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Density and distribution of nipah (*Nypa fruticans*) on the western coast of Aceh, Indonesia

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Abstract. *Fithria D, Basri H, Indra I, Muchlisin ZA. 2024. Density and distribution of nipah (*Nypa fruticans*) on the western coast of Aceh, Indonesia. Biodiversitas 25: 2967-2973. Nypa fruticans* Wurmb population on the west coast of Aceh, Indonesia, is under threat due to the frequent land conversion to plantations, aquaculture ponds, ports, and settlements, so reduced density and covered areas. Therefore, this study aims to analyze the density and distribution of nipah on the west coast of Aceh. The transect method was used with a size of 10x10m to count the number of trees, 5 x 5m to calculate the saplings, and 1 x 1m to count the seedlings. At each location, three sub-stations were determined purposively, namely (I) downstream near the mouth of the river, which is connected to sea waters, (II) towards upstream where nipah is still growing, as well as (III) between the upstream and downstream parts (mid area). The results showed that the density of nipah in Kuala Bubon for tree categories ranged from 12,700 to 14,800 ind. Ha^{-1}, saplings 2,400 to 4,400 ind. Ha^{-1}, and seedlings 110,000 to 140,000 ind. Ha^{-1}. Meanwhile, in Kuala Tadu, the density of tree categories ranged from 1,900 to 3,800 ind. Ha^{-1}, saplings 1,600 to 6,000 ind. Ha^{-1}, and seedlings 60,000 to 80,000 ind. Ha^{-1}. Moreover, the distribution index of Morishita in Kuala Bubon ranged from 0.02-0.72 and 0.05-0.58 in Kuala Tadu. The organic matter analysis in Kuala Bubon showed that C-organic ranged from 0.68-1.46%, N-total 0.09-0.12%, and P-total 1.55-4.1 mg/kg, while in Kuala Tadu, the values ranged from 0.66-3.63%, 0.05-0.15%, and 2.95-7.25 mg/kg respectively. Therefore, it was concluded that the density of nipah palm in both locations is very high and in good condition with uniformly distributed. However, the organic matter content at both locations was generally very low to low, except for C-organic at Kuala Tadu Station III and P element at Station II.

Keywords: Density, distribution pattern, ecological stress, *Nypa fruticans*

INTRODUCTION

Nipah *Nypa fruticans* Wurmb is one of the non-major mangroves that have a crucial role in coastal ecosystems (Tsuji et al. 2011), namely as a barrier to coastal areas (Robertson et al. 2020), nutrient trap, nursery, feeding and spawning grounds for aquatic biota (Hidayat 2015; Mantiquilla et al. 2019). It also has an economic function as an area for fishing, aquaculture, and food resources (Mondal et al. 2017; Sribianti et al. 2021; Khairi et al. 2023). The nipah plant produces sap water that can be processed as palm sugar, vinegar, alcohol, and biopharmaceutical purposes such as antioxidant and antimicrobial (Nugroho et al. 2022). The sap water of nipah also has the potential to be a source of bioethanol (Hidayat 2018). Meanwhile, the young palm fruit can be processed into jam, juice, and syrup (Iswari 2023).

The *N. fruticans* belongs to the Arecaceae family, is a monocot mangrove species and the sole species in its taxon (Wu et al. 2024) which occupies and grows along rivers or estuaries that are affected by tides (Widodo et al. 2020; Mantiquilla et al. 2022). It grows in dense, uniform formations and often forms a large single population along riverbanks to estuary waters (Lestari and Noor'an 2019; Fithria et al. 2022). Furthermore, the population is distributed around the equator, from Sri Lanka to Southeast Asia and Northern Australia (Clemente 2013; Hossain and Islam 2015). The growth and density of the nipah are strongly influenced by environmental factors, including salinity, pH, currents, substrate types, and nutrients (Tsuji et al. 2011; Mah 2014; Takarina et al. 2019).

