PHYTOPLANKTON SPECIES COMPOSITION, DISTRIBUTION AND ABUNDANCE IN KERIAN RIVER ESTUARY, MALAYSIA

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By

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ABSTRAK

Suatu kajian dijalankan dengan menggunakan komuniti fitoplankton sebagai penunjuk tahap kesihatan di muara Sungai Kerian dan implikasinya terhadap kualiti air sungai. Lima tapak kajian telah dipilih bermula April 2008 hingga Jun 2009. Pengambilan sampel air dikutip semasa air pasang perbani ketika air pasang dan surut. Hubungan antara kelimpahan fitoplankton dengan nutrien (nitrat, nitrit, ammonia dan fosfat) dan parameter persekitaran lain iaitu oksigen terlarut, saliniti, jumlah bahan terampai dan kejernihan air dikaji berdasarkan non-supervised Artificial Neural Network (non-supervised ANN) dan analisis korelasi Pearson dengan menggunakan perisian SPSS versi 16.0. Indeks Kepentingan Spesis (ISI's) digunakan untuk menilai spesis yang paling dominan, di mana spesies tersebut ; *Coscinodiscus* sp., *Scenedesmus quadricauda*, *Gomphosphaeria* sp., *Spirulina* sp., *Desmidium* sp. dan *Phacus acuminatus* boleh menjadi penunjuk di muara Sungai Kerian. Komposisi spesies fitoplankton dipengaruhi oleh kemasukan air tawar yang dialirkan dari empangan Ampang Jajar Kerian yang terletak di bahagian tengah sungai. Kehadiran spesies air tawar di lihat semasa air surut apabila saliniti merekodkan 0 ppt di sepanjang tapak kajian. Spesies yang paling dominan semasa air surut ialah *Gomphosphaeria* sp. dan *Phacus acuminatus* dengan nilai tertinggi ISI's masing-masing merekodkan 25.51 dan 16.82. Semasa air pasang dan dengan pengaruh pasang surut, saliniti mencapai sehingga 20 ppt, kehadiran kedua-dua spesies air laut dan air tawar di perhatikan. Spesies yang paling dominan semasa air pasang adalah *Coscinodiscus* sp. (spesies air laut) dan *Gomphosphaeria* sp. (spesies air tawar yang dijumpai terutama di stesen 4 dan 5). Jumlah kelimpahan fitoplankton semasa air pasang lebih tinggi (80,644 sel m^{-3}) berbanding semasa air surut (44,111 sel m^{-3}). Indeks kepelbagaian Shannon-Wiener (H') dan Kesamaan (J') masing-masing ketika air pasang ialah 3.34 dan 0.63 dan semasa air surut ialah 3.79 dan 0.71. Spesies penunjuk bagi air tercemar amat jarang ditemui di muara Sungai Kerian kecuali *Scenedesmus* sp. dan *Phacus* sp. kerana spesies ini bertolerasi terhadap pencemaran bahan organik. Oleh yang demikian, sistem Sungai Kerian ini perlu sentiasa dipantau untuk menghalang pencemaran yang berlanjutan dari aktiviti manusia, disamping untuk mengekalkan nilai estetik sungai ini.

PHYTOPLANKTON SPECIES COMPOSITION, DISTRIBUTION AND ABUNDANCE IN KERIAN RIVER ESTUARY, MALAYSIA

ABSTRACT

This study was conducted to characterize the health status of Kerian River estuary based on phytoplankton community and its implication to the river water quality. Five sampling stations were designated, and samples were collected from April 2008 to June 2009 during spring tide at low and high tide. The relationship of phytoplankton abundance and distribution toward nutrient concentration (nitrate, nitrite, ammonia and phosphate) and other environmental parameters such as dissolved oxygen, salinity, total suspended solid and water transparency were investigated based on the non-supervised Artificial Neural Network (ANN) and Pearson correlation analysis using the SPSS software version 16.0. The most dominant genera were identified based on the Importance Species Index (ISI's) value in which these following species can be considered as an indicator in the Kerian River estuary; the *Coscinodiscus* sp., *Scenedesmus quadricauda, Gomphosphaeria* sp., *Spirulina* sp., *Desmidium* sp. and *Phacus acuminatus*. The phytoplankton species composition was influenced by fresh water intrusion from Ampang Jajar Kerian dam located at the middle part of the river. The presence of fresh water species was observed during low tide, when salinity was 0 ppt throughout all the stations. The most abundant species during low tide were the *Gomphosphaeria* sp. and *Phacus acuminatus* with the maximum ISI's value of 25.51 and 16.82 respectively. During high tide and with tidal influence the salinity reached 20 ppt; the occurrence of marine and fresh water species was noted. The dominant species during high tide were *Coscinodiscus* sp. (marine species) and *Gomphosphaeria* sp. (fresh water species which commonly found in station 4 and 5). The total abundance of phytoplankton during high tide (80,644 cell m^{-3}) was higher compared to low tide (44,111 cell m^{-3}). The Shannon-Wiener diversity index (H') and Evenness (J') reading showed 3.34 and 0.63 at high tide and 3.79 and 0.71 at low tide respectively. The occurrence of polluted water indicator species was very rare in the Kerian River estuary except for the *Scenedesmus* sp. and *Phacus* sp. which were tolerant to organic pollution. Therefore, the Kerian River system should be monitored continuously to prevent further contamination from human activities as well as maintaining the aesthetic value of the river.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

