SEAGRASS INTERACTION WITH HEAVY METALS AT PULAI RIVER ESTUARY

FARIDAHANIM BINTI AHMAD

UNIVERSITI TEKNOLOGI MALAYSIA

SEAGRASS INTERACTION WITH HEAVY METALS AT PULAI RIVER ESTUARY

FARIDAHANIM BINTI AHMAD

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2016

This thesis is dedicated to my family.

ACKNOWLEDGEMENT

Praise Be To Allah S.W.T, the Lord of the World

I wish to express a special appreciation and deepest gratitude to my supervisor Dr. Shamila Binti Azman for her aspiring guidance, sharing the truthful and views on a number of issues related in enjoyable memories. My appreciation also extended to my co-supervisor Associate Professor Dr. Mohd Ismid Bin Mohd Said, Associate Professor Dr. Razali Bin Ismail and Dr. Aznah Nor-Anuar for valuable suggestions.

I would like to appreciate very special thanks to my father Hj. Ahmad Bin Hj. Aripin and mother Hjh. Jamilah Binti Hj. Ahmad. All your sacrifices, prayers, endless love, tears and encouraging for me that was what sustained me this far. I take this opportunity to thank my siblings Suzelah, Khaeromze, Suhaila, Suryati, and Suhaida who motivate me to strive towards my goal. Not forgetting, thank to my husband Sheikh Irfizzad who always passionate to persuade me to be calm in the moments when I feel stressful. I am also grateful to my beloved son Sheikh Rayyan who always accompany while writing this thesis.

I would also like to convey thanks to MyBrain15 from Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia (UTM RUG Vot 03J65) for scholarship and financial supports. Last but not lease, my sense gratitude to all staff, lectures, families and friends who directly or indirectly support me through out completing this thesis.

ABSTRACT

Environmentalists have raised their concerns that pollution from development along Pulai River Estuary will have an impact on marine ecosystem. In 1994 eleven seagrass species were found in the area. However, when this study were conducted in 2011 only seven seagrass species were identified at the area, namely *Enhalus acoroides, Halophila minor, Halophila spinulosa, Halophila ovalis, Thalassia hemprichii*, *Halodule uninervis* and *Cymodocea serrulata.* The seagrass can uptake metals and therefore plays the role as bioindicator. Field work was conducted between July 2011 and April 2014 where seagrass, water and sediment were collected for analysis. The samples were analysed using Perkin Elmer Atomic Absorption Spectrophotometer Model AAnalyst 400 for copper (Cu), cadmium (Cd), and lead (Pb). Flow Injection Mercury System Perkin Elmer model FIMS 100 was used for mercury (Hg) and arsenic (As) analysis. Analysis of variance and Pearson's correlation coefficients of metal concentrations were carried out using Statistical Package for the Social Science (SPSS) for seagrass tissues, seawater and sediment. Esri ArcGIS software was used to determine the metals distribution. The seagrass percent covers on the seagrass bed were determined by transect method. The study shows that *Halophila minor* was the most abundant species covering Pulai seagrass bed at 27% followed by *Halophila ovalis* (18%), *Halophila spinulosa* (8.8%), *Enhalus acoroides* (6.4%), *Thallasia hemprichii* (5.3%), *Cymodocea serrulata* (1%), and *Halophila uninervis* (0.3%). Among the seven seagrass species found, *Halophila ovalis* have the highest accumulation of metal and indicates positive significant correlation to translocation of metal in seagrass tissues, hence it meets the criteria to be selected as a bioindicator. Mapping using Esri ArcGIS, shows the metals distribution originated from land use. Monitoring conducted on 4th of April, 2014 indicated that land reclamation for Forest City has changed the condition of seagrass bed hydrodynamic and trophic state from upper-mesotrophic to light-eutrophic. Quantitative water, sediment and seagrass fugacity/equivalance mass balanced model was developed to describe the movement pattern of metals that ends up in the seagrass bed. Estimation rates of As, Cu, Cd, Hg and Pb concentration in seawater are at 3.18 µg/L, 32.35 µg/L, 39.94 µg/L, 4.99 µg/L and 99.86 µg/L, respectively for 1 day.

ABSTRAK

Pencinta alam sekitar sering melahirkan kebimbangan mereka tentang pencemaran disebabkan oleh pembangunan di sepanjang muara Sungai Pulai yang akan memberi kesan kepada ekosistem marin. Pada tahun 1994, sebelas spesies rumput laut dikenal pasti di kawasan tersebut. Walau bagaimanapun, apabila kajian ini dilakukan pada 2011 hanya tujuh spesies rumput laut dikenal pasti di kawasan tersebut iaitu *Enhalus acoroides, Halophila minor, Halophila spinulosa, Halophila ovalis, Thalassia hemprichii, Halodule uninervis* dan *Cymodocea serrulata.* Rumput laut boleh mengambil logam dan oleh itu memainkan peranan sebagai petunjuk biologi. Kerja lapangan telah dijalankan antara Julai 2011 dan April 2014 di mana sample rumput laut, air dan sediment telah diambil untuk analisis. Sampel tersebut telah dianalisis menggunakan Spektrofotometer Serapan Atom model Pekin Elmer AAnalyst 400 untuk kuprum (Cu), kadmium (Cd) dan plumbum (Pb). Sistem suntikan aliran mercuri model Perkin Elmer FIMS 100 telah digunakan untuk analisis mercuri (Hg) dan arsenik (As). Analisis varians dan pekali korelasi Pearson bagi kepekatan logam telah ditentukan menggunakan Pakej Statistik untuk Sains Sosial (SPSS) untuk tisu rumput laut, air laut dan sedimen. Pemetaan menggunakan Perisian Esri ArcGIS telah digunakan bagi penentuan taburan logam. Peratus rumput laut di atas beting pasir rumput laut ditentukan menggunakan kaedah transek. Kajian menunjukan bahawa *Halophila minor* merupakan spesies dengan litupan terbanyak di atas benting pasir Sungai Pulai pada 27% diikuti oleh *Halophila ovalis* (18%), *Halophila spinulosa* (8.8%), *Enhalus acoroides* (6.4%), *Thalassia hemprichii* (5.3%), *Cymodocea serrulata* (1%), dan *Halophila uninervis* (0.3%). Antara tujuh spesies rumput laut yang dijumpai, *Halophila ovalis* mempunyai penumpukan logam paling tinggi dan menunjukkan korelasi yang signifikan dan positif kepada translokasi logam dalam tisu rumput laut, oleh itu ia memenuhi kriteria untuk dipilih sebagai petunjuk biologi. Pemetaan menggunakan Esri ArcGIS, menunjukkan taburan logam adalah berasal daripada guna tanah. Pemantauan yang dijalankan pada 4 April 2014 menunjukkan bahawa penambakan tanah untuk Forest City telah mengubah keadaan hidrodinamik dan trofik benting pasir daripada mesotrofik-tinggi kepada eutrofik-rendah. Model kuantitatif fugasiti/keseimbangan jisim telah dibangunkan bagi air, sedimen, dan rumput laut untuk menggambarkan corak taburan logam yang berakhir di atas beting pasir. Anggaran kadar bagi kepekatan As, Cu, Cd, Hg dan Pb dalam air laut adalah 3.18 μg/L, 32.35 μg/L, 39.94 μg/L, 4.99 μg/L dan 99.86 μg/L untuk satu hari.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

SJER	-	South Johor Economic Region
AAS 400	-	Atomic Absorption Spectrophotometer Model AAnalyst 400
ANOVA	-	Analyses of variance
SPSS	-	Statistical Package for the Social Science
SG	-	Seagrass bed
CR	-	Reef
MG	-	Mangrove
PEL	-	Pelagic
IUCN	-	International Union for Conservation of Nature
SI	-	Surface irradiance
GIS	-	Geographic Information System
MMWQS	-	Malaysia Marine Water Quality Standard
ISQGs	-	Interim Marine Sediment Quality Guidelines
PELs	-	Probable Effect Levels
GPS	-	Global Positioning System
DO	-	Dissolved oxygen
ASEAN	-	Association of Southeast Asian Nations
PVC	-	Poly vinyl chloride
Ea	-	*Enhalus acoroides*
Hm	-	*Halophila minor*
Hs	-	*Halophila spinulosa*
Ho	-	*Halophila ovalis*
Th	-	*Thalassia hemprichii*
Hu	-	*Halodule uninervis*
Cs	-	*Cymodocea serrulata*
Wp	-	Whole plant
Rh	-	Rhizomes

Rt	-	Root
Sh	-	Shoot
Ulva sp.	-	Ulva specie
n	-	Number of sample
r	-	Correlation coefficient
p-value	-	Significance level
SE	-	Standard error
P	-	Input
Q	-	Output
A_{ij}	-	Flow of the chemical from compartment i to j
M_i	-	Mass of Compartment i
C_i	-	Concentration of the chemical in compartment i
d/dt	-	First derivative
$C_i^{t+\Delta t}$	-	Concentration of compartment i at time t+Δt
C_i^t	-	Concentration of compartment i at time t
Δt	-	Discretization of time

LIST OF SYMBOLS

ºC	-	Celsius
µm	-	Microgram
g	-	Gram
mL	-	Millilitre
mm	-	Millimetre
cm	-	Centimetre
m	-	Meter
km	-	Kilometre
ha	-	Hectare
ppm	-	Parts per million
mg/L	-	Milligrams per litre water
µg/L	-	Microgram per litre
µg/g DW	-	Microgram per gram Dry Weight
N	-	Northern
E	-	Eastern
°	-	Degrees
'	-	Minutes
"	-	Seconds
%	-	Percent
AS	-	Arsenic
Cu	-	Copper
Cd	-	Cadmium
Hg	-	Mercury
Pb	-	Lead
O_2	-	Oxygen

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Seagrasses are rooted angiosperms marine plants widely distributed in large areas known as seagrass beds (Kirkman, 1990; McKenzie *et al*., 2001; Vermaat *et al*., 2004; Bastyan and Cambridge, 2008). Seagrass beds are the most productive plant communities, they play ecological role as 'nursery habitats' in coastal ecosystems that supply food and shelter to vulnerable marine organisms such as sea cucumbers, starfish, seahorses, and thereby maintain a diverse biodiversity (Duarte and Chiscano, 1999; Waycott *et al*., 2005; Jackson *et al*., 2006; Lee *et al*., 2007; Eklöf *et al*., 2008; Choo *et al*., 2009).

Researchers from around the world are continuously searching for new seagrass species. Since the past decade, many issues have been raised on seagrasses, while documentation of seagrasses are still ongoing, some species have already been reported lost due to dredging activities (Erftemeijer and Robin Lewis III, 2006). It was reported that one way to measure the degree of pollution in estuaries is by using seagrasses as bioindicator for metal contamination (Schlacher-Hoenlinger and Schlacher, 1998; Prange and Dennison, 2000; Ferrat *et al*., 2003). Researchers also concur that seagrasses can be used rapidly to reflect the overall health of coastal waters due to their sharp sensitivity and variation in the environment (Nienhuis, 1986; Warnau *et al*., 1995; Costantini *et al*., 1991; Bortone and Turpin, 2000; Ferrat *et al*., 2003; Macinnis-Ng and Ralph, 2004). Seagrasses have remarkable metal bioaccumulation capacity because they interact directly with water column and pore water through leaves and roots as ionic uptake (Vermaat *et al*., 2004; Macinnis-Ng and Ralph, 2004; Llagostera *et al*., 2011). Furthermore, seagrass leaves cleans seawater by absorbing dissolved metals while their roots play a role in shoreline protection by reducing coastal erosion from raging storms (Macinnis-Ng and Ralph, 2002). Tropical seagrasses with the greatest diversity were identified in the Indo-Pacific region (Short *et al*., 2001; Short *et al*., 2011). However, the continuously increasing pollution will kill-off the seagrasses once pollution reaches lethal levels and this intertidal habitat will be lost for good as there is little opportunity for the habitat itself to migrate (Hadley, 2009).

'The Convention on Wetlands of International Importance' (commonly known as the Ramsar Convention, 1971) is generally understood to be the pioneer global agreement on nature conservation (Matthews, 1993). Ramsar established the first globally coordinated institutional framework for conservation of a threatened ecosystem and set the standard for major global conservation treaties that followed, such as the Convention on Migratory Species in 1983 and the Convention on Biological Diversity in 1993 (Hettiarachchi *et al*., 2014). The Ramsar Convention is a core part of the international biodiversity governance system. Ramsar Site is a protected area with international importance and need to avoid an anthropogenic impact (Bellio and Kingsford, 2013). Pulai River which is the study area chosen for this study was listed as Ramsar site on 31st January 2003.

