ASSESSING THE GROWTH PERFORMANCE OF RHIZOPHORA (*Rhizophora mucronata* and *Rhizophora apiculata*) FOR EFFECTIVE RESTORATION IN DELTA TUMPAT, KELANTAN

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resource Science) with Honours

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DECLARATION

I declare that this thesis entitled "Assessing the Growth Performance of Rhizophora (*Rhizophora mucronata* and *Rhizophora apiculata)* for Effective Restoration in Delta Tumpat, Kelantan" is the result of my own research except as cited in the references. The Thesis has not been accepted for any degree and is nor concurrently submitted in candidature of any other degree.

Signature : …………………………………………..

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Date : 2 SEPTEMBER 2024

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Assessing The Growth Performance of Rhizophora (*Rhizophora mucronata and Rhizophora apiculata*) For Effective Restoration in Delta Tumpat, Kelantan

ABSTRACT

Mangrove ecosystems, important for coastal protection, biodiversity, and providing a range of ecosystem services, are facing increasing vulnerability due to human activities and the effects of climate change. The study about "Assessing the Growth Performance of *Rhizophora mucronata* and *Rhizophora apiculata* for Effective Restoration in Delta Tumpat, Kelantan" aims to analyses the growth performance of Rhizophora species and determine their distribution in the Tumpat Delta area. Various methods are used to assess Rhizophora growth, including measuring DBH, height, crown diameter, soil pH, and water salinity. It is found that Mas, Layang-layang and Tujuh are mostly with most of *Rhizophora mucronata* that has been planted on the island. For Bedal A and Bedal B, *Rhizophora apiculata* is the most planted tree on the islands. Based on the that has been data collected, even though Pulau Mas was first planted the Rhizophora tree which is in 2003, however Pulau Bedal B that was planted in 2008 has the significant increase in compared to other five islands with the average DBH 2.41 cm and height 1.68 m, within 5 years between 2019 to 2024. For recommendation, more sampling and parameter should be conducted in future studies to obtain more accurate and better results for the research.

Menilai Prestasi Pertumbuhan Rhizophora (*Rhizophora mucronata dan Rhizophora apiculata*) untuk Pemulihan Berkesan di Delta Tumpat, Kelantan

ABSTRAK

Ekosistem bakau, amat penting untuk perlindungan pantai, biodiversiti, dan menyediakan pelbagai perkhidmatan ekosistem. Kini ia semakin terancam akibat aktiviti manusia dan kesan perubahan iklim. Kajian mengenai "Menilai Prestasi Pertumbuhan *Rhizophora mucronata* dan *Rhizophora apiculata* untuk Pemulihan Berkesan di Delta Tumpat, Kelantan" telah dijalankan bagi tujuan untuk menganalisis prestasi pertumbuhan spesies Rhizophora dan menentukan taburannya di kawasan Delta Tumpat. Terdapat beberapa kaedah telah digunakan untuk menilai pertumbuhan Rhizophora seperti mengukur DBH, ketinggian, diameter kanopi, pH tanah, dan kemasinan air. Didapati bahawa Pulau Mas, Layang-layang, dan Tujuh kebanyakannya telah ditanam dengan *Rhizophora mucronata*, manakala Pulau Bedal A dan Bedal B pula telah ditanam dengan *Rhizophora apiculata*. Berdasarkan data yang telah dikumpul, Pulau Mas merupakan pulau pertama yang ditanami pokok Rhizophora pada tahun 2003, namun Pulau Bedal B yang ditanami pada tahun 2008 menunjukkan peningkatan yang ketara berbanding dengan lima pulau lain dengan purata DBH 2.41 cm dan ketinggian 1.68 m dalam tempoh 5 tahun antara 2019 hingga 2024. Sebagai cadangan, lebih banyak pensampelan dan parameter perlu dilakukan dalam kajian masa hadapan untuk mendapatkan hasil yang lebih tepat dan baik bagi penyelidikan ini.

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LIST OF ABBREVIATION

ha	Hectare
cm	Centimetre
mm	Millimetre
m	Meter
m^2	Meters square
pH	potential of Hydrogen
ppt	parts per thousand
DBH	Diameter at Breast height
UMK	Universiti Malaysia Kelantan

LIST OF SYMBOLS

°C	Degree Celsius
mm	millimetres
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Ecological systems are quintessential complex systems. Understanding and being able to predict phenomena typical of complex systems is, therefore, critical to progress in ecology and conservation amidst escalating global environmental changes (Riva, 2023). To fulfil sustainable development goals, many countries are expanding efforts to conserve ecologically and societally critical coastal ecosystems. Due to extensive conversion for aquaculture, agriculture, and urbanisation, mangroves are now regarded as increasingly vulnerable ecosystems. Despite supporting unique biodiversity and offering several advantages to coastal people, these forests are under peril. Human activities have led to degradation of ecosystems globally including on mangrove ecosystem. There are plenty of reasons to restore mangroves throughout their range in order to replenish damaged habitat and ecosystem services due to their rapid decline, fragmentation, and degradation (Su, 2021).

Mangrove habitats are found in tropical and temperate locations, where they are protected and sheltered. Their worldwide reach, high production, and multitude of ecosystem services make them significant (Naidoo, 2016). Mangrove also is a vital ecosystem that straddles the interface between land and sea in coastal areas, serving as a crucial link between terrestrial and marine environments. As such, they provide important ecosystem services such as fish, timber, fuelwood, coastal protection, pollution control, and cultural values for hundreds of millions of people (Barbier, 2015). With evidence of global changes in mangrove distribution, particularly encroachment into salt marshes, these coastal ecosystems are also at risk from the impacts of climate change and increasing sea levels. (Kelleway, 2017).

Delta Tumpat, located in Kelantan, Malaysia, is a significant area characterized by its rich mangrove ecosystems. According to Stayanarayana *et al*, 2011, on the northeastern coast of Peninsular Malaysia, the lower stages of the river Kelantan form a large delta (1200 hectares) made up of bays, mangroves, and estuaries. Acccording Satyanarayana et al., 2011, the mangroves forest can be represented by tree species like *Avicennia alba., Bruguiera gymnorrhiza, Nypa fruticans (Thunb.) Wurmb., Rhizophora apiculata Bl., R. mucronata Lamk.,* and *Sonneratia caseolaris (L.)*. There are more than 17 small islands that make up the Delta Tumpat, which covers about 1,200 hectares (Rahim *et al*., 2022). For program restoration, Delta Tumpat Kelantan, Malaysia, has been selected for the programme for the Mangrove Tree Planting Program (MTPP). It is a long-term national initiative created to make sure that the coastal shoreline provides a solid and stable buffer zone area, a place and habitat for conservation and biodiversity, and a preventive measure against destruction brought on by waves, strong winds, and soil erosion (Jemali *et al.*, 2022).

1.2 Problem Statement

The apparent simplicity of the mangrove ecosystem is cheat mangroves are naturally stressed ecosystems-terms. Natural stresses include high soil salinity which increases the cost of obtaining fresh tidal water a flow that releases the potential energy stored in it forms of litter and dissolved organic matter, soil run off tides, storms and waves that can cause excess siltation or erosion, and periodic hurricanes or storm winds which disrupt the structure of the system (Lugo, 1980).

The current growth performance of Rhizophora species in Delta Tumpat, Kelantan, needs to be studied back. It is to understand the hindering effective mangrove restoration efforts. The lack of comprehensive insights into the factors influencing Rhizophora in this area hinders the development of targeted restoration strategies. A thorough investigation is needed to understand the current conditions of Rhizophora growth and identify key factors, which can help design and implement effective mangrove restoration initiatives.

1.3 Objectives

The generate objectives are:

- To analyse the growth performance Rhizophora species in Delta Tumpat
- To determine the distribution of Rhizophora species in the same area

1.4 Scope of Study

This study thoroughly examined how Rhizophora trees were grown in the mangrove areas of five selected islands in Delta Tumpat, Kelantan, Malaysia. Measurements were taken, including tree height, diameter, and density, to assess the current state of the Rhizophora population. The soil and climate in the area were analyzed to identify factors influencing Rhizophora growth. The aim of the study was not only to assess the existing conditions but also to recognize critical factors that contributed to Rhizophora growth and to ensure the resilience and well-being of this vital coastal ecosystem.

