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Structure of Mangrove Vegetation Community in the Tidal Area of Siak River, Riau

Struktur Masyarakat Vegetasi Mangrove di Daerah Pasang Surut Sungai Siak, Provinsi Riau

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Abstract

Global warming is one of the natural phenomena that impacts the flow of the Siak River. Among the impacts are sea level rise and seawater intrusion. These changes also affect the distribution of flora and fauna from the sea into the River. This study aims to determine the structure of mangrove vegetation communities and water quality conditions found in the tidal area of the Siak River. This research was conducted in October 2024. The research location consists of 4 stations, each station was placed in 3 plots following the flow of the River, with a distance of 100 m between each plot. Each plot has a size of 10 x 10 m. This research was conducted using the survey method. The study identified six mangrove species, consisting of 2 true mangroves and four associated mangroves. The density of mangrove vegetation in the research location is categorized as good, with the highest number of 1933.33 ind/ha at stations I and II, and the lowest at 1633.33 ind/ha at station IV. The results of the critical value index indicate that *Sonneratia caseolaris* plays a vital role in all research stations, with the highest percentage of 252.90% at station II and the lowest 230.20% at station I. The results of the ANOVA test analysis of density between stations showed a significant value. 0.148, which states that there is no significant difference between the four stations. Water quality measurements showed a temperature value of 28-30 ˚C; salinity 0 ppt, and pH 5.4-6. Sediment types at all stations were dominated by mud. The highest average organic matter was in station I, at 11.90%, while the lowest was in station II, at 6.83%. The value of Total Suspended Solid (TSS) at the study site ranged from 0.0153 to 0.1640 mg/L. Station II was dominated by muddy sand, and station III was dominated by sand with a total sediment organic matter content of 0.46-23.33%. The nitrate content found ranged from 0.0146-0.0583 mg/l, and the phosphate ranged from 0.0465-0.0996 mg/L. The linear regression test results for mangrove density with TSS, organic matter, and nutrient (nitrate and phosphate) content showed a weak relationship.

Keywords: Mangrove, Community structure, Tidal, Siak River.

Abstrak

Pemanasan global merupakan salah satu fenomena alam yang berdampak pada aliran Sungai Siak. Di antara dampaknya adalah kenaikan permukaan laut dan intrusi air laut. Perubahan ini juga mempengaruhi distribusi flora dan fauna dari laut ke sungai. Penelitian ini bertujuan untuk mengetahui struktur komunitas vegetasi mangrove dan kondisi kualitas air yang terdapat di daerah pasang surut Sungai Siak. Penelitian ini dilakukan pada Oktober 2024. Lokasi penelitian terdiri dari 4 stasiun, masing-masing stasiun ditempatkan dalam 3 plot mengikuti aliran sungai, dengan jarak 100 m antar masing-masing plot. Setiap plot memiliki ukuran 10 x 10 m. Penelitian ini dilakukan dengan menggunakan metode survei. Hasil penelitian menemukan 6 spesies mangrove, yang terdiri dari 2 mangrove sejati dan 4 mangrove terkait. Kepadatan vegetasi mangrove di lokasi penelitian masuk dalam kategori baik, dengan jumlah tertinggi 1933,33 ind/ha di stasiun I dan stasiun II, dan terendah 1633,33 ind/ha di stasiun IV. Hasil indeks nilai penting menyatakan *Sonneratia caseolaris* memiliki peran yang sangat penting di semua stasiun penelitian, dengan persentase tertinggi 252,90% di stasiun II dan terendah 230,20% di stasiun I. Hasil analisis uji anova kepadatan antar stasiun menunjukkan nilai yang signifikan. 0.148, yang menyatakan bahwa tidak ada perbedaan yang signifikan antara keempat stasiun. Pengukuran kualitas air menunjukkan nilai suhu 28-30 °C; salinitas 0 ppt, dan pH 5,4-6. Jenis sedimen di semua stasiun didominasi oleh lumpur. Bahan organik rata-rata tertinggi berada di stasiun I, dengan persentase 11,90% dan terendah di stasiun II, dengan persentase 6,83%. Nilai *Total Suspended* Solid (TSS) di lokasi penelitian berkisar antara 0,0153-0,1640 mg/l. Stasiun II didominasi oleh pasir berlumpur, dan stasiun III didominasi oleh pasir dengan kandungan bahan organik sedimen total 0,46-23,33%. Kandungan nitrat yang ditemukan berkisar antara 0,0146-0,0583 mg/l, dan fosfat berkisar antara 0,0465-0,0996 mg/L. Hasil uji regresi linier kepadatan mangrove dengan kandungan TSS, bahan organik, dan unsur hara (nitrat dan fosfat) menunjukkan hubungan yang lemah.

