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Analysis of Mangrove Vegetation Community Structure in Bukit Batu Village, Bukit Batu District, Bengkalis Regency, Riau

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ABSTRACT

The mangrove ecosystem in Indonesia is rich in biodiversity and plays an important role in maintaining coastal balance, but it is currently under pressure from human activities. This study was conducted in December in Bukit Batu Village, Bukit Batu District, Bengkalis Regency, an area with an extensive mangrove ecosystem that is vulnerable to anthropogenic pressure. The study aims to identify mangrove species and analyze density, importance value index (INP), and vegetation zonation patterns using a field survey at three stations. Stations were determined using purposive sampling, and mangrove observations were conducted using the line transect method, with each station consisting of 3 transects and each transect consisting of 3 plots (10m×10m for trees, 5m×5m for saplings, and 2×2 m^2 for seedlings). The results showed six mangrove species, i.e., *Rhizophora apiculata*, *Avicennia alba*, *Sonneratia alba*, *Bruguiera gymnorrhiza*, *Xylocarpus granatum*, and *Nypa fruticans*. Environmental conditions were dominated by mud substrate, with>75% containing 12.31–22.34% organic matter. Tree density ranged from 833.33–1,533.33 ind/ha and was dominated by R. apiculata, which also had the highest INP. Statistical analysis indicated no significant differences in density among stations ($p>0.05$). The zonation pattern showed differences in species composition between the sea and the land, at Station I, zones I–R. *Apiculata*, *B. gymnorrhiza*, and *N. fruticans* dominated III. At Station II, zone I was dominated by *S. alba*, while zones II–III were dominated by *R. apiculata*. At Station III, zones I–II were dominated by *R. apiculata* with *X. granatum* in zone II, and zone III was dominated by *X. granatum*.

Keywords: Mangrove, Community structure, Density, INP, Zonation

1. INTRODUCTION

Indonesia has approximately 3.31 million hectares of mangrove forests, covering 23% of the world's total mangrove forest area (BPS, 2022). This ecosystem spans numerous large islands in Java, Sumatra, Kalimantan, Sulawesi, Papua, the Maluku Islands, and Lombok and has high biodiversity, making it an important global player in coastal conservation. Ecologically, mangroves function as abrasion barriers, carbon absorbers, and habitats and nurseries for various fish and invertebrate biota (Febrian et al., 2021).

The structure and distribution of mangrove vegetation are influenced by environmental factors such as salinity, length of inundation, and substrate type (Ihrami et al., 2018). However, mangrove ecosystems in Indonesia are currently facing significant anthropogenic pressures, including land conversion, microorganism activity, and pollution. This pressure alters the structure and composition of mangrove vegetation, thereby reducing its ecological functions. Therefore, analysis of community structure using density, frequency, dominance, and the Importance Value Index (INP) is important for assessing the condition and stability of the mangrove ecosystem (Arfan et al., 2023).

Bengkalis Regency, Riau Province, is a coastal area with an extensive mangrove ecosystem, developed in estuaries and along the coast directly facing the Bengkalis Strait. Bukit Batu Village has significant mangrove potential but is also vulnerable to anthropogenic pressures, including land clearing, residential activities, ports, and tourism. This condition can influence the structure of the mangrove vegetation community. Based on this, this study aims to analyze the community structure of mangrove vegetation using density, frequency, dominance, and INP parameters, as well as to examine mangrove zoning patterns in response to environmental conditions in Bukit Batu Village, Bengkalis Regency.

2. RESEARCH METHOD

Time and Place

The study was conducted in December 2025. The study location was carried out in Bukit Batu Village, Bukit Batu District, Bengkalis Regency, Riau Province (Figure 1).

