POTENTIAL APPLICATION OF UNMANNED AERIAL VEHICLE (UAV) IN FINE SCALE SEAGRASS MAPPING AT PULAU GAZUMBO, PENANG, MALAYSIA

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UNIVERSITI SAINS MALAYSIA

2021

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by

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Thesis submitted in fulfilment of the requirements for the degree of Master of Science

September 2021

ACKNOWLEDGEMENT

Firstly, I would like to take this opportunity to humbly express my gratitude to the merciful lord, Allah S.W.T for giving me the capability and strength upon the completion of my master's degree. Next, I am immensely grateful for my parents as I would have not successfully completed my thesis without their blessings, support and encouragement. I pray that Allah would grant them paradise for being such supportive parents especially in what I chose to study. My research would have not been a success without the contributions from my supervisor (Dr. Md Noordin Abu Bakar) and co-supervisors (Prof. Mohd Zubir Mat Jafri and Assoc. Prof. Anisah Lee Abdullah). I am highly indebted to them as they provided me unconditional insights and priceless knowledge which I am so lucky to be one of their postgraduate students. I would also like to thank Dr. Ismal Ahmad Abir and Prof. Khiruddin Abdullah as they mentored me a lot on the fundamentals of remote sensing. A special thanks to my postgraduate friends and staffs from Geophysics Department, School of Physics, USM for the support and knowledge sharing especially in remote sensing mapping as I had zero experience when I first joined this department. I have gained a lot of memories and most importantly expanded my network throughout my studies. Lastly, I hope that my research does not end here, environmental management needs consistent monitoring in order to sustain for our future generation to cherish.

"*Every individual matter. Every individual has a role to play. Every individual makes a difference*" – Dr. Jane Goodall (conversationalist).

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a	Total Area of (Seagrass/Substrate) in a Quadrant
m	Total Area of a Quadrant
N	Total Number of Pixels
x_{ii}	Number of Correct Pixels (x_{ii}=1,2,3…N)
x_{i+}	Number of Marginal Pixels in Row *i* (Thematic Map Classes)
x_{+i}	Number of Marginal Pixels in The Column (Reference Data Classes)

LIST OF ABBREVIATIONS

CMOS	Complementary Metal Oxide Semiconductor
GIS	Geographic Information System
GPS	Global Positioning System
JPEG	Joint Photographic Group
K	Kappa
MWQS	Malaysian Marine Water Quality Standards
NaGISA	Natural Geography in Shore Areas
NPBD	Malaysia's National Policy on Biological Diversity
OBIA	Object-Based Image Analysis
RGB	Red Green Blue
ROI	Region of Interest
RS	Remote Sensing
RMSD	Root Mean Square Deviation
TDS	Total Dissolved Solids
UAV	Unmanned Aerial Vehicle
UV	Ultraviolet

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POTENSI APLIKASI *UNMANNED AERIAL VEHICLE* (UAV) DALAM PEMETAAN SKALA KECIL RUMPUT LAUT DI PULAU GAZUMBO, PULAU PINANG, MALAYSIA

ABSTRAK

Rumput laut skala halus biasanya tumbuh di tambalan di sepanjang zon intertidal yang diselaputi oleh epifit yang menghadkan pengimejan satelit untuk mendapatkan imej yang jelas. Oleh yang demikian, drone (DJI Spark) digunakan untuk memperoleh imej beresolusi tinggi. Kajian ini mengkaji penyebaran rumput laut dengan data lapangan, kandungan klorofil dan menentukan keadaan rumput laut. Kajian ini juga bertujuan untuk menentukan aplikasi UAV pada pemetaan dan pengelasan gambar taburan rumput laut skala halus. Taburan rumput laut lampau juga dianalisis di Pulau Gazumbo. Lapan stesen pensampelan terdiri daripada 3 kuadran di mana mewakili zon littoral atas, tengah dan bawah ditempatkan semasa air pasang rendah berukuran 0.5m × 0.5m. Keadaan persekitaran, pucuk dan daun dihitung dan direkod untuk analisis lebih lanjut sementara data temporal diambil dari kajian sebelumnya (2003, 2006 dan 2009). Daun rumput laut dikumpulkan untuk kaedah pengekstrakan klorofil konvensional di mana cerapan dibaca pada 647nm dan 664nm. Sementara itu, tinjauan RS merangkumi imej drone dari setiap kuadran pada ketinggian 1.5m dari permukaan tanah. Analisis GIS dilakukan dalam perisian ENVI 10.4 dan ArcMap 10.2 yang merangkumi pemprosesan imej, klasifikasi dan Pemetaan Kemungkinan Maksimum. Hasil kajian menunjukkan kewujudan *Halophila ovalis* diikuti oleh *Halophila beccarii* dan *Halophila spinulosa*. Anggapan statistik menunjukkan taburan rumput laut yang tidak signifikan antara zon littoral dan tahun temporal. Taburan rumput laut lebih tinggi di zon littoral atas (42.5%) dan tengah

(43.75%) berbanding dengan zon littoral bawah (37.5%) yang mana berkait rapat dengan keadaan persekitaran. Klorofil tertinggi di zon littoral tengah (5.189 mg/g DW) diikuti oleh zon littoral atas (4.998 mg/g DW) dan terakhir zon littoral (3.075mg/g DW). Variasi klorofil berlaku kerana sumber cahaya matahari langsung yang lebih tinggi yang terdedah sepenuhnya semasa air surut. Tekstur spektrum rumput laut jelas dan maklumat terperinci dibezakan dari imej drone dengan resolusi spasial ± 1cm hingga ± 2cm. Hasil kajian menunjukkan bahawa rumput laut adalah 43.31% (littoral atas), 41.82% (littoral tengah) dan 33.08% (littoral bawah). Oleh itu, pengedaran rumput laut dianggap agak baik di semua stesen. Kecenderungan rumput laut dipengaruhi oleh perubahan temporal di mana kepadatan pucuk tinggi hingga sederhana tinggi pada tahun 2003 dan 2006 sedangkan pada tahun 2009 dan 2020, penurunan menjadi sederhana rendah dan rendah. Kesimpulannya, imejan UAV berguna untuk pemetaan dan pengelasan rumput laut kerana ketepatan keseluruhannya adalah 86.05%. Taburan rumput laut dijangka menurun disebabkan oleh kesan persekitaran. Justeru, pendekatan ini bersifat konstruktif dalam menentukan taburan rumput laut skala halus terutama berkaitan dengan pemuliharaan dan pengurusan.

