ISSN 2522-9400 **European Modern Studies Journal** *Vol 8 No 2*
available at www.journal-ems.com
DOI: 10.59573/emsj.8(2).2024.42

Growth Performance of Mangrove Seedlings Planted with Guludan Technique at Elang Laut Area, Muara Angke, Jakarta

Asti Yuliyantini and Cecep Kusmana*
Department of Silviculture, Faculty of Forestry and Environment,
IPB University, Indonesia

Abstract. Elang Laut area is one of the mangrove areas on Muara Angke coast in the northern Jakarta. Mangrove rehabilitation with the guludan technique is applied in the Elang Laut to revegetated degraded mangrove in this area. This study aims to measure the growth of planted mangrove (*Rhizophora mucronata*) seedlings with guludan technique, seedling's health condition, and their survival rate in the Elang Laut area. The data collected in this study includes the growth of seedlings and their health condition, substrate condition, climatic factors, and water quality. On year after planting, it is observed that the seedlings' survival rate of 97,27%, average seedling's stem diameter of 1,42 cm, average seedling's height of 79,71 cm, average seedling's leaf number of 25 leaves, and the average seedling's internode number of 8 internodes, among them 64% of the seedlings are in a healthy condition.

Keywords: Elang Laut area, guludan technique, mangrove seedling, degraded mangrove

Introduction

Mangrove forest is a type of forest found in coastal areas and is influenced by tidal seawater. Mangrove forests have unique characteristics, especially their ability to thrive in high salinity conditions (Rahim & Baderan, 2017). Mangrove forests have a crucial ecological role in maintaining coastal stability against erosion, preventing seawater intrusion, buffering sedimentation from land to sea (Safuridar & Andiny, 2020), and providing habitat for various fish, shrimp, and other biodiversity (Majid *et al.* 2016). Mangrove forests also function as carbon sinks and stores (Azzahra *et al.* 2020), thus contributing to global warming mitigation efforts. One of the roles of mangrove forests for communities is as a source of livelihood, such as fish, shellfish, and crab production, and can also serve as ecotourism destinations (Niapele & Hasan, 2017).

In 2019, mangrove forests in Indonesia covered an area of 3,31 million hectares, accounting for 23% of the world's total mangrove area. By 2021, this area had increased to 3,36 million hectares (Ministry of Environment and Forestry of Indonesia 2021). Despite the increase in mangrove forest areas, there has been significant damage. According to Gustami *et al.* (2023) 2019, 0,63 million hectares of mangrove forests in Indonesia were critically damaged. Three main factors contribute to mangrove forest destruction are pollution, mangrove conversion, and excessive logging (Kusmana *et al.* 2005). Mangrove forest degradation can occur naturally or due to human activities. Natural causes include hurricanes or prolonged droughts, while human-induced destruction is caused by shrimp farming, settlements, industries, etc. (Ario *et al.* 2015). Mangrove forest degradation disrupts feeding and nursery grounds for marine life, fishes and shrimp stock regeneration in offshore waters dependent on mangrove forests (Hafni, 2016). Rinika *et al.* (2023) state that mangrove forest degradation harms environmental sustainability, triggers climate change impacts and harms communities.

The decline in mangrove forest quality and quantity threatens mangrove sustainability. Mangrove rehabilitation is one solution to maintain mangrove forest sustainability. One form of rehabilitation is through mangrove cultivation. Rehabilitation efforts aim to achieve a

* Corresponding Author

balance between mangrove forests' economic and environmental functions in coastal areas (Alwidakdo *et al*. 2014). The Elang Laut area in Muara Angke is one such mangrove area that has undergone rehabilitation. This area has inundated land in deep water, so rehabilitation is conducted using the guludan planting technique. The guludan planting technique can address mangrove rehabilitation issues in flooded areas. It is expected that mangroves planted using this technique will grow optimally, however, it requires evaluation to assess their seedlings' growth status. This evaluation helps determine the planted seedlings survival rate and performance of the seedlings growth as well as also serves as a reference for maintenance activities such as replanting, fertilization, and pest control to ensure the healthy growth of planted seedlings.

Methods

Time and Place

The research was conducted in September - October 2023. Data collection was carried out in the mangrove area of Muara Angke, Elang Laut, Penjaringan District, North Jakarta City (Figure 1). The data collection site is a mangrove stand planted using the guludan planting technique in 2022. Initially, it was an abandoned pond area that had never been planted.

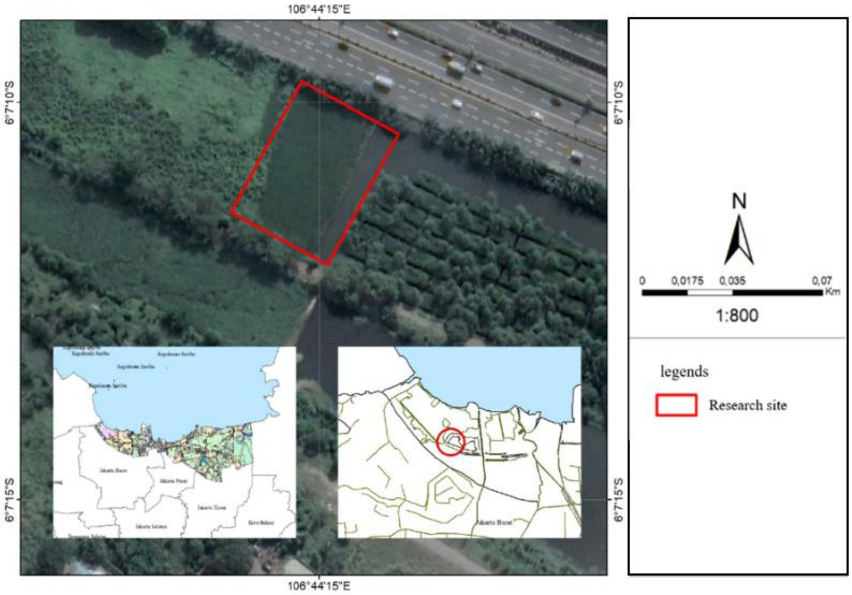

Figure 1. Research site

Equipments and Materials

The equipments used in this research include vernier callipers, tape measure, shovel, luxmeter, hygrometer, refractometer, multifunction 4 in 1 water quality tester version ATC EZ-9908, hand counter, plastic bags, tally sheet, writing utensils, laptop, ArcGIS, Microsoft Word, and Microsoft Excel software. The primary material used in this research is 1.7-year-old *Rhizophora mucronata* planted using the guludan planting technique in 2022.

Research Procedure

Observed Data

The observed data includes the growth of 1,7-year-old *Rhizophora mucronata* mangrove seedlings, including stem diameter, seedling height, number of leaves, number of internodes, number of dead plants, and number of plants affected by pests and diseases. Additionally, observations were made on the planting site conditions, including substrate conditions, climatic factors (light intensity, air temperature, air humidity), and water quality (water salinity, water temperature, water pH).