Indonesia has approximately 700,000 Ha of nipah, higher than Papua New Guinea at 500,000 Ha and the Philippines at 8,000 Ha (Megumi 2018). In Aceh, Indonesia, the nipah ecosystem is found in several areas on the west coast, including Kuala Bubon and Kuala Tadu, with an area of 35 Ha and 23 Ha, respectively (Fithria et al. 2022). Studies on the ecology of nipah in Indonesia are scarce, but several investigations, including (Widodo et al. 2020), examined its role as a green belt in the estuary area of the Bengawan, Sentolo, Tipar, Ijo, and Kalibenda Rivers. Eddy et al. (2022) studied the distribution population and benefits of nipah *N. fruticans* in Air Telang Protected Forest (ATPF), Banyuasin District, South Sumatra. Nipah habitat in the southern part of Java Island generally grows on muddy rivers and not on sandy soils. Ulyarti et al. (2017) explored the potency of nipah flour for substituting wheat and rice flour to produce high-fiber foods. There is no report from the Aceh Region, specifically from the west coast.

The mangrove population, including the nipah on the west coast of Aceh, is currently threatened by a massive land use conversion to palm oil plantations, aquaculture ponds, ports, and settlement areas (Djufri et al. 2016; Fithria et al. 2022). In addition, the potential for pollution in coastal areas is also increasing along with the increase in population and community activities, which produce pollutant substances (Maulana et al. 2022; Ramadhaniaty et al. 2023) that can suppress the density and distribution of nipah. In addition, climate change is worsening global water conditions and negatively impacting biodiversity in coastal ecosystems (Ward et al. 2016; Nur et al. 2020; Amir et al. 2022), including mangroves. This implies necessary plans for a sustainable management strategy for nipah to sustain its ecological, physical, and economic functions. Initial information on the density and distribution is important as baseline data for planning strategic management and monitoring. These parameters are crucial for population evaluation and monitoring (Aryawati et al. 2017; Mantiquilla et al. 2019; Emoyoma et al. 2020). Therefore, this study aims to analyze the density and distribution of nipah *N. fruticans* at two locations on the west coast of Aceh, Indonesia.

MATERIALS AND METHODS

Time and sampling site determination

During the initial survey conducted along the west coast of Aceh, Indonesia, it was observed that nipah was predominantly overgrown in two locations: Kuala Bubon, West Aceh, and Kuala Tadu, Nagan Raya (Figure 1). The study took place in these locations from February to March 2022. Sample analysis was carried out both in situ and ex-situ at the Integrated Laboratory, Teuku Umar University, Meulaboh. Three sub-stations were purposefully determined at each location, including (I) downstream near the river mouth connected to sea waters, (II) upstream where nipah is still growing, and (III) the mid area between the upstream and downstream parts. The GPS coordinates for each location can be found in Table 1.

Table 1. The description of the locations and the GPS coordinates of every sampling site

Location/station	GPS coordinate	Description
Kuala Bubon, West Aceh, Indonesia		
Downstream	96° 2'42.88"E; 4°12'49.38"N	Jetty and fish landing, market
Mid area	96° 3'4.63"E; 4°12'44.78"N	This location is close to settlements and traditional market
Upstream	96° 3'35.16"E; 4°13'27.00"N	The location is situated near the settlements
Kuala Tadu, Nagan Raya, Indonesia		
Downstream	96°16'24.20"E; 4° 1'8.43"N	Fish landing and settlement areas
Mid area	96°16'14.10"E; 4° 1'26.58"N	No anthropogenic activity was detected
Upstream	96°16'5.07"E; 4° 1'41.79"N	Plantation and fishpond

