Ecological Index And Ecosystem Status Of Mangroves In The Waters Of Parang Island, Seram Bagian Timur Regency, Maluku Province

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Abstract.

The mangrove ecosystem on Parang Island is one of the important habitats in supporting the productivity of the surrounding waters. Therefore, an analysis of the condition of the mangroves on Parang Island is very important to understand the status and trend of changes in the mangrove ecosystem, so that appropriate conservation and management strategies can be formulated. This study aims to determine the physical-chemical parameters of the waters, analyze the density, percent cover, and status of the mangrove ecosystem in the waters of Parang Island. Mangrove data was collected using the belt transect method, while the physical and chemical parameters of the waters were measured in-situ by making observations at 4 research stations. The results showed that the average water temperature at each station ranged from 29.5°C, the average salinity was 26 ppt, the average current speed was 0.24 m/s, the average pH was 5.25, and the average clarity was 73.18%. There are 4 species of mangroves in the waters of Parang Island, namely Rhizophora apiculata, Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza. The highest average relative density in the tree category is owned by Rhizophora apiculata, and the lowest is represented by Brugueira gymnorhiza. The highest sapling category is represented by Rhizophora stylosa, and the lowest by Brugueira gymnorhiza, while for the seedling category, the highest relative density is represented by Rhizophora apiculata, the lowest by Sonneratia alba. The highest average mangrove cover is owned by the Rhizophora apiculata species, and the lowest is represented by the Brugueira gymnorhiza species. The condition of the Rhizophora apiculata mangrove is in a moderate status, while Rhizophora stylosa, Sonneratia alba, and Brugueira gymnorhiza species are in a rare status.

Keywords: *Ecological Index, Mangrove Ecosystem, Mangrove Status and Parang Island.*

I. INTRODUCTION

Mangrove ecosystems are one of the important ecosystems in coastal areas that provide various ecosystem services to surrounding communities. Mangroves serve as habitats for various types of flora and fauna, maintain ecological balance, and protect coastal areas from abrasion and natural disasters (Sangaji M, et al., 2024). Mangroves are plants that thrive in tidal coastal areas (Ghufran and Kordi, 2012), serving as habitats for fauna due to their various ecological, physical, and economic functions (Lapolo et al., 2018). The mangrove forest ecosystem is home to various types of microorganisms (Retnowati et al., 2017) and plays a role in conserving biodiversity (Dharmawan et al., 2016).Parang Island is one of the areas in Seram Bagian Timur Regency, Maluku Province, that has a significantly extensive mangrove ecosystem. However, data on the condition and status of the mangrove ecosystem in Parang Island has been rarely collected to date, while various community activities around the mangroves, such as land conversion, logging, and increasing pollution, are predicted to impact the degradation of the ecosystem.Knowledge about the ecological condition and status of mangrove ecosystems in a given area is crucial information. This data can be used to monitor changes in mangrove conditions over time and to evaluate the effectiveness of management and conservation efforts that have been implemented. Additionally, data on ecological conditions and the status of mangrove ecosystems can provide valuable input for comprehensive planning of coastal natural resource management, including efforts for the recovery and protection of mangrove ecosystems in the future.

Furthermore, ecological indices and the status of mangrove ecosystems are important information for evaluating the condition and productivity of coastal waters, which can serve as a foundation for sustainable management and conservation efforts of mangrove ecosystems. In addition, the physicochemical parameters of the water play a crucial role in determining the productivity of mangrove ecosystems. Environmental conditions such as temperature, salinity, pH, dissolved oxygen, and nutrients are abiotic factors that influence the growth, development, and productivity of mangrove vegetation. Monitoring and evaluating the physicochemical parameters of the water surrounding the mangrove ecosystem can provide information about the suitability of environmental conditions for mangrove growth, serving as a basis for more effective management and conservation of mangrove ecosystems.To understand the physicochemical parameters of the water, ecological conditions, and the current status of the mangrove ecosystem in Parang Island, a comprehensive study is necessary. This research aims to assess the physicochemical conditions of the water, ecological indices, and the status of the mangrove ecosystem in the waters of Parang Island, Seram Bagian Timur Regency. The results of this study are expected to serve as a foundation for planning the management and conservation of mangrove ecosystems in the region.

