

Nutrient Concentrations

Sediment nutrient measurements were conducted to determine the distribution and variation of nitrate and phosphate concentrations at each station and along the observation transects. These differences reflect the dynamics of nutrient distribution within the study area, which may be influenced by varying environmental conditions.

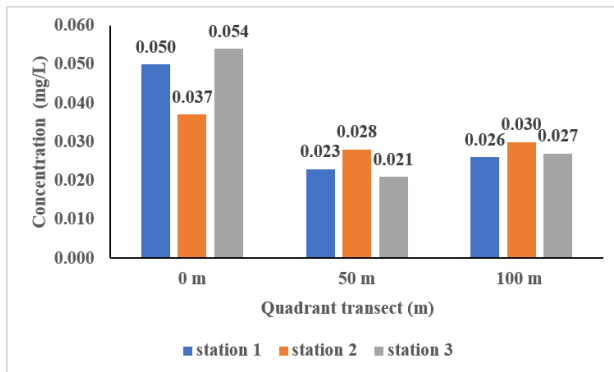


Figure 3. Nitrate (NO₃) concentration in the waters of Panjang Island

The measurement results generally showed differences in nutrient accumulation both horizontally and along the distance from the shoreline. Overall, the highest total nitrate concentration was recorded at Station 3 (0.102 mg/L), followed by Station 1 (0.099 mg/L) and Station 2 (0.095 mg/L), indicating differences in nitrate distribution among the

observation sites, as presented in Figure 3. Meanwhile, for total phosphate concentration, Station 2 showed the highest phosphate accumulation (0.211 mg/L), followed by Station 1 (0.145 mg/L), whereas the lowest value was recorded at Station 3 (0.095 mg/L). These differences indicate that environmental conditions and substrate characteristics at each station may influence nutrient accumulation in the sediment.

The measurement results showed that nitrate concentrations in the sediment extracts ranged from 0.021 to 0.054 mg/L. The nitrate concentrations obtained at each station were 0.050 mg/L at Station 1, 0.037 mg/L at Station 2, and 0.54 mg/L at Station 3.

Table 3. Nutrient concentrations in the waters of Panjang Island

Nutrient	Transect	Station			Total
		1	2	3	
Nitrate (mg/L)	a	0.050	0.037	0.054	0.141
	b	0.023	0.028	0.021	0.072
	c	0.026	0.030	0.027	0.083
Total nitrate		0,099	0.095	0.102	
Phosphate (mg/L)	a	0.053	0.082	0.042	0.177
	b	0.041	0.073	0.027	0.141
	c	0.051	0.056	0.026	0.133
Total Phosphate		0.145	0.211	0.095	

The measurement results showed that at the 0 m point from the shoreline, nitrate concentrations tended to be higher than those at the other sampling points, particularly at Station 3. This condition was presumably associated with the influence of anthropogenic activities around the study area. Station 3 was located in an area characterized by fishing boat activities and potentially received nitrogen inputs from fuel residues, domestic waste, and increased sediment mobilization caused by boat movement.

The results of sediment samples collected 50 m seaward showed a decrease in nitrate concentrations, with values of 0.023 mg/L at Station 1, 0.028 mg/L at Station 2, and 0.021 mg/L at Station 3. The decrease in nitrate concentration indicates that the influence of nutrient sources from the coastal area and human activities began to diminish with increasing distance from the shoreline. Furthermore, at the sampling point located

100 m seaward, nitrate concentrations ranged from 0.026 to 0.030 mg/L, with values of 0.026 mg/L at Station 1, 0.030 mg/L at Station 2, and 0.027 mg/L at Station 3.

The nitrate concentrations recorded at 100 m seaward were relatively uniform among stations, indicating that sediment conditions at this distance tended to be more homogeneous and relatively stable, with decreasing influence from terrestrial nutrient inputs. This condition is consistent with the characteristics of estuaries as one of the major sources of nutrient inputs into marine waters, where nutrient concentrations are generally higher in estuarine areas and gradually decrease toward the open sea (Mumtaz et al., 2025).

Phosphate concentrations in the sediment extracts obtained during the study ranged from 0.026 to 0.082 mg/L. At the sampling point located 0 m from the shoreline, phosphate concentrations tended to be higher than those at the other sampling points, with

values of 0.053 mg/L at Station 1, 0.082 mg/L at Station 2, and 0.042 mg/L at Station 3. The high phosphate concentration at the 0 m point at Station 2 was presumably related to the characteristics of aquatic activities at the site, which is a snorkeling area with relatively high human activity. Marine recreational activities may increase phosphate inputs into aquatic environments, for example through the release of domestic waste and increased sediment resuspension caused by human movement in shallow waters.