Sampling Design

A random sampling method is used to sampled mangrove seedlings to be measured. The number of sample units (measured seedlings) was determined using the Slovin formula with an error tolerance of 5% (Nalendra *et al.* 2021).

$$n = \frac{N}{1+N(e)^2}$$

Information:

n = sample size

N = population size

e = error tolerance

Data Collection in the Field

At the planting site, there are 15 guludan with a planting distance of 0,5 m × 0,5 m for each guludan. The initial number of mangrove seedlings planted is 3000 seedlings (200 seedlings/guludan), and 24 mangrove seedlings are sampled from each guludan for measuring stem diameter, plant height, number of leaves, and number of internodes. Survival rate and health condition measurements of the mangrove seedlings are conducted via a census of all mangrove seedlings present in each guludan.

Stem diameter and height of mangrove seedlings

The mangrove seedlings on the guludan are measured for stem diameter using vernier callipers, and height is measured using a tape measure.

Number of leaves and number of internodes

In each guludan, 24 mangrove seedlings are randomly selected to count the number of leaves and the number of internodes.

Plant health condition

The health condition of mangrove seedlings on the guludans is observed. The criteria for plant health are determined based on Minister of Forestry Regulation Number: P.70/Menhut-II/2008 concerning Plant Growth Conditions (Table 1).

Table 1. Criteria for plant health

Criteria	Characteristics of plant conditions
Healthy	Plants grow fresh and have straight stems
Unhealthy	Plants have yellow leaves, abnormal leaf color, and bent stems
Languish	Plants grow abnormally or are attacked by pests and diseases
Dead	The plants no longer have leaves, the stems dry out, and no life activity exists.

Number of dead seedlings

All dead mangrove seedlings on each guludan are counted. The characteristics of dead mangrove plants are listed in Table 1.

Planting environmental conditions

Observations of planting site conditions include climatic factors, substrate conditions, and water quality. Climatic factors are measured at several points in the planting area, including light intensity measured using a lux meter, air temperature, and air humidity measured using a hygrometer. Substrate sampling is done using a soil shovel at several points on each guludan, then composited and tested in the Laboratory of Soil Science and Land Resources Department, Faculty of Agriculture, IPB University. Assessment criteria for substrate chemical properties refer to the criteria for assessing soil chemical properties according to the Soil Research Center

(1983), as shown in Table 2. The water quality within the guludan includes water salinity measured using a refractometer, water temperature and water pH measured using a multifunction 4 in 1 water quality tester version ATC EZ-9908.

Table 2. Criteria for assessing soil chemical properties (Soil Research Center 1983)

Soil properties	Very low	Low	Moderate	High	Very high	
pH	<4,5 Very acid	4,5-5,5 Acid	5,6-6,5 A bit acid	6,6-7,5 Neutral	7,6-8,5 A bit alkalis	>8,5 Alkalis
C-organic (%)	<1,00	1,00-2,00	2,01-3,00	3,01-5,00	>5,00	
N-total (%)	<0,10	0,10-0,20	0,21-0,50	0,51-0,75	>0,75	
C/N	<5	5-10	11-15	16-25	>25	
P (ppm)	<10	10-15	16-25	26-35	>35	
K (ppm)	< 100	100-200	210-400	410-600	>600	
KTK (cmol$^{(+)}$/kg)	<5	5-16	17-24	25-40	>40	

Data Analysis

Growth of mangrove seedlings

For each guludan, the average growth parameters are calculated, including stem diameter, mangrove seedling height, number of leaves, and number of internodes. The equation to calculate the average is as follows:

$$\bar{x} = \frac{\sum x}{n}$$

Information:

$\bar{x}$ = average of growth parameters

$\sum x$ = sum of growth parameters

n = number of plants measured

Survival rate

Survival rate (SR) is used to measure the survival level or the percentage of success in the survival of planted mangrove seedlings. The equation to calculate the survival rate refers to Minister of Forestry Regulation Number: P.70/Menhut-II/2008 as follows:

$$Survival\ Rate\ (SR) = \frac{number\ of\ living\ plants}{number\ of\ plants\ planted} \times 100\%$$

Percentage of plant health

The data on the number of healthy plants and the number of surviving plants are used to calculate the percentage of plant health. The equation to calculate the percentage of plant health refers to Minister of Forestry Regulation Number: P.70/Menhut-II/2008 as follows:

$$Plant\ health = \frac{number\ of\ healthy\ plants}{number\ of\ living\ plants} \times 100\%$$

Climatic parameters

The daily average air temperature, air humidity, and sunlight intensity data are calculated using the formula (Aditio *et al*. 2023) as follows:

$$T_{daily} = \frac{2T_{morning} + T_{afternoon} + T_{evening}}{4}$$

$$RH_{daily} = \frac{2RH_{morning} + RH_{afternoon} + RH_{evening}}{4}$$

$$I_{daily} = \frac{I_{morning}+I_{afternoon}+I_{evening}}{3}$$

Information:

T = average daily air temperature (°C)

RH = average daily air humidity (%)

I = average daily sunlight intensity (lux)

Results and Discussion

Planting Environmental Conditions

Climatic Parameters

The climatic parameters measured in this study are air temperature, air humidity, and light intensity. These parameters are included in factors that influence microclimate. Microclimate plays a crucial role in mangrove forests as it can affect environmental quality (Aditio *et al.* 2023). The daily average measurements of climatic parameters are presented in Table 3.

Table 3. Results of measuring climatic parameters at planting locations

Measurement time	Climatic parameters		
	Air temperature (°C)	Humidity (%)	Light intensity (lux)
Morning	31,36	63	11120
Afternoon	33,82	40	57220
Evening	33,10	51	27780
Daily average	32,41	54	32040

The daily average air temperature at the research site in Elang Laut area reaches 32,41°C (Table 3). According to Setyowati (2008), this air temperature is included into the very hot category. The air temperature at the research site could be very hot due to the highly open environmental conditions, as illustrated in Figure 2, resulting in a higher influx of sunlight intensity.

Figure 2. General view condition of the research site

The air temperature in the morning is lower than in the afternoon or evening. This is because, in the morning, there is still cooling from radiation effects, so the air temperature is relatively low. In contrast, the air temperature peaks during the afternoon due to the most substantial sunlight radiation (Aditio *et al.* 2023). According to Kusmana (1995), the minimum average temperature for good mangrove growth is greater than 20°C, and seasonal temperature differences do not exceed 5°C. The following climatic parameter measured is air humidity. The daily average air humidity measurement at the research site is 54% (Table 3). Air humidity is inversely related to air temperature; during the afternoon, the air temperature is highest, but the humidity is lowest. Low humidity levels will increase transpiration rates, thereby increasing water and mineral absorption and increasing nutrient availability for plant growth (Hidayah *et al*. 2022).

Mangrove forests require high sunlight intensity. The daily average sunlight intensity at the research site reaches 32.040 lux (Table 3). Research conducted by Safitri (2019) regarding the physiology and leaf characteristics of *R. mucronata* planted using the guludan planting technique, after one year of planting, the environmental conditions of the guludan received very high light intensity exceeding >50.000 lux. Compared with this study, the sunlight intensity at the research site also falls into the high category. Another study by Hardiansyah and Noorhidayati (2020) regarding the magnitude of light intensity in the mangrove ecosystem of Aluh-Aluh Besar Village has a range of light intensity from 16.442 to >20.000 lux, and this light intensity supports mangrove growth. Meanwhile, Rahmadhani *et al.* (2021) stated that the optimal range of light intensity for mangrove growth is 3000 – 3800 lux. Sunlight intensity plays a crucial role for plants as it affects the photosynthesis process related to plant growth (Haneda *et al.* 2023).