1.5 Significant of Study

The significance of this study lies in the need to withstand and improve Rhizophora tree growth in Delta, Tumpat, Kelantan, Malaysia. By studying the growth performance of the tree and factors that potentially influence the growth of Rhizophora species, the data that has been collected will provide valuable insight for effective restoration. The health of the mangrove ecosystem and its positive impact on biodiversity, coastal protection, and local life can be anticipated through the implementation of the study's recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Mangrove ecology, distribution and importance

Mangroves are a popular type of coastal environment found worldwide, mostly built up of tropical trees and shrubs that have evolved specifically to withstand the tidal conditions of coastlines and the sea. The majority of the world's coastline is in low latitudes, where mangrove forests and the rivers that support them are dominant ecosystems in both the tropics and subtropics. Though they make up less than 1% of all coastal zones worldwide, mangroves cover about 152,000 km² of coastline (Alongi, 2018).

Malaysia is situated in the western part of the Maritime Continent of Southeast Asia, strongly influenced by the Southeast Asia Maritime monsoon (Tangang *et al*., 2012). Mangrove forests are located at the dynamic border between the land and the sea, which makes them dependent on a variety of disturbances that occur both in space and time. They also live in a difficult environment where they are constantly exposed to salt and water, fluctuating temperatures, and different levels of anoxia (Gilman *et al*., 2008). Mangroves are therefore resistant and highly adaptable to changing environments. Mangroves complex root systems also draw fish and other species looking for food and protection from predators.

2.1.1 Distribution of Mangrove

Mangroves are found in over 123 countries, cover an area of more than 150 000 km^2, and are home to more than 73 species and/or hybrids (Numbere & Camilo, 2017). Also based on the journal too, the best places mangroves can grow are in tropical climates, although intense heat speeds up evaporation and raises salt levels. In mangroves, temperature above 35°C has an impact on photosynthesis, seedling establishment, and root structure (Mondal, 2021). For example, New Zealand, southern Australia, southern Brazil, and South Africa are countries that have temperate weather, but have mangroves (Gilman, 2008).

According to (Cavanaugh *et al*., 2014), a persistent rise in temperature can cause changes, an increase in species variety, and the migration of some species into subtropical salt marsh regions and the Arctic pole. Rainfall controls the intake of nutrients and impacts the survival and production of mangroves. Mangrove populations are abundant in somewhat warm, humid, high-rainfall equatorial regions (Numbere & Camilo, 2017).

According to Juliana *et al.*, (2013), Malaysia is home to the third-largest mangrove forest in the Asia-Pacific region, with the highest species diversity and a humid tropical climate. The forests are primarily concentrated in Perak, Kedah, and Johor, with smaller areas in Kelantan, Terengganu, and Pahang. Sarawak and Sabah also have mangrove growth along their coastlines, estuaries, and rivers. The forests extend inland and influence sea tides. Most Malaysia's mangroves (60%) can be found in Sabah, with Sarawak (22%) and following with Peninsular Malaysia (18%) (Ahmad *et al*, 2019).

Table 2.1: Distribution of mangrove in Malaysia throughout the monitoring period

Region	Mangroves 1990 (ha)	Mangroves 2000 (ha)	Mangroves 2017 (ha)
Peninsular Malaysia	116,746	114,353	110,953
Sabah	385,630	382,448	378,195
Sarawak	147,936	145,263	139,890
Total	650,311	642,063	629,038

(Source: Omar *et al*, 2020)

Table 2.2: The existing of mangroves in Malaysia for 2017

Region	Mangroves for 2017 (ha)
Perlis	49
Kedah	7,725
Penang	1,967
Perak	44,990
Selangor	20,853
Negeri Sembilan	1,557
Melaka	1,241
Johor	26,818
Pahang	3,579
Terengganu	1,571
Kelantan	422
Sub Total: Peninsular Malaysia	110,953
Sabah	378,195
Sarawak	139,890
Total	629,038

(Source: Omar *et al*, 2020)

2.1.2 Importance of mangrove

Mangrove forests provide a crucial purpose in human existence that cannot be replaced by other uses. They serve as "nutrient export zones to open ocean, barrier of sea erosion, coastal stabilizers, and shelter belt areas" (Acharya, 2016). Mangrove forests offer ecologically important benefits such as providing shelter, laying eggs, and breeding fish (Afero, 2013). Regarding their ecological roles, mangrove forests provide protection against shoreline erosion, a location for the assimilation of waste materials, mud aggregates and landforms, habitats for wildlife and some aquatic animals, and land for a variety of human activities like mining, dumping, and adding fish and salt (Suwarsih, 2018). Additionally, mangroves serve as spawning, nursery, feeding, and nesting grounds for a variety of fish, shrimp, shellfish, birds, and other biota species. Its physical properties allow it to act as a land stabilizer, resist erosion from seawater, and prevent seawater from penetrating the soil. Mangrove forests provide societal purposes by providing people with roofing, charcoal, and fuel (Suprapti, 2019).

2.2 Rhizophora as key mangrove species

Rhizophora is one of the species that can be seen inside mangrove forest that are located along the shores of more than 100 nations. They offer a variety of ecosystem services that are important to the well-being and means to survive for many people. These wooded wetlands not only offer an excellent nursery habitat for marine life, but they also safeguard shorelines, which benefits local economies in around 123 nations and territories (Krauss & Friess, 2011). Despite their significance, researchers warned of "a world without mangroves" twelve years ago due to the significant loss of mangrove land worldwide (Duke, 2007).

Despite fluctuating in the environment, mangroves show a high degree of ecological stability and community perseverance. Mangrove ecosystems are shaped throughout time by a variety of physical and geological factors that operate within limitation of changing climatic and environmental variables in their intertidal context (Alongi, 2015). Shrubs or trees known as mangroves are found mostly along salty or brackish coastlines. Mangroves have roots that are partially above ground, called aerial roots. These serve as “snorkels’ for breathing when the soil is flooded or has little oxygen (Cadena & Ochoa-Gomez, 2023).

2.2.2 Morphology of *Rhizophora apiculata*

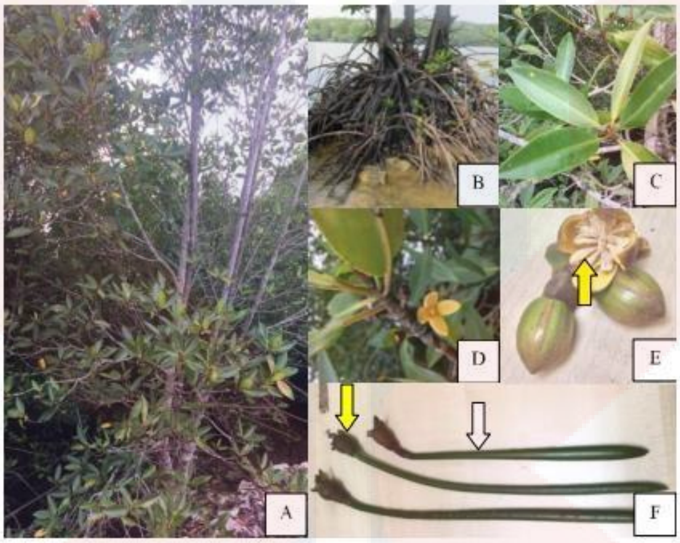

Figure 2.1: Morphological feature of Rhizophora apiculata

(A) Habit, tall, form; (B)Aerial and stilt root; (C) leafy rosette; (D) fertilized flower with bright yellow sepals. (E) stamen of flower (arrow) and mature bud (arrow); (F) fruit (yellow arrow).

(source: Shamin-Shazwan *et al*., 2021)

According to researchers who have done research in three different states, which are Johor, Terengganu, and Pahang (Shamin-Shazwan *et al*., 2021), *Rhizophora apiculata* has a bark, leaf, flower, fruit, and stilt root. The bark of *Rhizophora apiculata* is dark grey with a vertical fissure. For the leaf, this tree has a simple leaf with a petiole. Based on the journal too, the leaf was oppositely arranged, narrowly elliptic oblong, had a dark green color and a presence of black dotted underneath the leaf surface, and the venation was barely visible. The flower of *Rhizophora apiculata* is actinomorphic and polypetalous; it has 4-yellow sepals and 4-white sepals, a lanceolate shape, a hairless surface, and 10–12 stamens. The fruit is solitary, has a dull brown color when it is ripe, and has a pear shape. Lastly, the stilt root is present to support the tree's growth.

