Asian Journal of Aquatic Sciences, August 2024. Vol 7, Issue (2) 216-225
e-issn: 2716-4608
p-issn: 2655-366X

VERTICAL DIVERSITY OF EPIPHYTIC DIATOMS ON STEMS OF *Rhizophora* sp AND FRONDS OF *Nypa* sp IN KUNDUR WATERS KARIMUN REGENCY, RIAU ISLANDS PROVINCE

Yulia Sapta Rini[1*], Efriyeldi[1], Sofyan Husein Siregar[1]
[1]Department of Marine Science, Faculty of Fisheries and Marine,
Universitas Riau, Pekanbaru, 28293 Indonesia
*yulia.sapta0499@student.unri.ac.id

ABSTRACT

This study was conducted in the waters of Kundur Island, Karimun Regency, Riau Islands Province, to assess the type, abundance, and diversity of epiphytic diatoms on *Rhizophora* sp stems and *Nypa* sp fronds using a survey method and purposive sampling for station selection. One-way ANOVA, LSD tests, and the Independent Samples T-test were employed for data analysis. The research identified 11 species of epiphytic diatoms: 9 from the Bacillariophyceae class (including *Navicula* sp, *Pleurosigma* sp, *Pinnularia* sp, and *Skeletonema costatum*); *Isthmia* sp from the Coscinodiscophycidae class, and *Chaetoceros* sp from the Bacillariophyceae class. The results indicated a higher abundance of diatoms on *Nypa* sp fronds (17,822.94 ind/cm²) than *on Rhizophora* sp stems (13,884.16 ind/cm²). Significant differences in diatom abundance were observed between stations on *Rhizophora sp.* stems, particularly between stations II and III. In contrast, no significant differences were found between stations I and II or stations I and III. No significant differences in diatom abundance were observed between stations on *Nypa* sp fronds. The T-test results revealed significant vertical differences in diatom abundance between *Rhizophora* sp stems and *Nypa* sp fronds. Overall, the diversity of epiphytic diatoms was categorized as medium on both *Rhizophora* sp stems and *Nypa* sp fronds in the waters of Kundur Island, Karimun Regency, Riau Islands Province. This study contributes valuable insights into the ecological dynamics of epiphytic diatoms in mangrove and nipa palm habitats.

Keywords: Kundur Island, Diatom Epiphytic, Vertically, *Rhizophora* sp, *Nypa* sp

1. INTRODUCTION

Diatoms are microalgae with a wide distribution and are cosmopolitan. Because of their sensitivity to habitat conditions, diatoms can be used as bioindicators of environmental change. They can also describe water quality as accumulators of changes in water quality, such as sedimentation and nutrient enrichment. The extensive distribution of diatoms is found in various habitats, such as marine ecosystems, fresh waters, and sediments. Some are even found in mangroves, which are called epiphytic diatoms[1].

Epiphytic diatoms stick to plants such as seagrass, seaweed, roots, and mangrove stems, which seawater influences daily. Epiphytic diatoms are primary aquatic producers that can convert inorganic substances into organic substances in the mangrove ecosystem through photosynthesis. The mangrove litter will decompose and produce nutrients, including nitrate and phosphate, which are dissolved in water to support the growth process of diatoms[2]. One area where many mangroves are found is Kundur Island.

Kundur Island is located in Karimun Regency, Riau Islands Province, and has

Received: 17 June 2024
Accepted: 12 July 2024

abundant aquatic resources, both flora and fauna, such as the mangrove forest ecosystem. The types of mangroves most commonly found in this area are *Rhizophora* sp and *Nypa* sp[3]. *Rhizophora sp.* can adapt to extreme environmental conditions, flooding, less stable soil, and high salinity. Meanwhile, *Nypa* sp is a type of palm that grows as an associated mangrove, forms clumps (colonies), and can support the surrounding ecosystem.

The mangrove ecosystem is productive and has an essential role in the growth of diatoms. Research related to epiphytic diatoms has been carried out previously, including by Harun et al.[4], regarding the abundance of epiphytic diatoms in *Rhizophora* trees covered and not covered by plastic in the area of Pecinta Alam Bahari (PAB) Dumai. Other related research was conducted by Arifin et al.[5] regarding the community structure of epiphytic diatoms on *Nypa fruticans* fronds around Cawan Island, Indragiri Hilir Regency, Riau Province. Other research conducted by Susiyanti et al.[6] regarding the vertical distribution of epiphytic diatoms on stems of *Avicennia* sp in the Muara Sei Undan area, Indragiri Hilir Regency, was also conducted.