Water quality parameters

The quality of mangrove water is an essential component that influences mangrove growth. The quality of mangrove water also affects the health condition of mangrove plants. Although these plants adapt highly to changes in salinity, they are also vulnerable to changes in water quality, such as temperature and pH (Schaduw 2018). The water quality parameters measured in this study are pH, temperature, and salinity, as presented in Table 4.

Table 4. Average results of water quality measurements at the research site

Parameter	Value
pH	7,84
Temperature (°C)	29,40
Salinity (ppt)	0

The pH measurement at the research site yielded a value of 7,84 (Table 4). According to Wantasen (2013), the pH tolerance range is approximately 6 - 9,0, with the optimal pH range around 7,0 - 8,5. Based on this statement, the pH at the research site is considered good in supporting mangrove ecosystem stability. The pH value in a water body is influenced by several factors, such as temperature, dissolved oxygen, and alkaline content (Saru *et al*. 2017).

The water temperature parameter measurement resulted in 29,40°C (Table 4). A suitable temperature for mangroves is not less than 20°C (Kolehmainen *et al.* 1974, as cited in Schaduw 2018), indicating that the water temperature at the research site is suitable for mangrove growth. Mangrove forests are highly susceptible to environmental influences, including temperature change (Syahrial *et al.* 2020). Extreme temperature changes can disrupt organism life or even cause death (Schaduw 2018), reducing productivity and growth rate (Aini *et al.* 2016).

Another parameter is water salinity, which represents the salt content of a water body. The salinity measurement resulted in a value of 0 ppt (Table 4), indicating that the mangrove water condition at the research site is freshwater. Mangrove plants thrive in estuarine areas with salinity ranging from 10-30 ppt. If salinity exceeds the common salinity level (±35 ppt), it can negatively affect mangrove vegetation, resulting in stunted mangrove crowns and reduced species composition (Ario *et al.* 2015).

According to Duke *et al.* (1998), each mangrove species has different salinity tolerance. For example, *Rhizophora mucronata* has a salinity tolerance ranging from 0-30% of seawater. Based on this statement, even though the research site has a salinity of 0 ppt, it can still support the growth of Rhizophora mucronata species. Generally, low salinity results in good height growth. This is because mangrove plants do not require salt (salt demand) but are tolerant to salt (salt tolerance) (Dewi & Herawatiningsih, 2017).

Condition of the mangrove substrate

The quality of the growing site is crucial to consider in supporting rehabilitation efforts. The quality of the growing site analyzed in this study includes the chemical and physical properties of the mangrove substrate. The mangrove substrate is a mixture of mud and mineral soil in a 70% mineral soil ratio to 30% mud. The better the quality of the mangrove substrate, the higher the percentage of planted mangrove growth. The results of the chemical properties analysis of the mangrove substrate at the research site can be seen in Table 5.

Table 5. Results of analysis of soil chemical properties at planting site

Parameter	Unit	Value	Criteria
pH		$7{,}29 \pm 0{,}07$	Neutral
C-organic (Walkley & Black)	%	$3 \pm 0{,}22$	Moderate
N-total (Kjeldahl)	%	$0{,}19 \pm 0$	Low
C/N ratio		$15{,}77 \pm 1{,}52$	High
P (Bray I)	ppm	$15{,}50 \pm 1{,}41$	Moderate
K (Bray I)	ppm	$556 \pm 29{,}70$	High
KTK	$cmol^{(+)}/kg$	$37{,}39 \pm 1{,}94$	High

The analysis of substrate pH indicated a neutral pH value of 7,29 (Table 5). According to Fajar *et al.* (2013), the suitable soil pH for mangrove growth is 6-7. The pH value serves as an indicator of plants' nutrient availability. Neutral soil pH generally facilitates nutrient uptake by plant roots because most nutrients are soluble in water at neutral pH (Kusmana & Chaniago, 2017).

Organic carbon (organic matter) content is essential in supporting plant growth. The organic carbon analysis at the research site yielded a moderate value of 3% (Table 5). High organic carbon content indicates a mangrove ecosystem's productivity and fertility level. Mangrove areas have higher organic carbon content than others due to the decomposition of plants and animal remains in the mangrove area (Dewi & Herawatiningsih, 2017). Organic carbon content is influenced by vegetation density; the higher the vegetation density, the more litter produced, which decomposes into organic carbon (Bonita & Ratnaningsih, 2016).

Nitrogen (N) and phosphorus (P) are essential nutrients for plant growth and development. The analysis of total nitrogen content at the research site yielded a low value of 0,19% (Table 5). Nitrogen is crucial for plants in significant quantities; thus, nitrogen deficiency can limit cell division and enlargement (Pradipta 2016). The phosphorus (P) content analysis yielded a moderate value of 15,50 ppm (Table 5). Plants require phosphorus availability to aid in photosynthesis, energy transfer, flower and fruit formation, seed development, root growth, and stem strengthening (Asnindar *et al*. 2019). Poor phosphorus uptake can reduce plant tissue volume and darker leaf coloration (Pradipta 2016).

The carbon-to-nitrogen ratio (C/N ratio) is crucial in soil nutrient provision. Microorganisms need carbon as an energy source, while nitrogen is required for protein synthesis (Nopsagiarti *et al.* 2020). The C/N ratio at the research site yielded a high ratio of 15,77% (Table 5) due to the higher organic carbon content than total nitrogen. A high C/N ratio indicates that organic matter components have yet to fully decompose and undergo more extended decomposition than a low C/N ratio (Hersa *et al*. 2022). The C/N ratio value can be used to assess soil fertility levels. The C/N ratio is inversely related to nutrient availability; a high C/N ratio indicates fewer nutrients available for plants and vice versa (Adriany *et al.* 2018).

Potassium is a macro-nutrient most absorbed by plants after nitrogen and is absorbed in the form of K+ ions (Asnindar *et al.* 2019). The analysis of potassium content at the research site yielded a high value of 556 ppm (Table 5). Potassium plays a role in cell division and plant development (Trisnawati *et al.* 2017), so potassium deficiency can reduce plant production (Novizan 2005).

Cation Exchange Capacity (CEC) refers to the soil's ability to bind and release cations present in the soil (Sipayung *et al.* 2020). The analysis of CEC at the research site yielded a high value of 37,29 cmol$^{(+)}$/kg (Table 5). CEC is closely related to soil fertility, especially in providing plant nutrients. Soils with high CEC have a high nutrient availability capacity (Asnindar *et al.* 2019). Therefore, the mangrove substrate at the research site has a high nutrient availability capacity due to its high CEC value. Soil CEC is also influenced by organic matter; the more organic matter, the higher the soil CEC value. Additionally, soil texture affects CEC, clayey soil has a higher CEC value than sandy soil (Syahputera 2015).