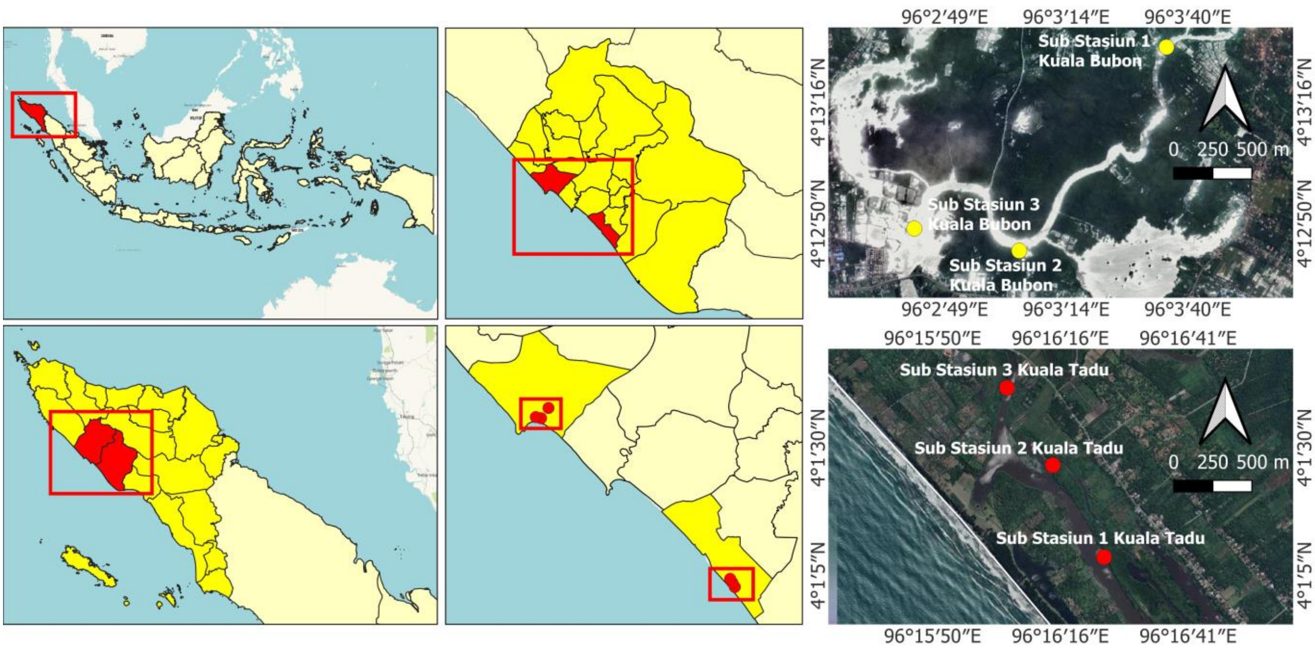

Figure 1. The map of Aceh Province, Indonesia, showing sampling locations (yellow dots in Kuala Bubon and red dots in Kuala Tadu)

Nipah sampling procedure

The quadratic transect method was used to collect the data on the nipah density. The plot size of 10 m x 10 m was used to calculate stands for tree categories (tree height >1 m and trunk diameter >4 cm), transect size of 5 m x 5 m was used to calculate sapling stands (tree height >1.5 m, and trunk diameter <10 cm), and a plot of 1 m x 1 m was used to count seedlings (tree height 1.5 m). A total of three plots were settled up at every station, and the distance from one plot to the next was 150 m, as shown in Figure 2.

Plant density and distribution pattern examinations

The plant density of nipah was calculated based on (English et al. 1997) as follows:

$$K = \frac{ni}{A}$$

Where:
K : Plant density of nipah (ind Ha^{-1})
ni : Total individual
A : Total area of plots (m^2)

Based on the density value, the condition of the nipah ecosystem was estimated based on the standard of the Ministry of Environment of Indonesia No. 201 of 2004 concerning Standard Criteria and Guidelines for determining mangrove condition, as shown in Table 2 (Indonesian Ministry of Environment Regulation No. 201 of 2004).

The nipah distribution pattern was calculated using the Morista Index as follows:

$$Id = \frac{N(\sum x^2 - \sum x)}{(\sum x)^2 - \sum x}$$

Where:
Id : Morista Index
N : Total individual
X : Total individual of respective species

Based on the Morista Index's value, the plant distribution pattern is divided into three categories: Id>1 = Grouped, Id = 1 = Random, and Id<1 = Uniform.

