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NUTRIENTS AND CHLOROPHYLL *a* VARIATIONS AT A FIXED STATION DURING THE RED TIDES IN THE JINHAE BAY

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ABSTRACT

12 or 25 hours continuous observations were made for the variations of nutrients and chlorophyll *a* with tidal cycle at a fixed station located at a mid-channel of the Masan Bay. High nitrate concentrations were observed at the time of low tides whereas high phosphate concentrations at the time of high tides. It is suggested that anoxic bottom waters could also be the possible source of high phosphates in the outer bay. Chlorophyll *a* concentrations were related to the nitrates in April and to the phosphates in June and August. The possible role of growth stimulators in causing the extensive blooms of red tide organisms is suggested.

INTRODUCTION

In recent years, frequent red tide outbreaks along the southern coast of Korea reveal a serious problem for coastal fisheries of the area. Red tides of which consequences are often dramatic and severe have been described in the Jinhae Bay by many authors (Cho, 1978, 1979, 1981; KORDI, 1980, 1981; Park, 1980; Yoo and Lee, 1980). Since the coastal waters of the Jinhae Bay have been heavily impacted by continuing urbanization and industrialization, efforts have been made to relate these undesirable phytoplankton blooms to the massive transport of pollutants from the land.

Attempts to quantify the extent of these impacts on coastal waters are usually hampered by the fact that the distribution of planktonic organisms as well as associated environmental factors are characterized by extreme variability in time and space.

Inner Masan Bay waters receiving domestic and industrial wastewaters are communicated with the open ocean by a narrow channel.

Since the mean tidal excursion in this area is approximated to be 7km (KORDI, 1980), variations of biologically important parameters due to the tidal variations are expected to be great at a mid-channel.

We attempted to observe the tide-induced variations of nutrients and chlorophyll *a* contents at a fixed station occupied continuously during 12 or 25 hours.

MATERIALS AND METHODS

The observations were conducted at a fixed station (station 7) located at a mid-channel in April, June and August, 1981 (Fig.1). Sea water samples were taken hourly from 0600 to 1900 on April 8 and August 12.

This station was also occupied from 1300 June 10 to 1400 June 11. Samples were collected from surface water with Van Dorn Sampler (51).

Measuring methods for the general water quality parameters (temperature, salinity, pH