The physical properties of the mangrove substrate analyzed include soil texture class. Soil texture indicates the proportion of sand, silt, and clay particles in the soil (Mahmud *et al.* 2014). The analysis of soil texture class at the research site can be seen in Table 6.

Table 6. Results of soil texture class analysis

Soil fraction (%)			Texture class
Sand	**Silt**	**Clay**	
6,02	22,16	71,83	Clay

Table 6 shows that the mangrove substrate at the research site has a clay texture class. This is because the soil fraction content is dominated by clay, silt, and sand, with percentages of 71,83%, 22,16%, and 6,02%, respectively. Generally, tropical mangrove forests worldwide do not have specific specifications regarding their soil fraction composition, but the observed pattern indicates that mangrove soil tends to contain clay. If the soil is predominantly sandy, there is concern that it may quickly disintegrate and be carried away by water (Hossain and Nuruddin 2016). According to Nurlailita (2015), the suitable substrate for mangrove growth is soft mud containing silt and clay. Species like Rhizophora sp. can thrive well in soft and muddy soil.

Growth of Mangrove Seedlings

Growth in stem diameter

Growth is the increase in the size of an organism due to the rise in the number and size of cells (Kusmana and Lestari 2021). The growth of mangrove seedlings observed in this study includes stem diameter, stem height, leaf count, and segment count. The measurement results of the stem diameter of mangrove seedlings are shown in Figure 3.

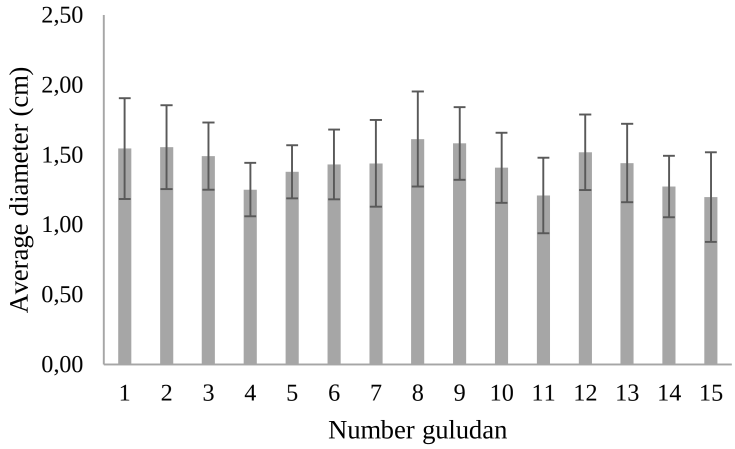

Figure 3. Average stem diameter of mangrove seedlings

The average stem diameter of the 15 guludans indicates that guludan 8 has the highest average diameter compared to other guludan at 1,61 cm, while guludan 15 has the lowest average diameter at 1,20 cm. The overall average diameter is 1,42 cm. The increase in diameter after 1,7 years is 0,84 cm/year. When compared to the study by Ashari (2018) regarding the growth of *R. mucronata* planted using the bunding technique in 2013 in the Angke Kapuk coastal area, which resulted in an average diameter of 2,53 cm after three years, the diameter increase is also 0,84 cm/year. Meanwhile, another study by Adliyandra (2019) on *R. mucronata* using the same bunding technique resulted in an average diameter of 0,71 cm after one year. Based on these studies, the growth of mangrove seedling diameter at the research site shows relatively high growth because at 1,7 years old, the increase in stem diameter is the same as the increase in stem diameter in mangrove seedlings already three years old.

The growth of stem diameter in each plot is not significantly different, but factors influence the growth of stem diameter. One of the factors affecting stem diameter growth is estimated to be sunlight intensity, which is closely related to the rate of photosynthesis. The rate of photosynthesis is proportional to the amount of sunlight received. Low light intensity causes suboptimal photosynthesis products, while high light intensity affects the stomatal cell activity in reducing transpiration, thereby inhibiting plant growth (Susilawati *et al*. 2016). According to Kusmana and Lestari (2021), mangrove plants have the most efficient photosynthesis capability compared to other plants. Light is crucial for plant growth, so when plants receive sufficient light for their physiological activities, they tend to grow laterally (Karyati 2019).

Height growth of mangrove seedlings

Primary growth activities influence the growth of mangrove seedling height in the apical meristem tissue (Farhaby and Anwar 2021). The mangrove seedling height measurement results vary across each plot (Figure 4).

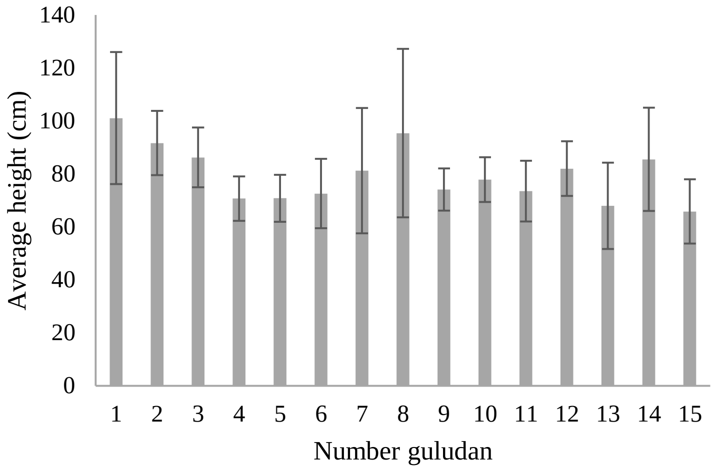

Figure 4. Average height of mangrove seedlings

The average height of mangrove seedlings is highest in Guludan 1 at 101 cm and lowest in Guludan 15 at 65,75 cm. The overall average height of seedlings across all 15 guludans reaches 79,71 cm. The increase in seedling height after 1,7 years is 46,89 cm/year. When compared to the research conducted by Ashari (2018) on the growth of *R. mucronata* planted using the guludan technique in 2013 in the Angke Kapuk coastal area, the average height after three years was 261 cm, resulting in a height increase of 87 cm/year. Meanwhile, another study by Adliyandra (2019) on *R. mucronata* using the same Guludan technique showed an average height of 88 cm after one year. Based on these studies, the growth of mangrove seedling height at the research site is lower compared to the research conducted by Ashari (2018) and Adliyandra (2019).

The differences in stem height among guludan may be due to sunlight intensity. The influence of sunlight intensity is evident in plant morphology, where higher sunlight intensity leads to more leaf production (Susilawati *et al.* 2016). This is supported by Farhaby and Anwar (2021), who state that the difference in leaf formation rate, which is highly influenced by the quality of the growing site, significantly affects plant height growth.

Planting distance also affects the growth of mangrove seedling height. Research by Husnaeni (2013) on the growth of *Avicennia marina* and *Rhizophora mucronata* seedlings at different planting distances using the guludan technique resulted in the tallest seedling growth at a planting distance of 0,5 m × 0,5 m. The closer the planting distance, the taller the growth of mangrove seedlings. This is because, in closer planting distances, competition for sunlight acquisition is higher, leading to growth being allocated more towards height to facilitate light acquisition.