Substrate sampling procedure

Substrate samples were taken using a soil ring sampler with a diameter of 5 cm. The soil was taken by plugging the soil ring into the substrate to a depth of 20 cm, and then the collected subtract was put in a plastic bag and placed in a box. The sample was transported to the Laboratory of Soil Chemistry and Plants, Faculty of Agriculture, Universitas Syiah Kuala, Indonesia, for nutrient analysis on Carbon (C), Nitrogen (N), and Phosphorus (P). The criteria of nutrient content followed *Lembaga Penelitian Tanah* (LPT) Bogor, Indonesia, as presented in Table 3.

C-organic analysis

A total of 20 g sediment samples were collected at every station, of which 10 g were used for total C analysis, and the remaining 10 g were used for C-organic analysis. C-organic was analyzed using the Loss of weight On Ignition (LOI) method with the following procedure: a total of 10 g of sediment samples were heated in a furnace at a temperature of 550°C for 5-6 hours (ashing process) and cooled in a desiccator, after cooling, the ash was weighed. Meanwhile, C-organic was analyzed: 10 g of sediment samples were soaked with 6 M HCl to remove the inorganic C, then rinsed with distilled water. The sample was dried in an oven, heated in a furnace at a temperature of 550°C for 5-6 hours, cooled in a desiccator, and weighed the final weight (Somarriba et al. 2013).

N-total analysis

The N-total was analyzed using the Kjeldahl method: 0.5 g of ground sample was added to a Kjeldahl flask, then 1 g of xylene and 5 mL of concentrated H_2SO_4 were added. The sample was destructed at 300°C for 4 hours and then cooled. Afterward, the sample was diluted with 100 mL of pure H_2O, 20 mL of 40% NaOH, and further distilled. The distillate result was accommodated in a tube filled with 20 mL of the boric acid indicator until the solution color became green at a volume of approximately 50 mL and then titrated with 0.01 N H_2SO_4.

Table 2. The mangrove (nipah) condition criteria are based on covered area and tree density (Indonesian Ministry of Environment Regulation No. 201 of 2004)

Criteria	Level	Density (ind./Ha)
Good	High density	>1,500
	Moderate density	1,000 to 1,500
Disturbed	Low density	<1,000

Table 3. Analysis criteria of soil chemical properties

Parameters	Very low	Low	Medium	High	Very high
C (%)	<1.00	1.00-2.00	2.01- 3.00	3.01- 5.00	>5.00
N (%)	<0.10	0.10- 0.20	0.21- 0.50	0.51- 0.75	>0.75
P Bray I (ppm)	< 4.4	4.4-6.5	6.6-10.9	11.0- 15.3	>15.3

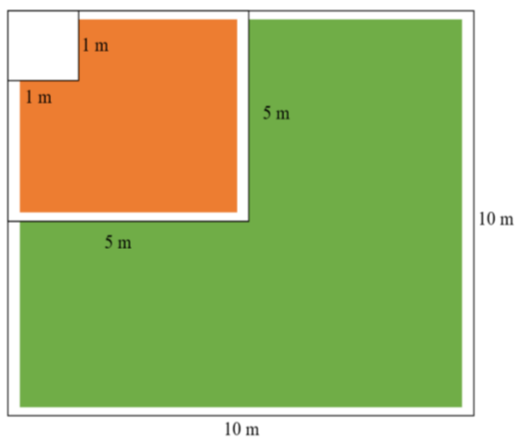

Figure 2. Transec plots for calculating nipah density. Green plot (10 m x 10 m) was used for tree stand categories, yellow plot (5 m x 5 m) was used sapling stand, and white plot (1 m x 1 m) was used to calculate the sadling category

Phosphate

Total phosphate was analyzed using the Bray method: 1.5 g of sifted soil sample was taken and put into a tube, then 15 mL of Olsen extracting was added and shaken for 30 minutes. The sample was filtered and kept for one night at room temperature. Furthermore, 2-20 mL of the soil sample solution was taken and put into a flask, and distilled water was added to reach a volume of 25 mL. About 8 mL of reagent B was added and placed at room temperature for 20 min; the percentage of absorbance was measured using a spectrophotometer (Shyla et al. 2011).