Kata kunci: Mangrove, Struktur Komunitas, Pasang surut, Sungai Siak

1. Introduction

In recent decades, international concern about global climate change has increased because it has harmed the sustainability of life on Earth, leading to rising temperatures known as global warming. Global warming can affect climate change. One of the impacts most felt by coastal communities due to global warming is the rise in water levels and seawater intrusion. Rising sea levels can affect changes in wetland areas and worsen water quality. Fitria (2021) revealed that ecosystems in coastal areas, including mangrove vegetation, have a vital role in inhibiting seawater intrusion.

Mangroves are vegetation that form communities commonly found in coastal areas and tidal areas that are part of the beach. Based on the research results by Norhadiah (2021), it is said that healthy mangroves can increase the protection ability of coastal areas against the threat of abrasion, storms, and tsunamis. Mangroves consist of true mangroves and associate mangroves. The significant difference between the two is the morphology of the roots and the specialized physiological mechanism to secrete salt to adapt to the environment (Sidik et al., 2018). True mangroves are vegetation that live in tidal areas and can absorb salt substances and adapt to their environment. Associated mangroves are terrestrial vegetation commonly found around true mangroves. Mangrove ecosystems can control seawater intrusion through the mechanism of preventing the deposition of $CaCO_3$ by the body of root exudates, reducing salt levels by organic matter from litter decomposition, the physical role of mangrove root structures that can reduce the reach of tidal water to land, and improving the physical and chemical properties of soil through litter decomposition (Faristy & Irma, 2024).

The Siak River is one of the major rivers in Indonesia that has received national attention and is included in the category of national strategic rivers, as determined by Presidential Decree No. 12 of 2012 concerning the determination of river areas. This is because the Siak River has a significant role in regional and economic development, both locally and nationally. The surrounding community is highly dependent because the Siak River serves as a source of livelihood, transportation, ecotourism, and residence. If there is a slight change in these conditions, it will significantly impact the community.

Global warming also has an impact on the flow of the Siak River. During high tide, the Siak River area from Siak Sri Indrapura City to Pekanbaru City experiences an increase in sea level. The rise in sea level due to global warming alters the strength of the tides and the discharge, no longer resulting in proper outcomes. The discovery of true mangrove vegetation and associations in the tidal area of the Siak River characterizes this change. Research conducted by Sittadewi (2007) found mangrove vegetation species *Nypa fruticans* Wurmb, *Pandanus* sp, and *Hibiscus tiliaceus*, L. in the tidal area of the Siak River in Buatan Village and Sigentil hamlet. Thus, this study aimed to determine the mangrove vegetation community and the water quality parameters in the tidal area of the Siak River.

2. Material and Method

2.1. Time and Place

This research was conducted in October 2024 in the Siak River tidal area, with sample management at the Marine Biology Laboratory, Chemistry Laboratory, and the Department of Marine Science at Universitas Riau. The research location can be seen in Figure 1.