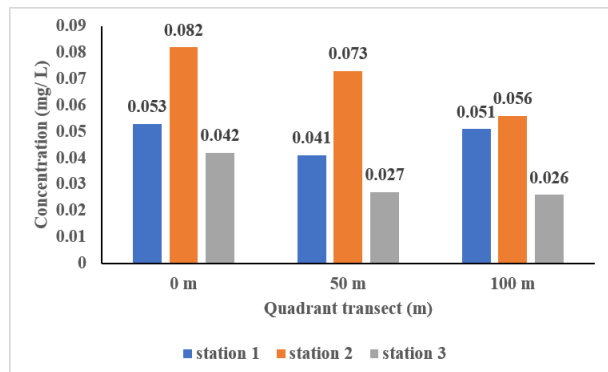


Figure 4. Phosphate (PO₄) concentration in the waters of Panjang Island

The results at the 50 m seaward sampling point showed that phosphate concentrations tended to decrease, ranging from 0.026 to 0.056 mg/L, with values of 0.041 mg/L at Station 1, 0.073 mg/L at Station 2, and 0.027 mg/L at Station 3. The decrease in phosphate concentration indicates that the influence of terrestrial inputs on phosphate concentrations in the sediment diminished with increasing distance from the shoreline. At the 100 m seaward sampling point, phosphate concentrations ranged from 0.026 to 0.056 mg/L, with values of 0.051 mg/L at Station 1, 0.056 mg/L at Station 2, and 0.026 mg/L at Station 3. The relatively stable values at this distance indicate that sediment conditions tended to be more homogeneous. This condition suggests that the influence of terrestrial phosphate inputs decreased with increasing distance from the shoreline. This finding is consistent with Karsetens et al. (2023), who stated that phosphate concentrations tend to increase in nutrient-rich bottom sediments, whereas phosphate concentrations decrease with increasing distance toward more open marine waters.

Species Identified

Two seagrass species were identified across all observation stations, namely

Enhalus acoroides (*E. acoroides*) and *Cymodocea rotundata* (*C. rotundata*), as presented in Table 4. The occurrence of these two species indicates that both species have relatively similar distributions within the study area, despite the stations being located in different areas.

Table 4. Seagrass species found in the waters of Panjang Island

Station	Transect (m)	Seagrass Species	
		<i>Enhalus acoroides</i>	<i>Cymodocea rotundata</i>
1	0	+	+
	50	+	+
	100	+	+
2	0	+	+
	50	+	+
	100	+	+
3	0	+	+
	50	+	+
	100	+	+

Note: (+) = found

The results obtained in this study are consistent with previous research, which stated that *E. acoroides* and *C. rotundata* are commonly found in the waters of Panjang Island with sandy substrate characteristics (Septiani, 2022). The distribution and abundance of seagrasses are strongly influenced by various environmental factors, both ecological and physical, including water depth, light availability, substrate characteristics, salinity, temperature, and water turbidity, which play important roles in determining seagrass distribution patterns (Nurmasari et al., 2023).

E. acoroides is one of the large-sized seagrass species commonly found in tropical waters, including Indonesian waters, and generally grows on sandy to muddy-sand substrates (Tulung et al., 2024). Meanwhile, *C. rotundata* is a medium- to small-sized seagrass species with a wide distribution in tropical waters and is often found growing alongside *E. acoroides*. However, the presence of *E. acoroides* can suppress the growth and density of smaller-sized seagrasses because this species has a strong and large root system, enabling it to absorb greater amounts of nutrients (Hanifah et al., 2025).

Species Density

Seagrass density is used to determine the density level of seagrass species at each observation station. Density values indicate

the number of seagrass individuals found within a certain unit area. Through density values, differences in seagrass density among stations and species with higher densities can be observed.

Seagrass density at the study site showed variation among species and observation stations, which were included in the sparse category. As shown in Table 5, *C. rotundata* had a higher density, with an average of 44 ind./m², compared with *E. acoroides*, which had an average density of 35 ind./m². This indicates that *C. rotundata* was more dominant in the seagrass community in the waters of Panjang Island. At Station 1, the density of *C. rotundata* was 50 ind./m², higher than that of *E. acoroides*, which had a density

of 31 ind./m², resulting in a total seagrass density of 81 ind./m² at this station. A similar pattern was also observed at Stations 2 and 3, where the density of *C. rotundata* was more dominant than that of *E. acoroides*. The density of *C. rotundata* at Station 2 was 40 ind./m², whereas *E. acoroides* had a density of 39 ind./m², with a total seagrass density of 79 ind./m² at Station 2. At Station 3, the density of *C. rotundata* was 40.4 ind./m², the same as at Station 2, whereas the density of *E. acoroides* was 35 ind./m², with a total density of 76 ind./m².

