2.0 LITERATURE REVIEW

2.1 SPATIAL AND TEMPORAL DISTRIBUTIONS OF PHYTOPLANKTON

Phytoplankton occurrence and distribution between months used to be the main topic to be discussed in studying the seasonal or temporal distribution of phytoplankton (Manna *et. al*., 2010; Chen *et. al*., 2010; Patil & Anil, 2008; Kim *et. al*., 2007; Facca & Sfriso, 2007).

Studies on temporal distribution of phytoplankton normally will have close relation to climate and weather of the study sites. By studying the temporal patterns, lots of information on how climate change for instance, global warming could alter the composition and distribution of phytoplankton at certain places. Philips *et. al*. (2010) suggested global warming triggers and increases the onset and the occurrence of monospecific bloom at Indian River Lagoon. Evidenced, global warming not only increased the temperature but able to influence alteration parameters such as salinity, water volume and light intensity, resulted promoting the growth of certain opportunistic species such as *Chaetoceros* and *Skeletonema* (Philips *et. al*., 2010).

Temporal records on phytoplankton also able to provide information on specific relation of phytoplankton with environmental variables which includes biological, physical and chemical parameters (Chen *et. al*., 2010). Nevertheless, phycologists even did temporal survey on specific species to gain knowledge on the effect of certain parameters on the species. For instance, Kim *et. al*. (2007) surveyed the relation between grazing on phytoplankton for 12 consecutive months, and indicated that continuous and long term measurements of microzooplankton grazing are required for better understandings of the interaction.

In India, most of temporal studies were done to investigate intercorrelation between phytoplankton and monsoon season which indirectly will include information on phytoplankton relations with its physiochemical parameters (Patil & Anil, 2008; Perumal *et. al*., 2009; Rajkumar *et. al*., 2009; Nahar, *et. al*., 2010). Monsoon season along with heavy or light rainfall will affect some of the parameters such as temperature, nutrients and light intensity.

On the other hand, study on spatial distribution of phytoplankton frequently done alone. Normally, spatial distribution will be carried out along with study on temporal distribution. Spatial distribution of phytoplankton was done purposely to determine the composition, abundance and species richness of total phytoplankton or specific species at different stations or transects at study site. Lassen *et. al*. (2004) chose 4 stations at Langat River Estuary to learn the phytoplankton composition and size distribution according to different stations' at study site.

Based on species occurrence, water profile and lots of information could be gained. For examples, information on pollutants and effect of aquaculture on phytoplankton could be gain. Furthermore, differences on species composition at mangrove ecosystem and estuarine ecosystem able to be determined. Skaloud *et. al*. (2006) spatially studied the composition and distribution of phytoplankton by correlating their dependence on the distance from coast, depth and other environmental factors. Via the study, dominant species and occurrence of phytoplankton showed different distribution between 2 different main stations which were located at oceanic and coastal parts. In addition, Skaloud *et. al*. (2006) also detected the occurrence of *Porosira glacialis* in high abundance at both parts, with same morphology but different ecological preferences.

2.2 PHYTOPLANKTON OF MANGROVE ECOSYSTEM

In wetlands such as in mangrove areas, there are phylogenetically diverse benthic producers that mostly are phytoplankton such as diatoms of division Bacillariophyta, green algae of Chlorophyta and Cyanobacteria. They usually floating on water and mediate numerous ecosystem functions, including a substantial fraction of total ecosystem productivity (Janousek, 2005). Mangrove ecosystem is believed to harboring more phytoplankton compared to estuary ecosystem (Rajkumar *et. al*. 2009).

Other than phytoplankton, there are also microalgae groups inhabiting the sediments of the mudflat, which are important as ubiquitous components of the flora of shallow subtidal, intertidal (Cahoon, 1999), sedimentary habitats such as salt and brackish marshes, mudflats and finally sandflats (Sullivan *et. al*., 2002). Together with the phytoplankton, they formed the base of the food chain of mangrove ecosystem. Phytoplankton inhabits the mangrove ecosystem also known as extremophile algae as they able to tolerate the unique surrounding of the ecosystem. These extremophiles are not only able to adapt in anaerobic condition of the ecosystem but also able to withstand exposure to tidal cycles, limited sunlight (Graham & Wilcox, 2000) and variable salinity levels (Owen, *et. al*., 2004).