Number of leaves

Leaves are one of the plant organs responsible for photosynthesis, which absorbs and processes sunlight and carbon dioxide (Kusmana & Lestari, 2021). *Rhizophora mucronata* generally has large-sized leaves that are almost the same as mature leaves because, before they bloom, they function as wraps for the shoot tips (Haris 2019). The observation results of the number of mangrove leaf seedlings are shown in Figure 5.

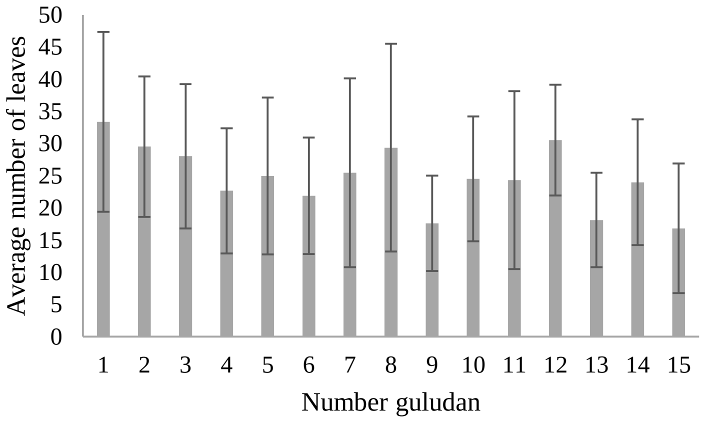

Figure 5. Average number of mangrove seedlings leaves.

The highest average number of leaves is found in guludan 1, amounting to 33 leaves, while guludan 15 has the lowest leaf number, 17 leaves. The overall average number of mangrove leaf seedlings from 15 guludans is 25 leaves, resulting in an increase of 15 leaves per year after 1,7 years. Research conducted by Haris (2019) on the growth model of 1-year-old *R. mucronata* seedlings planted using the Guludan technique in the Angke Kapuk coastal area yielded an average of 19 leaves. Compared to this study, the increase in the number of leaves in the research location is lower, but the difference in the increase in the number of leaves is not significant, only differing by four leaves.

The low increase in the number of leaves can be attributed to environmental factors such as the more shaded location of the guludan, resulting in lower sunlight intensity and, hence, fewer leaves, which are also thinner (Kusmana & Lestari, 2021). According to Trisnawati *et al.* (2017), an increase in the number of leaves in plants is partly due to an adequate supply of nutrients. One of the essential nutrients for leaf formation is nitrogen. Sufficient nitrogen availability will increase the number of leaves, and the leaves will grow larger. Mangrove plants have an optimal temperature range for photosynthesis of 28-32°C, and temperatures above 38°C can halt the photosynthesis process in the leaves (Aini *et al.* 2016). Mangrove plants also have specialized cells in their leaves that store salt, and thick and sturdy leaves contain a lot of water to regulate salt balance (Samiyarsih *et al.* 2016).

Number of internodes

Internodes are parts of the stem located between two nodes. Meanwhile, nodes are parts of the stem where the leaves attach. An increase in the number of internodes also means an increase in the number of leaves, as an adaptation to keep the leaves above the water surface and functioning properly (Kusmana & Septiarie, 2014). The observation results of the number of internodes are shown in Figure 6.

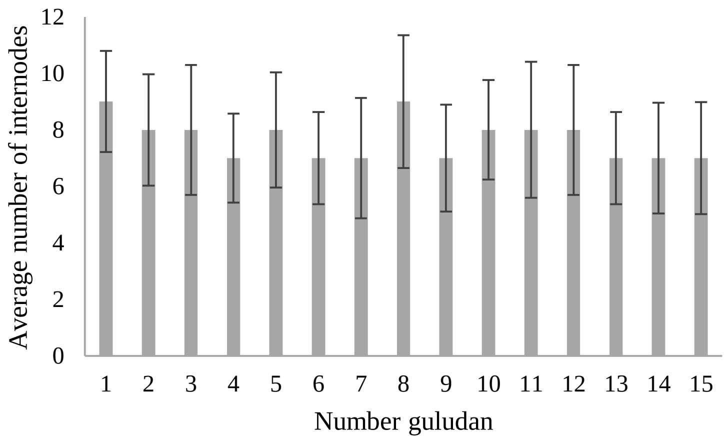

Figure 6. Average number of mangrove seedlings internodes

The average number of internodes on *Rhizophora mucronata* from 15 guludans resulted in 8 internodes, with almost the same average number of internodes in each guludan. The increase in the number of internodes after 1,7 years is five internodes/year. According to Kusmana and Septiarie (2014), the more internodes there are, the more leaves and food sources for growth there will be.

Research conducted by Haris (2019) regarding the growth model of 1-year-old *Rhizophora mucronata* seedlings planted using the Guludan technique in the Angke Kapuk coastal area yielded an increase in the number of internodes by three internodes/year. Compared to this study, the increase in the number of internodes per year in the research location is higher. The increase in internodes in mangroves is influenced by several factors, such as air temperature, ocean currents, sea waves, habitat, salinity, tidal zones, and mud substrates (Kusmana *et al.* 2008).

Health Condition of Mangrove Seedlings

The results of observations on the health condition of mangrove seedlings indicate that the condition of the mangrove seedlings is classified as fairly good because the majority fall into the healthy criteria at 64%. The results of observations on the health condition of mangrove seedlings are presented in Table 7.

Table 7. Percentage of health conditions of mangrove seedlings

Number	Criteria	Percentage
1	Healthy	64%
2	Unhealthy	30%
3	Languish	4%
4	Dead	3%

Mangrove seedlings classified as unhealthy amounted to 30%, while those classified as languishing and dead were only 4% and 3%, respectively. Damage to the mangrove seedlings was found on the leaf parts, such as discolouration ranging from yellow to brown, leaf curling, and hole formation in the leaves (Figure 7).

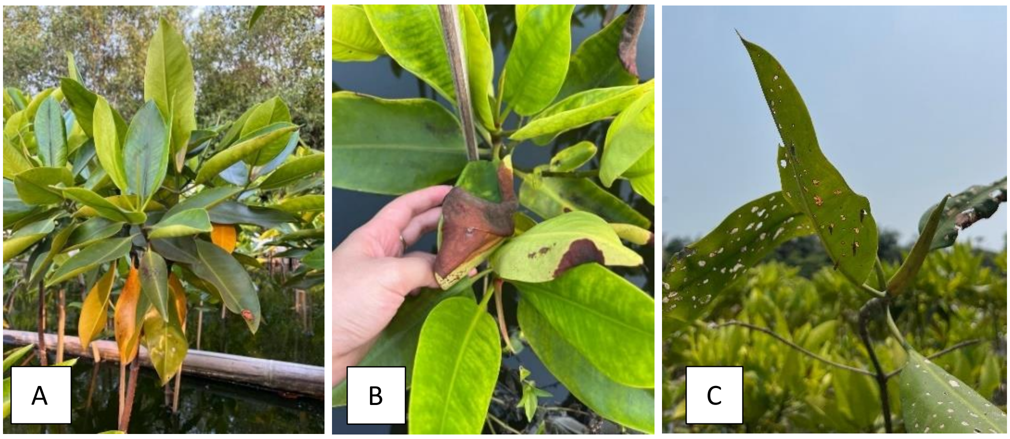

Figure 7. The types of mangrove seedlings damage, yellowing of leaves (A), leaves turning brown and curling (B), leaves with holes (C)