An estuary is known as the most valuable aquatic ecosystem with certain areas having seagrass beds that house extensive marine biodiversity (Danovaro and Pusceddu, 2007; Selleslagh *et al*., 2012; Liquete *et al*., 2013). Aside from biodiversity, economic growth can be generated in the vicinity of estuaries i.e. the development of ports, petrochemical hubs, cities and residential areas (Rizzo and Glasson, 2012). Due to increasing demand for coastal resources as well as human population growth, the coastal ecosystem is exposed to a wider variety of pollutants. They are exposed to anthropogenic contaminants including complex mixtures of heavy metals from industrial, agricultural and domestic waste, arriving via rivers or through atmospheric deposition (Lafabrie *et al*., 2007; Gillet *et al*., 2008; Villate *et al*., 2013; Emelogu *et al*., 2013). In addition, human activities such as coastal land disturbance, motor boating and dredging contribute to pollution (Burkholder *et al*., 2007; Lewis *et al*., 2007). Furthermore increasing rate of enrichment of organic matter in an ecosystem causes eutrophication (Nixon, 1995).

The public and environmentalists have often raised their concerns on the excessiveness of nutrients and heavy metal pollution around estuaries. Seagrasses can be also act as bioindicator to reflect the overall health of coastal waters because of their sharp sensitivity to variations in the environment. On top of that, they can also remove dissolved metal from seawater and sediment. In fact, this has raised curiosity and interest of many researchers. However, little supporting evidence on the ability of tropical seagrasses has been recorded. As stated by Ooi *et al*., (2011), data recorded for metal accumulation in tropical seagrasses in Southeast Asia is very limited. Therefore, this study was conducted to further explore the effectiveness of seagrasses in absorbing dissolved metals from their surroundings.

1.2 Background of Study

1.2.1 Case Study Locations

Two areas were selected in this study which is the upstream of Pulai River and seagrass bed of Pulai River Estuary. Figure 1.1 shows the aerial map of study location. Pulai River has several tributaries with associated mangrove, intertidal mudflats and inland freshwater that represent lowland tropical river basin. Pulai River flows from Mount Pulai up to the Johor Straits in which the seagrass bed of Pulai River Estuary is located. The seagrass bed of Pulai River Estuary is the largest in Malaysia with an approximate area of 3.15 km^2 (Nisha, 2008). Besides Johor Straits, Malacca Straits and Singapore Straits also contributes to water that flows into the seagrass bed at Pulai River Estuary.

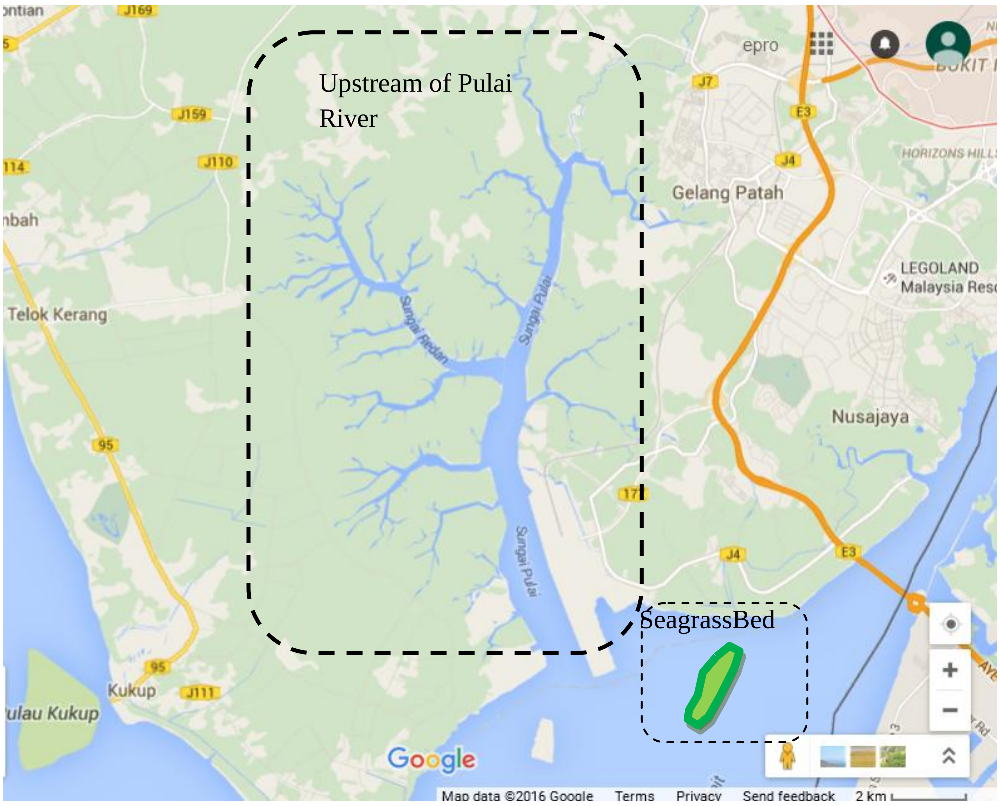


Figure 1.1 Location of study area

Seagrass bed of Pulai River Estuary is located between two powerful regional hubs of Johor and Singapore. Hence, its location is geographically strategic on the world's busiest shipping routes eastbound and westbound (Rizzo and Glasson, 2012). Furthermore, it is also surrounded by many projects such as Port of Tanjung Pelepas, Tanjung Bin Power Plant, Asia Petroleum Hub and development area from Tuas, Singapore as shown in Figure 1.2. The distance between Port of Tanjung Pelepas to the seagrass bed is 4 kilometers. The distance between Asia Petroleum Hub to the seagrass bed is 5.5 kilometres. The distance between Tuas, Singapore to the seagrass bed is 3 kilometers. Thus the seagrass bed is surrounded with pollution area.

1.3 Statement of Problem

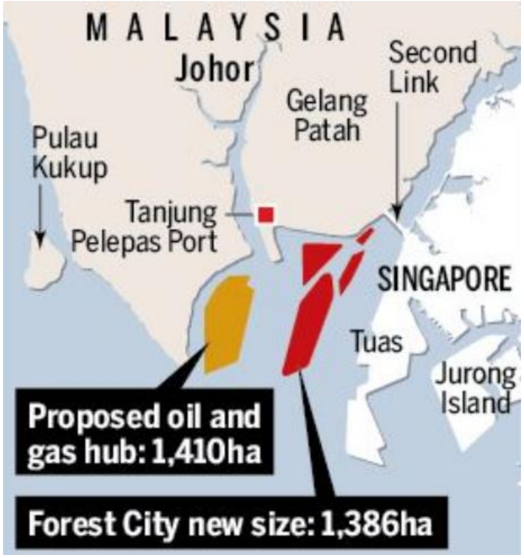
Currently, there are still ongoing construction at the Pulai River Estuary due to expansion of Port of Tanjung Pelepas, urbanizations and industrialisation. Port activities causes enhancement of shipping transits eastbound and westbound. Figure 1.2 shows the picture of shipping transits at mouth of Pulai River. Johor Port Authority plans to expand the port-handling operations and related activities at the Port of Tanjung Pelepas in 2016, hence Port of Tanjung Pelepas currently handled about 10.5 million tonnes of cargo yearly and the volume would rise to 15 million tonnes yearly when the project completed in 2019 (The Star, 2015). The increasing cargos have the probability to cause accidents between container cargos.

It was reported that within 10 years period from 2000 to 2010, 31% out of overall transit involved accidents of container cargo around Johor Straits (Rusli, 2012). Casual container cargo breakdowns are due to collision, foundering, fire or exploration (George, 2008). Hence cargo accidents contribute to major oil, hazardous and noxious substance spill incidents entail adverse impacts on the marine environment. The accidents need to be clean up urgently however clean up operation process is costly and depends on capacity of oil spills.

Figure 1.2 Shipping transits at Pulai River Estuary

Currently development at Iskandar Malaysia is swift with various undergoing projects. The latest development is Forest City, a mega-project with an artificial island of nearly 2000 hectares or half the size of Putrajaya which is located in the Johor Straits (Maznah, 2014). The huge island was reported to be a collaboration between renowned China developer Country Garden Holdings (based in Guangdong) and Johor state-owned People Johor Infrastructure Group (Nigel, 2014). The master plan was approved by Iskandar Malaysia, yet this project was not listed in the proposed South Johor Economic Region (SJER) master plan as in Flagship Zone C: Western Gate Development (Mahdzir, 2014).

In 2015, construction and reclamation for Forest City to be built on a man-made island in the Johor Strait was approved by Malaysia Department of Environment as long as they ensure that all compliance monitoring in terms of air, noise, water quality and sediment are robustly implemented and carried out. In order to comply with Malaysia Department of Environment standards, the total size of Forest City was slightly reduced from 1,623 hectares to 1,386 hectares and divided into four reclaimed islands instead of one huge island (Marissa Lee, 2015). The proposed revised size of Forest City and the new size of Forest City is shown in Figure 1.3. Even though Forest City is divided into four reclaimed island, the development will still effect seawater hydrodynamic. Apart from that, nearby the seagrass bed is also the expansion of 1,410 hectares reclamation project for an oil and gas hub. Thus, these construction activities are causing increase amounts of pollution via coastal land disturbance, dredging and accessibility improvement work.



a) b)

Figure 1.3 Reclamation area of Forest City that overlaps with Pulai River Estuary seagrass bed a) proposed reclamation area of Forest City (Azlan 2014), b) new Forest City with four islands after approval from Malaysia Department of Environment (Marissa Lee, 2015)

Seagrass bed of Pulai River Estuary helps to provide shelter and breeding grounds for various vulnerable marine animals. Figure 1.4 shows type of marine animals that inhabit the seagrass bed. The example of marine animals are spotted seahorse, knobbly sea star, smooth sea cucumber, alligator pipefish, white-spotted rabbit fish, spotted scat, blue-spotted fantail ray, fan-bellied filefish, sea urchin and etc. In fact there are vulnerable species facing high risk of extinction at seagrass bed such as coastal horseshoes crab, tiger-tail seahorse, and spotted seahorse (Choo *et al*., 2009). Environmentalists and public including Singaporean have raised concerns that pollution occurring at the development site along Pulai River Estuary will affect the aesthetics and ecosystem especially in sensitive areas like the seagrass bed. These marine animals should be protected to ensure that they are not extinct for the sake of future generations.

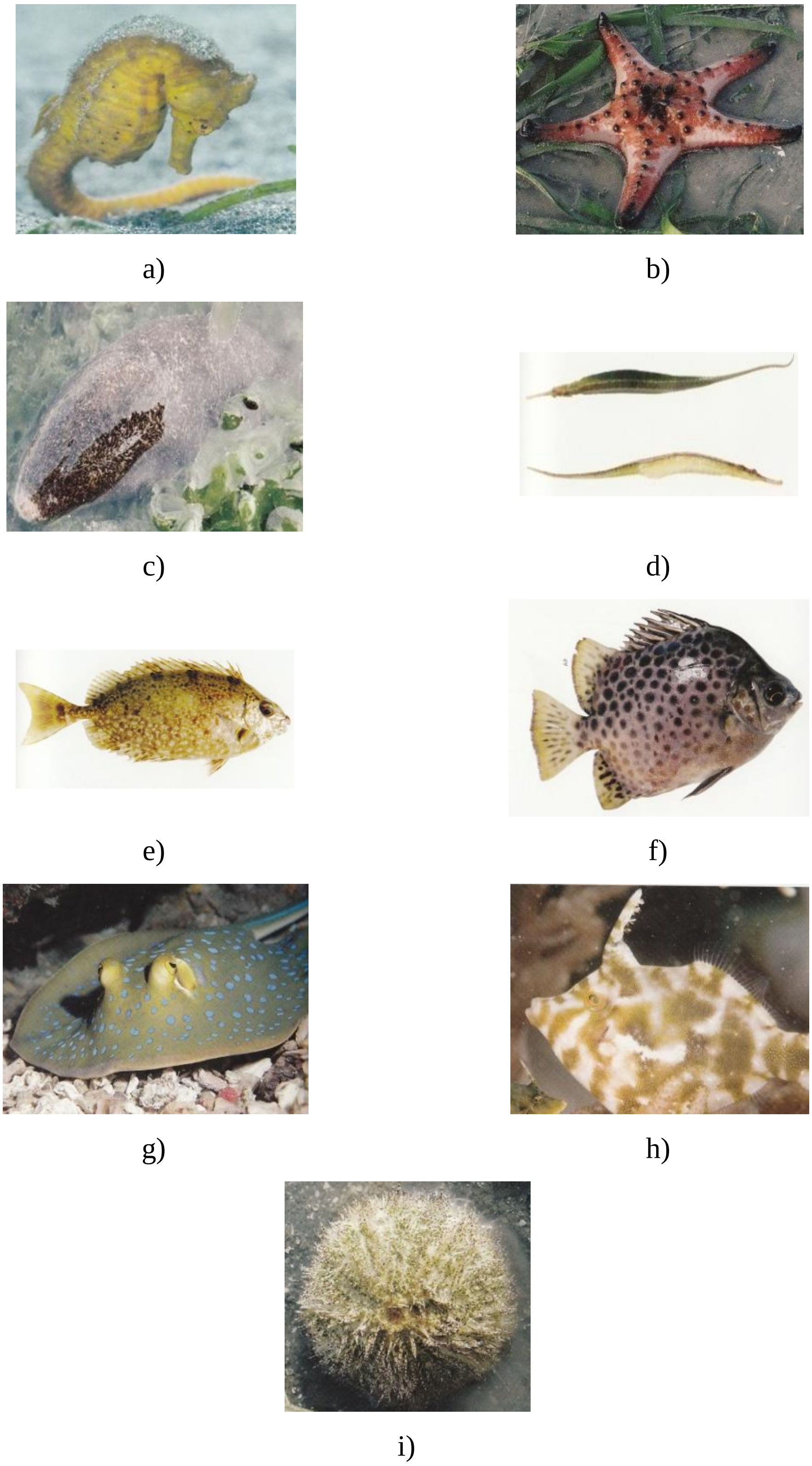


Figure 1.4 Example of marine animals found at seagrass bed, a) spotted seahorse, b) knobbly sea star, c) smooth sea cucumber, d) alligator pipefish, e) white-spotted rabbit fish, f) spotted scat, g) blue-spotted fantail ray, h) fan-bellied filefish, i) sea urchin (Choo *et al*., 2009)

Pollution disrupts marine life's lifecycle. As stated by Bahadori and Vuthaluru (2010), pollution is associated with low dissolved oxygen concentrations in water, which disturbs marine ecosystem and cause fish mortality, odours and anaerobic conditions. In fact, the population of vulnerable animals for examples seahorse and pipefish at seagrasss bed Pulai River Estuary were reported to decrease from 2007 to 2009 (Choo, 2009). In 2007, the number of seahorses is 170 unfortunately in 2009 the number of seahorses decreased to 46. On the other hand, the number of pipefish also decreased from 2008 to 2009 which is only 41. Table 1.1 shows the data recorded on the number of seahorses and pipefish during low tide. The data was counted during low tide condition because it is easier to catch seahorses and pipefish during low tide compared to high tide condition.