However, there is not much information about epiphytic diatoms in the waters of Kundur Island, Karimun Regency, especially on the stems of *Rhizophora* sp and fronds of *Nypa* sp. The sampling location on the stem of *Rhizophora* sp and fronds of *Nypa* sp was chosen because it is located in the dense mangrove forest zone and the back zone of the mangrove forest.

This research aims to determine the type, abundance, and diversity of epiphytic diatoms on the stems of *Rhizophora* sp and fronds of *Nypa* sp. Therefore, based on the explanation above, it is necessary to research the vertical diversity of epiphytic diatoms on the stems of *Rhizophora* sp and fronds of *Nypa* sp in Kundur waters, Karimun Regency, Riau Islands Province.

2. RESEARCH METHOD

Time and Place

This research was carried out in May - June 2023. The data was collected using the in situ method in the waters of Kundur Island, Karimun Regency, Riau Islands Province (Figure 1).

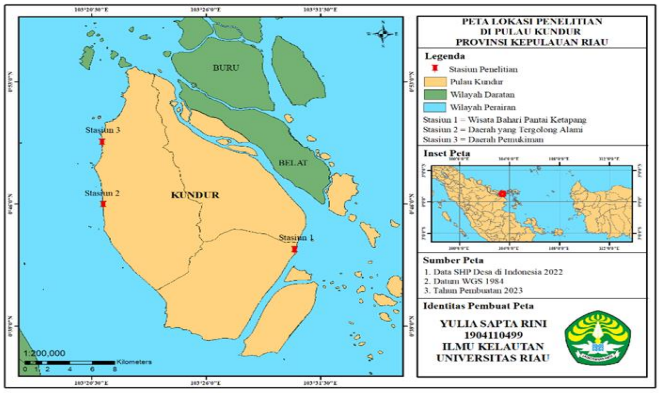

Figure 1. Maps of the locations and research stations

Method

This research used a survey method with direct observation and sampling in the field. Epiphytic diatom samples taken from the stems of *Rhizophora* sp and *Nypa* sp fronds were brought and explained at the Marine Biology Laboratory, Faculty of Fisheries and Marine, Universitas Riau.

Procedures

Determination of Sampling Locations

station points were carried out directly by purposive sampling in the mangrove forest area, divided into three stations considered representative sampling locations. Station I is in the Ketapang Beach Marine Tourism area, and Station II is in an area classified as natural and does not have

significant anthropogenic pressure. Station III is in an area near residential areas.

Sampling

The sampling location consists of 3 (three) *Rhizophora* sp and *Nypa* sp. Each tree was divided into three plots based on the boundary distance between daily high and low sea water, which is around ± 50 cm. Plot 1 is located at the high tide limit (top), Plot 2 is located in the middle between the high tide and lowest low tide (middle), and Plot 3 is located at the lowest low tide limit (bottom). Samples were taken at low tide by scraping the stem of *Rhizophora* sp. The scraping plot area was 5 x 5 cm, then sprayed with distilled water. Then, the sample was collected in a sample bottle until the concentrate volume was 100 mL. Then, it was labelled and preserved with four drops of Lugol 4%. A simulation of the sampling scheme on the stems of *Rhizophora* sp and fronds of *Nypa* sp can be seen in Figure 2.

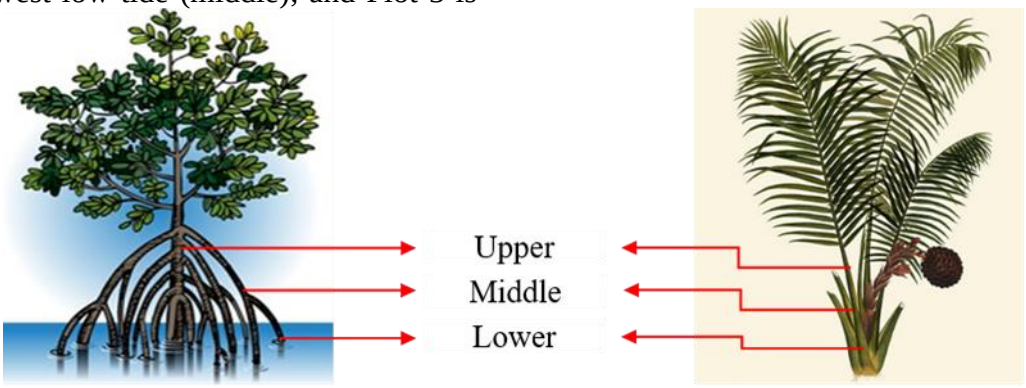

Figure 2. Simulation of sampling scheme for stems of *Rhizophora* sp and *Nypa* sp

Measurement of Water Quality Parameters

Water quality parameters are collected and measured directly at the sampling location during high tide. Measurement of water quality parameters includes temperature, salinity, brightness, pH, nitrate, and phosphate.