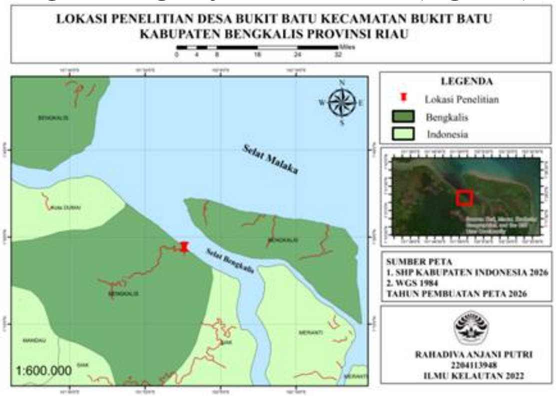

Figure 1. Study Location Map

Method

The method used is a survey method that involves making direct field observations and taking samples for laboratory analysis. The collected data include the type of mangrove vegetation. These environmental parameters include measurements of water quality (temperature, pH, and salinity), sediment type, and total organic matter (TOC) content. Station determination was carried out using purposive sampling. Station I is a mangrove forest far from residential areas, Station II is a mangrove forest close to residential areas, and Station III is a mangrove forest located in the port area.

Procedures

Mangrove observations were carried out using line transect and quadrant plot methods to identify species, count individuals, and measure stem diameter at breast height (DBH). Each station consists of 3 transects, and each transect consists of 3 sample plots (Transect Line Plot). In each plot for the tree category, 10 x 10 m^2 plots were used; 5 x 5 m^2 saplings; and 2 x 2 m^2 seedlings. The data obtained are then used to calculate density and the Important Value Index (INP), and to determine mangrove zoning descriptively. Sediment samples were collected using a PVCPVC pipe, and sediment fractions were analyzed using the sieving and pipette method and classified according to Sheppard's triangle (Rifardi, 2008), as well as the total organic matter content of the sediment using the Loss on Ignition method in the laboratory.

Data Analysis

Mangrove data analysis was done by using the formula, (Kordi, 2012).

$$K\ (\text{Ind/ha}) = \boldsymbol{ni/A} \quad (1)$$

$$\boldsymbol{KR}(\%) = \boldsymbol{ni/\sum n\ x\ 100}\% \quad (2)$$

$$\boldsymbol{Fi} = \boldsymbol{pi/\sum p} \quad (3)$$

$$\boldsymbol{FR}(\%) = \text{f}\boldsymbol{i/\sum F\ x\ 100}\% \quad (4)$$

$$\boldsymbol{BA}(\text{cm}^2) = \frac{\pi\ .\text{DBH(cm)}^2}{4} \quad (5)$$

$$\boldsymbol{Di} = (\ \Sigma \boldsymbol{BA/A}\ ) \quad (6)$$

$$\boldsymbol{DR}(\%) = (\boldsymbol{Di/\sum Di})\ \boldsymbol{x\ 100}\% \quad (7)$$

$$\text{INP}(\%) = \text{KR} + \text{FR} + \text{DR} \quad (8)$$

Information:
K = specific density; KR = relative density; Fi = frequency type; FR = relative frequency; BA = base area; Di = domination type; DR = relative dominance; INP = important value index

3. RESULT AND DISCUSSION

Water Quality Parameters

Water quality parameters measured in the field at each Station include temperature, salinity, and pH. The results of water quality parameter measurements in Bukit Batu Village show varying values. The water temperature ranged from 30–31℃, with the highest value at Station II and the lowest at Station III. Salinity ranges between 26–30‰, with Station I showing higher values than the other stations. The pH values range from 6.8 to 7.5 w, with the highest value at Station I and the lowest at Station III.

Sediment Fraction

The results of the sediment fraction analysis show that the sediment composition in Bukit Batu Village, Bukit Batu District, Bengkalis Regency, consisted of a mud fraction, with the highest percentage (99.41%) at the upper point at station II. In contrast, the lowest mud fraction was observed in the lower part at station I, namely 75.95%. In general, the mud fraction dominates the sediment at all stations and sampling points, with percentages exceeding 75% at each.

Total Sediment Organic Matter

The results show that the average total sediment organic matter content ranged from 12.31-22.34%. The highest average total organic matter content of sediment was shown at station III, 22.34%, followed by station II, 17.12% and the lowest at station I, 12.31%.

