D-1.1.1 Study on the development of method for oceanographic observation to understand the response of ecosystem and material cycle to the riverine load

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Abstract In order to understand the effect of the Changjiang River on the marine environment and the marine ecosystem in the East China Sea, an investigation was conducted offshore from the Changjiang River in October 1997 and May 1998. Temperature and salinity distributions were used to understand the structure of the water mass. It was shown that the Changjiang water plume (below 30‰ salinity) flows in the surface layer (less than 10 m depth) and reaches as far as long 123°E in autumn and long 124°E in spring. Nutrient distribution was used to understand nutrient supply from the river. The N/P atomic ratio in the coastal area was as high as 32 in autumn and 47 in spring, which indicates that there is an excess of nitrogen supplied from the river. The dominant phytoplankton species in autumn (diatoms) were different from those in spring (dinoflagellates). The reason for this was not depletion of silicate in spring, but other factors (stratification of water, N/P ratio, etc.). In order to examine the possible input of anthropogenic heavy metals from the river, the elemental compositions of suspended particles were analyzed; the main sources of 26 elements in the suspended particles were soil particles or plankton. Nutrient concentrations in the pore water of bottom sediments were analyzed to estimate what quantity of nutrients can be released from the sediment to the water column. PO_4^{3-} concentrations in pore water were 4 to 30 times higher than that of the water column, indicating that PO_4^{3-} can be supplied to the water by disturbance of bottom sediments, which is strongest in winter.

Key Words Changjiang estuary, Nutrient, Phytoplankton, Suspended particles

1. Introduction

The Changjiang River is the largest source of freshwater flowing into the East China Sea. The discharge of the Changjiang River is about 1×10^{12} m^3 annually [1], as large as 2% of the volume of East China Sea; therefore, the river affects not only the estuary but also the marine environment and ecosystem over a wide area of the East China Sea. Because of recent growth in population and agricultural production in the Changjiang River catchment, pollution by domestic waste and fertilizer released to East China Sea has increased, and occurrences of harmful algal blooms have been frequently reported. [2] Further human activity in the Changjiang catchment, including industrialization and water-resource development, such as the construction of the Three Gorges Dam, may alter the supply of freshwater, sediment, and nutrients to the East China Sea. It is essential to understand the present behavior of Changjiang River water and its relation with the marine ecosystem and element cycle in the East China Sea in order to predict and evaluate the effects of future anthropogenic loads from the Changjiang. The purpose of this sub-theme in the project is to estimate the effect of contaminants from the Changjiang River on the marine ecosystem (mainly phytoplankton) and the element cycle in the estuary of the Changjiang River and East China Sea. Here, the results of the investigation in the East China Sea are reported.

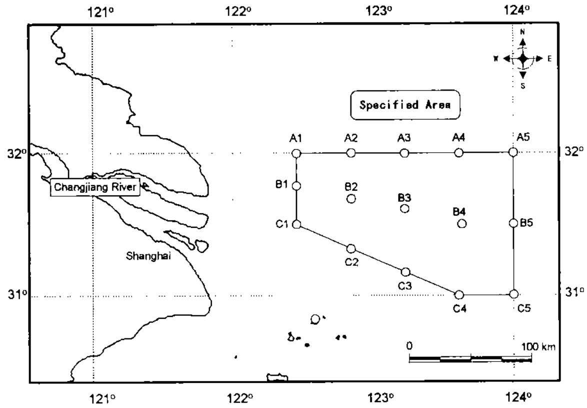

Figure 1. Location of the area specified in the agreement of Japan-China Collaborative Research in the East China Sea.

2. Method

The investigation was carried out between latitudes 31°00'N and 32°00'N and longitudes 122°30'E and 124°00'E , the area in the East China Sea specified in the agreement of the Japan-China Collaborative Research Project (Fig. 1). Two cruises were conducted from 19 to 20 October 1997 (autumn cruise) and 14 to 17 May 1998 (spring cruise), aboard the research vessel "Haijian 49" of the China State Oceanic Administration. At 15 stations in the specified area (A1 to C5, Fig. 1), vertical profiles of temperature, salinity, pH, dissolved oxygen, and redox potential of water were measured *in situ* using a Hydrolab's Surveyor II. At 9 stations (A1, A3, A5, B1, B3, B5, C1, C3, and C5), seawater was collected from the surface, middle (according to the water depth), and bottom (1 m above the sea bed) layers using 20-L Niskin samplers, and subjected to analyses of nutrients, particulate organic carbon and nitrogen, and dissolved organic carbon. For identification of phytoplankton and zooplankton, samples were taken with a plankton net. For analyses of the elemental composition of suspended particles, water was filtered on board using a

