CORAL DIVERSITY AND BENTHIC REEF COMMUNITIES IN SEPANGAR BAY, SABAH

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Hereby, I declare that all the material in my thesis are of my own except for quotations, excerpts, equations, summaries and references which have been duly acknowledged.

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ABSTRACT

Sepangar Bay is located approximately ten kilometres from Kota Kinabalu city. The bay is unprotected, and it is surrounded by the Sepangar Royal Malaysian Navy base, Sepangar Bay Container Port, Sepangar Bay Oil Terminal, several villages and nearshore islands. Two rivers, Menggatal River and Inanam River discharge into the bay. The area is rapidly losing its original mangrove, seagrass and coral reef habitats to rapid urbanisation. This study focuses on the percentage coral cover, coral diversity and environmental parameters that limit reef development in Sepangar Bay. Seven reef areas along the coast of Sepangar Bay and nearby islands (Sepangar Island and Pulau Island) were surveyed between 2015 to 2017. In each area, three replicate transects of 100 metres were deployed at approximately 5 - 10m depth. A total of 50 photo quadrats were taken along each transect and analysed using Coral Point Cover with Excel extensions (CPCe) software. Water physico-chemical parameters and sediment particle size were analysed for each site. The percentage coral cover ranged between 11.11% (Inner Sepangar Bay) and 52.86% (Udar Island), with the lowest recorded at the sheltered reef areas within the inner bay and the highest coverage at the islands and along the exposed coastline. Two areas were considered as Good, three as Fair while two were determined to be Poor. The sheltered areas had a higher percentage of silt and coral rubble on the reefs compared to others and significant difference in percentage coral cover among the areas was observed between sheltered areas and island, exposed areas. A total of 53 coral genera was identified with nine genera present at all sites and three genera observed at all transects (*Dipsastraea* spp., *Favites* spp. *Porites* spp.). Two sites recorded 44 genera (Udar Island and Tg. Gaya-Tg. Saban) which were the highest among all sites while the lowest had only 15 genera identified (Inner Sepangar Bay). According to Canonical Correspondence Analysis (CCA), turbidity, nitrate and phosphate were the parameters that displayed strong association in restricting reef development as they were heavily associated with silt and fine silt particles while the hard coral were more associated with Light and Luminescence Dissolved Oxygen (LDO) besides showing negative association with turbidity, nitrate and phosphate. This was supported by the distribution of the areas on the scatter plot where areas with high percentage coral cover was associated with light and LDO while areas with poor coral cover was associated with turbidity, nitrate and phosphate. Most coral genera showed negative association with those limiting parameters and displayed heavy association towards Light, LDO with preference of Rock and Sand substrate. However, several coral genera exhibit survivability and adaptability towards the limiting parameters and fine silt particles. The corals in Sepangar Bay were damaged more by bleaching compared to other damages observed where six out of seven areas had Bleached Coral Point. There are also several observations on damage by Crown-of-Thorns sea star and White Band Disease although the number is low. Hence, areas with higher percent coral cover had better environmental parameters that enables the coral reefs to sustain and remain healthy while poor coral cover areas were exposed to natural and anthropogenic stressors.

