CHAPTER 1

INTRODUCTION

1.1 Significance of the Study

Present concern about the preservation of biological diversity is partially based on the belief that loss of biodiversity would result in the loss of ecosystem functions and the many services they provide to society (see Constanza et al., 1997). These services encompass a number of functions that derive from the interactions of the organisms with their environment, both physical and chemical, as well as their own value as food or raw materials. Duarte (2000) listed all the expected role of marine biodiversity in general, and that of seagrass communities in particular, in sustaining ecosystem functions, good and services (Table 1.1). The basis, structural or trophic (relating to the nutritive value of food) of the functions is indicated for seagrass communities.

This study is significant according to the Malaysia's National Policy on Biological Diversity (NPBD). The first strategy cited in the Policy for effective management of biological diversity is to improve the scientific knowledge base. Even though Malaysia's marine ecosystem is extremely rich in the variety of life-forms, the marine flora (including phytoplankton, seaweeds and seagrasses) and fauna have been poorly documented and the conservation efforts are inadequate (MOSTE, 1998). The NPBD gives a number of reasons, but the reason that "several important habitats are under-represented" is so relevant to marine ecosystem especially for seagrasses. In line with NPBD to improve the scientific knowledge base, this study describe how effective is the Geographic Information System (GIS) to develop a database of biological diversity and an effective information dissemination system.

Table 1.1: Expected role of marine biodiversity

Ecosystem functions, services and goods	Role of biodiversity	Role of seagrass biodiversity	Basis
Ecosystem functions			
Primary production	High	High	Trophic
Carbon storage	Low	High	Trophic
Carbon flow	High	High	Trophic
Nutrient cycling	High	Moderate	Trophic
Ecosystem services			
Gas and climate regulation	Low/medium	Medium	Trophic
Disturbance regulation	High	High	Combined
Erosion and sedimentation control	Medium/high	High	Structural
Remineralisation	High	High	Trophic
Waste treatment	High	Low	Trophic
Biological control	High	Medium	Combined
Monitoring of global change and ecosystem health	High	High	Structural
Recreation tourism and education	High	High	Structural
Ecosystem goods			
Habitat and refuge	High	High	Structural
Food resources	High	High	Combined
Raw materials	High	Low	Structural
Genetic resources	High	High	Structural
Natural heritage	High	High	Combined

Source: Duarte (2000)

1.2 Research Background

1.2.1 Definition of Seagrasses

Ascherson (1871) probably was the first scientist to use the term 'seagrasses' or 'seegraser' to refer to the marine flowering plants in the scientific literature (Kuo and den Hartog, 2001). Following the tradition, seagrasses, in this study, are defined as monocotyledonous flowering plants that inhabit the coastal and marine environments of the tropical and temperate regions. Den Hartog (1970) recognizes 12 genera with 49 species. There are seven (7) genera which are characteristic of the tropical seas, while five (5) genera are found in the temperate waters. All seven (7) tropical genera are found in Malaysia with 15 species represented in the coastal waters of Malaysia (Phang, 2000).

Seagrasses are unique because they are the only group of flowering plants or angiosperms that spends its entire life cycle in seawater (den Hartog, 1970). These communities are highly productive and serve a number of important ecological functions (Duarte, 2010).

1.2.2 The Importance of Seagrasses

Seagrasses have emerged as an important area of scientific activity in recent years, provides food and shelter for many marine organisms; stabilizes sediments and prevents erosion along coastline; and take up dissolved nutrients and trap sediments in the water resulting in high water clarity.

Seagrass meadows support high densities of animals and are considered fundamentally important in providing habitat for commercially or recreationally harvested aquatic animals (Jackson et al., 2001). It is known that seagrass meadows served as spawning and nursery grounds for many species of aquatic organisms and invariably supports more fish and shellfish than bare areas (Torre-Castro and Ronnback, 2004). Hundreds of species are found living epiphytic on the leaves at any one meadow, and there is a large number of species that live in the refuge offered by the plant's canopy. Like coral reefs, the seagrass ecosystem harbours entire food chains and they serve as food for herbivores such as dugong (*Dugong dugon*) and several species of turtles (Fortes, 1989), both of which are endangered marine herbivores. Many of the animals associated with seagrass meadows are of commercial importance, including prawns and other crustaceans and fish. Hence seagrass meadows are important habitats for other species, thereby contributing to maintain marine biodiversity and the production of potential food for humans.

Seagrasses are sometimes labelled ecosystem engineers, because they partly create their own habitat: the leaves slow down water-currents and dissipate turbulence, thereby reducing sediment resuspension and increasing the retention of sediments within the meadows (see Terrados and Duarte, 1999) and the dense roots and rhizomes that form a secure mat stabilizes the sea bed. This sediment stabilization and erosion prevention is especially important during storms and hurricanes that often threaten the coastline.