POTENTIAL APPLICATION OF UNMANNED AERIAL VEHICLE (UAV) IN FINE SCALE SEAGRASS MAPPING AT PULAU GAZUMBO, PENANG, MALAYSIA

ABSTRACT

Fine scale seagrass usually grows in patches along the intertidal zone which is covered by epiphytes that limits satellite imagery to obtain a clear image. Hence, to overcome this, a drone (DJI Spark) was used to cater high resolution image. This study investigates seagrass distribution with ground data, chlorophyll content and distinguishes seagrass condition. This study also aims to determine application of UAV on mapping and classifying images of fine scale seagrass distribution. Temporal seagrass distribution was analyzed in Pulau Gazumbo. Eight sampling stations consists of 3 quadrants whereby represents upper, middle and lower littoral zones were placed during low peak tide the size of 0.5m × 0.5m. Environmental conditions, shoots and leaves were counted and recorded for further analysis whilst temporal data was retrieved from previous studies (2003, 2006 and 2009). Seagrass leaves were collected for conventional chlorophyll extraction method whereby absorbance was read at 647nm and 664nm. Meanwhile, RS survey comprises drone imagery from each quadrant at 1.5m above ground. GIS analysis was conducted in ENVI 10.4 and ArcMap 10.2 software which includes image processing, Maximum Likelihood classification and mapping. Results showed temporal existence of *Halophila ovalis* followed by *Halophila beccarii* and *Halophila spinulosa*. Statistical assumptions showed insignificant distribution of seagrass between littoral zones and temporal years. Seagrass distribution was higher in the upper (42.5%) and middle littoral zone (43.75%) compared to the lower littoral zone (37.5%) which relates to environmental measures. Chlorophyll was highest in the middle littoral zone (5.189 mg/g DW) followed by upper littoral zone (4.998 mg/g DW) and lastly lower littoral zone (3.075 mg/g DW). Variations of chlorophyll occurred due to higher direct source of sunlight exposed fully during low tide. Spectral texture of the seagrass was clear and detailed information were distinguished from drone imagery with ±1cm to ±2cm spatial resolution. Results portrayed that seagrass was 43.31% (upper littoral), 41.82% (middle littoral) and 33.08% (lower littoral). Thereby, seagrass distribution was considered rather good in all stations. Seagrass trends were impacted by temporal changes whereby shoot density was high to moderately high in 2003 and 2006 whereas in 2009 and 2020, it decreases to moderately low and low. In conclusion, UAV imagery is useful for mapping and classifying seagrass as overall accuracy was 86.05%. Seagrass distribution was expected to decline due to environmental impacts. Lastly, this approach is constructive in determining fine scale seagrass distribution particularly where conservation and management is concerned.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Seagrass is known as an exclusive flowering aquatic plant which profoundly influence the physical, chemical and biological environments in the coastal waters. At the present time, at least 72 disperse species of seagrass were discovered across the world (Short et al., 2016). In Malaysia, 14 major seagrass species was recorded in 78 sites across the west & east coasts of Peninsular Malaysia and in Sabah and Sarawak (Bujang et al., 2006). Unlike other aquatic plants which consist of a large taxonomy groups, seagrass has low taxonomic diversity where three independent lineage of seagrass (Hydrocharitaceae, Cymodoceaceae complex, and Zosteraceae) evolved from a single lineage of monocotyledonous flowering plants between 70 million and 100 million years ago (Orth et al., 2006). Despite of the low taxonomic group, seagrass still managed to survive up to today.

As a monocotyledonous angiosperm, seagrass usually grows along the coastal area which associates with the presence of mangrove, shoals and semi-enclosed lagoons. Subsequently, other coastal inhabitants namely saltmarshes, bivalves, crustaceans, reefs and mangrove forests interact with substrates where seagrass grows on (Duarte et al., 2008). In these habitats, meadows and beds have distinct characteristics which allows them to adapt well through environmental changes within the intertidal and submerged area (Misbari, 2017).

Seagrass significantly preserves water quality, provides oxygen and strengthens the substrate which they grew on by preventing siltation and erosion in coastal areas (Duarte & Kirkman, 2001; Misbari, 2017). The highly productivity rate among seagrasses contributes as a primary food source for most benthic marine organisms. Additionally, certain seagrass species such as *Enhalus acoroides* is also widely consumed and known as a part of food source especially in the Philippines.

Unfortunately, since the 19^{th} century, the global coverage of seagrass beds has declined by 29% and the rate of loss is estimated to have increased by an order of magnitude in the past 40 years (Waycott et al., 2009). This rapid contemporary fluctuation is highly related to the inadaptation of vast extreme surrounding such as light attenuation, sedimentation run-off, hydrological changes, urbanization and climate change.

In most countries, field-based seagrass study has been widely conducted to monitor seagrass changes over time for sustainability management. As technology evolves, adequate research techniques have been imposed to escalate seagrass monitoring across the world such as mapping. Seagrass mapping initiated from manually-based approaches to supervised and unsupervised machine learning classification techniques (Moniruzzaman et al., 2019). These approaches are used to produce dependable map for environmental monitoring as it improves data processing and classification sites over time.

