WATER QUALITY AND FISH DIVERSITY IN HABITAT OF CORAL REEF, SEAGRASS AND MANGROVE

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ABSTRACT

Water quality index has been produced in accordance with a particular interest for use as a tool for quality assessment of aquatic ecosystem. It is an important parameter touching all aspects of ecosystems which are essential to the health of the environment. Chlorophyll *a* is one of the water quality parameter which is widely used to estimate trophic state of an aquatic environment. The main purpose of this study was to determine the water quality and to compare the fish diversity in coral reef (CR), coral-sea grass (CR-SG) and coral-seagrass-mangrove (CR-SG-MG) ecosystem. Water samples were collected from nine stations in November 2013, January and March 2014, where three station for each three different areas of CR, CR-SG and CR-SG-MG. In this study, the method that was used to measure chlorophyll *a* is spectrophotometry. It is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength which involve the use of a spectrophotometer that can measure intensity as a function of the light source wavelength. The mean (± S.E.) of chlorophyll *a* in the CR area was 1.01 mg/m^3 (±1.06), in the CR-SG was 1.52 mg/m^3 (±2.32) and in the CR-SG-MR was 1.34 mg/m^3 (±1.89). While the *in-situ* parameter namely temperature, pH, DO, salinity and turbidity ranged from 25.1 °C to 30.9 °C, 7.71 to 8.65, 2.76 mg/L to 10.6 mg/L, 24.01 psu to 38.5 psu and 0 to 96.16 mg/L respectively. One-Way ANOVA analyses of chlorophyll *a* and the three different areas showed no significant different ($P>0.05$). As for the fish diversity at the three different areas shows that CR-SG area harbours a high species richness (23 species in 5 families) followed by CR (18 species in 8 families) and CR-SG-MG (9 species in 5 families). The results acquired from correlation and regression test proved that fish diversity have a poor relationship with chlorophyll *a* while the results acquired from correlation and regression showed that temperature and pH were positively correlate with fish diversity.

ABSTRAK

Indeks kualiti air telah dihasilkan menurut kepentingannya bagi kegunaan sebagai alat penilaian kualiti ekosistem akuatik. Ia merupakan parameter yang penting melibatkan semua aspek ekosistem yang mana penting untuk keseimbangan alam sekitar. Klorofil *a* merupakan salah satu parameter kualiti air yang mana digunakan secara meluas bagi mengukur keadaan persekitaran akuati. Tujuan utama kajian ini dijalankan adalah untuk mengenalpasti dan membandingkan kualiti air serta membandingkan diversiti ikan yang terdapat di ekosistem terumbu karang, terumbu karang-rumput laut dan terumbu karang-rumput laut-bakau. Pensampelan air telah dijalankan di sembilan lokasi pada bulan November 2013, Januari dan Mac 2014, dimana tiga stesen mewakili setiap ekosistem. Dalam kajian ini, kaedah yang digunakan untuk mengukur klorofil *a* adalah mengunakan kaedah spektofotometri. Ia merupakan pengukuran secara kuantitatif yang melibatkan pengunaanya dengan mengukur intesiti sumber cahaya. Purata ($\pm$S.E.) bagi klorofil *a* di terumbu karang adalah 1.01 mg/m^3 ($\pm$1.06), manakala di terumbu karang-rumput laut 1.52 mg/m^3 ($\pm$2.32) dan di terumbu karang-rumput laut-bakau adalah 1.34 mg/m^3 ($\pm$1.89). Sementara itu, bagi parameter in-situ iaitu suhu, pH, oksigen terlarut, saliniti dan kekeruhan, nilai bagi setiap parameter masing-masing berada dalam lingkungan 25.1 °C hingga 30.9 °C, 7.71 hingga 8.65, 2.76 mg/L hingga 10.6 mg/L, 24.01 hingga 38.5 psu dan 0 hingga 96.16 mg/L. Analisis ANOVA sehala bagi klorofil *a* dan ketiga-tiga kawasan yang berbeza menunjukkan tiada perbezaan ($P>0.05$). Manakala, bagi kepelbagaian ikan pada ketiga-tiga kawasan yang berbeza, terumbu karang-rumput laut mencatat kekayaan spesies yang tinggi (23 spesies dalam 5 famili) diikuti oleh terumbu karang (18 spesies dalam 8 famili) dan terumbu karang-rumput laut-bakau (9 spesies dalam 5 famili). Keputusan yang diperolehi melalui ujian korelasi dan regrasi menunjukkan bahawa diversiti ikan mempunyai perhubungan yang lemah dengan klorofil *a*. Manakala, perhubungan antara suhu dan pH menunjukkan perhubungan yang positif.