Data analysis

The data were presented in the tables and figures and then analyzed descriptively by comparing the findings with relevant reports and references.

RESULTS AND DISCUSSION

The density of nipah in Kuala Bubon for tree categories ranged from 12,700 to 14,800 ind. Ha^{-1}, saplings 2,400 to 4,400 ind. Ha^{-1}, and seedlings 110,000 to 140,000 ind. Ha^{-1}. Based on the sampling station, the highest density was found at Station I and the lowest at Station III, where the proportion of seedlings (seedlings) was dominant in all sampling stations, with an average density of 87.74%. Meanwhile, in Kuala Tadu, the density of tree categories ranged from 1,900 to 3,800 ind. Ha^{-1}, saplings 1,600 to 6,000 ind. Ha^{-1}, and seedlings 60,000 to 80,000 ind. Ha^{-1}. The highest density was found at sampling Station III, and the lowest was at Station II, where seedlings also dominated the nipah population in Kuala Tadu, with an average of 92.71% (Table 4). Therefore, in general, for the tree and seedling categories, the density of nipah in Kuala Bubon was higher than in Kuala Tadu, while for the sapling category, the density was closely similar in the two locations. The Morista Index in Kuala Bubon ranged from 0.00 to 0.02 for the tree category, 0.03 to 0.72 for saplings, and 0.05 to 0.19 for seedlings, while in Kuala Tadu, the values ranged from 0.05 to 0.21, 0.10 to 1.19, and 0.30 to 0-51 respectively. Therefore, nipah in both locations generally has a uniform distribution pattern, except at Station II in Kuala Tadu for the saplings category, which showed a grouped pattern (Table 5).

According to Irsadi et al. (2019) and Ellison (2021), oceanographic conditions such as temperature and salinity strongly influence the distribution of the mangrove population, including the nipah. In addition, the nutrient or organic matter contents of soil and water also affect the growth and density of the aquatic plants (Pérez et al. 2018). The results showed that the organic matter content in Kuala Bubon at Station I was 0.68% C-organic, 0.09% N, and 1.55 mg kg^{-1} P; at Station II, the proportion was 1.46% 0.12%, and 4.10 mg kg^{-1}, while at Station III, it was 1.22% 0.11%, and 3.70 mg kg^{-1} respectively. The analysis results of the substrate sample from Kuala Tadu showed that at Station I, C-organic was 0.66%, N was 0.05%, and P was 4.25 mg kg^{-1}. At Station II, the proportion was 1.10%, 0.07%, and 7.25 mg kg^{-1}, respectively; at Station III, it was 3.63%, 0.15%, and 2.95 mg kg^{-1}, respectively (Table 6). Based on the Soil Chemical Properties Criteria published by PPT (1995), the C-organic, N, and P content in Kuala Bubon ranges from low to very low. The C-organic and N contents in Kuala Tadu were in the low to very low category, while P elements ranged from very low to medium.

Table 4. The density of nipah *N. fruticans* according to the sampling station

Location	Station	Trees		Saplings		Seedlings		Total
		Ind. Ha^{-1}	%	Ind. Ha^{-1}	%	Ind. Ha^{-1}	%	(Ind. Ha^{-1})
Kuala Bubon	I	13,200	8.48	2,400	1.54	140,000	89.97	155,600
	II	14,800	10.69	3,600	2.60	120,000	86.71	138,400
	III	12,700	9.99	4,400	3.46	110,000	86.55	127,100
Average		13,566.7	9.72	3,466.7	2.53	123,333.3	87.74	140,367
Kuala Tadu	I	2,200	2.60	2,400	2.84	80,000	94.56	84,600
	II	1,900	2.99	1,600	2.52	60,000	94.49	63,500
	III	3,800	4.23	6,000	6.68	80,000	89.09	89,800
Average		2,633.3	3.27	3,333.3	4.01	73,333.3	92.71	79,300