Mangrove Vegetation Community Structure
Types of Mangrove Vegetation

The study results showed that in Bukit Batu Village, six mangrove species belonging to five families were found: *Rhizophora apiculata*, *Avicennia alba*, *Sonneratia alba*, *Bruguiera gymnorrhiza*, *Xylocarpus granatum*, and *Nypa fruticans* (Table 1). The number of these types is classified as moderate, indicating that environmental conditions still support the existence of various mangrove types. However, the distribution of types differs between stations, with Station I having more types than Stations II and III (Table 2). The dominance of *R. apiculata* at all stations indicates that this species has a strong ability to adapt to local environmental conditions. In contrast, the more limited presence of other species suggests the presence of certain limiting factors.

Table 1. Types of Mangrove Vegetation found in Bukit Batu Village

No.	Kingdom	Division	Class	Family	Genus	Species
1.	Plantae	Angiospermophyta	Dicotyledonae	Avicenniaceae	*Avicennia*	*Avicennia alba*
2.				Sonneratiaceae	*Sonneratia*	*Sonneratia alba*
3.				Rhizophoraceae	*Bruguiera*	*Bruguiera gymnorhiza*
4.		Magnoliophyta	Magnoliopsida	Rhizophoraceae	*Rhizophora*	*Rhizophora apiculata*
5.				Meliaceae	*Xylocarpus*	*Xylocarpus granatum*
6.			Liliopsida	Arecaceae	*Nypa*	*Nypa fruticans*

Table 2. Distribution of Mangrove Types found in Bukit Batu Village

Mangrove Types	Station I	Station II	Station III
Sonneratia alba	-	+	-
Rhizophora apiculata	+	+	+
Nypa fruticans	+	-	+
Bruguiera gymnorhiza	+	-	-
Avicennia alba	-	+	-
Xylocarpus granatum	+	-	+

Ket : (+) = found (-) = not found

This condition is thought to be influenced by relatively homogeneous environmental characteristics, especially the dominance of mud substrates. Muddy substrates tend to support the growth of certain species, such as *R. apiculata*, but are less suitable for species that require a variety of substrates. Apart from that, other factors such as tidal dynamics, abrasion in the front zone, and anthropogenic activities also influence the distribution and regeneration of mangroves. As a result, vegetation composition is less diverse than in mangrove ecosystems, which have more heterogeneous environmental conditions.

the water quality parameters measured during the study were still within the optimal range for mangrove growth. This is in accordance with Alongi (2015), who stated that the ideal temperature for mangroves is around 25–32°C and the optimal pH is between 6–8. In addition, *R. apiculata* is known to have a wide salinity tolerance (15–30‰), allowing it to grow well under the conditions at the study location (Labuga et al., 2023). The suitability of these environmental parameters supports the dominance of this species and shapes the structure of the mangrove community at the study location.

Tree Categories

In the tree category (Table 3), the structure of the mangrove vegetation community in Bukit Batu Village shows variations in density between stations which indicates differences in ecosystem conditions. Based on the Decree of the Minister of Environment No. 201 of 2004 concerning Standard Criteria for Mangrove Damage, the condition of the mangroves at Station I is classified as moderately good, Station II is very dense, and Station III is classified as rarely damaged. This classification shows that the ability of mangrove vegetation to grow to the mature phase is greatly influenced by environmental conditions and the level of disturbance at each station.

Table 3. Mangrove community structure tree categories at each station

ST	Species	Total	BA (cm^2)	K (Ind/ha)	KR (%)	D (m^2/ha)	DR (%)	F	FR (%)	INP (%)
I	*R. apiculata*	19	1635,86	211,11	18,10	0,25	24,89	1,00	33,33	76,32
	B. gymnorhiza	26	3726,39	288,89	24,76	0,57	56,70	0,33	11,11	92,57
	X. granatum	10	1209,85	111,11	9,52	0,18	18,41	0,67	22,22	50,15
	N. frutican	50	0,00	555,56	47,62	0,00	0,00	1,00	33,33	80,95
	Total	105	6572,10	1166,67	100,00	1,00	100,00	3,00	100,00	300,00
II	*R. apiculata*	65	7075,06	722,22	47,10	0,38	38,50	1,00	42,86	128,46
	A. alba	40	6919,26	444,44	28,99	0,38	37,65	0,67	28,57	95,21
	S. alba	33	4383,16	366,67	23,91	0,24	23,85	0,67	28,57	76,34
	Total	138	18377,49	1533,33	100,00	1,00	100,00	2,33	100,00	300,00
III	*R. apiculata*	31	4049,07	344,44	41,33	0,67	67,48	1,00	50,00	158,82
	X. granatum	24	1951,16	266,67	32,00	0,33	32,52	0,67	33,33	97,85
	N.frutican	20	0,00	222,22	26,67	0,00	0,00	0,33	16,67	43,33
	Total	75	6000,23	833,33	100,00	1,00	100,00	2,00	100,00	300,00