South-East Asia is known as the centre of seagrass biodiversity but at the present time, there are only a few areas which have been mapped (Duarte et al., 2008; Duarte et al., 2013). Estimated seagrass loss and status can be monitored using strong mapping technique. As a result, biophysical properties mapping on seagrass has been successfully recorded with the prove of percentage cover and above-ground biomass.

Apart from the methods of gathering remote sensing data sets, data processing including satellite imageries, classifying methods and processing techniques can alternate the results of mapping accuracy in an area. Depending on image retrieved, close view data such as acoustic sensors and underwater footage are beneficial to monitor submerged seagrass condition whilst remotely sensed image such as multispectral approach produces fast and deliberate results which are suitable for seagrass areas (Roelfsema et al., 2009; Duffy et al., 2018). In the light of existing literature review, many scientists concluded that in situ data have higher accuracy percentage however it is very time consuming and practical. As an alternative method, aerial imagery was imposed to help researchers produce fast, cost effective and reliable results however, it still has limitations when mapping patchy seagrass.

Henceforth, to overcome the limitations and gaps of some existing literatures, an alternative method was discovered by coalescing high spectral resolution survey with field measurements. The aim of this study is to determine whether high resolution imagery from UAV also known as drone is reliable for mapping diverse composition of seagrass and other land classes using visual classifiers. This study also aims to determine seagrass status, trends and distribution in the study area.

Pulau Gazumbo, Penang was the islet that this study has been conducted entirely. The study area consists of eight sampling stations documented as overall representatives of seagrass from the whole islet.

1.2 Problem Statement

Human activities are driven by the rising population which are proven from an increase in coastal development, aquaculture, agriculture and industrial projects (Griffiths et al., 2020). The population settlements are widely located along the coastlines which drives an increase in economic and demographic growth as compared to non-coastal areas. This highly driven pattern is critical as it triggers more risks of pollution damage to its natural resources especially on seagrass as they are the bioengineer of the ecosystem which maintains the water quality in the area (Patterson & Glavovic, 2009). These issues have led to imposing numerous stresses to the coastal ecosystem which disrupts the seagrass community. In order to monitor and manage seagrass community, field-based surveys have been widely conducted in most areas however this method promotes long hours on field and high financial support to cover the study area.

As an alternative means to field-based surveys, satellite imagery has been imposed to produce a cost-effective and fast results. However, the main concern which lingers among scientists is the accuracy among remotely sensed imagery based on the types of seagrass (Howari et al., 2009). Satellite imagery offers a wide range of resolutions though it is not dependable for fine-scale seagrass and small study areas.

In most common mapping methods which have been imposed to map macroalgae and seagrass in the intertidal zones at a scale of 2m to 20m, there are no civil remote sensing technique is yet available for finer scale (Krause Jensen et al., 2001). Moreover, the ability of satellite imagery to detect fine-scale seagrass are often affected by cloud cover, scattering & absorption of light in the atmosphere and variable tide states. As a result, pixelated imagery increases high inaccuracy percentage as well as causes difficulty when selecting the training sites.

Another most critical issues in seagrass mapping are that most fine-scale seagrass grows in patches especially *Halophila ovalis* which colonizes mainly in the intertidal zone of Pulau Gazumbo. Aerial imagery offers a highly distinctive spatial resolution image which covers fine-scale seagrass features. Unfortunately, patchy seagrass is bound to alter its feature because of the presence of extensive unvegetated and vegetated substrate found in between seagrass colonies when mapped. Henceforth, this issue causes researchers to have the inability to depend on unsupervised training sites in order to identify and classify actual seagrass area in patchy habitats or to measure fine-scale seagrass spatial pattern.

Synoptic studies have shown that global seagrass habitat fragmentation and disruption are at a rate of 110km per year between 1890 to 2006 (Orth et al., 2006). Unfortunately, only 5 – 10% of the world's seafloor is mapped (Wright & Heyman, 2008). Ideally, the lack of temporal study emphasizing on seagrass trends and distribution may be a fundamental reason why seagrass is at risk of extinction. Thereby, it will lead to the unknown status of seagrass abundance and poor management of seagrass ecosystem in future.

1.3 General Aim

The intention of this study is to determine the distribution and condition of seagrass by implying visual classification and field techniques to map seagrass using UAV. To ensure the research aim is successfully retrieved, the specific objectives of study are:

1.3.1 Objectives 1

To investigate fine scale seagrass distribution with ground data, chlorophyll content and distinguish seagrass condition in Pulau Gazumbo.

1.3.2 Objectives 2

To study the potential application of remote sensing technology using UAV on fine scale seagrass distribution which is used for mapping and classifying images.

1.3.3 Objectives 3

To analyze the time trend of fine scale seagrass distribution in Pulau Gazumbo, Penang.

1.4 Scope of Study

This study emphasizes of the following subtopics:

1.4.1 Intertidal Fine Scale Seagrass in Penang

Intertidal fine scale seagrass refers to seagrass species *Halophila ovalis* which grows near the shoreline. It is much likely exposed to the surface around the intertidal zone during lowest tide. This shows that water column can be outsourced as aerial image can be captured during lowest tide. However, since intertidal seagrass is known as a fine-scale vegetative plant, satellite imagery is unreliable to conduct mapping and monitoring process due to certain desired resolution needed to obtained clearer image.

1.4.2 Application of UAV on Seagrass Monitoring

The usage of UAV from a commercial drone is implied to cater a clearer image of seagrass in the intertidal zone during lowest peak tide. Moreover, the inexistence of atmospheric corrections and cloud cover lessens processing time when mapped. However, light scattering is difficult to control as the type of camera used in this study is solely based on common commercial camera which was equipped with the drone. Knowledge of the phenology of target species, tides, wind speed and direction can improve image selection when sampling (Ferguson & Korfmacher, 1997).