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LIST OF SYMBOLS AND ABBREVATIONS

°C	Degree Celsius
mg/l	milligram per litre
mL	millilitre
mg m^{-3}	milligram meter per cube
HPLC	High Performance Light Chromatography
DO	Dissolved oxygen
Nm	Nanometre
UVC	Underwater Visual Census
S.U	SCOR/UNESCO
N	NORTH
WQSA	Seawater Quality Standard
ANZECC	Australianand New Zealand Environment and Conservation Council
AMWQC	Asean Marine Water Quality Criteria
APHA	American Public Health Association

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Water quality is an important parameter touching on all aspects of ecosystems and human well-being such as the health of a community, food to be produced, economic activities, ecosystems health and biodiversity. Therefore, water quality also is influential in determining human poverty, wealth and educational levels. From a management perspective, water quality is defined by its desired end use. Consequently, water for recreation, fishing, drinking, and habitat for aquatic organisms require higher levels of purity, whereas for hydropower, quality standards are much less important. For this reason, water quality takes on a broad definition as the physical, chemical, and biological characteristics of water necessary to sustain desired water uses. It needs to be noted that after its use water usually returns back to the hydrological system and if left untreated can severely affect the environment.

Worldwide water quality is declining mainly due to human activities. Increasing population growth, rapid urbanization, discharge of new pathogens and new chemicals from industries and invasive species are key factors that contribute to the deterioration of water quality. In addition, climate change will further affect water quality. Major risks are the lack of water quality data and monitoring worldwide as well as lack of knowledge about the potential impact of natural and anthropogenic pollutants on the environment and on water quality. The lack of prioritization of water quality in many countries has resulted in decreased allocation of resources, weak institutions and lack of coordination in addressing water quality challenges.

Water is essential to human life and the health of the environment. As a valuable natural resource, it comprises marine, estuarine, freshwater and groundwater environments that stretch across coastal and inland areas. Water has two dimensions that are closely linked which are quantity and quality. Water quality is commonly defined by its physical, chemical, biological and aesthetic characteristics. A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health. Water quality in a body of water influences the way in which communities use the water for activities such as drinking, swimming or commercial purposes.

The condition or quality of coastal waters is very important for health and safety reasons and also for visual impact. Disease-carrying bacteria and viruses (or pathogens) associated with human and animal wastes pose threats to humans by contaminating seafood, drinking water and swimming areas. Eating seafood and even swimming can result in hepatitis, gastrointestinal disorders, and infections. There are several sources of bacterial contamination in coastal waters such as leaking septic tanks, poorly maintained sewage treatment plants, discharges from boats, and runoff from the land during heavy rains and storms.

Various process causes the increase of nutrient in coastal environments which induce the growth and biomass of phytoplankton. Coastal marine environment including bays, estuaries and wetlands are particularly sensitive to long and short term external factors. Coastal zones are especially exposed to diverse anthropogenic influences including industrial and domestic effluent, marine transportation, agricultural activities and alluvia carried by rivers and creeks. In return, with high level of nutrient content to coastal areas it may cause eutrophication. For all these reasons, water quality analyses of coastal ecosystems play a very important role in the environment impact assessment of the marine environment. Thus, it is essential to analyse, characterise and monitor the ecological status of coastal systems in terms of marine environmental health.