II. METHODS

The res earch was conducted from September 2023 to May 2024. This study was carried out in the mangrove ecosystem of Parang Island. The data collection stations consisted of four stations: Station 1 in the northern part of Parang Island, Station 2 in the southern part of Parang Island, Station 3 in the eastern part of Parang Island, and Station 4 in the western part of Parang Island.

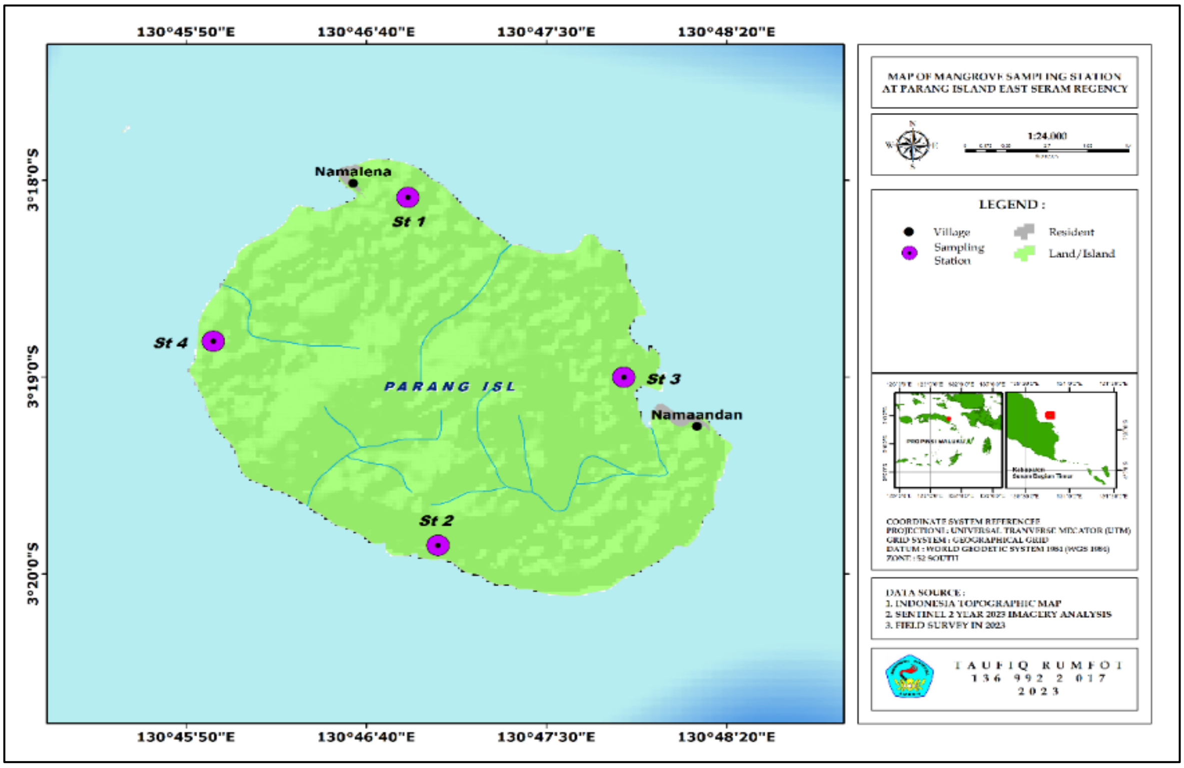

Fig 1. Map of mangrove sampling station at Parang Island

Data Collection Method

Data collection was conducted through two stages: the collection of primary data and secondary data. Primary data collection involved gathering information on species, distribution, and the extent of the mangrove ecosystem. Species and distribution data for the mangrove ecosystem were collected using belt transects with quadrats of 10 x 10 meters for trees, 5 x 5 meters for saplings, and 1 x 1 meter for seedlings. Data was also collected on physicochemical parameters of the water through direct surveys and field measurements, including data on temperature, salinity, current velocity, turbidity, and pH (acidity level) of the water.The distribution and extent of the mangrove ecosystem were analyzed using Sentinel 2 imagery from 2023. The secondary data collected for this study included relevant information from reports by related agencies or institutions, as well as internet searches. Mangrove species found in the field were analyzed or identified directly using the "Field Guide to Mangrove Identification in Indonesia" by Rosila et al. (2006). Identified mangrove species were then compiled into a taxonomic composition and presented in table form.