Normally, studies or researches on algae in mangrove ecosystem would cover the whole groups of microalgae which includes commonly benthic (Sullivan & Currin, 2002), epiphytic (Chen, *et. al*., 2010) and floating microalgae or phytoplankton. Studies on phytoplankton inhabits the mangrove ecosystem are normally discussed on its relation to hydrographic environmental factors. Due to reason that the ecosystem receives a huge amount of nutrient out welling from runoff water (Tanaka & Choo, 2000), that usually contained domestic discharge or anthropogenic influence (Saravanakumar *et. al*., 2008; Manna et. al., 2010) that embedded into the ecosystem.

The additional nutrient will double up the available nutrient concentration that originated from decomposing mangrove's litter fall which able to cause eutrophication (Tanaka & Choo, 2000; Perumal, *et. al*., 2009).

Loading of nutrients into mangrove ecosystem is enhanced during monsoon period, in which rainfall runoff carries along nutrients from terrestrial straight into the ecosystem. However, most studies suggested that abundance of phytoplankton decreased during monsoon months, due to the fact that water column in mangrove is stratified to large extent, high turbidity, reduced salinity and decreased temperature and pH (Manna, *et. al*., 2010; Perumal, *et. al*., 2009; Rajkumar, *et. al*., 2009). Contrarily during summer, high density is attributed to high salinity, high pH, high temperature and high light intensity which able to stimulate rapid growth of phytoplankton. While in post monsoon, available high accumulation of nutrient that carried by rainfall runoff contributed to high density of phytoplankton (Rajkumar *et. al*., 2009).

Study was done on phytoplankton in Pichavaram mangrove water in Southeast Coast of India by Rajkumar *et. al*. (2009). The result proved there were significant difference between phytoplankton density in post-monsoon and summer with monsoon period. High density of phytoplankton was recorded in both post-monsoon and summer. The phytoplankton density was lower during monsoon season.

Most researches done on phytoplankton at mangrove ecosystem showed that diatoms are the most dominant and common groups to inhabit the ecosystem. Essien *et. al*., (2007) recorded 5 divisions of phytoplankton at Que Iboe Estuary Mangrove Swamp in Nigeria, which are the Bacillariophyta, Cyanophyta (Cyanobacteria), Chlorophyta, Chrysophyta and Euglenophyta. Pennate diatom of Baccilariophyta, genus *Tabellaria* contributed more than 20% of the total density of phytoplankton at the research area. Bacillariophyta was the most dominant division recorded in both dry and wet season, though there was significant difference in species composition between the 2 seasons. Centric diatom *Actinophycus undulatus* was the most dominant in wet season and pennate diatoms *Navicula radiosa* and *Amphora ovalis* were the most common and abundant in dry season.

In India, a research on seasonal phytoplankton assemblages was done along the Bhagirathi-Hooghly estuary that associated with Sundarban Mangrove Reserve by Chaudhury & Pal (2010). Study showed in most seasons, diatoms recorded to be the most common phytoplankton. Genus *Nitzschia* and *Scenedesmus* were the most representative species while *Leptocylindricus danicus* was the most abundant species followed by *Cyclotella meneghiniana* and *Thalassiothrix frauenfeldii*. However, during brief monsoon transition period, division Chlorophyta recorded as the highest phytoplankton group, with *Pediastrum tetras* became the most abundant species. However, previous researches proved there were no wide differences in density of phytoplankton in mangrove ecosystem (Dahlin *et. al*., 1985; Essien *et. al*., 2007). Explanation to different observation in Chaudhary & Pal (2010) study was maybe due to influence of high turbidity in wet season and increased salt level during dry season (Davies, 1972; Essien *et. al*., 2007).

Later research on seasonal variation of phytoplankton in other part of India, which was done in Pichavaram mangrove ecosystem by Rajkumar *et. al.* (2009), found diatoms of Bacillariphyta and Dinoflagellate present in high numbers in both summer and post monsoon season. Common diatom genera sampled in both seasons were *Odontella, Coscinodiscus, Nitzshia, Thalassionema, Thalassiothrix, Rhizosolenia, Skletonema* and *Navicula*. On the other hand, even present in quite high density only 2 genera of dinoflagellate were recorded at Pichavaram mangrove ecosystem, which were the *Ceratium* and *Prorocentrum*. In Western Mangrove area of Kachchh-Gujarat, Pakistan, diatoms of species *Bacillaria paradoxa, Bellerochea malleus, Odontella* *pulchella, O. heteroceros,Ørerautlina bergonii* and *Chaetoceros compressus* were recorded as the common species to inhabit the mangrove ecosystem (Saravanakumar, *et. al.*, 2008).