ABSTRAK

DIVERSITI KARANG DAN KOMUNITI BENTIK TERUMBU TELUK SEPANGAR, SABAH

*Teluk Sepangar terletak lebih kurang sepuluh kilometer dari bandar Kota Kinabalu. Teluk ini tidak dilindungi dan dikelilingi Markas Tentera Laut Diraja Malaysia Sepangar, Pelabuhan Kontena Teluk Sepangar, Terminal Minyak Teluk Sepangar, beberapa buah kampung dan pulau pesisir. Dua sungai iaitu Sungai Menggatal dan Sungai Inanam mengalir ke dalam teluk tersebut. Kawasan ini mengalami kehilangan paya bakau, rumput laut dan terumbu karang asal dengan pantas ekoran pembangunan yang pesat. Kajian ini memberi tumpuan pada peratusan karang, kepelbagaian karang dan parameter persekitaran yang menghadkan pertumbuhan terumbu karang di Teluk Sepangar. Tujuh kawasan terumbu karang sepanjang pesisiran Teluk Sepangar dan pulau berdekatan (Pulau Sepangar dan Pulau Udar) telah ditinjau antara 2015-2017. Tiga replikat transek sepanjang 100 meter telah dipasang pada kedalaman 5-10m di setiap kawasan. Sejumlah 50 kuadrat foto telah diambil sepanjang setiap transek dan analisis telah dilakukan menggunakan perisian "Coral Point Cover with Excel extensions (CPCe)". Parameter fiziko–kimia air dan sedimen juga dianalisis bagi setiap kawasan. Peratus liputan karang adalah antara 11.11% (Dalam Teluk Sepangar) dan 52.86% (Pulau Udar), dengan peratusan terendah direkodkan di kawasan terumbu karang yang terlindung dalam teluk dan peratusan tertinggi di pulau-pulau dan sepanjang pesisiran yang terdedah. Dua kawasan dinilai sebagai Baik, tiga sebagai Sederhana manakala dua kawasan telah ditentukan sebagai Teruk. Kawasan terlindung juga mempunyai peratusan selut dan serpihan karang yang tinggi berbanding kawasan pulau dan pesisiran yang terdedah. Sejumlah 53 genera batu karang telah dikenalpasti (49 skleraktinia dan 4 bukan skleraktinia) dengan sembilan genera ditemui di setiap kawasan dan tiga genera ditemui pada setiap transek (*Dipsastrea spp.*, Favites *spp.* Porites *spp.*). Dua kawasan merekodkan 44 genera (Pulau Udar dan Tg. Gaya-Tg. Saban) yang mana merupakan yang tertinggi antara semua kawasan manakala kawasan terendah hanya merekodkan 15 genera (Dalam Teluk Sepangar). Berdasarkan Analisis Koresponden Kanonikal (CCA), kekeruhan, nitrat dan fosfat merupakan parameter yang menunjukkan perkaitan yang lebih kuat dalam menghadkan perkembangan terumbu karang di mana ia turut berkait dengan kelodak dan saiz partikel kelodak halus manakala karang keras lebih cenderung terhadap cahaya dan LDO selain menunjukkan perkaitan negatif terhadap kekeruhan, nitrat dan fosfat. Ini turut disokong oleh kedudukan kawasan dalam plot taburan yang mana kawasan yang mempunyai peratusan taburan karang yang tinggi mempunyai lebih perkaitan dengan cahaya dan LDO manakala kawasan dengan taburan karang yang teruk menunjukkan lebih perkaitan dengan kekeruhan, nitrat dan fosfat. Kebanyakan genera batu karang menunjukkan perkaitan negatif terhadap parameter penghad tersebut dan menunjukkan perkaitan yang tinggi terhadap cahaya, LDO dan lebih menggemari substrat batu dan pasir. Namun begitu, sebahagian genera batu karang menunjukkan kebolehan hidup dan kemampuan untuk beradaptasi dengan parameter-parameter yang menghadkan perkembangan karang dan saiz partikel kelodak halus. Batu karang di Teluk Sepangar lebih terjejas oleh pelunturan karang berbanding kerosakan lain di*

mana enam daripada tujuh kawasan mempunyai rekod Karang Luntur. Terdapat juga pemerhatian yang menunjukkan kerosakan oleh tapak sulaiman Mahkota Berduri dan penyakit jalur putih (White Band Disease) walaupun rekodnya sangat rendah. Justeru, kawasan yang mempunyai peratusan liputan batu karang yang tinggi mempunyai parameter persekitaran yang lebih baik serta membolehkan terumbu karang untuk kekal dan sentiasa sihat manakala kawasan dengan liputan batu karang yang teruk terdedah kepada tekanan persekitaran dan antropogenik.