Observation of Epiphytic Diatom Samples

Diatom samples were observed under a binocular microscope at 100 times magnification using a 12-field-of-view method with three repetitions. The diatoms found are identified, and then the number of diatoms found is calculated.

Calculation of the Abundance of Epiphytic Diatoms

Diatom abundance was calculated using the modified Lackey Drop Microtransecting Methods formula[4]:

$$N=\frac{3Oi}{Op} \times \frac{Vr}{3Vo} \times \frac{1}{A} \times \frac{n}{3p}$$

Information:

N = Number of epiphytic diatoms per unit wide (ind/cm^2)
Oi = Cover glass area (6,25 cm^2)
Op = Microscope field of view unit with a magnification of 10x10 (1,306)
Vr = Sample bottle volume (100 mL)
Vo = Volume 1 drop of sample (0,06 ml)
A = Scraping area (5 × 5 cm^2)
n = Number of epiphytic diatoms found
p = Number of fields of view (12)

Species Diversity Index (H')

To determine the diversity of epiphytic diatom types, the Shannon-Winner formula[5] is used as follows:

$$H' = -\sum_{i=1}^{s} pi \, Log_2 \, pi$$

Information:

H' = Species Diversity Index
pi = The proportion of individuals of the i-th species to the total of all individuals species (pi = ni/N)

ni = The total number of individuals of the i-th type (ind/cm^2)
N = Total individuals of all types (ind/cm^2)

Criteria: H' < 1= The biota community does not have water balance or quality very polluted; 1 ≤ H' ≤ 3 = Biota community balance medium, and water quality moderately polluted; H' > 3 = Internal biota balance excellent condition and quality clean water.

Data Analysis

The data obtained was tabulated and analyzed descriptively and statistically. If there are any differences in the abundance of epiphytic diatoms vertically between stations, a one-way Analysis of Variance (ANOVA) test is carried out; if there are significant differences, a further test (LSD) is carried out[7]. The Independent Samples T-test was used to determine differences in the abundance of epiphytic diatoms between *Rhizophora* sp stems and *Nypa* sp fronds.

3. RESULT AND DISCUSSION

General Conditions of Research Locations

Kundur Island is the largest island in the Karimun Regency, Riau Islands Province, and it has a strategic location and area when viewed from a trade-economic approach. Kundur Island has an area of 1380 km^2 consisting of 596 km^2 of land and 784 km^2 of sea with a geographical location of 0º46'0" N and 103 º25'43" E[8].

The station I in the research area is geographically located at coordinates 0°43'19.1" N 103°30'14.5" E. The location of station I is located in the Ketapang Beach Marine Tourism area and influences marine tourism activities. Station II in the research area is situated astronomically at coordinates 0°42'04.1" N 103°22'41.7" E. Station II is located in an area classified as natural and does not experience significant anthropogenic pressure. Station III in the research area is situated astronomically at coordinates 0°43'17.6" N 103°30'15.3" E. Station III is located near residential areas and experiences significant influence from anthropogenic activities.

Water Quality

The results of measurements of the water quality parameters of Kundur Riau Islands around the stems of *Rhizophora* sp and fronds of *Nypa* sp. It was found that the average water pH ranged between 7,5 – 7,6 and 6.4–7.7. The lowest and highest pH values are found around *Nypa sp.* at stations I and II, with values of 6.4 and 7.7. The water temperature at the research station location ranges between 26–28°C. The salinity values obtained in Kundur waters range from 10 – 27 ppt. The water brightness value at each station ranges from 19.5 to 36 cm. The results of measuring water quality parameters around the stems of *Rhizophora* sp and fronds of *Nypa* sp can be seen in Table 1.