Phytoplankton community abundance and richness in mangrove ecosystem are normally related to aquaculture activities. Influx of effluents from aquaculture ponds believed to have promoted nutrient enrichment that principally consists of uneaten food, fecal and urinary waste from aquaculture area to adjacent mangrove ecosystem (Lassen, *et. al*, 2004; Manna, *et. al*, 2010). Thus change the structure and function of phytoplankton in the ecosystem (Beveridge, *et. al*, 1994). Manna *et. al*. (2010), suggested nutrient rich discharge from adjacent shrimp aquaculture at Sundarban mangrove ecosystem was reflected in the presence of high density of Dinoflagellate, such as *Ceratium* sp., *Prorocentrum* sp., *Protoperidinium* spp., *Peridinium* spp. and *Polykriskos* sp.

2.3 RESEARCH ON MANGROVE PHYTOPLANKTON IN MALAYSIA

In Malaysia, there were few studies were done on phytoplankton inhabits the mangrove ecosystem. Most of researches were mainly discussed on the relation of the phytoplankton with nutrients (Tanaka & Choo, 2000; Lassen *et. al*., 2004; Lee *et. al*., 2006), and on their seasonal composition and abundance (Lassen *et. al*., 2004; Lee *et. al*., 2006). Lassen *et. al*., (2004) did a study on phytoplankton species composition at Langat River, Malaysia that is located in a mangrove area. He recorded differences in phytoplankton community between mangrove areas that located upstream and downstream towards the river mouth to the sea. Upstream, centric diatoms dominated almost 90% of the diatoms sampled, while moving downstream, the dominance of centric diatoms have been replaced by *Skletonema costatum*, genus *Chaetoceros* and genus *Eucampia*. Salinity level that ranges along the upstream and downstream are usually the main factor contributed to different species composition between the two locations (Chen *et. al*., 2010).

Study on mangrove phytoplankton was done in Matang Mangrove Forest in Malaysia by Tanaka & Choo (2000). However, the research does not provide detailed composition of species inhabiting the ecosystem. It was mainly discussed on certain species that formed bloom due to increased nutrient concentration. Nutrient out welling from Matang Mangrove ecosystem that comprised of concentrated phosphate was responsible to initiate Dinoflagellate, *Ceratium kofoidii* and benthic *Nitzschia* sp. to dominate most sampling stations in the ecosystem.

Earlier study on phytoplankton inhabiting Carey Island was done by Salleh & Tajuddin (2006). Though the study was done on the whole area of Carey Island, there are 2 stations were located in mangrove area of the island. The study recorded 148 mangrove. However there was no information on the relation between phytoplankton with environmental parameters since the study was mainly to produce a checklist of phytoplankton in the island.

2.4 ECOLOGICAL RESEARCH OF PHYTOPLANKTON

Generally, algae distribution is frequently determined by abiotic requirements and further influenced by biotic interactions. Thus, studies on the ecology are also crucial to study the distribution of them in particular places (Stevenson, 1997). Ecological research on phytoplankton can be organized into different ecological levels such as divisions, functional groups, genus and finally species (Smith, 2001).

A wide variety of methods has contributed greatly to the understandings of phytoplankton ecology, but the lack of standardization frequently makes comparisons between studies difficult if not impossible (South & Whittick, 1987). In studying the phytoplankton ecology, details of the contributions of individual species are required, microscopic examination and counting methods must be employed (Sournia, 1981). Phytoplankton ecology has been characterized by the development of a large body of theory and mathematical modeling (Graham & Wilcox, 2000), with two main topics discussed the competition theory and trophic dynamics. However, phycologists believed that the physical and chemical environment of the places that is inhabited by the phytoplankton is more crucial if compared to the two mentioned above (Barsanti & Gualtieri, 2006).

In recent years, studies on ecology of phytoplankton were carried out by means of monitoring program (Watson *et. al.*, 1992). Monitoring includes observing the phytoplankton density and relates it with the environmental parameters and nutrient levels (Graham & Wilcox, 2000). Combinations of ecological factors that affect phytoplankton include light, temperature, salinity, pollution, grazing and nutrients (Normawaty, 1998). Lots of researches were done on phytoplankton and its relation with factors that affect their distribution, composition and biomass. For example, studies were carried out on the correlation of phytoplankton with nutrient concentration (Graneli, 1987; Carter *et. al.*, 2005; Facca & Sfriso, 2007; Frankovich, *et. al.*, 2010), tidal ranges (Brunet & Lizon, 2003; Nurhidayah, 2007), and also other environmental factors that include both physical and chemical parameters.

