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Investigating the Influence of Suspended Sediment on Mangrove Characteristics in Pantai Perpat, Johor, Malaysia

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ABSTRACT

Coastal ecosystems like mangroves, the littoral zone or estuaries play a significant role in maintaining the health and functionality of marine food chains by protecting and securing local rivers from water pollution and sediment delivery. Nevertheless, the coastal regions on the West Coast of Malaysia, particularly in Johor which includes Pantai Perpat (sandy-muddy beach) have undergone notable changes in mangrove vegetation due to the occurrence of excessive suspended sediment that could contribute to the fragmentation of mangrove trees. Thus, this study aims to exert the influence of suspended sediment on mangrove characteristics in Pantai Perpat, Johor. The study area has been divided into two (2) separate zones (Zone A and Zone B). The data in determining suspended solid and physical characteristics has been collected through laboratory tests and primary sources. Then, the data were analysed by using some statistical methods to achieve the objectives of the study. The result of suspended sediment analysis shows the relationship between turbidity and total suspended solids (TSS) in Zone A is higher compared to Zone B. It shows, that the higher the turbidity reading, the higher the TSS levels, thus weakening the soil condition at the location. Moreover, the result illustrates the relationship between TSS and physical characteristics of mangrove trees (diameter of breast height (DBH) and leaf size) and turbidity against physical characteristics: Zone A recorded significantly higher compared to Zone B. It proves, that the higher the TSS levels and turbidity reading, the lower the DBH and leaf size reading. It shows that suspended sediment influences the mangrove characteristics. Therefore, the study aims to exert the influence of the suspended sediment on mangrove characteristics in Pantai Perpat, Johor has achieved. Through this study, a better understanding of suspended sediment dynamics in coastal areas has been completed as well as providing essential information for conservation practices and future planning.

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1. Introduction

Coastal zones are particularly prone to erosion and changes caused by wave action. This is commonly referred to as the restricted area of land close to the coast where the sea and land meet [1]. The coastal zone is a complex and dynamic environment where a variety of activities and processes take place. Malaysia is located in Southeast Asia and is surrounded by the sea, providing a rich environment with abundant biological diversity and natural resources. It is known that the land area of Malaysia is 329,758 km2 and the coastal zone is 4,809 km in length [2]. However, according to the report on the National Coastal Erosion Study (NCES, 1980), 1,380 km of the country's coastline was subject to erosion, amounting 29 % increase [3]. Coastal erosion is a phenomenon that occurs when sediment accumulates over a long period in coastal zones due to changes in hydrodynamic processes, as well as natural processes caused by interactions between human activities and Mother Nature's systems [4]. For example, the movement of sediments, which is referred to as sediment transport and hydrodynamics.

Sediment transport in coastal areas is mainly influenced by dynamic nearshore processes and site-specific environmental conditions, including sediment characteristics, wind, waves, currents, tides and exchange processes between estuaries and nearshore regions [5]. A beach will experience erosion or sedimentation being dependent upon the equilibrium of incoming and outgoing sediment on the beach [6]. According to Zahari *et al.,* [7], sedimentation has negatively affected energy production and efficiency, as well as weakened flood mitigation capabilities. The effects of this phenomenon can lead to the loss of life, the disruption of economic activities and the degradation of natural ecosystems and biodiversity [8]. From these effects alone, environmental problems have been observed to affect more than 30 % of Malaysia's coastal population [9]. As a result of this, many coastal countries have initiated coastal protection to mitigate the issues. In coastal locations, one such effort is a mangrove tree plantation. Mangrove forests possess multiple functions for the environment and society through their valuable ecosystem services, including provisioning, regulating, habitat and cultural services [10].

Coastal ecosystems like mangroves, the littoral zone or estuaries play a significant role in maintaining the health and functionality of marine food chains by protecting and securing local rivers from water pollution and sediment delivery. Nevertheless, these ecosystems faced several difficulties, including sea level rise, climate change and human activities related to pollution, urban growth and land protection over the years [11]. Due to coastal development, pond extension and excessive logging, the area of mangrove forests worldwide has shrunk by 30 to 50 % over the past 50 years [12]. Other than that, suspended sediment also can influence mangrove in various of ways and the interaction between can have implications for their health and potential fragmentation of mangrove trees. Excessive sedimentation, especially in the form of fine sediments, can lead to waterlogged soils and reduce oxygen availability in the root zone, potentially causing stress to mangrove vegetation, thus contribute to the mangrove trees to shrunk [13]. The survival rate of young mangroves from restoration and conservation efforts proved to be highly challenging, as front mangrove areas frequently smothered by the sediment on the aerial roots [14]. Also, through the availability of nutrients in the soil, the state of the ground with an acid-to-base balance also has an impact on the growth of mangroves [15]. Consequently, natural processes have been drawn to the potential reactions of the mangrove population to changes in the coastal area [15].