Table 1. Water quality parameters on stems of *Rhizophora* sp and fronds of *Nypa* sp

Parameters	*Rhizophora* sp				*Nypa* sp			
	Station			Average	Station			Average
	I	II	III		I	II	III	
pH	7.5	7.6	7.5	7.53	6.4	7.7	7.5	7.2
Temperature (°C)	27	26	28	27	28	26	28	27.3
Salinity (ppt)	27	24	23	24.67	10	11	10	10.3
Brightness (cm)	20	19.5	22	20,5	34.5	33.5	36	34.67
Nitrate (mg/L)	0.78	0.90	0.74	0.80	0.82	0.83	0.90	0.85
Fosfat (mg/L)	0.52	0.54	0.53	0.53	0.60	0.69	0.76	0.68

Types of Diatoms in Kundur Waters

Based on the results of vertical identification of epiphytic diatoms on the stems of *Rhizophora* sp and fronds of *Nypa* sp, 11 species were found. The most frequently found diatoms come from the Bacillariophyceae class with nine species, including *Navicula* sp, *Pleurosigma* sp, *Pinnularia* sp, *Melosira* sp, *Synedra* sp, *Nitzschia* sp, *Coscinodiscus* sp, *Amphora* sp, and *Skeletonema costatum*. Furthermore, from the class Coscinodiscophycidae, the species *Isthmia* sp was found, and from the Bacillariophyceae class, the species *Chaetoceros* sp was found. Classification of diatoms found in the stems of *Rhizophora* sp and fronds of *Nypa* sp during the research can be seen in Table 2.

Table 2. Classification of epiphytic diatoms on *Rhizophora* sp stems and frond *Nypa* sp in the waters of Kundur Island

Class	Ordo	Family	Genus	Species
Coscinodiscophycidae	Biddulphiales	Biddulphiaceae	Isthmia	*Isthmia* sp
Florideophyceae	Ceramiales	Ceramiaceae	Chaetoceros	*Chaetoceros* sp
		Naviculaceae	Navicula	*Navicula* sp
	Naviculales	Pleurosigmataceae	Pleurosigma	*Pleurosigma* sp
		Pinnulariaceae	Pinnularia	*Pinnularia* sp
	Melosirales	Melosiraceae	Melosira	*Melosira* sp
Bacillariophyceae	Fragilariales	Fragilariaceae	Synedra	*Synedra* sp
	Bacillariales	Bacillariaceae	Nitschia	*Nitzschia* sp
	Coscinodiscales	Coscinodiscaceae	Coscinodiscus	*Coscinodiscus* sp
	Thalassiophysales	Catenulaceae	Amphora	*Amphora* sp
	Thalassiosirales	Skeletonemaceae	Skeletonema	*S.costatum*

Table 3. Distribution of epiphytic diatoms on the stems of *Rhizophora* sp and the frond of *Nypa* sp

No	Species	*Rhizophora* sp			*Nypa* sp		
		Station			Station		
		I	II	III	I	II	III
1	*S. costatum*	+	+	+	-	-	+
2	*Isthmia* sp	+	+	+	+	+	+
3	*Pleurosigma* sp	+	+	+	+	+	+
4	*Pinnularia* sp	+	+	+	+	+	+
5	*Melosira* sp	+	+	+	+	+	+
6	*Synedra* sp	+	+	+	+	+	+
7	*Nitzschia* sp	+	+	+	+	+	+
8	*Chaetoceros* sp	-	+	+	-	-	-
9	*Navicula* sp	+	+	+	-	-	-
10	*Coscinodiscus* sp	+	+	-	-	-	-
11	*Amphora* sp	-	-	-	+	+	+
Total		9	10	9	7	7	8

The distribution of epiphytic diatom types found in Kundur waters varies at each station. Ten epiphytic diatoms were found on the stems of *Rhizophora* sp and eight species on the fronds of *Nypa* sp. In the stems of *Rhizophora* sp, ten species of epiphytic diatoms were found, including *Isthmia* sp, *Pleurosigma* sp, *Pinnularia* sp, *Melosira* sp, *Chaetoceros* sp, *S. costatum*, *Synedra* sp, *Nitzschia* sp, *Coscinodiscus* sp, and *Navicula* sp. Distribution of diatoms on stems of *Rhizophora sp.* varies by station and species. When compared with research Harun et al.[4], the stems of *Rhizophora* sp in the area of Pecinta Alam Bahari (PAB) Dumai, nine species were found, and there

are 5 of the same species, including *Isthmia* sp, *Navicula* sp, *Melosira* sp, *Synedra* sp, and *Coscinodiscus* sp.