1.4.3 Field Data Monitoring

On field data can be used for biological and in situ monitoring of seagrass whereby it is collected from primary and secondary data. Sampling coordinates was solely based on previous study conducted by Krishnan (2009). In this study, leaves and shoots of the seagrass were quantified by referring to the sampling guidelines conducted by McKenzie (2003) which are also practiced by SeagrassWatch Organization to document seagrass coverage globally. Chlorophyll pigment extraction was conducted in the lab using samples collected. Secondary data for shoots and leaves were also studied to overlay the distribution of seagrass over time in Pulau Gazumbo.

1.5 Significance of Study

The development of longing sustainability in coastal areas would be significant as it is in relation of food security and provides sustainable ecosystem functioning. Globally, seagrass is important for maintaining ocean productivity and mitigating unpredicted natural hazards due to climate change (Misbari, 2017). Furthermore, seagrass have been major contribution to the national wealth creation whereby based on Unsworth & Cullen-Unsworth (2014), the estimated annual economic value of seagrass bed is at 19 000 US$ per hectare. According to the NPBD, the fist strategy cited for effective management of biological diversity plan whereby to improve scientific knowledge base (MOSTE, 1998).

Although Malaysia is popularly known as one of the twelve "megadiversity" countries in the world, there are still concerns regarding inadequate monitoring and poor conservation efforts documented. Thereby, aligned with the NPBD's policy strategy, this study provides documented information on seagrass distribution and trends in Penang.

Seagrass ecosystems in Malaysia remained outside of the common topic in marine related recent studies. Specifically, in Pulau Gazumbo whereby the trend, status and distribution of seagrass are hardly monitored and conducted. Adequate scientific techniques for seagrass monitoring are crucial depending on the types of seagrasses and RS approach that is believed to provide better results in terms of technical operations and minimize destructive sampling of its natural habitat.

In addition, this approach reduces time and cost for field sampling and caters distinctive image pixels which improves the accuracy of image when classifying. Hence, updated information on seagrass communities can be achieved therefore minimizing threats and increases seagrass biodiversity in the study area.

At a local scale, this study helps to educate the community on the status and effects of reduced seagrass in Pulau Gazumbo whereby critical environmental issues awaits if it is not monitored. Stakeholders, policy makers, ecologist, planners and government may rely on this study to help in conducting conservation awareness thus preserving the marine biodiversity for eco-sustainability. Lastly, the findings from this study helps to assist preserving seagrass in Penang for the benefit of future generation.

1.6 Novelty

As technology evolves, the usage of UAV has been widely imposed in many economic industries such as agriculture, surveying and many others. Therefore, to cater demands of providing a safe, fast and reliable results, UAV is often used by professional pilots to meet client demands.

As technology evolves, the usage of UAV has been widely imposed in many economic industries such as agriculture, surveying and many others. Therefore, to cater demands of providing a safe, fast and reliable results, UAV is often used by professional pilots to meet client demands.

Similarly, the novelty in this study relates to the usage of commercial drone to replace satellite imagery which is used to classify intertidal seagrass and other land cover classes in Pulau Gazumbo at a constant height of 1.5m above ground. This method is predicted to create acute orthophotos of the study area whereby it minimizes classifier errors during classification process thus provides successful accuracy at the end of this study.

Secondly, in the light of existing literature, there are very few studies associated with seagrass in Penang. The lack of new techniques for documentation and monitoring of seagrass will result in shortage of temporal quantitative data. At the present time, no primary study associated with seagrass mapping using commercial drones were found in Pulau Gazumbo. Hence, this study experiments on the suitability of using commercial drones with the environmental conditions in Pulau Gazumbo.

1.7 Limitations

In this study, there are two limitations that needs to be addressed and acknowledge. Firstly, the distribution map of seagrass only represents the estimated percentage of seagrass cover around the islet. This is due to the image captured was entirely based on commercial drone whereby lack professional handling experience thus the inability to collect distinctive image overlay and to mosaic each image of the whole islet are almost impossible and difficult to be achieved.

Secondly, there were no temporal seagrass data associated between period of 2009 to 2020. Consequently, 3-year gap data can be seen from 2003, 2006 and 2009 however, this trend could not be done to compare with the primary data in year 2020. The lack of secondary data and inability to archive a 3-year gap data for the remaining years causes a slight limitation in this study in order to determine the trend for every 3 years.

1.8 Output of Study

The output of this study reflects with the objectives as mentioned in 1.3. At the end of this study, the effectiveness of drone imagery will be determined by the post classification accuracy result. Meanwhile, the result of the image processing catered from the drone was also predicted to achieve a highly accurate and precise (> 70%) result classification of seagrass and other land cover classes. Next, a seagrass percent cover map was expected to show and represents fine scale seagrass distribution around the islet. Additionally, ground data and chlorophyll content support data from drone imagery whereby it distinguishes seagrass condition based on intertidal zones across the islet. At the end of this study, an up-to-date seagrass trends and changes will be portrayed for Pulau Gazumbo islet whereby future monitoring and management can be implemented by referring to this study.

1.9 Thesis Structure

This thesis consists of five chapters. Chapter 1 represents a background study of the main topic of this study, main issues of seagrass, objectives, novelty and limitation of this study. In this section, a general structure illustration of the workflow and detailed reasoning on the study are explained thoroughly. Thereby, this chapter effectively introduces the condition of seagrass by implying visual classification and field techniques to map seagrass using UAV as the main topic and specific mission of study that needs to be completed.

Next, Chapter 2 focuses on summarization of several literature reviews from a detailed background and supporting information on the research topic which includes seagrass morphology, distribution of seagrass in Malaysia, significance of seagrass in the ecosystem, threats, basic concepts on seagrass monitoring that includes conventional and remotely sensed techniques, strengths and constrains of methods, previous studies and expansion of related field which are to be implemented.