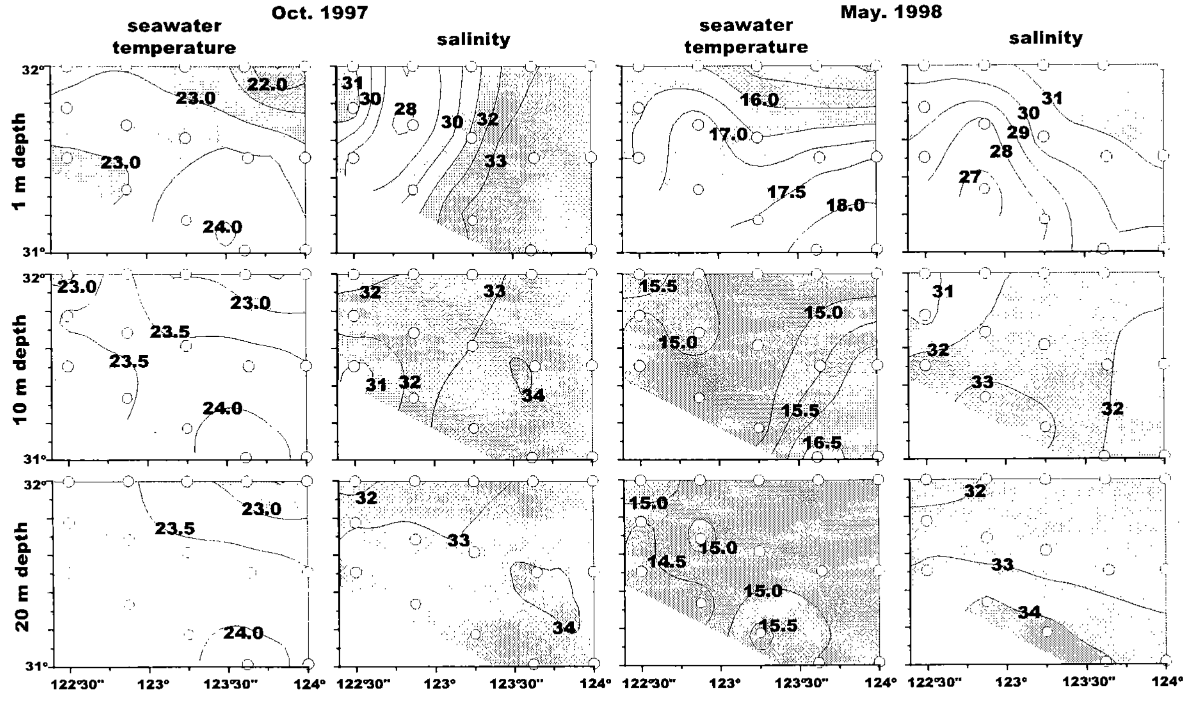

Figure 2. Horizontal distributions of temperature and salinity in autumn and spring.

Nuclepore filter (0.4-µm pore size) and the filters were subjected to ICP-AES and NAA analysis. At 5 stations (A1, A3, B1, C1, and C3), bottom sediment samples were taken with a multiple corer. Pore water in the sediments was extracted on board then subjected to nutrient analysis in the laboratory.

3. Results and Discussion

1) Structure of the water mass in the investigation area in the East China Sea

The structure of the water mass was examined from distributions of temperature and salinity. Horizontal temperature profiles (Fig. 2) show that the Taiwan Warm Current from the south and the Yellow Sea Coastal Current from the north influenced the area under investigation in the East China Sea. The horizontal salinity profiles at 1 m depth (Fig. 2) show that the fresh water from the Changjiang River mixed with water from the Taiwan Warm Current (34‰ salinity) and the Yellow Sea Coastal Current (31‰) and formed a plume of low-salinity Changjiang water (less than 30‰). In the vertical temperature and salinity profiles (Fig. 3), both the thermocline and halocline were found at a depth of 10 m. The low-salinity Changjiang water forms a thin layer less than 10 m deep that flows over the high-salinity water mass. The plume of Changjiang water reached as far as long 123°E in autumn and long 124°E in spring; it is larger in spring than in autumn possibly because snowmelt in the upper catchment of the Changjiang River increased discharge.