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LIST OF ABBREVIATIONS

BMRI	-	Borneo Marine Research Institute
$CACO_3$	-	Calcium carbonate
CCA	-	Canonical Correspondence Analysis
CO_2	-	Carbon dioxide
COT	-	Crown-of-Thorns
CPCe	-	Coral Point Count with Excel extension
DIN	-	Dissolved Inorganic Nutrients
DON	-	Dissolved Organic Nutrients
eg.	-	Example given
ntu	-	Nephelometric turbidity units
ODEC	-	Outdoor Development Centre
PAST	-	Paleontogical Statistics
RMN	-	Royal Malaysian Navy
SBCP	-	Sepangar Bay Container Port
SBOT	-	Sepangar Bay Oil Terminal
SL	-	Sepangar Island Leeward
sp.	-	Species
spp.	-	Species
SPSS	-	Statistical Package of Social Sciences
SW	-	Sepangar Island Windward
Tg	-	Tanjung

UiTM	-	Universiti Teknologi MARA
UMS	-	Universiti Malaysia Sabah
et al.	-	And others

LIST OF SYMBOLS

°C	-	Degree Celsius
%	-	Percentage
km	-	Kilometre
m	-	Metre
mm	-	Millimetre
µm	-	Micrometre
g	-	Gramme
mg/L	-	Milligramme per litre
mL	-	Millilitre
L	-	Litre
unit/mL	-	Unit per millilitre
pH	-	Potential Hydrogen
DO	-	Dissolved Oxygen
LDO	-	Luminescence Dissolved Oxygen
ppt	-	Parts per thousand
S/m	-	Siemens per meter
PSU	-	Practical Salinity Unit
≤	-	Less than and equal to
≥	-	More than and equal to

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Coral Reefs

According to Veron (2009), reef could bring different meaning for most people. Geologists and palaeontologists see reefs as rock formations and massive rampart of limestones. To them, reef had been built by organisms in the distant past but may no longer be animate. But to biologists, reef is a compilation of living organisms forming ecosystems that are as complex and fragile as any other on Earth. Meanwhile Hubbard (1997), mentioned that coral reefs are piles of wave-resistant limestones and calcareous sediments that were built by a thin layer of living organisms. Coral reefs are the largest durable bioconstruction projects of colossal scale on earth (Knowlton and Jackson, 2001). In addition, coral reefs are also one of the most biologically rich and productive ecosystems that extends across 250 000^2 km of the ocean which is less than 0.1% of the world's ocean (Hixon, 1997; Wild *et al.*, 2011). Reefs are usually restricted to a relatively narrow band fringing islands, concentrated from about 6-18m depth on outer reefs and from the surface to 8-12m depth on the inner banks, depending on the depth of sand bottom surrounding reef areas (Kleypas *et al.*, 1999a).

Scleractinian corals are the corals that are responsible in building reefs. These corals grow and form colonies. Multiple coral colonies form massive reef structures over time. Without scleractinian corals, there would not be any reefs but without reefs, scleractinian corals still exist (Veron, 2009). Nevertheless, stony

hydrozoans or known as hydrocorals also plays an important role in reef building especially the fire corals, Milleporina (=Anthoathecata) (Knowlton and Jackson, 2001).

One of the important criteria to define "true" coral reef development according to geologists are the existence of framework constructed by colonial metazoans containing endosymbionts or by crustose coralline algae (Knowlton and Jackson, 2001). Hence, even though coral reefs are mostly made up of $CaCO_3$ derived from corals, the corals alone are incapable of constructing reefs on their own (Veron, 2009). Encrusting coralline algae help to build coral reefs by depositing considerable amounts of calcium carbonate and keep reefs from washing away via alga ridge, a distinct ridge on the outer edge of reefs that absorbs waves force (Castro and Huber, 2010). Another function of coralline algae is to 'cement' the corals to the substrate in order to form reefs (Veron, 2009). Sediments that settled on and between corals are overgrown by encrusting algae as they accumulate, which cements the sediments in place for coral to bind to (Castro and Huber, 2010). Hence, coralline algae go hand in hand with corals as they determine where the reefs are most likely to develop, speed of reef formation and depth of the reef as the coralline algae flourish in shallow, turbulent and sufficient sunlit environment (Veron, 2009).

Besides coral and coralline algae, the symbiotic zooxanthellae are also important in reef building as they increase $CaCO_3$ deposition of the corals (Garrison, 2010). Fixation of inorganic carbon photosynthetically is carried out by zooxanthellae and part of the fixed carbon was passed on to the corals (Muscatine, 1990). Zooxanthellae supply corals nutritional benefits which are liable for high calcification rates in reefs formation (Muller-Parker and D'elia, 1997).