Table 1.1 : Summary of seahorses and pipefish in 2007, 2008, and 2009 during low tide (Choo, 2009)

Species	Seahorse			Pipefish		
Year	2007	2008	2009	2007	2008	2009
Male	92	77	19	53	63	20
Female	77	69	26	27	44	19
Juvenile	1	-	1	1	2	2
Total	170	146	46	81	109	41

In addition, increase in pollution around Pulai River Estuary can also decrease seafood supply. As we know, fish are the most abundant in the seagrass bed, hence fisherman rely on surrounding seagrass bed to earn a living (Unsworth *et al*., 2010). The detail number of fish on type of fish found is attached in Appendix A. Data was requested from Jabatan Perikanan Johor Bahru. There are several types of fish caught by fisherman such as black pomfret, siver pomfret, mullet, shad, marine catfish, jewfish, mixed fishes, cahcunda shad, grouper, dorab wolf-herring, ray, catfish eel, barramundi and barred Spanish mackerel. The main catches of fish at Johor Straits are jewfish, marine catfish and mullet. Figure 1.5 shows data of fish catch from 2009 to 2014. The number of fish in unit metric ton from year 2009 to 2014 is 1321, 1324, 1275, 1269, 1133 and 890, yearly. From the bar chart, it was found that the numbers of fish at Johor Bahru district continuously decreased from year 2010 until 2014. It is believed that the decreasing numbers of fish is due to progressive reclamation projects at Johor Straits. Hence this prove that reclamation project contributes to pollution in seawater and can disturbs marine ecosystem.

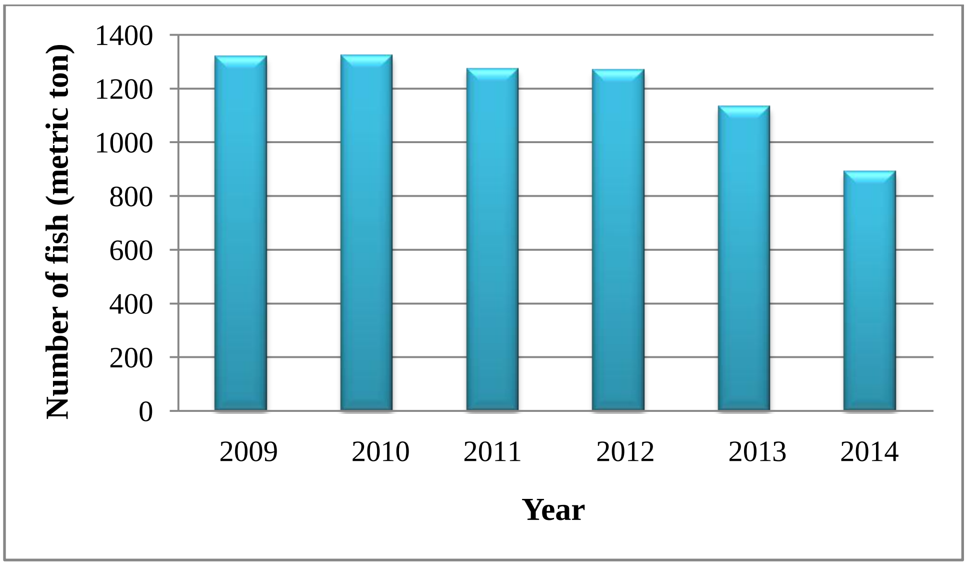


Figure 1.5 Fish landings in Johor Bahru area from 2009 to 2014

1.4 Objectives of Study

Objectives of the study are achieved:

i. To identify seagrass species and it's coverage on the seagrass bed.

ii. To determine the amount of accumulated metals in different part of seagrass species, sediment and seawater. The metals investigated are arsenic (As), copper (Cu), cadmium (Cd), mercury (Hg) and lead (Pb).

iii. To determine the correlation of metal content between seagrass tissues, sediment and seawater, in order to ascertain seagrass as metal indicator.

iv. To identify landuse activities in the study area and movement pattern of metals that ends up in the seagrass bed.

1.5 Scope of Study

In-situ parameters which include dissolved oxygen, salinity, temperature, pH, chlorophyll-a and secchi depth were measured and results were compared with the guidelines of National Marine Water Quality Standard for Malaysia. In this study, seagrasses was observed and identified at the seagrass bed. The percentage cover of each species on the seagrass bed was estimated using transect method (0.5 m x 0.5 m) with data recorded into a datasheet. Three types of samples (seagrasses, sediment and seawater) were collected from the seagrass bed. The samples were collected, digested and analyzed using Atomic Absorption Spectrophotometer (AAS) for accumulation of As, Cu, Cd, Hg and Pb.

Data of seagrasses, sediment and seawater obtained were further analysed to identify variances and correlations. Analysis of variance (ANOVA) and Pearson's correlation coefficients for seagrasses, sediment and seawater were carried out using Statistical Package of Social Science (SPSS) version 16. In addition, the correlations of metal concentration between different parts (leaves, rhizomes and roots) of the seagrass have also been analysed in order to attain the metal translocation pattern in the entire plant system. This is one of the factors of consideration in selecting the most suitable bioindicator. Seawater samples were collected from 17 different locations in the catchment area of Pulai River Estuary. The samples were taken near to the sources of pollution. The metal content of the seawater samples were also analysed using AAS. Data were then exported to ArcGIS software for data interpolation by kriging method with confidence interval from the area of land use around Pulai River Estuary. Thus, the interaction fugacity model for water, sediment and seagrass be obtained.

There are also some limitations in this study; i.e, seagrass samples could only be collected during low tide; sampling could only be carried out during day time and therefore monthly analysis could not be achieved due to irregular tide level. Sampling had to be stopped immediately whenever the weather turned bad due to safety reasons as conditions like strong wind and heavy rain or thunderstorm that is unsafe for field works.

1.6 Significance of Study

This study has produced insight knowledge on selection of the most suitable seagrass species as a bioindicator. Seagrass are sensitive to changes in seawater quality, and therefore can be a valuable indicators of metals and reflect the overall health of an estuarine ecosystem. Moreover observation for the decrease intensity of seagrasses in coastal waters is an easy and practical way to monitor pollution. Less intensity of seagrass cover indicates high intensity of pollution. In fact, it can be monitored by educating the local community (fisherman and villagers) to be watchful on pollution. However, equipment used to measure the intensity of pollution in seawater and sediment are excessively expensive and requires a certain level of proficiency to operate. Hence the concept of observation on monitoring seagrass ability to indicate pollution would be an easy task.

1.7 Organization of Thesis

This thesis consists of six chapters, Chapter 1 is the introduction part. It describes the background of this study related to the benefits of seagrasses and the pollution caused by development projects. Chapter 2 consist of literature review, which discuss the issues and information gathered by various researchers. It also gives an overview of the current state of seagrass including guidelines on standards for seawater, sediment and seagrass. In Chapter 3, methodology describes appropriate research designs, procedures, instrumentations, data processing and software used to analyze the samples. Chapter 4 discuss the results obtained from the field work and experiments conducted. This chapter summarize the collected data and discuss major findings: identification of seagrass species, length and width of seagrass bed and percentage of seagrass distribution. It also describes the amount of metals and their correlations in seawater, sediment and seagrasses. The selections of seagrass species as bioindicator was also determined.

Chapter 5 describes the water quality due to land use, the impact of land use and land reclamation on Pulai River Eatuary. The seagrasses might perish and vulnerable marine animals can be extinct due to excessive project construction work in the area. Seawater, sediment and seagrass interaction fugacity model was also developed at Pulai River Estuary. Finally, conclusions are presented in Chapter 6 together with recommendations for future research.

REFERENCES

Ali, B. Mahsa, M. G., Farhad, G. A., and Mahmoud, A. (2015). Effects of Copper Slag and Recycled Concrete Aggregate on the Properties of CIR Mixes with Bitumen Emulsion, Rice Husk Ash, Portland Cement and Fly Ash. *Construction and Building Materials.* 96, 172 - 180.

Aioi, K., and Nakaoka, M. (2003). The Seagrasses of Japan. In Green, E.P., and Short, F. T. (Ed.). *World Atlas of Seagrasses.* (pp. 185 – 192). Berkeley: University of California Press.

Andersson, P., Borg, H., and Karrhage, P. (1995). Mercury in the Fish Mussle in acidified and Lined lakes. Water, Air and Soil Pollution. 80, 889 – 892.

Andres, S., Ribeyre, F., and Boudou, A. (1998). Effects of Temperature and Exposure Duration on Transfer of Cadmium between Naturally Contaminated Sediments and Burrowing Mayfly Nymphs (*Hexagenia rigida*). *Archives of Environmental Contamination and Toxicology*. 35 (2), 295 - 301.

Ankley, G. T., Mattson, V. R., Leonard, E. N., West, C. W., and Bennett, J. L. (1993). Predicting the Acute Toxicity of Copper in Freshwater Sediments: Evaluation of the Role of Acid-valatile Sulphide. *Environmental Toxicology Chemistry.* 12 (2), 315 - 320.

Anne – Maree, S., Mark, M., Ian, H., and Jane, H. (2006). *Physical and Biological Characteristics of a Rare Marine Habitat: Sub-tidal Seagrass Beds of Offshore Islands.* New Zealand Department of Conservation: Science & Technical Publishing.

Bahadori, A., and Vuthaluru. (2010). Simple Arrhenius-Type Function Accurately Predicts Dissolved Oxygen Saturation Concentrations in Aquatic Systems. *Process Safety and Environmental Protection*. 88 (5), 335 - 340.

Balaguer, P., Diedrich, A., Sarda, R., Fuster, M., Canellas, B., and Tintore, J. (2011). Spatial Analysis of Recreational Boating as a First Key Step for Marine

Spatial Planning in Mallorca (Balearic Islands, Spain). *Ocean & Coastal Management*. 54 (3), 241 - 249.

Balogh, S. J., and Nollet, Y. H. (2008). Methylmercury Input to the Mississippi River from a Large Metropolitan Wastewater Treatment Plant. *Science of The Total Environment*. 406 (1 - 2), 145 - 153.

Bastyan, G. R., and Cambridge, M. L. (2008). Transplantation as a Method for Restoring the Seagrass *Posidonia Australis*. *Estuarine, Coastal and Shelf Science*. 79 (2), 289 - 299.

Bell, J. D., and Pollard, D. A. (1989). Ecology of Fish Assemblages and Fisheries Associated with Seagrasses. In Antony. W. D. L. *Biology of Seagrasses*. (pp. 565 - 609). Amsterdam: Elsevier.

Bellio, M., and Kingsford, R. T. (2013). Alteration of Wetland Hydrology in Coastal Lagoons: Implications for Shorebird Conservation and Wetland Restoration at a Ramsar Site in Sri Lanka. *Biological Conversation*. 167, 57 - 68.

Benes, P., Cejchanova, M., and Havlik, B. (1985). Migration and Speciation of Lead in a River System Heavily Polluted From a Smelter. *Water Research*. 19 (1), 1 - 6.

Berry, J., and Bjorkman, O. (1980). Photosynthetic Response and Adaptation to Temperature in Higher Plants. *Annual Review of Plant Physiology*. 31 (1), 491 - 543.

Bortone, S. A., (2000). *Seagrass Monitaring, Ecology, Physiology, and Management*. United State of America: CRC Press LLC.

Bortone, S. A., and Turpin, R. K. (2000). Tape Grass Life History Metrics Associated with Environmental Variables in a Controlled Estuary. In Stephen, A. B., *Seagrass Monitaring, Ecology, Physiology, and Management* (pp. 65 - 79). CRC Press LLC.