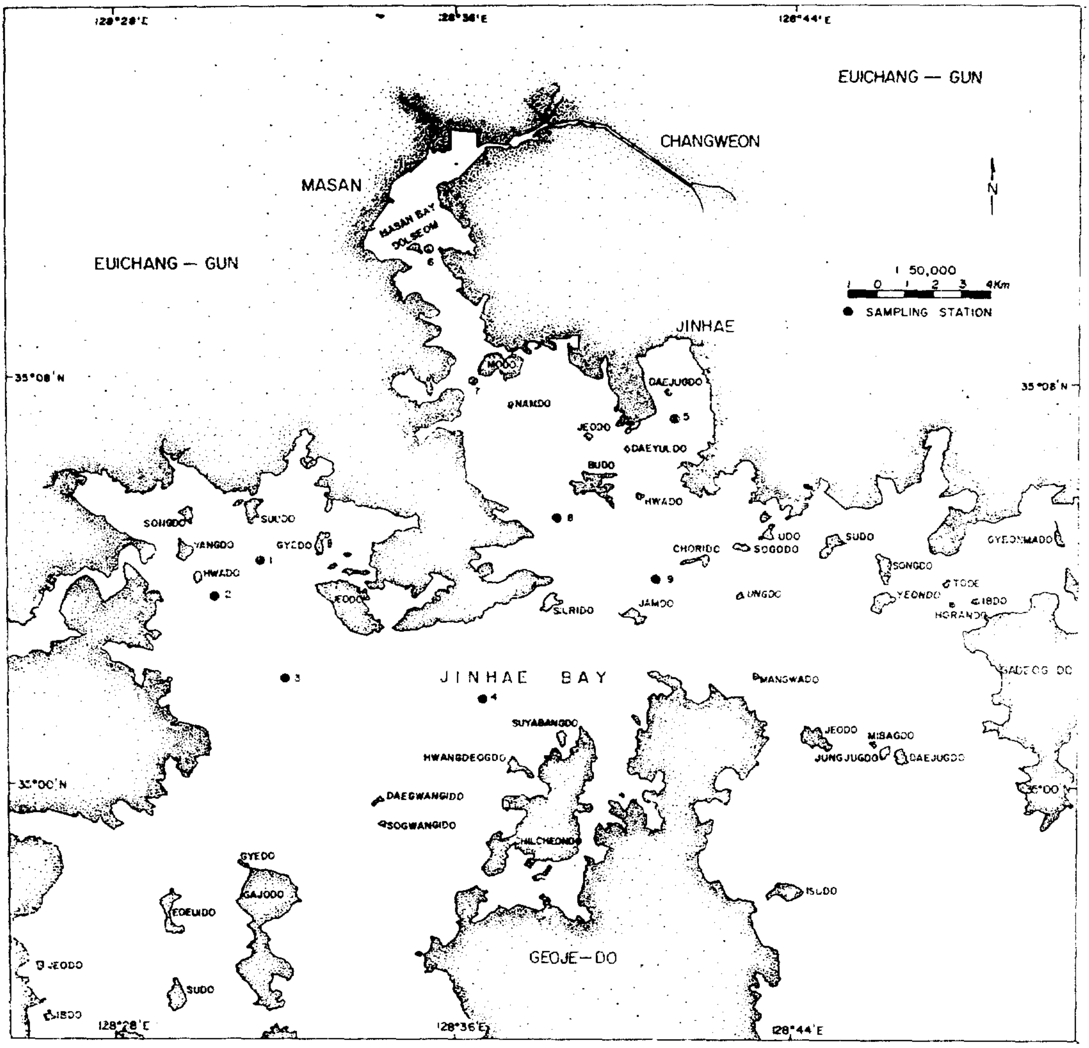

Fig. 1. Sampling stations of the Jinhae Bay.

and dissolved oxygen) are described elsewhere (KORDI, 1981). Nutrient analyses for nitrates and phosphates followed the spectrophotometric methods of Wood *et al.* (1967) and Murphy and Riley (1962) as described by Strickland and Parsons (1972). For the samples taken in August, nutrient analyses were carried out on Technicon Autoanalyzer AA II by the method of Zimmermann *et al.* (1977). Chlorophyll *a* was determined on acetone extracts by the SCOR-UNESCO (1966) method.

RESULTS

Figure 2 presents the vertical distribution of general water quality parameters observed at 0800, April 8. The whole water column was thoroughly mixed in this month. The bottom waters were well oxygenated and pH in the surface waters were not very different from those in the bottom waters.

Diurnal variations of nutrients and chloro-

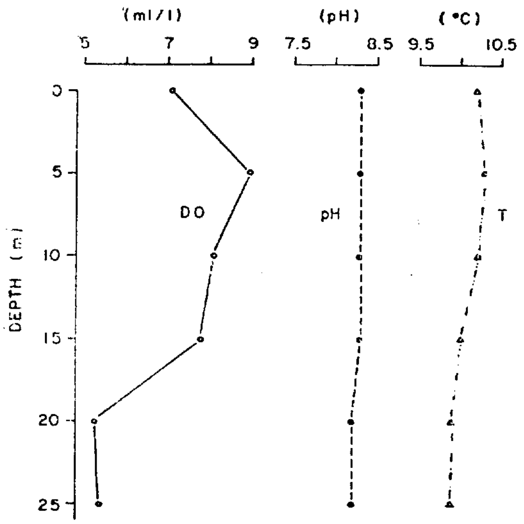

Fig. 2. Vertical distribution of general water quality parameters in April.

phyll *a* concentrations are shown in Fig. 3. Nitrate concentration reached daily maximum about 2 hours before the time of low tide (269μgN/1 at 1500), daily minimum about 3 hours before the time of high tide (52μgN/1 at 0800). Chlorophyll *a* concentrations in all 13 samples were below 10μg/1 indicating that extensive phytoplankton blooms were not yet to be initated.

In April, high nitrate contents were related to the high chlorophyll *a* contents as shown in Fig.4.

The water column became relatively well stratified in June (Fig.5). The water temperature exceeded 23°C at surface and decreased rapidly with depth. Below the thermocline, oxygen deficient layer was developed due to the intense degradation of organic matter fallen down through the thermocline.

Nitrate concentrations which varied from 375 to 664 μgN/1 with sampling time did not show the noticeable change with the tidal variations (Fig.6).