2) Plankton abundance and nutrient supply in the investigation area in the East China Sea

The dominant phytoplankton were diatoms in autumn and dinoflagellates in spring. Factors known to determine the dominant phytoplankton species include selective grazing by zooplankton, nutrient conditions such as Si concentration or N/P ratio, and vertical distribution of nutrients.

Diatoms need Si in order to proliferate; if Si is depleted diatoms cannot increase and dinoflagellates may become dominant. However, there was enough Si in the area studied in both seasons (Fig. 4), and the dominance of dinoflagellates in spring cannot be attributed to low Si concentrations.

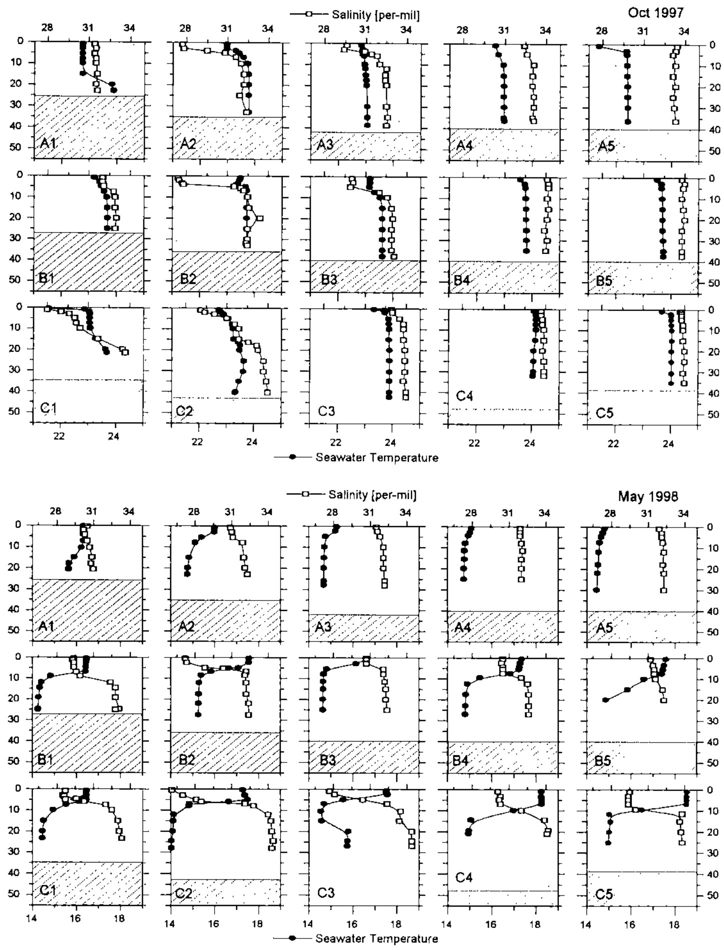

Figure 3. Vertical profiles of temperature (˚C) and salinity (‰ [per-mill]) in autumn and spring.

The N/P ratio is thought to influence the annual transition of dominant phytoplankton for various reasons, among which are the following: the rate at which phytoplankton increase is influenced by N/P ratio, different species of phytoplankton favor different N/P ratios,[3] and cyst formation is related to N/P ratio. The atomic ratio of N/P (dissolved inorganic nitrogen : dissolved inorganic phosphorous) at station C1 was 32 in autumn and 47 in spring (Fig. 5), either of which was higher than the Redfield ratio (16:1). This means that water from the Changjiang River delivered an excess of nitrogen to station C1 in both seasons. Higher N/P ratios were observed at stations B3 and C3 in spring. However, these high N/P ratios might be a result of DIP consumption by phytoplankton and cannot be a reason for dinoflagellate dominance. Using only the data of autumn and spring, we cannot conclude that a difference in the N/P ratio was the reason for the difference in dominant phytoplankton species. However, it is reported that the winter N/P ratio is as small as the Redfield ratio and the summer N/P ratio is higher than the values observed in this study. Therefore, seasonal changes in the N/P ratio may occur as a result of seasonal changes in the Changjiang discharge. The N/P ratio in winter or summer may influence cyst formation or germination of phytoplankton and consequently cause blooms in spring or autumn. The influence of the N/P ratio on species succession may be revealed after consideration of the annual lifecycle of phytoplankton.