Note: I: Downstream near the mouth of the river, which is connected to sea waters; II: Between the upstream and downstream parts (mid area); III: Lead upstream where nipah is still growing

Table 5. The Morista Index of nipah *N. fruticans* according to location and sampling site

Location	Station	Morista Index					
		Tree		Sapling		Seedlings	
		Value	Category	Value	Category	Value	Category
Kuala Bubon	I	0.02	Uniform	0.72	Uniform	0.19	Uniform
	II	0.00	Uniform	0.07	Uniform	0.06	Uniform
	III	0.00	Uniform	0.03	Uniform	0.05	Uniform
Kuala Tadu	I	0.16	Uniform	0.58	Uniform	0.33	Uniform
	II	0.21	Uniform	1.19	Grouped	0.51	Uniform
	III	0.05	Uniform	0.10	Uniform	0.30	Uniform

Table 6. The average organic matter content (C, N, and P) in the nipah ecosystem at Kuala Bubon and Kuala Tadu, western coast of Aceh, Indonesia

Parameters	**Unit**	**Kuala Bubon**			**Kuala Tadu**			**Average**		
		I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
C-organic	%	0.68	1.46	1.22	0.66	1.10	3.63	0.67	1.28	2.43
Total Nitrogen (N)	%	0.09	0.12	0.11	0.05	0.07	0.15	0.07	0.10	0.13
Phosphor	mg kg^{-1}	1.55	4.10	3.70	4.25	7.25	2.95	2.90	5.68	3.33

Note: I: Downstream near the mouth of the river, which is connected to sea waters; II: Between the upstream and downstream parts (mid area); III: Leads upstream where nipah is still growing

This study showed that the average density of nipah in Kuala Bubon for all age categories was 140,367 ind. Ha^{-1}, while in Kuala Tadu, it was 79,300 ind. Ha^{-1}, with seedlings dominating in both locations. Referring to the Decree of the Minister of the Environment of Indonesia No. 201 of 2004, the nipah ecosystem in both locations is in good condition. However, the results showed that the density in Kuala Bubon was higher than in Kuala Tadu. This is because the ecosystem in Kuala Tadu is highly disturbed due to land conversion for oil palm plantations and aquaculture ponds (Matatula et al. 2019; Nopiana et al. 2020). Therefore, damage to mangrove forests can occur due to land conversion and illegal logging; hence, government policies and public awareness are crucial to preserving mangrove forests (Rudianto et al. 2020). According to current data, the area of the nipah forest in Kuala Tadu was 23 Ha, and based on local residents, it has decreased sharply in the last 10 years. Meanwhile, in Kuala Bubon, the nipah forest was rehabilitated with *Rhyzophora* and *Avicenna* mangroves by the Food and Agriculture Organization (FAO) in 2004. Currently, the population of nipah in Kuala Bubon has been dominant in the mangrove population. According to information from the local community, before the 2004 tsunami, the nipah population in Kuala Bubon was more dominant than *Rhizophora* and *Avicenna*; the nipah condition was damaged afterward but has now recovered. A similar phenomenon also occurred in the Mahakam Delta, East Kalimantan, Indonesia, where the sedimentation zone of the estuary was initially dominated by *Sonneratia caseolaris* (L.) Engl. This species gradually decreased in density and was replaced by *N. fruticans*, which covered almost the entire delta (Mah 2014).

The size composition showed that for the tree category at Kuala Bubon, the abundance of nipah at every sampling was almost the same. At the same time, Kuala Tadu showed different density values among the sites, where the value upstream of the estuary (Station III) was higher than the downstream and middle (Stations I and II). Furthermore, the saplings were relatively the same between stations, while the seedlings were predominant at the station, which led to the downstream area. This phenomenon indicates that the regeneration in the downstream area was higher than in the upstream and might be due to ripe fruit or seedlings from upstream areas drifting downstream and growing there. In addition, the type of substrate downstream tends to be sandy mud, which is more suitable for nipah growth (Karniati et al. 2021).