Data Analysis Method

1. Physicochemical Analysis of Water

Measurements of the physicochemical environmental data of the water were conducted in situ. The obtained data were then tabulated, presented in the form of matrices or diagrams, and described or discussed descriptively.

2. Ecological Index Analysis

The analysis of ecological index data in this study includes species density and percentage cover of mangroves. Density and percentage cover of mangroves were analyzed based on the data analysis procedures according to Bengen (2001), as follows:

a) Species density (Di) of Mangrove Species is the number of individuals of species i in a unit area.

$$Di = \frac{ni}{A}$$ and $$Rdi = \frac{ni}{\sum n} \times 100\ \%$$

Notation:

Di = Species density (ind/m²)
ni = Total number of individuals of species *i*
A = Total area of the sampling site
Rdi = Relative density importance (%)
n = Total number of individuals across all species.

b) Species Cover (Ci) of Mangroves

$$Ci = \frac{\sum BA}{A}$$ Where : $$BA = \frac{\pi DBH^2}{4}$$ $$DBH = \frac{CBH}{\pi}$$

$$RCi = \frac{Ci}{\sum c} x100$$

Notation : Ci = Species cover, BA (in cm²)
DBH = Diameter at Breast Height (diameter of the tree at breast height for species i)
π = Constant (3,1416);
CBH = Circumference of the tree at breast height.

3. Analysis of Mangrove Ecosystem Status

The determination of the status of mangrove conditions in the coastal waters of Parang Island is based on the criteria set forth in the Minister of Environment's Decree No. 201 of 2004 regarding standard criteria for mangrove damage, as detailed in Table 1. The status of the mangrove ecosystem was also analyzed using satellite imagery data to assess the distribution and extent of mangroves on Parang Island.

Table 1. Standard Criteria for Mangrove Damage (Minister of Environment Decree No. 201 of 2004).

No.	Criteria		Cover (%)	Density (trees/ha)
1.	Good	Very Dense	≥ 75	>1500
		Moderate	≥ 50 - <75	≥ 1000 - < 1500
2.	Damaged	Sparse	< 50	< 1000

III. RESULTS AND DISCUSSION

Condition of Physicochemical Parameters of Parang Island Waters

Several physicochemical parameters measured in this study include temperature, current turbidity, salinity, and pH.

a. Temperature

Temperature is a measure of the average kinetic energy of translation associated with the random motion of atoms and molecules. It is a system that determines whether heat energy will be transferred to or from an object. Qualitatively, temperature can be described in relation to the condition of a water body. Additionally, temperature plays a crucial role in regulating the conditions of an ecosystem within the water (Kusumaniggryas et al., 2014, in Restu.I.W and Ernawati M., 2021). The results of temperature measurements on Parang Island are presented in the following table.

Table 2. Water Temperature at Parang Island

No.	Position Coordinates	Temperature (°C)	Location Description
1	-3^0 18 ′ 221″LS, 130^0 46′ 272 ″ BT	30	Station 1
2	-3^0 19 ′ 995″ LS, 130^0 47′ 193″ BT	31	Station 2
3	-3^0 18,63 LS,130^0 47′ 901″ BT	30	Station 3
4	-3^0 18,731″ LS, 130^0 45′ 881″BT	29	Station 4
	Average	29,5	

The measurement results indicate that the temperature ranges from 29 °C to 31 °C. Stations 1 and 3 recorded the same temperature of 30 °C, likely due to measurements taken during the day when the sun was obscured and it was raining. In contrast, Station 4 recorded a temperature of 29 °C because measurements were taken in the late afternoon, while Station 3 had a temperature of 31 °C due to the measurement being taken during a slightly warmer period of the day. Temperature distribution significantly affects mangrove growth, particularly during the seedling and growth phases (Gillis G.L. et al., 2019).

b. Current Velocity

Current measurements were conducted at the sampling points of the study, which consisted of four main research stations (Table 3). The measurements taken during high tide indicated that the water current velocity ranged from 0.11 to 0.35 m/s. The highest current velocity was observed near Station 2 (0.35 m/s), while the lowest was recorded at the western station (0.11 m/s).