2.2.3 Morphology of *Rhizophora mucronata*

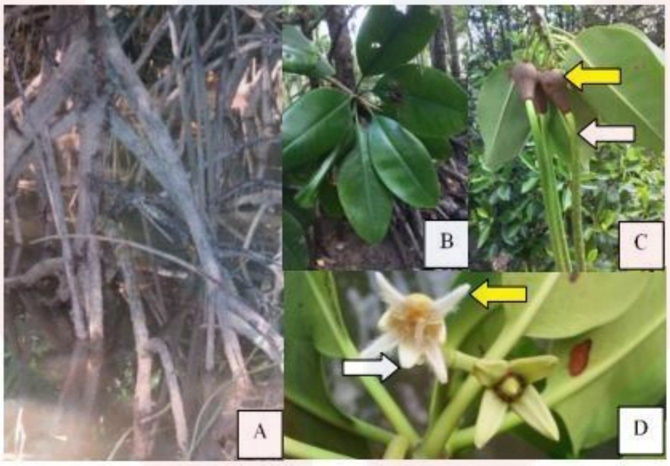

Figure 2.2: Morphological features of Rhizophora mucronata

(A) Aerial and stilt roots; (B) leafy rosette; (C) fruit (yellow arrow) and hypocotyl (white arrow); (D) creamy white flower (yellow arrow) and fertilized flower with creamy white sepals (white arrow).

(Source: Shamin-shazwan *et al*., 2021)

Based on the journal morphological structures of *Rhizophora apiculata* and *Rhizophora mucronata* (Shamin-Shazwan *et al.*, 2021), the anatomy shows that it has bark, leaf, inflorescence, flower, fruit, and stilt root. For the bark of *Rhizophora mucronata*, it has a dark black color with a horizontal fissure. The leaf of this tree is a simple leaf with a petiole, oppositely arranged, broadly elliptic-oblong, apex acute; the base is cuneate; the entire margin has a leathery surface; dark green and the presence of black dotted underneath the leaf surface; and penni-veined with a deep pattern. For the flower part, it has actinomorphic and polypetalous, 4-creamy white sepals, 4-creamy white petals, a lanceolate shape, a densely hairy surface, and 8 stamens. For the fruit, it has solitary fruit that is dull brown when ripe, and the fruit has a pear shape. The stilt root is present to support tree growth.

2.2.4 Importance of Rhizophora

The protection, conservation, and sustainable use of Rhizophora are important as they make valuable contributions to ecosystems functioning, providing a wide variety of goods and services. Mangroves produce wood for building, fuel and fixing and storing large amounts of carbon (Krauss *et al*., 2008). In South Africa, mangroves are used for charcoal, firewood, building material for housing, fences, and fish traps. Mangroves have been considered efficient systems for the removal of nutrients and other pollutants (Lewis *et al*., 2011).

Mangroves serve as crucial habitats and breeding grounds for a variety of semiterrestrial and estuarine organisms, including fish, crustaceans, birds, reptiles, mammals, and many more. Terrestrial and marine plants, algae, invertebrates, and vertebrates all make their home in the mangrove roots. Many different species, some of which are found in great quantities, find a home in mangrove habitats. They are fruitful environments that may sustain fish and prawn coastal fisheries (Nagelkerken *et al*., 2008). Mangrove's complex root systems also draw fish and other species looking for food and protection from predators.

They also mitigate the effects of extreme weather events like cyclones and tsunamis, provide a renewable supply of wood for housing and fuel, as well as food and traditional medicines, and are significant sites for the accumulation of sediment, carbon, nutrients, and contaminants (Alongi, 2015).

2.3 Factors affects Rhizophora growth.

2.3.1 Salinity

Previous studies have shown that a seedling's Rhizophora capability to tolerate saltwater changes based on its maturity or stage of growth. Rhizophora seedlings that were placed in low-salinity environments survived better than those planted in moderate- and high-salinity environments. Research has been done on how salinity affects Rhizophora early development performance and how seedling age affects the ideal salinity, which changes from low to moderate (Kodikara *et al*., 2017).

2.3.2 Precipitation Changes

In more humid environments, precipitation and outflow through freshwater river discharge and groundwater outflow habitats drain salt from mangrove bottoms while delivering nutrients. Saline flats may appear near high tide levels under drier circumstances as a result of high concentrations of salt resulting from evaporation from the mangrove substrate during low tide (Hanum *et al*., 2014).

2.3.3 Increased Temperature

Mangroves are tropical plants that can only survive at temperatures over 66°F (19°C). They cannot withstand temperature swings below freezing or beyond 18°F (10°C) (Alongi, 2018). Based on the journal from Ward et al. (2016), its is discusses that the increases in global temperatures projected to rise by up to 4.8°C by the end of the century can significantly influence mangrove health and sustainability.

2.4 Previous restoration effort in similar environments

A variety of parties involved are required for mangrove restoration and rehabilitation, including communities, government agencies, regulatory agencies, research organisations, and the media. Successful attempts to protect mangroves depend on the involvement and assistance of several stakeholders who have similar interests and values (Omar *et al.,* 2020).

Based on the journal Evaluation of knowledge and perception of locals toward the conservation effort in mangrove forest at Delta Tumpat, Kelantan, Malaysia (Rahim *et al.,* 2022) there are 116 of respondents that has been given the questionnaire survey to answered about the general knowledge of mangrove. The questionnaire was given to the respondents for the researcher to get information from them about their knowledge of mangroves, and perception of the mangrove. The effectiveness of the mangrove protection in Tumpat is largely dependent on the community's dedication and awareness.

Delta Tumpat in Kelantan had also previously undergone restoration. From Nor Syahirah *et al.,* 2018, it is to determine the diversity of mangrove tree species and forest content, including the number of species, tree height, diameter breast height (DBH), and tree density of mangrove species in disturbed and undisturbed areas at delta Tumpat, Kelantan, Malaysia. The study also determined that the primary causes of anthropogenic disturbance in this delta were invasive species introduction, port expansion, sand dredging to deepen the closest river, and land conversion for agricultural use. It is to make sure that mangrove area on Delta Tumpat Kelantan will be restore even better than before.

CHAPTER 3

MATERIAL AND METHOD

3.1 Study Area

This research has been conducted in the captivating mangrove ecosystem of Delta Tumpat, Kelantan, situated at approximately 6.20º95ºN latitude and 102.15º74ºE longitude (figure 3.1). Five selected islands were inventoried for this study, which is Pulau Bedal A, Pulau Bedal B, Pulau Mas, Pulau Layang-layang, and Pulau Tujuh. According to Nor Syahirah *et al*., (2018) Kelantan Delta have a small island, Malaysia. The Kelantan Delta is vulnerable to powerful waves, especially from November to February during the yearly monsoonal season. With an average temperature of 26.8ºC and 83.7% relative humidity, the northeast and southeast monsoons had the most influence on the climate.