Seagrasses alter the environment they colonize in different ways. Their roots and rhizomes penetrate into the sediments releasing oxygen therein, which stimulates bacterial activity and attenuates the reduced condition of the sediments, thereby avoiding the accumulation of toxic compounds, such as sulfide. All seagrass tissues, particularly below-ground ones, decompose slowly (Harrison, 1989), such that some of the carbon and nutrients in the tissues are buried for time scales of at least centuries.

Hence, seagrass meadows tend to be autotrophic ecosystems (i.e. they produce more organic carbon than that been used in the ecosystem), which are areas of net oxygen release and CO_2 and nutrient sinks (Hemminga and Duarte, 2000)

Seagrasses are efficient at removing dissolved nutrients and filtering some pollutants from waters that often enter coastal waters as a result of runoff from the land. They filter suspended sediments and nutrients from coastal waters, dissipate wave energy and stabilize sediments (Koch, 2001; Orth et al., 2006). The settle out of the water column become trapped among the blades and roots of the seagrasses. The removal of sediments and nutrients from the water results in high water clarity and nutrient-poor waters required for the survival of coral reefs. The trapping and stabilization of bottom sediments, and the consequent increase in water clarity is one of the important ecological functions (Gacia et al., 2003). Clearer waters improve light penetration, and consequently increase photosynthesis and rates of organic matter production. Obviously, environmental changes that threaten the vitality and persistence of seagrass beds also endanger indirectly the ecological functions that seagrass meadows may have.

Besides their contribution to all important aspects that already discussed, in many countries, seagrasses are utilised for several traditional and contemporary purposes (Fortes, 1989). Among the traditional economic uses is their utilization for weaving the baskets; burning for salt and soda, and for warmth; stuffing for mattresses; composting for fertilisers; and fibre substitute for making nitro-cellulose. Among contemporary uses as mentioned earlier are: as sewage filters; stabilisers of coastal areas; fertiliser and fodder; and food and medicine for human uses.

It is of interest to note that based on their distribution, recreational value, and commercial fishery harvests, Dunton (1998) estimated the annual total value of seagrass beds (95,142 ha) in Texas, United States of America to be approximately USD12.6 million. Globally, these ecosystem services have been valued at approximated US$19,000 per hectare per year (Costanza et al., 1997).

1.2.3 Threats to Seagrasses

Incidences of seagrass loss have been reported in tropical and temperate regions worldwide. Many of these declines have been attributed to factors such as increased eutrophication, turbidity, sedimentation and pollution, often associated with a localised source (Den Hartog and Polderman, 1975). Although natural events have been responsible for both large-scale and local losses of seagrass habitat, recent evidence suggests that human population expansion is now the most serious cause of seagrass habitat loss. Increasing anthropogenic inputs to the coastal oceans are primarily responsible for the enhanced nutrient input from the land and the worldwide decline in seagrasses (Abal and Dennison, 1996). Human activities that most affect seagrasses are those that alter water quality or clarity (Ruiz and Romero, 2003). These activities can include nutrient and sediment loading from agricultural run-off and sewage disposal, dredging and filling, urban storm water, upland development, and certain fishing practices.

Land reclamation schemes by Singapore at Pulau Tekong and Pulau Ubin (located to the north-east of Singapore) gave a great concern to Malaysia. The reclamation works are predicted to have an adverse effect on: coastal hydrodynamics and wave characteristics; sediment fluxes, erosion and siltation rates; tidal flushing, salinity and water quality; hydro-ecology, habitats and fisheries; navigation, moorings and jetty stability; and further consequences on the economy and on coastal villages. The implications of these projects for Malaysia's coastal and estuarine waters and the risks they present to the aquatic environment would lead to degradation of water quality, destruction of corals and destruction of seagrass (ITLOS, 2003).

1.2.4 Issues and Problems

Seagrass meadows are noted for their extremely high productivity and contribution of valuable ecosystem functions and services to coastal zone. Since recent global studies show that seagrasses are sensitive to nutrient enrichment and water quality problems, as well as physical stress from human disturbances, many scientists and environmentally-aware community have become concerned about the ecosystem health of its habitats. Recent declines in seagrasses have led to a consensus that concerted planning and actions are needed to address seagrass problems and to promote effective conservation and management solutions. In order to deal effectively with the diversity of issues, planning should focus on three (3) separate issue categories; seagrass research, seagrass management/policy, and seagrass education/outreach.