Chapter 3 compromises of research methodology and collected secondary data involved in this study which are structurally emphasized in detail. The method implied profoundly explains in a sequence in each stage. The results and discussions after the implementation of techniques and processed data in this study are displayed and discussed further in Chapter 4. In the last chapter, a summary and recommendation of the study was carried out. Appendix pages included in this thesis is to show several collections of field data sheets, images of additional marine biodiversity which was found in the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Seagrass Morphology

Seagrass is a monocotyledonous benthic plant that is globally spread in all continents except the Antarctic (Unsworth et al., 2019). The existence of different types of seagrass at which have been recorded are about 72 species worldwide (Short et al., 2016). The anatomy of seagrass consists similar tissues and organs as other vegetative plants such as stems, roots and leaves which contain lignified conducting tissue (veins) and air channels named as lacunae (Bujang, 2012).

In the upper part of the plant, the leaves contain green pigments on the surface known as chlorophyll which varies from thin strips to oval structures and it may be classified into shoots (Bujang, 2012). Seagrass possess thin, strong, flat and flexible leaves due to the existing internal tissues such as fibre bundles, aerenchyma, lacunae and bundle sheaths (xylem & phloem) as shown in Figure 2.1. Oxygen transport flow initiates from the rhizomes and roots during daylight due to the presence of oxygen release into the aerenchyma when photosynthesis takes place (Papenbrock, 2012).

The oxidized rhizomes uptake specialized nutrients needed for the seagrass and discrete toxic elements using oxygenation technique. At night, aerenchyma which consists of large air-space tissues diffuses oxygen kept during daylight around the roots into the anoxic sediment (Kuo & Hartog, 2006) while oxygen flow halts and alcoholic fermentation occurs in the roots (Pedersen et al., 1999).

At a maturity stage, distinctive above and below ground parts can be identified in seagrass. Below ground parts usually consists of roots, rhizomes and stems which are designed to anchor and provide stable support whilst the above part consists of shoots bearing several leaves (Kuo & Hartog, 2006). Horizontal stems also known as rhizomes are very extensive and usually buried in the muddy or sandy substrate.

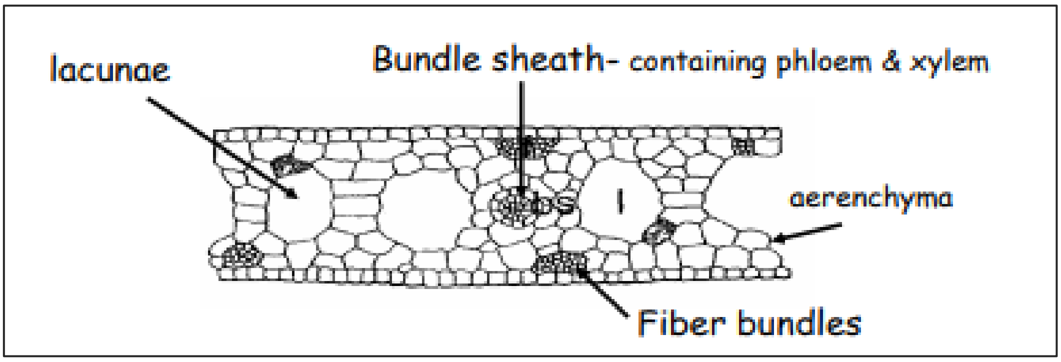

Figure 2.1 The Anatomy of Seagrass Leave (Bujang, 2012)

Meanwhile in the reproductive stage, seagrass is proficient of producing both sexually and asexually. The variation among seagrass features disrupts non-taxonomist to clearly identify morphologically on seagrass species because in some seagrass, the flower which the distinct morphological trait is missing (Papenbrock, 2012). The only feature that differentiates seagrass and other aquatic plant is the filiform pollen. Figure 2.2, 2.3 and Table 2.1 shows the taxonomy, anatomy and terminology used for seagrass identification based on its species.

Photosynthesis process in seagrass takes place in low CO_2 concentration areas such as shallow water and confined regions hence result in low molecular diffusion among boundary layer around the leaves. To overcome this uncontrolled measure, seagrass adapts a biochemical process whereby it converts seawater into CO_2 from anhydrase enzymes at the outer tangential walls of epidermal cells and presence of proton pump at the plasmalemma in the leaves (Papenbrock, 2012).