On the fronds of *Nypa* sp, eight diatom species were found, including *Isthmia* sp, *Synedra* sp, *Pinnularia* sp, *Nitzschia* sp, *Pleurosigma* sp, *S.costatum*, *Melosira* sp, and *Amphora* sp. Judging from research by Arifin et al.[5], 18 genera of diatoms were found around Cawan Island, Indragiri Hilir Regency. From the results of this research, there are similarities in the genus found in the fronds of *Nypa* sp, except for the *S.costatum*. According to Harun et al.[4], the most commonly found diatoms can adapt to various conditions of water pollution, both organic and inorganic, as well as the ability to utilize nutrients so that certain tolerant species can survive.

From the research results, the species *Amphora* sp is not found on stems of *Rhizophora* sp. In contrast to this, the fronds of *Nypa* sp species *Amphora* sp were found quite abundantly, but species such as Chaetoceros sp, *Navicula* sp, and *Coscinodiscus* sp were not found on fronds of *Nypa* sp. The Bacillariophyceae class dominates the most commonly found species. This can be due to adaptability, good water quality, cosmopolitan nature, resistance to extreme conditions, and high reproductive capacity[9]. Bacillariophyceae is one of the aquatic unicellular organisms that can indicate changes in marine ecosystems in the form of physics, chemistry, and biology, and it can indicate water quality[10].

Abundance of Epiphytic Diatoms Between Stations

The abundance of epiphytic diatoms varies at each station. The abundance of epiphytic diatoms on the stems of *Rhizophora* sp and frond *Nypa* sp can be seen in Figure 3.

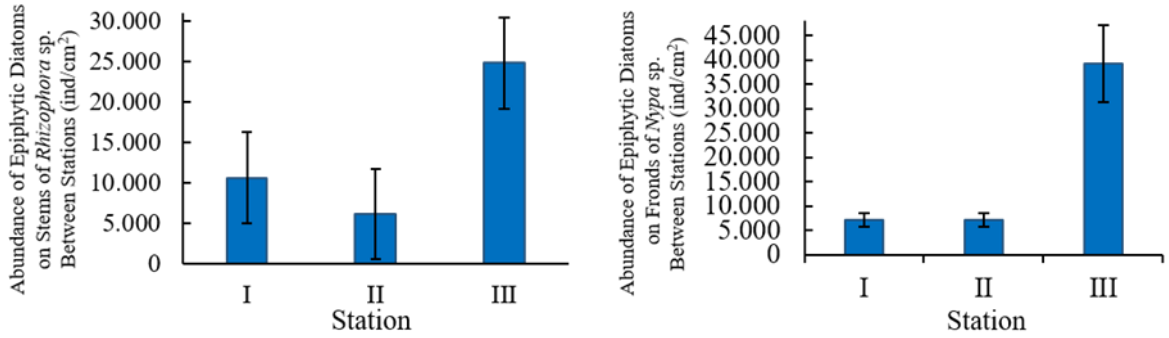

Figure 3. Abundance diagram of epiphytic diatoms on (a) the stems of *Rhizophora* sp and (b) the frond *Nypa* sp between stations

The abundance of epiphytic diatoms on the stems of *Rhizophora* sp between stations range from 6.203,56 – 24.814,25 ind/cm^2 with an average value of 13.884,16 ind/cm^2. The high abundance of diatoms at station III can be caused by the still good water quality levels and the input of organic material and nutrients from the remains of anthropogenic activities. The lowest abundance at Station II can occur because it has denser mangrove forest vegetation, which can block the spread of sunlight. If there is a lack of sunlight, diatoms will have a lower opportunity for photosynthesis[4]. According to Padang et al.[11], different intensities of sunlight can affect the abundance of diatoms.

The abundance of epiphytic diatoms on the fronds of *Nypa* sp between stations range from 7.089,78–39.89,23 ind/cm^2 with an average value of 17.822,94 ind/cm^2. The much higher abundance at Station III (close to residential areas) could be caused by the still good water quality levels and the input of organic matter and nutrients from the remains of anthropogenic activities. At station III, nitrate (0,90 mg/L) and phosphate (0,76 mg/L) are higher than at other stations. They can influence the abundance of diatoms and play an essential role in marine primary productivity, nutrient cycles, and

food webs[4]. This follows the opinion of Radiarta[12] that waters near estuaries or residential areas generally have high levels of nitrate and phosphate.