Moreover, Table 6 showed that the organic matter content, namely C, N, and P, at all locations ranged from very low to low, except for C-organic at Station III Kuala Tadu, which was classified in the high category, and P at the Kuala Tadu Station II in the medium category. Therefore, in general, the organic matter content in Kuala Tadu is higher than in Kuala Bubon, but in terms of nipah density, Kuala Bubon was actually higher. Aside from anthropogenic influences and intense land use change in Kuala Tadu, the low nipah density might also be due to the different types of substrates between the two locations, where in Kuala Bubon, the substrate is muddy sand (predominant sand), while in Kuala Tadu is sandy mud (predominantly mud). This estuary has higher turbidity and frequent flooding during the rainy season (Annas et al. 2017). According to Weiss et al. (2016), differences in the substrate in the mangrove ecosystem affect the organic materials contained therein, where sandy substrates tend to be low.

Based on the element composition, in Kuala Bubon, C-organic, total N, and P were dominant in the substrate at Station II. Meanwhile, in the Kuala Tadu, C-organic and total N were higher at Station III, and the P element was higher at Station II. According to Imra et al. (2021), the organic matter contained in the substrate in the mangrove ecosystem is generally derived from local primary productivity; it is mostly contributed by mangrove vegetation and river flows. Hence, mangrove density and anthropogenic activities affect the level of total organic matter in the mangrove ecosystem (Kaseng 2018). Alongi (2013) stated that the N element is one of the important organic materials for growth, reproduction, productivity, and plant physiology.

Table 4 shows that the distribution of nipah at both locations was uniform for all size categories. The uniform distribution pattern was assumed due to the low nutrient content in the substrate. This is in agreement with Yuvaraj et al. (2017) and Rahardjanto et al. (2020), who stated that the uniform distribution pattern is due to the low content of nutrients in the substrate, thereby triggering high food competition among organisms, causing a decrease in species diversity. Based on the direct observation during survey in the sampling sites, the plant diversity was low, and nipah was predominant. Therefore, it is suspected that aside from utilizing low nutrients in the substrate, nipah can also absorb nutrients directly from the water.

Additionally, the distance of the source strongly influences the organic matter content in the estuary; for example, the downstream area at the infront of the estuary, which is directly related to the offshore, has a lower organic matter content. This presumably caused the Station I low organic matter content, directly connected to the sea and frequently affected by tides and waves. Furthermore, tides and waves cause an increase in dissolved oxygen, thereby triggering bacteria to oxidize C and release it back into the atmosphere through respiration, culminating in low content in the substrate (Senger et al. 2021) and the strong waves hindering the substrate from being deposited. Therefore, stations near sandy beaches have relatively low organic matter content because the substrate mixes with sand, as noted in this study. The organic matter content in the upstream estuary tends to be higher; therefore, the density of nipah palms in the area was also high.

In conclusions, Aceh Province is one of the provinces in Indonesia with a significant potential for aquatic resources; one of these potencies is mangrove forests. One of the secondary mangrove species in Aceh *N. fruticans*. The nipa palm ecosystem in Aceh Province is found in several areas, including on the west coast of Aceh; an extensive nipa forest is found in two estuaries, namely Kuala Bubon, West Aceh District, and Kuala Tadu in Nagan Raya District. However, the condition of the nipa palm ecosystem in those locations is threatened by land conversion to plantations, aquaculture ponds, and settlements. This condition causes the area to decrease over the years. Fortunately, this study indicates that nipah density at Kuala Bubon and Kuala Tadu is high and in good condition, where seedlings are more predominant and mostly found near the river mouth or downstream estuary. Based on the Morisita Distribution Index, the population of nipah in both locations is uniformly distributed. However, the organic matter content at both locations ranges from very low to low categories, except for the C element at Station III and P at Station II, both in Kuala Tadu, which are in high and medium categories. Therefore, this information is valuable for the government and conservationists to immediately take essential steps to prevent the destruction of the nipah forest in this area, especially in these two study locations. The preparation of regulations to limit the use of nipah plants must be implemented immediately.

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