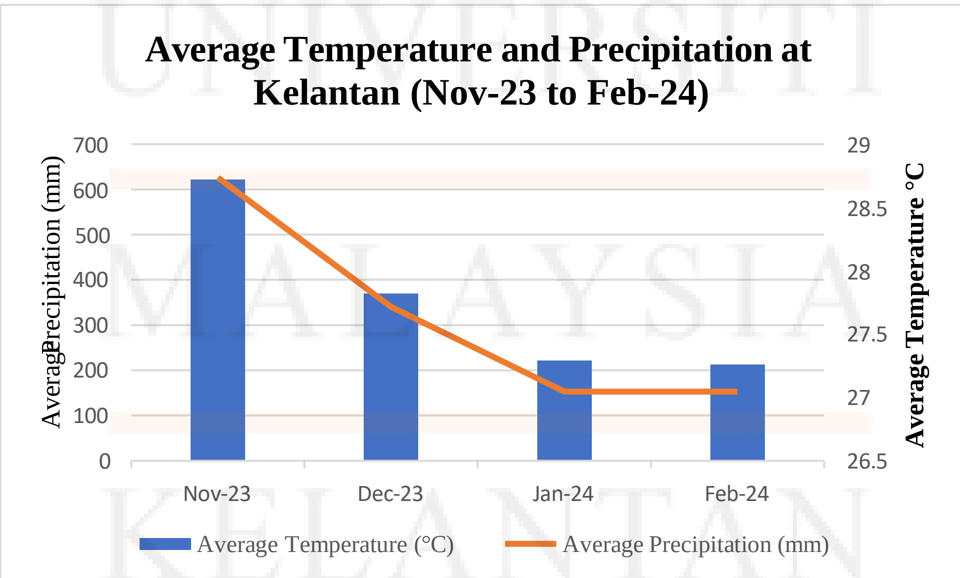

Figure 3.1: Average Temperature and Precipitation at Kelantan (Nov-23 to Feb-24)

Sources: (Weather Kelantan in November 2024: Temperature & climate n.d

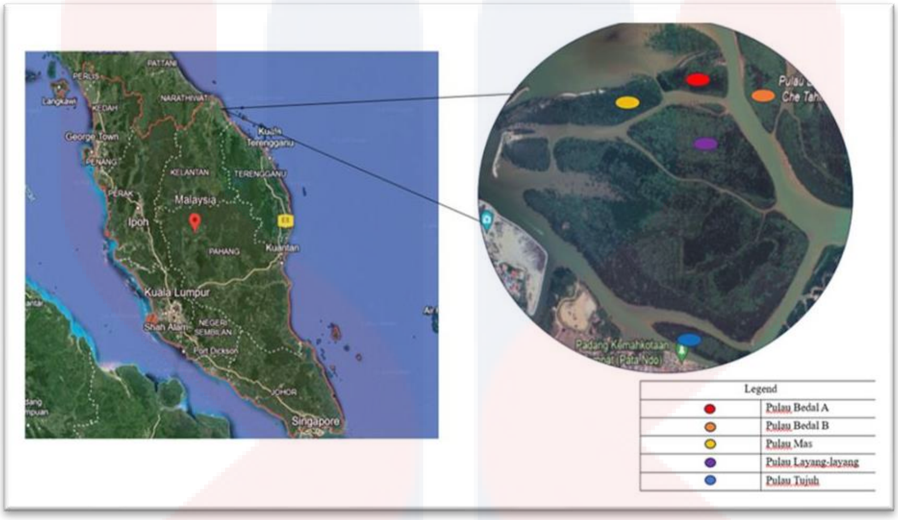

Figure 3.2: A map illustrating maps of Peninsular Malaysia (in red line) and study area, Delta Tumpat, Kelantan (Source: Google Earth 2018)

3.2 Method

The sampling that has been used is to assess a few parameters such as salinity, soil pH, DBH (cm), and height (m).

3.2.1 Material

For growth performance study, a few items that will be used for example:

Table 3.1: Material and function

Material	Function
DBH tape	To measuring Rhizophora tree diameter.
YSI multiparameter	To measure the salinity of water.
pH meter	To measure the pH soil of Rhizophora area
Field book	To record the data.
Raffia rope	To set the plot on Rhizophora area which are 20 x 20m
GPS	To Rhizophora area that has been recorded.

3.3 Data Collection

To study the growth performance of *Rhizophora mucronata* and *Rhizophora apiculata*, the following data collection methods has been applied:

3.3.1 Field Sampling Design

A 20m x 20m plot was set up at each study site. The plot was the same plot from the past study which is from Sunaini (2018). Among the parameters that were measured were DBH, tree height, crown diameter, and density of the Rhizophora. Other than that, soil analysis was conducted, which included pH, salinity, and. Climate data collection was also measured, such as temperatures and precipitation.

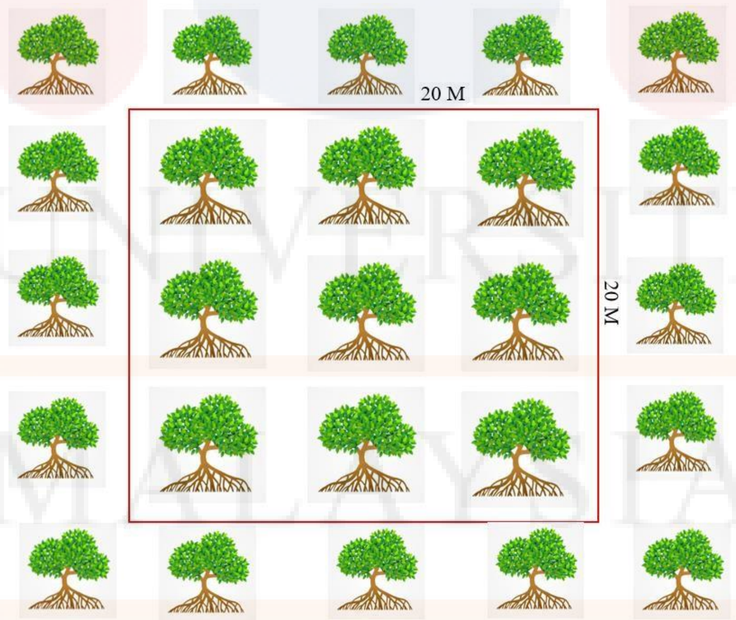

Figure 3.3: Size of the sampling design plot in the area

Table 3.2: Formula for parameter

No	Parameter	Formula	Area	Year	Author
1.	Mean crown diameter	$\sqrt{C} = \frac{1}{n}\sum C_d$	Tropical Area	2016	Suhardiman *et al*
2.	Basal area	$BA(cm^2) = \frac{\pi d^2}{4}$	Tropical Area	1984	Cintron & Schaeffer-Novelli
3.	Salinity	$Salinity(ppt) = \frac{Ptactical\ Salinity(PSU)}{1.80655}$	Tropical Area	1978	Lewis & Perkin
4.	pH soil Quality	$pH = -\log_{10}(H^+)$	Tropical Area	2022	Xie *et al*

3.4 Data Analysis

Data collected was recorded and tubulated in MS Excel. Data was analyzed and compared within study sites on the growth performance.

3.4.1 Descriptive Statistics

For descriptive statistics, the data that has been collected is used to measure central tendency. It is to find out the mean, median, and mode for each type of Rhizophora available for the five islands. Comparing Rhizophora growth rates across different locations or under different conditions can reveal significant patterns.

3.4.2 Comparative Analysis

The comparison between total number of trees, DBH, and height of Rhizophora species in five islands were done including a few other parameters such as soil conditions and water salinity levels.

3.4.3 Correlation Analysis

Correlation coefficient was carried out to analyzed Rhizophora growth performance, identifying and quantifying relationships between Diameter at Breast Height (DBH) and Height of Rhizophora It is to correlate Rhizophora species growth if there are any other factor in environmental ecosystem with DBH and height of five islands on Delta Tumpat that has been selected.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis of Tree Density, Basal Area, Soil pH and Salinity

Table 4.1 presents the data about tree density by calculating the number of trees collected in the sampling design by tree per hectare. Additionally, it includes data on the basal area of the plot, maximum diameter at breast height (DBH) in centimeters, tree height in meters, and soil pH of the plot. Pulau Tujuh, with *Rhizophora mucronata*, has the highest tree density (1300 trees per ha), followed closely by Pulau Bedal B, which is *Rhizophora apiculata* and has a second highest density (1,250 trees per ha). Pulau Mas has the lowest tree density (575 trees per ha). Pulau Bedal A ranks third in tree density but still has a high density (1,125 trees per ha), and lastly, the fourth location with the second lowest density (1,100 trees per ha) for tree density is Pulau Layang-layang. Other than the size of islands, there is another reason that can explain the difference result in tree density between different islands. The species composition of mangroves can vary between islands, and different mangrove species have varying growth rates, survival rates, and natural densities. This can lead to differences in overall density (Chen *et al.,* 2020).