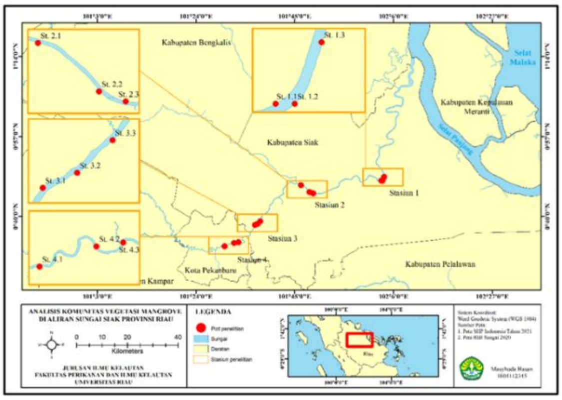

Figure 1. Research location map

2.2. Methods

The research method is the survey method, which involves direct observation of the research area, conducting sampling, and performing direct measurements to obtain data on water quality parameters, organic matter, TSS (Total Suspended Solids), nutrients (nitrates and phosphates), and the structure of the mangrove vegetation community in the field. The mangrove vegetation community structure studied consisted of species density, relative density, species frequency, relative frequency, species cover, relative cover, and importance value. The samples were then identified and analyzed at the Marine Biology and Marine Chemistry Laboratory, Department of Marine Science, Faculty of Fisheries and Marine Sciences, Universitas Riau.

2.3. Procedures

Station determination was carried out using a purposive sampling method; this technique is one of the sampling techniques with specific considerations. Researchers indirectly determine the area by considering vegetation thickness and geographical location through observations using the Google Earth application. The research location consists of 4 stations, with station 1 located in Siak Sri Indrapura City. The plot at this station begins at the former Kampung Dalam Police Station, with a local crossing towards the downstream of the Siak River. This station is densely populated on both sides of the riverbank. Station 2 is located in Buatan 1 Sub-district Village, the plot at this station starts from the Buatan 1 crossing pier towards the upper reaches of the Siak River. This station is far from community settlements. Areas on both sides were generally found to be natural forests, small areas, and oil palm farming. Station 3 is located in Perawang City. The plot at this station starts from the Perawang Sunday Market Port jetty and extends downstream along the Siak River. This station is densely populated on the left side and has an oil palm forest on the right side of the riverbank. Station 4 is located in Pekanbaru City, the plot at this station starts from opposite the Tengku Cik Port towards the downstream of the River. This station has many small and large ports on both sides of the riverbank. At the end of the station, towards the downstream, several riverside tourist attractions and oil palm plantations can be found. Water quality parameters measured were temperature, pH, and salinity. Each research station has three plots parallel to the river flow, each measuring 10 x 10 m^2. The plot plan can be seen in Figure 2.

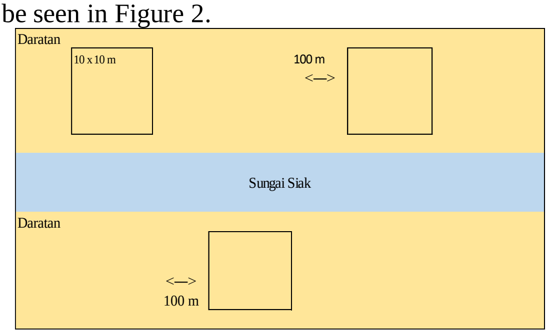

Figure 2. Plan of the plotted path

Identification of mangrove species in the plots was conducted by observing various morphological parts of the plants, including leaves, flowers, fruits, stems, and root types. The data were then identified using the mangrove identification book "Guide to Monitoring Mangrove Community Structure in Indonesia" (Dharmawan et al., 2020). The observed mangroves were also measured for stem diameter. Diameter at breast height (DBH) was measured using a meter on the stem at chest height or a height of 1.3 m from the root. In this study, sediment samples were also taken to measure organic matter and sediment fraction. Sediment samples were taken using a 4-inch diameter pipe with a depth of 15 cm.

2.4. Data Analysis

2.4.1. Important Value Index (INP)

To determine the important value index of a vegetation type, the Bengen formula in Agustini et al. (2016) was used, as follows:

$$INP = RDi + RFi + RCi$$

Description:

INP : Important Value Index
RDi : Relative Density
RFi : Relative Frequency
RCi : Relative Cover

The important value of a species ranges from 0 to 300%. This important value provides an overview of the influence or role of a mangrove plant species in mangrove communities (Parmadi et al., 2016).