The coastal regions on the West Coast of Malaysia, particularly in Johor which includes Pantai Perpat (sandy-muddy beach) have undergone notable changes in mangrove vegetation due to the occurrence of excessive suspended sediment that could contribute to the fragmentation of mangrove trees. These coastal areas are encountering various pressures, including accelerated coastal development, human impacts and the effects of climate change. The expansion of urban areas, infrastructure development and other human activities have resulted in modifications to coastal habitats and alterations in the dynamics of sediment transportation [16]. The coastal region of West Coast Malaysia has encountered amplified difficulties due to climate change, which comprises rising sea levels and extreme weather occurrences, pose a threat to mangroves as well as reducing the capacity of mangroves to provide many important ecosystem services.

This study concentrated on assessing mangrove areas in Pantai Perpat, Batu Pahat, Johor, since the state of the mangrove forest has deteriorated. In order to address this issue, the study aims to:

i. Determine the suspended sediment content.
ii. Determine the physical characteristics of mangrove trees, the diameter of breast height (DBH) and the leaf size at the study location.
iii. Exert the influence of suspended sediment on mangrove characteristics in Pantai Perpat, Johor.

The data in determining suspended solid and physical characteristics has been collected through laboratory tests and primary sources, with samples taken from the study location. Furthermore, the data were analysed by using some statistical methods in order to see the influence of suspended sediment on mangrove characteristic.

In the end, it shows that understanding suspended sediment dynamics plays a crucial role in conservation and planning. Understanding suspended sediment dynamics helps identify the areas where sediment deposition occurs, thus promoting mangrove growth. Conservation efforts can then focus on preserving these sedimentation zones to support the natural expansion of mangrove forests. Other than that, a better understanding of suspended sediment dynamics aids in identifying areas prone to erosion and determining the sediment retention capacity of mangrove ecosystems. Then, conservation measures can be implemented to protect mangroves and enhance their role in stabilizing the coastlines as it is already known that mangroves act as natural buffers against coastal erosion. Aside from that, excessive sedimentation can negatively impact water quality, affecting the health of mangrove ecosystems. Therefore, understanding sediment dynamics helps in developing strategies to maintain or improve water quality in mangrove habitats.

Hence, through this study, a better understanding of suspended sediment dynamics in coastal areas will be achieved as well as providing essential information for conservation practices and future planning. By addressing the objectives outlined, this research endeavours to contribute to the preservation and sustainable management of coastal and environmental areas, ensuring the long-term health and resilience of these critical ecosystems.

2. Methodology

The methodology used for determining the suspended sediment content and physical parameters of the mangrove trees in Pantai Perpat, Johor consists of several major steps. These steps include data collection for water sampling, DBH, the leaf of the mangrove tree, the colour and the shape of the leaf, laboratory analysis, data analysis and interpretation DBH. The combination of these steps provides a comprehensive understanding of the suspended sediment content and physical parameters of the mangrove trees.

2.1 Sampling Location

In this study area, Pantai Perpat, Batu Pahat Johor have been selected. This coastal area was chosen due to its location which has important qualities for water sampling. Figure 1 shows the location of the study area.

Fig. 1. Location of Pantai Perpat, Johor

The area for sampling data sites has been divided into two (2) zones (Zone A and Zone B) at different distances from the shoreline, 50 m to ensure the precision of the analysis, as shown in Figure 2. Each zone possesses a different environment that influences the development of mangroves. The implementation of this zoning system enables an in-depth investigation of the influence of suspended sediment on mangrove characteristics. On top of that, it is crucial to show the variables of the mangrove ecosystem in each zone. Thus, by selecting several sampling points, the research examined possible variations in soil composition, hydrological effects and climate change that affect the complex pattern of mangrove growth.