For the basal area, the highest basal area (1.095 square meters per hectare) is Pulau Bedal B because, based on the area per plot, which is 400 square meters. For the other island such as Pulau Layang-layang had the basal area high basal area was too, with a per plot of

1.064 square meters per hectare. For the basal area at Pulau Tujuh, it had the third lowest which is 0.958 square meters per hectare, while Pulau Bedal A had the second lowest 0.923 square meters per hectare, and lastly Pulau Mas is the lowest among the five islands which is 0.920 square meters per hectare. The result of the basal area has a different number even though the recorded data tree per plot is different. For example, Pulau Bedal B had the second highest recorded data per tree, which is 50 trees per plot, while Pulau Tujuh had the highest recorded data per tree, which is 52 trees per plot. The reason the basal area had a different result is because the average diameter of the trees in each plot was different.

Then for the soil pH, based on the data, it is shown that the highest soil pH for at the islands is Pulau Layang-layang and Pulau Bedal A with the same number of pH which is 6.2. This indicates that the soil for Rhizophora species can tolerate that type of range. This is because, according to Idrus et al., (2021), the optimal soil pH Rhizophora species is typically between 6.0 to 7.5, which allows for better nutrient availability and plant health. In contrast, Pulau Tujuh has the lowest soil pH at 3.0, followed by Pulau Mas with a soil pH of 4.0, and Pulau Bedal B with a ph of 5.8. These soil pH variations across the islands bring out diverse soil conditions that influence the growth and health of Rhizophora species.

For salinity, the data that has been collected showed that the island of Rhizophora planted is more likely to have brackish water. with the highest salinity is Pulau Layang-layang, which is 15.77 parts per thousand (ppt). Then after that, the second highest salinity is Pulau Mas, which is 13.71 ppt, followed by Pulau Bedal B (12.94 ppt), Pulau Tujuh (12.31 ppt), and lastly Pulau Bedal A (11.51 ppt). However, most mangroves do better in salinity ranges between 3 to 27 ppt. Mangrove ecosystems typically experience a wide range of salinities, with porewater salinity ranging from 15 to 30 parts per thousand (ppt) (Hogan *et al.,* 2021). Also, according to Andik Dwi Muttaqin et al. (2024), the recommended salinity range for mangrove ecosystems is between 10 to 30 parts per thousand (ppt). According to Marappillige (2011), mangrove ecosystems are highly sensitive to environmental conditions such as salinity, temperature, and water depth. These conditions can vary significantly between islands, leading to differences in tree density.

Table 4. 1: Tree density, Basal area, soil pH, and Salinity

Islands	Coordinate	N	Tree Density (N/ha)	Basal Area (m2/h)	Soil pH	Salinity (ppt)
Mas	06°12’44.1” N 102°10’04.5” E	23	575	0.920	4	13.71
Layang- layang	04°47’56.7” N 101°56’06.4” E	44	1,100	1.064	6.2	15.77
Tujuh	04°48’15.1” N 101°57’01.5” E	52	1,300	0.958	3	12.31
Bedal A	04° 47’51.5” N 101°56’58.4” E	45	1,125	0.923	6.2	11.51
Bedal B	04°64’49.6” N 101°56’17.4” E	50	1,250	1.095	5.8	12.94

4.2 Growth of Rhizophora species in 2024

According to Mitra et al. (2017), an ecosystem can be considered healthy if it can maintain its structure and function under extreme stress conditions. Crown diameter is important because it is an indicator of a tree's health and growth potential. Based on study data that has been conducted by Hai et al. (2022) (table 4.2) which is about mangrove forest, an average crown diameter of greater than 8m are in "very good" health, while those with an average crown diameter of 5-8m are considered "good". The average crown diameter of 3-5m is considered "moderate" and finally the average crown diameter less than 3m are considered "worst" (Hai *et al.*, 2022). This can be observed in Table 4.3 which is Pulau Mas, despite having the fewest tree data collected in the sampling design that has been created. The island has the highest average crown diameter, which is 7.54 cm, placing it in the rank of 'Good' for characteristic of mangrove forest, nearly the ranks of 'Very Good'. Other than that, even though the number of crown diameters is far from Pulau Mas, Pulau Layang-layang with the diameter of the crown is 5.74 cm, and Pulau Bedal B with the diameter of 5.25 cm are also in the same ranks as Pulau Mas, which is 'Good'. Then the number of diameters for Pulau Tujuh is 4.12 cm and Pulau Bedal A is 4.25 cm, the ranks of the characteristics of mangrove forest for both are considered in 'Moderate'.

Table 4. 2: Classes of indicator for crown diameter

Characteristics of mangrove forest	**Ranks**
The average crown diameter of plants in the rich mangrove rehabilitation mangrove forest or *perennial mangrove forest > 8 m*	Very good
The average crown diameter of plants in the rich mangrove rehabilitation or *perennial mangrove forest*: 5 – 8m	Good
The average crown diameter of plants in the rich mangrove rehabilitation or *perennial mangrove forest*: 3 – 5m	Moderate
The average crown diameter of plants in the rich mangrove rehabilitation or *perennial mangrove forest* less than: 3m	Worst

(Source: Hai *et al.*, 2022)

Based on Table 4.3, the number of trees collected within a sampling design plot varies across the five islands. This can be looked at the data where are Pulau Tujuh has the highest count with 52 trees, meanwhile Pulau Mas has the lowest with only 23 trees. Then, the second highest data trees that collected is Pulau Bedal B with 50 trees in the sampling plot. Data trees that collected at Pulau Layang-layang is 44 trees and Pulau Bedal A is 45 trees. From the data, Pulau Bedal B has the highest average of DBH trees at 14.34 cm. Pulau Layang-layang comes next, with an average of DBH is 14.14 cm. At Pulau Mas, the DBH average is the lowest at 12.99 cm. The third highest average of DBH trees is Pulau Bedal A with 13.54 cm, and the second lowest average is Pulau Tujuh with 13.40 cm.

After that we go to the data about the average tree height that has been collected. The tallest tree data that recorded is at Pulau Bedal A with 13.38 m, followed by Pulau Bedal B which is 11.60 m. While the shortest of tree height recorded is Pulau Mas with 9.67 m. The second low is Pulau Tujuh with tree height recorded is 10. 32 m, and the third low is Pulau Layang-layang which is 11.28 m. Here we can see that, despite the tree age Rhizophora at Pulau Mas is the first planted which is 21-year-old compared to the other islands, but in terms of average DBH and tree height it is the lowest. In contrast to Pulau Bedal B which, although only 16 years old, has rapid growth in terms of average tree DBH and tree height. This can be looked at the data at table 4.1 where the conducive environment was at Pulau Bedal B where we can see that the most suitable for Rhizophora species to be planted.

Table 4. 3: Average of trees diameter, height, and crown diameter of each island

Islands	Rhizophora Species	No of tree/ ha	Average			Tree Age
			DBH (cm)	Tree Height (m)	Crown Diameter (cm)	
Mas	*R.mucronata*	23	12.99	9.67	7.54	21
Layang-layang	*R.mucronata*	44	14.14	11.28	5.73	20
Tujuh	*R.mucronata*	52	13.40	10.32	4.12	18
Bedal A	*R.apiculata*	45	13.54	13.38	4.25	18
Bedal B	*R.apiculata*	50	14.34	11.60	5.25	16

Figure 4.4 shows the graph of correlation between DBH (cm) and height (m) for the data collection that has been collected. Additional data that has been collected, which is under 10 cm below has been added to this graph to make sure to get a better projection of the result. The scatter plot of the Rhizophora species demonstrates a strong positive correlation between the height and diameter at breast height (DBH) of the trees. The plot shows that as the DBH of Rhizophora trees increases, their height also tends to increase. This is supported by the coefficient of determination, R^2 which is 0.7013, indicating that approximately 70.13% of the variance in tree height can be explained by variations in DBH.

The scatter plot reveals a cluster of data points with lower DBH values, specifically around the 2 to 5 cm range, where the heights of the trees vary significantly but generally remain below 10 meters. As DBH values increase beyond 10 cm, the heights of the trees also increase, albeit with some variability. Most data points for larger DBH values correspond to tree heights between 10 and 15 meters, with a few outliers extending to approximately 18 meters.The positive correlation observed in this plot can be attributed to the natural growth patterns of trees, whereas trees mature, their trunk diameter (DBH) generally increases, which is often accompanied by an increase in height.