Table 5. Seagrass species density in the waters of Panjang Island

No.	Species	Station (Ind/m ²)			Average
		1	2	3	
1.	<i>Enhalus acoroides</i>	31	39	35	35
2.	<i>Cymodocea rotundata</i>	50	40	40	44
Total Density		81	79	76	

Differences in seagrass density among stations are influenced by differences in environmental characteristics and the intensity of human activities (Dwiputra et al., 2025). Station 1, which is located in a mangrove area, tended to have a higher density because the water conditions were relatively more protected and nutrient availability was better. Station 2, which is a snorkeling area, showed moderate density because tourism activities were presumed to have the potential to cause minor physical disturbance. Meanwhile, Station 3, which is located in an area with boat activities, had a lower density due to disturbances such as boat propellers and anchoring activities that can damage seagrass structure (Fahrudin et al., 2017).

Relationship between Nutrient Content and Sediment Type and Seagrass Density

The PCA results presented in the form of a biplot showed that the two principal components, namely F1 at 83.99% and F2 at 16.01%, were able to explain 100% of the data variation. The first principal component (F1) represented the physical environmental gradient that had the greatest influence on seagrass density. On the negative side of the F1 axis, seagrass density was associated with clay-textured sediment. This relationship indicated that seagrass density tended to be higher in waters with fine-textured substrates because clay sediments have a better ability

to bind nutrients and provide stability for seagrass root systems (Riniatsih, 2016).

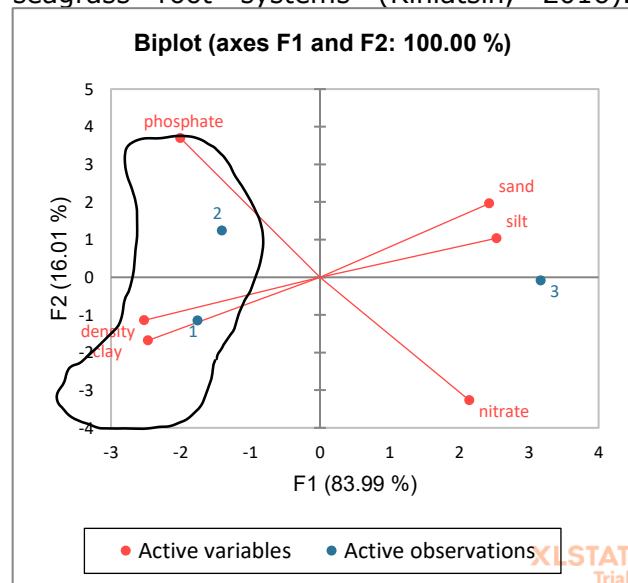


Figure 5. Relationship between nutrient concentrations and sediment types with seagrass density in the waters of Panjang Island

The results of the relationship between nutrient concentrations and sediment types with seagrass density presented in Figure 5 showed that the positive side of the F1 axis consisted of sand, mud, and nitrate. The positions of these variables were in the opposite direction to seagrass density, indicating a negative relationship between these factors and seagrass density. Phosphate was positioned in the same direction as

seagrass density, although its contribution was not as strong on the F1 axis. This indicated that based on the distribution of the station points, Stations 1 and 2 were characterized by seagrass density and clay sediment, indicating environmental conditions that were more supportive of seagrass growth. This condition may occur because clay sediment has smaller particle sizes, allowing it to bind and retain nutrients more effectively than sandy sediment (Permatasari et al., 2019). Conversely, the sandy sediment at Station 3 had a highly porous structure, allowing nutrients to be more easily leached and resulting in low nutrient concentrations. Seagrasses are more dependent on nutrients accumulated in sediments, particularly phosphate, which plays an important role in root and rhizome growth (Rayyis et al., 2021).

CONCLUSION

The seagrass species found in the waters of Panjang Island, Central Bangka, consisted of two species, namely *Enhalus acoroides* and *Cymodocea rotundata*, with densities categorized as sparse. The PCA results showed that the relationship between nutrient concentrations (nitrate and phosphate) and sediment types with seagrass density indicated that seagrass density was more influenced by phosphate concentration and clay-textured sediment.

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