



UNIVERSITI PUTRA MALAYSIA

***DIVERSITY AND MORPHOMETRIC OF
SIBUTI MANGROVE GASTROPOD***

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DIVERSITY AND MORPHOMETRIC OF SIBUTI MANGROVE GASTROPOD

BY

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ABSTRACT

Gastropods are the most common species in shallow water. These gastropods are easily found in areas where sunlight, which plays a role in algal growth and affects humidity in mangrove areas, saltwater tides, salinity, and substrate type can all affect gastropod dispersal. The lack of documented information on gastropod diversity and morphology in mangrove areas makes it difficult to assess the structural health of mangrove gastropod communities from Sibuti mangroves. This study was conducted to identify gastropod species in the Sibuti mangrove area and to identify the diversity and morphometric diversity in different section in the Sibuti mangrove. Quadrat and transect methods were used in this study to obtain samples of pore water, river water, and gastropods. morphometric analysis was used to determine the morphological measurements of gastropod shells. There are 8 species of 4 families and 5 genera found and station 2 recorded high diversity. station 1 has the highest value of uniformity and richness compared to stations 2 and 3 and *Cerithidea charbonnieri* has the most abundant individuals of 73 ind/10m². While the morphometric shows that the Littorinidae family has little significant difference compared to other families. The Potamididae family shows that *Cerithidea charbonnieri* has the greatest height compared to *Cerithidea quoyii* and *Neripteron violaceum* has many high measurements compared to the two species of the family. Thus, the Sibuti mangrove forest needs to be preserved to maintain the diversity of gastropods to support the ecosystem in the mangrove area.

ABSTRAK

Gastropod adalah spesies yang paling biasa di air cetek. Gastropod ini mudah ditemui di kawasan di mana cahaya matahari, yang memainkan peranan dalam pertumbuhan alga dan menjejaskan kelembapan di kawasan bakau, pasang surut air masin, kemasinan, dan jenis substrat semuanya boleh menjejaskan penyebaran gastropod. Kekurangan maklumat yang didokumenkan tentang kepelbagaian gastropod dan morfologi di kawasan bakau menyebabkan sukar untuk menilai kesihatan struktur komuniti gastropod bakau dari bakau Sibuti. Kajian ini dijalankan untuk mengenal pasti spesies gastropod di kawasan bakau Sibuti dan mengenal pasti kepelbagaian dan kepelbagaian morfometrik di bahagian yang berbeza dalam bakau Sibuti. Kaedah kuadrat dan transek digunakan dalam kajian ini untuk mendapatkan sampel air liang, air sungai, dan gastropod. Analisis morfometrik digunakan untuk menentukan ukuran morfologi cengkerang gastropod. Terdapat 8 spesies daripada 4 famili dan 5 genera ditemui dan stesen 2 merekodkan kepelbagaian yang tinggi. stesen 1 mempunyai nilai keseragaman dan kekayaan yang paling tinggi berbanding stesen 2 dan 3 dan *Cerithidea charbonnieri* mempunyai individu yang paling banyak iaitu 73 ind/10m². Manakala morfometrik menunjukkan famili Littorinidae mempunyai sedikit perbezaan yang ketara berbanding famili lain. Keluarga Potamididae menunjukkan bahawa *Cerithidea charbonnieri* mempunyai ketinggian yang paling tinggi berbanding dengan *Cerithidea quoyii* dan *Neripteron violaceum* mempunyai banyak ukuran yang tinggi berbanding dua spesies famili tersebut. Justeru, hutan bakau Sibuti perlu dipelihara bagi mengekalkan kepelbagaian gastropod bagi menyokong ekosistem di kawasan bakau.

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APPROVAL SHEET

I certify that this research project report entitled Diversity and “Morphometric of Sibuti Mangrove Gastropod” has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Science (Honors) Aquaculture in the Faculty of Agricultural Science and Forestry, Universiti Putra Malaysia Bintulu Sarawak Campus.

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TABLE OF CONTENT

	Page
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGMENT	iii
APPROVAL SHEET	iv
TABLE OF CONTENTS	v
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF ABVREVIATIONS	xiii

CHAPTER

1	INTRODUCTION	Page
1.1	Background study	1-2
1.2	Problem statement	2-3
1.3	Objective	3
2	LITERATURE REVIEW	
2.1	Mangrove in Sarawak	4-5
2.2	Gastropod species in Sarawak	5
	2.2.1 Taxonomy	5-6

2.2.2 Family Neritidae	6
2.2.3 Family potamididae	6-7
2.3 Morphology and Morphometric	7-8
2.3.1 Classification and Morphology	8-9
2.4 Mangrove Gastropod Distribution in Sarawak	9-10
2.4.1 Mangrove Gastropod Diversity and Distribution in Sematan Sarawak	10
2.4.2 Mangrove Gastropod Diversity and Distribution in Pendam Sarawak	11
2.5 Environmental Characteristic in Mangrove	12
2.5.1 Soil	13
2.5.2 Salinity	13
2.5.3 Temperature	14
2.5.4 Soil and water pH	14
2.5.5 Dissolved Oxygen	14-15

3

MATERIAL AND METHODS

3.1 Study area	16
3.2 Gastropod and water Sampling procedure	17-18

3.3	Gastropod Identification	17-18
3.4	Gastropod Morphometric	18-19
3.5	Statistical Analysis	19
3.5.1	Diversity Analysis	19
3.5.2	Ex situ (pore water) and In-situ (river) water One-Way ANOVA	20
3.5.3	Morphometric One-Way ANOVA	20
3.5.4	T test statistical analysis	20
3.5.5	Relationship between Abiotic factor and Biotic	21
4	RESULT	
4.1	Gastropod species	22
4.2	Gastropod morphological structure	23-30
4.3	Gastropod Diversity, Richness, and Evenness index	31-32
4.3.1	Gastropod diversity, Richness and Evenness index	32
4.4	Gastropod Morphometric	33
4.4.1	Neritidae morphometric	33-34
4.4.2	Potamididae Morphometric	34-35
4.4.3	Littorinidae morphometric	35-36

4.5	Physio- chemical Water Parameters	36
4.5.1	One-Way ANOVA Pore water analysis	36-37
4.5.2	One-Way ANOVA <i>In situ</i> water analysis	37-38
4.6	Pearson Correlation of Pore Water Parameter	
4.6.1	Shannon Weiner Diversity Index	39-40
4.6.2	Pieluo's evenness index	40-41
4.6.3	Margalef Richnes Index	41-42
4.7	Pearson Correlation of <i>In-situ</i> Water Parameter	43
4.7.1	Shannon Weiner diversity index Correlation at Sibuti Mangrove	43
4.7.2	Evenness Correlation at Sibuti Mangrove	44
4.7.3	Margalef Richness Index Correlation at Sibuti Mangrove	44-45
5	DISCUSSION	
5.1	Gastropod Diversity	46-47
5.2	Morphometric of Gastropod	48
5.2.1	Neritidae Morphometric	48
5.2.2	Potamididae Morphometric	49
5.2.3	Littorinidae Morphometric	50

5.3	Physicochemical Parameters of Pore Water and The Association of Diversity Index	51-55
5.4	Physicochemical Parameters of <i>In situ</i> with diversity index association.	55-58
6	CONCLUSION	59
	REFERENCES	60-71
	APPENDICES	
	Appendix A: study site	72
	Appendix Appendix B: Equipment for Sampling	72-73
	Appendix C: Gastropod on Mangrove	74

List of Table

Table	Page
2.1 Gastropod spesies in Sematan Sarawak	10
2.2 Gastropod diversity in Pendam Sarawak	11
4.1 Gastropod species collected from three station of Sibuti mangrove.	22
4.2 One-Way ANOVA morphometric of Neritidae families from the Sibuti	34
4.3 T-test analysis on morphometric of Potamidæ families from the Sibuti	35
4.4 T-test analysis on morphometric of Littorinidae families from the Sibuti	36
4.5 One- Way ANOVA of Pore water parameter from Sibuti mangrove	37
4.6 One-Way ANOVA of <i>In situ</i> water analysis from Sibuti mangrove river	38
4.7 Person correlation of Shannon Wiener diversity index with pore water parameter at Sibuti mangrove	40
4.8 Pearson correlation of Evenness with pore water parameter at Sibuti mangrove	41
4.9 Pearson correlation of Margalef richness index with pore water parameter at Sibuti mangrove	42

4.10	Person correlation of Shannon Weiner diversity index with <i>In-situ</i> water parameter at Sibuti Mangrove	43
4.11	Pearson correlation of Evenness with <i>In-situ</i> water parameter at Sibuti Mangrove	44
4.12	Pearson correlation of Margalef richness index with <i>In-situ</i> water parameter at Sibuti Mangrove	45



List of Figure

Figure	Page
1.1 The shell's basic anatomy	9
3.1 Sampling site (Sibuti mangrove)	16
3.3 shell morphometric and characteristic	19
4.1 Morphological <i>Littoraria scabra</i> (Linnaeus, 1758)	23
4.2 Morphological <i>Littoraria carinifera</i> (Menke, 1830)	24
4.3 Morphological <i>Neripteron violaceum</i> (Gmelin, 1791)	25
4.4 Morphological <i>Vittina coromandeliana</i> (G.B. Sowerby I, 1836)	26
4.5 Morphological <i>Neripteron cornucopia</i> (W. H. Behson, 1836)	27
4.6 Morphological <i>Cerithidea quoyii</i> (Hombron & Jacquinot, 1848)	28
4.7 Morphological <i>Cerithidea charbonnieri</i> (Petit de la Saussaye, 1851)	29
4.8 Morphological <i>Ellobium aurismidae</i> (Linnaeus, 1758)	30
4.9 Number of gastropod species at Sibuti Mangrove	31
4.10 Individuals of gastropod species at Sibuti Mangrove	31
4.11 Diversity index at Sibuti Mangrove	32

LIST OF ABBREVIATIONS

N	Latitude
E	Longitude
TDS	Total Dissolved Solid
DO	Dissolved Oxygen
NTU	Nephelometric Turbidity Unit
PPM	Part Per Million
SL	Standard Length
SD	Shell Depth
SW	Shell Width
BW	Body Width
AL	Aperture Length
AW	Aperture Width
LPL	Lower Lip Thickness
LPM	Middle Lip Thickness
LPU	Upper Lip Thickness

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Mangrove areas in Sarawak are 26% of the total of 126,400 ha (Hanum et al. 2014). Mangroves have been considered the most productive environments in ecology. (Berger et al., 2008). Mangrove forests have high biodiversity and habitat, shelter, and food for various fauna species. The mangrove ecosystem presents a variety of related fauna, including gastropods, and the distribution of species, abundance, diversity, and biomass of gastropods change depending on the ecology of the mangrove environment. (Zvonareva et al., 2015). However, this seasonal pattern in Southeast Asia has increased the diversity of gastropods in this region by providing a nutrient-rich environment (Faunas et al. 2000).

These gastropods live in tidal and muddy areas as habitats, and some species have been reported to have varying levels of adherence within the mangrove ecosystem, even though they can be found in areas other than mangroves (Lozouet & Plaziat 2008). Gastropods also inhabit areas with salt water such as seas and fresh water such as rivers. Some groups live in highly saline environments such as the Caspian Sea or salt lakes in Central Asia, Africa, and Australia, especially some *rissooidean* families. (Strong et al., 2008). Except Antarctica, Freshwater gastropods can be identified on every continent as well as in practically every aquatic habitat, including rivers, lakes, streams, swamps,

subterranean aquifers, and springs, as well as temporary lakes, drainage ditches, and other transitory and seasonal waterways (Strong et al., 2008)

According to Puryono and Suryanti (2019) gastropods are the most common collection of species in shallow water. These gastropods are easy to find in areas where sunlight, which plays a role in algae growth and influences humidity in mangrove regions, saltwater tides, salinity, and substrate type can all influence the dispersion of gastropods. Therefore, in some mangrove habitats, gastropods can achieve very high species diversity (Nagelkerken et al., 2008). It is the most diverse class of the phylum Mollusca, which includes almost all the 110,000 or more species of molluscs (Brown and Lydeard 2010). Therefore, this gastropod is important in directly or indirectly supporting the mangrove function. It is important to consider the significance of gastropods in the food chain of other living creatures and some gastropods are predators, and some are herbivores eating on algae or plant matter. They also eat fallen plants and dead animal matter. These gastropods might be recognized one of the ecosystem's decomposing organisms (Puryono & Suryanti 2019).