Fig. 2. Location of sampling area by zone

2.2 Sampling Collection

Collecting water samples to determine the total suspended solid (TSS) and turbidity of the sampling in a shoreline area involves several essential steps. First, wide-mouthed glass or plastic sample bottles were prepared with tight closures to avoid contamination. Then, it is recommended to prepare a sampling pole or rod with a solid handle and a measuring tape to ensure the accuracy of water depth measurements while minimizing sediment disturbance. In addition, it is necessary to use waterproof markers when labelling the sampling bottles with precision.

2.3 Laboratory Test

Laboratory tests are carried out on water samples taken from the study area. It is to determine the parameters for water quality to meet the formula's requirements. TSS and turbidity tests are the parameters that will be analysed in order to identify the water quality of the study area.

2.4 Physical Characteristics of Mangrove Trees

The evaluation of the effects of climate changes in the coastal area of characteristics for mangrove trees in the study area involved several crucial factors, such breadth of trees and leaf characteristics (size, colour and shape). To assess growth patterns and habitat structure, a measuring tape was used to measure the breadth of mangroves. The width of the mangrove tree, the parameter was taken at DBH. Also, the analysis of leaf characteristics was taken through the size, colour and shape of the leaf. The length and the breadth of the leaf were measured by measuring tape, while the colour and shape were observed visually and categorized using standard botanical terminology.

2.5 Data Analysis

The core data analysis process involves obtaining important insights and patterns from raw data including TSS, turbidity and influence analysis. Statistical and analytical methods translate the data into useful information, allowing informed decision-making. This study used data analysis to gain valuable insights into the Batu Pahat shoreline region and contribute to a better understanding of shoreline characteristics. Microsoft Excel 2019 was used as the software tool for conducting the data analysis and specific formulas were applied to calculate relevant statistical measures and characteristics.

2.5.1 Total suspended solids (TSS)

The TSS data of the sediment samples were analysed by using DR6000. A 30 ml water sample was prepared, stirred and divided into three (3) 10 ml sample cells. A separate cell with 10 ml of dilution water served as a reference. A blank sample cell was cleaned and inserted into the Hach DR6000 Spectrophotometer, along with the three (3) sample cells and the dilution water in order to obtain accurate readings. This method ensured a systematic and reliable assessment of TSS levels. The formula for TSS can be referred to Eq. (1) [17]:

$$TSS = \frac{(W2\ (g) - W1(g)) \times (1{,}000\ \times 1{,}000)}{v\ (mL)} \tag{1}$$

2.5.2 Turbidity

A nephelometer or turbidimeter measured the turbidity data. Turbidity measurements are in Nephelometric Turbidity Units (NTU), representing turbidity readings captured using white light at a 90-degree detection angle as a light beam passes through a water sample. The average turbidity values of the water samples for each station were calculated using the arithmetic mean formula. The arithmetic mean was calculated to determine the average value for each variable at each station. The formula for calculating the arithmetic mean can be referred to Eq. (2):

Mean, $\overline{x} = \frac{\sum x}{n}$ (2)

2.6 Influence Analysis

A thorough analytical analysis was developed to derive the data by using Microsoft Excel functions, charts and statistical tools. Influence analyses were used to determine how the two variables are related. The factors of suspended sediment and mangrove physical characteristics were determined for this study and the relationship between two (2) factors was analysed using the influence analysis in order to see where one variable can influence the other.

3. Results

This section discusses the results obtained from laboratory tests, TSS and turbidity tests as well as the finding obtained from the physical characteristics of mangrove trees in the study area. Then, the analysis between the suspended sediment test and physical characteristics will be elaborated in order to achieve the objectives of the study.

3.1 Total Suspended Solids (TSS)

TSS is a solid particle suspended in the water column of organic and inorganic materials, sized more than two micrometres [18,19]. The high concentration of TSS in the waters causes a decrease in water clarity, increases turbidity and potentially reduces dissolved oxygen which can threaten the life of aquatic biota [20-22]. Table 1 shows the data for TSS level fluctuations during the Southwest Monsoon across different zones of the study area. TSS was found at Zone A, 663 mg/L and significantly higher compared to Zone B, 228 mg/L, respectively. These variations underscore the spatial disparity in suspended sediment within the studied aquatic ecosystems.