1.2 Coral Reefs in Malaysia

Malaysia consists of two main components, Peninsular Malaysia and part of Borneo Island (Sabah, Sarawak and Federal Territory of Labuan) which are separated by the South China Sea. However, the west part of Peninsular Malaysia is bordered by Straits of Malacca while in Sabah, the northern part is bordered by Sulu Sea and the eastern part is bordered by the Celebes Sea. With a coastline approximately

4800 km (2100 km for Peninsular Malaysia and 2700 km for East Malaysia), Malaysia's coral reefs was initially estimated to cover around 3000 km^2 (Burke *et al.*, 2001; Burke *et al.*, 2012). More recent studies by Cros *et al.* (2014) revealed that only approximately 1687km^2 of coral reefs were left, with most of the corals located in Sabah (Burke *et al.*, 2011; Burke *et al.*, 2012).

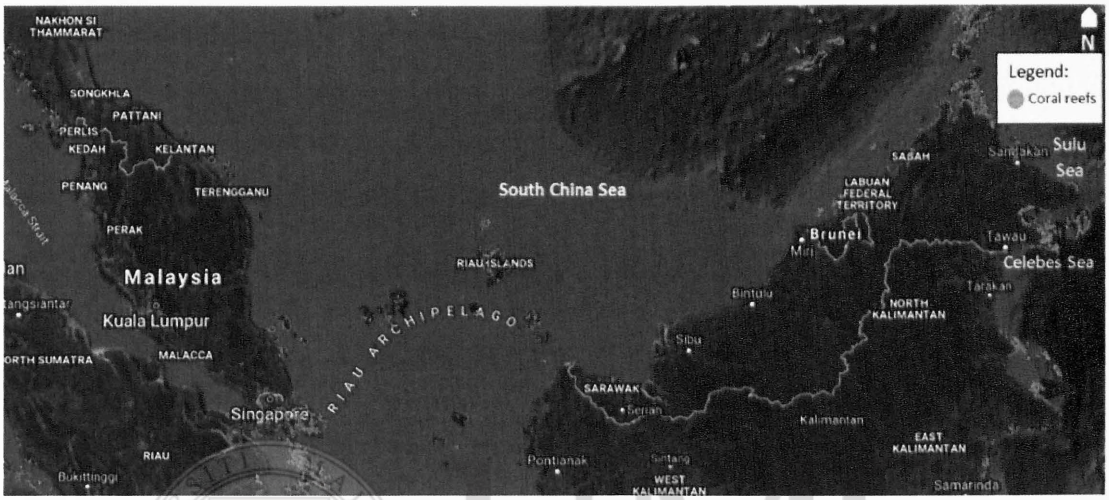

Figure 1.1: Distribution of Coral Reefs in Malaysia
Source : http://ctatlas.reefbase.org

Chou (1998) stated that the coral reefs in Malaysia were richer on the east coast compared to the west coast of Peninsular Malaysia (Figure 1.1). On the northern offshore islands such as Langkawi Island, Payar Island and Perak Island in Kedah and Pangkor Island, Jarak Island and Sembilan Island in Perak, there are presence of fringing reefs (Praveena *et al.*, 2012). Payar Island was gazetted under Payar Marine Park while Sembilan Island in Perak is gazetted under the Perak State Park. Meanwhile, there are also poorly developed and highly degraded reefs present in Port Dickson, Negeri Sembilan and Tanjung Tuan, Malacca, in the southern part of Peninsular Malaysia (Praveena *et al.,* 2012). On the east coast of Malaysia, there are reefs in the islands in Johor (Besar Island, Pemanggil Island, Aur Island, Sibu Island and Tinggi Island) which are gazetted under Sultan Iskandar Marine Park, Tioman Island Marine Park in Pahang, while in Terengganu there are Perhentian Island Marine Park, Redang Island Marine Park and Tenggol Island.