The abundance of epiphytic diatoms at Stations I and II was not statistically different but varied in the replications of each station. This is thought to occur because the location at this station has more or less the same water quality and nitrate and phosphate content, thus affecting the primary productivity of the waters, especially the epiphytic diatom biota.

Vertical Abundance of Epphytic Diatoms

The abundance of epiphytic diatoms vertically between stations on the stems of *Rhizophora* sp and the frond of *Nypa* sp can be seen in Figure 4.

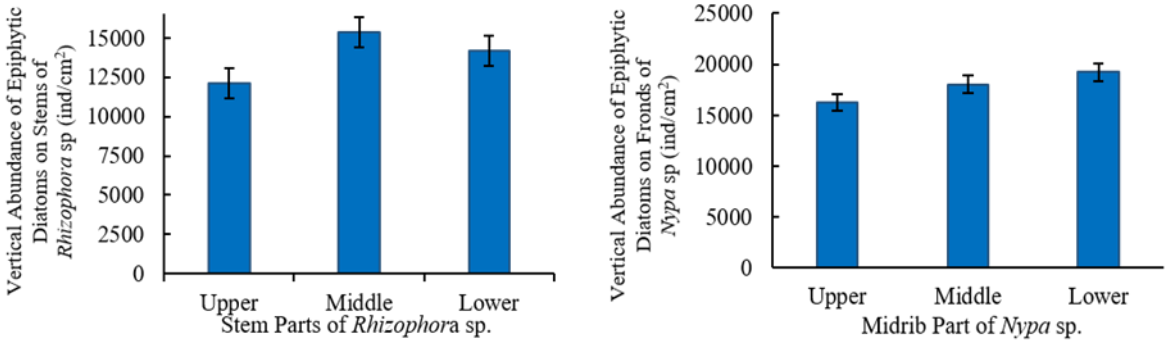

Figure 4. The vertical abundance of epiphytic diatoms (a) on the stems of *Rhizophora* sp and (b) the fronds of *Nypa* sp

Epiphytic diatoms found in mangroves' roots and lower stems are important in estuary ecosystems as primary producers and food chains. The abundance of epiphytic diatoms on the stems of *Rhizophora* sp vertically, the highest was found in the middle with an average of 15.361,20 ind/cm^2, followed by the bottom with an average of 14.179,57 ind/cm^2. The lowest abundance was at the upper boundary, with an average of 12.111,72 ind/cm^2. This difference can occur due to differences in the adhesive strength or grip of diatoms on the substrate. Diatoms have a kind of gelatin (Gelatinous extrusion) that provides adhesion and movement to the substrate.

Differences in abundance can occur along with the intensity of water and light on the stems of *Rhizophora* sp. The more often the stem is exposed to water, the more moisture the substrate will maintain, and the diatoms will grow. Generally, epiphytic diatoms prefer to stick to locations that are not too dry or have sufficient humidity. Dredging locations frequently receiving seawater immersion provide more significant opportunities for diatoms to attach to mangrove stems[6].

The abundance of epiphytic diatoms on the fronds of *Nypa* sp vertically, the highest was found at the bottom with an average of 19.201,50 ind/cm^2, followed by the middle part with an average of 18.019,87 ind/cm^2. The lowest abundance is at the top, with an average of 16.247,45 ind/cm^2. The difference in the abundance of diatoms vertically is in line with the location of the dredging, which is the area that receives the longest and most frequent seawater immersion, so the opportunity for diatoms to stick to the fronds of *Nypa* sp will get higher.

The Independent Samples T-test can determine differences in the vertical abundance of epiphytic diatoms between *Rhizophora* sp stems and *Nypa* sp fronds. The T-test results show a sig (2-tailed) value of 0,037 where p = value < 0,05. This value indicates a significant difference in the vertical abundance of epiphytic diatoms.

From the results of observations and calculations during the research, it was found that epiphytic diatoms were more abundant on the fronds of *Nypa* sp with an average value of 17.822,94 ind/cm^2

compared to *Rhizophora* sp with an average value of 13,884.16 ind/cm^2. Although *Nypa* sp texture is smoother than *Rhizophora* sp stem texture, better water quality around *Nypa* sp frond plants can support this higher abundance.

