CHAPTER 1

INTRODUCTION

Primary production is very important for being the basic step of marine food chain. Production and biomass of phytoplankton are controlled by a combination of several factors, namely physical (light, temperature, turbulence etc.), biological (grazing and parasitism etc.) and chemical (available nutrients such as carbon, nitrogen, phosphorous and silicon etc.). The most important of these micronutrients are nitrogen and phosphorous, but some other trace elements such as iron and organic materials are essential to the growth and photosynthesis as will, even in minute amounts. These essential organic compounds may be supplied from mangrove, coral reef and human activities i.e. sewage discharge and tin mine water (Provasoli, 1963).

There are 3 indirect procedures to estimate the rate of primary production. A consideration of the overall equation of photosynthesis:

$$CO_2 + H_2O \longrightarrow (CH_2O) + O_2$$

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suggests that the gross rate of photosynthesis could be determined by (Riley & Chester, 1971).

1. The rate of liberation of oxygen (Light and dark bottles oxygen method).

2. The rate of removal of carbon dioxide (^{14}C - Technique).

3. The rate at which carbon is converted into plant tissue (Chlorophyll analysis).

In this work the light and dark bottles oxygen method, followed Strickland & Parsons (1968), is used for studying primary production because this method is suitable for rather high productivity areas. Moreover, provided that primary production is enough for accurate measurements to be made after 24 hours, the oxygen method seems to be a more reliable method.

Phuket island, the selected site, with the total area of 550 sq. km., is located on the west coast of the peninsula of Thailand, approximately between latitude $7^{\circ} 3^{\prime}$ N and $8^{\circ} 30^{\prime}$ N and longitude $98^{\circ} 15^{\prime}$ E and $98^{\circ} 40^{\prime}$ E. On the east coast of phuket and Phangnga bay are extensive mangrove areas. There are coral reef on almost every beaches in Phuket region. Drainage of Phuket town is by a natural stream, Klong Bang Yai running through the town. The majority of land use in Phuket is agriculture which includes pararubber, coconut and rice. Tin mining also scattered all over the island. Most of tin production in Thailand is from Phuket region (Ludwig, 1976).

The objective of this research is to find out the effect of water quality on the primary production. The study is designed to investigate the limitation of various nutrients, (nitrate, phosphate, silicon, ammonia, iron and chelator EDTA), describing the effect of coral water, mangrove water, domestic sewage discharge and tin mine water on the primary production.

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LITERATURE REVIEW

1. Nutrients

For a long time it has been known that some chemical nutrients, such as nitrogen and phosphorous are essential micro - nutrients. Dissolved in water, in available form, these nutrients are important in controlling phytoplankton production, that is many studies have shown that nitrogen and phosphorus are limiting factors for phytoplankton growth (Goldman, 1962, Riley & Chester, 1971, Sander & Moore, 1979, Fitzgerald, 1981, Graneli, 1981, Lean & Pick, 1981, Rhee & Gotham, 1981). Riley et al. (1949) have suggested that N:P ratios in tropical sea might indicate that nitrogen is the more important limiting factor for these areas. Also in the temperate zone Graneli (1981) was able to point out that phosphorous alone did not stimulate growth in bioassay experiments. The ratio of nitrogen to phosphorous is important for maxiumum photosynthesis of phytoplankton. For example, Sander & Moore (1979) stated that N:P ratios should be 9.8:1. In Phuket coastal water Thinakul (1981, unpublished) did experiments in Phuket Bay, showing that N:P ratios best for phytoplankton's growth should be from 7:1 to 9:1. Besides, nitrate as important form of nitrogen, ammonia was also found to be a valuable nitrogen source (Ryther, 1954; Ryther et al., 1966; Thomas, 1970 b; Vince & Valiela, 1873; Sander & Moore, 1979). In addition to P and N, some trace elements such as iron, manganese, molybdenum, zinc, cobalt, copper are essential to the growth of phytoplankton also. Iron in available form is essential in photosynthesis (Riley & Chester, 1971).

Since some trace elements cannot be utilized right away by phytoplankton, the chelated forms of such elements was added, for example by using the chelating compound EDTA (Ethylene diamene tetraacetic acid). This permitted phytoplankton to utilize trace elements without risk of precipitation of their hydroxides. Very little is known about the concentrations of trace elements required by phytoplankton.