Ambong and Usukan bays plays an important role in supply of water resource for catchment. In recent years, the pressure of increasing population, the resulting expansion of cultural land and industrial area as well as urban development have caused a significant decrease of the Sabah's mangrove resource. Mangrove ecosystems and its associate marine life species can be threatened by various forms of human pressure such as pollution and reclamation (Farnsworth & Ellison, 1997, Hamilton & Snedaker, 1984). Most of the mangrove areas in Kota Belud are located in the southern part of the district such as Kuala Abai and along the shoreline of Ambong Bay.

Anthropogenic pollutants originated from domestic activities and dumping of waste into the sea contributed to the water pollution. Determination of the existence of fish fauna and chlorophyll *a* level in seas has allowed the quality of aquatic environment to be assessed. Appearance of fish species at particular location is influence by various factors, including physic-chemical parameters which usually affected by pollutants from anthropogenic sources. Detection of the primary interaction between toxicant and fish serve as an early warning indicator. According to Simon & Helliwell (1998), an accurate quantification of chlorophyll *a* is an important step in estimating phytoplankton biomass and its productivity in aquatic studies.

1.2 Significance of study

Throughout this study, it will gives an overall idea of water quality in Ambong and Usukan bay in terms of its chlorophyll *a* concentration as well as the fish diversity available in the study site. Hence, hopefully this study will provide a baseline data or as a reference for follow up studies on water quality and its fish diversity in the study area and elsewhere.

1.3 Objectives

In this project, there are three objectives to be achieved:

i. To determine the water quality namely chlorophyll *a*, temperature, pH, DO, salinity and turbidity in coral reef, coral-seagrass and coral-seagrass-mangrove areas.
ii. To compare the water quality namely chlorophyll *a*, temperature, pH, DO, salinity and turbidity in coral reefs, coral-sea grass and coral-seagrass-mangrove areas.
iii. To compare fish diversity in coral reef sites, coral reef adjacent to sea grass site and coral reef adjacent to sea grass and mangrove areas.

1.4 Hypotheses

H_0: There is no significance difference of water quality in coral reef, coral reef-seagrass and coral reef-seagrass-mangrove areas.
H_1: There is a significance difference of water quality in coral reef, coral reef-seagrass and coral reef-seagrass-mangrove areas.

H_0: There is no significance difference of fish diversity in coral reef sites, coral reef adjacent to seagrass site and coral reef adjacent to seagrass and mangrove site.
H_1: There is a significant difference of fish diversity in coral reef sites, coral reef adjacent to seagrass sites and coral reef adjacent to seagrass and mangrove site

CHAPTER 2

LITERATURE REVIEW

2.1 Water quality indicator

Water quality index has been produced in accordance with a particular interest for use as a tool for quality assessment of àquatic ecosystems. Chlorophyll present in many organisms including algae and some species of bacteria. It is also the most abundant pigment within photosynthesis organisms which gives plants their green colour. Besides than chlorophyll *a*, there are other form of chlorophyll, coded *b*, *c* and *d*. However, in this study the chlorophyll that will be focus on is chlorophyll *a* as it is the most abundant form in photosynthetic organisms which also being stated by Dillon (1975) where chlorophyll *a* is the major photosynthetic pigment of phytoplankton and a trophy index in aquatic ecosystem.

The measurement and distribution of microscopic living plant matter, commonly referred to as phytoplankton or algae, have been of interest to scientist, researchers and aquatic resource managers for decades. Thus, a better understanding regarding the composition and population of phytoplankton will help researcher to point out the water body's health, and its ecological status.

The terms algae and phytoplankton has its own distinct meaning. Algae is a simple aquatic organism such as seaweed and plankton which are plant-like organisms that would contain chlorophyll pigment in order to carry out photosynthesis process to obtain their food. While on the other hand, phytoplankton is a subset of algae and the suspended aquatic microorganism that contain chlorophyll which for *in-situ* monitoring, chlorophyll contained within the phytoplankton will be measured.