River is the most important natural resource of fresh water for human survival and there is no substitute to it. It has served many societal functions and is considered as the most intensively economical generate ecosystems for residents around it (Vugteveen *et al.*, 2006). However, socio economic development led to the degradation and pollution of rivers. In Malaysia, the rapid changes in the natural environment were mainly driven by the continuous eco-social growth and industrialization (Yasser, 2003). Major activities that affected land use in Malaysia were residential activities, forest management, agriculture activities, industrial, manufacturing activities, mining and energy sector (Hua Hin, 2002).

Based on the Department of Environment (DOE, 2009) in 2003, a total of 80 rivers in Malaysia were found to be clean, 59 rivers were slightly polluted and 7 rivers were polluted. Generally, the upper part of a river system was clean while those downstream were either slightly polluted or polluted. In 2007, the rivers recorded to be polluted accelerated to about 16 rivers in which the majority of the rivers were located in Pulau Pinang, Kuala Lumpur and Johor (DOE, 2009).

The major pollutants that entered into the river in Malaysia were mostly caused by the discharge from agro-based and manufacturing industries, ammonia-nitrogen (NH_3-N) from sewage of livestock farming and domestic sewage. Activities such as road construction, clearing of land for agriculture purposes and sand mining activities without adequate control resulted in the sedimentation and siltation of the river. For example, since year 2000 the DOE reported the total suspended solid (TSS) value especially in Perak state mostly exceeded 50 mgl^{-1}. High TSS could lead to fishery loss, decrease in recreational values and could also have impact on the mangrove ecosystems. Therefore, the government of Malaysia has provided about RM500 million under "9th Malaysia Plan" (RMK-9) to the Department of Water and Irrigation for river conservation (Yulpisman, 2007). The situation showed that the Government of Malaysia and general public has been increasingly concern about maintaining the water quality of the rivers.

Kerian River Basin has been selected for this study due to its function and ecological services in agriculture, aquaculture, fishery, plantation and other agro-ecosystems. Kerian River Basin is located in the Northern Corridor of the Peninsula of Malaysia. The river bordered three states; Perak, Kedah and Penang at N05^{o}10' longitude and E100^{o}25' latitude. The Kerian River flows westward through the southern part of Kedah and northern part of Perak state into the Straits of Malacca. It is a microtidal shallow estuary with the distance of about 10 km, with width of approximately 300 m to 500 m and the depth ranges from 2 m to 6 m. This microtidal estuary is subjected to tidal influenced varied from 0.4±0.19 m (low tide) to 2.9±0.55 m (high tide) (JPS, 2010).

Kerian River is an important source of water for the population in Kerian region and other activities including water supply, fishery and irrigation water. The Kerian River estuary is also heavily impacted from human activities such as domestic, industrial and aquaculture. The estuary has also been impaired by the fresh water discharged from the Ampang Jajar Kerian dam that is located at the middle part of Kerian River. The dam was originally built for fresh water supply to the agriculture field as well as to stop the sea water intrusion into paddy fields. However, the river water discharged from the dam especially during low tide prevailed on the water movement from the sea resulted in the decreased in salinity condition of the estuary (Goudie, 2000).

Previous studies on the Kerian River have indicated that the river is slightly polluted with the Water Quality Index (WQI) recorded at 69.73% (Ameilia, 2000; Majlis Daerah Kerian, 1997). The land surrounding this river has been converted into oil palm estates, aquaculture pond, fishery activities, bird housing, industrial, sand mining activities, constructions and urbanization (Abdullah *et al*., 2004). Consequently, the discharged from these activities flowed into the river which contained nutrients, sediments and pollutants thus, became the driving forces that affected the ecological condition of primary producer i.e. the phytoplankton (Aktan *et al*., 2005). In addition, nutrient transportation (mobilizing of nitrogen and phosphorous) that is related to human disturbance into the river basin (Costa *et al*., 2009) such as land clearing, domestic sewage and usage of fertilizers are the main factors that accelerated the fluxes of these elements into the estuary thus changing the water quality of the river and impacted to the assemblages of phytoplankton (Cloern, 2001).