Table 3. Current Velocity of Waters around Parang Island

No.	Position Coordinates	Average	Location Description
1.	-3^0 18 ′ 221″LS, 130^0 46′ 272 ″ BT	0,33	Station 1
2.	-3^0 19 ′ 995″ LS, 130^0 47′ 193″ BT	0,35	Station 2
3.	-3^0 18,63 LS, 130^0 47′ 901″ BT	0,14	Station 3
4.	-3^0 18,731″ LS, 130^0 45′ 881″BT	0,12	Station 4
	Average (m/s)		0,24

The high current velocity in the waters near Station II may be attributed to the constriction of water mass flow in the strait between Parang Island and the main Seram Island (Tanah Besar), resulting in a higher current velocity compared to other stations around Parang Island. Generally, the direction of surface currents is influenced by wind flow. Additionally, the movement of water masses in the waters of Parang Island is also affected by tidal movements.

c. Turbidity

Turbidity is a measure of the clarity of water. The higher the turbidity, the deeper light can penetrate the water. A decrease in water clarity will reduce the photosynthetic capacity of aquatic plants. Measurements of water turbidity in the waters of Parang Island, in front of the mangrove area divided into several research stations, are presented in Table 4 below.

Table 4. Results of Water Clarity Measurements at Parang Island.

No.	Location	Position Coordinates	Clarity (%)	Depth (meters)
1	Station 1	-3^0 18 ′ 221″LS, 130^0 46′ 272 ″ BT	71,06	4,25
2	Station 2	-3^0 19 ′ 995″ LS, 130^0 47′ 193″ BT	71,16	4,23
3	Station 3	-3^0 18,63 LS, 130^0 47′ 901″ BT	55,10	2,45
4	Station 4	-3^0 18,731″ LS, 130^0 45′ 881″BT	95,40	4,35
		Average	73,18	

d. Salinity

Salinity refers to the concentration of all dissolved salts in the water, which affects the osmotic pressure of the water; higher salinity corresponds to higher osmotic pressure. Differences in water salinity can arise due to variations in evaporation and precipitation (Hamun et al., 2018, in Restu.I.W and Ernawati M., 2021). Salinity distribution serves as a benchmark for assessing the environmental conditions for mangrove growth (Matatula J. et al., 2019). Measurements of salinity near the mangrove area at the four research stations are presented in Table 5 below.

Table 5. Salinity Measurements at Parang Island

No.	Location	Position Coordinates	Salinity (ppt)
1	Stasiun 1	-3^0 18 ′ 221″LS, 130^0 46′ 272 ″ BT	26
2	Satsiun 2	-3^0 19 ′ 995″ LS, 130^0 47′ 193″ BT	27
3	Satsiun 3	-3^0 18,63 LS, 130^0 47′ 901″ BT	26
4	Stasiun 4	-3^0 18,731″ LS, 130^0 45′ 881″BT	26
		Average	26

e. pH Level

Measurements of pH in the waters of Parang Island at Stations I-IV ranged from 5 to 6. The pH level provides insight into the acid-base balance, which is primarily determined by the concentration of hydrogen ions (H^+) in the water.

Table 6. pH Levels in the Waters of Parang Island

Measurement Results	Station 1	Station 2	Station 3	Station 4	Average
pH Level	5	5	6	5	5,25

The pH level is crucial in determining the usability of water for the life of organisms and other needs, and is generally influenced by several factors such as photosynthesis, temperature, and the presence of anions and cations. Changes in pH values can lead to alterations in the balance of carbon dioxide, bicarbonate, and carbonate content in the water (Siburian et al., 2017).