Chlorophyll *a* can be an effective measure of trophic status as it could be used to reflect algal biomass and hence, level of primary production (Lee, 1999). Stanley *et al.,* (2003), also point out that chlorophyll *a* is often used as an estimate of algal biomass, and in blooms concentration chlorophyll *a* goes above 40 microgram per litre. Chlorophyll is also vital to the existence of phytoplankton. It can be used to indicate the health of a particular body of water. By monitoring the chlorophyll levels in the water body it will help in tracking the algal bloom. High level of chlorophyll condition in surface water indicate that there is a high nutrient level in terms of phosphorus and nitrogen composition.

An elevated of chlorophyll *a* concentration in the water body often indicate poor water quality due to excess nutrient loading while low level often suggest good condition which was reported by Ogamba *et al.,* (2004). High in nutrient will result in algal to bloom and as the algal growth is being dominant in the water body, it will cause in depletion of oxygen levels causing a primary factor of fish being killed. However, high levels of chlorophyll *a* are not necessarily bad as increased phytoplankton growth tends to support larger heterotroph population such as fish. It is the long term persistence of high levels that is a problem. It may be linked to harmful algal bloom.

Thus, it can be said that by measuring the chlorophyll levels, it indirectly becomes the indicator for nutrient levels in particular water body in the seas. Simon & Helliwell (1998), also stated that, an accurate quantification of chlorophyll *a* is an important step in estimating phytoplankton biomass.

2.2 Measurement of chlorophyll *a*

There are various techniques to measure chlorophyll, including spectrophotometry, high performance liquid chromatography (HPLC), and fluorometry. However, in this study, the method that will be used to measure chlorophyll *a* is spectrophotometry. It is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength. Spectrophotometry involves the use of a spectrophotometer that can measure intensity as a function of the light source wavelength.

2.3 Fish diversity

'Species' is a "genetically distinctive group of population whose members are able to interbreed freely under natural conditions and are reproductively isolated from all members of other such group" as stated by McFadden & Keeton (1995). This has been noted in relation to taxonomic features, size, shape, environment preferences, interactions with other biota, and strategies for survival (Sigee, 2005). Thus, it can be said that diverse of fish species can be found in three different marine ecosystems of coral reefs, seagrass and mangrove areas.

Discrete population, small breeding pools, sedentary and non-migratory nature and association with specific habitats are striking characters of coral reef fishes. A variety of habitats found in coral reef areas may be rich or poor in species in each habitat or between differing habitat, supporting markedly different fish communities of which some may be cosmopolitan. Dependence on a particular food item, behavioral interaction and depths across reefs are other factors known to limit reef fish distribution (Sale, 1980).

According to Talbot (1965), in comparing fish collections from areas with either few or many species of corals present, states "It is probable that the greater variety of coral species...allow for a more varied fish population than the single species," and, "It is probable that the more complex coral population in the mixed stand provides more ecological niches than are available in the single species stand". Coral reefs support very diverse fish communities.

Throughout the tropics, shallow-water habitats such as seagrass and mangrove are favored as juvenile habitats by marine fish, and it is assumed that they function as nursery areas (Pollard, 1984). It is thought that these habitats can contribute to fish communities on the coral reef through migration of adults or sub adults from these nurseries. The diversity of fish in this ecosystem would be because of the source of food available in this areas as stated by Odum & Heald (1972), Carr & Adam (1973) and Nagelkerken *et al.,* 2000) where these habitat provide a great abundance of food for fishes result in abundance fish there.

Mangrove hold vital habitat for animals to live in. More importantly aquatic organisms that we as humans rely on are found in tangled roots of the mangroves. Many juvenile fish from the nearby coral reefs for example snapper and grouper come to take refuge in the tangled roots of the mangroves. Here the juvenile can grow with much less competition and predation. Even from previous study conducted by Cintron – Molero, (1987) and Boulon, (1992) also stated that mangrove lagoon also served as an important habitat for juvenile of many fish.

Nearby seagrass beds are considered part of the mangrove ecosystem. It is known that the organisms from the mangroves often interact with those of the seagrass beds. Based on Peter (2006) previous study on the Caribbean fish, they stated that juvenile reef fish occupy the submerged prop roots of Rhizophora mangle and make frequent foraging runs into adjacent seagrass beds. Species that often seen lives in mangrove areas are variety of gobies, spotted trout, pipefish and others.

