CHAPTER 4

DISCUSSION

1. Nutrients

Phytoplankton production in Phuket coastal water was rather limited by nutrients such as the result of the experiments shown. The reference sea water showed relatively low gross primary production except when the nutrient level of the water was high. A small increase in concentration by addition of nutrient and micro elements can increase the gross primary production in the order of 100%. Of course, it must be considered that the bioassay experiments were carried out at the optimum condition such at temperature and light for phytoplankton photosyntesis. However, as shown on Figure 1, the situation is not so different from the natural situation. This experiment is in agreement with the ration N: P = 9.8 : 1, considered best for phytoplankton (Riley & Chester, 1971, Sander & Moore, 1979). Regarding phosphorous, an experiment in Barbadis, West Indies, showed that this nutrient alone was a limiting factor, eventhough not as important as nitogen. Graneli (1981) did an experiment and found that phosphorous alone did not stimulate phytoplankton growth.

Nutrient deficiency has long been, recognized as one of the factors controlling phytoplankton growth. However, different localities and conditions gave different results leading to controversies. Phytoplankton in coastal waters often has been considered as nitrogen-limited (Ryther & Dunstan 1971, Goldman 1974, Gargas 1975, Goldman 1976 and Graneli 1981), but some experiments are not in harmony with this suggestion. For examples Chu (1946) and Sander & Moore (1979), showed that not only nitrogen but also phosphorous were the limiting nutrients. The present work agreees with the latter findings since both N and P were essential factors for Phuket coastal water. This work also shows much higher gross primary production of sea water when nitrogen was added than that of phosphorous which agrees with Ryther & Dunstan (1971)'s work which stated that it is unquestionably nitrogen that limits and controls algal growth and eutrophication.

2. <u>Coral water</u>

Only few studies have been carried out on phytoplankton productivity and related parameters in coral reef areas, hence, it is difficult to compare the data. Sournia & Richard (1976) foun found that phytoplankton of coral reefs was rich in species but exceedingly poor in individuals, and they believed that flagellates and similar organisms escaped counting. This is regretable because the smallest phytoplankton organisms, such as flagelletes, have been found responsible for 34 - 91% of the primary production in the area the same area as the present study (Wium - Andersen, 1979). No attempt has been made to identify or count organisms present in the coral water of this study. Nevertheless, it is sugested that small but very productive organisms developed within the plastic bags during the 4 hours incubation prior to extraction of the water used in the bioassay experiments. Furthermore, the result also suggested that the organisms are specialized in an unknown way since dilution of the coral water influenced the rate of primary production to a significant degree. These organisms could be unicellular blue green algae and/or flagellates. The former group of organisms would favour the high concentration of phosphate shown in Table 3. It is well that many blue green algae can fix atmospheric nitrogen, thereby contributing to the high productivity of coral reef areas (Wiebe, 1975). With respect to the flagellates, it is less bovious to suggest advantages from the coral water environment, since there might be some competition for nutrients between zooxanthellae in the corals and the phytoplankton in the water surrounding the corals.

Furthermore, when the corals are enclosed in a plastic bag, nitrate is taken up, there by reducing the concentration to half value over the 4 hours incubation period. This shows a great demand of this nutrient within the bag. In comparison, nitrite could not be detected in the pure sea water, and the concentration was 0 - 0.03 ug-at N/L in water surrounding the corals. After the 4 hours incubation, nitrite had doubled compared to the concentration outside the plastic bag. Of course it should be emphasized that the values in Table 3 are pool size values which cannot be directly compared to rates of production. However, it is obvious that production of both phosphate and nitrite within the bags must exceed consumption since the pool sized increase with time.