Damage in the form of yellowing to browning and curling of leaves can be caused by nutrient deficiency. Nutrients are a factor required in plants' growth and development process. A deficiency in nutrients can lead to several damages, such as leaves drying up and turning white to brown (necrosis), leaf curling, and changes in leaf colour to yellow (chlorosis) (Pan *et al.* 2022). Leaf yellowing occurs due to a nitrogen (N) nutrient deficiency. This aligns with Pan *et al.* (2022) statement that a nitrogen (N) deficiency can disrupt chlorophyll formation, decrease protein content, and increase anthocyanins, resulting in leaf yellowing (chlorosis) and eventual shedding.

Symptoms of leaves with holes occur due to bagworm caterpillar infestation. The bagworm caterpillar (*Acanthopsyche* sp.) hangs on the underside of mangrove leaves. Early symptoms of bagworm caterpillar infestation include the formation of drying spots on the leaves in circular shapes, which eventually fall off, forming holes in the leaves. According to Darmawan *et al.* (2020), *Acanthopsyche* sp. is synonymous with *Pteroma* sp. and has a basic conical bag shape that tends to be oval and small. The bag's position is found hanging freely on branches, stems, and leaf surfaces. Based on the research by Haneda and Suheri (2018), besides *Acanthopsyche* sp., another type of bagworm caterpillar that usually attacks leaves in mangrove stands is *Pagodiella* sp. *Pagodiella* sp. is a major pest that attacks leaves in large mangrove forest stands, causing significant damage.

Survival Rate of Mangrove Seedlings

The survival rate of mangrove seedlings indicates the percentage ratio between live seedlings and initial planted seedlings in the planting area. The Survival Rate (SR) can be used to determine the success of the planting efforts. The survival rate of *R. mucronata* mangrove seedlings planted at the research site in 2022 can be seen in Figure 8.

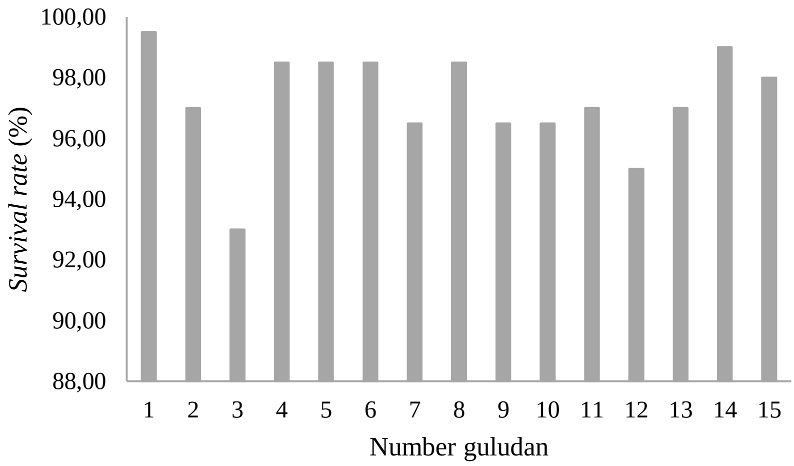

Figure 8. Percentage of survival rate of mangrove seedlings at each guludan

Based on Figure 8, it can be seen that the survival rate value of *Rhizophora mucronata* mangrove seedlings from all guludan yielded values >90%, even in guludan one where only one mangrove individual was found dead out of 200 seedlings planted per guludan, resulting in a survival rate of 99,5%. The average survival rate of all guludan is 97,27%, indicating that the mangrove rehabilitation can be considered successful according to Minister of Forestry Regulation No.P.70/Menhut-II/2008, which states that if the growth percentage is ≥70%, it is considered successful.

Based on interviews with the parties responsible for maintaining the Elang Laut mangrove rehabilitation site, it was stated that three months after planting, replanting was carried out, resulting in high survival rates after one year of planting. Maintenance activities such as replanting dead plants are essential to improve planting success. Makaruku and Aliman (2019) state that replanting should be done in the ongoing maintenance year (T+0), 15-30 days after planting. Optimal maintenance will result in optimal stand growth as well.

Maintenance against weed infestation was also carried out at the research site so that mangrove seedlings could grow well. According to Ashari (2018), rehabilitation protocols using guludan techniques require maintenance activities to eradicate growing weeds in guludan areas. This maintenance process is carried out consistently until *Rhizophora mucronata* is three years old. Afterwards, the seedlings are considered to enter the guludan stage and can grow independently without requiring additional maintenance. The absence of maintenance in the constructed guludan resulted in stands on the guludan dying due to weed infestation. This is similar to the research conducted by Ashari (2018), where the absence of maintenance on the guludan resulted in stand deaths due to weed infestation, with a weed infestation percentage on the guludan reaching 53,33%.

Mangrove rehabilitation at the research site used the guludan techniques, which can increase the survival percentage of planted seedlings. Based on the research by Kusmana *et al.* (2016) regarding the growth of *R. mucronata* seedlings in guludan with a planting distance of 0,5 m × 0,5 m, it was found that at 3,4 years of age, the percentage of surviving individuals was 100% with an average diameter of 3,04 cm and an average height of 2,78 m. The success of mangrove planting is also indicated by vigorously growing plants with fresh green leaves and new leaf shoots (Farhaby & Anwar, 2021). Mangrove seedlings at the research site are also dominated by healthy criteria with fresh green leaves, as presented in Table 7, indicating that the rehabilitation efforts in the Elang Laut area can be considered successful.

Conclusion

The growth of *Rhizophora mucronata* mangrove seedlings resulting from rehabilitation using the guludan techniques in the Elang Laut area, Muara Angke, after one year of planting, yielded an average stem diameter growth of 1,42 cm, an average height of 79,71 cm, an average leaf number of 25 leaves, and an average internode number of 8 internodes. The health condition of the mangrove seedlings resulted in a high health percentage dominated by healthy criteria (64%). The survival rate of planted mangrove seedlings achieved optimal results (97.27%), thus categorizing the planting as successful because the growth percentage is above 70%.

References

[KLHK] Kementerian Lingkungan Hidup dan Kehutanan. 2008. Peraturan Menteri Kehutanan Nomor 70 Tahun 2008 tentang Kondisi Pertumbuhan Tanaman. Jakarta: KLHK.

[KLHK] Kementerian Lingkungan Hidup dan Kehutanan. 2021. *Peta Mangrove Nasional*. Jakarta: Ditjen PDASRH.

Aditio R, Sudiar NY, Dwiridal L, Amir H. 2023. Microclimate characteristics in mangrove forest areas in Padang City. *Journal of Climate Change Society*. 1(1):1-10.