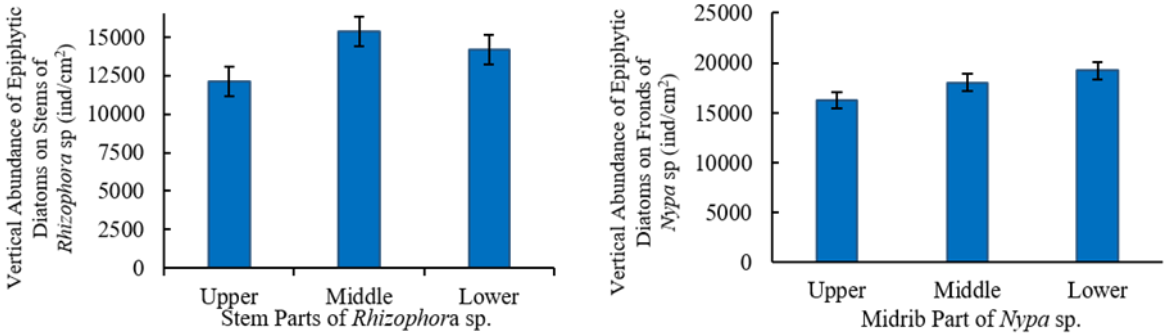

Figure 5. Vertical abundance of epiphytic diatoms on (a) the stems of *Rhizophora* sp and (b) the fronds of *Nypa* sp

Vertical diversity of epiphytic diatoms on the stems of *Rhizophora* sp has an almost uniform average value. Overall, the diversity of vertical epiphytic diatoms on the stems of *Rhizophora* sp has an average value of 2.204. Based on the diversity value of 2.155 ≤ H' ≥ 2.259, it is included in category 1 ≤ H' ≤ 3 (medium diversity). So that the balance of the epiphytic diatom community is moderate, and the water quality is moderately polluted, the aquatic environment experiences disturbances that are not too high, or the structure of the existing organisms is in a moderate condition[5,13].

The highest diversity values at the upper limit can occur if environmental conditions still support diatom species in developing and photosynthesizing. During the study, the vertical distribution of epiphytic diatom species was more diverse at the daily high tide limit (upper). However, the abundance of epiphytic diatoms is lower in the upper part compared to the middle and lower parts.

According to Paszek et al.[14], several diatom species can be found more abundantly in less humid areas and even tend to dry out after being submerged again. Vegetation type, water level, and shade are the most critical factors in distinguishing diatom assemblages at sampling locations. The influence of physicochemical water parameters such as sea tides, salinity, pH levels, high temperatures, and high levels of organic matter and isolation are the most critical factors influencing the development of diatom communities in waterways such as estuaries.

Vertical diversity of epiphytic diatoms on the fronds of *Nypa* sp has an average value of 2.025. Based on the diversity value of 1.691 ≤ H' ≥ 2.289, it is included in category 1 ≤ H' ≤ 3 (medium diversity). So, the balance of the biota community is moderate, and the water quality is moderately polluted[5]. Suppose changes in the quantitative amount of biota do not accompany qualitative changes in the vertical diatom ecosystem (sea tides). In that case, the diatom diversity index will not show significant changes in composition and diversity.

The highest vertical diversity found in the middle part (H' 2.289) can occur because this part is not too humid and dry, so that epiphytic diatom species can grow with moderate diversity accompanied by the discovery of relatively abundant diatoms. The lowest diatom diversity was found in the upper part (H' 1.691), in line with the lowest abundance value found in the upper part of the frond of *Nypa* sp. The species diversity index value can be used to determine the

Vertical Diversity of Epiphytic Diatoms

Figure 5 shows the diversity (H') of epiphytic diatoms between stations and zones on the stems of *Rhizophora* sp and the frond of *Nypa* sp.

level of community balance of the observed species and is closely related to habitat characteristics and the level of pollution in ecosystems inhabited by epiphytic diatoms.