Boudou, A., and Ribeyre, F. (1983). Contamination of Aquatic Biocenoses by Mercury Compounds: An Experimental Toxicological Approach. In Nriagu (Ed.) *Aquatic Toxicology*. (pp. 73 - 116). New York: John Wiley.

Boudouresque, C. F., Bernard, G., Bonhomme, P., Charbonnel, E., Diviacco, G., Meinesz, A., Pergent, G., Pergent -Martini, C., Ruitton, S., and Tunesi, L. (2009). *Preservation et Conservation Des Herbies a Posidonia Oceanica*. (pp. 1 - 202). France: Ramoge pub, Marseille.

Bryan, G. W., and Langston, W. J. (1992). Bioavailability, Accumulation and Effects of Heavy Metals in Sediments with Special Reference to United Kingdom Estuarine: A Review. *Environmental Pollution.* 76 (2), 89 - 131.

Bulthuis, D.A. (1983). Effects of Temperature on the Photosynthesis - Irradiance Curve of the Australian Seagrass, *Heterozostera tasmanica*. *Marine Biology Letters*. 4 (1), 47 - 57.

Bulthius, D.A. (1987). Effects of Temperature on Photosynthesis and Growth of Seagrasses. *Aquatic Botany*. 27 (1), 27 - 40.

Burkholder, J. M., Tomasko, D. A., and Touchette, B. W. (2007). Seagrass and Eutrophication. *Journal of Experimental Marine Biology and Ecology*. 350 (1 - 2), 46 - 72.

Buxton, L., Takahashi, S., Hill, R., and Ralph, P. J. (2012). Variability in the Primary Site of Photosynthetic Damage in *Symbiodinium* sp. (*Dinophyceae*) exposed to thermal stress. *Journal of Phycology*. 48 (1), 117 - 126.

Cabello Pasini, A., Muniz Salazar, R., and Ward, D. H. (2003). Annual Variations of Biomass and Photosynthesis in *Zostera Marina* at its Southern End of Distribution in the North Pacific. *Aquatic Botany*. 76 (1), 31 - 47.

Cambridge, M. L., and McComb, A. J. (1984). The Time Course and Magnitude of Seagrass Decline in Elation to Industrial Development. The Loss of Seagrass in Cockburn Sound. I. *Aquatic Botany*. 20, 229 - 243.

Cambridge, M. L., Chiffings, A. W., Brittan, C., Moore, L., and McComb, A. J. (1986). The Loss of Seagrass in Cockburn Sound, Western Australia. II. Possible Causes of Seagrass Decline. *Aquatic Botany*. 24 (3), 269 - 285.

Campbell, S. J., McKenzie, L. J., and Kerville, S. P. (2006). Photosynthetic Responses of Seven Tropical Seagrasses to Elevated Seawater Temperature. *Journal of Experimental Marine Biology Ecology*. 330 (2), 455 - 468.

Canadian Council of Ministers of the Environments. (2001). *Canadian Sediment Quality Guidelines for the Proctection of Aquatic Life*. Retrieved April 20, 2015, from https://www.elaw.org/system/files/sediment_summary_table.pdf.

Chandra Sekhar, K., Chary, N. S., Kamala, C. T., Suman Raj, D. S., and Sreenivasa Rao, A. (2004). Fractionation Studies and Bioaccumulation of Sediment - Bound Heavy Metals in Kolleru Lake by Edible Fish. *Environment International*. 29 (7), 1001 - 1008.

Chappuis, E., Gacia, E., and Ballesteros, E. (2014). Environmental Factors Explaining the Distribution and Diversity of Vascular Aquatic Macrophytes in a Highly Heterogeneous Mediterranean Region. *Aquatic Botany*. 113, 72 - 82.

Choo, C. K. (2009). Save Our Seahorse. *Final Project Report 2008 – 2009*. Gelang Patah, Malaysia.

Choo, C. K., Serina, R., and Khor, H. M. (2009). S.O.S. *Files A journey to Sungai Pulai*. Gelang Patah, Malaysia.

Chris, B., and Steven, L. F. (2015). Potential Relation between Equatorial Sea Surface Temperatures and Historic Water Level Variability for Lake Turkana, Kenya. *Journal of Hydrology*. 520, 489 - 501.

Christine, K. (2013a). pH of Water. Fundamentals of Environment Measurements. *Fondriest Environmental, Inc.* Retrieved 20 August 2015 from http: //www. fondriest. com/ environmental -measurements/ parameters/ water-quality /ph/#p11.

Christine, K. (2013b). Dissolved Oxygen. *Fondriest Environmental, Inc.* Retrieved March 11, 2015, from http: // www. fondriest. com/ environmental – measurements / parameters / water – quality / dissolved – oxygen / >.

Cocking, D., Rohrer, M., Thomas, R., Walker, J., and Ward, D. (1995). Effects of Root Morphology and Mercury Concentration in the Soil on Uptake by Terrestrial Vascular Plants. *Water, Air, and Soil Pollution*. 80 (1 - 4), 1113 - 1116.

Coles, S. L., and Jokiel, P. (1977). Effects of Temperature on Photosynthesis and Respiration in Hermatypic Corals. *Marine Biology*. 43 (3), 209 - 216.

Cole, G. A. (1994). *Textbook of Limnology.* 4th ed. Waveland Press, Prospect Heights, IL.

Coles, R. G., Lee Long, W. J., Mckenzie, L., Roelofs, A., and De'ath, G. (2000). Stratification of Seagrasses in the Great Barrier Reef World Heritage Area, Northeastern Australia. *The Implications for Management. Biologica Marina Mediterranea*. 7 (2), 345 - 348.

Collier, C. J., Uthicke, S., and Waycott, M. (2011). Thermal Tolerance of Two Seagrass Species at Contrasting Light Levels: Implications for Future Distribution in the Great Barrier Reef. *Limnology and Oceanography*. 56 (6), 2200 - 2210.

Costantini, S., Giordano, R., Ciaralli, L., and Beccaloni, E. (1991). Mercury, Cadmium and Lead Evaluation in *Posidonia Oceanica* and *Codium Tomentosum*. *Marine Pollution Bulletin*. 22 (7), 362 - 363.

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., and Hannon, B. (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature*. 387, 253 - 260.

Creed, J. C., and Amado Filho, G. M. (1999). Disturbance and Recovery of the Macroflora of a Seagrass (*Halodule Wrightii*) Ascherson Meadow in the Abrohols Marine National Park, Brazil: An Experimental Evaluation of Anchor Damage. *Journal of Experimental Marine Biology and Ecology*. 235 (2), 285 - 306.

Creed, J. C. (2003). The Seagrasses of South America: Brazil, Argentina, and Chile. In Green, E.P., and Short, F.T. (Ed.). *World Atlas of Seagrasses*. (pp. 243 – 250). Berkeley: University of California Press.

Cunha, D. G. F., Calijuri, M. D. C. and Lamparelli, M. C. (2013). A Trophic State Index for Tropical / Subtropical Reservoirs (TSItsr). *Ecological Engineering*. 60, 126 - 134.

Dahlan, N. D., Jones, P. J., and Alexander, D. K. (2011). Operative Temperature and Thermal Sensation Assesments in Non-Air-Conditioned Multi-Storey Hostels in Malaysia. *Building and Environment*. 46 (2), 457 - 467.

Dalla Via, J., Sturmbauer, C., Schonweger, G., Sotz, E., Mathekowitsch, S., Stifter, M., and Rieger, R. (1998). Light Gradients and Meadow Structure in *Posidonia oceanica*: Ecomorphological and Functional Correlates. *Marine Ecology Progress Series.* 163, 267 - 278.

Danovaro, R., and Pusceddu, A. (2007). Biodiversity and Ecosystem Functioning in Coastal Lagoons: Does Microbial Diversity Play Any Role?. *Estuarine, Coastal and Shelf Science*. 75 (1 - 2), 4 - 12.

David, P. K. (2004). Methylmercury Contamination of Aquatic Ecosystem: A Widespread Problem with Many Challenges for the Chemical Sciences. In Parry, N. Frankie, W-B., Tina, M. M. *Water and Sustainable Development: Opportunities for the Chemical Sciences: A Workshop Report to the Chemical Sciences Roundtable.* Washington: National Academies Press.

Da Silva, J. F., Duck, R. W., and Catarino, J. B. (2004). Seagrasses and Sediment Response to Changing Physical Forcing in a Coastal Lagoon. *Hydrology* *and Earth System Sciences*. 8 (2), 151 – 159.

Demayo, A., Taylor, M. C., Taylor, K. W., and Hodson, P. V. (1982). Toxic Effects of Lead and Lead Compounds on Human Health, Aquatic Life, Wildlife Plants, and Livestock. *CRC Critical Reviews in Environmental Control*. 12 (4), 257 - 305.

Demers, M. C. A., Davis, A. R., and Knott, N. A. (2013). A Comparison of The Impact of 'Seagrass-Friendly' Boat Mooring Systems on *Posidonia Australi*s. *Marine Environmental Research*. 83, 54 - 62.

Dennison, W. C. (1987). Effects of Light on Seagrass Photosynthesis, Growth and Depth Distribution. *Aquatic Botany*. 27 (1), 15 - 26.

Dennison, W. C., Orth, R. J., Moore, K. A., Stevenson, J. C., Carter, V., Kollar, S., Bergstrom, P. W., and Batiuk, R. A. (1993). Assessing Water Quality with Submersed Aquatic Vegetation. *Bioscience*. 43 (2), 86 - 94.

Department of Environment. (2009). *Malaysia Environment Quality Report 2008.* Putrajaya: Department of Environment, Ministry of Natural Resources and Environment.

Devai, I., Delaune, R. D., Patrick JR, W. H., and Gambrell, R. P. (2001). Changes in Methylmercury Concentration During Storage: Effect of Temperature. *Organic Geochemistry*. 32 (5), 755 - 758.

Devlin, M. J., Barry, J., Mills, D. K., Gowen, R. J., Foden, J., Sivyer, D., and Tett, P. (2008). Relationship Between Suspended Particulate Material, Light Attenuation and Secchi Depth in UK Marine Waters. *Estuarine, Coastal and Shelf Science*. 79 (3), 429 - 439.

Duarte, C. M., and Chiscano, C. L. (1999). Seagrass Biomass and Production: A Reassessment. *Aquatic Botany*. 65 (1 - 4), 159 - 174.

Duarte, C. M. (2002). The Future of Seagrass Meadows. *Environmental Conservation*. 29 (2), 192 - 206.

Dunton, K. H. (1994). Seasonal Growth and Biomass of the Subtropical Seagrass *Halode Wrightii* in Relation to Continous Measurements of Underwater Irradiance. *Marine Biology*. 120, 479 - 489.

Durako, M. J., and M. D. Moffler. (1987). Factors Affecting The Reproductive Ecology of *Thalassia Testudinum Hydoeharitaceae*. *Aquatic Botany*. 27, 79 - 96.

De Cock, A. W. A. M. (1981). Influence of Temperature and Variations in Temperature on Flowering in *Zostera Marina* Under Laboratory Conditions. *Aquatic Botany*. 10, 125 - 132.

De Jong, R., Van Gelderen, P., Lindo, M., and Fernandez, J. (2005). Dubai's Extreme Reclamations. *CEDA Dredging Days 2005 Conference*. 2 - 4 November 2005, Rotterdam, The Netherlands.

De Oliveria, F. E. C., Pirani, J. P., and Giulietti, A. M. (1983). The Brazilian Seagrasses. *Aquatic Botany*. 16 (3), 251 - 267.

Earth Imaging Journal. (2014). Unmanned Aircraft Zooms in on Sea grass, Coral Reefs. Retrieved August 30, 2015, from http://eijournal.com/news/industry-insights-trends/unmanned-aircraft-zooms-in-on-sea-grass-coral-reefs.

Eisler, R. (1981). *Trace Metal Concentration in Marine Organisms*. New York: Pergamon Press.

Eisler, R. (1984). Trace Metal Changes Associated with Age of Marine Vertebrates. *Biological Trace Element Research*. 6 (2), 165 - 180.

Eisler, R. (2000). *Handbook of Chemical Risk Assessment Health Hazard to Humans, Plants, and Animals Volume 3 Metalloids, Radiation, Cumulative Index to Chemicals and Species.* United States of America: Lewis Publishers.

Eklöf, J. S., De La Torre - Castro, M., Gullstrom, M., Uku, J., Muthiga, N., Lyimo, T., and Bandeira, S. O. (2008). Sea Urchin Overgrazing of Seagrasses: A Review of Current Knowledge on Causes, Consequences, and Management. *Eustarine*, *Coastal and Shelf Science*. 79, 569 - 580.

Elizabeth Irlandi (2006). *Literature Review of Salinity Effects on Submerged Aquatic Vegetation (SAV) Found in the Southern Indian River Lagoon and Adjacent Estuaries. Final Report October 13, 2006.* Melbourne, Florida: Department of Marine and Environmental Systems.