Dominance in the tree category shows that *B. gymnorrhiza* dominates Station I, while *R. apiculata* dominates Stations II and III. The high dominance of Rhizophora is in line with study by Tis'in et al. (2025) which states that this species is generally dominant on muddy substrates. The calculation of the three parameters (relative frequency, relative density, and relative dominance) produced the Important Value Index (IVI), with a maximum value of 300% (Ulyah et al., 2022). The high dominance and INP values of this species indicate an important role in controlling growing space and forming stand structure. In addition, the high frequency values in *R. apiculata* show a wide distribution in various observation plots, which indicates good adaptability to muddy substrate conditions and tidal dynamics.

Vegetation density in the tree category is also related to the organic matter content of the sediment. At Stations I and II, the correspondence between vegetation density and organic matter content indicates environmental conditions that still support mangrove growth. In contrast, at Station III, even though the organic matter content is relatively high, the tree density is low. This is connected to anthropogenic pressures such as fish port activities and settlements which inhibit mangrove growth, thus affecting ecosystem conditions in accordance with standard criteria for mangrove damage.

The results of this study are relatively consistent with those reported by Yoswaty et al. (2022), who recorded mangrove densities of 1,122.21–1,798.80 ind/ha in Anak Setatah Village, Riau Province, and Prasetia et al. (2025), who reported densities of 733.33–1,266.67 ind/ha in the Kelapa Beach Mangrove Area, West Tanjung Jabung Regency. These comparisons indicate that mangrove density in Bukit Batu Village remains within the general density range of mangrove ecosystems along the coast of Sumatra, although differences among stations suggest the influence of environmental and anthropogenic factors on mangrove vegetation structure and density.

The average density of mangrove tree categories shows variations between observation stations (Figure 2). The standard deviation value shows the variation in density between types at each station, with the largest variation being at Station I (±384.42), indicating that the density distribution is more varied than at other stations. Based on the results of the One-Way ANOVA test in the tree category, a significance value of 0.204 ($p>0.05$) was obtained, which shows that there is no real difference in tree density between stations.

Category of Saplings

The structure of the mangrove community in the sapling category in Bukit Batu Village, Regency shows variations in values at each observation station. In the sapling category (Table 4), the mangrove community structure reflects ongoing vegetation regeneration. Density and relative density values in this category indicate that several mangrove species exhibit strong regeneration capacity, especially *R. apiculata*, which is dominant at Stations II and III. Meanwhile, at Station I, *B. gymnorrhiza* showed high dominance, indicating that this species regenerated well under relatively more stable environmental conditions.

The dominance and frequency values in

the sapling category also show a pattern that is relatively in line with the tree category, especially for equally dominant species. This shows that there is continuity between growth phases, with the species that dominate in the tree category also able to maintain their regeneration. However, at several stations, other species, such as *X. granatum*, have quite high frequencies, indicating that this species also has the potential to play a role in community structure in the future.

The Important Value Index (IVI) can be defined as an index that describes the role of vegetation species within an ecosystem (Parmadi et al., 2016). The IVI also indicates the level of species dominance in mangrove vegetation and identifies species with important ecological roles in a mangrove ecosystem (Descasari et al., 2016). In this study, the high IVI values in the sapling category indicate that R. apiculata and B. gymnorrhiza have important roles in the mangrove regeneration process at the study site, reflecting not only their structural dominance but also their strong potential to maintain the sustainability of the mangrove community in the future.

The average density of mangroves in the sapling category shows variations between observation stations (Figure 3). The standard deviation value shows variations in density at each station, with the largest variation found at Station I (±1035.66). In general, *R. apiculata* is the dominant species at most stations. Based on the results of the One-Way ANOVA test in the sapling category, a significance value of 0.887 ($p>0.05$) was obtained, which indicated that there was no significant difference in the density of mangrove saplings between observation stations.