Silicon is also important for some plankton, such as diatom and silicon flagellates which possess siliceous skeletons. However, although essential, silicium in normally not considered a limiting factor for marine diatoms (Paasche and Ostergern, 1980).

2. Coral water

According to Odum & Odum (1955), the coral reef communities of the world are tremendously varied associations of plants and animals growing luxuriantly in tropical waters of impoverished plankton content. This statement is of course a generalization. For example, it has been found that the planktonic primary production can be high, approximately 400 $g.C\ m^{-2}.y^{-1}$, in coral reef areas on the east coast of Phuket Island (Sundstrom et al., 1983) and coral growth measured as lenght increment can also be high in the same area (Charuchinda & Hylleberg, 1983). However, the relationship between plankton and coral growth is not straight forward since maximum primary production occurred during the wet monsoon when coral growth was at a minimum. During the dry monsoon the opposite was found, indicating the element of truth in the above quotation of Odum & Odum. We see that yearly production and coral growth can be high but not at the same time because abundant plankton will exclude essential light form reaching the corals. Maybe the definition should be rephrased taking the significance of shifting monsoons into consideration. Furthermore, phytoplankton and zooplankton abundance may not be fully correlated. It has, therefore, been suggested that zooplankton might feed on detrital matter (Emery, 1968; Johannes et al., 1972) for example mucous, and various aggregates including dead organic matter (Kohn & Helfrich, 1957). Very little phytoplankton is generally included in the aggregates (Marsh, 1970; Sorokin, 1973; Muscatine, 1980). Communities of Corals are characterized by high rates of biological productivity (Littler, 1972). The corals obtain their nutrients from the overlying water. However, tropical water are generally characterized by low levels of dissolved and particulate nutrients (Marsh, 1970; Smith, 1973; Wiebe, 1975; Porter, 1980; Raymont, 1980). This indicates that even if the pool size of nutrients is low the turnover rate must be high in order to sustain the high rates of productivity. Bacteria may also play an important role in coral reef production because bacteriological activities encompass active uptake mechanism for nutrients, especially of phosphorus and some organic substances (Odum & Odum, 1955; Doty, 1958; Wright & Hobbie, 1966). In this way bacteria compete with phytoplankton for nutrients. Yet, bacteria may enter the food web via zooflagellates and zooplankton which again may be eaten by corals. Corals have predatory habits but it should be noted that the endosymbiotic, unicellular marine algae (Zooxanthellae) play an essential role in the life cycle of reef building corals (Muscatine, 1973; Sorokin, 1973; Muscatine, 1980). Recently Lewiss (1977) presented a review of organic matter production in coral reefs. Wiebe

(1975) found that bluegreen algae appeared to be dominant nitrogen fixers. Other sources of primary production within coral reefs included fleshy macrophytic algae and marine grasses, in addition to the Zooxanthallae. Interestingly Woodwell et al., (1979) suggested that most of the primary production was due to marine macroalgae. The fringing reefs of Phuket Island do not carry abundant macroalgae so the above suggestion should be studied in this area.

Much work has been done, comparing primary production between two coral areas. Sournia & Richard (1976) found that in one lagoon (Taihura) which is narrow and shallow, phytoplankton standing crop and production were both extremely low. Pelagic primary production ranged from 4 - 27 mg C/m^2/day, which is less than in the impoverished open ocean. This finding can be compared with another lagoon (Vairao) which is deep and wider and to a great extent subjected to land fertilizers. This lagoon was more productive (103 - 420 mg C/m^2/day). Finally, the production was surprisingly high at a station just outside the Barrier Reef (645 mg C/m^2/day). Johannes et al., (1972) compared the production of whole coral reef communities at two sites. The result was that gross primary productivity, including coral production, was more than twice as high (10 g C/m^2/day) in an area with negligible coral cover compared to an area with well developed coral component (4 g C/m^2/day). The highest value of coral reef production reported is from a Hawaian fringing reef with 11,680 g C/m^2/year gross primary production (Gordon & Kelley, 1962). In contrast, the estimates of gross production of the ambient water in the vicinity of the reefs are very low. The cause of high productivity of coral reef communities is still not fully understood. Concentration of phosphorous and nitrogen in waters flowing over reefs are relatively low, but nevertheless there is a constant supply of nutrients (Nienhuis, 1981).