Emelogu, E. S., Pllard, P., Dymond, P., Robinson, C. D., Webster, L., Mckenzie, C., Dobson, J., Bresnan, E., and Moffat, C. F. (2013). Occurance and Potential Combined Toxicity of Dissolved Organic Contaminants in the Forth Estuary and Firth of Forth, Scotland Assessed Using Passive Samplers and an Algal Toxicity Test. *Science of The Total Environment*. 461 - 462, 230 - 239.

Environmental Affairs Consultants. (2005). Third Annual Progress and Seagrass Mitigation Credit / Success Confirmation Report. *Environmental Affairs Consultants Inc*. United State: Palmetto, Florida.

Environmental Protection Agency. (2006a). Voluntary Estuary Monitoring Manual, Chapter 14: Salinity. *EPA United States Environmental Protection Agency*. Retrieved 2014, February, 13 from http: //www. epa. gov/ owow/ estuaries/ monitor/.

Environmental Protection Agency. (2006b). Voluntary Estuary Monitoring Manual Chapter 10: Nutrients - Nitrogen and Phosphorus. *United States Environment Protection Agency*. Retrieved February 14, 2016, from http: // www. epa. gov/ owow/ estuaries/ monitor/.

Environmental Protection Agency. (2013). Basic Information About Copper in Drinking Water. *EPA United States Environmental Protection Agency*. Retrieved 2015, August, 17 from http: // water. epa. gov/ drink /contaminants /basicinformation /copper.cfm.

Environmental Protection Agency. (2014). Water Quality Standard for Surface Water. *EPA United States Environmental Protection Agency*. Retrieved 2015, July, 2 from http://water.epa.gov/scitech/swguidance/standards/.

Erftemeijer, P. L. A., and Robin Lewis III, R. R. (2006). Environmental Impacts of Dredging on Seagrass: A Review. *Marine Pollution Bulletin*. 52 (12), 1553 - 1572.

Ferrat, L. P., Pergent-Martini, C., and Romeo, M. (2003). Assessment of the Use of Biomarkers in Aquatic Plants for the Evaluation of Environmental Quality: Application to Seagrass. *Aquatic Toxicology*. 65 (2), 187 - 204.

Ferreira, J. G., Andersen, J. H., Borja, A., Bricker, S. B., Camp, J., Cardoso Da Silva, M., Garces, E., Heiskanen, A. S., Humborg, C., Ignatiades, L., Lancelot, C., Menesguen, A., Tett, P., Hoepffner, N. and Claussen, U. (2011). Overview of Eutrophication Indicators to Assess Environmental Status Within the European Marine Strategy Framework Directive. *Estuarine, Coastal and Shelf Science*. 93 (2), 117 - 131.

Fjeld, E., and Rognerud, S. (1993). Use of Path Analysis to Inverstigate Mercury Accumulation in Brown Trout (*Salmo trutta*) in Norway and the Influence of Environmental Factors. *Canada Journal of Fisheries and Aquatic Science*. 50 (6), 1158 – 1167.

Filho, G. M. A., Creed, J. C., Andrade, L. R., and Pfeiffer, W. C. (2004). Metal Accumulation by *Halodule Wrightii* Populations. *Aquatic Botany*. 80 (4), 241 - 251.

Fitch, K., and Christine, K. (2014). Algae, Phytoplankton and Chlorophyll. *Fundamentals of Environmental Measurements. Fondriest Environmental, Inc.* Retrieved October, 22 2014, from http: //www. fondriest. com/ environmental - measurements/ parameters/ water – quality / algae – phytoplankton – and - chlorophyll.

Fleming-Lehtinen, V., and Laamanen, M. (2012). Long-Term Changes in Secchi Depth and the Role of Phytoplankton in Explaining Light Attenuation in the Baltic Sea. *Estuarine, Coastal and Shelf Science*. 102 - 103, 1-10.

Fong, T. C. W. (2001). Problems and Prospects of Seagrass Conservation and Management in Hong Kong and China. *International Symposium on Protection and Management of Coastal Marine Ecosystem*. 12 – 13 December 2000. Bangkok, Thailand, 5.

Fonseca, M. S., and Fisher, J. S. (1986). A Comparison of Canopy Friction and Sediment Movement between Four Species of Seagrass with Reference to Their Ecology and Restoration. *Marine Ecology Progress Series*. 29, 15 - 22.

Forest City Johor. (2016). Forest City Johor By Country Garden Pacific View in Iskandar Malaysia, Next to Singapore. *Forest City Johor*. Retrieved April, 15 2016, from http: // forestcityjohor. com / review /.

Gambi, M. C., Dappiano, M., Iacono, B., Flagella, S., and Buia, M. C. (2005). Chronicle of a Death Foretold. Features of a *Posidonia Oceanica* Bed Impacted by Sand Extraction. *Proceedings of the Seventh International Conference on the Mediterranean Coastal Environment.* 25 - 29 Oktober 2005. Kusadasi, Turkey, 441 - 450.

Garmendia, M., Borja, A., Franco, J., and Revilla, M. (2013). Phytoplankton Composition Indicators for the Assessment of Eutrophication in Marine Waters: Present State and Challenges Within the European Directives. *Marine Pollution Bulletin*. 66 (1 - 2), 7 - 16.

Garrote - Moreno, A., Fernández - Torquemada, Y., and Sánchez-Lizaso, J. L. (2014). Salinity Fluctuation of the Brine Discharge Affects Growth and Survival of the Seagrass *Cymodocea nodosa*. *Marine Pollution Bulletin*. 81 (1), 61 - 68.

Gavin, F. B., and Marco, A. O. (2008). Sediment – Bound Heavy Metals as Indicators of Human Influence and Biological risk in Coastal Water Bodies. *Journal of Marine Science*. 68 (8), 1407 1413.

George, M., 2008. Legal Regime of the Straits of Malacca and Singapore: LexisNexis Malaysia Sdn Bhd.

Giesen, W. B. J. T., Van Katwijk, M. M., and Den Hartog, C. (1990). Eelgrass Condition and Turbidity in the Dutch Wadden Sea. *Aquatic Botany*. 37 (1), 71 - 85.

Gillet, P., Mouloud, M., Durou, C., and Deutsch, B. (2008). Response of Nereis Diversicolor Population (Polychaeta, Nereididae) to the Pollution Impact - Aunthie and Seine Estuaries (France). *Estuarine, Coastal and Shelf Science*. 76, 201 - 210.

Goggle Earth. (2016). Sungai Pulai Johor. *Goggle*. Retrieved April, 15 2016, from https: // www. google. com. my / maps / place / Pulai + River / @ 1.3386514 , 103.5364419, 11335m / data = ! 3m1! 1e3 !4m2! 3m1 !1s0x 31d0a 757 ed 18457d: 0 x 645 c3 fcbcebe 7 e 15 ? hl = en.

Grant, A. J., Graham, K., Frankland, S., and Hinde, R. (2003). Effect of Copper on Algal-Host Interactions in The Symbiotic Coral *Pleasiastrea Versipora*. *Plant Physiology and Biochemistry*. 41 (4), 383 - 390.

Green, E. P., and Short, F. T. (2003). World Atlas of Seagrasses. *UNEP World Conservation Monitoring Centre*. University of California Press, Berkeley, USA.

Hadley, D. (2009). Land Use and the Coastal Zone. *Land Use Policy*. 26, Supplement 1 198 - 203. University of New England.

Hanakson, L., Andersson, T., and Nilsson, A. (1990). Mercury in Fish in Swedish Lakes – Linkages to Domestic and European Sources of Emission. *Water, Air and Soil Pollution.* 50 (1), 171- 191.

Hall, W. S., Bushong, S. J., Hall, L.W. Jr., Lenkevich, M. S., and Pinkney, A. E. (1988). Monitoring Dissolved Copper Concentrations in Chesapeake Bay, U.S.A. *Environmental Monitoring and Assessment*. 11 (1), 33 - 42.

Hammerschmidt, C.T, and Fitzgerald, W.F. (2004). Geochemical Controls on the Production and Distribution of Methylmercury in Near-shore Marine sediments. *Environmental Science and Technology*, 38 (5) 1487 – 1495.

Hao, Y., Guo, Z., Yang, Z., Fan, D., Fang, M., and Li, X. (2008). Tracking Historical Lead Pollution in the Coastal Area Adjacent to the Yangtze River Estuary Using Lead Isotopic Compositions. *Environmental Pollution*. 156 (3), 1325 - 1331.

Harlin, M. M., and Thorne-Miller, B. (1981). Nutrient Enrichment of Seagrass Beds in a Rhode Island Coastal Lagoon. *Marine Biology*. 65, 221 - 229.

Harrison, R. M., and Laxen, D. P. H. (1981). *Lead Pollution Causes and Control*. New York: Chapman and Hall.

Harrison, P. G. (1982). Seasonal and Year-to-Year Variations in Mixed Intertidal Populations of *Zostera Japonica* and *Ruppia Maritima*. *Aquatic Botany*. 14, 357 - 372.

Harvard T. H. C. (2013). Geographic Information System (GIS) in Public Health Research. Retrieved July 29, 2015, from http://www. hsph. harvard. edu/ gis/ arcgis-tips /kriging/.

Heck Jr., K. L., and Westone, G. S. (1977). Habitat Complexity and Interbrate Species Richness and Abundance in Tropical Seagrass Meadows. Journal of *Biogeography*. 4 (2), 135 - 142.

Hettiarachchi, M., McAlpine, C., and Morrison, T. H. (2014). Governing the Urban Wetlands: A Multiple Case - Study of Policy, Institutions and Reference Points. *Environmental Conservation.* 41 (3), 276 -289.

Hoven, H. M., Gaudette, H. E., and Short, F. T. (1999). Isotope Ratios of 206Pb/207Pb in Eelgrass, *Zostera Marina*, Indicate Sources of Pb in an Estuary. *Marine Environmental Research*. 48 (4 - 5), 377 - 387.

Huh, S. H., and Kitting, C. L. (1985). Trophic Relationships Among Concentrated Populations of Small Fishes in Seagrass Meadows. *Journal of Experimental Marine and Biology Ecology*. 92 (1), 29 - 43.

Huo, S., Ma, C., Xi, B., Su, J., Zan, F., Ji, D., and He, Z. (2013). Establishing Eutrophication Assessment Standards for Four Lake Regions, China. *Journal of Environmental Sciences*. 25 (10), 2014 - 2022.

Ibáñez Civera, J., Garcia Breijo, E., Laguarda Miro, N., Gil Sanchez, L., Garrigues Baixauli, J., Romero Gil, I., Masot Peris, R., and Alcaniz Fillol, M. (2011). Artificial Neural Network onto Eight but Microcontroller for Secchi Depth Calculation. *Sensors and Actuators B: Chemical.* 156 (1), 132 - 139.

Iskandar Regional Development Authority (2014). Iskandar Regional Development Authority. Retrieved Febrruary, 7 2016, from http: // www. iskandarmalaysia. com. my/ flagship - c – western – gate - development.

Jackson, E. L., Rowden, A. A., Attrill, M. J., Bossey, S. J., and Jones, M. B. (2001). The Importance of Seagrass Beds as a Habitat for Fishery Species. *Oceanography and Marine Biology* 39, 269 - 303.

Jackson, E. L., Attrill, M. J., Rowden, A. A., and Jones, M. B. (2006). Seagrass Complexity Hierarchies: Influence on Fish Groups Around the Coast of Jersey (English Channel). *Journal of Experimental Marine Biology and Ecology*. 330 (1), 38 - 54.

Jaleel, C. A., Gopi, R., Maniyannan, P., and Panneerselvam, R. (2007). Responses of Antioxidant Defense System of *Catharanthus Roseus* (L.) G. Don. to Paclobutrazol Treatment Under Salinity. *Acta Physiol Plant.* 29, 205 - 209.

Jaleel, C. A., Gopi, R., Manivannan, P., Gomathinayagam, M., Murali, P. V., and Panneerselvam, R. (2008). Soil Applied Propiconazole Alleviates the Impact of Salinity on *Catharanthus Roseus* by Improving Antioxidant Status. *Pesticide Biochemistry and Physiology*. 90 (2), 135 - 139.

Jagtap, T.G. (1996). Some Quantitative Aspects of Structural Components of Seagrass Meadows from the Southeast Coast of India. *Botanica Marina.* 39 (1), 39 - 45.

Jagtap, T. G., Komarpant, D. S., and Rodrigues, R. (2003). The Seagrasses of India. In Green, E.P., and Short, F.T. (Ed.). *World Atlas of Seagrasses*. (pp. 101 – 108). Berkeley: University of California Press.

Jenkin, D. W. 1980. Biological Monitoring of Toxic Trace Metals. *Toxic Trace Metals in Plants and Animals of the World.* U. S. environment Protection Agency. Rep. 600 / 3 - 80 - 091: 505 - 618.

Jones, R. J., Hoegh - Guldberg, O., Larkum, A. W. D., and Schreiber, U. (1998). Temperature Induced Bleaching of Corals Begins with Impairment of the CO_2 Fixation Mechanism in Zooxanthellae. *Plant Cell and Environment*. 21 (12), 1219 - 1230.