2.4.2. Species Density and Relative Density

Species density (D_i)is the number of stands of the i-th species in a unit area. To determine the density of mangrove species using the formula (Parmadi et al., 2016):

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

Description:

Di : Density of type i (ind/m^2)
Ni : Total number of individuals of the i-th species (ind)
A : Total sampling area (m^2)

Relative density (RD_i) is the ratio between the number of stands of the i-th species (Ni) and the total stands of all species (∑n) (Parmadi et al., 2016):

$$Rdi = \frac{Ni}{\Sigma n}\, x\, 100\ \%$$

Description:

$RD_{(i)}$:Relative Density (%)
N_i: Number of individuals of the i-th species (ind)
∑n : Total number of individuals (ind)

2.4.3. Species Frequency and Relative Frequency

Frequency (Fi) is the probability of finding an i-th species in all plots (Parmadi et al., 2016):

$$Fi = \frac{pi}{\Sigma p}$$

Description:

Fi : Frequency of the i-th species
Pi : Number of sample plots made
∑p : Total number of sample plots made

Relative Frequency (RF_i)is the ratio between the species frequency (Fi) and the total frequency of all species (∑F) (Parmadi et al., 2016):

$$RFi = \frac{Fi}{\Sigma F}\, x\, 100\ \%$$

Description:

RF_i : Relative Frequency (%)
F_i : Frequency of the i-th species (ind)
∑F : Total frequency of all species (ind)

2.4.4. Species Cover and Relative Cover

Species cover (Ci) is the area of cover of the i-th species in an area (Parmadi et al., 2016):

$$Ci = \frac{\Sigma BA}{A}$$

Description:

Ci : Area of cover of the i-th species

BA : $BA = \frac{\pi DBH}{4}, \pi = 3{,}14$
DBH: Tree diameter of the i-th species
A : Total area of collection (plot)

Relative cover (RC_i)is the ratio between the area of cover of the i-th species (Ci) and the total area of cover for all species (∑ C) (Parmadi et al., 2016):

$$RCi = \frac{Ci}{\Sigma C}\ x\ 100\ \%$$

Description:
RC_i: Relative Cover (%)
Ci : Area of closure of the i-th species
∑C : Total area covered by all species

2.4.5. Sediment Fraction and Total Organic Matter

The sediment fraction analysis used two methods: the wet sieving method and the pipette method. The graded sieve method was used to obtain Ø-1 - Ø4, while the pipette method used a volumetric pipette to obtain Ø5-Ø7. Rifardi (2008) was used to analyze the sediment fraction type. Rifardi (2008) was used to analyze the sediment fraction type. The concentration of total organic matter in the sediment was measured using the following formula:

$$\text{BOT} = \frac{(Wt - C) - (Wa - C)}{Wt - C}\ \text{x}\ 100\%$$

Description:
Wt = total weight (crucible + sample) before burning,
Wa = total weight (crucible + sample) after burning, and
C = empty crucible weight

2.4.6. Total Suspended Solid (TSS)

The method used to calculate TSS (Total Suspended Solid) is the Graphimetric method with the TSS formula (SNI, 2004) as follows:

$$\text{TSS (mg/L)} = \frac{(\text{A} - \text{B})\ \text{x}\ 100}{\text{V}}$$

Description:
A : Weight of filter paper + dry residue (mg)
B : Weight of filter paper (mg)
V : Volume of sample used (ml)

The data obtained through calculations are presented in graphs and then discussed descriptively. A simple regression test was performed to determine the relationship and influence of organic matter variables, TSS concentrations, and nutrient concentrations (nitrate and phosphate). To determine the difference between mangroves at the stations, an ANOVA one-way test was performed using the SPSS application. Because there was no significant difference, no further tests were conducted.

3. Result and Discussion

3.1. Water Quality

The measured water quality parameters include physical parameters, such as temperature and salinity, and chemical parameters, such as acidity (pH). These parameters help understand the water conditions in the tidal area of the Siak River at the time of the study. The results of the water quality parameter measurements can be seen in Table 1.

Table 1. Measurement results of water quality parameters in the Siak River Tidal Area

Station	Water Quality Parameters		
	Temperature (°C)	pH	Salinity (ppt)
1	28	5,4	0
2	29	5,5	0
3	30	5,9	0
4	29	6	0

The water quality measurements at each station show that the water temperature ranges from 28 to 30 °C. This temperature range is in the good category based on Government Regulation No. 22 of 2021; the temperature range of 28 - 30°C is conducive to the survival of biota and mangroves. The pH measurements at each station ranged from 5.4 to 6, placing them in the low category according to the average criteria for living tropical mangrove vegetation in PP RI Number 22 of 2021. Several factors, including the mixing of water from small ditches and tributaries, plantation and farming activities, and docks or ports around the research station, can cause poor water pH.