In terms of seagrass research, the following major objectives were identified as major research issues related to seagrass distribution, productivity and ecology:

(i) To regularly assess status and trends of seagrass distribution. This includes the development of long-term monitoring plans for mapping and measurement of key parameters to assess both changes in water quality and seagrass health;

(ii) To determine causes of changes in seagrass species composition and coverage, including area losses and gains;

(iii) To identify habitat functions and productivity of natural seagrass community types and identify linkages with other habitats to support habitat conservation, creation, enhancement and restoration; and

(iv) To provide data for development of management policies in response to human-induced impacts.

In addressing the major research objectives, studies should present information on the relationship between seagrass presence, abundance (coverage and dry weight biomass), nutrient state, depth, water quality parameters and sediment structure. These relationships might be explained primarily by differences in location, (i.e. the geographic setting of the meadow and its adjacent catchments, the disturbance regime at that location) and to some extent the species present at that location (i.e. function and form of structurally small seagrass cf. structurally large seagrass). Hence regional-scale management plans for intertidal tropical seagrasses may be inadequate. Management plans for specific locations developed with a common conceptual framework should lead to a better correspondence between the environmental influences on the system and the management unit.

Geographical Information Systems (GIS) offer the ability to manipulate and analyze spatially distributed data and very useful for coastal research (in this case, seagrass) which usually has large set of data of a diverse nature. GIS can process large amount of spatial data and can integrate different types and sources of data. Some part of this study will demonstrate these benefits. Since there is no comprehensive information exists on the distribution of seagrass or the factors responsible for observed distribution patterns in Malaysia, researchers should take advantage of the GIS capabilities to do it. The ability of GIS to integrate digital spatial data, visualize results, and perform raster data modelling is essential for landscape-scale seagrass analyses, and made it an essential tool for managers to investigate seagrass environments on a landscape-scale. GIS analyses and products (both maps and tabular data) developed, provided needed information to resource managers, regional and county governments, and other interested parties.

With limitations of this study, major objectives which have been identified as major research issues for seagrass will be touch only at basic level. However, the findings of the study should be able to clarify some research issues related to seagrass distribution and ecology.

1.2.5 Limitations of the Study

There are two (2) limitations that need to be acknowledged and addressed regarding this study. The first and probably most important limitation associated with this study concerns the water quality data. Lack of available and reliable water quality data (from Department of Environment (DOE) and the UMMRec Project) gives a significant hurdle in finding a trend and meaningful relationship between seagrass and water quality. The water quality parameters chosen for this study should represent those likely to have the greatest influence on seagrass growth and distribution. However, not all of water quality data supplied by the DOE and the UMMRec Project can accommodate this requirement since not all can be analyzed statistically.

The second limitation has to do with the extent to which the findings can be generalized beyond the areas studied. The quantity of data is too limited for broad generalizations. It is quite difficult to find significant relationships from the data, as statistical tests/analysis normally require a larger sample size to ensure a representative distribution of the population and to be considered representative of clusters of seagrass meadow, where results will be generalized. Adding to that, literature of seagrass ecology was dominated by descriptive study. Not many efforts were taken to synthesis results and derived general relationships in tropical seagrass research studies which limit our capacity to predict seagrass responses and making generalizations.

1.3 Objective of Study

The basic objective of the study is to determine the spatial distribution pattern of seagrass in the study area and to understand the relationships between water quality and seagrass community structure.

The ensuing sub-objective is to design and develop a GIS-based seagrass database for the area. This work will describe and demonstrate the usage of GIS as one of the most suitable technology for management of aquatic biodiversity.

1.4 Scope of the Study

The study emphasizes on the following methodology analysis, which are:

(i) Using the Geographical Information Systems (GIS) capabilities to determine the relevant Water Quality Monitoring Stations (WQMS) (under the authority of Department of Environment) to the seagrass area. Water quality data from the selected WQMS will be used later in the analysis. GIS was used to construct the spatial database for the DOE WQMS, locations of survey by the UMMRec Project team and the seagrass community in the study area;

(ii) Statistical analysis will be performed on water quality data from selected DOE WQMS and the UMMReC Project to determine the reliability of the data;

(iii) Statistical analysis will be applied to clarify the distribution patterns of the seagrass community in the study area as well as to relate the biological parameters to water quality using correlation and regression techniques; and

The study will also define the extensive available functionality of geodatabase which is considered the most natural solution for handling the growing amount of digital spatial data in seagrass research and coastal management in general.

1.5 Dissertation Structure

This dissertation is organize as follows: Chapter 2 – Literature Review, presents a review of previous work undertaken in the fields of seagrasses and water quality analysis; Chapter 3 – Materials and Methods, describes the methods adopted in the study; Chapter 4 – Results and Discussions, presents the result and then interpreted and discussed; and Chapter 5 – Conclusion, the dissertation is concluded with the summary of the major findings of the study.