Jonsson, A. L., Lindstrom, M., and Bergback, B. (2002). Phasing Out Cadmium and Lead - Emissions and Sediment Loads in an Urban Area. *Science of The Total Enviornment*. 292 (1 - 2), 91 - 100.

Kaldy, J. E. (2006). Carbon, Nitrogen, Phosphorus and Heavy Metal Budgets: How Large is the Eelgrass (*Zostera Marina* L.) Sink in a Temperate Estuary?. *Marine Pollution Bulletin*. 52 (3), 342 - 353.

Khazanah National. (2006). Flagship C: Important Facts and Details on Western Gate Development. *Iskandar Regional Development Authorities*. Retrieved 11 Febuary 2015 from http: // www. iskandarmalaysia. com. my/ pdf/ brochures/ Flagship-C-EN.pdf.

Kilminster, K. (2013). Trace Elemet Content of Seagrasses in the Leschenault Estuary, Western Australia. *Marine Pollution Bulletin*. 73 (1), 381 - 388.

King, J. K, Kostka, J.E, Frischer, M. E, and Saunders, F. M. (2010). Sulfate - Reducing Bacteria Methylate Mercury at Variable Rates in Pure Culture and in Marine Sediments. *Applied and Environmental Microbiology*. 66 (6), 2430 – 2437.

Kirkman, H. (1990). Seagrass Distribution and Mapping. In Philips, R. C. and McRoy, C. P. *Seagrass Research Method.* (pp. 19 - 25). United Nation Educational.

Koch, E. W. (2001). Beyond Light: Physical, Geological and Geochemical Parameters as Possible Submerged Aquatic Vegetation Habitat Requirements. *Estuaries*. 24 (1), 1 - 17.

Koch, M. S., Schopmeyer, S. A., Holmer, M., Madden, C. J., and Kyhn - Hansen, C. (2007). *Thalassia testudinum* Response to the Interactive Stressors Hypersalinity, Sulphide and Hypoxia. *Aquatic Botany.* 87 (2), 104 - 110.

Komatsu, T., Sawayama, S., Otaki, T., Sakamoto, S., Miyamoto, H., Nishida, S., Buranapratheprat, A., Noiraksar, T., Prathep, A., and Hyashizaki, K. (2014). Mapping of Seagrass Beds in Thailand Under COMSEA Project. *International Workshop on Integrative Research on Seagrass Ecosystems (IER) in Southeast Asia.* 16 – 18 December 2014. Marine Science Centre, Universiti Putra Malaysia, Malaysia, 33 - 34.

Kotnik, J., Horvat, M., and Jereb, V. (2002). Modelling of Mercury Geochemical Cycle in Lake Velenje, Slovenia. *Environmental Modelling & Software*. 17 (7), 593 - 611.

Kumar, S., Dubey, R. S., Tripathi, R. D., Chakrabarty, D., and Trivedi, P. K. (2015). Omics and Biotechnology of Arsenic Stress and Detoxification in Plants: Current Updates and Prospective. *Environment Internationa.* 74, 221 - 230.

Kvesitadze, E., Sadunishvili, T., and Kvesitadze, G. (2009). Mechanisms of Organic Contaminants Uptake and Degradation in Plants. *World Academy Science Engineering Technology*. 55 (6), 458 - 468.

Lafabrie, C., Pergent, G., Kantin, R., Pergent-Martini, C. and Gonzalez, J. L. (2007). Trace Metals Assessment in Water, Sediment, Mussel and Seagrass Species-Validation of the Use of *Posidonia Oceanica* as a Metal Biomonitor. *Chemosphere*. 68 (11), 2033 - 2039.

Laugier, T., Rigollet, V., and de Casabianca, M. L. (1999). Seasonal Dynamics in Mixed Eelgrass Beds, *Zostera marina* L. and *Zostera noltii* Hornem., in a Mediterranean Coastal Lagoon (Thau lagoon, France). *Aquatic Botany*. 63 (1), 51 - 69.

Lee, K. S., and Dunton, K. H. (1996). Production and Carbon Resetve Dynamics of the Seagrass *Thalassia Testudinum* in Corpos Christi Bay, Texas, USA. *Marine Ecology Progress Series*. 143, 201 - 210.

Lee, K. S., and Dunton, K. H. (2000). Effects of Nitrogen Enrichment on Biomass Allocation, Growth, and Leaf Morphology of the Seagrass *Thalassia Testudinum*. *Marine Ecology Progress Series*. 196, 39 - 48.

Lee, K. S. and Lee, S. Y. (2003). The Seagrasses of the Republic of Korea. In Green, E.P., and Short, F.T. (Ed.). *World Atlas of Seagrasses*. (pp. 193 – 198). Berkeley: University of California Press, Berkeley.

Lee, K. S., Park, S. R., and Kim, Y. K. (2007). Effects of Irradiance, Temperature, and Nutrients on Growth Dynamics of Seagrasses: A. Review. *Journal of Experimental Marine Biology and Ecology*. 350 (1 - 2), 144 - 175.

Lee, L., W. J., Mellors, J. E., and Coles, R. G. (1993). Seagrasses Between Cape York and Hervey Bay, Queensland, Australia. *Australian Journal of Marine and Freshwater Research.* 44 (1), 19 - 31.

Lee Long, W. J., Coles, R. G., and McKenzie, L. J. (1996). Deepwater seagrasses in Northeastern Australia - How Deep? How meaningful?. In Kuo, J., Phillips, R. C., Walker, D. I., and Kirkman, H. (Ed.). *Seagrass Biology.* (pp. 41 – 50). Proceedings of an international workshop. Perth: Sciences University of Western Australia.

Lelian, E., Fazrullah, R. A. R., and Agnie, A. N. F. (2008). *Rumput Laut Perairan Sabah*. Dewan Bahasa dan Pustaka.

Lenge, T. R., Royals, H. E., and Connor, L. L. (1993). Influence of Water Chemistry on Mercury Concentration in Largemouth Bass Florida Lakes. *Transactions of the American fisheries Society.* 122, 74-84.

Len McKenzie. (2008). Seagrass Educators Handbook. *Seagrass Watch-HQ*. Retrieved June 4, 2014, from www.seagrasswatch.org/seagrass.html.

Lewis, M. A., Dantin, D. D., Chancy, C. A., Abel, K. C., and Lewis, C. G. (2007). Florida Seagrass Habitat Evaluation: A Comparative Survey for Chemical Quality. *Environmental Pollution*. 146 (1), 206 - 218.

Lièvremont, D., Bertin, P. N., and Lett, M. C. (2009). Arsenic in Contaminated Waters: Biogeochemical Cycle. Microbial Metabolism and Biotreatment Processes. *Biochimie*. 91 (10), 1229 - 1237.

Ling, H., Diamond, M., and Mackay, D. (1993). Application of the QWASI Fugacity/Aquivalence Model to Assessing Sources and Fate of Contaminants in Hamilton Harbour. *Journal of Great Lakes Research*, 19 (3), 582 - 602.

Lipkin, Y., Beer, S., and Zakai, D. (2003). The Seagrasses of the Eastern Mediterranean and the Red Sea. In Green, E. P., and Short, F.T. (Ed.) *World Atlas of Seagrasses.* (pp. 65 – 73). Berkeley: University of California Press.

Liquete, C., Zulian, G., Delgado, I., Stips, A., and Maes, J. (2013). Assesment of Coastal Protection as an Ecosystem Service in Europe. *Ecological Indicators*. 30, 205 - 217.

Lizumi, H., and Hattori, A. (1982). Growth and Organic Production of Eelgrass (*Zostera Marina* L.) in Temperate Waters of the Pacific Coast of Japan. III. The Kinetics of Nitrogen Uptake. *Aquatic Botany.* 12, 245 - 256.

Llagostera, I., Perez, M. and Romero, J. (2011). Trace Metal Content in The Seagrass *Cymodocea Nodosa*: Differential Accumulation in Plant Organs. *Aquatic Botany*. 95 (2), 124 - 128.

Lord, D., Paling, E., and Gordon, D. (1999). Review of Australian Rehabilition and Restoration Programs. In *Seagrass in Australia - Strategic Review and Development of an R & D Plan.* (pp. 65 - 115). Australia: CSIRO Marine Research, Collingwood.

Macinnis-Ng, C. M. O., and Ralph, P. J. (2002). Towards a More Ecologically Relevant Assessment of the Impact of Heavy Metals on the Photosynthesis of the Seagrass, *Zostera Capricorni*. *Marine Pollution Bulletin*. 45 (1 - 12), 100 - 106.

Macinnis-Ng, C. M. O., and Ralph, P. J. (2004). Variations in Sensitivity to Copper and Zinc Among Three Isolated Populations of the Seagrass, *Zostera*

Capricorni. *Journal of Experimental Marine Biology and Ecology*. 302 (1), 63 - 83.

Mackay, D., and Diamond, M. (1989). Application of the QWASI (Quantitative Water Air Sediment Interaction) Fugacity Model to the Dynamics of Organic and Inorganic Chemicals in Lakes. *Chemosphere,* 18 (7 - 8), 1343 - 1365.

Mackay, D., Hughes, L., Powell, D. E., and Kim, J. (2014). An Updated Quantitative Water Air Sediment Interaction (QWASI) Model for Evaluating Chemical Fate and Input Parameter Sensitivities in Aquatic Systems: Application to D5 (Decamethylcyclopentasiloxane) and PCB-180 in Two lakes. *Chemosphere,* 111**,** 359 - 365.

Mackay, D., Joy, M., and Paterson, S. (1983). A Quantitative Water, Air, Sediment Interaction (QWASI) Fugacity Model for Describing the Fate of Chemicals in Lakes. *Chemosphere,* 12 (7 - 8), 981 – 997.

Mahdzir Ibrahim. (2014, May 7). Projek Tambak Laut Mangsakan Nelayan Pantai Johor. *Harakah.* Retrieved July 17, 2014, from http: // www. harakahdaily. net / index .php / berita – utama /27719 – projek – tambak – laut – mangsakan – nelayan – pantai - johor.

Malea, P. (1994). Seasonal Variation and Local Distribution of Metals in the Seagrass *Halophila Stipulacea* (Forsk). Aschers. In the Antikyra Gulf, Greece. *Environmental Pollution*. 85 (1), 77 - 85.

Mamindy-Pajany, Y., Hurel, C., Géret, F., Galgani, F., Battaglia-Brunet, F., Marmier, N. and Roméo, M. (2013). Arsenic in Marine Sediments From French Mediterranean Ports: Geochemical Partitioning, Bioavailability and Ecotoxicology. *Chemosphere.* 90 (11), 2730 - 2736.

Manasa, R. B., Cui, C., Sundarambal, P., and Pavel, T. (2013). Temporal Variability and Climatology of Hydrodynamic, Water Property and Water Quality Parameters in the West Johor Straits of Singapore. *Marine Pollution Buletin*. 77 (1 - 2), 380 - 395.

Manzanera, M., Perez, M., and Romero, J. (1995). Seagrass Mortality due to Over Sedimentation: an Experimental Approach. Proceedings of the Second International Conference on the Mediterranean Coastal Environment, MEDCOAST 95. 24 - 27 October 1995. Taragona, Spain.

Mao, J. S., Dong, J., and Graedel, T. E. (2008a). The Multilevel Cycle of Anthropogenic Lead: II. Results and Discussion. *Resources, Conversation and Recycling*. 52 (8 - 9), 1050 - 1057.

Mao, J. S., Dong, J., and Graedel, T. E. (2008b). The Multilevel Cycle of Anthropogenic Lead: I. Methodology. *Resources, Conservation and Recycling*. 52 (8 - 9), 1058 - 1064.

Mao, J. S., Cao, J. and Graedel, T. E. (2009). Losses to the Environment from the Multilevel Cycle of Anthropogenic Lead. *Environmental Pollution.* 157 (10), 2670 - 2677.

Marba, N., and Duarte, C. M. (1994). Growth Response of the Seagrass *Cymodocea nodosa* to Experimental Burial and Erosion. *Marine Ecology Progress Series*. 107 (3), 307 - 311.

Marissa Lee. (2015, January 16). Controversial Johor Strait Land Reclamation Project Forest City Gets The Go - Ahead. *The Straits Times.* Retrieved April 14, 2016 from http:_//www._straitstimes._com/_business/_controversial – johor – strait – land – reclamation – project – forest – city_-gets-the-go-ahead.

Marsh, J., Dennison, W. C., and R. S. Alberte (1986). Effects of Temperature on Photosynthesis and Respiration in Eelgrass (*Zostera Marina* L.). *Journal of Experimental Marine and Biology Ecology*. 101 (3), 257 - 268.

Masini, R. J., and Manning, C. R. (1997). The Photosynthetic Responses to Irradiance and Temperature of Four Meadow - Forming Seagrasses. *Aquatic Botany*. 58 (1), 21 - 36.

Mason, R. T, and Lawrence, A. L. (1999). Concentration, Distribution, and Bioavailability of Mercury and Methylmercury in Sediments of Baltimore Harbor and Chesapeake Bay, Maryland, USA. *Environmental Toxicology and Chemistry*, 18 (11) 2438 – 2447.