1.2 Problem Statement

The lack of documented information on the diversity and morphology of gastropods in mangrove areas makes it difficult to assess the mangrove gastropod community structure health from the Sibuti mangrove. However, gastropod diversity and morphology data can be compared within the mangrove section. Therefore, the results of this study will be used in the future to provide significant knowledge regarding the diversity of gastropod

species found in the mangrove habitat environment and the density of gastropod species in each part of the mangrove.

1.3 Objective

The objective of this study is:

1. To identify gastropods species in the Sibuti mangrove.
2. To evaluate the diversity and morphometric of gastropods at the different section in Sibuti mangrove.

CHAPTER 2

LITERATURE REVIEW

2.1 Mangrove in Sarawak

Mangrove forests are a common backwoods biological system that develops near the coast or estuaries and is influenced by tide and stream with a broad range of circumstances all through the tropical and subtropical zones (Irma & Sofyatuddin 2012). Mangroves are primarily intertidal ecosystems that occur across the (sub)tropics along sheltered and shallow water coasts. Mangrove forests often develop in the intertidal zone, where the soil is muddy, clayey, and sandy and is not inundated every day or every full moon (Komalasari 2018).

Mangrove tree prop-roots and pneumatophores spread into the intertidal and subtidal zones, where they become an unusual component: Hard substrata in an otherwise soft sediment environment (Ellison and Farnsworth' 1992). Mangroves, among other natural systems, defend against floods and storms, minimise coastline and riverbank erosion, and maintain wildlife. Mangrove biological systems are extremely beneficial and contribute a few essential natural administrations, for example, territorial arrangement, supplement dissemination, environmental change moderation, coastal security, and diversion, as well as for human survival and employment. Mangroves' capacity to sustain mollusk, fish, and shrimp aquaculture is another aspect of their role as life-support systems. (Rö, 1999). One of the most significant components of the mangrove fauna are gastropod molluscs that process mangrove-derived and algal debris through feeding and bioturbation (Bouillon et al. 2002).

Kanniah et al. (2015) has stated that, the entire global coverage of mangrove forests is 15.62 Mha, with Malaysia accounting for 3.7% of this total. Mangroves are predominantly found along Peninsular Malaysia's west coast and in Malaysian Borneo's states of Sabah and Sarawak. Many types of mangrove trees grow in Malaysia, but those in the Rhizophoraceae family are notably common. On the other hand, the diversity of these plants is immense, with no fewer than 70 species originating from 28 distinct plant families that thrive and exist here (Status of Mangroves in Malaysia, 2020). The Kisap Forest Reserve has record 1217 trees, which include 7 species and 5 genera from three families. *Ceriops tagal*, *Rhizophora apiculata*, *R. mucronata*, *Bruguiera parviflora*, and *B. gymnorhiza* (Rhizophoraceae), *Xylocarpus granatum* (Meliaceae), and *Avicennia officinalis* (Avicenniaceae) were among the plants present (Omar et al. 2018).

2.2 Gastropod species in Sarawak

2.2.1 Taxonomy

Gastropods are the largest and diverse class of animals in the phylum Mollusca. Many gastropods have shells, but some do not (Venkatesan & Mohamed 2015). The British began taxonomic research of mollusks in Peninsular Malaysia and Sabah in the early 1930s. They documented every gastropod found in Batu Cave, Selangor. Meanwhile, in Sarawak, the Dutch began studying mollusk taxonomy in the early 1890s, collecting gastropods from hills and rivers (Schepman, 1890). Several research on the gastropods of Sarawak have been published. Wet markets in Kuching, Sibul, Mukah, Bintulu, Miri,

Limbang, and Lawas, for example, sell 21 kinds of edible gastropods (Hamli et al., 2013). Unfortunately, the intertidal mollusk population appears to have diminished because of changes in water conditions caused by human activities, pollution levels, and climate change. (Ahmad et al. 2011)

2.2.2 Family Neritidae

According to Tan and Clements (2008) The gastropods of the family Neritidae can be found in freshwater, marine, and saline environments. These herbivores are gregarious and reside in the intermediate to higher intertidal zones along the coast. The majority of neritids are euryhaline; *Clithon* and *Neritina* species living in freshwater or brackish environments, whilst *Nerita* species are more intimately related with the marine environment. The most extensively dispersed local species is *Nerita articulata*, which is regularly found on monsoon canal walls and mangrove trees and can occasionally number in the hundreds in a single site. It was discovered in more than 70% of the sample locations.

2.2.3 Family potamididae

Potamidids are among the most specialized molluscan inhabitants of this ecosystem, and a long evolutionary association between mud whelks and mangroves has been hypothesized. The *Potamididae* consist of five living genera: *Potamides*, *Cerithidea*, *Terebralia*, *Telescopium* and *Tympanotonos*. These each occupy a distinct range of microhabitats within mangrove forests, among saltworts, in saltmarsh and on adjacent tidal flats and saltpans (Reid et al. 2008).

Houbrick (1991) has discovered *Terebralia* and *Telescopium* species are massive prosobranchs that occur in large numbers and could regulate the outer layer of mangrove sloppy bottoms. All the extant Potamididae genera live in mangroves and rely on the trees for food, refuge, and protection from predators. *Terebralia palustris* has a feeding specialisation, benefiting as an adult from fallen *Rhizophora* leaves via an extremely altered radula.

2.3 Morphology and Morphometric

Form and morphology have always been important in taxonomic categorization. Despite recent genetic discoveries, morphological evaluation remains the major method of species grouping and categorization. As a result, methodological comparisons for morphological data gathering and analysis are critical. The 'geometric-morphometric revolution' has enhanced the study of morphology in recent decades, referring to a family of methodologies that employ landmark- or outline-based methods to record morphology as a collection of Cartesian coordinates or outline contours. Using multivariate statistics, this morphological information may subsequently be compared between populations or species (Marcus et al. 1993 ; Adams et al. 2004)

According to Houbrick (1991). *Telescopium* *Slieii* is massive, thick, and conical. It features a shell base with a deep channel around the columellar pillar and concentric cords, as well as multiple flat-sided whorls with spiral grooves on them. The outer lip is bent towards the short, central siphonal canal, and the aperture is narrowly oval and tangential (perpendicular) to the shell's axis. The columella is channelled and twisted. The operculum's core nucleus is round, multispiral, and corneous. A tooth having a prominent lateral lamella. The radula of the taenioglossate is relatively short, and the

snout is quite long with a modest buccal mass. An oval rachidian tooth with a prominent central cusp. Pallai eye, a mantle siphonal light-sensing organ on the right side of the foot, there is a female ovipositor.

2.3.1 Classification and Morphology

A lot of study has been done on the molluscan shell in the previous 300 years, but it hasn't helped much in understanding how mollusks developed in general. A significant portion of the gathering's revolutionary improvement has been explained by suitable morphological translation of the fragile biological structures. (Yonge 1939). Acquired shell and operculum characteristics that were useful for identification. Although many species exhibit significant diversity in shell characteristics, shell morphology is utilised to define taxa. Pleurocerid shells are solid, and the opening may have a channel anteriorly. The operculum is paucispiral and corneous (Brown and Lydeard 2010). Most mangrove gastropods are semi-aquatic animals with a protective exterior shell that prevents water loss through heat, allowing them to survive desiccation and persist above water for extended periods of time. Some can breathe in both air and water. The capacity to osmoregulation is the basic physiological need of mangrove gastropods (Long & Marzuki, 2008).

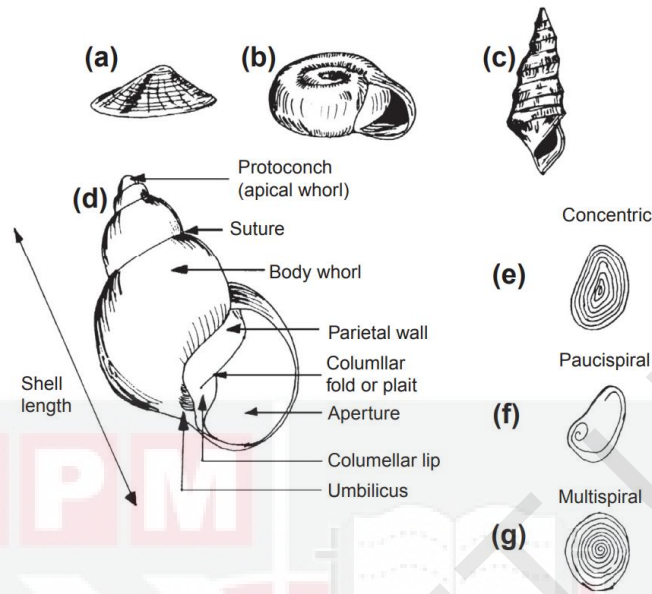


Figure 1.1: The shell's basic anatomy includes shell architecture (conical, a; planospiral, b; spiral c, d); main shell characteristics (d); and three forms of opercula (e, concentric; f, paucispiral; and g, multispiral) (Pyron and Brown 2015).

2.4 Mangrove Gastropod Distribution in Sarawak

Nagelkerken et al. (2008) discovered multitude of variables impact the distribution of gastropod species in the mangrove environment, including light as a primary factor controlling algal development and as a factor influencing humidity, tidal height, salinity, sediment textures, and forest type. Molluscs are one of the most important families of invertebrates in the structure and operation of mangrove ecosystems.

Mollusks is one of the largest animal phyla after Arthropod which has distinctive characteristics that is a soft body (Imamsyah et al. 2020a). Mollusks can become a bio-indicator to determine the stability of mangrove ecosystem because of its specificity of microhabitat and nutrition each species (Carpenter et al., 1998a). The diversity and abundance of mollusks was very influenced by the characteristic of vegetation of

mangrove, therefore, the structure of community of mollusks be able to determine the mangrove ecosystem health (Eddiwan et al. 2017)

2.4.1 Mangrove Gastropod Diversity and Distribution In Sematan Sarawak

Molluscan macrofauna abounds in the Sematan mangrove forest. When compared to earlier studies on mangrove macrofauna in South-East Asia, the amount of 75 recognised species documented is high. The molluscan species found in Sematan are like those found in other rivers and estuaries in Peninsular Malaysia. (Sasekumar, 1974).

molluscan (gastropod and bivalve) species were documented inside each vegetative plot. Around the mangrove tree species characteristic of that plot, the quantity and variety of molluscs on the mud surface and at height intervals up the tree were recorded. Forty-four species of mollusks are found Summary of mollusks and among the gastropods found are:

Table 2.1 Source from: Gastropod species in Sematan Sarawak (Ashton et al. 2003)

Families	Species
Ellobiidae	<i>Ellobium aurismidae</i>
Muricidae	<i>Chicoreus capucinus</i>
Littorinidae	<i>Littoraria carinifera</i>
Potamididae	<i>Cerithidea quadrata</i>
Potamididae	<i>Cerithidea largillerti</i>
Ellobiidae	<i>Ellobium aurisjudae</i>

2.4.2 Mangrove Gastropod Diversity and Distribution in Pendam Sarawak

According to Long et al. (2008) Eleven distinct gastropod species were discovered in the Sungai Sejaie mangrove area. The species has a population density of three to one person per square metre. Most species were visible within 100 metres of the increased tide. *Nerita antiquata* and *Naita lineata* were found crawling on the mudflat and attached to the prop roots of *Avicennia alba* and *Avicennia marina*, while *Cerithidea obtusa*, *Cerithidea cingulata*, and *Cerithidea rhizophorarum* were found on the substrate around the base of mangrove trees.