Vertical distribution of nutrients may also explain the dominant phytoplankton species. In stratified water, where

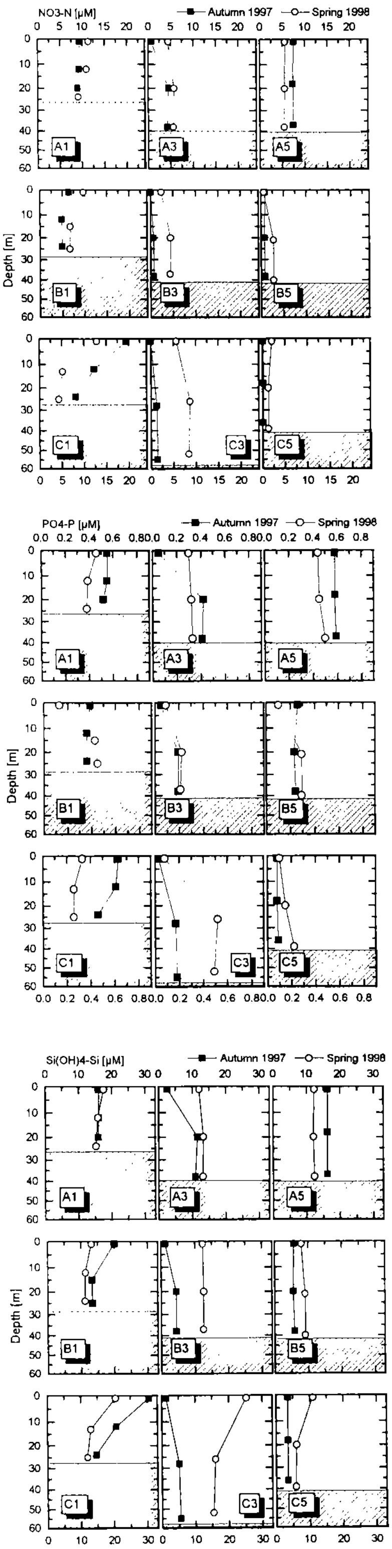

Figure 4. Concentrations of NO_3 (upper), PO_4^{3-} (middle), and $Si(OH)_4$ (lower).

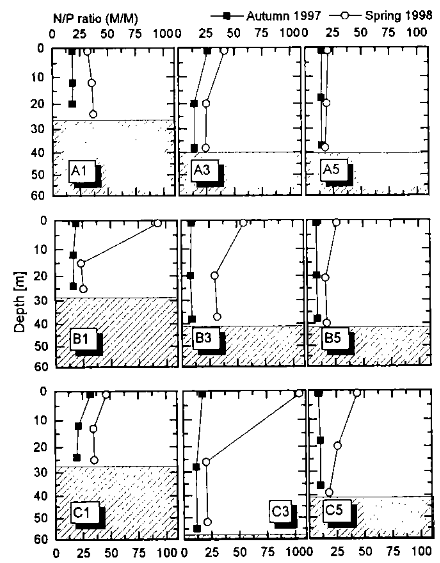

Figure 5. N/P atomic ratios

nutrients are more abundant in the lower layer than in the upper layer, phytoplankton can increase rapidly if they are able to take up nutrients in the lower layer and photosynthesize in the upper layer which has stronger light.[4] Dinoflagellates can swim and can make the vertical migration, whereas diatoms cannot. In spring, stratification of water was observed at almost all stations (Fig. 2), whereas in autumn, stratification of water was observed at only a few stations. As the result of the stronger stratification in spring there was a larger difference in nutrient concentration between the surface water and middle water. Therefore, it seems that vertical distribution of nutrients in spring created conditions suitable for a dinoflagellate bloom.