Adliyandra MR. 2019. Evaluasi pertumbuhan mangrove dengan sistem guludan di Kawasan Muara Angke, Jakarta Utara [skripsi]. Bogor: Institut Pertanian Bogor.

Adriany, Fahruddin, Abdullah A. 2018. Pengaruh jenis bioaktivator terhadap laju dekomposisi serasah daun jati *Tectona grandis* L.f., di wilayah kampus Unhas Tamalanrea. *Bioma: Jurnal Biologi Makassar*. 3(2):31-42.

Aini A, Budihastuti R, Hastuti ED. 2016. Pertumbuhan semai *Rhizophora mucronata* pada saluran tambak Wanamina dengan lebar yang berbeda. *Jurnal Biologi*. 5(1):48-59.

Alwidakdo A, Azham Z, Kamarubayana L. 2014. Studi pertumbuhan mangrove pada kegiatan rehabilitasi hutan mangrove di Desa Tanjung Limau Kecamatan Muara Badak Kabupaten Kutai Kartanegara. *Jurnal Agrifor*. 13(1):11-18.

Ario R, Subardjo P, Handoyo G. 2015. Analisis kerusakan mangrove di pusat restorasi dan pembelajaran mangrove (PRPM), Kota Pekalongan. *Jurnal Kelautan Tropis.* 18(2):64-69.

Ashari R. 2018. Evaluasi tegakan mangrove hasil rehabilitasi dengan teknik guludan di Kawasan Pesisir Angke Kapuk, Jakarta [tesis]. Bogor: Institut Pertanian Bogor.

Asnindar, Korja IN, Rukmi. 2019. Sifat kimia tanah pada hutan mangrove di Desa Tolai Barat Kecamatan Torue Kabupaten Parigi Moutong. *Jurnal Warta Rimba*. 7(3):113-120.

Azzahra FS, Suryanti S, Febrianto S. 2020. Estimasi serapan karbon pada hutan mangrove Desa Bedono, Demak, Jawa Tengah. *Journal of Fisheries and Marine Research*. 4(2):308-315.

Bonita MK, Ratnaningsih Y. 2016. Karakteristik faktor habitat mangrove rehabilitasi di Teluk Sepi Desa Buwun Mas Kecamatan Sekotong Kabupaten Lombok Barat. *Ganec Swara*. 10(1):58-63.

Darmawan UW, Triwidodo H, Hidayat P, Haneda NF, Lelana NE. 2020. Spesies ulat kantong dan musuh alaminya yang berasosiasi dengan tanaman sengon (*Falcataria moluccana* (Miq.) Barneby & J.W.Grimes). *Jurnal Penelitian Hutan Tanaman*. 17(1):1-13.

Dewi SK, Herawatiningsih R. 2017. Kondisi tanah dalam kawasan mangrove di Desa Nusapati Kabupaten Mempawah Kalimantan Barat. *Jurnal Hutan Lestari*. 5(2):177-182.

Duke NC, Ball MC, Ellison JC. 1998. Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology and Biogeography Letters*. 7(1):27-47.

Fajar A, Oetama D, Afu A. 2013. Studi kesesuaian jenis untuk perencanaan rehabilitasi ekosistem mangrove di Desa Wawatu Kecamatan Moramo Utara Kabupaten Konawe Selatan. *Jurnal Mina Laut Indonesia*. 3(12):164-176.

Farhaby AM, Anwar MS. 2021. Tingkat keberhasilan penanaman mangrove pada lahan bekas tambang timah di Desa Rebo Kabupaten Bangka sebagai bentuk pemanfaatan lahan dalam wilayah hutan mangrove di pesisir timur Pulau Bangka. *Bioma*. 23(2):143-148.

Gustami E, Marganof, Indra G. 2023. Ancaman deforestasi ekosistem mangrove serta dampaknya terhadap masyarakat Nagari Kataping Kecamatan Batang Anai Kabupaten Padang Pariaman. *Strofor Journal*. 7(1):167-176.

Hafni R. 2016. Analisis dampak rehabilitasi hutan mangrove terhadap pendapatan masyarakat Desa Lubuk Kertang Kabupaten Langkat. *Jurnal Ekonomikawan.* 16(2):1-12.

Haneda NF, Suheri. 2018. Hama mangrove di Kecamatan Batu Ampar, Kabupaten Kubu Raya, Kalimantan Barat. *Jurnal Silvikultur Tropika*. 9(1):16-23.

Haneda NF, Kusmana C, Naziah SMS. 2023. Keanekaragaman jenis serangga pada berbagai umur tegakan *Rhizophora mucronata* yang ditanam dengan teknik guludan di Muara Angke, Jakarta. *Jurnal Silvikultur Tropika*. 14(1):70-79.

Hardiansyah, Noorhidayati. 2020. Keanekaragaman jenis pohon pada vegetasi mangrove di Pesisir Desa Aluh-Aluh Besar Kabupaten Banjar. *Wahana-Bio: Jurnal Biologi dan Pembelajarannya*. 12(2):70-83.

Haris AM. 2019. Model pertumbuhan semai Rhizophora mucronata Lamk dengan teknik penanaman guludan di Kawasan Pesisir Angke Kapuk Jakarta [skripsi]. Bogor: Institut Pertanian Bogor.

Hersa T, Efriyeldi, Amin B. 2022. Decomposition rate of litterfall mangrove *Rhizophora* sp. at sungai bersejarah mangrove area, Kayu Ara Permai Village, Sungai Apit District, Siak Regency, Riau Province. *Asian Journal of Aquatic Sciences*. 5(2):191-199.

Hidayah I, Hardiansyah, Noorhidayati. 2022. Keanekaragaman herba di kawasan mangrove Muara Aluh-Aluh. *Jurnal Al-Azhar Indonesia Seri Sains Dan Teknologi*. 7(1):58-64.

Hossain MD, Nuruddin AA. 2016. Soil and mangrove: a review. *J Environ Sci Technol*. 9(2):198-207.

Husnaeni A. 2013. Pertumbuhan anakan *Avicennia marina* dan *Rhizophora mucronata* pada jarak tanam yang berbeda dengan menggunakan teknik penanaman guludan [tesis]. Bogor: Institut Pertanian Bogor.

Karyati. 2019. *Mikroklimatologi Hutan*. Samarinda: Mulawarman University Press.

Kusmana C. 1995. *Manajemen Hutan Mangrove Indonesia*. Bogor: IPB Press.

Kusmana C, Wilarso S, Hilwan I, Pamoengkas P, Wibowo C, Tiryana T, Triswanto A, Yunasfi, Hamzah. 2005. *Teknik Rehabilitasi Mangrove*. Bogor: Fakultas Kehutanan Institut Pertanian Bogor.

Kusmana C, Istomo, Wibowo C, Wilarso SBR, Siregar IZ, Tiryana T, Sukardjo S. 2008. *Manual Silvikultur Mangrove di Indonesia*. Jakarta: Korea International Cooperation Agency (KOICA).

Kusmana C, Septiarie M. 2014. Respon pertumbuhan semai bakau (*Rhizophora mucronata* Lamk.) terhadap tingkat kedalaman dan lama penggenangan. *Jurnal Silvikultur Tropika*. 5(3):155-159.