3. Mangrove water

Mongroves are considered to be among the most productive areas of marine environments. They are characterized by complex interactions between various kinds of organisms and also between living and nonliving things. These ecosystems are breeding, feeding and nursing grounds for many marine organisms (Chirarochana, 1978). The mangrove trees themselves are dominant but significant contributions also come from phytoplankton, and also various macrophytes, benthic diatoms and bacteria. Detritus food webs have been studied in mangroves (Chirarochana, 1979; Pomeroy, 1980; Tantichodok, 1981), showing different patterns and different kinds of orgnism in the different mangrove forest types. Bacteria were thought to be important secondary producers in the detrital food web based on biodecomposition of mangrove leaves (Golley et al., 1962), dead organisms and excretions (Lugo & Snedaker, 1974; Boonruang, 1978; Chirarochana, 1978; Zottoli 1978; Aksornkoae, 1979; Pomeroy, 1980). The property "nutrient trap" of mangroves also support the characteristic of high productive areas. Lugo & Snedaker (1974) summarized 5 important processes (primary productivity, above ground respiration, respirations of the muds, recycling of mineral nutrients and the export of organic matter to estuaries or other contiguous - ecosystems) causing mangroves to be productive areas. Phytoplankton is an important source of primary production which contributes with dead cells and excretion to bacterial activity in biodecomposition (Lugo & Snedaker 1974; Fogg 1980). Most of the phytoplankton is bluegreen algae.

Physical factors and nutrients in mangroves have been studied widely in many areas (Lugo & Snedaker, 1974; Limpasaichol, 1978; Aksornkoae, 1979; Ketakorn, 1979; Siripong, 1980). Stefa nsson and Richard (1963) studied dissolved NO_3^- and found that the concentration of NO_3^- varied directly with salinity. Rochford (1951); Jitts (1959) found that $PO_4^{\equiv}$ was constant at salinity ranging from 0 - 32%. and that mangroves had phosphorous trap properties (Hesse, 1962). The increase in availability of nutrients was due to water run-off and regeneration in shallow water. Similarly there was abundant nutrients export to the sea with drainage from the mangrove swamp. Prakish (1971) emphasized that coastal fertility is generally many times higher than that of oceanic waters in respect of phytoplankton production. While increased inorganic nutrient concentration may be partly responsible, it cannot always account for the difference. Teixerira et al., (1969) found considerable variation in a mangrove swamp area in Brazil: production could be very high with a maximum gross primary production of 640 mg C/m^3/day in August and 580 mg C/m^3/day in March. Production was generally lower from April to July. Gasim and Gopinathan (1969) determined daily primary production in the tropical estuary of Cochin Backwater which amounted to 1,500 mg C/m^3/day at the surface and about 400 mg C/m^3/day at one meter depth.

Primary production of mangrove trees have also been investigated, for example, Golley et al., (1962); Miller (1972); Joshi et al. (1974); Lugo & Snedaker (1974) and Wium - Andersen (1979).