Owen *et. al*. (2004), proved diatoms demonstrated clear correlation between species abundances and nitrate at wetland of Semi-arid Bogoria-Baringo Rift, Kenya. However, silica was the main nutrient to have had close relations with the diatoms and nitrate being of secondary importance. Smith (2001) observed the response of phytoplankton to chemical parameters in Florida Everglades and found phosphorus run off has caused major change in phytoplankton assemblages. The ecological survey was done according to genus and species level. Most of phytoplankton from the divisions Bacillariophyta and Cyanophyta for examples *Amphora, Anomoeneis, Chroococcus,* *Nitzshia* and *Rhopalodia* showed positive correlation to phosphorus while some genera such as *Mastogloia* and *Synedra* showed a negative correlation. In study on phytoplankton at Putrajaya Wetlands Malaysia by Nadia (2008), phytoplankton inhabiting the wetlands found to have negative correlation with phosphate concentration. She stated the low levels of phosphate stimulate the phytoplankton growth, due to the fact that the species inhabits the lakes might be adapted to low level of phosphate. However, no further discussion was discussed in her findings.

Smetacek *et. al*. (1991), cited in Normawaty (1998), suggested that nitrogen is the limiting nutrient of the sea, thus the addition of nitrogen into the sea will able to stimulate phytoplankton growth. However, some studies showed that nitrogen only critical for diatoms, whereas in other division of phytoplankton such as Dinoflagellate, phosphorus concentration plays vital role to enhance their growth (Carter, *et. al*., 2005; Biswas, *et. al*., 2010). But still, nevertheless, nitrogen also essential for dinoflagellate growth though in low concentration (Normawaty, 1998).

Redfield (1958), quoted by Reynolds (2006) suggested that marine phytoplankton uptakes nitrogen and phosphate according to 16:1 ratio. However, it is questionable whether the ratio is valid to be used in other ecosystems or other regions. Cai *et. al*. (2009), carried out experiment to examine nitrogen and phosphorus intake by phytoplankton along Xiamen Bay, China, and recorded whether there was a difference in the uptake ratio between two different places. The result showed between two places, which are Baozhu Islet and Qingyu Islet, intake of N:P was 20:1 and 36:1 respectively. Hence the result indicates that the N:P ratio can vary significantly from region to region.

Both chemical and physical parameters are the most important factors affecting phytoplankton growth. However, physical parameters such as pH, temperature, conductivity and dissolved oxygen proved to be more essential, with chemical parameter being the secondary importance (Owen, 2004). Light is no doubts, the most essential physical factors that affect the growth and the production of phytoplankton. Supply of light is crucial for phytoplankton to go on photosynthesis (Taylor, 1988). Shen (2002), stated light at 4000 lux was the most optimum intensity for phytoplankton to go on photosynthesis. Carter *et. al*. (2005) observed significant reduction in both diatom and dinoflagellate biovolume due to shading. Dinoflagellate biovolume decreased when manipulated with added nitrate and ambient light, proved that the limiting factors of dinoflagellate is light intensity and not the nitrate. Similarly in diatoms, nitrate addition had no significant effect in chain forming diatoms but shading had a significant negative effect on chain forming diatoms such as genus *Chaetoceros* and *Skletonema*.

Nevertheless, there are some species of phytoplankton that do tolerate poor light availability. Some examples are *Nitzschia microcephala*, *Surirella ovalis* and *Nitzschia sigma* (Facca & Sfriso, 2007). A study on diatoms in wetlands by Owen (2004) found that they do not show intercorrelation with light but showed close relationship to other environmental factors such as silica, pH and temperature. The observation was due to reason that the sampling was done in mangrove ecosystem that already has limited light intensity. Thus enable the species inhabiting the ecosystem to adapt in limited light surrounding. Other than helping phytoplankton in photosynthesis, light also vital in determining the degree of toxin in toxic phytoplankton, for instance the dinoflagellate (Normawaty, 1998).