The estuary part of Kerian River flows through a thin buffer of mangrove area, mainly dominated by *Sonneratia caseolaris* and *Nypa fruiticans.* Urbanization and other land used for development were observed along the Kerian River especially at the estuary area. Thus, severe human activities can cause nutrient loading and other pollutant entering into the river. These accumulations of nutrients could eventually lead to eutrophication. Furthermore, any changes in environment such as construction and agricultural activities can also lead to soil erosion which increases the sediment transport in the river systems, reduces the dissolved oxygen concentration hence affecting the phytoplankton assemblages. The composition of phytoplankton community would reflect the water quality in the river especially the estuarine area which is the productive area and if the algal bloom goes uncontrolled, the river risked suffering from euthrophic problems which has been experienced by many marine coastal areas (Toming and Jaanus, 2007). The pollutants entering into the river from agricultural land usually have high level of nitrogen and phosphorus. These pollutants can be used by phytoplankton as nutrients to support its growth. Hence, overloading of nutrients is a main factor resulting excessive of phytoplankton growth or known as blooms, and these blooms contributed many effects such as:

i. Dead phytoplankton will be decomposed by bacteria and uses up the oxygen in the water which eventually decreases the amount of dissolved oxygen in the water.

ii. Furthermore, phytoplankton blooms also caused ugly foam on the water bodies that reduced its aesthetic value (Goldman and Horne, 1983).

1.2 Justification on the use of phytoplankton community in the study

Phytoplankton is an ecologically important group in most aquatic ecosystems and functions as a primary producer in most freshwater and marine water, as the energy base for many aquatic food webs and plays an important biochemical role for nutrient fixation. Alteration and shift in their species composition can affect the feeding habit, population growth and structure in the higher tropic level. Therefore, phytoplankton can be a good indicator to assess the environmental status of aquatic ecosystem. Phytoplankton also responds rapidly and predictably to a wide range of pollutant thus provides potentially useful warning signals of deteriorating conditions and possible causes (McCormick and Cairns, 1994).

In order to evaluate the relationship between phytoplankton composition and environmental parameters, the phytoplankton community was measured based on its density, abundance and species diversity. In addition, the water samples were also studied to evaluate the nutrient concentration (Nitrate-N, Nitrite-N, Orthophosphate and Ammoniacal-N) in the Kerian River estuary. The environmental parameters that could affect the assemblages of phytoplankton such as dissolved oxygen, salinity, tidal fluctuation, temperature, pH, total suspended solid and water transparency were also determined.

In order to elucidate the relationship between the phytoplankton assemblages and the environmental properties, the non-supervised Artificial Neural Network (ANN) will be used in ecological modeling where the Self Organizing Map (SOM) was practiced to order the data by similarity and to cluster the same input variables into groups of similar input (Gevrey *et al*., 2006). This application shows a classification on the phytoplankton composition and the relationship of environmental parameters towards phytoplankton distribution.

1.3 The aim of the study is to understand the factors influencing the assemblages of phytoplankton. Therefore the objectives of this study are :

i. To identify the species, abundance and trend of phytoplankton community in the Kerian River estuary.

ii. To study the correlation between phytoplankton with nutrients concentration (Nitrate-N, Nitrite-N, Orthophosphate and Ammoniacal-N) and physicochemical parameters (Dissolved oxygen, salinity, water transparency, total suspended solid, pH, temperature and etc.).

iii. To assess the phytoplankton species as a biological indicator used to classify the ecosystem's health.

CHAPTER 2

LITERATURE REVIEW

2.1 Phytoplankton composition and distribution in an aquatic ecosystem

Phytoplankton is a microscopic photosynthetic organism that floats freely in water (Sze, 1998; Harris, 1986). Most of the species are non motile, living at the mercy of water movements and their own sinking ability in lentic water (Round, 1981). There are hundreds of phytoplankton species where each species has their own unique form and this characteristic reveals their great diversity through microscopic examination of the water samples (Day *et al*., 1989). The phytoplankton also known as algae belongs to various groups of lower, non-flowering plant and exists either as a single or simple multicellular forms (Round, 1981). Phytoplankton sizes ranged from the smallest form of prokaryotic and eukaryotic cells and grow to the largest size which is visible by the naked eyes (Harris, 1986).