The results of salinity measurements show the same number at each station in the form of 0 ppt, which can be categorized as incompatible with true mangroves generally live well, which has a salinity of 10 - 30 ppt, in the sea water zone to brackish water and good salinity for mangroves in brackish water zone to fresh water 0 - 10 according to Badu (2022), *Sonneratia caseolaris* is a type of true mangrove that grows in less saline parts of the mangrove forest, on deep mud soils, often along small rivers with slow-flowing water. It is affected by tides and also grows along rivers starting from the upstream, where tidal influence is still felt, as well as in areas still dominated by fresh water (Patty, 2024). Associated mangrove vegetation was *Cerbera manghas*, *Hibiscus tiliaceus*, *Morinda citrifolia*, and *Terminalia catappa*. Associated mangrove vegetation was found to be a type that can adapt to extreme environments with 0 ppt salinity. The adaptability of mangrove vegetation associations in extreme environments is often observed along the edge of the highway or as ornamental plants and herbs in community environments away from the sea (Amelya, 2023).

3.2. Fishing Sediment Type and TSS

The results of the sediment fraction calculation at each station show the same sediment type at all stations, namely, the mud type. Mud type is one of the criteria for mangrove vegetation thriving in the field. Sediment types in mangrove ecosystems often include clay material from weathering and sandy mud carried by seawater currents (Jana et al., 2024). The mud sediment type indicates that the sedimentation process is high, so the area generally has high nutrient levels. This statement is also corroborated by the value of total suspended solids (TSS) analyzed in the laboratory. The results of the TSS value at each station in Table 2 show an average ranging from 0.0153 to 0.1640 mg/L. This indicates a low sedimentation process, in accordance with Government Regulation of the Republic of Indonesia Number 22 of 2021, with a concentration of 50 mg/l. Several factors, including calm currents, cause the small TSS value. Waves and currents increase when there are anthropogenic activities in the form of ships passing by, but not much. This is because the surrounding community and those from outside the area have other route options (land routes) and ports in the Panjang Strait and Bengkalis when the research was conducted. The measurement results of sediment type and TSS can be seen in Table 2.

Table 2. Measurement results of sediment type and total suspended solids (TSS) in the tidal area of the Siak River

Station	Sediment Type	Average TSS (mg/l)
1	Mud	0,0153
2	Sludge	0,1640
3	Mud	0,0373
4	Mud	0,0373

3.3. Organic Matter and Nutrients (Nitrate and Phosphate)

The availability of food also assesses the adaptability of mangrove vegetation. The availability of food can be seen from the nutrients analyzed by researchers on mangrove vegetation substrates, specifically in the form of organic matter and nutrients (nitrates and phosphates). The results of the analysis of organic matter in the substrate are presented in Table 3, which shows an average range of 7.25 - 11.90%. This amount is high because it is greater than 5% (Hartati, 2018). The results of measuring organic matter can be seen in Table 3.

Table 3. Percentage of organic material measurement results in the Siak River tidal area

Station	Substation			Average (%)
	1	2	3	
1	11,21	9,84	11,59	10,88
2	9,09	6,77	4,64	6,83
3	13,12	12,55	10,04	11,90
4	7,19	7,66	6,91	7,25

The results of substrate analysis at each station showed nitrate concentrations ranging from 0.0146 - 0.0583 mg/l and phosphate concentrations ranging from 0.0465 - 0.0996 mg/l. The levels of nitrate and phosphate concentrations analyzed were in the bad category. Based on Government Regulation No. 22 of 2021, the maximum nitrate concentration is 0.008 mg/L and the maximum phosphate concentration is 0.015 mg/L, suitable for marine biota and mangroves. The availability of these nutrients can come from several sources, including residential areas through ditches and tributaries around the station area, and nutrients carried by rain from oil palm plantation areas. The results of nutrient measurements can be seen in Table 4.