This relationship is particularly important in forestry and ecological studies, where DBH and height are critical parameters for assessing tree biomass, carbon storage, and overall forest health. Based on the study that has been conducted by Irsadi et al., (2019), the result from their research about the nearby locations which is located in Timbulsloko village, Bedono Village and Trimulyo Village of mangrove ecosystem while the sites were geographically close, found that it can have different factors that influence mangrove ecosystem growth.

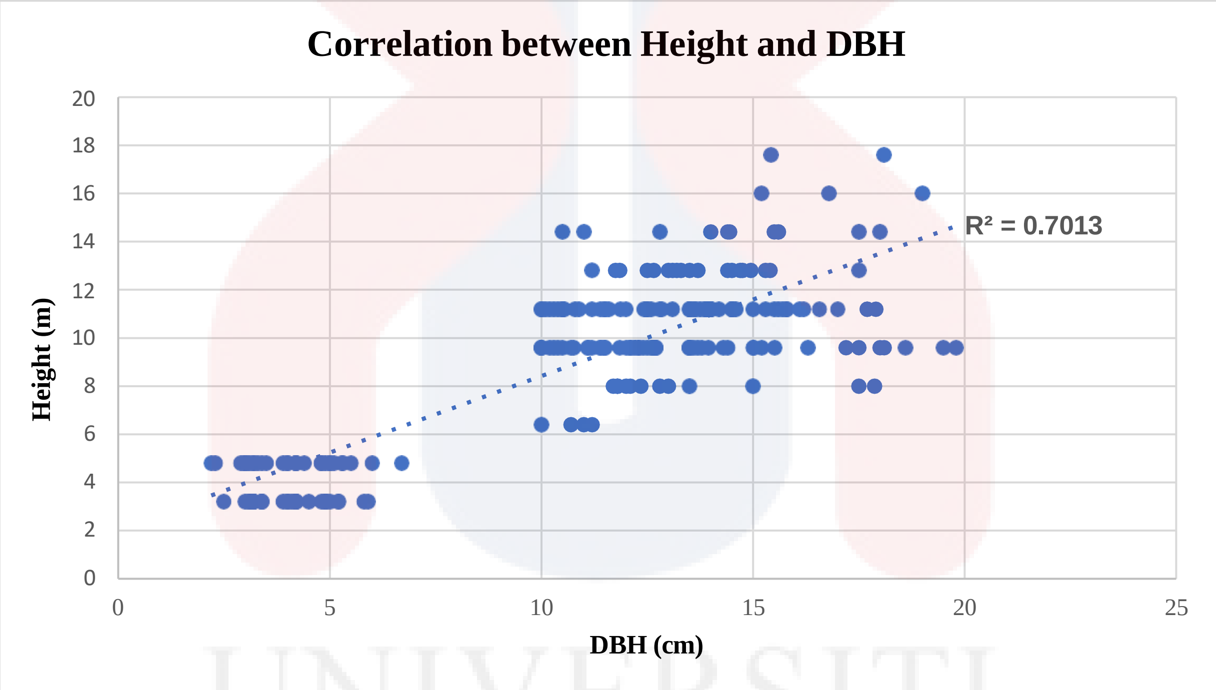

Figure 4.1: Graph of DBH (cm) and height (m) of Rhizophora sp. in each island

4.3 Distribution of Rhizophora species, DBH Classes, and Mean for Five Selected Islands

For the distribution of Rhizophora Species, based on table 4.4, most of the distribution of *Rhizophora mucronata* is on Pulau Mas, Pulau Layang-layang and Pulau Tujuh. Meanwhile, for the distribution of *Rhizophora apiculata* is on Pulau Bedal A and Pulau Bedal B. For the clear position of distribution Rhizophora species, it can be saw at figure 4.2 According to Akmar and Juliana (2012), *Rhizophora mucronata* is often preferred for planting over *Rhizophora apiculata* due to its broader ecological adaptability, superior growth characteristics in variable conditions, and higher reproductive success. Also based on the study, it is found that only 7.3% of flower buds from *Rhizophora apiculata* resulted in open flowers, with a mere 1.4% being fertilized, while *Rhizophora mucronata* showed significantly better reproductive output.

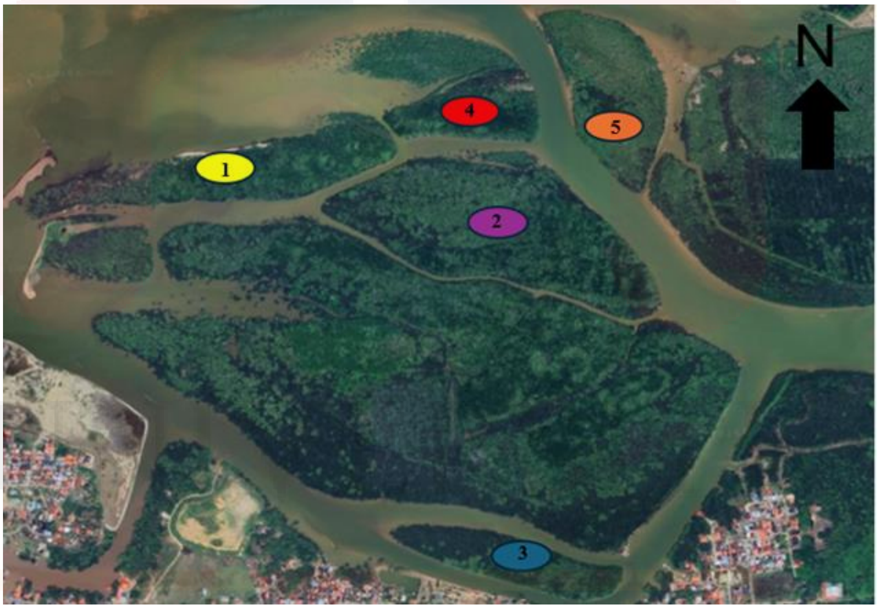

Figure 4.2: Distribution of Rhizophora species

Table 4. 4: Distribution of Rhizophora species

No	Islands	Distribution of Rhizophora species
1	Mas	*Rhizophora mucronata*
2	Layang-layang	*Rhizophora mucronata*
3	Tujuh	*Rhizophora mucronata*
4	Bedal A	*Rhizophora apiculata*
5	Bedal B	*Rhizophora apiculata*

In Table 4.5, the total number of recorded *Rhizophora apiculata* trees is 93, while the total for *Rhizophora mucronata* trees is 119. The highest number of trees, with diameters at breast height (DBH) in the 10 cm - 14.99 cm range, is 159. For the DBH class of 15 cm - 19.99 cm, the total number of trees is 49. In the DBH classes of 20 cm - 24.99 cm and 25 cm - 29.99 cm, there are only two trees in total. Based on the study that has been made by Sukardjo (1996), the researchers are trying to examine the relationship litterfall, basal area, and climatic variables in a *Rhizophora mucronata* plantation in Central Java, Indonesia. The factors influencing the DBH classes in Rhizophora species are primarily related to environmental conditions such as temperature and rainfall. Other than that, the study also found that the spatial patterns emerging from local tree interactions influence growth, mortality, and regeneration processes in the mangrove ecosystem.

Table 4. 5: DBH classes

DBH Classes (cm)	*Rhizophora apiculata*	*Rhizophora mucronata*
10- 14.99	69	90
15 – 19.99	22	27
20 – 24.99	1	1
25 – 29.99	1	1

Table 4.6 shows the data about mean DBH and height of trees across five different islands, and with the standard deviation. For Pulau Mas the mean DBH was 12.99 cm, with a standard deviation of 3.97cm, and the mean height was 9.67 m, with a standard deviation of 1.32 meters. That would mean that there was quite a wide range of variability in terms of tree trunks size but quite a narrow range about tree heights. Then, the data for Pulau Layang-layang trees shows the mean DBH of 14.14 cm with a standard deviation of 2.41 cm, and a mean height of 11.28 m, with a standard deviation of 2.43m, suggest that the trees on Pulau Layang-layang has a moderate variability in both their trunk diameter and heights.