Phytoplankton can be found in marine, brackish and fresh water environments (Lindsey and Scott, 2010; Paerl *et al.*, 2007). The phytoplankton groups mainly comprise of Bacillariophyceae, Cryptophyceae, Pyrrophyta, Cyanophyceae, Haptophyceae and Chrysophyceae (Round, 1981). The Bacillariophyceae is considered as the major group of phytoplankton that lives in the marine ecosystem (Ekwu and Sikoki, 2006). The dominant genera of the Bacillariophyceae present in the marine water are the *Thalassiosira*, *Skeletonema*, *Cyclotella*, *Chaetoceros*, *Bacteriastrum*, *Ditylium* and *Biddulphia*. Species such as the *Bacillaria paradox, Fragilaria* sp. and *Nitzschia* *closterium* are the common species that could survive in both marine and brackish water (Round, 1965; Härnström *et al*., 2009). Whereas species such as the *Cosmarium* sp., *Pediastrum simplex, Scenedesmus granulatus, Staurastrum* sp. and *Phacus acuminatus* prefer to survive in the brackish water system (Muylaert *et al*., 1997). In Penang River, Malaysia, marine species that were identified include species such as *Coscinodicus argus* Ehr., *Diploneis ovalis* (Kuetz.) Cl., *Nitzchia littolaris* Grun., *N. Obtusa* W. Sm. and *Stauroneis obtuse* Lag (Wan Maznah and Mansor, 2002). Furthermore, the *Cyclotella choctawhatcheeana, Cylindrotheca closterium* and *Skeletonema costatum* (Bacillariophyta) were the example of species that can be found in the marine water which received high nutrient enrichment mainly nitrogen and phosphorous. Therefore, excessive growth of these species in the marine systems should be monitored to prevent eutrophication problems (Tilman *et al*., 1982; Vuorio *et al*., 2005).

Meanwhile, the Chlorophyta and Cyanophyta are common phytoplankton groups present in the freshwater system (Muylaert *et al*., 1997). Round (1981) also stated that the difference between marine and freshwater phytoplankton species was based on the assemblages of species of the Chlorophyta and Cyanophyta. The common genera of the Chlorophyta exist in fresh water and slow flowing rivers namely are the *Pediastrum*, *Melosira*, *Surirella*, *Fragilaria*, *Scenedesmus*, *Synedra* and *Pleurosigma* (Round, 1981; Muylaert *et al*., 1997). Excessive growth of certain species that live in the freshwater system such as *Heterocapsa triquetra* (Dinophyte) may cause red tides (Tilman *et al*., 1982; Vuorio *et al*., 2005). Phytoplankton requires nitrogen and phosphorous for their growth. The *Oscillatoria* (Cyanobacteria), *Eutreptiella gymnastic*, *Euglena*, *Phacus* (Euglenophyta), *Monoraphidium contortum* (Chlorophyte) and *Pseudoanabaena* were the examples of phytoplankton species that prefer to grow in high nutrient concentration within low salinity environment mainly in the stream in agricultural area (Tilman *et al*., 1982; Vuorio *et al*., 2005).

In shallow microtidal estuary, the tidal regimes, flow and the sea water intrusion may influence the phytoplankton assemblages, thus subjected the phytoplankton species to be distributed based on the salinity gradient, moving from the lower to the higher salinity along the estuarine (Day *et al*., 1989; Muylaert *et al*., 1997; Jouenne *et al*., 2005). Generally, the dominant group in the estuary comprises of the Diatom (Bacillariophyta), Dinofagellates, Cryptophytes, Chlorophytes (green algae) and Chrysophytes (golden brown algae) species. The Dinoflagellates can always be found dominant in lower salinity areas. Apart from salinity, the phytoplankton distribution in the estuary may be influenced by temperature fluctuation and nutrient availability (Day *et al*., 1989). Nitrogen and phosphorous are the factors that regulate the biomass, diversity and composition of phytoplankton community (Mc Cormick and Cairns, 1994; Zheng and Stevenson, 2006). The *Scenedesmus quadricauda*, *Rhizosolenia* sp., *Asterionellopsis* and *Chaetoceros socialis* are the common species observed in the estuary where their abundance are influenced by the nutrients concentration, temperature and salinity (Jouenne *et al*., 2005).

Human activities and river modification such as dam construction also contributed to the degradation of phytoplankton assemblages (Cloern and Jassby, 2010). They are believed to be the key factors to eutrophication and severe pollution will change the phytoplankton distribution (Gao and Song, 2005). Therefore, any changes in physical forces such as flushing, salinity, light penetration due to turbid water and nutrient concentration may alter the biodiversity of aquatic ecosystem (Ferreira *et al*., 2005).