Table 1
TSS levels for southwest monsoon

Location	TSS level (mg/L)
A	663
B	228

3.2 Turbidity

Turbidity is a physical property of fluids related to reduced optical transparency due to the presence of suspended and dissolved materials [23]. These materials can be of organic or inorganic origin, vary in colour, composition and size and are typically in the range of 0.004 mm (clay) to 1.0 mm (sand). The measurements are often used to indicate water quality based on clarity and estimated total suspended material [24]. Table 2 shows the data for turbidity during the Southwest Monsoon across different zones of the study area. Turbidity recorded at Zone A, 607 NTU while recorded at Zone B, 211 mg/L significantly lower to be compared.

Table 2
Turbidity reading for southwest monsoon

Location	Turbidity (NTU)
A	607
B	211

3.3 Relationship Between Turbidity and TSS

Table 3 shows the relationship between turbidity and TSS levels at different zones of sampling point in the study area. The predicted values indicate variations in both turbidity and TSS levels, prompting an examination of the potential causative factors behind these fluctuations.

Table 3
The relationship between the turbidity and TSS level for water samples

Location	Turbidity (NTU)	Total Suspended Solids, TSS (mg/L)
A	607	663
B	211	228

Figure 3 illustrates the relationship between the turbidity and TSS levels in different zones in the study area. Noteworthy, Zone A recorded the highest reading for turbidity and TSS levels as of 607 NTU and 663 mg/L compared to Zone B, respectively. The readings recorded for Zone B are 211 NTU for turbidity and 228 mg/L TSS levels. From the graph, it shows that the higher the turbidity reading, the higher the TSS levels. As Zone A resulting a high TSS and turbidity content, it proves that the water quality condition in the area is full of suspended sediment, thus weakening the soil condition at the location.

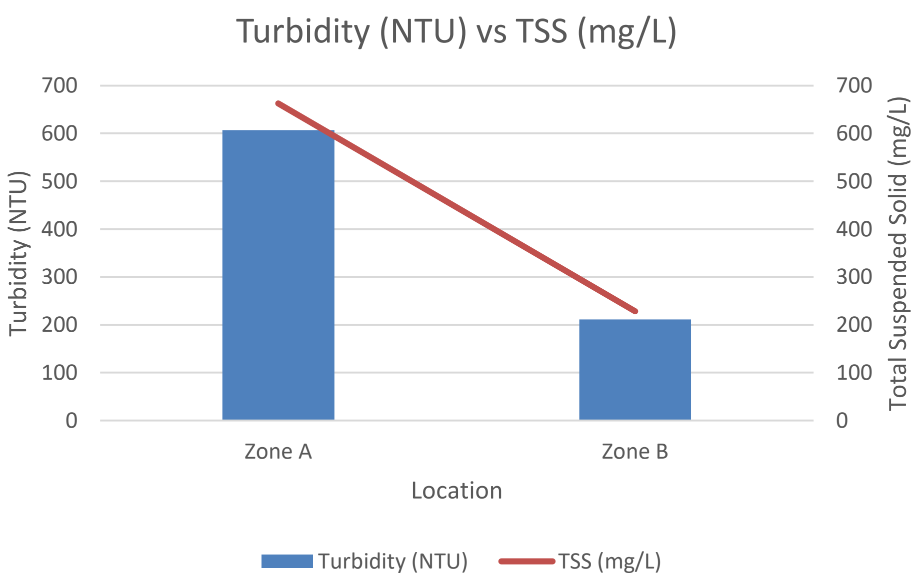

Fig. 3. The method used for measurement of biophysical parameters of mangrove trees

3.4 Physical Characteristics of Mangrove Trees

Table 4 shows mangrove tree characteristics in two (2) different zones at 50 m distances from the shoreline. Zone A recorded the DBH is 11.35 cm which is slightly lower than Zone B which is 17.23 cm, respectively. On the other hand, as for the area size of the leaf, Zone A recorded 41.72 cm2 while Zone B recorded 45.24 cm2 which is slightly bigger. However, the shape and colour of the leaf for both zones are recorded same characteristics, oblanceolate and dark green, respectively.

Table 4
Physical characteristics of mangrove trees at Pantai Perpat, Johor

Location	Diameter of Breast Height, DBH (cm)	Leaf size (cm2)	Shape	Colour
A	11.35	41.72	Oblanceolate	Dark Green
B	17.23	45.24	Oblanceolate	Dark Green

3.5 Relationship between Total Suspended Solids and Physical Characteristics of Mangrove Trees

Table 5 shows the reading recorded between the TSS and physical characteristics of mangrove trees int terms of DBH and leaf size. The data show the TSS levels for Zone A is 663 mg/L with 11.35 cm DBH and the area of size leaf is 41.72 cm2. Meanwhile, for Zone B, the TSS levels recorded are 228 mg/L, 17.23 cm DBH and 45.24 cm2, respectively.