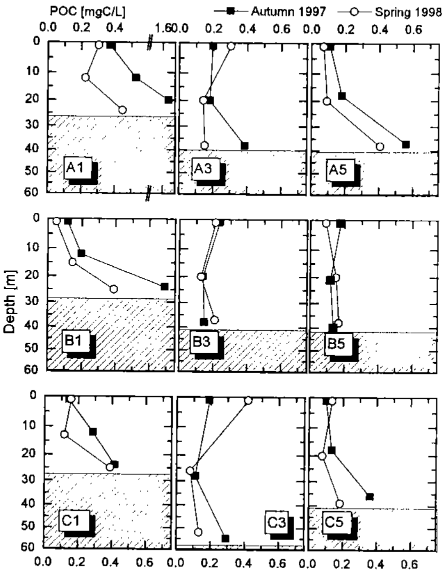

Figure 6. POC concentration

3) Origin of suspended particles in the investigated area in the East China Sea

The concentration of particulate organic carbon (POC) in water (Fig. 6) was related to the abundance and species of plankton. POC in bottom water was higher than that in surface water, which reflected the sedimentation of phytoplankton from the surface to the bottom, and POC in bottom water was higher in autumn than in spring. This may be because the predominant phytoplankton in autumn were diatoms, which cannot swim and sink more easily to the bottom. The average concentration of dissolved organic carbon (DOC) was also related to species of plankton. It is often reported that diatoms release semi-refractory DOC when nutrients are depleted during diatom blooms in coastal waters.[5] In this study, higher DOC was observed in autumn (1.46 mgC/l) than in spring (1.06 mgC/l), one of the reasons for which may be DOC released by diatoms.

The X/Al ratios (the concentration of the element X as a fraction of Al concentration) in the suspended particles are expected to have different values depending on the main source of the element X. We derived the X/Al ratios for 24 elements in suspended particles. For 7 elements, there were large differences between the X/Al

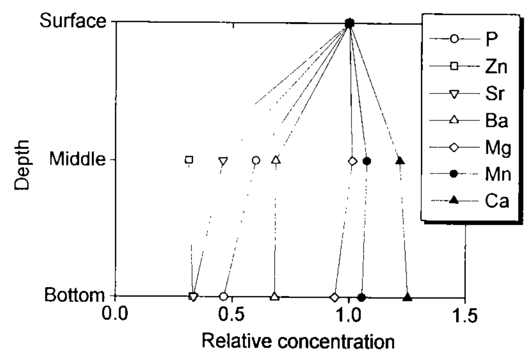

Figure 7. Elemental compositions of suspended particles (autumn, Station C5).
Relative concentration = $(X/Al)/(X/Al)_{surface}$

Table 1. X/Al values of suspended particles (this study), mean crust and median soil content (Bowen, 1979).

Ele.	X/Al (ppm/ppm)		
	Suspended particles	Mean crust	Median soil content
As	2.0E-04	1.8E-05	8.5E-05
Ce	8.0E-04	8.3E-04	7.0E-04
Co	2.0E-04	2.4E-04	1.1E-04
Cs	1.0E-04	3.7E-05	5.6E-05
Fe	4.9E-01	5.0E-01	5.6E-01
Hf	5.0E-05	6.5E-05	8.5E-05
La	4.0E-04	3.9E-04	5.6E-04
Ni	6.0E-04	9.8E-04	7.0E-04
Pb	5.0E-04	1.7E-04	4.9E-04
Sc	1.0E-04	2.0E-04	9.9E-05
Sm	7.0E-05	9.6E-05	6.3E-05
Th	2.0E-04	1.5E-04	1.3E-04
Ti	5.0E-02	6.8E-02	7.0E-02
V	1.4E-03	2.0E-03	1.3E-03
Y	3.0E-04	3.7E-04	5.6E-04
Yb	4.0E-05	4.0E-05	4.2E-05

ratios in the surface and bottom waters (Fig. 7). The X/Al ratios of P, Zn, Sr, Ba and Mg in particles from bottom waters were lower than in those from surface waters, and Mn/Al and Ca/Al in bottom water particles were higher than in those from surface waters. Plankton in surface waters may be the source of particulate P, Zn, Sr, Ba and Mg, resulting in the higher concentrations of these 5 elements in surface waters. Higher Mn and Ca concentrations may result from re-suspension of bottom sediments, which contain more Mn and Ca than do particles suspended in surface waters. The X/Al ratios of As, Ce, Co, Cs, Fe, Hf, La, Ni, Pb, Sc, Sm, Th, Ti, V, Y and Yb remained constant regardless of season, station, or depth, which implies that the sources of these 16 elements do not change. The X/Al ratios of this group of elements were close to either mean crust or median soil contents,[6] except for As/Al and Cs/Al ratio, which were twice as high as the median soil content (Table 1). In this preliminary observation, no influence of anthropogenic heavy metals could be detected. However, this does not mean there is no input of pollutants from the river—because large amounts of naturally occurring particles from the river exist in this area, they can dilute and hide the effects of pollutants.