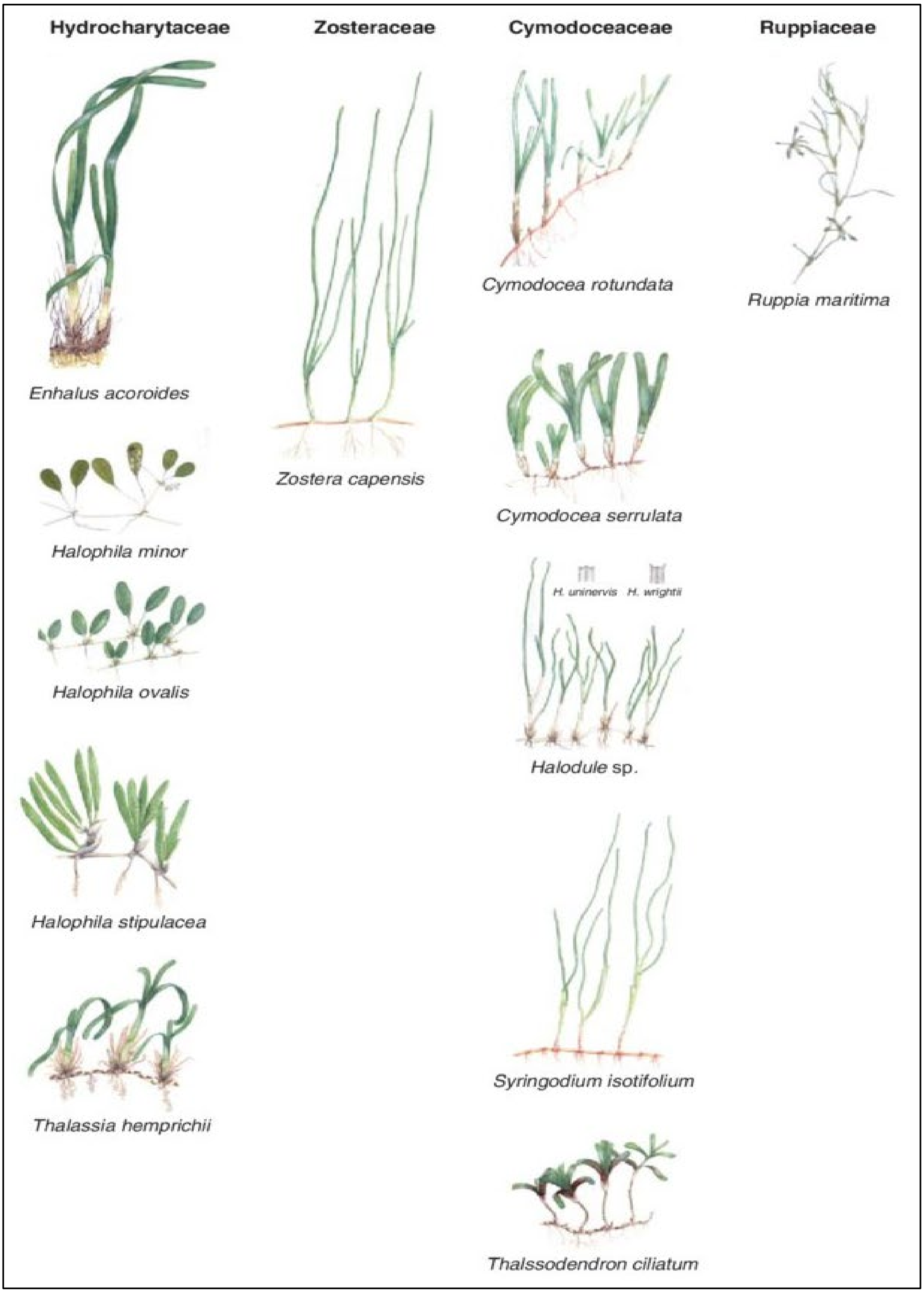

Figure 2.2 Seagrass Taxonomy (Gullström et al., 2002)

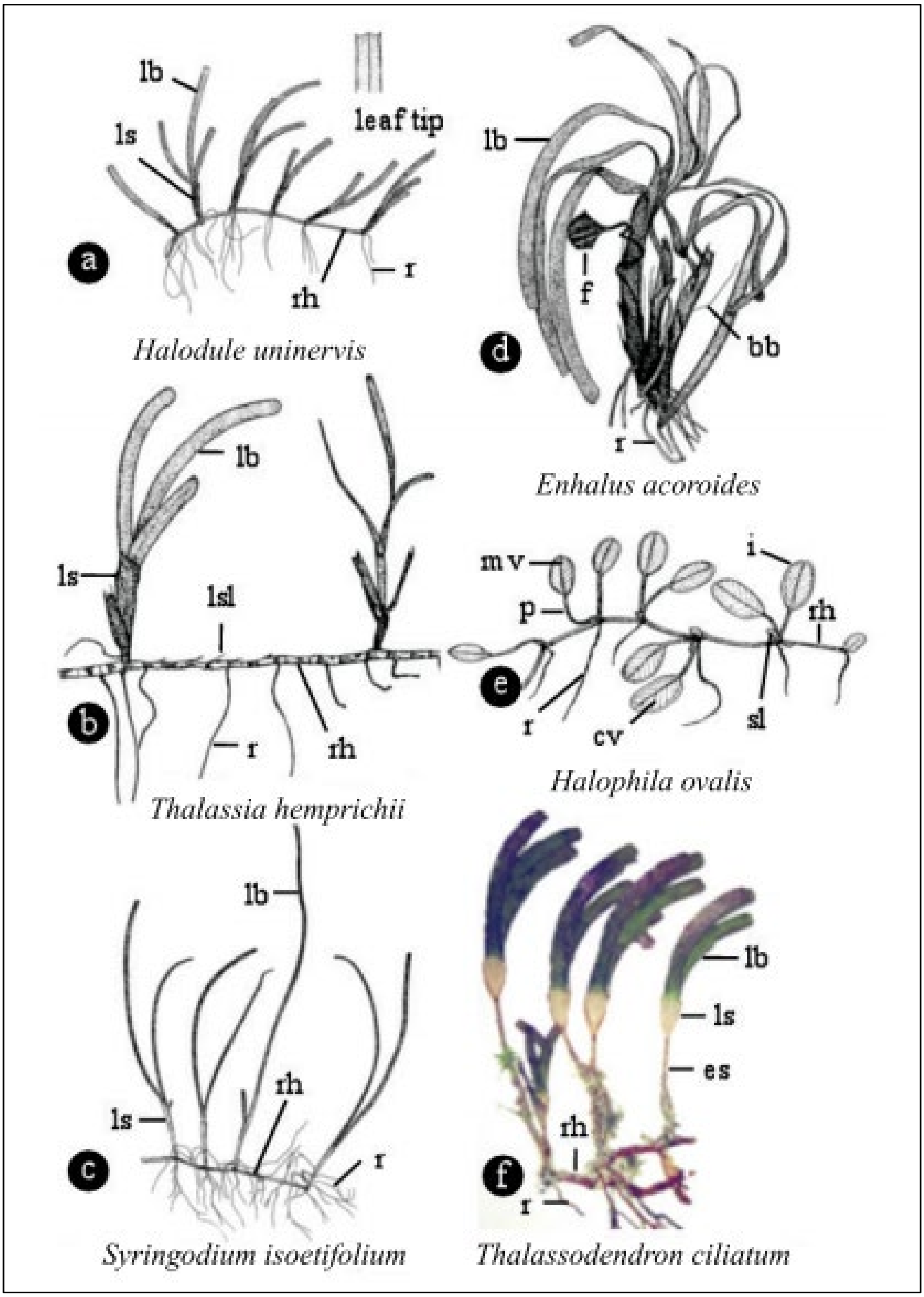

Figure 2.3 The Anatomy of Seagrass Species (Bujang, 2012)