Ecological Index of Mangroves at Parang Island

The mangrove ecosystem surrounds Parang Island, as illustrated in Figure 2. The total area of mangroves, based on the analysis of Sentinel 2A satellite imagery from 2023, is 379.40 hectares. This area consists of 105.94 hectares in the western part (Station 4), 110.12 hectares in the eastern part (Station 3), 115.27 hectares in the southern part (Station 2), and 48.07 hectares in the northern part (Station 1) of Parang Island. The distribution and extent of the mangrove ecosystem can be visually observed in Figure 2.

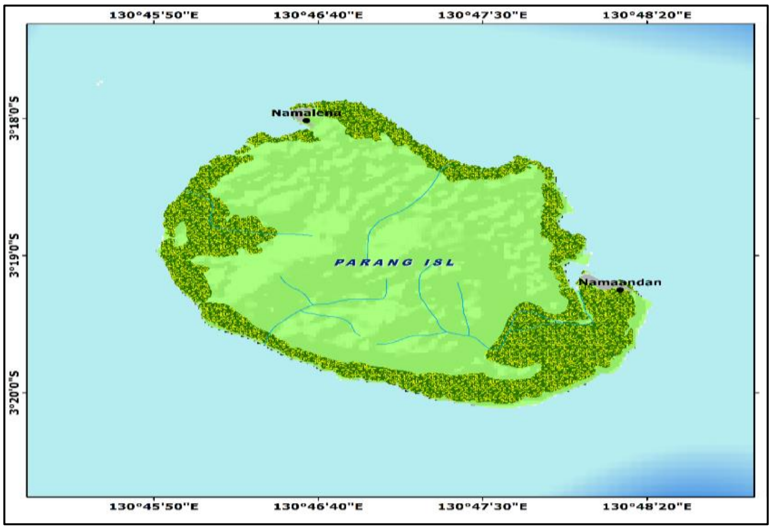

Fig 2. Map of Mangrove Ecosystem Distribution at Parang Island

Field findings indicate the presence of four species of mangroves from one family found on Parang Island. The mangrove species identified belong to the family Rhizophoraceae, which includes Rhizophora apiculata, Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza. Based on these results, the calculations for density, relative density, and percentage cover of mangroves at Parang Island are illustrated in the following graph.