Table 5
The reading for TSS and physical characteristics of mangrove trees

Location	Total Suspended Solids, TSS (mg/L)	Diameter of Breast Height, DBH (cm)	Leaf size (cm2)
A	663	11.35	41.72
B	228	17.23	45.24

Figure 4 shows the relationship between the TSS levels and DBH and Figure 5 shows the relationship between the TSS levels and leaf size of mangrove trees in two (2) different zones at 50 m distances from the shoreline. The graph illustrated that Zone A, 663 mg/L recorded high TSS levels compared to Zone B, 228 mg/L. As for the DBH reading, Zone A shows 11.35 cm slightly lower than Zone B, 17.23 cm reading. On top of that, the leaf size for Zone A is 41.72 cm2 while for Zone B, 45.24 cm2, respectively. Due to this event, the relationship shows that the higher the TSS levels, the lower the DBH and leaf size reading. This can be proved that the suspended sediment influences the mangrove characteristics. The water quality of the coastal areas thus causes the breadth height to decrease and the smaller leaf size of the mangrove trees, resulting slowly mangrove deterioration. This can be proved by a study that mentioned that excessive TSS levels, especially in the form of fine sediments, can lead to waterlogged soils and reduced oxygen availability. This may negatively impact root health and hinder nutrient uptake, potentially causing stress to mangrove vegetation [25].