After that we move to the data for Pulau Tujuh, which are the mean DBH is 13.40 cm with a standard deviation of 2.28 cm, and the mean height is 10.32 m, with a standard deviation of 1.35 m. This island can be seen that the Rhizophora on that island is more consistently in tree height than in trunk diameter. Pulau Bedal A has trees with a mean DBH of 13.54 cm with a standard deviation of 2.94 cm, and for the mean height is 13.38 m with a standard deviation of 2.16 m indicating that a considerable range in both DBH and height. Lastly, for Pulau Bedal B the mean DBH of 14.34 cm with a standard deviation of 2.63 cm, and a mean height of 11.6 m with a standard deviation of 3.32 m, show that the most by far it's the largest variability in tree height among the five islands.

Table 4. 6: Mean DBH and Mean Tree Height

Islands	**2024**	
	Mean DBH (cm)	Mean Tree Height (m)
Mas	12.99 ± 3.97	9.67 ± 1.32
Layang-layang	14.14 ± 2.41	11.28 ± 2.43
Tujuh	13.40 ± 2.28	10.32 ± 1.35
Bedal A	13.54 ± 2.94	13.38 ± 2.16
Bedal B	14.34 ± 2.62	11.6 ± 3.32

4.4 Growth Rate performance of Rhizophora trees species after 5 years

Table 4.7 shows the growth rate performance of Rhizophora trees species in 5 years. First based on the data that has been collected in 2019 by Sunaini (2018), the average DBH of trees shown that the smallest DBH is Pulau Bedal B with 2.3 cm, While the largest DBH of tree for Rhizophora tree is Pulau Mas with 6.9 cm. Then the average tree height at that time is Pulau Tujuh with the highest which is 7.47 m, while the lowest is Pulau Bedal B is 3.22 m. Then we compared it with the data that collected on 2024 which is the average DBH for Pulau Mas is 12.99 cm and the average of tree height is 9.67 m. While the average DBH of Pulau Bedal B is 13.34 and the average tree height is 11.6 m.

Through this study, there has been a significant increase in trees for Pulau Bedal B. With an increase in DBH of 2.41 cm every year and an increase in height of 1.68 m, the area of Rhizophora trees on that island grows faster. Then we compared the data from Pulau Layang-layang in 2019 and 2024. The data that was collected in 2019 shows that Pulau Layang-layang had an average DBH of 6.03 cm and an average tree height of 7.22 m. In 2024, the data show that the increase in each year with the average per year in DBH, which is 1.62 cm and 0.81 m, led to the average Rhizophora growth on this day with the DBH being 14.14 cm and the height being 11.28 m. Pulau Tujuh data collected in 2019 shows that the average DBH for that year was 5.79 cm, and for the tree height was 7.47 m. Based on the data collected this year, the average DBH is 13.40 cm and the height is 10.32 m. The increased number per year for DBH is 1.51 cm and the height is 0.57 m. Finally, for Pulau Bedal A the comparison between 2019 and 2024 shows that the increased average number per year in 5 years for DBH is 1.60 cm and the height is 1.68 m. The average DBH of trees in 2019 was 5.54 cm and their height was 5 m, become in 2024 with the average number of DBH has been 13.54 cm and the height of trees is 13. 38 m.

According to Maina (2014), human physical disturbance, such as overharvesting and digging for fish bait, can significantly alter mangrove forest structure. This can lead to a decline in forest complexity and changes in dominant tree species, ultimately affecting forest functioning and regeneration. This can be seen even more through the map in figure 3.1 which is the area of Pulau Mas, Pulau Tujuh, and Layang-layang, may often be involved with human activities causing a decrease in terms of growth per year, while Pulau Bedal A and Pulau Bedal B may be rare occurring with human activities such as development for aquaculture activity and likely that can cause annual growth for both islands to increase. Other than that, there can be another reason why mangroves growth pear year can be affected, such as vulnerable to sea level rise, which can lead to increased erosion and sediment loss, ultimately affecting them growth rate. For example, a study from Wilson (2017), found that mangrove sediment surface elevations are not keeping pace with sea level rise, making them more susceptible to inundation and degradation.

Table 4. 7: Comparison of data on year 2019 and year 2024

Island	**Data collected from 2019**		**Data collected from 2024**		**Growth rate performance in 5 years**	
	Average DBH (cm)	Average Height (m)	Average DBH (cm)	Average Height (m)	DBH (cm/year)	Height (m/year)
Mas	6.9	7.14	12.99	9.67	1.22	0.51
Layang-Layang	6.03	7.22	14.14	11.28	1.62	0.81
Tujuh	5.79	7.47	13.40	10.32	1.51	0.57
Bedal A	5.54	5	13.54	13.38	1.60	1.68
Bedal B	2.3	3.22	13.34	11.6	2.41	1.68

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, a comparative analysis of growth performance and distribution of Rhizophora species has been done from five islands (Pulau Mas, Pulau Layang-layang, Pulau Tujuh, Pulau Bedal A, and Pulau Bedal B) between 2019 and 2024. Based on the objective, it is found that Mas, Layang-layang and Tujuh are mostly with most of *Rhizophora mucronata* that has been planted on the island. For Bedal A and Bedal B, *Rhizophora apiculata* is the most planted tree on the islands. Then, also from this study, both Pulau Bedal A and Bedal B containing Rhizophora experienced enormous relative increases in both DBH and height as compared to the other islands which were dominated by *Rhizophora mucronata*. Bedal B showed somehow the fastest patter of growth with a yearly increment in DBH of 2.41 cm and height of 1.68 m. This may mean that *Rhizophora apiculata* is more vigorous and well suited to the conditions present on these islands, which makes it perform better. On the contrary, the islands having *Rhizophora mucronata* did not show wide growth compared to that of islands having *Rhizophora apiculata*, suggesting that there might be the possibility of species behavioral variation in growth under similar environmental factors.

5.2 Recommendation

For recommendation, more sampling and parameter should be conducted in future studies to obtain more accurate and better results for the research. one plot does not enough to assessing the overall growth performance of the mangrove area that has been selected at Delta Tumpat, Kelantan. Besides, the data collected in this research study can be referenced for future researcher and latest data update. Further study and more sampling points should be done in the area to add data and information on Delta Tumpat, Kelantan. This will help other related organizations in managing and conserving the area for its importance. More sampling in future study to obtain good results.

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APPENDIX

APPENDIX A

APPENDIX B

No	Pulau	Species	DBH (cm)	Height (m)
1	Pulau Tujuh	*R.mucronata*	10	16
2		*R.mucronata*	15.5	24.8
3		*R.mucronata*	11.8	18.88
4		*R.mucronata*	19.8	31.68
5		*R.mucronata*	15.7	25.12
6		*R.mucronata*	10	16
7		*R.mucronata*	17.2	27.52
8		*R.mucronata*	17.5	28
9		*R.mucronata*	13.5	21.6
10		*R.mucronata*	10.9	17.44
11		*R.mucronata*	Dead	Dead
12		*R.mucronata*	13.5	21.6
13		*R.mucronata*	13.5	21.6
14		*R.mucronata*	12.8	20.48
15		*R.mucronata*	13.1	20.96
16		*R.mucronata*	15.6	24.96
17		*R.mucronata*	14.4	23.04
18		*R.mucronata*	11.5	18.4
19		*R.mucronata*	16.2	25.92
20		*R.mucronata*	11.6	18.56
21		*R.mucronata*	13.5	21.6
22		*R.mucronata*	18.6	29.76
23		*R.mucronata*	14.2	22.72
24		*R.mucronata*	12.6	20.16
25		*R.mucronata*	10.5	16.8
26		*R.mucronata*	10.77	17.232
27		*R.mucronata*	Dead	Dead
28		*R.mucronata*	Dead	Dead
29		*R.mucronata*	14	22.4
30		*R.mucronata*	15	24
31		*R.mucronata*	10.1	16.16
32		*R.mucronata*	14	22.4
33		*R.mucronata*	11.5	18.4
34		*R.mucronata*	11.1	17.76
35		*R.mucronata*	11.5	18.4
36		*R.mucronata*	15.2	24.32
37		*R.mucronata*	11.2	17.92
38		*R.mucronata*	15.5	24.8
39		*R.mucronata*	13.6	21.76
40		*R.mucronata*	15.8	25.28
41		*R.mucronata*	11.4	18.24
42		*R.mucronata*	10.4	16.64
43		*R.mucronata*	12.7	20.32
44		*R.mucronata*	12.65	20.24
45		*R.mucronata*	11.75	18.8
46		*R.mucronata*	15	24
47		*R.mucronata*	12.8	20.48
48		*R.mucronata*	12.43	19.888