Additionally, when a particularly harmful algae blooms, the accumulative effect of the entire toxin released may affect other marine organisms and can cause mass mortality, thus resulted in serious ecological and socioeconomic problems (Mandal, 2005). In year 1993, several potentially toxic phytoplanktons were found in the Baltic Sea, and the species were: *Anabaena flos aquae*, *A. lemmermannii*, *Anabaena* sp., *Aphanizomenon flos-aquae, Coelosphaeriuim kuetzingianum, Gomphosphaeria lacustris, Microcystis aeruginosa, M. flos aquae, Nodularia spumigena, Oscillatoria* sp. and *Planktothrix agardhii*. Besides, eight species of Dinophyceae (*Alexandrium* sp., *Dinophysis acuminate, D. acuta, D. rotundata, D. norvegica, Gymnodinium* sp., *Heterocapsa trirquetra and Prorocentrum minimum*), one species of Dictyocophyceae (*Dictyoca speculum*) and two species of Prymnesiophyceae (*Chrysochromulina* sp. *and Prymnesium* sp. (Leppänen *et al*., 1995). Bioaccumulation of toxin from species such as *Pseudo-nitzschia* sp., *Dinophysis acuta, D.fortii, Gymnodinium* cf. *breve, Alexandrium* sp. and *Gymnodinium* may accumulate in the fish, cockle, cuttlefish and other marine life could cause symptoms such as nausea, vomiting, abdominal cramps, diarrhea and gastrointestinal when consumed by human. In severe cases, neurological symptoms that could appear include headache, disorientation and asthma (Jasprica, 2003). Furthermore, Cyanobacterial blooms which commonly contain hepatotoxin, microcystins and nodularins could cause liver damage (Vuorio *et al*., 2005).

Another study in Discovery Bay Jamaica indicated that eleven potentially harmful polyplankton species were found to be the Nitzschia *pungens, Pyrodinium bahamense, Prorocentrum sp., Nitzshia serata, Skeletonema costatum, Nostoc commune, Skeletonema subsalsun, Nostoc piscinall, Thallassioria aestivalis, Oscillatoria tenius and Thallassioria gravide* (Webber *et al*., 2005).

In Malaysia, several studies on phytoplankton have been conducted in polluted water and human disturbance area. Wan Maznah and Mansor (2002) had identified the phytoplankton indicator for the clean water, slightly polluted and polluted water condition in Penang River, Malaysia. Results from their research showed that the *Achnanthes oblongella* Oestrup, *Cocconeis placentula* Ehr., *C. pediculus* Ehr., *Fragilaria Capucina* Desm., *Psammothidum biorettii* (Germ) were found in clean water. The *Fragilaria* sp, *Diatoma* sp., *Navicula cryptocepala* Kuetz., *Gomphonema subventricosum* Hust. and *G. Gracile* Ehr., were found in both clean and slightly polluted water particularly during wet season. Meanwhile, the *Achanthes exigua* Grun., *Gomphonema parvulum* (Kuet.) Grun., *Hantzshia amphioxys* Grun., *Nitzschia palea* (Kuetz.) W. Sm., *Pinnularia biceps* Cl., *Pinnularia biceps* f. *petersenii* Ross and *P. microstauron* (Ehr) Cl were dominant in polluted water.

2.2 Phytoplankton as an indicator of environmental change

Phytoplankton can be a good indicator for any environmental change since it usually is the major source and sink of organic matter, when the phytoplankton dies it will decomposed and also can be as primary producer and food source for higher trophic organism (Zheng and Stevenson, 2006). Phytoplankton absorbs nutrient during its growth and releases it back to the water after it dies and decomposed (Bunyat *et al*., 1999). Their position at the base of the aquatic food web and their response to the environment (i.e. nutritional needs) for photosynthesis provides much information concerning ecosystem status (Zheng and Stevenson, 2006; McCormick and Cairns, 1994).

Phytoplankton is a good biological indicator to study as some communities are highly sensitive to any changes in nutrient concentration, able to respond rapidly to anthropogenic stresses and the fluctuation of environmental conditions such as light availability, tides and vertical mixing (Tanaka and Choo, 2000). Onyema (2007) stated that phytoplankton is the most suitable indicator as it is simple, capable in quantifying changes in water quality, applicable over large geographic area and could also provide data on its natural condition (Toming and Jaanus, 2007). In the estuary system, the phytoplankton especially diatoms (Bacillariophyta) have been used as indicators of ecological conditions to evaluate the biological conditions, pollutants and fluctuation of environment factors mainly the nutrients concentration and salinity condition (McCormick and Cairns, 1994; Muylaert *et al*., 1997; Wang *et al*., 2006; Zheng and Stevenson, 2006; Narashima Rao and Pragada, 2010).

Phytoplankton distribution and production are determined based on the nutrient concentration and other factors such as sedimentation and loading that could occur during flood, rainfall or discharged from the upstream area (Eyre and Balls, 1999). In the river estuary, nutrients input which are mainly nitrogen and phosphorus are the main factors that limit the growth and biomass of the phytoplankton. Therefore, the nutrients should be monitored from their point of sources to prevent excessive nutrient input into the estuary in order to hinder eutrophication (Toming and Jaanus, 2007). Phytoplankton is more sensitive to toxic chemicals and pollutant, thus providing ecologically relevant signals of ecosystem change that can be used to predict an environmental condition (Kauppila, 2007).