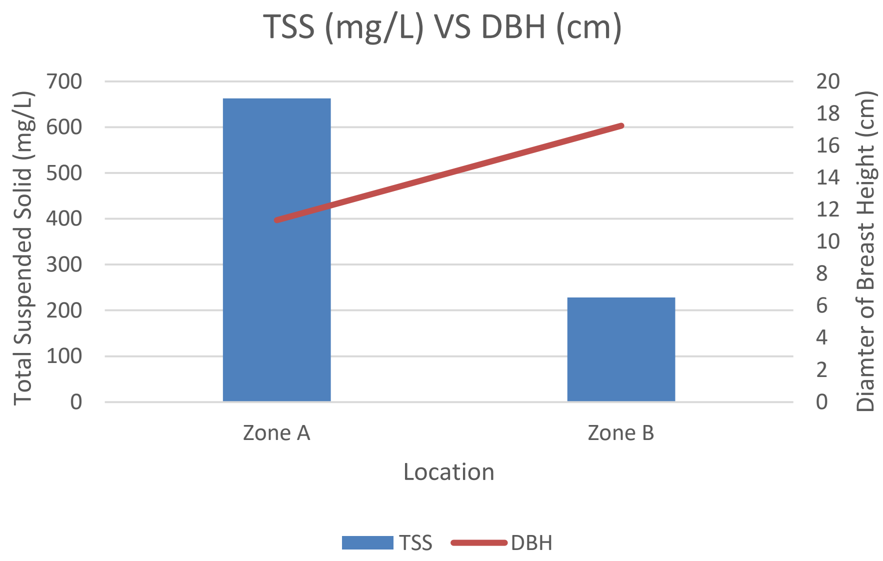

Fig. 4. The relationship between the TSS levels and DBH

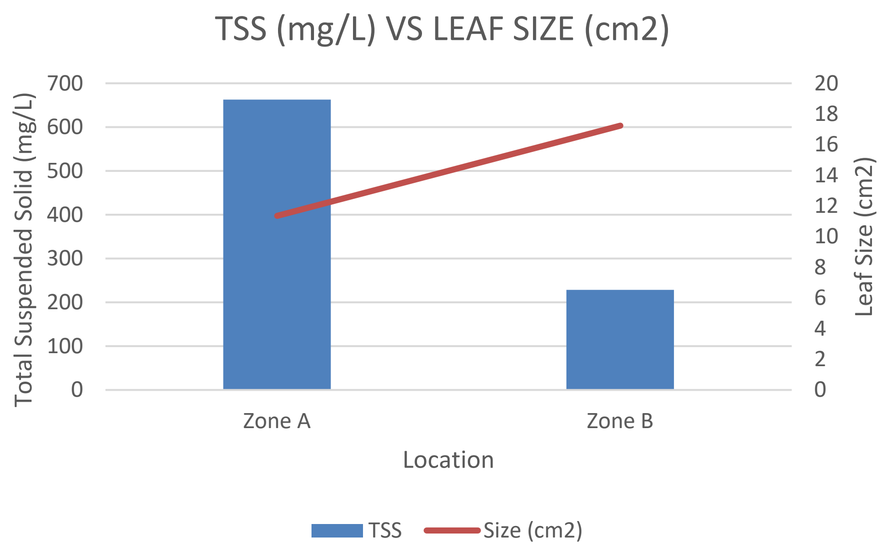

Fig. 5. The relationship between the TSS levels and leaf size

3.6 Relationship Between Turbidity and Physical Characteristics of Mangrove Trees

Table 6 shows the reading recorded between the turbidity and physical characteristics of mangrove trees int terms of DBH and leaf size. The data show the turbidity levels for Zone A is 607 NTU with 11.35 cm DBH and the area of size leaf is 41.72 cm^2. Meanwhile, for Zone B, the turbidity levels recorded are 211 NTU, 17.23 cm DBH and 45.24 cm^2, respectively.

Table 6
The reading for TSS and physical characteristics of mangrove trees

Location	Turbidity (NTU)	Diameter of Breast Height, DBH (cm)	Leaf size (cm^2)
A	607	11.35	41.72
B	211	17.23	45.24

Figure 6 shows the relationship between the TSS levels and DBH and Figure 7 shows the relationship between the TSS levels and leaf size of mangrove trees in two (2) different zones at 50 m distances from the shoreline. The graph illustrated that the turbidity reading for Zone A, 607 NTU was significantly higher than Zone B, 211 NTU. Nevertheless, the DBH and leaf size readings for Zone A, 11.35 cm and 41.72 cm2 are slightly lower than Zone B, 17.23 cm and 45.24 cm^2, respectively. Thus, the hypotheses can be made from this result the higher the turbidity reading, the lower the DBH and the smaller the leaf size of mangrove trees. It can be seen, that the suspended sediment influences the mangrove characteristics as result shown in the graph. From this point forward, it shows that the water of the coastal areas with high content of suspended sediment that later transported to the mangrove trees area, causing the breadth height to decrease and smaller the leaf size of mangrove trees. This goes well with a study stated high turbidity levels associated with excessive suspended sediment can reduce the light availability for photosynthesis. Prolonged periods of low light can hinder the growth of mangrove seedlings and may contribute to the decline of existing vegetation, leading to fragmentation and gaps in mangrove stands [26].