Table 4. Nutrient measurement results in the Siak River Tidal Area

Station	Substation	Nitrate (mg/l)	Phosphate (mg/l)
1	1.1	0,0313	0,0465
	1.2	0,0271	0,0531
	1.3	0,0250	0,0509
2	2.1	0,0250	0,0951

	2.2	0,0208	0,0996
	2.3	0,0229	0,0929
	3.1	0,0250	0,0509
3	3.2	0,0146	0,0465
	3.3	0,0229	0,0531
	4.1	0,0417	0,0509
4	4.2	0,0583	0,0686
	4.3	0,0458	0,0553

3.4. Mangrove Vegetation Community Structure

The results of observations in the Siak River, Riau Province's tidal area, found two types of true mangroves and four associated mangroves in the observation area. The true mangroves found were *Sonneratia caseolaris* and *Acrostichum aureum*. The mangrove species found were *Cerbera manghas*, *Hibiscus tiliaceus*, *Morinda citrifolia*, and *Terminalia catappa*. The mangrove community structure observed at each station has different values. The analysis results have been measured in the form of density, frequency, and essential value. Calculation of mangrove vegetation structure found in the field is divided into two categories: trees and ferns.

Based on the total calculation of tree-level mangrove vegetation density in the Siak River tidal area at each station, it ranged from 1633 to 1933 ind/ha. The highest density of mangrove vegetation types is at station 2, with a total of 1800 ind/ha of *S. caseolaris*. The calculation results for the highest mangrove density of the four stations are at stations 1 and 2, with a total of 1933 ind/ha. The results of the mangrove vegetation density calculation at each station can be seen in Table 5.

Table 5. Results of density calculation at each station (ind/ha)

No.	Type	Shape	Station			
			1	2	3	4
1	*Sonneratia caseolaris*	Tree	1600	1800	1666,67	1500
2	*Cerbera manghas*		266,67	100	-	-
3	*Hibiscus tiliaceus*		66,67	33,33	166,67	66,67
4	*Morinda citrifolia*		-	-	-	33,33
5	*Terminalia catappa*		-	-	-	33,33
	Total		1933	1933	1833	1633

Based on the calculation of the frequency of tree-level mangrove vegetation in the Siak River tidal area at each station, it ranged from 1.67 to 2.33. The results of calculating the highest frequency of mangrove vegetation types at all stations show a total of 1 individual in each plot of *S. caseolaris*. In contrast, the highest mangrove vegetation frequency calculation for the four stations is at station 4, with a total of 2.33. The results of calculating the frequency of mangrove vegetation at each station are shown in Table 6.

Table 6. Results of frequency calculation at each station

No.	Type	Shape	Station			
			1	2	3	4
1	*Sonneratia caseolaris*	Tree	1,00	1,00	1,00	1,00
2	*Cerbera manghas*		0,67	0,33	-	-
3	*Hibiscus tiliaceus*		0,33	0,33	0,67	0,67
4	*Morinda citrifolia*		-	-	-	0,33
5	*Terminalia catappa*		-	-	-	0,33
	Total		2,00	1,67	1,67	2,33

Based on the calculation of the dominance of tree-level mangrove vegetation in the tidal area of the Siak River at each station, the values ranged from 44.94 to 138.02 m^2/ha. The calculation results show the highest dominance of mangrove vegetation types at station 1, with an area of 134.50 m^2/ha of *S. caseolaris*. The calculation results for the highest mangrove dominance of the four stations are at station 1, with a total of 138.02 m^2/ha. The results of the calculation of the dominance of mangrove vegetation at each station are shown in Table 7.

Table 7. Results of Dominance Calculation at Each Station (m^2/ha)

No.	Type	Shape	Station			
			1	2	3	4
1	*Sonneratia caseolaris*	Tree	134,50	124,01	112,97	44,56
2	*Cerbera manghas*		3,41	0,15	-	-
3	*Hibiscus tiliaceus*		0,11	0,11	0,33	0,12
4	*Morinda citrifolia*		-	-	-	0,09
5	*Terminalia catappa*		-	-	-	0,18
	Total		138,02	124,26	113,30	44,94

3.5. Indian Important Value Index (INP)

The Important Value Index (INP) calculation results for tree-level mangrove vegetation types in the Siak River tidal area at each station ranged from 16.73 - 252.90%. The calculation results for the highest INP of mangrove vegetation types are at station 2, with a percentage of 252.90% for the Sonneratia caseolaris type. At the same time, the results of the calculation of the INP of the lowest mangrove species of the four stations are at station 4, with a percentage of 16.73% of the type of *M.citrifolia* and the type of *T. catappa*. The results of the INP calculation for mangrove vegetation in the tree category at each station are shown in Table 8.