Based on the report Long et al. (2008), the group was scattered from the sediment's surface to 0.1 metre height on the trees and the second group were found from the sediment's surface to two metres up on the trees are:

Table 2.2 Source from; Gastropod diversity in Pendam Sarawak (Long et al. 2008)

Families	Species
Ellobiidae	<i>Ellobium aurisjuddae</i>
Batillariidae	<i>Batillaria cumingi</i>
Ellobiidae	<i>Cassidula nucleus</i>
Potamididae	<i>Cerithidea obtusa</i>
Potamididae	<i>Cerithidea cingulata</i>
Potamididae	<i>Cerithidea rhizophorarum</i>
Littorinidae	<i>Littorina scabra</i>
Littorinidae	<i>Littorina fasciata</i>
Muricidae	<i>Thais acuelata</i>
Neritidae	<i>Nerita lineata</i>

2.5 Environmental Characteristic in Mangrove

Mangroves have a wide range of environmental diversity because to their water ascent and discharge features. Such variances are typically associated with different mangrove species along certain segments of intertidal profiles, and they may be classified according on their intertidal conditions. These variations in normal conditions, for example, salinity, normal matter piece, temperature, and soil profile, influence the topographical conveyance of molluscan networks in various zones. (Pagliosa & Barbosa 2006). Because of the availability of nutrients in the soil, the state of the soil with an acid to base condition will affect the growth of mangroves. The availability of nutrients will also have an impact on the diversity of mangroves since each form of mangrove has the potential to adjust to soil pH and the availability of different nutrients, allowing the type of mangrove that can adapt to the environment to grow (Irsadi et al. 2019)

Based on Nurfitriani et al. (2019) study the association found between the density of mangrove vegetation and the number of gastropods is precisely proportional. The greater the density of mangroves, the more gastropods that grow. This happens because the density of mangrove vegetation affects the amount of trash produced and available organic material. This is consistent with the assertion that the density of mangroves is strongly tied to the availability of organic materials in the environment, which promotes the proliferation of decomposers to decompose organic waste. DO concentration, high salinity, and high mangrove density on sandy substrates are all environmental conditions that have a significant impact on gastropod and bivalve density.

2.5.1 Soil

Mangrove habitats were able to maintain a wider diversity of infaunal assemblages due to their high organic matter content and suitable soil particle size (Hajializadeh et al. 2020). Despite its high organic matter content, mangrove soil includes between 26 and 80% sand and can range from sandy loam to loamy sand (Dewiyanti et al., 2021)

Based on (Tan and Clements, 2008) study, in Singapore clithon species are found in brackish canals and drains near the shore, as well as muddy sand sections of lagoons and estuaries with little tidal effect. Both species were discovered on the sandy banks of a stream in Punggol's mangrove forest. *Clithon faba* appears to favour a sandier substrate and is likely more tolerant of brackish conditions. This species was neither discovered on somewhat muddy intertidal sand lats, nor on mud amid mangroves, where *Clithon oualaniensis* is present.

2.5.2 Salinity

One of the most significant abiotic environmental elements influencing the distribution and physiological metabolism of aquatic mollusks is salinity (Jacobsen et al. 1997), This shows that salinity is very important in mangroves for the presence of gastropods. Bathmann et al. (2021) state that mangrove species can develop mangrove zonation to reduce the impact of tidal inundation, water salinity, and limited nutrient availability because mangrove species have salt and water excreting and accumulating glands that function as a specific metabolism in permanent water inundation areas.

2.5.3 Temperature

Temperature is one of the most important environmental factors affecting mangrove distribution worldwide (Liu et al., 2016). also has a long-term influence on the structure and composition of mangrove ecosystems (Stevens et al. 2006). Based on Rusnaningsih et al. (2020) study has stated that temperature in the Pangkal Babu mangrove forest runs between 29-34 °C, which is still within Gastropod tolerance, the temperature range is between 25-32 °C, and the greatest temperature is 29-34 °C, since it is located near the shore and is more open.

2.5.4 Soil and water pH

According to Wiraatmaja et al. (2022) have state, the degree of acidity (pH) is critical for the survival of mollusk creatures. This is because pH may influence the kind and availability of nutrients, as well as the toxicity of trace elements. (Odum & Barrett 2002) also stated waters and soils with a pH of 6-9 are fertile because they can facilitate the breakdown of organic debris in the water, and soils rich in minerals are suitable for mollusc life. This shows that the pH of water and soil can affect the life in the mangrove area because of toxicity.

2.5.5 Dissolved Oxygen

Dissolved Oxygen (DO) is the concentration of oxygen in water. DO content is one of the most significant markers of the biological and chemical health of the water (Rajwa-Kuligiewicz et al. 2015). The reaction of dissolved oxygen to tidal flooding is very varied. It is affected by the time of day and night floods, as well as the site's

connectivity, whether it is a freely connected fringe or a blocked mangrove basin. Distance from tidal sources is especially essential in mangrove basins due to tidal buffering capacity and the cumulative effect of actions that diminish DO (Knight et al. 2013).



CHAPTER 3

METHODOLOGY

3.1 Study Area

Study area will conduct at Sibuti mangrove forest, encompassing an area of 678 acres, is located on the shore of the South China Sea, 45 km west of Miri town (Shah et al. 2016). The coordinates for station 1 are 03°59.479' N/ 113°44.581' E, while for station 2 it is 03°58.924'N/ 113°44.300'E and followed by station 3 is 03°59.443'N/ 113°43.866. The forest is flanked to the north by Bungai farmlands and to the south and east by the Sibuti River. This location is a pristine tropical mangrove forest (Shah et al., 2016b) The forest receives an average of 3762.1 mm of precipitation annually, with monthly amounts ranging from 141.8 mm to 691.2 mm (Shah et al. 2016). According to (Gandaseca et al., 2011) *Rhizophora apiculata* dominates mangrove forests in Sibuti, followed by *Xylocarpus Granatum* and *Nypa fruticans*.

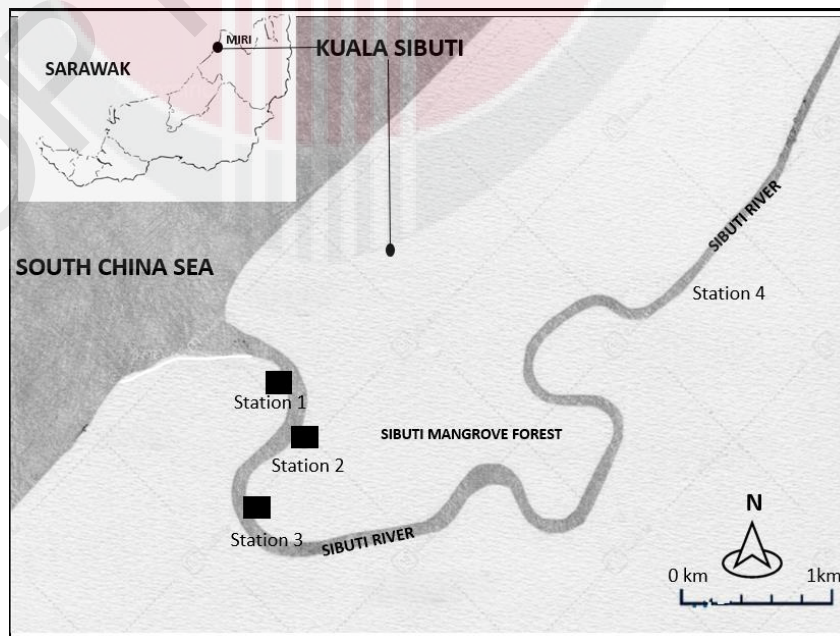


Figure 3.1 Sampling site (Sibuti mangrove)

3.2 Gastropod and water Sampling procedure

The study was conducted in September 2023 in Sibuti, Sarawak. Sample collection was done by dividing the mangrove area into 3 stations using the transect sampling method which is between the upstream, middle and end downstream. Quadrat and transect techniques were used in this random sampling method. The equipment used to sample collection include plastic bag, bottle, and measuring tape. each station is divided into three plots and the quadrat technique will be used which is a distance between 10 x 10m (100m²) in area. then through the quadrature technique, the transect was used to measure the distance and determine the straight line between each station and plot. Therefore, the collection of gastropods will be done for each station 1,2, and 3 also, using the Garmin eTrex 10 GPS to denotes station coordinate. The gastropods collected have been put in plastic bags that have been marked stations and compartments to facilitate the identification of the amount of diversity between gastropods at each station.

In addition to that, river water parameters were taken by multi-parameter model WQC-24 readings three times for each parameter, namely pH, TDS (g/L), Salinity (ppt), Temperature (°C), Conductivity (mS/m), TDS meter (ppm), Turbidity meter (NTU), dissolved oxygen meter (mg/L). Each parameter is read instantaneously throughout the sampling procedure for all stations. However, pore water has been taken at each station which has been divided into three plots and brought back to the laboratory to analyse its parameters. To get pore water is to dig the mangrove soil 0.5m deep to get the water and store the water sample in a bottle. Among the parameters taken for groundwater are pH,

TDS (g/L), Salinity (ppt), Temperature (°C), Conductivity (mS/m), TDS meter (ppm), Turbidity meter (NTU), DO meter (mg/L), Ammonia, Nitrite, Phosphate, and Nitrate.

3.3 Identification

Following collection, the sample was taken to the Aquatic Ecology Laboratory, Department of Animal Science and Fisheries, Universiti Putra Malaysia Bintulu Campus, Sarawak. The samples obtained will be identified using (FAO species identification guide for fishery purposes 1998)

3.4 Gastropod Morphometric

Morphological analysis, additionally known as morphometrics, is the quantitative description, evaluation, and interpretation of biological structure size and form (Rohlf & Marcus 1993). Counts, ratios, and angles were occasionally utilised in addition to linear distance measurements. Covariation in morphological parameters was measured using these methods, and patterns of variation within and between samples could be examined. (Adams et al. 2004) The morphometric method is performed by measuring the minimum size and the maximum size, namely shell length (SL), shell width (SW), body width (BW), shell/aperture length (Al), shell opening width (AW), shell depth (SD), lower lip thickness (LPL), middle lip thickness (LPM), and upper lip thickness (LPU) by using A2583 Calliper Vernier 0-150x0,01mm digital . Thus, all gastropod shell measurements will be divided by standard length to get an average for statistical analysis.