Meanwhile phosphate concentrations ranging from 14.2 to 52.5 μgP/1 with sampling time showed its maximum at the time of high tide and its minimum at the time of low tide implying that phosphate contents are higher at

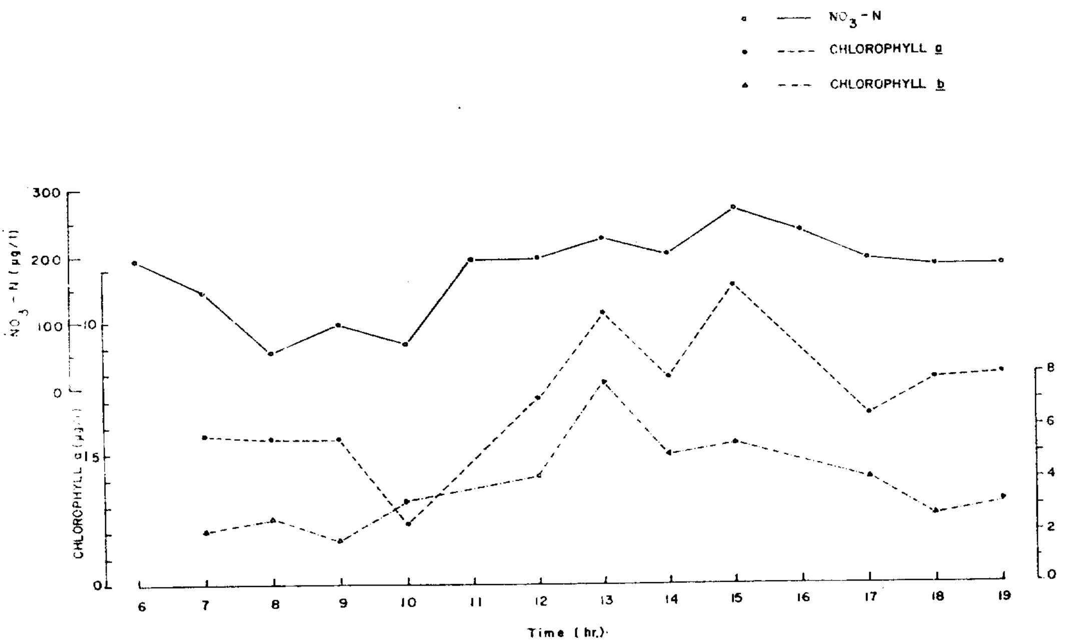

Fig. 3. Variations of nitrate-nitrogen, chlorophyll *a* and chlorophyll *b* at a fixed station in the Jinhae Bay in April.

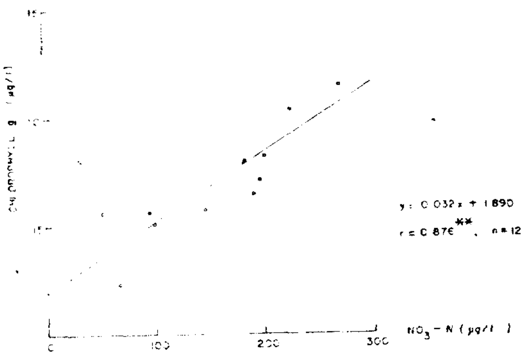

Fig. 4. Relationship between nitrate-nitrogen and chlorophyll *a* at a fixed station in April.

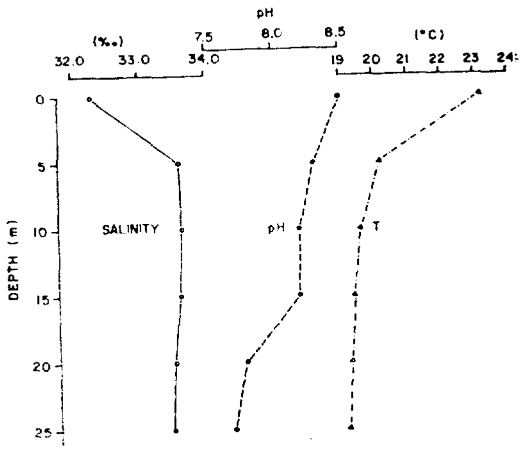

Fig. 5. Vertical distribution of general water quality parameters in June.

station 8 than at station 6. High chlorophyll *a* concentrations were related to the high water phase. It appears that the water characteristics at the time of high tides of 1532 June 10 and 0358 June 11 are different from each other. The latter did not accompany the increase in salinity, phosphate and chlorophyll *a* contents as the former. It seems that water displacement in the Jinhae Bay during the tidal cycle are so complicated that we could not observe the same water masses comming in and out of the bay. Relationship between phosphates and chlorophyll *a* for all 25 samples taken in June are shown in Fig. 7.

