D-3.1 Study on the Time-Space Variability of the Marine Biogeochemical Parameters Based on the *in situ* Ferry Monitoring and Satellite Ocean Color Sensing

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Abstracts: From biogeochemical time series obtained from ferry-based monitoring system, three types of seasonal cycles in (DIP, DIN, DSi and phytoplankton species composition) were defined. Type (a) is characterized by the less anthropogenically affected area, where DIN, DIP are depleted and DSi remains after the termination of diatom-based blooms. In Type (b), residual DIN and DIP favors dinoflagellates after the bloom. In Type (c), the remineralization of sedimental organic matters keep the level of nutrients. There is a possibility of ecological changes from type (a) to type (b) or (c) in the Asian marginal seas because of the change of Si and other nutrient loading originated from large scale land-use modifications on the continent.

1.Introduction

Increase of human activities due to population increase, rapid industrialization and the consequent increase in fertilizers production have strongly impacted the cycling of elements such as C, N, and P. These perturbations are thought to have impacted the ocean in the sense of the long-term ecological changes. They are caused by complicated combinations of physical, chemical and biological factors. One of the points of marine ecological changes has been caused by over-loading of N and P and/or depletion of Si. The shifts in dominant phytoplankton from diatom to non-diatom species may be attributed to such anthropogenic factors1). While the supply of Si is mainly due to natural weathering, the discharges of N and P are largely due to human activities. When Si is depleted by uptake of diatoms in the spring bloom and residual N and P still remain, non-diatom species are thought to cause secondary blooms.

It is an urgent issue to build an appropriate methodology to evaluate these changes meeting following requirements: (a) holistic approach for the conprehensive understanding of ecosystem health; (b) spatial and temporal intervals sufficient to resolve phenomena over various scales; (c) linkage with satellite missions, particularly to those with ocean color sensors; (d) long duration; (e) minimazation of the cost for the operation and maintenance of the observation platform.

2.Research objectives

Above reauirements are fulfilled by using ship-of opportunities or voluntary observation ships (VOS), particularly using their sea water intake. We have been performing marine