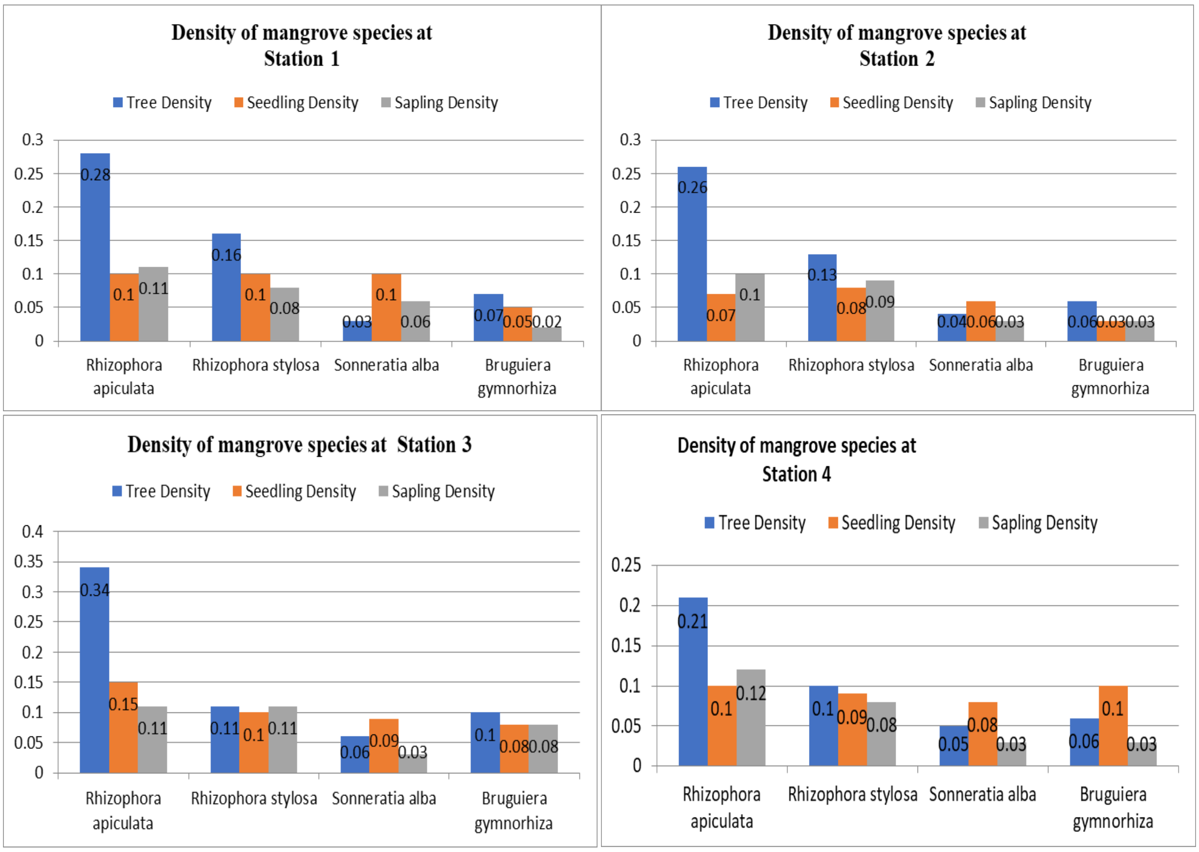

Fig 3. Graph of density,relative density, and Percentage cover of mangroves at parang island

From the graph above, it can be observed that the density of mangrove species varies at each station due to the differing substrate conditions around the mangrove area on Parang Island, which are influenced by the variety of substrate types. At Station I, the highest density in the tree category is represented by *Rhizophora apiculata* (0.28), while the lowest density is represented by *Sonneratia alba* (0.03). In the sapling category, the highest density is also represented by *Rhizophora apiculata* and *Rhizophora stylosa* (0.1), with the lowest density represented by *Bruguiera gymnorhiza* (0.09). For the seedling category, the highest density is represented by *Rhizophora apiculata* (0.11) and the lowest by *Bruguiera gymnorhiza* (0.02). At Station II, the highest density in the tree category is again represented by Rhizophora apiculata (0.28), while the lowest is represented by *Sonneratia alba* (0.04). In the sapling category, the highest density is represented by *Rhizophora stylosa* (0.08), with the lowest represented by *Bruguiera gymnorhiza* (0.03).

For the seedling category, the highest density is represented by *Rhizophora apiculata* (0.1), and the lowest is represented by *Sonneratia alba* and *Bruguiera gymnorhiza* (0.03). At Station III, the highest density in the tree category is represented by *Rhizophora apiculata* (0.34), while the lowest is represented by *Sonneratia alba* (0.06). In the sapling category, the highest density is represented by *Rhizophora apiculata* (0.15), with the lowest represented by *Bruguiera gymnorhiza* (0.08). For the seedling category, the highest density is represented by *Rhizophora apiculata* and *Rhizophora stylosa* (0.11), and the lowest by *Sonneratia alba* (0.03). At Station IV, the highest density in the tree category is represented by *Rhizophora apiculata* (0.21), while the lowest is represented by Sonneratia alba (0.05). In the sapling category, the highest density is represented by *Rhizophora apiculata* and *Bruguiera gymnorhiza* (0.1), with the lowest represented by *Sonneratia alba* (0.08). For the seedling category, the highest density is represented by *Rhizophora apiculata* (0.12), and the lowest by *Sonneratia alba* and *Bruguiera gymnorhiza* (0.03).