With respect to nitrate, consumption must be higher production. The nitrate is produced during the process of nitrification, involving various bacteria. The first step is the production of nitrite from ammonia excreted by the coral head and cryptic fauna associated with the coral. However, nitrification is a complicated process influenced by many factors (Cushing + Walsh, 1976). In addition, ammonia can be used directly by phytoplankton and the concentration of ammonia was found high around corals by Muscatine (1973) and Zottoli (1978). Recently, measurements of primary production in coral waters had been done in water flowing over reefs. Thus the nutrients supply was replenished and mixed with nurients recycled by organisms in the sea water and in the coral reef. In contrast, this experiment had no replenishment from sea water, so the high gross primary production of coral water, compared to sea water, is rather puzzing. Specialized planktonic algae and bacteria are suggested to be the cause of this result. However, the complexity of the interaction and relation among Zooxanthellae, bacteria, nurients, zooplankton and coral polyps themselves cannot be explained clearly as yet. It is still not fully understood how the events connect together to explain the high primary production of coral reefs.

3. Mangrove water

This study shows that the area in the mangrove is more productive with respect to phytoplankton primary production than sea water when comparing stations I with M and O. Chirarochana (1978) stated that most phytoplankton of mangrove is composed of blue green algae, probably adapted to live in this special biotope. Phytoplankton of the open sea is dominated by diatoms. Other factors, such as nutrients, could also explain this result because station I recieved run - off from land more than the other stations M and O. Besides, Fogg (1980) showed that some dissolved organic growth factor was essential for phytoplankton. However, the precise nature of this factor is not fully understood. Emperically it has been shown that soil extract should be added to cultures of marine phytoplankton in order to secure good growth.

4. Domestic sewage

When the sewage water was collected from the klong it looked rather harmful but from the type-1 incubations the result shows that the klong was not so bad at the time of water sampling. At least heavy metals or toxic substances that can block photosynthesis were at low levels. The sewage was of a normal, urban discharge type mixed with small scale industrial effuence.

The method of this study is based on the presence of dissolved O_2, and it is obvious that oxygen can only be produced during photosynthesis which only takes place in the light. The higher concentration of dissolved O_2 in the dark bottles cannot be due to the production of O_2 from photosynthesis . The lower O_2 concentration in the light bottle as compare to the dark of type 4 incubations must be because of some process which can increase oxygen consumption in light bottles.

Apart from the possibility of experimental error, four different groups of compounds are known to interfere with the Winkler method because of their red-ox capacities, namely: reducing organic matter, nirite, hydrogen sulphide, and ferrous ion. Of all these, hydrogen sulphide is easily oxidized in the flowing, oxygenated klong water. It is unlikely that any of the organisms producing or utilizing nitrite and organic matter will do so in a way that is light dependent. If, for example nitrite is formed by nitrification of ammonia, this process should occur to the same extent in both dark and light. The process will certainly introduce some error in the absolute values of gross primary production but bacteria of the intrification process are not known to be light dependent. Therefore, the discussion has emphasis on the last compound, Fe^{++}, since Fe^{++} can enter chemical oxidation reactions using O_2. Unfortunately, red-ox transformations of Fe (and also of Mn and P) are not easily characterized because, superimposed on the many physical-chemical variables are biological variables. Aquatic organisms influence the concentration of these substances directly by metabolic uptake, transformation, storage and release. However, it should be noted that the process of Fe^{++} oxidation is strongly pH dependent. Oxidation is very slow below pH 6. Above pH 6 a 100-fold increase in the rate of oxidation had been measured for an increase of one unit of pH (Stumm & Morgan, 1970, Rheinheimer, 1971). At the same time Fe^{++} can be reduced reasonably fast by a variety of organic substances (phenols, polyphenols, tannic acid, cysteine, and many more). The same type of substances that reduce Fe^{+++} can also catalyze the oxidation rates. This can be shown by the following reaction sequences:

Fe^{++} + 1/4 O_2 + organic matter $\longrightarrow$ Fe^{+++} - organic complex

Fe^{+++} - organic complex $\longrightarrow$ Fe^{++} + oxidized organic matter

This reaction pattern depends upon pH and concentrations of the compounds.