In August, surface temperature often exceeded 30°C and vertical thermal gradient is steeper than that being ever measured during the year (Fig. 8).

Dissolved oxygen was quasi-depleted in the bottom waters and pH showed a marked decrease from surface to bottom.

High nitrate concentrations were found at 1100 (432μgN/1) and at 1300 (379μgN/1), which are around the time of low tide (Fig. 9).

Phosphate concentrations were again high at the time of high tide suggesting strongly that phosphate supply was more active in the outer bay than in the inner bay. Diurnal chlorophyll *a* distribution pattern is very much similar to that of phosphates. Phosphates were again related to chlorophyll *a* in August (Fig. 10).

DISCUSSION

The inner Masan Bay waters receive wastewaters directly from the urban and industrialized area and are believed to contain high concentrations of nutrients as well as those of other pollutants (KORDI, 1981).

Thus it is natural to observe that nutrient concentrations decrease from the inner bay to the outer bay. But as shown above, nitrogen seems to be mainly supplied from the outfalls of Masan area while phosphates from Budo area.

Since the phosphate concentrations are related to the chlorophyll *a* concentrations in this area, it is of interest to discuss in further detail the origin of high phosphate water in the outer bay.

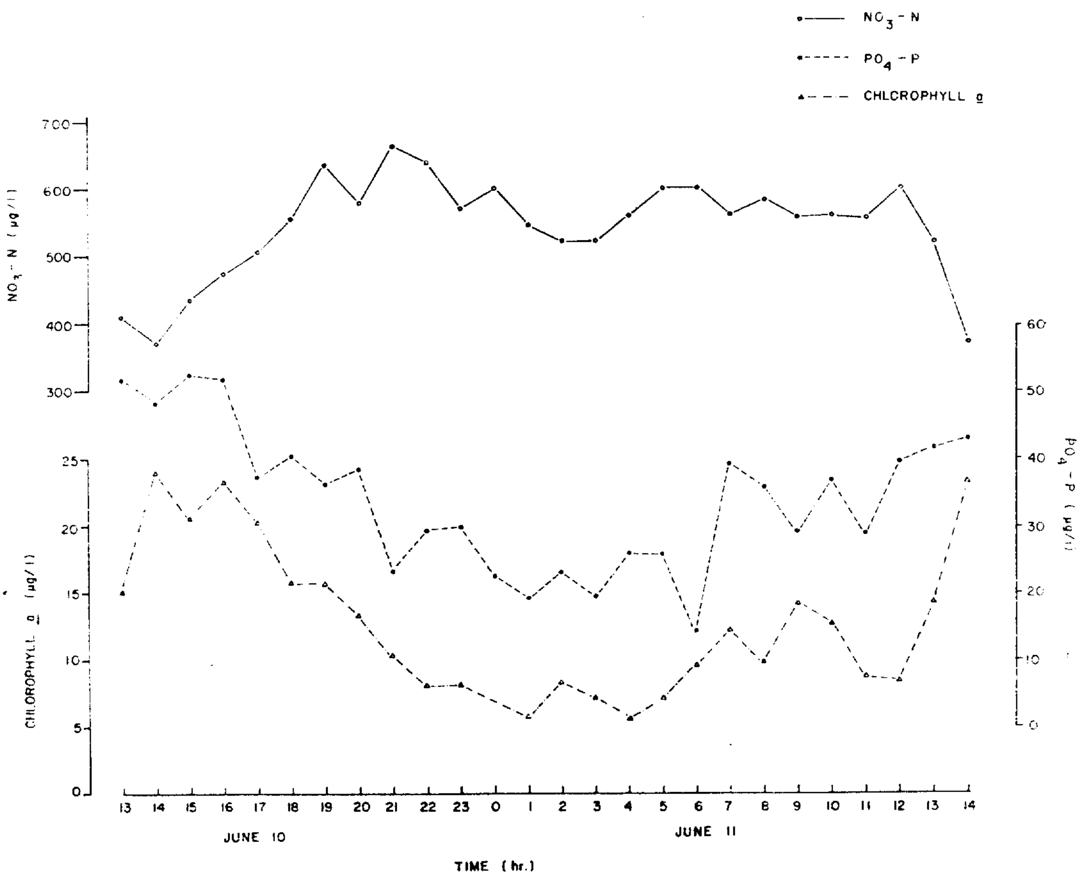

Fig. 6. Variations of nitrate-nitrogen, phosphate-phosphorus and chlorophyll *a* at a fixed station in June