Table 2.1 Terminology of Seagrass (Bujang, 2012)

Label	Terminology
lb	leaf blade
ls	leaf sheath
rh	rhizome
r	roots
lsl	leaf scale
bb	black bristle
f	fruit
mv	mid vein
cv	cross vein
i	intra marginal vein
es	erect stem

One of the most unique traits of seagrass is the adaptation and survival rate towards subjective environment which are consequently high. This is because seagrass have the capability to bioengineer its surrounding thus an extensive arrays of biodiverse fauna depends on its coping mechanism to revive in extreme conditions (Unsworth et al., 2019). Rapid urbanization and industrial activity near to the coastal areas disrupts the productivity and distribution of seagrass, however they were not yet close to extinction (Abdullah & Anscelly, 2015). Terrestrial plants consists both vegetative and regenerative characteristics that is similar to seagrass which its morphological changes from time to time under different environmental conditions with the combination of environmental stressors (Pérez-Harguindeguy et al., 2013).

Figure 2.4 Decolouration of Seagrass Pigment in *Halophila ovalis* (Kaewsrikhaw & Prathep, 2014)

The physical differences of seagrass are influenced by the area that it grows on and exposed to depending on heterogeneity of substrate (Kaewsrikhaw & Prathep, 2014). However, the inimitable feature of seagrass is the transformation colouration of seagrass pigment from green to dark purple when exposed to sunlight in order to protect itself from excessive UV radiation (Tevini & Teramura, 1989). Figure 2.4 shows the decolouration of pigment in seagrass. Subsequently, seagrass has the ability to produce food in high light source of 10% of surface light however in some seagrass species which inhabits deeper water region, it can survive at only 5% of surface light (Papenbrock, 2012).

2.2 Seagrass Distribution in Malaysia

Based on the preliminary study conducted by (Department of Fisheries, 1990), seagrass were initially found merely around the coastal waters of Peninsular Malaysia. Several areas which were identified are Pulau Sibu, Pulau Babi group of islands, Johor and Pulau Langkawi.

There are mainly sixteen major seagrass species were identified in Malaysia which are *Enhalus acoroides, Halophila beccarii, Halophila decipiens, Halophila ovalis, Halophila major, Halophila minor, Halophila spinulosa, Halophila sp., Halodule pinifolia, Halodule uninervis, Cymodocea rotundata, Cymodocea serrulata, Thalassia hemprichii, Syringodium isoetifolium, Thalassodendron ciliatum,* and *Ruppia maritima* (Bujang et al., 2018). Figure 2.5 shows the location of seagrass species distributed in Malaysia.

The distribution of seagrass is affected by the amount of sunlight that reaches the sediment thus a slight change in turbidity from resuspension of fine sediment or anthropogenic factors will alter the abundance and growth of seagrass in an area (Papenbrock, 2012). Subsequently, species abundance are also affected by persistence of a seed in the seed bank as it depends on residence time in the sediment, initial timing of dormancy during development or seed release or mechanisms preventing germination process such as environmental pollution (Orth et al., 2000). Based on Figure 2.6, the presence of seagrass distribution is most common in West Peninsular Malaysia as compared to the East Malaysia