Massa, S., Arnaud - Haond, S., Pearson, G., and Serrão, E. (2009). Temperature Tolerance and Survival of Intertidal Populations of the Seagrass *Zostera noltii* (Hornemann) in Southern Europe (Ria Formosa, Portugal). *Hydrobiologia*. 619 (1), 195 - 201.

Matthews, G. V. T. (1993). The Ramsar Conventional on Wetlands: its History and Development. Gland, Switzerland: Ramsar Conventional Bureu.

May, T. W., and McKinney, G. L. (1981). Cadmium, Lead, Mercury, Arsenic and Selenium Concentration in Freshwater Fish 1976-77 - National Pesticide Monitoring Program. *Pesticide Monitoring Journal.* 15 (1), 14 - 38.

Maznah Mohd Arsad. (2014, July 11). Kerajaan Negeri Nafi Ambik Balik Tanah PTP. *Utusan.* Retrieved February 11, 2015, from http: //ww1. utusan. com. my/ utusan/ Ekonomi/ 20140711/ ek_05/ Kerajaan – negeri – naïf – ambil – balik – tanah - PTP.

McArthur, L. C., and Boland, J. W. (2006). The Economic Contribution of Seagrass to Secondary Production in South Australia. *Ecological Modelling.* 196 (1 - 2), 163 - 172.

McKenzie, L. J., Finkbeiner, M. A. and Kirkman, H. (2001). Methods for Mapping Seagrass Distribution. In Short, F. T. & Coles, R. G. *Global Seagrass Research Methods.* (pp. 101 - 121). Amsterdam, The Netherlands: Elsevier Science B.V.

McKenzie, L. J., and Campbell, S. J. (2002). Seagrass-Watch: Manual for Community (Citizen) Monitoring of Seagrass Habitat. *Western Pacific Edition (QFS, NFC, Cairns).* Australia: The State of Queensland, Department of Primary Industries.

McMillan, C. (1982). Reproductive Physiologyof Tropical Seagrasses. *Aquatic Botany.* 14, 245 - 258.

McRoy, C. P. (1977). Production Ecology and Physiology of Seagrasses Ecosystem. *A Scientific Perspective.* 53 - 81.

McRoy, C. P., and Philips, R. C. (1990). *Monographs on Ocean Graphic Methadology Seagrass Research Methods*. Paris: Nation Education.

Meling - Lopez, A. E., and Ibarra-Obando, S. E. (2000). Life Histories Comparison of *Zostera Marina* from the Northwest Coast of Mexico. *Biologia Marina Mediterranea*. 7, 95 - 98.

Michael Porter. (2002). A Secchi Disk is Used to Measure Water Clarity. *Ag News and Views.* Retrieved February 14, 2016, from http: // www. noble. org/ ag/ wildlife/ secchidisk/ last.

Milchakova, N. A. (1999). On the Status of Seagrass Communities in the Black Sea. *Aquatic Botany*. 65 (1), 21 - 32.

Mills, K. E., and Fonseca, M. S. (2003). Mortality and Productivity of Eelgrass *Zostera marina* Under Conditions of Experimental Burial with Two Sediment Types. *Marine Ecology Progress Series.* 255, 127 - 134.

Mobile Geographics. (2014). *Sembawang, Singapore Tidal Chart.* Retrieved July 17, 2014, from http: // tides. mobilegeographics. com/locations/5729. html?y=2014&m=6&d=14.

Munn, M. D., and Short, T. M. (1997). Spatial Heterogeneity of Mercury Bioaccumulation by Walleye in Franklin D. Roosevelt Lake and the Upper Columbia River, Washington. *Transections of the America Fisheries Society*. 126 (3), 477 - 487.

Murray, L., Dennison, W. C., and Kemp, W. M. (1992). Nitrogen Versus Phosphorus Limitation for Growth of an Estuarine Population of Eelgrass (*Zostera Marina* L.). *Aquatic Botany*. 44 (1), 83 - 100.

Nadiarti. (2010). *Strategy Design for Seagrass Ecosystems Management Based on Productivity Approach of Fisheries Resources in the Spermode Archipelago, Indonesia.* Dissertation proposal. Environment and Natural Resources Management, Bagor Agricultural University.

New South Wales Government. (2016). Hunter River Salinity Trading Scheme. *New South Wales Government*. Retrieve February, 27 2016, from http: // waterinfo. nsw. gov. au / hunter / trading . shtml

Newell, R. C., Seiderer, L. J., and Hitchcock, D. R. (1998). The Impact of Dredging Works in Coastal Waters: A Review of the Sensitivity to Disturbance and Subsequent Recovery of Biological Resources on the Seabed. *Oceanography and Marine Biology – An Annual Review*. 36, 127 – 178.

Nicolaidou, A. and Nott, J. A. (1998). Metals in Sediment, Seagrass and Gastropods Near A Nickel Smelter in Greece: Possible Interactions. *Marine Pollution Bulletin*. 36 (5), 360 – 365.

Nienhuis, P. H. (1986). Background Levels of Heavy Metals in Nine Tropical Seagrass Species in Indonesia. *Marine Pollution Bulletin*. 17 (11), 508 - 511.

Nigel Aw. (2014, July 14). The Case of Forest City and the Johor Sultan. *Malaysia Kini*. Retrieved July 16, 2014, from http: // www. malaysiakini.c om /news /268649.

Nisha Sabanayagam. (2008, January 10). Food for Marine Life Under Treat. *New Straits Times.* p. 13.

Nixon, S. W. (1995). Coastal Marine Eutrophication: A Definition, Social Causes and Future Concern. *Ophelia*. 41, 199 - 219.

Oh, S., Kim, M-K., Yi, S-M, and Zoh, K-D. (2010). Distributions of Total Mercury and Methylmercury in Surface Sediments and Fishes in Lake Shihwa, Korea. *Science of the Total Environment,* 408 (5), 1059-1068.

Ong, E., and Gong, W. K. (2007). *The Seas.* (pp. 48). Archipelago Press.

Onuf, C. P. (1994). Seagrasses, Dreging and Lightin Laguna Madre, Texas, U.S.A. *Estuarine. Coastal and Shelf Science*. 39, 75 - 91.

Onuf, C. P., Phillips, R. C., Moncreiff, C. A., Raz-Guzman, A., Herrera - Silveira, and J. A. (2003). The Seagrasses of the Gulf of Mexico. In Green, E. P., and Short, F. T. (Ed.). *World Atlas of Seagrasses*. (pp. 224 – 233). Berkeley: University of California Press.

Ooi, J. L. S., Kendrick, G. A., Van Niel. K. P., and Affendi, Y. A. (2011). Knowledge Gaps in Tropical Southeast Asian Seagrass Systems. *Estuarine, Coastal and Shelf Science*. 92 (1), 118 - 131.

Orth, R. J. (1977). Effect of Nutrient Environment on Growth of the Eelgrass *Zostera Marina* in the Chesapeake Bay, Virgin, USA. *Marine Biology*. 44, 187 - 194.

Orth, R. J., and Moore, K. A. (1983). Chesapeake Bay: An Unprecedented Decline in Submerged Aquatic Vegetation. *Science*. 222 (4619), 51 - 53.

Orth, R. J., Heck Jr., K. L., and Van Montfrans, J. (1984). Faunal Communities in Seagrass Beds: A Review of the Influence of Plant Structure and Prey Characteristics on Predator - Prey Relationships. *Estuaries*. 7 (4A), 339 - 350.

Parida, A. K., and Das, A. B. (2005). Salt Tolerance and Salinity Effects on Plants: A Review. *Ecotoxicology and Environmental Safety.* 60 (3), 324 - 349.

Pathak, T. S., Yun, J.-H., Lee, J., and Paeng, K.-J. (2010). Effect of Calcium Ion (Cross - Linker) Concentration on Porosity, Surface Morphology and Thermal Behavior of Calcium Alginates Prepared From Algae (*Undaria pinnatifida*). *Carbohydrate Polymers,* 8 (3), 633 - 639.

Pergent - Martini, C., and Pergent, G. (2000). Marine Phanerogams as a Tool in the Evaluation of Marine Trace - Metal Contamination: An Example from the Mediterranean. *International Journal Environment and Pollution*. 13, 126 - 147.

Pérez, M., Romero, J., Duarte, C. M., and Sand-Jensen, K. (1991). Phosphorus Limitation of Cymodocea Nodosa Growth. *Marine Biology*. 109, 129 - 133.

Pérez, M., and Romero, J. (1992). Photosynthetic Response to Light and Temperature of the Seagrass *Cymodocea nodosa* and the Prediction of its Seasonality. *Aquatic Botany*. 43 (1), 51 - 62.

Phillips, R. C., McMillan, and K. W. Bridges (1983). Phenology of Eelgrass, *Zostera Marina* L., Along Latitudinal Gradients in North America. *Aquatic Botany*. 15 (2), 145 - 156.

Phillips, R. C., Milchakova, N. A., and Alexandrov, V.V. (2006). Growth Dynamics of *Zostera* in Sevastopol Bay (Crimea, Black Sea). 85 (3), 244 - 248.

Prange, J. A., and Dennison, W. C. (2000). Physiological Response of Five Seagrass Species to Trace Metals. *Marine Pollution Bulletin*. 41 (7 - 12), 327 - 336.

Purkis, S. J., and Riegl, B. (2005). Spatial and Temporal Dynamics of Arabian Gulf Coral Assemblages Quantified from Remote - Sensing and *In-situ* Monitoring. *Marine Ecology Progress Series.* 287, 99 - 113.

Ralph, P. J., Durako, M. J., Enriquez, S., Collier, C. J., and Doblin, M. A. (2007). Impact of Light Limitation on Seagrasses. *Journal of Experimental Marine Biology and Ecology*. 350 (1 - 2), 176 - 193.

Ranft, S., Pesch, R., Schroder, W., Boedeker, D., Paulomaki, H., and Fagerli, H. (2011). Eutrophication Assessment of the Baltic Sea Protected Areas by Available Data and GIS Technologies. *Marine Pollution Bulletin*. 63 (5 - 12), 209 - 214.

Ramond, J-B., Petit, F., Quillet, L., Ouddane, B., and Berthe, T. (2011). Evidence of Methylmercury Production and Modification of the Microbial Community Structure in Estuary Sediments Contaminated With Wastewater Treatment Plant Effluents. *Marine Pollution Bulletin,* 62 (5), 1073-1080.

Rasheed, M. A., and Unsworth, R. K. F. (2011). Long - Term Climate - Associated Dynamics of a Tropical Seagrass Meadow: Implications for the Future. *Marine Ecology Progress Series.* 422, 93–103.

Rensing, C., and Rosen, B. P. (2009). Heavy Metals Cycle (Arsenic, Mercury, Selenium, others). In Moselio S. (3rd.). *Encyclopedia of Microbiology.* Oxford: Academic Press.

Ripperger, S., Rehkamper, M., Porcelli, D., and Halliday, A. N. (2007). Cadmium Isotope Fractionation in Seawater - A Signature of Biological Activity. *Earth and Planetary Science Letters*. 261 (3 - 4), 670 - 684.

Rizzo, A., and Glasson, J. (2012). Iskandar Malaysia. *Cities*. 29, 417 - 427.

Ruiz, H., and Ballantine, D. L. (2004). Occurrence of the Seagrass *Halophila stipulacea* in the Tropical West Atlantic. *Bulletin of Marine Science*. 75 (1), 131 - 135.

Rusli, M. H. B. M. (2012). Protecting Vital Sea Lines of Comminication: A Study of the Proposed Designation of the Straits of Malacca and Singapore as a Particularly Sensitive Sea Area. *Ocean and Coastal Management*. 57, 79 - 94.

Sabol, B. M., and Shafer, D. J. (2005). Dredging Effects on Seagrasses: Case Studies from New England and Florida. In *25th Annual Western Dredging Association Conferences*. (pp. 335 – 346).

Sabol, B., Shafer, D., and Lord, E. (2005). Dredging Effects on Eelgrass (*Zostera Marina*) Distribution in a New England Small Boat Harbor. *US Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory*. Technical Report ERDC/EL TR -05-8, 31.

Sanchiz, C., M. Garcia-Carrascosa, A., and Pastor, A. (2000). Heavy Metal Contents in Soft - Bottom Marine Macrophytes and Sediments Along the Mediterranean Coast of Spain. *Marine Ecology*. 21 (1), 1 - 16.

Sanchiz, C., Garcia-Carrascosa, A. M., and Pastor, A. (2001). Relationship Between Sediment Physico - Chemical Characteristics and Heavy Metal Bioaccumulation in Mediterranean Soft - Bottom Macrophytes. *Aquatic Botany*. 69 (1), 63 - 73.

Saves Our Seahorses (2014). Saving the Seahorse Means Saving the Sea. *Saves Our Seahorses*. Retrieved January, 20 2016, from http: // www. sosmalaysia. org / ptp _ map. html.

Schlacher - Hoenlinger, M. A., and Schlacher, T. A. (1998). Differential Accumulation Patterns of Heavy Metals Among the Dominant Macrophytes of a Mediterranean Seagrass Meadow. *Chemosphere*. 37 (8), 1511 - 1519.