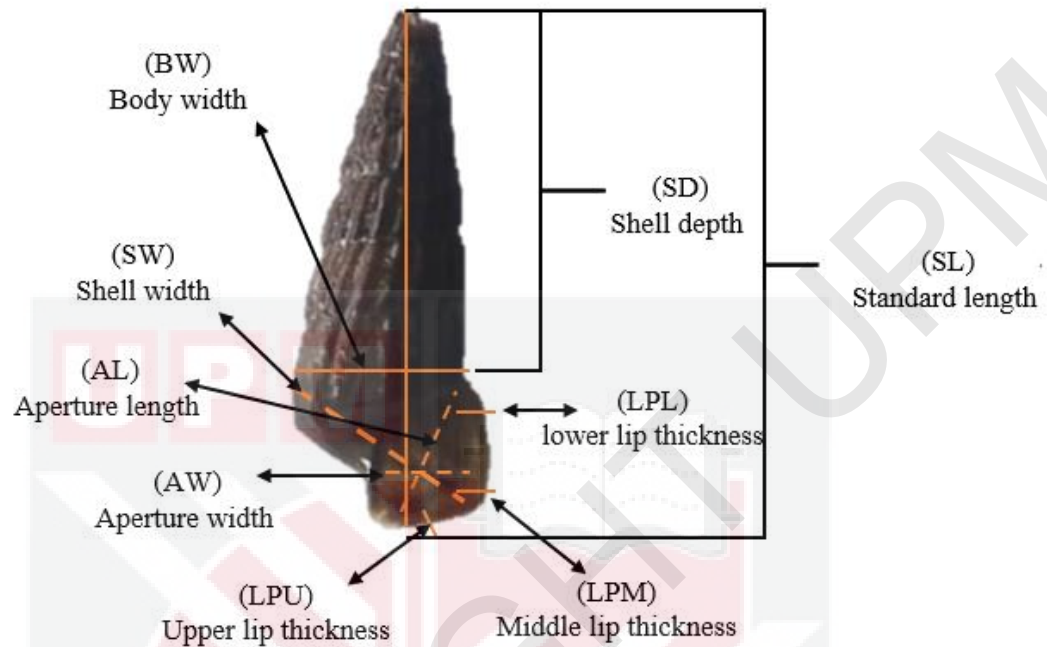


Figure 3.3: shell morphometric and characteristic

3.5 Statistical Analysis

3.5.1 Diversity Analysis

Data on the individual number and species were analysed with (H'), richness (D), and evenness (J') indices were tabulated based on the formula suggested by Shannon (1948), (Margalef, 1958) and (Pielou, 1966) respectively. The formula for species diversity, richness, and evenness shown below:

a) Shannon's diversity index (H')

$$H = \sum \frac{N_i}{N} \log_e \frac{N_i}{N}$$

b) Pielou's evenness (J):

$$J = H / \log_e S$$

c) Margalef index of species richness (D):

$$D = S - 1 / \log_e N$$

where,

N = sample size,

N_i = number of specimens per species,

S = total number of species

3.5.2 Ex situ (pore water) and In-situ (river) water One- Way ANOVA

Ex situ (pore water) and In-situ (river) water analysis has been used one-way analysis of variance (ANOVA) at a 5% level of significance was conducted using the PAST with turkey's mean comparison test.

3.5.3 Morphometric One- Way ANOVA

The PAST with turkey's mean comparison test was used for Neritidae morphometric analysis, using one-way analysis of variance (ANOVA) at a 5% level of significance.

3.5.4 T test Statistical Analysis

T-tests were conducted for morphometric analysis for Littorinidae and potamididae because each family has two species. Therefore, differences can be seen through statistical analysis conducted between two species for each family found in Sibuti mangroves.

3.5.5 Relationship between Abiotic factor and Biotic

Pearson correlation was used to identify the relationship between evenness, Shannon, and Margalef with pore and river water parameters.



CHAPTER 4

RESULT

4.1 Gastropod species

A total of 264 species have been collected encompassing 8 species, 4 families and 5 genus. The families and genus of gastropod species identified at the three stations in this study are summarized in Table 4.1.

Table 4.1 Gastropod species collected from three station of Sibuti mangrove.

Family/Genus/ Species	Station		
	S 1	S2	S3
Littorinidae, Littoraria			
<i>Littoraria scabra</i> (Linnaeus 1758)	+	+	-
<i>Littoraria carinifera</i> (Menke, 1830)	+	+	+
Potamididae, Cerithidea			
<i>Cerithidea charbonnieri</i> (Petit de la Saussaye, 1851)	-	+	+
<i>Cerithidea quoyii</i> (Hombron & Jacquinot, 1848)	+	+	-
Neritidae, Neripteron			
<i>Neripteron violaceum</i> (Gmelin, 1791)	+	+	+
<i>Neripteron cornucopia</i> (W. H. Behson, 1836)	+	+	-
Neritidae, Vittina			
<i>Vittina coromandeliana</i> (G.B. Sowerby I, 1836)	+	+	+
Ellobiidae, Ellobium			
<i>Ellobium aurismidae</i> (Linnaeus, 1758)	-	-	+

Notes: (+) the presences of species

(-) no presences of species

4.2 Gastropod morphological structure

Littoraria scabra (Linnaeus, 1758)

Family : Littorinidae

Genus : *Littorina*

Species : *Littoraria scabra* (Linnaeus, 1758)

Synonyms : *Buccinum lineatum* Gmelin, 1791, *Helix scabra* Linnaeus, 1758, *Melarhappe scabra* (Linnaeus, 1758)

Habitat : Abundant on trees and roots, near the seaward edge of mangrove habitats, and occasionally on driftwood on sandy beaches where mangroves do not exist. On sheltered rocks, this would be uncommon.

Morphology : *Littoraria scabra* is a tiny species, with shell lengths ranging from 8 to 15 millimetres (Figure 4.1). With a high, conical spire and low sculpting, the shell is thin yet sturdy. Convex spire whorls with a narrowly channelled, incised suture, many, thin, low, and flattened spiral cords, and a raised, rounded cord defining a well-marked angle at the perimeter



Figure 4.1 Morphological *Littoraria scabra* (Linnaeus, 1758)

Littoraria carinifera (Menke, 1830)

Family : Littorinidae

Genus : *Littoraria*

Species : *Littoraria carinifera*

Synonyms : *Littorina carinifera* (Menke, 1830), *Littorina rubropicta* E. von Martens, 1887, *Phasianella carinifera* Menke, 1830

Habitat : *Littoraria carinifera* dispersed clumpedly in the *Rhizophora apiculata* zone. *L. carinifera* like to stay at mangrove trees with short stems that branch and roots that protrude so that they can transfer from one stem to another mangrove stem for a wide range of reasons, such as food.

Morphology : The length of this species (Figure 4.2) is between 0.74 mm - 18 mm. Consistent in shape and colour, with a high keel around the shell.



Figure 4.2 Morphological *Littoraria carinifera* (Menke, 1830)

Neripteron violaceum (Gmelin, 1791)

Family : Neritidae

Genus : *Neripteron*

Species : *Neripteron violaceum* (Gmelin, 1791)

Synonyms : *Dostia depressa* (W. H. Benson, 1836), *Nerita violacea* Gmelin, 1791, *Neritina montrouzieri* Gassies, 1875

Habitat : Shallow brackish water pools found amid mangroves, on rocks, in mud, or on mangroves and other bog plants. With a mud-covered shell among dead leaves in tannin-stained water, this species is difficult to identify.

Morphology : Has a length between 15mm - 26mm and has columella teeth between 9 – 15 (Figure 4.3). This species also has contained small spiral cords on the surface of the shell that are a combination of yellow and brown colours, as well as a round aperture, outer lip, and inner lip that are reddish in colour and has a shell width between 10mm - 19mm



Figure 4.3 Morphological *Neripteron violaceum* (Gmelin, 1791)

Vittina coromandeliana (G.B. Sowerby I, 1836)

Family : Nerithidae

Genus : Vittina

Species : *Vittina coromandeliana* (G.B. Sowerby I, 1836)

Synonyms : *Neritina triangularis* Mörch, 1852, *Neritina pulcherrima* Mousson, 1857, *Neritina cochinsinae* Récluz, 1850 ·

Habitat : In the mangrove intertidal zone, where it is subject to continuous tidal variations. Mudflats, tidal flats, and mangrove roots are the habitats for this species to be found.

Morphology : This species (Figure 4.4) has a length between 8mm - 22mm and a shell width between 5mm - 16mm and the number of columella teeth is 5 - 9. The color is brown and has black stripes on the shell.

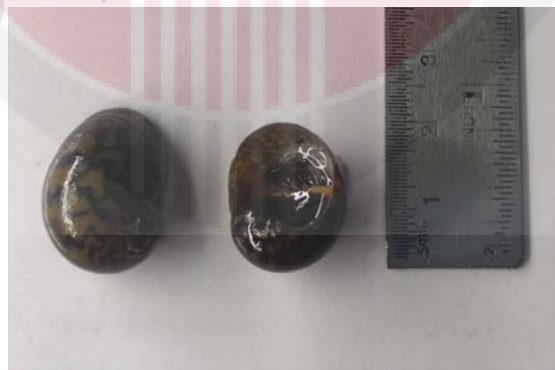


Figure 4.4 Morphological *Vittina coromandeliana* (G.B. Sowerby I, 1836)

Neripteron cornucopia (W. H. Behson, 1836)

Family : Nerithidae

Genus : *Neritina*

Species : *Neripteron cornucopia* (W. H. Behson, 1836)

Synonyms : -

Habitat : Neripteron are frequently found in mangrove intertidal zones, where they are subjected to constant tidal variations. Mudflats, tidal streams, and mangrove roots are examples of such habitats. Mangrove roots create a diverse and protected habitat that Neripteron may find appealing. The roots provide attachment surfaces, protection from predators, and access to food sources.

Morphology : It has a length between 19mm - 25mm and a body width between 12mm - 16mm and has columella teeth between 9 – 18(Figure 4.5). The color of the shell is quite gray and has a straight line across its body.



Figure 4.5 Morphological *Neripteron cornucopia* (W. H. Behson, 1836)

Cerithidea quoyii (Hombron & Jacquinot, 1848)

Family : Potamididae

Genus : *Cerithidea*

Species : *Cerithidea quoyii* (Hombron & Jacquinot, 1848)

Synonyms : *Cerithium quoyii* Hombron & Jacquinot, 1848, *Cerithidea quadrata* G. B. Sowerby II, 1866, *Cerithidea obtusa quadrata* G. B. Sowerby II, 1866 .

Habitat : They are found in estuaries and mangroves on mudflats, sandy places, and root of *Rhizophora apiculata*.

Morphology : The shell length is between 34mm- 44mm and has a body width between 0.33mm - 0.39mm. and his black lips. The depth of the shell is between 26mm – 32 mm has shown in Figure 4.6.



Figure 4.6 Morphological *Cerithidea quoyii* (Hombron & Jacquinot, 1848)

Cerithidea charbonnieri (Petit de la Saussaye, 1851)

Family : Potamididae

Genus : *Cerithidea*

Species : *Cerithidea charbonnieri* (Petit de la Saussaye, 1851)

Synonyms : -

Habitat : They are suited to brackish water environments, where freshwater from rivers and saltwater from the ocean mingle. They are commonly found in estuaries and mangroves on mudflats, sandy places, and root of *Rhizophora apiculata*.

Morphology : *Cerithidea* sp. (Figure 4.7) shell has a tall and thin spiral form with unusual elevated spiral ridges that give it a "horned" look and the length is between 20mm – 47mm. The shell's colour might vary, although it's usually brown or tan.



Figure 4.7 Morphological *Cerithidea charbonnieri* (Petit de la Saussaye, 1851)

Ellobium aurismidae (Linnaeus, 1758)

Family : Ellobiidae

Genus : *Ellobium*

Species : *Ellobium aurismidae* (Linnaeus, 1758)

Synonyms : *Auricula midae* Lamarck, 1801, *Bulla aurismidae* Linnaeus, 1758, *Voluta aurismidae* (Linnaeus, 1758)

Habitat : are frequently found in mangrove environments, which are coastal ecosystems characterised by the presence of salt-tolerant flora, including a variety of mangrove tree species. *E. aurismidae* are frequently linked with the intertidal zones of mangrove ecosystem, including mudflats and places around mangrove roots.