For many fish species, they start their lives in the seagrass beds, they migrate into the mangroves as they grow slightly larger, and then when they are just about fully mature they will migrate across the flats of the coral reefs. Among the juvenile fish species which migrate to the coral reefs once reached maturity are various species of grouper, snapper, jacks, schoolmaster and others. According to Christopher C. Koenig *et al.,* (2007), among the grouper species that live in these habitats is the endangered Goliath grouper. This fish will breed in mass swarms in the open ocean and their fry will grow in the seagrass beds and then they migrate to the nearby tangle of the mangroves before they emigrated from mangrove at about 1.0 m total length.

2.4 Factor affecting the fish diversity in marine ecosystem

There are few factors that would affect the fish diversity in marine ecosystem. According to Kottelat & Whitten (1996), the main caused in decreased diversity of ichthyofauna is due to biological changes, water pollution, increased sedimentation, flow alteration and introduced species. Da Silva *et al.,* (2006) stated that the relationship between water quality and fish diversity is an important factor affecting fish communities. A great variety of physical and chemical condition provides more diversity of fish seen in a water bodies (Peralta, 2004). According to study conducted by Barrela & Petrere (2003) water bodies in urban areas showed complete absence of fish species due to the low water qualities parameters.

2.4.1 Temperature (°C)

Temperature is an important parameter in determining the water quality. An increase in temperature will increase the solubility of salt and this will indicate that high temperatures will facilitate water flow of electric current. Even so, the solubility of oxygen gas would also decrease with increasing temperature (Schwitz, 1996). A low value of DO will harms the aquatic ecology. In addition, the level of respiration of the aquatic organisms will also be affected. Temperature is a physical property that underline the common notions of hot and cold and the scale used to measure temperature is the degree Celsius (°C) (Maniavanan, 2008). According to Munro & Roberts (2004), water temperature also affect the aquatic environment that is important for fish health. Fish have their optimum, upper and lower temperature tolerance limits. These optima vary with species and may be different for different parameters such as oxygen tension, and water pH.

2.4.2 pH

The scale which used to describe the concentration of acid or base in water is known as pH. According to Staddon (2010), pH 7 is neutral, pH above 7 are alkaline and below 7 are acidic, and the scale runs from 0 which is very acidic to 14 which is highly alkaline. Thus the best level of pH water for most fish species are 6 mg/l to 9 mg/l. pH able to determine the properties of acids and bases in the water. pH can influence a chemical reactions in acidity and alkalinity of the water in which it will affect the aquatic life and the abundance of phytoplankton in seawater. In biological processes, some aquatic organisms are very sensitive to the acidity of the water (APHA, 1989).

The pH value will decrease if there are a lot of organic matter in the water. This caused aquatic life uses organic materials for the process of respiration and decomposition of the organic material. This process uses oxygen in the water and releases carbon dioxide. Concentration of carbon dioxide will then increase the pH in the water (Lamb, 1983).

2.4.3 Dissolved Oxygen (DO)-mg/L

Dissolved oxygen is the oxygen that freely available in water, which is essential to fish and any other aquatic organisms and it is usually used as a water quality indicator in most water bodies (Maniavanan, 2008). According to Sturman & Matthew (2004), in fish, the amount of oxygen consumed is dependent on temperature, where the higher the temperature, the more rapid they uptake the oxygen. This is due to fish natural biology of cold blooded so when the temperature goes up, their metabolism will rise. Typically, fish prefer DO concentration between 5 to 8 mg/l, minimum concentration from 3 to 4 mg/l and desired concentration from 5 to 7 mg/l (Palmer, 2001). Any drop of DO below 5 mg/l will often results in fish kills (Staddon, 2010).

Dissolved oxygen is produced by phytoplankton in the sea during the photosynthetic proccess running with a gas or dissolved oxygen in the air with the water surface. In addition, oxygen gas is also can be produced from photosynthetic plants such as seaweed, algae and others. Dissolved oxygen content in water bodies is dependent on temperature. Higher temperature would encourage the reduction in gas solubility in seawater (Jackson, 1993).

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