2.2.1 Species Diversity Index

In order to protect and maintain the health of natural and healthy waters, it is important to protect the biological diversity and variety of the aquatic communities. Therefore, a study on the phytoplankton trend, diversity and abundance can be used as ecosystem's health indicators (Lassen *et al*., 2004).

Diversity Index is a tool used to measure biodiversity based on the abundance, evenness and richness among organisms in its community (Ludwig and Reynolds, 1988). The most common Diversity Indexes used are the Shannon-Wiener Index Diversity Index (H'), evenness (J') and species richness (Cairns & Pratt, 1993).

Shannon-Wiener Index Diversity Index (H') is characterized by the number of individual observed in a sample or in an area. Species diversity (H') was estimated by both species richness and evenness, (J') (McGinley, 2008; Cheng, 2004). In the river systems, species diversity (H') is a good indicator to assess the state of an ecosystem. The species diversity typically declines in an aquatic system where there is a severe eutrophication and pollution caused by human activities (Odum, 1985). The number, abundance and percentage of sensitive species were expected to decrease with increasing human impact whereas, the tolerant species were expected to increase with escalating stressor levels (Wang *et al*., 2006).

Evenness index is used to measure the similarity proportion of species in a sample, in which a higher diversity is considered when a more similar proportion of each species found in a sample (Nolan and Callahan, 2006).

Species richness is the total number of different organisms present in a sample while the similarity index is a statistical analysis used for comparing the similarity of species distribution between two samples based on the Sorensen Similarity Index (Onyema *et al*., 2006).

2.2.2 Artificial Neural Network (ANN)

The ecological modeling application such as The Artificial Neural Network (ANN) has been used widely to analyze the phytoplankton assemblages. Previous researcher Talib *et al.* (2007), Millie *et al.* (2006) and Recknagel (2003) have used the ANN as an alternative method to analyze the ecology, abundance, composition and diversity dynamics of phytoplankton community as the indicator of an ecosystem as well as their relationship to various environmental conditions.

The Artificial Neural Network (ANN) is a support tool using computer simulation or mathematical equation to address questions that cannot be answered directly through experiment or observation. It provides information on ecological system and interaction graphically. Modeling is also used to forecast on particular population of organisms and ecosystem. ANN was performed as the best modeling method in studying phytoplankton assemblages and interaction.

2.3 Factors influence the phytoplankton distribution

Phytoplankton assemblages and distribution are mostly related to the water quality (Round, 1981). Factors that controlled phytoplankton distribution are nutrient availability, light availability, temperature and tidal flushing. In some estuaries, human development subjected to the eutrophication process due to the algal bloom, which in turn can lead to the changes in the structure and function of the affected ecosystem (Cloern, 2001). For examples, Patani River (Sungai Patani) Kedah, Malaysia was categorized as moderately polluted by high level of chemical oxygen demand (COD) and high nutrient content (nitrate and nitrite) due to the discharge of wastewater from the housing area. This situation increases the amount of total suspended solid (TSS) in the water. Besides, high biological oxygen demand (BOD) concentration also occurred due to the decomposition process of organic matter by microorganism which reduced the dissolved oxygen in the water (Hazzeman and Wan Maznah, 2007). The same problems also occurred in the Shatt al-Arab Estuary which received pollutant from its eutrophic tributaries, the contaminants mainly from sewage disposals and agricultural wastes eventually entered into the estuary. This situation decreases the dissolved oxygen content of the estuary as well as increases of organic load into the water systems (Masoud and Samir, 1983). Therefore, the anthropogenic factors such as agriculture, industrial and urbanization play an important role in determining the water quality. As the populations grow, a serious water crisis such as polution due to poor planning can cause environmental degradation and a decline in the beneficial use of river (Hazzeman and Wan Maznah, 2007).

Water quality is assessed by measuring the physical, chemical and biological parameters. In order to ascertain the quality of the environment in Malaysia, the Department of Environment (DOE) Malaysia has monitored the water quality in the rivers, coastal and estuarine systems which involved specific criteria i.e. the measurement of Total Suspended Solids (TSS), Biochemical Oxygen Demands (BOD), Chemical Oxygen Demand (COD), Ammoniacal nitrogen, nutrients and selected heavy metals (Abdullah, 1995). Nutrient availability is the dominant physico-chemical factors influence the growth and distribution of phytoplankton. Vuorio *et al*., (2005) mentioned that the increasing concentration of nitrogen and phosphorous may cause a change in the phytoplankton community.