Table 7. Analysis of Relative Density and Relative Coverage Percentage of Mangroves at Parang Island

Species	**Kerapatan Relatif**														
	Trees				Average by Species	Saplings				Average by Species	Seedlings				Average by Species
	ST 1	**ST 2**	**ST 3**	**ST 4**		**ST 1**	**ST 2**	**ST 3**	**ST 4**		**ST 1**	**ST 2**	**ST 3**	**ST 4**	
Rhizophora apiculate	51.85	53.06	55.74	50	**52.66**	28.57	29.17	23.81	24.32	**26.47**	40.74	40	33.33	46.15	**40.06**
Rhizophora stylosa	29.63	26.53	18.03	23.81	**24.50**	28.57	33.33	35.71	27.03	**31.16**	29.63	36	33.33	30.77	**32.43**
Sonneratia alba	5.56	8.16	9.84	11.9	**8.865**	28.57	25	21.43	21.62	**24.16**	22.22	12	9.09	11.54	**13.71**
Bruguera gymnorhiza	12.96	12.24	16.39	14.29	**13.97**	14.29	12.5	19.05	27.03	**18.22**	7.41	12	24.24	11.54	**13.80**

Species	**Relative Coverage Percentage (%) Average**				Average
	ST 1	**ST 2**	**ST 3**	**ST 4**	
Rhizophora apiculata	53.57	42.57	53.87	51.35	**50.34**
Rhizophora stylosa	26.77	28.28	20.84	22.34	**24.56**
Sonneratia alba	13.54	17.02	12.42	16.42	**14.85**
Bruguera gymnorhiza	6.12	12.13	12.87	9.88	**10.25**

From the table above, it can be observed that the relative density of mangrove species varies at each station due to the differing substrate conditions around the mangrove area on Parang Island. The highest relative density for the tree category, Rhizophora apiculata, was found at all Stations 1, 2, 3, and 4. For Rhizophora stylosa, the highest density was at Stations 1 and 2, with the lowest at Stations 3 and 4. Sonneratia alba had the highest density at Station 4 and the lowest at Station 1, while Bruguiera gymnorhiza was highest at Station 4 and lowest at Station 2. For the sapling category, the highest relative density of Rhizophora apiculata was at Station 2, and the lowest was at Station 3. Rhizophora stylosa had the highest density at Station 3 and the lowest at Station 4. The highest relative density of Sonneratia alba was at Station 1, and the lowest was at Station 3, while Bruguiera gymnorhiza had the highest at Station 4 and the lowest at Station 2. In the seedling category, the highest relative density of Rhizophora apiculata was at Station 4, while the lowest was at Station 3.

Rhizophora stylosa had the highest density at Station 2 and the lowest at Station 1. Sonneratia alba had the highest density at Station 1 and the lowest at Station 3, while Bruguiera gymnorhiza was highest at Station 3 and lowest at Station 1.The relative coverage percentage of mangroves according to the sampling transects at each station also differs. Rhizophora apiculata showed the highest coverage above 50% at Stations 1, 3, and 4, while it was below 50% at Station 2. For Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza, all stations were below 50%. According to the Minister of Environment’s Decree No. 201 of 2004, the status of mangroves on Parang Island is categorized as moderate for Rhizophora apiculata, while Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza are categorized as sparse.The density of mangrove species in a given area can be influenced by environmental conditions, such as substrate type, the lack of debris around the plot that does not hinder mangrove growth, and the spacing between trees (Salim et al., 2019). Low density, vegetation levels, and mangrove density in an area can also be attributed to human activities (Nanulaita et al., 2019). A lower density of trees can be beneficial for seedlings, as sunlight can penetrate easily and illuminate the growing seedlings.

IV. CONCLUSION

Four species of mangroves were found in the waters of Parang Island: Rhizophora apiculata, Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza. The highest relative density in the tree category is represented by Rhizophora apiculata, while the lowest is represented by Bruguiera gymnorhiza. For the sapling category, the highest density is represented by Rhizophora stylosa, and the lowest by

Bruguiera gymnorhiza. In the seedling category, the highest relative density is represented by Rhizophora apiculata, and the lowest by Sonneratia alba.The highest mangrove coverage is represented by Rhizophora apiculata, while the lowest is represented by Bruguiera gymnorhiza. The condition of mangroves on Parang Island shows that Rhizophora apiculata is in a moderate status, while Rhizophora stylosa, Sonneratia alba, and Bruguiera gymnorhiza are in a sparse status. Water parameters at each station show an average temperature of 29.5 degrees Celsius, average salinity of 26 ppt, average current velocity of 0.24 m/s, average pH of 5.25, and average clarity of 73.18.

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