49		R.mucronata	13.6	21.76
50		R.mucronata	15.4	24.64
51		R.mucronata	11.85	18.96
52		R.mucronata	13.65	21.84

No	Pulau	Species	DBH (cm)	Height (m)
1	Pulau Mas	R.mucronata	11.2	6.4
2		R.mucronata	13	8
3		R.mucronata	11.8	8
4		R.mucronata	12.1	8
5		R.mucronata	13.95	9.6
6		R.mucronata	10.3	9.6
7		R.mucronata	12.8	8
8		R.mucronata	12.5	9.6
9		R.mucronata	11.4	9.6
10		R.mucronata	10	9.6
11		R.mucronata	11.1	9.6
12		R.mucronata	10.55	11.2
13		R.mucronata	19.5	9.6
14		R.mucronata	11.5	11.2
15		R.mucronata	27.8	9.6
16		R.mucronata	13.5	9.6
17		R.mucronata	10.2	9.6
18		R.mucronata	10.4	11.2
19		R.mucronata	11.87	11.2
20		R.mucronata	12.3	9.6
21		R.mucronata	17.9	11.2
22		R.mucronata	10.3	11.2
23		R.mucronata	12.85	11.2

No	Pulau	Species	DBH (cm)	Height (m)
1	Pulau Layang - Layang	*R.muconata*	11.4	11.2
2		*R.muconata*	13.85	11.2
3		*R.muconata*	Dead	Dead
4		*R.muconata*	12.35	8
5		*R.muconata*	Dead	9.6
6		*R.muconata*	Dead	11.2
7		*R.muconata*	13.9	11.2
8		*R.muconata*	Dead	Dead
9		*R.muconata*	12.5	11.2
10		*R.muconata*	12.3	9.6
11		*R.muconata*	17.87	8
12		*R.muconata*	Dead	Dead
13		*R.muconata*	13.75	11.2
14		*R.muconata*	15.8	11.2
15		*R.muconata*	15.43	17.6
16		*R.muconata*	10.5	11.2
17		*R.muconata*	10.5	14.4
18		*R.muconata*	12.62	9.6

19		*R.muconata*	11	6.4
20		*R.muconata*	13.5	12.8
21		*R.muconata*	10.8	11.2
22		*R.muconata*	16.1	11.2
23		*R.muconata*	13.8	9.6
24		*R.muconata*	Dead	Dead
25		*R.muconata*	12	8
26		*R.muconata*	14.6	11.2
27		*R.muconata*	15.3	12.8
28		*R.muconata*	Dead	Dead
29		*R.muconata*	14.5	11.2
30		*R.muconata*	18	14.4
31		*R.muconata*	16.57	11.2
32		*R.muconata*	21.5	6.4
33		*R.muconata*	17.5	14.4
34		*R.muconata*	12.6	8
35		*R.muconata*	12.5	8
36		*R.muconata*	14.75	12.8
37		*R.muconata*	11.85	12.8
38		*R.muconata*	14.45	14.4
39		*R.muconata*	13.1	12.8
40		*R.muconata*	17.5	12.8
41		*R.muconata*	15.6	14.4
42		*R.muconata*	14	11.2
43		*R.muconata*	13.5	11.2
44		*R.muconata*	15.5	14.4

No	Pulau	Species	DBH (cm)	Height (m)
1	Pulau Bedal A	*R. apiculata*	Dead	Dead
2		*R. apiculata*	13.7	14.8
3		*R. apiculata*	14.6	19.6
4		*R. apiculata*	Dead	Dead
5		*R. apiculata*	Dead	Dead
6		*R. apiculata*	Dead	Dead
7		*R. apiculata*	16	14.8
8		*R. apiculata*	14.8	16.4
9		*R. apiculata*	Dead	Dead
10		*R. apiculata*	Dead	Dead
11		*R. apiculata*	Dead	Dead
12		*R. apiculata*	12.3	16.4
13		*R. apiculata*	11.4	13.2
14		*R. apiculata*	15	14.8
15		*R. apiculata*	14.9	13.2
16		*R. apiculata*	19.3	13.2
17		*R. apiculata*	15.5	14.8
18		*R. apiculata*	15.2	14.8
19		*R. apiculata*	13.4	14.8
20		*R. apiculata*	10.6	16.4
21		*R. apiculata*	12.2	14.8
22		*R. apiculata*	13.4	18

23		*R. apiculata*	13.8	10
24		*R. apiculata*	11.2	11.6
25		*R. apiculata*	25.3	10
26		*R. apiculata*	14.7	11.6
27		*R. apiculata*	13.9	11.6
28		*R. apiculata*	11	13.2
29		*R. apiculata*	10.4	13.2
30		*R. apiculata*	11.2	13.2
31		*R. apiculata*	16.5	11.6
32		*R. apiculata*	14.7	11.6
33		*R. apiculata*	10.3	11.6
34		*R. apiculata*	11	13.2
35		*R. apiculata*	11.6	13.2
36		*R. apiculata*	12	13.2
37		*R. apiculata*	10.4	11.6
38		*R. apiculata*	10.9	13.2
39		*R. apiculata*	10	11.6
40		*R. apiculata*	13.3	11.6
41		*R. apiculata*	13	11.6
42		*R. apiculata*	15.1	11.6
43		*R. apiculata*	14.7	11.6
44		*R. apiculata*	Dead	Dead

No	Pulau	Species	DBH (cm)	Height (m)
P1	Pulau Bedal B	*R.apiculata*	11	14.4
P2		*R.apiculata*	13	12.8
P3		*R.apiculata*	18.1	17.6
P4		*R.apiculata*	14	14.4
P5		*R.apiculata*	13.2	12.8
P6		*R.apiculata*	12.8	14.4
P7		*R.apiculata*	13.3	12.8
P8		*R.apiculata*	14.4	14.4
P9		*R.apiculata*	15.2	16
P10		*R.apiculata*	19	16
P11		*R.apiculata*	10.5	11.2
P12		*R.apiculata*	24	14.4
P13		*R.apiculata*	Dead	Dead
P14		*R.apiculata*	14.7	12.8
P15		*R.apiculata*	11.2	11.2
P16		*R.apiculata*	Dead	Dead
P17		*R.apiculata*	12.5	12.8
P18		*R.apiculata*	13.7	12.8
P19		*R.apiculata*	14.5	12.8
P20		*R.apiculata*	15.6	14.4
P21		*R.apiculata*	11.2	12.8
P22		*R.apiculata*	16.8	16
P23		*R.apiculata*	17.5	8
P24		*R.apiculata*	18.1	9.6
P25		*R.apiculata*	11.7	8
P26		*R.apiculata*	16.3	9.6

P27		*R.apiculata*	12.7	9.6
P28		*R.apiculata*	12	11.2
P29		*R.apiculata*	14.5	11.2
P30		*R.apiculata*	17.7	11.2
P31		*R.apiculata*	12.1	9.6
P32		*R.apiculata*	14.3	9.6
P33		*R.apiculata*	18	9.6
P34		*R.apiculata*	17	11.2
P35		*R.apiculata*	12.5	11.2
P36		*R.apiculata*	14.5	11.2
P37		*R.apiculata*	12.7	9.6
P38		*R.apiculata*	15.3	11.2
P39		*R.apiculata*	12.1	9.6
P40		*R.apiculata*	12.4	9.6
P41		*R.apiculata*	12.6	9.6
P42		*R.apiculata*	12.2	9.6
P43		*R.apiculata*	14.4	9.6
P44		*R.apiculata*	17.7	11.2
P45		*R.apiculata*	14	11.2
P46		*R.apiculata*	15	11.2
P47		*R.apiculata*	13.7	9.6
P48		*R.apiculata*	11.8	8
P49		*R.apiculata*	15	9.6
P50		*R.apiculata*	12	9.6