Kusmana C, Husnaeni A, Tiryana T. 2016. *Rhizophora mucronata* seedling growth model at different spacings using guludan planting technique. *IJTS*. 5(12):457-464.

Kusmana C, Chaniago ZA. 2017. Kesesuaian lahan jenis pohon mangrove di Bulaksetra, Pangandaran Jawa Barat. *Jurnal Silvikultur Tropika*. 8(1):48-54.

Kusmana C, Lestari DAP. 2021. Pengaruh media tanam dan intensitas naungan terhadap pertumbuhan bakau minyak (*Rhizophora apiculata*). *Jurnal Silvikultur Tropika*. 12(3):157-163.

Majid I, Muhdar MHIA, Rohman F, Syamsuri I. 2016. Konservasi hutan mangrove di Pesisir Pantai Kota Ternate terintegrasi dengan kurikulum sekolah. *Jurnal Bioedukasi*. 4(2):488-496.

Mahmud, Wardah, Toknok B. 2014. Sifat fisik tanah di bawah tegakan mangrove di DSA Tumpapa Kecamatan Balinggi Kabupaten Parigi Moutong. *Warta Rimba*. 2(1):129-135.

Makaruku A, Aliman R. 2019. Analisis tingkat keberhasilan rehabilitasi mangrove di Desa Piru Kecamatan Seram Barat Kabupaten Seram Bagian Barat. *Jurnal Rekayasa Lingkungan*. 19(2):1-17.

Nalendra ARA, Yanti R, Agus P, Ibnu S, Retno R, Rina L, Suwantica K, Ria Y, Dewi A, Jeffry L, Martinus WP, Vina AZ. 2021. *Statistika Seri Dasar dengan SPSS*. Bandung: Media Sains Indonesia.

Niapele S, Hasan MH. 2017. Analisis nilai ekonomi hutan mangrove di Desa Mare Kofo Kota Tidore Kepuluan. *Jurnal Ilmiah Agribisnis dan Perikanan*. 10(2):7-16.

Nopsagiarti T, Okalia D, Marlina G. 2020. Analisis c-organik, nitrogen, dan C/N tanah pada lahan agrowisata Beken Jaya. *Jurnal Agrosains dan Teknologi*. 5(1):11-18.

Novizan. 2005. *Petunjuk Pemupukan yang Efektif*. Jakarta: Agromedia Pustaka.

Nurlailita. 2015. Evaluasi kesesuaian lahan dan strategi rehabilitasi hutan mangrove Kecamatan Birem Bayeun dan Kecamatan Rantau Selamat Kabupaten Aceh Timur [tesis]. Bogor: Institut Pertanian Bogor.

Pan R, Sudarmanto A, Putra EP. 2022. Identifikasi kerusakan tanaman mangrove di Pulau Baii Kota Bengkulu. *Indonesian Science Education Journal*. 3(1):9-14.

Pradipta N. 2016. Studi kandungan nitrogen (N) dan fosfor (P) pada sedimen mangrove di wilayah ekowisata Wonorejo Surabaya dan Pesisir Jenu Kabupaten Tuban [skripsi]. Surabaya: Universitas Airlangga.

Pusat Penelitian Tanah. 1983. *Survei Kapabilitas Kesuburan Tanah*. Bogor: Lembaga Pusat Penelitian Tanah.

Rahim S, Baderan DWK. 2017. *Hutan Mangrove dan Pemanfaatannya*. Yogyakarta: CV Budi Utama.

Rahmadhani T, Rahmawati YF, Qalbi R, Fithriyyah NHP, Husna SN. 2021. Zonasi dan formasi vegetasi hutan mangrove: studi kasus di Pantai Baros, Yogyakarta. *J. Sains Dasar*. 10(2):69-73.

Rinika Y, Ras AR, Yulianto BA, Widodo P, Saragih HJR. 2023. Pemetaan dampak kerusakan ekosistem mangrove terhadap lingkungan keamanan maritim. *Equilibrium: Jurnal Pendidikan*. 11(2):170-176.

Safitri LRDA. 2019. Fisiologi dan karakteristik daun *Rhizophora mucronata* Lam. pada berbagai umur tanaman dengan teknik penanaman guludan di Angke Kapuk Jakarta [skripsi]. Bogor: Institut Pertanian Bogor.

Safuridar, Andiny P. 2020. Dampak pengembangan ekowisata hutan mangrove terhadap sosial dan ekonomi Masyarakat di Desa Kuala Langsa, Aceh. *Jurnal Samudra Ekonomi dan Bisnis*. 11(1):43-52.

Samiyarsih S, Brata T, Juwarno. 2016. Karakter anatomi daun tumbuhan mangrove akibat pencemaran di Hutan Mangrove Kabupaten Cilacap. *Biosfera*. 33(1):31-36.

Saru A, Amri K, Mardi. 2017. Konektivitas struktur vegetasi mangrove dengan keasaman dan bahan organik total pada sedimen di kecamatan Wonomulyo Kabupaten Polewali. *Jurnal Ilmu Kelautan*. 3(1):85-95.

Schaduw JNW. 2018. Distribusi dan karakteristik kualitas perairan ekosistem mangrove Pulau Kecil Taman Nasional Bunaken. *Majalah Geografi Indonesia*. 32(1):40-49.

Setyowati DL. 2008. Iklim mikro dan kebutuhan ruang terbuka hijau di Kota Semarang. *Jurnal Manusia dan Lingkungan*. 15(3):125-140.

Sipayung JY, Arthagama IDM, Supadma AAN. 2020. Evaluasi status kesuburan tanah di DAS Yeh Ho Kabupaten Tabanan berbasis sistem informasi geografis untuk menentukan arahan pengelolaan lahan. *Jurnal Agroteknologi Tropika*. 9(4):268-278.

Susilawati, Wardah, Irnasari. 2016. Pengaruh berbagai intensitas cahaya terhadap pertumbuhan semai cempaka (*Michelia champaca* L.) di persemaian. *J. ForestSains*. 14(1):59-66.

Syahrial, Saleky D, Samad APA, Tasabaramo IA. 2020. Ekologi perairan Pulau Tunda Serang Banten: keadaan umum hutan mangrove. *Jurnal Sumberdaya Akuatik Indopasifik*. 4(1):53-68.

Syahputera E, Fauzi, Razali. 2015. Karakteristik sifat kimia sub grup tanah ultisol di beberapa wilayah Sumatera Utara. *Agroekoteknologi*. 4(1):1-8.

Trisnawati, Wardati, Yulia AE. 2017. Pertumbuhan bibit mangrove (*Rhizophora* sp.) pada medium *hydraquent* yang diberi beberapa dosis NPK. *JOM Faperta*. 4(2):1-10.

Wantasen AS. 2013. Kondisi kualitas perairan dan substrat dasar sebagai faktor pendukung aktivitas pertumbuhan mangrove di pantai pesisir Desa Basaan I, Kabupaten Minahasa Tenggara. *Jurnal Ilmiah Platax*. 1(4):204-209.