Morphology : On the surface of the *Ellobium aurismidae* shell (Figure 4.8), it has fine spiral cords, the size of the shell is around 74mm – 91mm, with brown and white fading colors. Aperture on *Ellobium aurismidae* is oval shaped, outer lip and inner lip are brown



Figure 4.8 Morphological *Ellobium aurismidae* (Linnaeus, 1758)

4.3 Gastropod Diversity, Richness, and Evenness index

Figure 4.9 shows species of gastropods recorded at three distinct stations labelled as S1, S2, and S3. This means that there were 5 distinct taxa or species of gastropods recognised at Station 1 and 3. Station S2 exhibited a higher variety, with 7 distinct gastropod families or species detected. Stations 1 and 2 exhibited similar levels of diversity with 5 different gastropod taxa or species detected. The number of families indicates the species richness of each station.

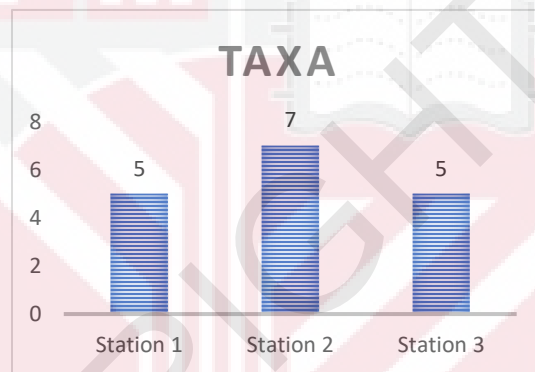


Figure 4.9 Number of gastropod species at Sibuti Mangrove

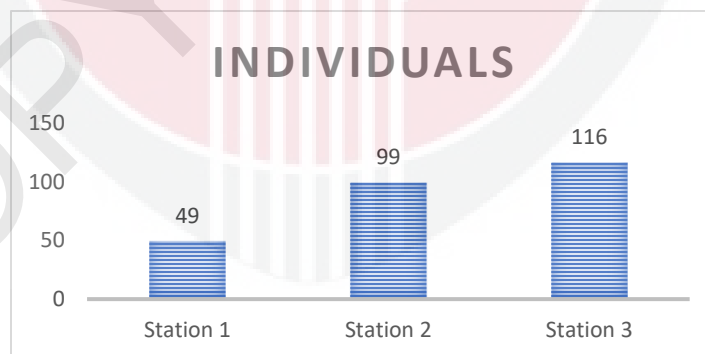


Figure 4.10 Individuals of gastropod species at Sibuti Mangrove

Figure 4.10 shows individual of gastropods recorded at three distinct stations labelled as Station 1, Station 2, and Station 3 individual in each station (Station 1, Station 2 and

Station 3) has shown Station 3 has more individuals followed by Station 2 and Station 1 has the lowest individuals at Sibuti mangrove.

4.3.1 Gastropod diversity, Richness and Evenness index

The findings for three separate stations (labelled as Station 1, S2, and S3) utilising three ecological indicators (Shannon diversity index (H), Pieluo's evenness (J), and Margalef index of species richness (D)) are shown in Figure 4.11. The Shannon index assesses species diversity in a community by considering both species richness and evenness. Greater variety is indicated by higher values. Station 2 has the most diversity in this scenario, followed by Station 1 and finally Station 3. Evenness quantifies how evenly the amount of people is distributed among species. A value of one denotes complete equality. Station 1 has the highest level of equality, followed by Station 3, then Station 2. The Margalef Index is concerned with species richness, or the number of species in a community. Higher numbers imply a greater diversity of species. In this scenario, Station 1 has the most species, followed by Station 2, and at last Station 3.

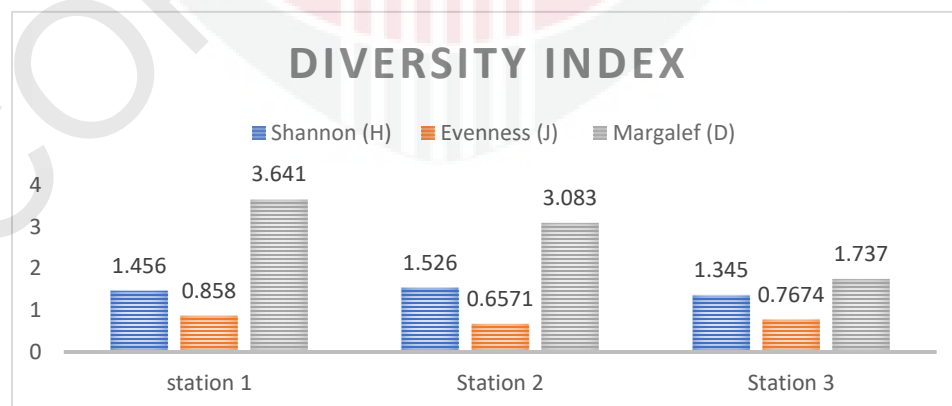


Figure 4.11 Diversity index at Sibuti Mangrove

4.4 Gastropod Morphometric

4.4.1 Neritidae Morphometric

Several critical parameters were evaluated in the morphometric study of the three species (Table 4.2) *Neripteron violaceum*, *Vittina coromandeliana*, and *Neripteron cornucopia* to understand the variance in their shell and body dimensions. Here are the results, along with accompanying *p* values showing the significance of the differences shown. There is a significant difference in shell width between the three species with *N. violaceum* and *N. cornucopia* having the same size but *V. coromandeliana* having a much smaller size than the other two species. besides, the aperture width has significant differences with *N. cornucopia* the highest followed by *V. coromandeliana* and then *N. violaceum*. In addition, there is a significant difference in the thickness of the lower lip with *N. violaceum* and *N. cornucopia* having almost the same size and *V. coromandeliana* having a very low average compared to the other two species. The thickness of the middle lip between the three species also has significant differences with *N. violaceum* being higher, followed by *N. cornucopia* and the lowest being *V. coromandeliana*. In addition, there is a significant difference in the thickness of the upper lip between the three species, the species *N. violaceum* is the same as *N. cornucopia* and the lowest *V. coromandeliana*. whereas, no significant differences were observed in shell depth, body width and aperture length between the three species.

Table 4.2 One-Way ANOVA morphometric of Neritidae families from the Sibuti mangrove

Morphometric characteristic	<i>Neripteron violaceum</i>	<i>Vittina coromandeliana</i>	<i>Neripteron conucopia</i>	<i>P</i>
SD/SL	0.45±0.04 ^a	1.47±6.96 ^a	0.38±0.17 ^a	0.529 ^{NS}
SW/ SL	0.8±0.14 ^{ab}	0.7±0.05 ^a	0.82±0.05 ^b	0.000*
BW/SL	0.68±0.07 ^a	0.7±0.05 ^a	0.64±0.01 ^a	0.085 ^{NS}
AL/SL	0.63±0.41 ^a	0.55±0.08 ^a	0.48±0.04 ^a	0.321 ^{NS}
AW/SL	0.30±0.02 ^a	0.32±0.04 ^a	0.35±0.03 ^b	0.000*
LPL/SL	0.12±0.10 ^a	0.04±0.01 ^b	0.08±0.01 ^a	0.000*
LPM/SL	0.12±0.03 ^a	0.04±0.01 ^b	0.08±0.00 ^c	0.000 *
LPU/SL	0.10±0.01 ^{ab}	0.04±0.02 ^a	0.09±0.01 ^b	0.000*

Notes: (*) significance differences

(NS) Non significance differences

4.4.2 Potamididae Morphometric

Various parameters of two gastropod species, *Cerithidea quoyii*, and *Cerithidea charbonnieri*, were evaluated to analyse variations in shell and body size. The result is shown in Table 4.6 together with the accompanying *P* values showing the significance of the observed discrepancies. There is a significant difference between the two species in shell width (SW), lower lip thickness (LPL), middle lip thickness (LPM), and aperture length (AL) with *C. charbonnieri*, being larger than *C. quoyii*. However, there is a significant difference in upper lip thickness (LPU), between the two species, with *C. quoyii* measuring longer than *C. charbonnieri*. In addition, there was no significant difference in shell depth (SD), body width (BW), or aperture width (AW) between the two species.

Table 4.3 T-test analysis on morphometric of Potamidae families from the Sibuti mangrove

Morphometric characteristic	<i>Cerithidea quoyii</i>	<i>Cerithidea charbonnieri</i>	<i>P</i>
SD/SL	0.71±0.02 ^a	0.71±0.02 ^a	0.477 ^{NS}
SW/SL	0.47±0.4 ^a	0.42±0.2 ^b	0.001*
BW/SL	0.36±0.2 ^a	0.35±0.3 ^a	0.268 ^{NS}
AL/SL	0.19±0.01 ^a	0.28±0.01 ^b	0.000 *
AW/SL	0.17±0.01 ^a	0.17±0.01 ^a	0.169 ^{NS}
LPL/SL	0.05±0.2 ^a	0.02±0.1 ^b	0.000*
LPM/SL	0.05±0.01 ^a	0.03±0.01 ^b	0.000 *
LPU/SL	0.04±0.01 ^a	0.02±0.00 ^b	0.000*

Note: (*) significant differences

(NS) non-significant differences

4.4.3 Littorinidae Morphometric

In the morphometric analysis of two gastropod species, *Littoraria carinifera* and *Littoraria scabra*, various characteristics were measured to evaluate differences in their shell and body dimensions. The results, along with the corresponding P values indicating the significance of the differences observed, are presented in Table 4.7. there is a significant difference in shell width and aperture length (AL) between the two species with is *L. carinifera* has higher average than *L. scabra*. However, there is no significant difference in shell depth (SD), body width (BW), aperture width (AW), lower lip thickness (LPL), middle lip thickness (LPM), and upper lip thickness (LPU) between the two species.

Table 4.4 T-test analysis on morphometric of Littorinidae families from the Sibuti mangrove

Morphometric characteristic	<i>Littoraria carinifera</i>	<i>littoraria scabra</i>	<i>P</i>
SD/SL	0.66±0.10 ^a	0.63±0.02 ^a	0.0571 ^{NS}
SW/SL	0.77±0.07 ^a	0.74±0.03 ^b	0.0361*
BW/SL	0.56±0.09 ^a	0.54±0.06 ^a	0.276 ^{NS}
AL/SL	0.46±0.08 ^a	0.42±0.01 ^b	0.002*
AW/SL	0.27±0.04 ^a	0.28±0.02 ^a	0.703 ^{NS}
LPL/SL	0.05±0.01 ^a	0.05±0.01 ^a	0.507 ^{NS}
LPM/SL	0.05±0.01 ^a	0.05±0.01 ^a	0.575 ^{NS}
LPU/SL	0.04±0.01 ^a	0.04±0.02 ^a	0.931 ^{NS}

Note: (*) Significant differences

(NS) non-significant differences

4.5 Physio- chemical Water Parameters

4.5.1 One-Way ANOVA Pore water analysis

The pore water analysis provides critical insights into the water quality parameters of three distinct stations (S1, S2, and S3) in Table 4.9. Dissolved oxygen levels differed significantly between stations ($P < 0.014$), showing variance in oxygen availability, with S1 being somewhat greater than S2 and S3, which were almost the same value. Ammonia levels differed significantly between scenarios ($P < 0.014$); the table implies that ammonia levels that change with S3 are greater than those that fluctuate with S1 and S2, which are about the same value. Nitrite levels were significantly differed between stations ($p < 0.049$), indicating difference in nitrites compound concentrations, with S3 being greater than S1 and S2, which were nearly the same value. The concentration of phosphate compounds shows a difference with S3 greater than S1 and S2, whose values

are almost the same. Phosphate levels differ significantly between stations ($P < 0.014$). Total turbidity (NTU) also differed significantly between stations ($p < 0.008$), with S2 greater than S1 and S3. However, pH levels were found to be similar across situations, with no statistically significant change ($p > 0.163$). TDS (Total Dissolved Solids) in ppm, on the other hand, did not differ significantly between stations ($p > 0.490$). Salinity levels did not change significantly between scenarios ($P > 0.457$). Temperature also shows a trend, but is not statistically significant, with a p value of 0.094. Conductivity levels across stations did not change significantly ($P > 0.521$). Nitrate also has no significant difference between each station ($P > 0.171$).