In East Malaysia, coral reefs could be found in Sarawak, Labuan and Sabah. In Sarawak, there are patches of coral reefs in Talang–Satang National Park which comprised of Talang–Talang Besar Island, Talang–Talang Kecil Island, Satang Besar Island and Satang Kecil Island. In addition, coral reefs were found in Miri primarily in the offshore Luconia reefs (Ridwan and Cabanban, 1994) which were gazetted in 2018 as Luconia Shoals Marine National Park, forming the largest marine park in Malaysia covering an area of 1,101,772 hectares (Yussop, 2018). There are also extended coral reef patches in Miri–Sibuti National Park which is closer to the mainland. In the Federal Territory of Labuan, coral reefs were found in Labuan Marine Park which comprises of Kuraman Island, Rusukan Besar Island and Rusukan Kecil Island. In Sabah, fringing coral reefs and patch reefs could be found on the west coast, north coast and east coast. On the west coast, there are two marine parks which are Tiga Island Marine Park in Kuala Penyu and Tunku Abdul Rahman Park in Kota Kinabalu. Besides that, coral reefs are also present in Sepangar Bay islands in Kota Kinabalu, Dinawan Island in Papar, Mantanani islands and Usukan Bay in Kota Belud, as well as Mengalum Island which is located offshore Kota Kinabalu. Further offshore is the Layang–Layang atoll which is well known for its marine megafauna. Tun Mustapha Marine Park, the largest marine park in Sabah, which covers an area of 898,762.76 hectares are located at north of Sabah which covers Kudat, Kota Marudu and Pitas district and comprised of more than 50 islands (Ponnampalan, 2018). Meanwhile on the east coast, coral refs were found in Sugud Islands Marine Conservation Area in Sandakan which comprises Lankayan Island, Billean Island and Tegapil Island, the Turtle Islands Park in Sandakan that comprises of Selingan Island, Gullisan Island and Bakungan Kecil Island. There are several islands in Semporna including the Tun Sakaran Marine Park and Sipadan Island Park and several islands nearby Darvel Bay. Sipadan Island coral reefs were found to possess the best reef condition in Sabah (Praveena *et al.* 2012).

Under federal legislation, coral reefs of Malaysia are protected under Environmental Quality Act (1974), Fisheries Act (1985), Pesticides Act (1974), Plant Quarantine Act (1976) and Customs (Prohibition of Exports Amendment No. 4) Order (1993) (Fourth National Report to the Convention on Biological Diversity 2009). In Peninsular Malaysia and Labuan Federal Territory, 40 islands were gazetted as marine parks under the jurisdiction of Marine Parks and Resource

Management Division, Department of Fisheries Malaysia covering 235,723 hectares. In Sarawak, more than 1.4 million hectares of marine protected areas are managed by Sarawak Forestry Corporation. Meanwhile in Sabah, the marine parks which covers nearly one million hectares of six marine parks (Tunku Abdul Rahman Park, Tiga Island Park, Tun Mustapha Park, Tun Sakaran Marine Park, Turtle Islands Park and Sipadan Island Park) are managed by Sabah Parks.

Diversity wise, a total of 501 species from 84 genera of scleractinian corals had been identified in Malaysia (Fenner, 2001; Affendi and Rosman, 2012; Waheed *et al.*, 2012; Huang *et al.*, 2016 and Waheed, 2016). Nevertheless, only the reefs in the east coast of Sabah are included within the Coral Triangle boundary (Veron *et al.*, 2009, 2011) that are shared with six other countries namely Indonesia, Philippines, Solomon Islands, Papua New Guinea and Timor-Leste although there is a recent review that suggest an extention of the boundary to include parts of South China Sea that overlays the Sunda Shelf based on comprehensive coral distribution, diversity and affinity data (Veron *et al.*, 2015), which includes coral species records that were published by researchers working in the South China Sea (Huang *et al.*, 2015).

1.3 Research Objectives

This research focuses on the coral cover, diversity and the environment parameters that limit coral reef development in Sepangar Bay.

Detailed objectives of the research are as follows:

1. To survey the Sepangar Bay coral reefs in terms of coral cover and genera diversity.
2. To compare the coral cover and genera diversity around Sepangar Bay.
3. To study the influence of sediment and water parameters that limit reef development in terms of coral cover and genera diversity.