Table 8. The results of the calculation of INP mangrove trees at each station (%)

No.	Type	Shape	Station			
			1	2	3	4
1	*Sonneratia caseolaris*		230,20	252,90	250,62	233,83
2	*Cerbera manghas*		49,60	25,29	-	-
3	*Hibiscus tiliaceus*	Tree	20,20	21,81	49,38	32,92
4	*Morinda citrifolia*		-	-	-	16,52
5	*Terminalia catappa*		-	-	-	16,73
	Total		300,00	300,00	300,00	300,00

The analysis of mangrove vegetation structure at the four observation stations showed that the true mangrove species, Sonneratia caseolaris, had the highest importance value at each station. This indicates that the type of *S. caseolaris* has a significant role in its environment. Associated mangrove species found at station 4 include *H. tiliaceus*, *M.citrifolia*, and *T. catappa*. The considerable value of the types of mangrove associations at each station is low, indicating that these types of mangrove vegetation play a minor role in the environment.

The mangrove fern category is done by counting the number of clumps in each type of individual vegetation found. Of the four observation stations, there is only 1 type of fern category. The calculation of the density and frequency of mangrove vegetation in the fern category, as observed at each station, can be seen in Table 9. The mangrove vegetation fern category is dominated by the Acrostichum aureum type, with the highest number of individuals found in station 3, totaling 20 individuals. This is followed by stations 2, 1, and 3, with totals of 12, 7, and 5 individuals, respectively.

Table 9. Calculation results of density, frequency, and INP mangrove fern category

Type	Number	K (Ind/ha)	KR (%)	F	FR (%)	NP(%)
			Station 1			
Aa	7	233,33	100	0,67	100	200
			Station 2			
Aa	12	400	100	1	100	200
			Station 3			
Aa	20	666,67	100	1	100	200
			Station 4			
Aa	5	166,67	100	1	100	200

3.6. Relationship between Density and Environment

The relationship between mangrove vegetation density and environmental quality was studied to determine the effect and extent of its statistical influence. Simple linear regression tests were performed on ecological parameters, specifically the results of measurements of organic matter, TSS, and nutrients (nitrate and phosphate) in relation to the total density of mangrove vegetation. An ANOVA test was performed before a simple linear regression test to determine the difference in density between stations. The results of the ANOVA test analysis of mangrove density between stations showed a significant difference. 0.148, which indicates that there is no significant difference between each station. The results of the correlation analysis using a simple linear regression test between organic matter content, total suspended solid content, and nutrient content (nitrate and phosphate), and the total density of mangrove vegetation showed an r value that is not significantly different from the influence of each variable on mangrove density. The regression results show an R value below 0.19, indicating a weak relationship between the variables. The relationship of the four variables to mangrove density can be seen graphically in Figures 3 – 6.