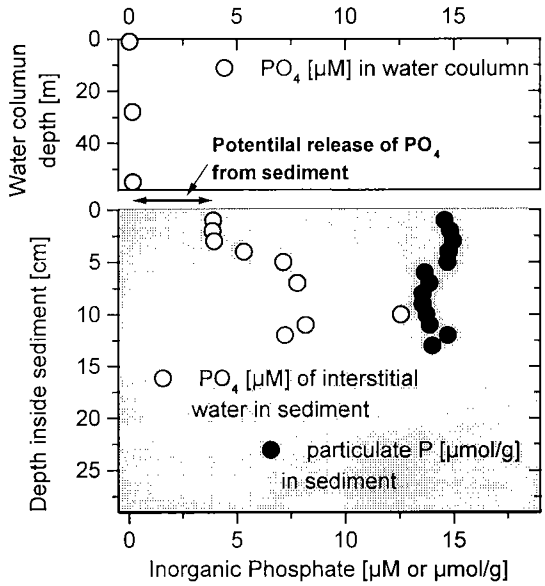

Figure 8. Concentrations of phosphorus in the water column, sediment, and pore water (autumn, Station C3)

4) Nutrient stock in the bottom sediment of the investigated area in the East China Sea

In shallow coastal seas like the area studied (20 to 50 m depth), bottom sediments play a role as a stock of organic matter sedimented from the water column. The organic matter in the sediment is decomposed to inorganic nutrients and released back to the water column. To estimate the quantity of nutrient that can be released from sediment, we analyzed nutrient concentrations in the interstitial water of the sediment. The concentrations of PO_4^{3-} in interstitial water (1.4 to 6.0 μM) was higher than in the water column (0.1 to 0.4 μM) (Fig. 8); that means release of interstitial water can increase the concentration of PO_4^{3-} in the water column. In spring, PO_4^{3-} in pore water was lower than in autumn. It is known that re-suspension of bottom sediments is stronger in winter than in other seasons and, therefore, it is assumed that PO_4^{3-} in pore water decreases in winter as it is released to the water column.

4. Conclusion

The investigations conducted in autumn and spring in the Changjiang estuary showed the following points:

1) The Changjiang water plume (below 30‰ salinity) flowed in the surface layer (less than 10 m depth) and reached as far as long 123°E in autumn and long 124°E in spring.

2) The dominant species in autumn (diatoms) were different from those in spring (dinoflagellates), the reason for which was not depletion of silicate in spring but other factors (stratification of water,

N/P ratio, etc.). The N/P atomic ratio in the coastal area was as high as 32 in autumn and 47 in spring, which indicates an excess supply of nitrogen from the river.
3) The main sources of 26 elements analyzed in the suspended particles were soil particles or plankton. This reflects the condition in this area that there is a large amount of natural particles from the river, which can dilute and hide the effect of pollutants.
4) PO_4^{3-} concentrations in pore water was 4 to 30 times higher than in the water column, suggesting that PO_4^{3-} can be supplied to the water by disturbance of bottom sediments, which is strongest in winter.

References

1) Fairbridge, R. W. (1980) The estuary: its definition and geodynamic cycle. In: Olausson, E., Cato, I. (eds.) Chemistry and biochemistry of estuaries. John Wiley & Sons, New York, pp.1-35.
2) Zhu, M., Li, Ruixiang.,Mu, Xueyan., Ji, Rubao. (1997) Harmful algal blooms in China Seas. Ocean Research, vol. 19, no. 2, pp.173-184.
3) Yamaguchi, M. (1993) Influence of N:P ratio on rate of increase of phytoplankton. In: N:P ratio of water and marine biology. Kouseisya-Kouseikaku, Tokyo, pp.11-19 (In Japanese)
4) Watanabe, M., Kohata, K., Kimura, T., Takamatsu, T., Yamaguchi, S., and Ioriya, T. (1995) Generation of a Chattonella antiqua bloom by imposing a shallow nutricline in a mesocosm. Limnol. Oceanogr., 40, 1447-1460.
5) Norrman, B., Zwifel, U. L., Hopkinson C. S. Jr., Fry, B. (1995) Production and utilization of dissolved organic carbon during an experimental condition diatom bloom. Limnol. Occeanogr. 40, pp.898-907.
6) Bowen, H.J.M. (1979) Environmental Chemistry of the Elements, Acad. Press (London), pp.333.