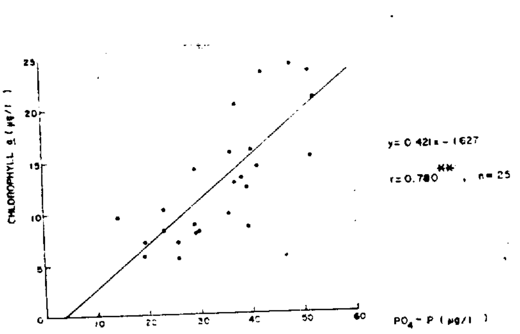

Fig. 7. Relationship between phosphate-phosphorus and chlorophyll *a* at a fixed station in June.

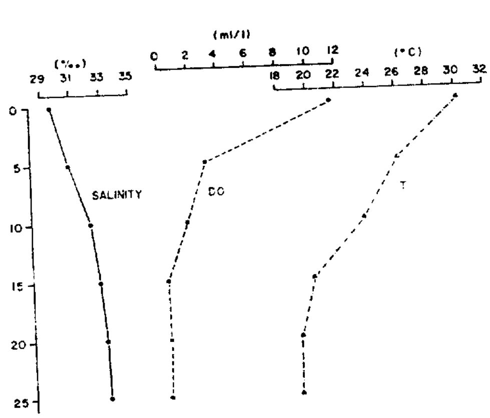

Fig. 8. Vertical distribution of general water quality parameters in August.

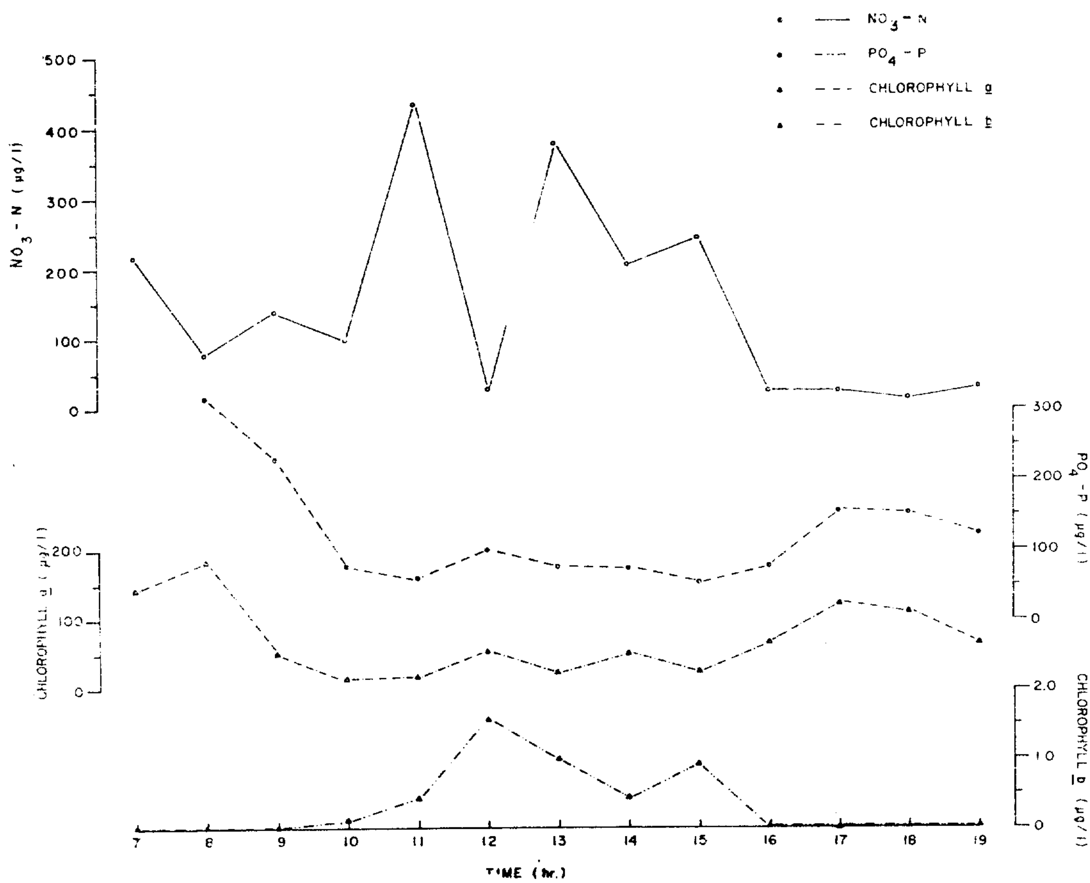

Fig. 9. Variations of nitrate-nitrogen, phosphate-phosphorus, chlorophyll *a* and chlorophyll *b* at a fixed station in August.