4. Domestic sewage

Pollution from land can occur in various kinds of discharges, such as domestic sewage, industrial sewage, agricultural sewage and water from tin mines. The problems about waste water disposal have increased rapidly during this century all over the world The effects of pollution may cause damage in both direct and indirect ways and it is also necessary to distinguish between long time and short time effects. The direct harmful effect is mostly caused by toxic substances in high concentration, radioisotopes and diseases. The direct effect is due to the fact that low, harmless concentrations can become harmfull concentrations by passing up through the trophic levels. A classic example is the dangerous levels of DDT found in carnivorous birds feeding on fish which feed on zooplankton which again feed on algae. The concentration of DDT in the water is low but becomes increasingly concentrated via the food chain. It is difficult to control and protect life or environments from this pollution. Sewage treatment plants have exerted an increasingly important influence in the coastal marine environment (Cronin, 1957; Dunstan & Menzel, 1971). Most of the developed countries have these plants consisting of 3 steps: first, secondary and tertiary treatment, while nearly all of the developing or undeveloped countries still used simple channels for water run off without any treatment plant. Sewage discharge that pass through the overall 3 steps treatment will have inorganic nutrients, such as nitrogen and phosphorous removed or strongly reduced (Thomas, 1969; Ryther & Dunstan, 1971; Ryther et al., 1972; Goldman et al., 1973; Graneli, 1981). It is well known that the nutriets, nitrogen and phosphorous are growth limiting factors for phytoplankton. Algal bioassay experiments concerning waste water and nutrients have demonstrated that nitrogen removal is necessary to prevent increasing algal growth potential of coastal marine waters, receiving waste water discharges. (Goldman et al., 1973; 1974). When nitrogen was removed from secondarily treated domestic waste water the waste water in varying dilution with sea water could not support algae growth better than the sea water alone. By adding nitrogen to the treated waste water the algae growth potential was increased to that of the untreated waste water. Mixtures of waste water and sea water are almost complete media for culturing marine algae. (Dunstan & Menzel, 1971; Goldman & Stanley, 1974). Recently Ryther et al., (1972) and Goldman et al., (1974) also demonstrated the feasibility of utilizing treated waste water effluent as the nutrient source for the mass cultivation of marine algae. Graneli (1981) also tested the influence of sewage on alae growth and found that nitrogen is a limitting factors for phytoplankton growth. A bioassay experiment was done to evaluate nutrient limitation in Laugh Neagh water (Parr & Smith, 1976). From last mentioned bioassays no single nutrient appeared to cause limitation of algae growth in Laugh Neagh, but simultaneous addition of nitrate + phosphate + chelated iron) produced growth similary to that of a complete algal medium. In contrast Lange (1971) and Wood & Gibson (1979) emphasized that phosphorous could be a growth limiting nutrient. All the bioassays showed dependence on phosphorous for a significant growth response. Bacteria form the most important group of living organisms that can grow well in sewage discharges. In sewage rich in organic matter Chlamydomonas bacteria are important, but also Sphaerotilus natans which often covers the bottom of strongly polluted waters like a thick, hairy mat, visible to naked eyes. Massive occurrence of S. natans can occur at temperature 5^o - 20^o C, pH 6 - 9, if O_2 supply is good. However, reduced growth of S. natans can be found in various kinds of waste, in areas of stagnant water and in complete absence of O_2 (Wood, 1967; Strickland & Parsons, 1968; Hynes, 1971; Rheinheimer, 1971; Poole & Hobson, 1979). When S. natans die and undergo putrefaction, H_2S is formed among other products. Sewage water may also contain sulphur oxidizing bacteria such as Thiobacillus and Beggiatoa, which consume reduced sulphur compounds (e.g. H_2S) rapidly and deposit elemental sulphur outside, respectively inside the cells. Putrefying bacteria keep on liberating ammonia which thus becomes available to the green plants as a source of nitrogen (Rheinheimer, 1971; Reeves, 1972; Goldman & Stanley, 1974). Iron bacteria also play an important role in waste water. In brackish water, in calm shallow estuarine areas, iron bacteria may be found adhering to particles of iron oxide. Iron bacteria normally require for their growth ferrous salt, CO_2, O_2. Iron is usually present in water in the form of dissolved Fe $(HCO_3)_2$. The process of Fe^{++} oxidation by O_2 is strongly pH dependent. Oxidation is very slow below pH 6. However, above pH 6 a 100 - fold increase has been measured in the rate of reaction for one unit increase in pH (Wood, 1967; Stumm & Morgan, 1970; Rheinheimer, 1971). These bacterial groups can oxidize ferrous to ferric compounds on a large scale.

Many kinds of fungi are also abundant in sewage water. They are often harmfull and can cause diseases. The importance of urban effluent on detrital food webs was studied by Soule & Soule (1981).

To the surprise of many people they found that domestic sewage was quickly utilized by benthos which had high production.

5. <u>Tin mine water</u>

Thailand produces about 30,000 tons of tin ore concentrates per month, most of which comes from the Phuket region, both onshore and offshore. In 1976 Ludwig estimated that of the total area of Phuket island (550 km^2) about 26 km^2 had been mined of this only about 2.6 km^2 or 10% has been properly rested and put to productive uses, such as cropping. The remaining 23.4 km^2 of 90% has been environmentally degraded. Therefore, water discharged from on land tin mine should be studied to understand its effect on the primary production in the natural sea water.

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