Science Dairy. (2015). An Algal Bloom or Marine Bloom or Water Bloom is a Rapid Increase in the Population of Algae in an Aquatic System. *ScienceDairy*. Retrieved February 14, 2016, from https: // www. sciencedaily. com/ terms/ algal _ bloom. htm.

Scoffin, T. P. (1979). The Trapping and Binding of Subtidal Carbonate Sediments by Marine Vegetation in Bimini Lagoon, Bahamas. *Journal of Sedimentary Petrology*. 40 (1), 249 - 273.

Scoullos, M. J. (1986). Lead In Coastal Sediments: The Case Of The Elefsis Gulf, Greece. *Science of The Total Environment*. 49, 199 - 219.

Selleslagh, J., Lobry, J., Amara, R., Brylinski, J. M., and Boet, P. (2012). Trophic Functioning of Coastal Ecosystems Along an Anthropogenic Pressure Gradient: A French Case Study with Emphasis on a Small and Low Impacted Estuary. *Estuarine, Coastal and Shelf Science*. 112, 73 - 85.

Serkut, A., Feza, K., Ashhan, K., and Ertuğrul, A. (2011). A GIS Based Method for Shallow Lake Eutrophication Assessment. *Journal of Biodiversity and Environment Sci*ences. 5 (15), 195 - 202.

Shannon Teoh. (2015, march 19). Developers of Johor's Forest City, Near Second Link, Say Environmental Concessions Were Made. *The Straits Times.* Retrieved April, 15 2016, from http: // www. straitstimes. com / asia / se-asia / developers - of - johors - forest - city - near - second - link - say - environmental - concessions - were.

Sharma, V. K., and Sohn, M. (2009). Aquatic Arsenic: Toxicity, Speciation, Transformations, and Remediation. *Environment International.* 35 (4), 743 - 759.

Shaw, B. J. (2000). Bali: Paradise Sustainable?. *Current Issues in Tourism*. 3 (1), 81 – 85.

Shepherd, S. A., McComb, A. J., Bulthuis, D. A., Neverauskas, V., Steffensen, D. A., and West, R. (1989). Decline of Seagrasses. In Larkum, A. W. D., Mc Comb, A. J., and Shepherd, S.A. (Ed.). *Seagrasses: A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region*. (pp. 346 – 387). North Holland, Elsevier.

Short, F. T., Dennison, W. C., and Capone, D. G. (1990). Phosphorus - Limited Growth of the Tropical Seagrass *Syringodium Filiforme* in Carbobnate Sediments. *Marine Ecology Progress Series*. 62 (1 - 2), 169 - 174.

Short, F. T., and Wyllie-Echeverria, S. (1996). Natural and Human - Induced Disturbance of Seagrasses. *Environmental Conservation*. 23 (1), 17 - 27.

Short, F. T., and Wyllie-Echeverria, S. (2000). Global Seagrass Declines and Effect of Climate Change. In Shepperd, C. R. C. (Ed.) *Seas at the Millennium: An Environmental Evaluation.* (pp. 10 - 11). Amsterdam: Pergamon, Elsevier.

Short, F. T., and Coles, R. G. (2001). Global Seagrass research Methods. Netherlands, Amsterdam: Elsevier.

Short, F. T., Coles, R. G., and Pergent-Martini, C. (2001). Global Seagrass Distribution. In Short F. T. *Global Seagrass Research Methods.* (pp. 5 - 30). Netherlands, Amsterdam: Elsevier.

Short, F. T. (2003). Loss and Restoration of Seagrass Ecosystems. *5th International Conference on Environmental Future (5th ICEF)*. March 23 - 27. Zurich, Switzerland.

Short, F. T., Fernandez, E., Vernon, and A., Gaeckle, J. L. (2006). Occurrence of *Halophila baillonii* Meadows in Belize, Central America. *Aquatic Botany*. 85 (3), 249 - 251.

Short, F. T, Carruthers, T., Dennison, W., and Waycott, M. (2007). Global Seagrass Distribution and Diversity: A Bioregional Model. *Journal of Experimental Marine Biology and Ecology*. 350 (1 - 2), 3 - 20.

Short, F. T., Carruthers, T. J. R., Van Tussenbroek, B., Zieman, J. and Kenworthy, W.J. (2010). The IUCN Red List of Threatened Species. *Union for Conservation of Nature and Natural Resources, Red List*. Retrieved April, 15 2016, from http: // www. iucnredlist. org / details / 173324 / 0.

Short, F. T., Polidoro, B., Livingstone, S. R., Carpenter, K. E., Bandeira, S., Bujang, J. S., Calumpong, H. P., Carruthers, T. J. B., Coles, R. G., Dennison, W. C., Erftemeijer, P. L. A, Fortes, M. D., Freeman, A. S., Jagtap, T. G., Kamal, A. H. M., Kendrick, G. A., Judson Kenworthy, W., La Nafie, Y. A., Nasution, I. M., Orth, R. J., Prathep, A., Sanciangco, J. C., Tussenbroek, B. V., Vergara, S. G., Waycott, M., and Zieman, J. C. (2011). Extinction Risk Assessment of the World's Seagrass Species. *Biological Conservation*. 144 (7), 1961 - 1971.

Sim Bak Heng. (2011, January 21). Murky Water Affecting Fishermen's Catch. *New Straits Times*. p. 8.

Summerson, H. C., and Peterson, C. H. (1984). Role of Predation in Organizing Benthic Communities of a Temperate - Zone Seagrass Bed. *Marine Ecology Proggress Series*. 15, 63 - 77.

Stafford, C. P., and Haines, T. A. (1997). Mercury Concentration in Maine Sport Fishes. *Transections of the America Fisheries Society*. 126 (1), 144 - 152.

Teasdale, P. R., Apte, S. C., Ford, P. W., Batley, G. E. and Koehnken, L. (2003). Geochemical Cycling and Speciation of Copper in Waters and Sediments of Macquarie Harbour, Western Tasmania. *Estuarine, Coastal and Shelf Science.* 57 (3), 475 - 487.

Terrados, J., Duarte, C. M., Fortes, M. D., Borum, J., Agawin, N. S. R., Bach, S., Thampanya, U., Kamp - Nielsen, L., Kenworthy, W. J., Geertz - Hansen, O., and Vermaat, J. (1998). Changes in Community Structure and Biomass of Seagrass Communities Along Gradients of Saltation in SE Asia. *Estuarine Coastal and Shelf Science.* 46 (5), 757 - 768.

The Star. (2015). Port of Tanjung Pelepas to embark on RM5bil expansion. Retrieved April 14, 2016 from http: // www. thestar. com. my/ business/ business -news/ 2015/ 10/ 19/ port – of – tanjung – pelepas – to –embark-on-rm5bil-expansion/

Uchimura, M., Faye, E. J., Shimada, S., Arai, S., Inoue, T., and Nakamura, Y. (2006). A Re - Evaluation of the Taxonomic Status of *Halophila euphlebia* Makino (*Hydrocharitaceae*) Based on Morphological Features and ITS Sequence Data. *Botanica Marina*. 49 (2), 111 - 121.

Unsworth, R. K. F., Cullen, L. C., Pretty, J. N., Smith, D. J., and Bell, J. J. (2010). Economic and Subsistence Values of the Standing Stocks of Seagrass Fisheries: Potential Benefits of No - Fishing Marine Protected Area Management. *Ocean & Coastal Management*. 53 (5 - 6), 218 - 224.

U.S. Geological Survey. 2014. *Aquatic Cycling of Mercury in the Everglades*. Retrieved July, 5, 2015, from http: _// scifun. _chem. _wisc. _edu / chemweek / mercury / mercury . htm.

U. S. Public Health Service. (1993). Toxicological Profile for Cadmium Update Agenda. *Agency for Toxic Substance and Disease Registry*. 92 (6), 182.

Vance, D., Archer, C., Bermin, J., Perkins, J., Statham, P. J., Lohan, M. C., Ellwood, M. J., and Mills, R. A. (2008). The Copper Isotope Geochemistry of Rivers and the Oceans. *Earth and Planetary Science Letters*. 274 (1 - 2), 204 - 213.

Vermaat, J. E., Agawin, N. S. R., Fortes, M. D., and Uri, J. S. (1997). The Capacity of Seagrasses to Survive Increased Turbidity and Siltation: The Significance of Growth Form and Light Use. *Ambio*. 25 (2), 499 - 504.

Vermaat, J. E., Rollon, R. N., Lacap, C. D. A., Billot, C., Alberto, F., Nacorda, H. M. E., Wiegman, F., and Terrados, J. (2004). Meadow Fragmentation and Reproductive Output of the SE Asian Seagrass *Enhalus Acoroides*. *Journal of Sea Research*. 52 (4), 321 - 328.

Villate, F., Iriarte, A., Uriarte, I., Intxausti, L., and De La Sota, A. (2013). Dissolved Oxygen in the Rehabillitation Phase of an Estuary: Influence of Seawage

Pollution Abatement and Hydro-Climatic Factors. *Marine Pollution Bulletin*. 70 (1 - 2), 234 - 246.

Voegborlo, R. B., Matsuyama, A., Adimado, A. A., and Akagi, H. (2011). Determination of Methylmercury in Marine and Freshwater Fish in Ghana Using a Combined Technique of Dithizone Extraction and Gas - Liquid Chromatography with Electron Capture Detection. *Food Chemistry*. 124 (3), 1244 - 1248.

Waeles, M., Riso, R. D., and Le Corre, P. (2005). Seasonal Variations of Dissolved and Particulate Copper Species in Estuarine Waters. *Estuarine, Coastal and Shelf Science*. 62, 313 - 323.

Wakibya, J.G. (1995). The Potential Human-Induced Impacts on the Kenyan Seagrasses. *UNESCO Reports in Marine Science*. 66, 176 – 187.

Walker, D. I., and McComb, A. J. (1992). Seagrass Degradation in Australian Coastal Waters. *Marine Pollution Bulletin*. 25 (5 - 8), 191 - 195.

Wang, J., Liu, R. H., Yu, P., Tang, A. K., Xu, L.Q., and Wang, J.Y., (2012). Study on the Pollution Characteristics of Heavy Metals in Seawater of Jinzhou Bay. *Procedia Environmental Sciences*. 13, 1507 - 1516.

Warnau, M., Ledent, G., Temara, A., Bouquegneau, J. M., Jangoux, M., and Dubois, P. (1995). Heavy Metals in *Posidonia Oeceanica* and *Paracentrotus Lividus* from Seagrass Beds of the North- Western Mediterranean. *Science of The Total Environment*. 171 (1 - 3), 95 - 99.

Watson, R. A., Coles, R. G., and Lee Long, W. J. (1993). Simulation Estimates of Annual Yield and Landed Value for Commercial *Penaeid* Prawns from a Tropical Seagrass, Northern Queensland, Australia. *Marine and Freshwater Research*. 44 (1), 211 - 219.

Waycott, M., Longstaff, B. J., and Mellors, J. (2005). Seagrass Population Dynamics and Water Quality in The Great Barrier Reef region: A Review and Future Research Directions. *Marine Pollution Bulletin*. 51 (1 - 4), 343 - 350.

Wetzel, R. L., and Penhale, P. A. (1983). Production Ecology of Seagrass Communities in the lower Chesapeake Bay. *Marine Technology Society Journal*. 17, 22 - 31.

Wiener, J. G., Krabbenhoft, D. P., Heinz, G. H., and Scheuhammer, A. M. (2003). Ecotoxicology of mercury. In Hoffman, D. J., Rattner, B. A, Burton, Jr. G.A, Cairns, Jr. J. *Handbook of Ecotoxicology.* Boca Raton, FL: Lewis Publishers.

Williams, S. L., and Ruckelshaus, M. H. (1993). Effects of Nitrogen Availability and Herbivory on Eelgrass (*Zostera Marina*) and Epiphytes. *Ecology*. 74, 904 - 918.

Wong, P. T. S., Silverberg, B. A., Chau, Y. K., and Hodson, P. V. (1978). Lead and the Aquatic Biota. In Nriagu, J. O. (Ed.) *The Biogeochemistry of Lead in the Environment Part B. Biological Effects.* (pp. 279 - 342). Amsterdam: Elsevier north Holland Biomedical Press.

World Weather and Climate information. (2015). Average Weather in Johor Bahru Malaysia. Retrieved April 1, 2015, from http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,johor-bahru,Malaysia.

Yüzügüllü, O., and Aksoy, A. (2011). Determination of Secchi Disc Depths in Lake Eymir Using Remotely Sensed Data. *Procedia - Social and Behavioral Sciences.* 19**,** 586 - 592.

Zainal, A. J. M., Dalby, D. H., and Robinson, I. S. (1993). Monitoring Marine Ecological Changes on the East Coast of Bahrain with Landsat TM. *Photogrammetric Engineering and Remote Sensing*. 59 (3), 415 - 421.

Zhan, X. H., Ma, H. L., Xhou, L. X., Liang, J. R., and Xu, G. H. (2010). Accumulation Ofphenanthrene by Roots of Intact Wheat (*Triticum acstivnm* L.) Seedings: Passive or Active Uptake?. *BMC Plant Biology*. 10, 52.