Table 4.5 One- Way ANOVA of Pore water parameter from Sibuti mangrove

Parameter	S1	S2	S3	p value
pH	6.467±0.118 ^a	6.427±0.050 ^a	6.293±0.050 ^a	0.163 ^{NS}
TDS (ppm)	10.600±2.052 ^a	10.467±1.762 ^a	9.033±0.289 ^a	0.490 ^{NS}
Salinity	6.800±1.153 ^a	6.733±1.185 ^a	5.800±0.173 ^a	0.457 ^{NS}
Temp (°C)	26.100±0.100 ^a	25.800±0.458 ^a	25.267±0.252 ^a	0.094 ^{NS}
Turbidity (NTU)	179±65.818 ^{ab}	816.67±174.749 ^a	463.33±121.821 ^b	0.008*
Cond (S/m)	1.175±0.183 ^a	1.167±0.185 ^a	1.033±0.029 ^a	0.521 ^{NS}
DO (mg/L)	4.017±0.316 ^a	3.057±0.250 ^b	2.470±0.397 ^b	0.014*
Ammonia analysis	0.873±0.153 ^a	1.268±0.250 ^a	2.364±0.504 ^b	0.014*
Nitrite analysis	0.480±0.260 ^a	0.661±0.161 ^a	1.390±0.370 ^b	0.049*
Phosphate analysis	0.214±0.083 ^a	0.573±0.081 ^b	0.851±0.062 ^c	0.003*
Nitrate analysis	0.376±0.230 ^a	0.439±0.227 ^a	1.094±0.547 ^a	0.171 ^{NS}

Notes: (*) Has significance difference
(NS) Non significance difference

4.5.2 One-Way ANOVA *In situ* water analysis

The result of the in-situ water study gives important insights into the environmental conditions of three different stations labelled (S1, S2, and S3) in Table 4.6. The pH levels differ dramatically between circumstances. S1 has a higher pH than S2, and S3

has a higher pH than both S1 and S2. The p value of 0.002 suggests that the pH levels differ significantly. Salinity varies greatly between circumstances. The greatest salinity is S1, followed by S2, and the lowest salinity is S3. A significant difference between salinity levels is shown by a p value of 0.000. The temperatures in the situations varied significantly. S1 and S3 have temperatures that are close, whereas S2 has a slightly elevated temperature. The p value of 0.002 indicates that there is a significant difference in temperature. Conductivity values differ greatly between circumstances. S1 has the greatest conductivity, followed by S2, while S3 has the lowest. A p value of 0.000 shows that there is a considerable variation in conductivity. The TDS recorded by the meter differs significantly between the circumstances. S2 has the highest TDS meter measurement, followed by S3, with S1 having the lowest. A p value of 0.000 indicates that there is a considerable variation in TDS meter readings. Turbidity values vary greatly between settings. S2 has the most turbidity, followed by S3, and S1 has the least. A substantial change in turbidity is shown by a p value of 0.012. The amounts of dissolved oxygen vary significantly between conditions. S1 has the greatest DO, followed by S3 and S2, while S2 has the lowest. A p value of 0.000 indicates that there is a significant difference in dissolved oxygen levels.

Table 4.6 Ones-Way ANOVA of *In situ* water analysis from Sibuti mangrove river

Parameter	S1	S2	S3	p value
pH	5.807± 0.012 ^a	4.763±0.357 ^b	6.000±0.154 ^c	0.002
Salinity (ppt)	1.567±0.058 ^a	0.800±0.000 ^b	0.267±0.058 ^c	0.000
Temperature (°C)	28.067±0.058 ^{ab}	28.233±0.058 ^a	28.000±0.000 ^b	0.002
Conductivity (mS/m)	0.303±0.003 ^a	0.170±0.002 ^b	0.062±0.006 ^c	0.000
TDS meter (ppm)	138.000±1.000 ^a	858.667±4.933 ^b	334.333±4.619 ^c	0.000
Turbidity meter (NTU)	61.900±3.061 ^a	72.167±3.272 ^b	68.000±1.833 ^c	0.012

DO meter (mg/L)	3.347±0.040 ^a	2.760±0.135 ^b	3.707±0.136 ^c	0.000
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Notes: (*) Has significant differences
(NS) non-significant differences

4.6 Pearson Correlation of Pore Water Parameter

4.6.1 Shannon Weiner Diversity Index

Sibuti mangrove has no significant difference, Pearson correlation coefficients for the Shannon diversity index and several environmental factors are shown. Table 4.7 shows an explanation for each parameter. The Shannon diversity index has a highly positive association with pH and temperature. The positive association implies that as pH and temperature rise, so does the diversity index. The strength of the correlation is modest. The Shannon diversity index has a very positive correlation with total dissolved solids (TDS), salinity, and conductivity. The positive correlation implies that when TDS, salinity, and conductivity increase, so does the diversity index and the relationship is relatively frail.

The Shannon diversity index and two parameters (turbidity and dissolved oxygen (DO)) have a moderately positive connection. The positive association shows that as turbidity and dissolved oxygen rises, so does the variety index. On the other hand, the connection is quite strong. The Shannon diversity index and (ammonia and nitrite levels) have a significant negative association. However, the negative association implies that when ammonia and nitrite levels fall, the variety index rises. The strength of the correlation is modest. The Shannon diversity index and phosphate levels have a moderately negative connection. The negative connection implies that when phosphorus levels fall, the variety index rises. The connection is quite strong. The Shannon diversity

index and nitrate levels have a very high negative correlation. The negative association implies that when nitrate levels fall, the variety index rises, and the relationship is weak.

Table 4.7 Person correlation of Shannon Wiener diversity index with pore water parameter at Sibuti mangrove

parameter	Correlation coefficient	<i>r</i> value
pH	0.816	0.392 ^{NS}
TDS (g/L)	0.891	0.299 ^{NS}
Salinity	0.899	0.289 ^{NS}
Temp (°C)	0.727	0.482 ^{NS}
Turbidity (NTU)	0.440	0.710 ^{NS}
Cond (S/m)	0.902	0.284 ^{NS}
DO (mg/L)	0.493	0.672 ^{NS}
Ammonia analysis	-0.795	0.415 ^{NS}
Nitrite analysis	-0.835	0.371 ^{NS}
Phosphate analysis	-0.549	0.630 ^{NS}
Nitrate analysis	-0.890	0.301 ^{NS}

Notes: (*) Has significant differences
(NS) non-significant differences

4.6.2 Pieluo's evenness index

Pearson correlation coefficients are offered for evenness and several environmental conditions. Each parameter's significance is given below (4.8). There is a perfect negative correlation and a considerable difference between evenness and turbidity.

A negative correlation shows that as turbidity increases, so does similarity. There is no significant difference for the evenness exhibited, indicating that the equation has a weak positive correlation with the following parameters: pH, total dissolved solids (TDS), and salinity. A positive correlation suggests that when the pH, total dissolved solids (TDS), and salinity rise, so does the similarity. The relationship between them is strong.

The Evenness also has a moderately favorable association with the following parameters: temperature and dissolved oxygen (DO). A positive correlation means that

when the temperature and dissolved oxygen (DO) rises, so does the similarity, and the relationship is rather strong. Furthermore, evenness has a very slight negative correlation with the following parameters: conductivity, ammonia, nitrite, phosphate, and nitrate. A negative correlation shows that as the following parameters are increased, the similarity decreases, and the connection becomes almost perfect.

Table 4.8 Pearson correlation of Evenness with pore water parameter at Sibuti mangrove

parameter	Correlation coefficient	<i>r</i> value
pH	0.165	0.895 ^{NS}
TDS (g/L)	0.020	0.987 ^{NS}
Salinity	0.003	0.998 ^{NS}
Temp (°C)	0.302	0.805 ^{NS}
Turbidity (NTU)	-1.000	0.004*
Cond (S/m)	-0.004	0.997 ^{NS}
DO (mg/L)	0.569	0.615 ^{NS}
Ammonia analysis	-0.201	0.871 ^{NS}
Nitrite analysis	-0.133	0.915 ^{NS}
Phosphate analysis	-0.514	0.657 ^{NS}
Nitrate analysis	-0.023	0.985 ^{NS}

Notes: (*) Has significant differences
(NS) non-significant differences

4.6.3 Margalef Richnes Index

The Pearson correlation coefficients for the Margalef Index and various environmental parameters in a thesis are shown at sibuti Magrove station. Each parameter (4.9) has an interpretation. The Margalef Index and pH have an extraordinarily high correlation and the *r* value of 0.05, implying that, while the connection is statistically significant due to the high correlation coefficient, its practical importance or strength is negligible. Temperature has a very significant positive relationship with the Margalef Index and the *r* value for temperature correlation is $r > 0.05$, indicating a statistically significant but

practically weak association. The Margalef Index and ammonia levels have a completely negative correlation, and the relationship is statistically significant, the relationship is quite weak.

The Margalef Index and Turbidity have a modest negative association. The correlation is statistically insignificant, and the intensity of the relationship is mild. Furthermore, the Margalef index and dissolved oxygen (DO) have a very significant positive association. The link is statistically insignificant, and the intensity of the relationship is mild. The Margalef index has a very significant negative connection with these two parameters (phosphorus and nitrate levels). The association is statistically insignificant, and the relationship is only moderately strong. These correlations shed light on the relationship between the Margalef index, a measure of species richness, and several environmental conditions.

Table 4.9 Pearson correlation of Margalef richness index with pore water parameter at Sibuti mangrove

parameter	Correlation coefficient	<i>r</i> value
pH	0.998	0.043*
TDS (g/L)	0.978	0.135 ^{NS}
Salinity	0.974	0.146 ^{NS}
Temp (°C)	0.997	0.047*
Turbidity (NTU)	-0.225	0.856 ^{NS}
Cond (S/m)	0.972	0.151 ^{NS}
DO (mg/L)	0.931	0.237 ^{NS}
Ammonia analysis	-1.000	0.019*
Nitrite analysis	-0.995	0.063 ^{NS}
Phosphate analysis	-0.953	0.195 ^{NS}
Nitrate analysis	-0.978	0.133 ^{NS}

Notes: (*) Has significant differences
(NS) non-significant differences

4.7 Pearson Correlation of *In-situ* Water Parameter

4.7.1 Shannon Weiner diversity index Correlation at Sibuti Mangrove

The correlation coefficient (r value) expresses the magnitude and direction of a linear relationship between two variables in Sibuti Mangrove (Table 4.10). There is no significant relationship between the Shannon diversity index and the parameters. The Shannon Diversity Index has a slightly positive connection with Total Dissolved Solids (TDS), Salinity, Conductivity, and Turbidity. The positive connection implies that when TDS grows, so does the diversity index. The correlation is quite strong. The Shannon Diversity Index, on the other hand, has a very high positive connection with temperature in degrees Celsius. The positive association implies that as temperature rises, so does the diversity index. The bond, however, is frail. The Shannon Diversity Index has a substantial negative connection with pH and Dissolved Oxygen (DO). The negative correlation implies that when pH lowers, the diversity index rises. The strength of the correlation is modest.