In this study changes in pH during the bioassays could not be recorded. At the first place the changes during a 4-hours incubation must be relatively small in the whole bottle, though locally shifts in pH may be significant in microenvironments, such as material settling on the bottom. For the second place, in order to measure such changes in the microenvironment the advanced equipment is needed and it is not available at PMBC. The discussion must be based on general knowledge of the relationship between phytoplankton production and pH. In a heterotrophic system such as the dark bottle, the carbon dioxide equilibrium will be shifted to the left (in the following equation) because the organisms release CO_2 due to respiration. The pH will be lowered as well as the concentration of dissolved oxygen. In the light bottles the equilibrium will be shifted to the right because of the photosynthetic uptake of CO_2 and hydrogen carbonate. In consequence pH will increase and so should the concentration of dissolved oxygen. The reaction sequences of the carbon-dioxide equilibrium can be illustrated as follows:

$$CO_2 + H_2O \rightleftarrows H_2CO_2 \rightleftarrows H^+ + HCO_3^- \rightleftarrows 2H^+ + CO_3^-$$

Low pH High pH

If the argument based on chemical oxidation of Fe^{++} should make sense in terms of explaining $D_{oxygen} > L_{oxygen}$, at least three conditions should be met:

Firstly, photosynthesis must occur in the light bottles. This condition was checked by using C-14 isotopes added to the wewage. By this method a small, but clear, primary production could be stated.

Secondly, the primary production should mainly occur in micro-environments. This condition was checked by microscopic examination of the material settling on the bottom of the light bottles. This material was rich in organisms, for example photosynthetic flagellates (the Euglena type), filiform blue - green algae (the Oscillatoria type), and benthic diatoms.

Thirdly, Fe^{++} should be present. This conditon was difficult to check directly because the lack of the chemicals necessary for photometric determination of iron compounds. Circumstantial evidence, however, was provided by the fact that a dense film of iron bacteria developed on the surface of the water left over-night in the laboratory. These bacteria, dominated by Sphaerotilus natans, can only oxidize Fe^{++} to Fe^{+++}. The latter was present as brown granules in the coating surround the bacteria floating on the surface.

In conclusion, the following hypothesis can be presented: due to strong heterotrophic activity, the pH was low in the dark bottles compared to the light bottles, where some photosynthesis took place. However, the result in the increase of pH, increased the chemical oxidation of Fe^{++} to such a degree that the whole amount of oxygen produced during photosynthesis was comsumed, in addition to some of the oxygen, present at the beginning of the experiment. The lowered pH in the dark bottle inhibited Fe^{++} oxidation, and the higher pH in the light bottle enhanced Fe^{++} oxidation. The result of $D_{oxygen} > L_{oxygen}$ is supposed to occur in water characterized by high heterotrophic activity, low production and high amounts of ferrous iron.

It is also to be noted that, the concentration of phosphate in this situation was rather high. Therefore, this sitation might be as a cause to inhibit the primary production. This reason agrees with what Ryther & Dunstan (1971) had poinled out that much of the phosphate in domestic waste has it origin in detergents. Too much phosphorous will raised the ratio of N:P slightly higher than 5:1 by atoms and this ratio is normally found in waste water with very low or no more production.

5. Tin mine water

The experimetns with tin mine water agree with Fitzgerald's work (1981) about the effect of tin mine water on phytoplankton. He summarized the following:

1. reduction in primary production is caused by increased light attenuation.

2. enhancement of primary production occurs due to addition of nutrient rich bottom waters.

About 26 km^2 of the total of 550 km^2 of the Phuket Island have been mined. Thus drainage from tin mines must contribute significantly through the run off from land. The load of fine sediment particles increases the turbidity of tin mine water and deposition of this sediment hamper the flow of water in the klongs. On the other hand, trapping by sediment particles can reduce the spreading of harmful particles in sewage as well. However, when sewage and run off from tin mines are combined, there is a risk of build-up of organic material in marine sediments. This will result in formation of strongly anaerobic, bad smelling sediments due to bactrial fermentation and the sulphate reducing bacteria decomposing the organic matter. This is an undesirable situation, fogether with the consideration of the general disturbance of the marine evironment caused by turbid water, the Government putastrong measure or closed the tin mines situated on the beach or in coastal waters of Phuket Island.

If the tin mines are operaing in a closed system like those from which water was collected for the present experiments, then pollution due to turbid water is practically non-existent and no damage can occur outside the tin mining area.