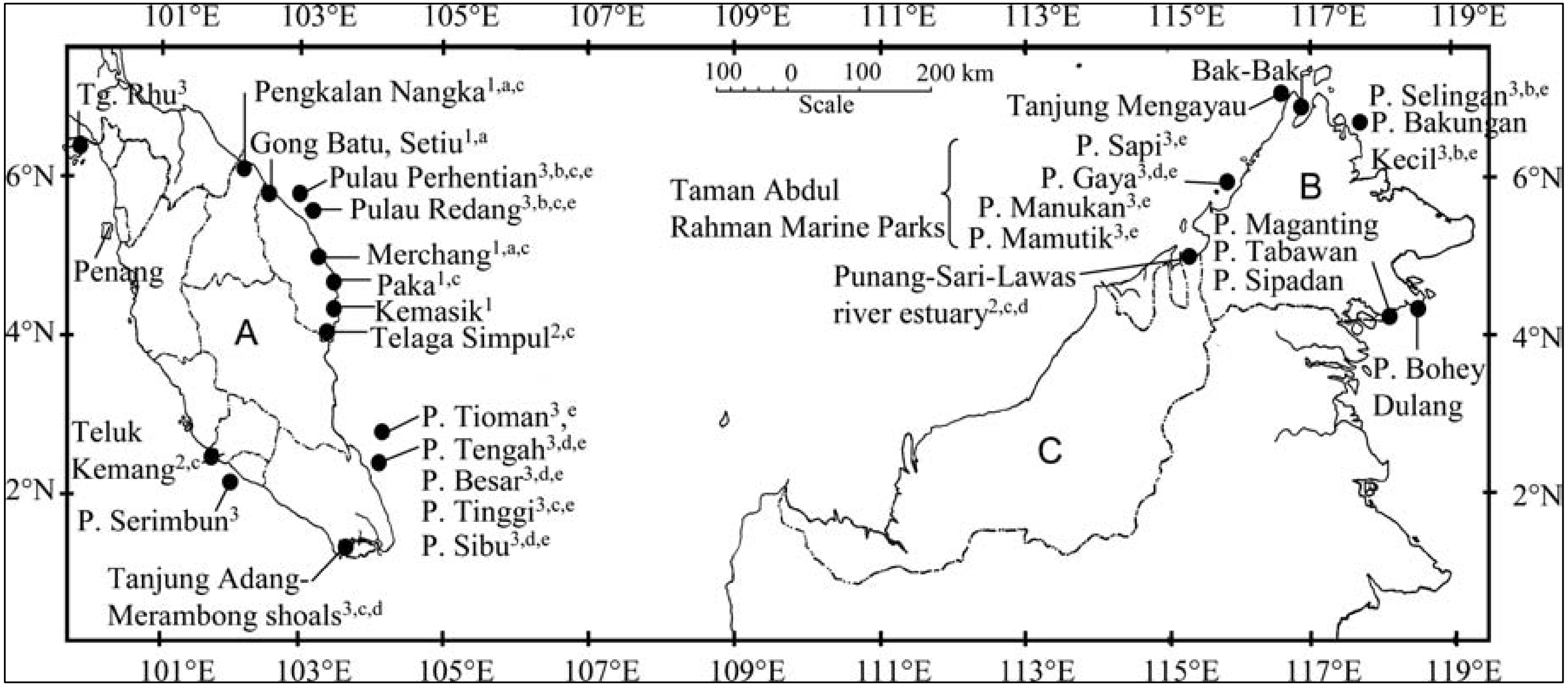

Figure 2.5 The Distribution and Existence of Seagrass in Malaysia (Bujang et al., 2006)

Family	Name	Site																
		Peninsular Malaysia													East Malaysia			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Hydrocharitaceae	*Enhalus acoroides* (L.*f*.) Royle	*	*				*					*			*	*		
	Thalassia hemprichii (Ehrenb.) Aschers.	*	*	*											*	*		*
	Halophila beccarii Aschers.							*	*					*				
	Halophila decipiens Ostenfeld	*									*	*			*		*	
	Halophila minor (Zoll.) den Hartog		*						*	*	*	*			*		*	*
	Halophila ovalis (R. Br.) Hook. f.	*	*	*	*	*	*			*		*	*		*	*	*	*
	Halophila spinulosa Aschers.		*		*										*			
Cymodoceaceae	*Cymodocea serrulata* (R. Br.) Aschers. & Magnus		*	*	*										*	*		*
	Halodule pinifola (Miki) den Hartog	*	*			*		*	*	*	*	*	*	*	*	*	*	*
	Halodule uninervis (Forssk.) Aschers	*	*	*	*	*		*							*	*		
	Syringodium isoetifolium (Aschers.) Dandy	*	*	*	*	*												

Figure 2.6 Seagrass Abundance in Malaysia; 1. Teluk Kemang; 2. Tanjung Adang- Merambong; 3. Pulau Tinggi; 4. P. Besar; 5. P. Tengah; 6. P. Sibu; 7. Telaga Simpul; 8. Paka; 9. Merchang; 10. P. Redang; 11. P. Perhentian; 12. Gong Batu, Setiu; 13. Pengkalan Nangka; 14. Pulau Gaya; 15. Sepangar Bay; 16. P. Selingan, P. Bakungan Kecil; 17. Punang-Sari (Bujang et al., 2006)

2.3 Seagrass Distribution in Penang

Initially, the existence and abundance of seagrass in Penang is very rare and limited. In spite of this situation, seagrass colonies were able to mottle in Pulau Gazumbo due to the presence of neighbouring seagrass beds which are located nearby which are Pulau Langkawi in Kedah, Malaysia and Had Chao Mai National Park in Trang, Thailand (Razalli et al., 2011). Therefore, these neighbouring seagrass beds acts as a contributor of seagrass seedlings to the islet as it travels from the initial location. In the late 20th century, there were exclusive records of seagrass species spotted in Pulau Gazumbo, Penang (Ahmad, 1995). During this era, *Halophila ovalis* were found to be the supreme species which inhabits the area (Choong, 2003).

The species abundance of seagrass in Pulau Gazumbo can be easily identified during low tide as it colonizes in the intertidal zone. Four types of seagrass were identified which are *Halophila ovalis, Halophila ovata, Halophila beccarii* and *Halophila spinulosa* around the islet in Pulau Gazumbo, Penang (Shau Hwai et al., 2007). Although multitemporal alternation occurs in Pulau Gazumbo, the supreme species in this area remained by *Halophila ovalis* which majorly inhabits the intertidal zone (Abdullah & Anscelly, 2015) while small patches of *Halophila beccarii* can be found merely near the mangrove area (Krishnan, 2009). This is because *Halophila ovalis* have the ability to reproduce at higher range which is about 60 seeds compared to other seagrass that produce lesser (Larkum et al., 2006).

2.4 Significance of Seagrass in Ecosystem

The coastal zone is naturally managed by seagrass as it controls many parameters such as water quality, dissolved oxygen and many others. The growth of seagrasses spreads into the reefs, mediate the movement of the waves and trap sediments, clarifies water quality and protect the coast from erosion (Gumusay et al., 2019). Seagrass is usually located in the shallow water areas hence indirectly they provide protection towards predation for some high abundance animals (Unsworth et al., 2019). Benthic invertebrates, fish and birds depends on seagrass as their primary food source whilst coral reef fish hinge on seagrass for its productivity (Waycott et al., 2009). In fact, most benthic communities co-depend on seagrass for sustaining food, oxygen and good water quality in the ecosystem (Larkum et al., 2006).

Extensive evidence portrays that seagrass contributes to revitalising climate change as seagrass stores remaining carbon that represents 50% of carbon transfer from ocean to sediments (Crooks et al., 2011). Organic carbon stocks are mainly found in the substrate of seagrass where it is believed to be accumulated over millennia (Mateo, et al., 1997). This is because seagrass has the ability to capture, retain and elevate the seafloor thus making it one of the wetlands vegetative plant to mitigate climate impacts especially in the marine ecosystem (Serrano et al., 2018). Consequently, seagrass stabilizes sediment and prevents coastal erosion from the strength of its roots. This unique plant also reduces about 50% exposure in the relative abundance of potential bacterial pathogens capable of causing disease in humans and marine organisms in the ecosystem (Lamb et al., 2017).