Table 4.10 Person correlation of Shannon Weiner diversity index with *In-situ* water parameter at Sibuti Mangrove

Parameter	Correlation coefficient	r value
pH	-0.874	0.323 ^{NS}
Salinity (ppt)	0.523	0.650 ^{NS}
Temperature (°C)	0.931	0.237 ^{NS}
Conductivity (mS/m)	0.560	0.622 ^{NS}
TDS meter (ppm)	0.606	0.586 ^{NS}
Turbidity meter (NTU)	0.281	0.818 ^{NS}
DO meter (mg/L)	-0.964	0.170 ^{NS}

Notes: (*) Has significant differences

(NS) non-significant differences

4.7.2 Evenness Correlation at Sibuti Mangrove

The correlation coefficient (R value) expresses the magnitude and direction of a linear relationship between two variables in Sibuti mangrove (Table 4.11). Evenness has a moderate positive correlation with all metrics (Total Dissolved Solids (TDS), pH, Salinity, Conductivity, and Oxygen (DO)). The p value, on the other hand, suggests that this finding is not statistically significant. Similarity and parameters (Temperature, Total Dissolved Solids (TDS), and Turbidity) also have a high negative correlation. However, the p value suggests that this finding is not statistically significant.

Table 4.11: Pearson correlation of Evenness with *In-situ* water parameter at Sibuti Mangrove

parameter	correlation coefficient	r value
pH	0.818	0.390 ^{NS}
TDS (g/L)	0.517	0.654 ^{NS}
Salinity (ppt)	0.540	0.637 ^{NS}
Temperature (°C)	-0.733	0.476 ^{NS}
Conductivity (mS/m)	0.502	0.665 ^{NS}
TDS meter (ppm)	-0.980	0.128 ^{NS}
Turbidity meter (NTU)	-0.986	0.105 ^{NS}
DO meter (mg/L)	0.658	0.543 ^{NS}

Notes: (*) Has significant differences

(NS) non-significant differences

4.7.3 Margalef Richness Index Correlation at Sibuti Mangrove

At Sibuti mangrove, Pearson correlation coefficients for the Margalef Index and several environmental characteristics are shown. Each parameter has shown in Table 4.12. The Margalef Index has a very significant positive association with salinity, temperature, and conductivity. The positive connection implies that when parameters grow, so does the Margalef Index. The relationship, however, is frail. The Margalef Index has a negative connection with these three parameters (pH, dissolved oxygen (DO) and turbidity). The

negative association implies that when pH, dissolved oxygen and turbidity levels fall, the Margalef Index rises. The strength of the relationship is modest. The Margalef index has a very modest negative correlation with TDS. The negative correlation implies that the Margalef index has a very tiny tendency to drop as TDS meter readings rise. The connection is quite weak.

Table 4.12: Pearson correlation of Margalef richness index with *In-situ* water parameter at Sibuti Mangrove

parameter	Correlation coefficient	r value
pH	-0.371	0.758 ^{NS}
Salinity (ppt)	0.943	0.215 ^{NS}
Temperature (°C)	0.493	0.672 ^{NS}
Conductivity (mS/m)	0.957	0.187 ^{NS}
TDS meter (ppm)	-0.032	0.980 ^{NS}
Turbidity meter (NTU)	-0.387	0.747 ^{NS}
DO meter (mg/L)	-0.582	0.605 ^{NS}

Notes: (*) Has significant differences
(NS) non-significant differences

CHAPTER 5

DISCUSSION

5.1 Gastropod Diversity

Station 1 showed 5 different gastropod taxa and station 2 had 7, also station 3 had 5 taxa (Figure 4.9). This leads to station 2 having a high number of taxa compared to other stations while the study compared to the study conducted by Abdunnur et al. (2023), only six species were found. Therefore, this diversity is due to environmental factors that affect the diversity of taxa in the Sibuti mangrove area. Among the factors are physicochemical considerations in the environment (Udayantha & Munasinghe 2009) and the substrate such as soil and trees (Dmitrović et al. 2016).

The individuals (Figure 4.10) discovered through the diversity index analysis with station 3 have a high number of individuals followed by station 2 and station 1 (Figure 4.10), with *Cerithidea charbonnier* (Petit de la Saussaye, 1851) having the highest number of 73 ind/10m², and Galgani et al. (2023) study also recorded cerithidae among the individuals with the highest number. Because this species can adapt to changing environmental circumstances. This is supported by Riyandi et al. (2018) who stated that cerithidae have high adaptability and a wide distribution, and that they are usually found on the branches of mangrove trees and move to the substrate during high tide to find nutrition, as well as the substrate conditions of sand and clay suitable support by Baderan et al. (2019).

Station 2 has a higher diversity followed by station 1 and station 3. This is because of the environmental differences between all stations. Elevation gradients can influence the distribution and composition of gastropoda communities at the local level, as they can be used as proxies for many environmental variables that are related to altitude (e.g. temperature, rainfall, productivity, and habitat type) (Baur et al. 2014; Liew et al. 2010). However, evenness index shows that station 1 has more equality than station 3 and followed by station 2. According to Shaheen et al. (2011) and Zhang et al. (2012), a station with a high equality index shows that no species dominates. If the community has a low evenness index, the number of individuals in each species is not evenly distributed, and one species tends to dominate. this shows that no species dominates at station 1 because of harsh environment will result when there is one gastropod individual, and the other benthos dominates the area (Farooq & Siddiqui 2020). Besides that, Margelef index shows the species richness in station 1 the highest because this habitat has more mangrove roots and provides protection to gastropods. Mangrove forests are important to gastropods as they provide breeding and nursery grounds, food supply and protection from predators (Vermeij, 1973). This shows the wealth owned by station 1 due to the habitat and ecosystem provided for gastropods to obtain sufficient resources to ensure their abundance.

5.2 Morphometric of Gastropod

5.2.1 Neritidae morphometric

The three nerite species that have been found during collection are *N. violaceum*, *V. coromandeliana*, and *N. cornucopia*. The presence of this species has been supported by the condition of Sibuti mangroves which have suitable habitats for this species. This species is also encoded by (Tudu & Mohapatra 2017);(Mustapha et al., 2021a) These three species were found at station 1,2, and 3 but only *N. cornucopia* was not found at station 3.

Through the One way ANOVA analysis that was conducted (table 4.2) there was a significant difference between the eight characteristics of the analysis carried out for the neritidae family except for three characteristics that had no significant difference, SD, BW, and AL. SW shows that *N. violaceum* has the same morphometric average as *N. cornucopia* and it is possible that it is due to the consumption of a diet in a similar habitat causing the formation of shells that prevent the same because studies from Mustapha et al. (2021b) report that the species of *N. violaceum* and *N. cornucopia* are more abundant in the high estuary area. Furthermore, the AW, LPM, LPU, and LPL measurement of *N. cornucopia* has a longer measurement due to genetic factors that shape the aperture. A variety of genetic factors can show differences in the existing neritina species. Saleky et al. (2020) states that genetic diversity can be used as a basis for understanding in studying diversity. Therefore, the morphology of the formation of gastropods will be visible through the genetic diversity that exists.

5.2.2 Potamididae Morphometric

Through table 4.3 reported there are two potamididae species that have been found from Sibuti mangroves *Cerithidea charbonnieri* and *Cerithidea quoyii*. This family was also reported by Ashton et al. (2003) in Sarawak and same morphometric study was also done to *Cerithidae obtusa* Iwan Eddiwan et al. (2017b). Therefore, this species has shown the level of mangrove health with its presence as one of the mangrove ecosystems. There is a significant difference between the morphometric analysis conducted with T test with SW, AL, LPL, LPM, and LPU. While no significant difference was shown between SD, BW, and AW.

Between SW, LPL, LPM, and LPU, the substantial average difference shows that *Cerithidea quoyii* is higher than *Cerithidea charbonnieri*. This is because the type of substrate at this area, which is a sort of muddy substrate with algae, influences the morphological development of organisms (Phanang et al. 2007). While the AL size difference between *C. quoyii* and *C. charbonnieri*, the interplay between species that compete for nutritional supplies and reproductive variety influences the development of shell construction. Gastropods release calcium carbonate, which hardens into a chitin shell and serves as self-protection (Hasan et al. 2020).

No significant difference was shown between SD, BW, and AW with a P value > 0.05. This is because of the adaptation to mangroves that make the formation of the shell of this species the same. Various factors that can affect the formation of shells as stated by (Rao et al. 2018; Saleky et al. 2019.) such as age, salinity pollution and temperature. Hence, the adaptation that occurs to the species does not produce any changes to its morphometric measurements.

5.2.3 Littorinidae morphometric

Two species from the Littorinidae family (Table 4.4) were found in Sibuti mangroves between stations 1, 2, and 3. But station 3 did not find *Littoraria scabra* species, possibly because of the different environmental factors between the other two stations, which showed low levels of dissolved oxygen. The average oxygen level at station 3 is 2,470 mg/L which is not suitable as a habitat for gastropods. $P < 0.002$ shows a significant difference between *L. scabra* and *L. carinifera* in AL and SW. The same morphometric study was also carried out among these families in Bidong Island (Baharuddin et al., 2019). Morphometric variation between these two species may be linked to sex. Sexual variation in globosity can also be explained by the theory of fecundity selection, because females with a relatively spherical shell have a larger internal volume (Kemp & Bertness 1984; Min Ho Son et al. 2000), where AL and SW differences can occur due to sex dimorphism.

Furthermore, there is no significant difference shown between SD, BW, AW, LPL, LPM, and LPU with $p > 0.05$. This happens because the species *L. carinifera* and *L. scabra* are in the same habitat and get a similar supply of resources in Sibuti mangroves. These Littorinidae are mostly collected from *Rhizophora apiculata* trees which are abundant in mangroves. This is because this family usually spends a lot of its life in the air because they are air inhalers. Like other lizards and amphibians (Frey 2010; Reid et al. 2012). Therefore, the amount of nutrients obtained from the habitat has caused no change or difference between *L. carinifera* and *L. scabra*.

5.3 Physicochemical Parameters of Pore Water and The Association of Diversity

Index

Pore water is the water in the soil that fills the space between the soil particles in the sediment of the mangrove ecosystem. (Table 4.5). This water plays an important role in the biogeochemical process and nutrient cycle for mangrove life. all the parameters taken indicate the characteristics found in the water. The pH shown for pore water does not show a significant difference, the average is 6.395. gastropods need a suitable pH to inhabit the area. As is known, if the pH is below 7 it means the water is acidic and if it is more than 7 it means it is alkaline. Correlation between the Margalef Index and pH is extremely strong, with a r value of 0.05, meaning that, while the association is statistically significant due to the high correlation coefficient, its practical usefulness or strength is minimal. Therefore, the pH value found to be slightly acidic means that the gastropods in the Sibuti mangrove area have adapted to the pH condition.

Total dissolved solids (TDS) are the mass that is in the water such as salts, metals, minerals, and other chemicals. No significant difference was shown between the three station and the average was 10.03ppm and diversity index (shannon, evenness and margalef) shows a positive correlation with TDS but no significant difference can be seen. According to Weber-Scannell & Duffy (2007), TDS measurements incorporate all anions and cations in the sample, and certain ions or combinations of ions are significantly more toxic than others. Therefore, the presence of high TDS may cause acidity in pore water.

With an average of 6.44ppt, there is no significant difference between all stations. The prevalence and quantity of gastropods in mangrove areas is determined by

the amount of salt in the pore water but, different from the salt content found to be quite high reaching up to 50ppt due to the difference in soil depth in French Guiana (Marchand et al., 2004). This will have an immediate impact on development and health and may stress gastropods. The second external element that controls surface salinity is the intensity and length of rainfall; during the beginning of the rainy season, the salinity value is stable at a depth of 25 cm, where it will be stable up to a depth of 60 cm (Marchand et al., 2004). Diversity index (shannon, evenness and margalef) shows a positive correlation with salinity but no significant difference can be seen. Consequently, knowing and understanding the salinity requirements of gastropods is essential to effectively manage mangrove environments.