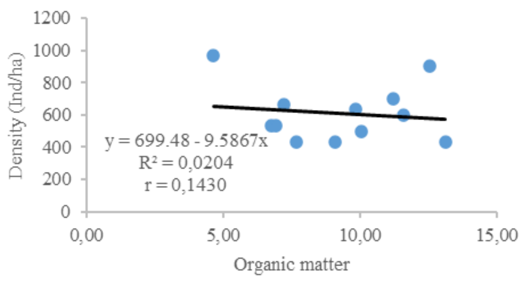

Figure 3. Relationship of organic matter content and density

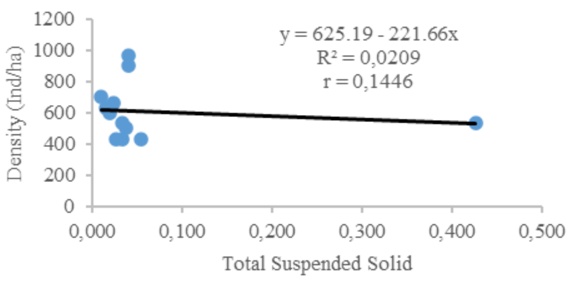

Figure 4. Relationship of TSS content and density

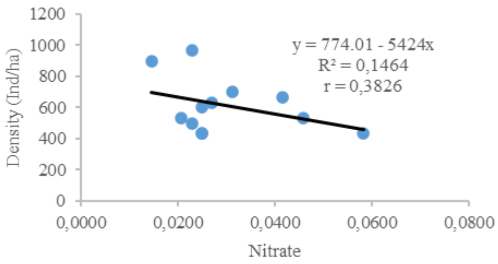

Figure 5. Relationship of nitrate content and density

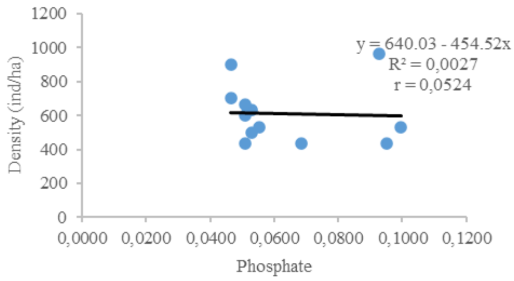

Figure 6. Relationship of phosphate content and density

Based on the results of a simple linear regression test, the relationship between organic matter in the substrate and the total mangrove density is very weak. This is expressed by the formula y = 699.48 - 9.5867x and the value of r = 0.1430 of R^2 ^{2}= 0.0204. The results of the graph in Figure 2 state that the higher the concentration of organic matter, the lower the density. Based on the simple linear regression test results, the relationship between TSS content and total mangrove density is very weak. This is expressed by the formula y = 625.19 - 221.66x and the value of r = 0.1446 of R^2 ^{2}= 0.0209. The graph results in Figure 3 state that the higher the TSS concentration, the lower the density.

Based on the results of a simple linear regression test, the relationship between nitrate content and total mangrove density is weak. This is expressed by the formula y = 774.01 - 5424x and the value of r = 0.3826 of R^2 ^{2}= 0.1464. The results of the graph in Figure 4 state that the higher the nitrate concentration, the lower the density. Based on the simple linear regression test results, the relationship between phosphate content and total mangrove density is very weak. This is expressed by the formula y = 640.03 - 454.52x and the value of r = 0.0524 of R^2= 0.0027. The graph in Figure 5 indicates that a higher concentration of organic matter correlates with a lower density. According to Nugraha et al. (2023), the availability of food plays a crucial role in the survival of mangrove vegetation. It is also stated that variables such as organic matter content, TSS, and nutrients in the total density of mangrove vegetation in normal conditions are directly proportional to the level of plant vegetation density in the observation area. This result does not align with the calculation of simple linear regression values, as other factors cause it. From the results of interviews with people around the research area, it was stated that there were mangrove planting activities of the *S. caseolaris* type carried out several times in the 5 years before this study was conducted, allowing the observation area to show the results of the calculation of the density value of the *S. caseolaris* type, which was very high. However, the availability of nutrients in the form of organic matter, nutrients (nitrate and phosphate), and TSS concentrations that are suitable for living mangrove vegetation indicates that the six mangrove species can adapt to extreme conditions in the study area.

4. Conclusions

The results of observations in the tidal area of the Siak River, Riau Province, found two types of true mangrove vegetation, namely *S.caseolaris* and *Acrostichum aureum*, and four types of associated mangrove vegetation, namely *C. manghas*, *H. tiliaceus*, *M. citrifolia*, and *T.catappa*. Water quality at all stations for the water temperature parameter is categorized according to the quality standards for living mangrove vegetation water temperature. In contrast, pH and salinity are included in the low category. All four stations showed the substrate type as muddy. The concentration of Total Suspended Solid (TSS) and nutrients (nitrate and phosphate) was found to be in the low category. The most dominant mangrove vegetation type at each station is *S. caseolaris*. The relationship between the density of mangrove vegetation types states that there are no significant differences between the four stations. The relationship between organic matter content, Total Suspended Solids (TSS), and nutrients (nitrate and phosphate) indicates that each variable plays a weak role in mangrove vegetation density.

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