4. CONCLUSION

There are nine epiphytic diatoms from the Bacillariophyceae class and one species from Coscinodiscophycidae and Florideophyceae. 10 and 8 species of epiphytic diatoms were found, respectively, on the stems of *Rhizophora* sp and fronds of *Nypa* sp. A higher abundance of epiphytic diatoms was found on the fronds of *Nypa* sp. with an average value of 17.822,94 ind/$cm^{2,}$ and a lower abundance was found in the stems of *Rhizophora* sp with an average of 13.884,16 ind/cm^2. There were significant differences in the abundance of epiphytic diatoms between stations on the stems of *Rhizophora* sp. There were no significant differences in the abundance of epiphytic diatoms between stations on the fronds of *Nypa* sp. There were no differences in the abundance of epiphytic diatoms vertically on the stems of *Rhizophora* sp and fronds of *Nypa* sp. The T-test results showed significant values and differences in the vertical abundance of epiphytic diatoms between *Rhizophora* sp stems and fronds of *Nypa* sp. The diversity of moderate epiphytic diatoms on the stems of *Rhizophora sp.* and fronds of *Nypa* sp in Kundur Waters, Karimun Regency, Riau Islands Province.

REFERENCES

1. Hariyati, R., Soeprobowati, T.R., Chotidjah, S. Vertical Distribution of Epipelic Diatoms in the East Semarang Flood Canal River Estuary Mangrove Ecosystem. *Fmipa UNDIP*, 2012;17(1): 1–17.
2. Harahap, N. *Economic Assessment of Mangrove Forest Ecosystems and Applications in Coastal Planning*. Yogyakarta. Graha Ilmu, 2010.
3. Kamalia, R.T.S., Efrizal, T. Community Structure of Mangrove Forests in Coastal Waters, Sawang Village, West Kundur District, Karimun Regency. *Jurnal Budidaya Perairan,* 2013; 1(1): 1-8.
4. Harun, L., Siregar, S.H., Nurrachmi, I. Abundance of Epiphytic Diatoms on *Rhizophora* Trees Covered and Not Covered by Plastic in the Area Pecinta Alam Bahari (PAB) Dumai. *Jurnal Online Mahasiswa* (*JOM*), 2018; 6: 1-12.
5. Arifin, N., Siregar, S.H., Nurrachmi, I. Community Structure of Epiphytic Diatoms on *Nypa fruticans* Fronds Around Cawan Island, Indragiri Hilir Regency, Riau Province. *Jurnal Perikanan dan Kelautan*, 2018; 23(1): 1-7.
6. Susiyanti, N., Siregar, S.H., Nurrachmi, I. Vertical Distribution of Epiphytic Diatoms on the Stems of *Avicennia* sp. in the Muara Sei Undan area, Indragiri Hilir Regency. *Jurnal Online Mahasiswa* (JOM), 2014; 1(1): 1-11.
7. Tanjung, A. *Experimental Design*. Pekanbaru. Tantaramesta, 2014.
8. Febriyanti, A., Efawani, E., Deni, E. Diversity of Bivalves and Gastropods in the Coastal Waters of Kundur Island, Karimun Regency, Riau Islands Province. *Jurnal Online Mahasiswa* (JOM), 2016; 3(2): 1-12.
9. Dewi, H.N., Endrawati, H., Widianingsih, W. Study of Phytoplankton Distribution in Relation to the Fertility of the Waters of Kartini Beach and Estuary Wiso Jepara. *Journal of Marine Research*, 2023; 12(2): 1-8.
10. Audina, N., Khairuddin, K., Japa, L. Community Structure of Bacillariophyceae Class Microalgae in Interidal Waters, Gili Strait, East Lombok. *Jurnal Biologi Tropis*, 2023; 23(1): 116-123.
11. Padang, A., Dari, A.L., Latuconcina, H. Effect of Different Light Intensities on the Growth of *Navicula sp.* Laboratory Scale. *Bifamika*, 2013; 5: 560–565.

12. Radiarta, I.N. The Relationship Between Phytoplankton Distribution and Water Quality in the Ala Strait, Sumbawa Regency, West Nusa Tenggara. *Jurnal Bumi Lestari*, 2013; 13(2) : 234-243.
13. Aini, Z., Mulyadi, A., Amin, B. Analysis of the Composition of Epipelic Diatoms as Bioindicators of Coastal Waters Pollution in Dumai City, Riau Province. *Jurnal Penelitian Sosial Keagamaan*, 2015; 18(1): 7-18
14. Paszek, L., Zgrundo, A., Noga, T., Kochman-Kÿdziora, N., Poradowska, A., Rybak, M., Puchalski, C., Lee, J. The Influence of Drought on Diatom Assemblages in a Temperate Climate Zone: A Case Study from the Carpathian Mountains, Poland. *Ecological Indicators*, 2021; 125(2021) 107579: 1-13.