Temperature is an important component to maintain production in Sibuti mangrove areas. Therefore, no significant difference was shown between the three stations with the average being 25.72 °C. Due to the same temperature at each station, this means that the temperature of the pore water found during sampling is suitable for the conditions of gastropods and their environment. Based on Rusnaningsih et al. (2020) study has stated that temperature in the Pangkal Babu mangrove forest runs the temperature range is between 25-32 °C, and the greatest temperature is 29-34 °C. Temperature has a very significant positive relationship with the Margalef Index and the r value for temperature correlation is $r > 0.05$, indicating a statistically significant but practically weak association.

The average turbidity is 486.33 NTU and station 2 has higher turbidity than the other two stations. Turbidity shows the penetration of light into the air and this turbidity occurs due to the mixture of TDS particles present in table 4.5. There is a negative

correlation and a considerable difference between evenness and turbidity. Negative correlation shows that as turbidity increases, so does similarity. The TDS that appears due to gastropods also contributes to sediment breakdown due to feeding and digging activities that produce an effect on the pore water. the turbidity found in this study is higher than the study conducted by Kadarsah et al. (2020) in South Kalimantan mangrove (Kuala Tambangan, Setarap, Angsana and Kampung Bunati). This shows that if the turbidity condition is too high it will affect the habitat and suitable resources for gastropods.

The conductivity found in Sibuti mangroves is 1.13 S/m-1 and no significant difference is shown at all stations. This means the conductivity for this mangrove area is the same where gastropods are part of the nutrient cycle in the mangrove ecosystem. This is because this conductivity occurs with the presence of dissolved ions including nutrients. According to Gandaseca et al. (2011) this conductivity is caused by inorganic dissolved solids, such as nitrates, nitrites, sulphates, and magnesium. Therefore, the dissolved solids content will further increase the conductivity in the water pores. The correlation shows that diversity and margalef have a positive association while evenness is negative.

Dissolved oxygen showed significant variation ($P < 0.014$), with station 3 having the lowest measurement (2.47 mg/L) and correlation shows that diversity, evenness and margalef have a positive association between oxygen solutions. This low volume may be produced by an excessive load of organic matter, which requires a breakdown process and consumes oxygen, resulting in very low dissolved oxygen in the pore water. Organic waste, such as leaves and fallen tree branches, will be reduced by bacteria that need

oxygen to digest them, as shown by Bouillon et al. (2008). As a result, gastropods at station 3 can tolerate the amount of oxygen found in the mangrove area.

Ammonia shows significant variation with $P = 0.014$ and the highest average is at station 3, which is 2.364. Ammonia is a nitrogen that contributes to the nutrient cycle. The Margalef Index and ammonia levels have a completely negative correlation, and the relationship is statistically significant. This is due to the breaking down activity that occurs in the nitrogen-containing mangroves. Because of tidal action, ammonia concentrations increase, causing soil sediments to absorb nitrogen sources. Tidal pump research, as described by Wang et al. (2019), primarily drives nitrogen exchange between mangroves and estuaries. As a result, ammonia is an important component of mangroves that supplies nutrients through tidal activity.

Based on the data, it was discovered that there is a substantial difference between the study's stations, with station 3 having a greater nitrite concentration in the pore water with an average of 1.390 ppm and correlation shows that diversity, evenness and margalef have a negative association between nitrite. If the quantity of nitrite in the pore water is too high, it will most likely result in a loss in oxygen and an increase in acidity. Nitrite is critical to the nitrogen cycle. as state by Schutte et al. (2018) the nitrogen cycle in intertidal sediments is very dynamic, with significant temporal and geographical variability influenced by sediment permeability, transport routes, tidal cycles, plant species, and microbiological activity. As a result, this demonstrates that nitrite is present in the mangrove environment and can influence the occurrence of gastropods.

Phosphate is an important component for shell formation and growth. Through the research done, there is a significant difference between all sites and station 1 has a

low phosphate content, the average of which is 0.214 mg/100g. The condition of the station which is dense with trees has absorbed nutrients at a high rate compared to the study conducted by Supriyantini et al. (2018) state that the content of mangrove plants will increase the phosphate content in the sediment. It is therefore very important that phosphate is available to the mangroves to guarantee the abundance of gastropods. The correlation shows that diversity, evenness and margalef have a negative association between phosphate in Sibuti mangroves.

The pore water in the mangroves has been influenced by the nitrate concentration of the sediment. With a p value of 0.171, the study found no significant difference between each location and correlation shows that diversity, evenness and margalef have a negative association between phosphate in Sibuti mangroves. The presence of nitrates is critical for the provision of protective structures and habitats. The availability of nitrate as a resource for mangroves demonstrates mangrove health. Tidal flooding, height in the tidal frame, soil type, redox status and soil microbial activity, plant species, waste generation, and decomposition are among the aspects of nitrate production as a nutrient that may be seen (Reef et al. 2010). As a result, the presence of this nitrate will aid in population growth and expansion.

5.4 Physicochemical Parameters of *In situ* with diversity index association.

Seven physio-chemical parameters including temperature, pH, dissolved oxygen (DO), turbidity, total dissolved solids (TDS), salinity, and conductivity were measured during river water sampling for each station. all the parameters showed no significant

correlation differences but have significant differences parameters on three stations because the further away from the sea the more different the parameter readings. According to Mama et al. (2021) estuary is a semi-enclosed body of coastal water that has an independent connection with the open sea, extends upstream to the limit of tidal impact, and contains seawater that has been significantly diluted by freshwater produced from land drainage. Due to its high nutrient content, which drives primary production, it is biologically more productive than adjacent rivers and oceans in their natural state.

The pH for each station which shows an average of 4.76-6 while Ngurah Rai Forest Park Bali get normal pH (Imamsyah et al. 2020b). This is because of the high microbial activity at each station which causes the process of composting through branches that fall into the river producing acid to the water. Therefore, pH is an important variable in the quality assessment water because it affects many biological and chemical processes. A pH higher than 7 indicates increased salinity and acidity while a value lower than 7 tends towards acidity (Mama et al., 2021). The correlation shows that diversity and margalef have a negative association between pH in the Sibuti mangrove river. while evenness shows a positive correlation between pH in Sibuti mangrove river.

Furthermore, Sibuti River's salinity ranges between 1.567 to 0.267. This is because the river's route narrows as it moves upstream due to the greater distance between the river and the sea, and rainwater causes the river to flow fast towards the sea. According to Conkright et al. (1999) the combined effect of rainfall and river flow decreases salinity. As a result, gastropods in the Sibuti mangrove area have been able to adapt to the area's saline level. The correlation shows that diversity, evenness and margalef have a positive correlation between salinity in Sibuti mangrove river.

Water temperature is an important component for the existence and survival of gastropods. The average temperature value at the three stations ranges between 28 °C- 28.23 °C where the air temperature depends on the surrounding conditions same as those obtained in other tropical and subtropical estuaries (Davies et al. 2013). Which affects the air temperature. Correlation shows that diversity and margalef have a positive correlation between temperature in Sibuti mangrove river. while the evenness correlation is negative between temperatures.

Conductivity shows a significant difference to the river water at each station which is $p > 0.00$ with ranged between 0.062-0.303s/m and in the previous study is 0.805-89.5 $\mu\text{S cm}^{-1}$ at Mangrove Sibuti (Gandaseca et al. 2011). The conductivity of most freshwater ranges between 10 and 1000 S cm^{-1} . However, in polluted water, the value may exceed 1000 S cm^{-1} (Harun et al., 2010) Therefore, substances that become pollutants to the air need to be eradicated to reduce conductivity activity. The correlation shows that diversity, evenness and margalef have a positive correlation between temperature in Sibuti mangrove river.

Total dissolved solids (TDS) revealed a significant difference with a p value of 0.00 and TDS shown in the Kertih River, Terengganu has a high value with a range of total dissolved solids, 22.94 - 27.56 g/l (Nor et al., 2022). This is due to the tidal action that occurs in the Sibuti mangrove area. The increase in suspended particulate matter in river estuaries can be attributed to high overland runoff and heavy suspended solids loads carried from the subsurface during small and large rainy seasons. Suspended solids or particles are natural pollutants in surface water that produce turbidity in water, especially river water (Mahvi & Razavi 2005). Correlation shows that diversity has a

positive correlation between TDS in Sibuti mangrove river. while evenness and margalef have a negative correlation to TDS with no significant difference.

Turbidity shows a significant difference which is p value of 0.012 and station 2 has the highest mean turbidity 72.167 NTU but the study conducted by Gandaseca et al. (2011) in the previous study at Sibuti mangroves has ranged 11.2-14.3 NTU. This is because of the presence of suspended particles such as clay, silt, and organic materials that produce turbidity. Therefore, the constantly moving flow is also one of the factors in increasing the turbidity of the river water which prevents the Light to reach the bottom. As (Yisa & Jimoh 2010) state, water currents from the surface, river flow, and overland flow all contribute to increased turbidity in natural waterways.

The volume of oxygen dissolved in water is known as dissolved oxygen (DO). Water temperature, salinity, and pressure all influence how much oxygen it can contain. The oxygen solution also differs significantly with station 3 showing an oxygen solution of 2.760mg/L which is almost the same as the study conducted by Imamsyah et al. (2020b) who got an oxygen reading of 2.74-4.19 mg/l. Aquatic life needs adequate oxygen to thrive, and the process of photosynthesis and diffusion from the atmosphere is critical to supplying oxygen to the river. DO concentration is one of the most important indicators of water's biological and chemical health. (Rajwa-Kuligiewicz et al. 2015). Correlation shows that evenness has a positive correlation between dissolved oxygen in Sibuti mangrove river. while Shannon and Margalef have a negative correlation to oxygen with no significant difference

CHAPTER 6

CONCLUSION

In total, a total of 264 species have been collected including 8 species, 4 families and 5 genera have been collected from Sibuti mangroves. Station 2 has a higher diversity than the other three stations. this study also shows that the station has 1 a high evenness index and Margalef index compared to the other three stations. the results of morphometric analysis for families Neritidae show that *Neripteron violaceum* has many high measurements compared to other species. while the Potamididae family shows that *Cerithidea quoyii* has the largest height compared to *Cerithidea charbonnieri*. in addition to that also for the Littorinidae family showing only two significant differences between morphometrics. water parameters and tree density in mangrove areas determine species diversity as well as morphometric measurements of gastropods. as a result, this Sibuti mangrove forest needs to be preserved to maintain the diversity of gastropods to support the ecosystem in the mangrove area.

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APPENDICES

Appendix A: Study Site



Study Site: Sibuti mangrove

Appendix Appendix B: Equipment for Sampling



Garmin eTrex 10 GPS



Multi-parameter model WQC-24



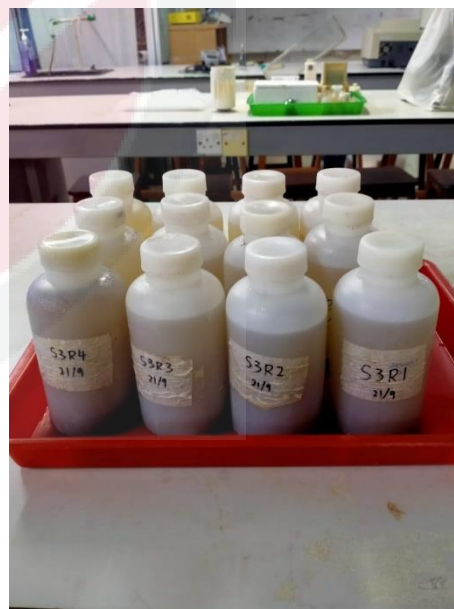
2000P Portable Turbidimeter



Plastic bag



A2583 Calliper Vernier 0-150x0,01mm
digital



Sampling bottles

Appendix C: Gastropod on Mangrove



Vittina coromandeliana (G.B. Sowerby I, 183



Littoraria scabra (Linnaeus, 1758)



Littoraria carinifera (Menke, 1830)



Neripteron violaceum (Gmelin, 1791)