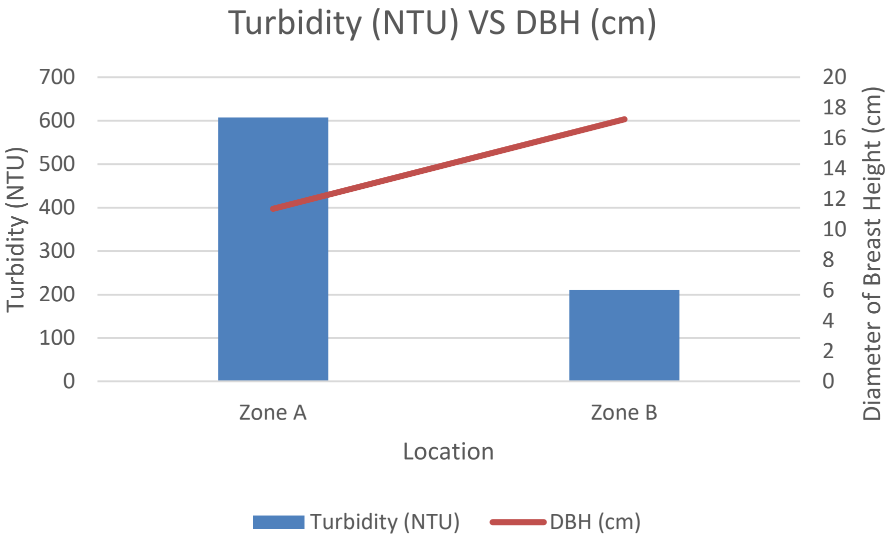

Fig. 6. The relationship between the turbidity and DBH

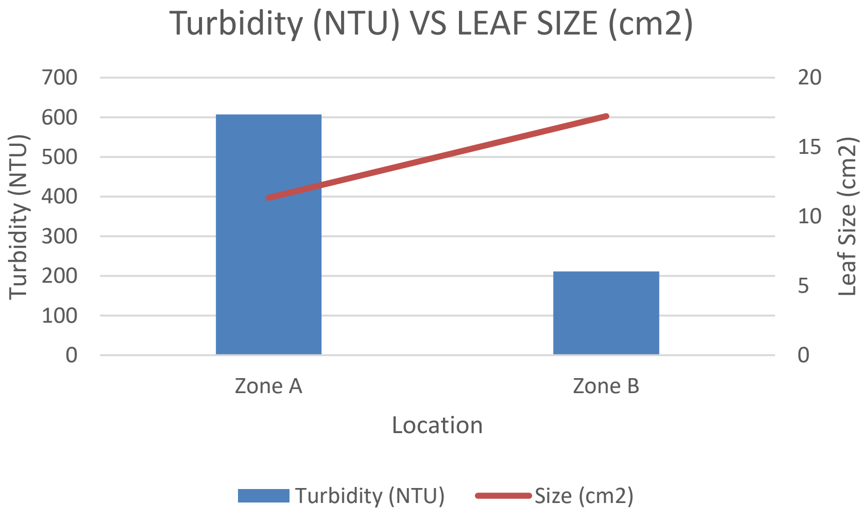

Fig. 7. The relationship between the turbidity and leaf size

4. Conclusions

Coastal ecosystems like mangroves, the littoral zone or estuaries play a significant role in maintaining the health and functionality of marine food chains by protecting and securing local rivers from water pollution and sediment delivery. Nevertheless, these ecosystems faced several difficulties, including sea level rise, climate change and human activities related to pollution, urban growth and land protection over the years. The issue at hand is the coastal regions on the West Coast of Malaysia, particularly in Johor which includes Pantai Perpat (sandy-muddy beach) have undergone notable changes in mangrove vegetation as the occurrence of excessive suspended sediment that could contribute to the fragmentation of mangrove trees. The coastal region has encountered amplified difficulties due to climate change, which comprises rising sea levels and extreme weather occurrences, posing a threat to mangroves as well as reducing the capacity of mangroves to provide many important ecosystem services. Therefore, this study concentrated on assessing mangrove areas in Pantai Perpat, Batu Pahat, Johor, since the state of the mangrove forest has undergone notable changes in mangrove vegetation. Intentionally to exert the influence of suspended sediment on mangrove characteristics in Pantai Perpat, Johor.

The result shows the relationship between two (2) laboratory tests, turbidity and TSS levels where Zone A (607 NTU and 663 mg/L) while Zone B (211 NTU and 228 mg/L). It shows that the higher the turbidity reading, the higher the TSS levels. The hypothesis made proves that the water quality condition at the area of Zone A has a high content of suspended sediment, thus weakening the soil condition at the location. On the other hand, the result illustrates the relationship between TSS levels and physical characteristics of mangrove trees, DBH and leaf size: Zone A (663 mg/L, 11.35 cm, 41.72 cm2) and Zone B (228 mg/L, 17.23 cm, 45.24 cm2). The relationship shows that the higher the TSS levels, the lower the DBH and leaf size readings. The water quality of the coastal areas has contended the suspended sediment thus influencing the breadth height to decrease and the smaller leaf size of the mangrove trees, resulting slowly mangrove deterioration. Meanwhile, the results show the relationship between turbidity and physical characteristics of mangrove tree, DBH and leaf size: Zone A (607 NTU, 11.35 cm, 41.72 cm2) and Zone B (211 NTU, 17.23 cm, 45.24 cm2). It can be seen, that the suspended sediment influences the mangrove characteristics as the higher the turbidity reading, the lower the DBH and the smaller the leaf size of mangrove trees.

Hence, it can be proved that the suspended sediment influences the mangrove characteristics as shown by the result above. Therefore, the study aims have been achieved to investigate the influence of the suspended sediment on mangrove characteristics in Pantai Perpat, Johor. Nonetheless, the limitation this study faces is the location of the study area only focusing on one (1) place. Thus, the recommendation that can be made for future research in finding a full concentration of the suspended sediment is by conducting in a different location and multiplying the study location in one (1) study. Through this study, a better understanding of suspended sediment dynamics in coastal areas has been completed as well as providing essential information for conservation practices and future planning.

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