In aquatic and freshwater ecosystem, temperature level is strongly affected by rainfall, flow, physiography of water body and amount of development in watershed (Nadia, 2008). Temperature has strong influenced on phytoplankton growth rate since it is related to algal cellular processes and photosynthesis. Any steep changes in temperature will able to denature the enzymes crucial to carry out both processes. Study done by Chaneva *et. al*. (2007) showed *Arthronema africanum* of Cyanobacterium has a wide temperature range which is between 16ºC to 47ºC. However, in culture, the species observed to decrease its biomass at extremely low and high temperature at 15ºC and 48ºC respectively, regardless the light intensity. He found extreme temperature able to destroy phycobiliprotein content that is essential as pigment to absorb light thus decreasing the species growth rate.

Nonetheless, there are some phytoplankton that has high temperature optimum for their growth and photosynthesis (Lee, 2008). *Chlorella sorokinana* in a controlled photo bioreactor able to grow to high population densities in temperature ranges 40ºC to 50ºC (de-Bashan, *et. al*., 2008). Philips *et. al*.,(2010) carried out study along Indian River Lagoon Florida on climatic trend of phytoplankton. He observed total phytoplankton showed positive correlation with temperature. Appearance of tropical species was common at sites during warm season. Dinoflagellate, *Pyrodinium bahamense* was one of the examples of tropical species that appeared during warm season and disappeared from water column for the most of cold season. Increased temperature that associated with global warming believed able to lead the species to other region of Florida (Philips *et. al*., 2006). In Baltic Sea, increased of temperature from 0ºC to 10ºC changed phytoplankton community from diatom and dinoflagellate to mixotrophic nanoflagellate (Anderson, *et. al*., 1994). Hence proving that different temperatures also able to affect phytoplankton assemblages in the aquatic or marine ecosystem.

Salinity has been shown and proved to be one of the main factors influencing phytoplankton composition and assemblages (Cota & Horne, 1989). Besides, it is also responsible to effect photosynthetic behavior of several phytoplankton species (Moisander *et. al*., 2002). In brackish water such as in mangrove ecosystem, phytoplankton community is normally exposed to rapid and irregular changes in salinity (Pilkaityte *et. al*., 2003). Rajkumar (2009) suggested that change of salinity in brackish water ecosystem was due to monsoon or by tidal variations. Salinity believed to act as limiting factor to the distribution of planktonic community mainly, the phytoplankton (Sridhar, *et al*., 2006).

Balkis *et. al*. (2004) carried out a research on relation between phytoplankton composition and abiotic parameter, found only salinity appeared to play role in affecting species composition. The species number of phytoplankton observed to have negative correlation to salinity. He also found salinity was positively correlated to temperature. For years, salinity-temperature intercorrelation has proved to have significant effect on phytoplankton such as dinoflagellate. Nielsen and Tonseth (1991) cited in Normawaty (1998) observed *Gyrodinium aureoulum* does not grow at temperature less than 10ºC or greater than 25ºC and salinity less than 12%. Pilkaityte *et. al*. (2003) treated phytoplankton with salt (NaCl) enrichment and found only filamentous Cyanobacteria were promoted by the enrichment, while the salt addition had no effect on overall phytoplankton biomass.

Studies on the effect of tidal ranges towards phytoplankton composition, assemblages and distribution normally involve the vertical distribution of phytoplankton. However, most of researches carried out to study vertical distribution were obtained from pigment analysis using high performance liquid chromatography (HPLC) (Mantoura & Llewellyn, 1983) or by means of chlorophyll a (Brunet & Lizon, 2002). Barlow *et. al*. (1993) in his research has proved that pigment composition able to reflect taxonomic composition of phytoplankton.

According to Biswas *et. al*. (2010), phytoplankton species composition was higher during high tide compared to low tide. Dey *et. al*. (1987) quoted by Biswas *et. al*.

(2010) suggested that nutrient variability which in high concentration during high tide and in low concentration in low tide was due to tidal mixing of river water and seawater. The phenomenal during high tide promoted phytoplankton growth thus increasing phytoplankton numbers. In mangrove ecosystem, nutrient concentration which is relatively low during low tide used to be the main reason of the phenomenal.

Decreasing of water level in low tide also will contribute to the lower cells abundance, since most of phytoplankton susceptible to attach to the substrate such as macrophyte during outgoing tide. Thus, decreasing the cells abundance of phytoplankton recorded in low tide. During low tide, low light intensity penetrates into water column because of high turbidity, thus resulting to a non significant increase in phytoplankton productivity (Ahsen *et. al*., 2006; Hoai *et. al*., 2006). Nurhidayah (2007) observed significant difference in species composition of phytoplankton between high tide and low tide at three locations along Batu Pahat River Estuary. She recorded 23 and 16 phytoplankton species during high tide and low tide respectively.