Category of Seedling

The structure of the mangrove community in the seedling category in Bukit Batu Village, Bukit Batu District, Bengkalis Regency shows variations in values at each observation station.

Table 4. Mangrove community structure in sapling category

ST	Species	Total	BA (cm^2)	K (Ind/ha)	KR (%)	D (m^2/ha)	DR (%)	F	FR (%)	INP (%)
I	*R. apiculata*	9	8,13	400,00	32,14	0,32	32,12	0,67	40,00	104,26
	B. gymnorhiza	13	11,53	577,78	46,43	0,46	45,54	0,33	20,00	111,96
	X. granatum	6	5,66	266,67	21,43	0,22	22,35	0,67	40,00	83,78
	Total	28	25,32	1244,44	100,00	1,00	100,00	1,67	100,00	300,00
II	*R. apiculata*	14	13,08	622,22	43,75	0,49	49,40	1,00	42,86	136,01
	A. alba	11	8,74	488,89	34,38	0,33	33,02	0,67	28,57	95,96
	S. alba	7	4,65	311,11	21,88	0,18	17,58	0,67	28,57	68,03
	Total	32	26,47	1422,22	100,00	1,00	100,00	2,33	100,00	300,00
III	*R. apiculata*	13	7,81	577,78	61,90	0,64	63,69	0,67	50,00	175,60
	X. granatum	8	4,45	355,56	38,10	0,36	36,31	0,67	50,00	124,40
	Total	21	12,26	933,33	100,00	1,00	100,00	1,33	100,00	300,00

Table 5. Mangrove community structure seedling category at each station

ST	Species	Total	K (Ind/ha)	KR (%)	F	FR (%)	INP (%)
I	*R. apiculata*	4,00	1111,11	40,00	1,00	33,33	73,33
	A. gymnorhiza	2,00	555,56	20,00	0,33	11,11	31,11
	X. granatum	1,00	277,78	10,00	0,67	22,22	32,22
	N. fruticans	3,00	833,33	30,00	1,00	33,33	63,33
	Total	10,00	2777,78	100,00	3,00	100,00	200,00
II	*R. apiculata*	6,00	1666,67	46,15	1,00	42,86	89,01
	A. alba	4,00	1111,11	30,77	1,00	42,86	73,63
	S. alba	3,00	833,33	23,08	0,33	14,29	37,36
	Total	13,00	3611,11	100,00	2,33	100,00	200,00
III	*R. apiculata*	11,00	3055,56	68,75	1,00	50,00	118,75
	X. granatum	3,00	833,33	18,75	0,67	33,33	52,08
	N. fruticans	2,00	555,56	12,50	0,33	16,67	29,17
	Total	16,00	4444,44	100,00	2,00	100,00	200,00

In the seedling category (Table 5), the density and relative density of mangrove vegetation in Bukit Batu Village show that *R. apiculata* is the most dominant type, especially at Stations II and III. This high value indicates that the regeneration process is going quite well and is supported by environmental conditions such as muddy substrates and high organic matter content. At Station I, in addition to *R. apiculata*, *N. fruticans* also made a fairly large contribution, indicating that regeneration varied more widely than at other stations.

Based on frequency values, *R. apiculata* has a high presence and is relatively evenly distributed across almost all observation plots, especially at Stations II and III. This high frequency indicates the ability to spread propagules widely and achieve high growth success across various environmental conditions, so this species has a strong opportunity to persist into the next growth stage.

The Importance Value Index (INP) value in the seedling category shows that *R. apiculata* has the greatest role in community structure, especially at Stations II and III. The high INP at the seedling stage at Station III is thought to be related to the high production of propagules and the species' ability to adapt to environmental conditions. However, the low density of the tree category at this station indicates that there is environmental pressure that inhibits continued growth, one of which is high anthropogenic pressure due to activities in port and residential areas. These activities can cause physical disturbances, changes in the substrate, and pollution which inhibits the development of seedlings into saplings and trees. Thus, even though the regeneration potential is relatively high, the sustainability of mangrove vegetation at Station III still faces pressures that could affect community structure in the future.