Nutrients are the great factors that limit the growth and biomass of phytoplankton. Excessive input of nutrient concentration particularly nitrogen and phosphorous into the water column lead to various problems related to nutrient enrichment known as eutrophication (Toming and Jaanus, 2007). Eutrophication is a process that affects the phytoplankton assemblages and production thus any changes in phytoplankton community and composition could result in the increasing development of harmful algae blooms and other habitat disturbances that may alter trophic interactions and biogeochemical process. Therefore, nutrients are the main focus for science and management of the water systems (Glibert, *et al*., 2006). Table 2.1 below shows the water quality parameters that may influence the phytoplankton assemblages.

Table 2.1: Water quality indicators usually assessed in river monitoring (Browne, 2002; Chapman, 1996).

Category	**Indicator**	**Description**
Nutrients	Nitrate, Nitrite, Phosphorous	Nutrients such as nitrogen and phosphorous are essentials for phytoplankton growth. Therefore, high concentrations indicate the potential for excessive algal growth. The nutrient concentration also regulates the distribution and composition of algae in the water systems.
Microalgal growth	Chlorophyll-a, Phytoplankton density	An indicator of algal biomass in the water. An increase in chlorophyll-a indicates high biomass and potential eutrophication of the systems. Consistently high biomass (chlorophyll-a) concentrations indicate the occurrence of algal blooms which can be harmful to other aquatic organism.
Water clarity	Suspended solid, Secchi depth	Small particles (soil, plankton, organic debris) that are suspended in the water. High concentration of suspended solid could limit the light penetration into the water column thus limiting the growth of phytoplankton.
Oxygen	Dissolved oxygen	Essential for life process of aquatic organisms. Low concentration of dissolved oxygen in the water column indicates the excessive load of organic loads in the systems. Many aquatic organisms will suffocate if the dissolved oxygen in the water is insufficient which may lead to high oxygen demand in the water.
pH	pH	A measure of acidity or alkalinity in the water. Changes of extreme pH can be toxic to aquatic organisms.
Salinity	Conductivity	A measure of the amount of dissolved salt in the water and as indicator of salinity.

2.4 The health status of an aquatic ecosystem

The health of an aquatic ecosystem is dependent on the health of its communities such as plankton, algae, fishes, aquatic plants and aquatic insects. These organisms particularly the phytoplankton community plays essential roles in maintaining the ecology of river systems, and also serves economic and social benefits to human (McCormick and Cairns, 1994).

The phytoplankton community is a key component at the base of aquatic food web as a primary producers, thus reflects the trophic status of the environment. The phytoplankton growth is more dependent on tides, turbidity, water clarity, temperature and nutrient in the water column (Silva, 2006). Therefore, any environmental changes and disturbances on the river system such as discharging of wastes and contaminants may alter the growth and phytoplankton assemblages and thus affecting the structure and functionality of the river systems (Onyema, 2007).

The Kerian River estuary is one of the rivers in Malaysia that is threatened by various human activities mainly leaching of fertilizer traces from the agricultural sector and also effluent discharges from the aquaculture as well as domestic sewage from residential areas. In addition, the downstream of Kerian River is being impacted by sedimentation due to urban construction and sand mining at the upper reach of the river. This leads to high in turbidity and low in dissolved oxygen level at the downstream of the river and thus increases in high oxygen demand. In severe cases, this situation could lead to eutrophication (Costa *et al*., 2009). Eutrophication occurs when the water system received excessive nitrogen, phosphorous and ammonia. It accelerates the growth of phytoplankton (aquatic algae) and changes the water transparency as well as dissolved oxygen concentration in the water. High turbidity will lead to water quality deterioration, declining in photosynthesis rate hence impacting the health of the aquatic ecosystem and caused mass mortality of aquatic organism (Diao *et al*., 2010) due to changes in the species composition, food chain structure and element cycling in the aquatic ecosystems (Gao and Song, 2005). Therefore, the investigations on the phytoplankton community are important to assess the health status of the river ecosystem in terms of water quality deterioration.

2.5 The Status of River in Malaysia

In Malaysia, since 1996, about 43 percent of the total land area estimated at 14.17 million hectares (ha) has been changed into cultivation areas mainly permanent crops or large scale plantations such as rubber, oil palm and cocoa, while the remaining 4.4×10^5 ha was converted to mainly paddy fields (Kundell, 2007). The development for agricultural activities that are related to the oil palm and rubber plantation has been identified as one of the major sources of pollution into the river systems in Malaysia (DOE, 2009). The conversion of the natural land into the agricultural land resulted in soil erosion as well as pollutant entering into the river. Furthermore, heavy usage of fertilizers and pesticides has increased nutrients loading particularly nitrogen and phosphate into the river (Abdullah, 1995).