Origin of high phosphate

The monthly observations of KORDI(1981) on the whole area of the Jinhae Bay from April through November 1981 showed also

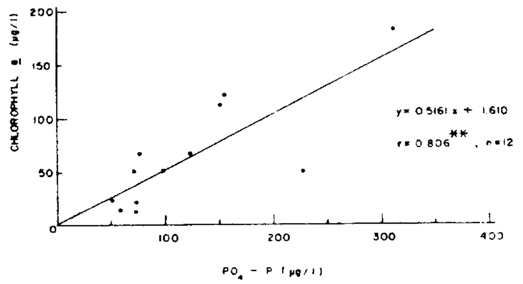

Fig. 10. Relationship between chlorophyll *a* and phosphates at a fixed station in the Jinhae Bay in August.

that phosphate concentrations at our fixed station exceeded largely that of a station which is located further inside the Masan Bay.

Our fixed station is located in the vicinity of the Haengam Bay which receives also domestic and industrial wastewaters from Jinhae area but to a lesser extent than in the Masan Bay.

The surface waters of the Haengam Bay are known to contain much more phosphates than other neighboring areas and it is believed that this high concentrations of phosphates would disperse into the whole Jinhae Bay (Park, 1975). Nevertheless observations from April through November in 1981 (KORDI, 1981) showed that the waters at our fixed station frequently contained more phophates than the waters of the Haengam Bay contrary to the previous observations.

Although these data are based upon the analyses of discrete samples taken without considerations of tidal variations, it suggests at least that the high phosphate contents in the Jinhae Bay were not always related to the waters of the Haengam Bay.

Another possible source of phosphate supply is from bottom waters rich in phosphates. At our fixed station (station 7) phosphate concentration in bottom waters in June, July and August, 1981 were 64.1, 110.5 and 136.8μgP/1 respectively (KORDI, 1981).

These high phosphate concentrations could not be found out in both surface and bottom waters of the Haengam Bay throughout the year 1981. Fitzerald (1970) has already shown that in anaerobic conditions, phosphates in lake muds would disperse out into bottom water. Honjo (1974) has pointed out that in Hakata Bay, phosphates and ammonia are sufficiently supplied into seawater from bottom mud when the concentration of oxygen or pH is low in bottom layer water. He suggested also that surface water could be enriched with these nutrients when there is a mixing which breaks discontinuous layers, and supplies directly nutrients from bottom water.

In the Jinhae Bay, we could also suppose that high phosphates could be resulted from the bottom mud since dissolved oxygen conc entrations in the bottom waters were nearly zero in summer and pH ranges from 7.5 to 7.9 which is comparable to the anoxic conditions of the Hakata Bay (Honjo, 1974). This hypothesis might be supported by the fact that at our fixed station, bottom phosphate concentrations increased as oxygen deficient conditions became more and more severe from June to August.

Nutrients and phytoplankton blooms

Although chlorophyll *a* concentrations were related to the nitrate contents in April and to the phosphate contents in June and August during our observations, phytoplankton growth are not likely to be limited by these nutrients. In June and August, phosphate contents mostly exceeded 20μgP/1 above which level phytoplankton growth are not limited according to Kuhl (1974). Thus it is more probable that the role of unknown growth promoting substances were major in provoking the extensive phytoplankton blooms in the area studied. Honjo (1974) suggested that in the Hakata Bay, growth stimulators are formed on the anoxic sediment and that these materials upon arriving on surface could enhance massive blooms of red tide organisms. In our sampling area, these materials could also be formed on the anoxic sediment which liberates phosphates as well. In this case we could observe high biomass together with high concentrations of phosphates at the time of phytoplankton blooms. But it should make clear whether there exists intense vertical mixing which allows bottom waters to reach the surface during the blooming period. In August 1981, it was reported that in the Jinhae Bay, red tides were initiated from the intermediate layer after the passage of violent typhoon "Ogden".

But more detailed physical survey and biological experiments should be performed in the Jinhae Bay to complete the understanding of red tide outbreaks.

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