The average density of mangrove seedling categories shows variations between observation stations (Figure 4). The standard deviation value shows that there are variations in density at each station, with the largest variation being at Station III (±1272.94), which shows that the distribution of seed density at that station is more varied than at other stations. In the seedling category, the data did not meet the assumption of homogeneity ($p<0.05$), so the analysis was continued using the non-parametric Kruskal–Wallis test. The test results showed a significance value of 0.458 ($p>0.05$), which indicated that there was no real difference in seedling density between stations.

Mangrove Zoning

The zoning of mangrove vegetation in Bukit Batu Village shows a distribution pattern of species that follows an environmental gradient from sea to land (Table 6).

Table 6. Mangrove type zoning at each station

Station	Zone I	Zone II	Zone III
I	*Rhizophora apiculata*	*Bruguiera gymnorrhiza*	*Nypa fruticans*
II	*Sonneratia alba*	*Rhizophora apiculata*	*Rhizophora apiculata*
III	*Rhizophora apiculata*	*Rhizophora apiculata* *Xylocarpus granatum*	*Xylocarpus granatum*

Kilinau et al. (2023) stated that mangrove zoning is generally divided into three parts, namely the coastline zone (proximal), the middle zone (middle), and the rear zone (distal). This division shows that mangrove distribution is strongly influenced by variations in the physical and chemical conditions of coastal waters, so that each zone has distinct vegetation characteristics, reflecting the tolerance and adaptability of each type.

At Station I, the front zone is dominated by *R. apiculata*, the middle zone by *B. gymnorrhiza*, and the back zone by *N. fruticans*. This pattern cannot be separated from the substrate conditions, which are dominated by mud but vary in stability across zones. The front zone has a relatively unstable mud substrate, influenced by currents and waves, so only species with high adaptability, such as *R. apiculata*, can survive. In the middle zone, the substrate becomes more stable with a more even distribution of mud, thus supporting the growth of *B. gymnorrhiza*. Meanwhile, the back zone has a fine mud substrate with the most stable conditions and low water energy, which is suitable for *N. fruticans*, which generally grows in protected areas near the land.

At Station II, the zoning pattern shows that the front zone is dominated by *S. alba*, while R. apiculata dominates the middle and back zones. Variations strongly influence this difference in substrate fraction. The front zone has a coarser substrate composition with higher sand and gravel content, making it more dynamic and suitable for *S. alba*, which is tolerant of these conditions. This is in line with the study by Koroy et al. (2020), which found that the mangrove front zone is generally dominated by *S. alba*, a species adapted to seaward areas with muddy substrates, often influenced by coarse materials such as sand and gravel, compared to inland zones. In contrast, the middle and rear zones are dominated by fine mud substrates with higher organic matter content and more stable conditions. This environment really supports the growth of *R. apiculata*, which has a supporting root system and high adaptability to muddy substrates. This shows that changes in substrate composition, from coarse to fine, play an important role in determining the distribution of mangrove types within each zone.

At Station III, mangrove vegetation zoning also shows a close relationship with substrate characteristics. R. apiculata still dominates the front to middle zones, while X. granatum dominates the back zone. All zones at this station have a substrate dominated by mud, with very low sand and gravel fractions. Even in the middle and back zones, the mud content exceeds 97%. This condition creates a relatively homogeneous and stable environment, thus supporting the dominance of *R. apiculata* in zones still influenced by tides. At the same time, *X. granatum* thrives more in the back zone, which is more protected and closer to land.

4. CONCLUSION

Based on the results of a study on the structure of the mangrove vegetation community in Bukit Batu Village, 6 mangrove species were identified, with *R. apiculata* as the most dominant and widespread. The density of the tree category ranged from 833.33–1,533.33 ind/ha, while R. apiculata dominated the sapling and seedling categories. The highest INP values at all stations also generally belong to this species, indicating its role as the main constituent of the community. The mangrove zonation pattern follows an environmental gradient from sea to land, with *S. alba* and *R. apiculata* dominating the outer zone, and *B. gymnorrhiza*, *X. granatum*, and *N. fruticans* in a more stable zone towards land.

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