The need in water usage for domestic, irrigation and industrial has increased the awareness of the government, non-government and public about the importance to conserve and maintain the river ecosystems (Haliza, 2007). Therefore, the river management has become a critical issue in Malaysia. The government agencies responsible for the river protection are the Department of Water and Irrigation (JPS) and the Department of Environment (DOE). One of the government efforts in order to safeguard the sustainability of a water resources is by the establishment of The Integrated Water Resources Management (IRWM) policy by the participation of all level stakeholders under Ninth Malaysia Plan (2006 – 2010) and National Physical Plan (2006 – 2020). Apart from that, the Integrated River Basin Management (IRBM) concept was also introduced to focus on the river management and to balance the man's need with the necessity of conserving resources to ensure sustainability (Keizrul, 2007).

CHAPTER 3

STUDY SITES

3.1 Introduction

The Kerian River basin is located predominantly in the State of Perak with a total area of 1, 321 km^2. The Kerian River is bordered into three states namely Perak, Kedah and Pulau Pinang at 5^{o}09' and 5^{o}21' North Latitude and 100^o 36.5' and 100^{o}50' East Longitude. Figure 3.1 shows the map of Kerian River and various human activities along the estuarine area of Kerian River. The Northern part of Kerian River basin (the upstream and the middle stream areas) is encroaching into the State of Kedah, and the estuary part is spreaded in the mainland of Pulau Pinang situated near Nibong Tebal Town in the District of Seberang Perai Selatan, Pulau Pinang. The river originates at the Bintang Range and flows westward into the Straits of Malacca. The stretch of Kerian River is 65 km long consist of more than 35 tributaries. The main tributary of Kerian River is the Selama River located at the upstream area of Kerian River. Meanwhile other tributaries such as the Ijok River, Samagagah River and the Ulu Mengkuang River are mainly located in the middle stream area (ASPEC, 2010).

Kerian River received high amount of total rain per year recorded 895 mm in 2008 and 1,946 mm in 2009 (JPS, 2010). The average flow rate in Kerian River recorded was 37.91 m^3s^{-1} in 2008 and 38.14 m^3s^{-1} in 2009 (JPS, 2010). During low tide, the water level height that was recorded varied from 0.5 m to 1.0 m while during high tide the water level height reaches from 2.7 m up to 2.9 m (JPS, 2010).

Kerian River is categorized as an intensive plantation and urbanization area (Plate 3.1). Since 1995, 77.8% of 19,441.4 hectares of the land use in Kerian was reserved for plantation activities, followed by infrastructure of utility (6.1%), residential area (5.7%), reserved utility (4.3%), bare land (3.4%), industrial (1.1%), businesses (0.5%) and 1.1% for others (Majlis Daerah Kerian, 1997).

Most of the area near the Kerian River basin was converted into plantation such as the oil palm (*Elaies guinensis*), rubber (*Hevea braziliensis*) and paddy (*Oryza sativa*). Other vegetation and plants that grew along the Kerian River are mainly coconut tree (*Coccos nucifera*), ara (*Ficus* sp.), tualang (*Kompasia* sp.), meranti (*Shorea* sp.), lalang (*Imperata cylindrical*) and nipah palms (*Nypa fruiticans*) (Plate 3.3). Wild trees that grow along the river are trees such as rambutan liar (*Nephelium lappaceum*), nangka pipit (*Arthocarpus scortechinii*), durian kuning (*Durio graveolens*), bananas (*Musa paradisiacal*) and petai (*Parkia speciosa*). Certain areas in the upstream of Kerian River have not been disturbed and vegetation also grows in the area such as buluh semeliang and bamboo trees.

Several human activities were observed in the upstream of Kerian River, for example logging and sand mining activities situated near the Mahang River (Plate 3.4) causes sedimentation and high total suspended solid concentration (Plate 3.5). Another tributary i.e. Kechil River received effluent discharge from the factories resulted the river water being very turbid and polluted (Figure 3.7)

A dam was built in 1976 located in the middle part of Kerian River named the Ampang Jajar dam and equipped with water gates to control the water level intrusion of sea water into the upstream area especially during high tide (JPS Kerian, 2010) (Plate 3.6). Besides being used as water control, the Ampang Jajar dam functions as a reservoir and supplies water to the Bukit Merah Dam through the operation of Kerian's Pump in Bogak River. The water from Bukit Merah Dam is then used to irrigate the paddy field through the Selinsing and Basar canals. The level of water in the canals can be increased by controlling the water gate of Ampang Jajar Dam. Opposite the Ampang Jajar Dam is a recreational park for multipurpose usages such as picnic, camping, exercising and fishing (JPS Kerian, 2010).

Plate 3.1: The oil palm is a large scale plantation spreading along the stretch of Kerian River and the main permanent crops that contributed to the economy's development in Malaysia.

Plate 3.2: Mangrove tree spreading along the Kerian River estuary covers a total area of 62,800 ha.