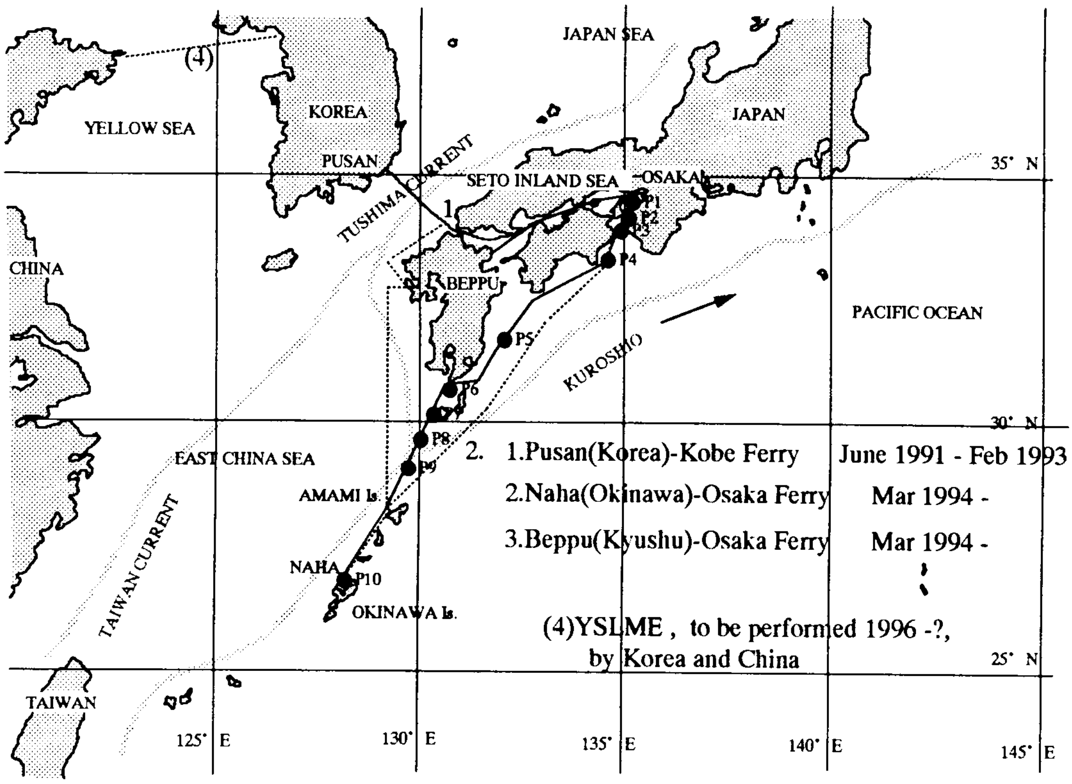

Fig.1 Ferry cruise tracks.

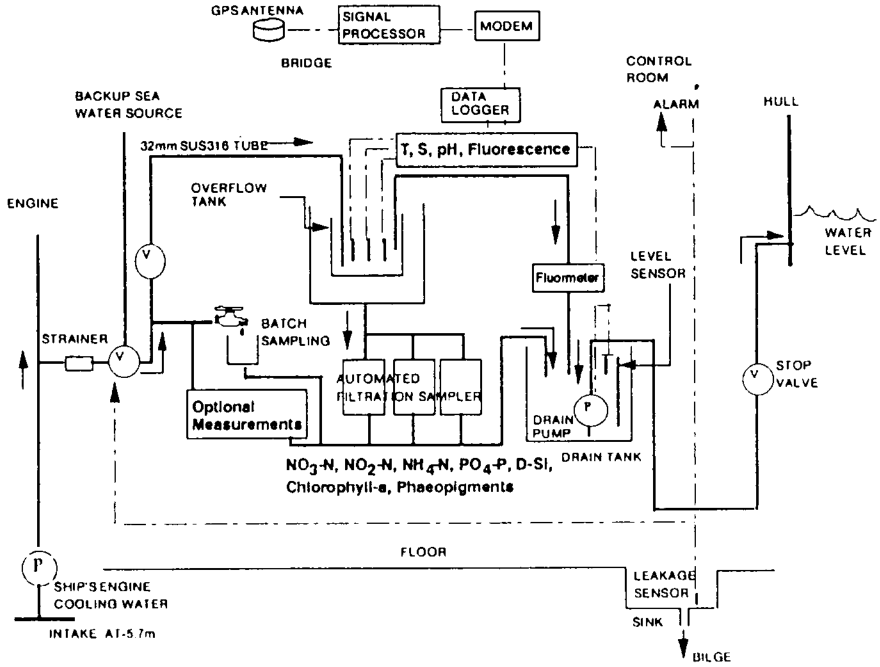

Fig.2 Set up of the batch sampling and optional measurement units built in the unmanned monitoring system. This system was deployed on Sunflower2 (Kansai Kisen, Co., Ltd).

biogeochemical monitoring based on ferry lines between (1) Pusan - Kobe[1),2)]; (2) Beppu -

Seto Inland Sea - Osaka and (3) Okinawa - Osaka5) (Fig.1). A part of these data were published in a CD-ROM4) and distributed to the pertinent organizations including JODC and NOAA-NODC. These data showed the basic seasonal cycles of phytoplankton biomass and environmental variables (water temperature, salinity, pH, chlorophyll-fluorescence, NO_3-N, NO_2-N, NH_4-N, PO_4-P, Dissolved Si). The objectives of the present D3(1) is to clarify the anthropogenic components in the ecological changes from the detailed time series of phytoplankton characteristics (species constituents, size spectra). It was done by carrying out manned cruises using the batch sampling and optional measurement units shown in Fig.2.

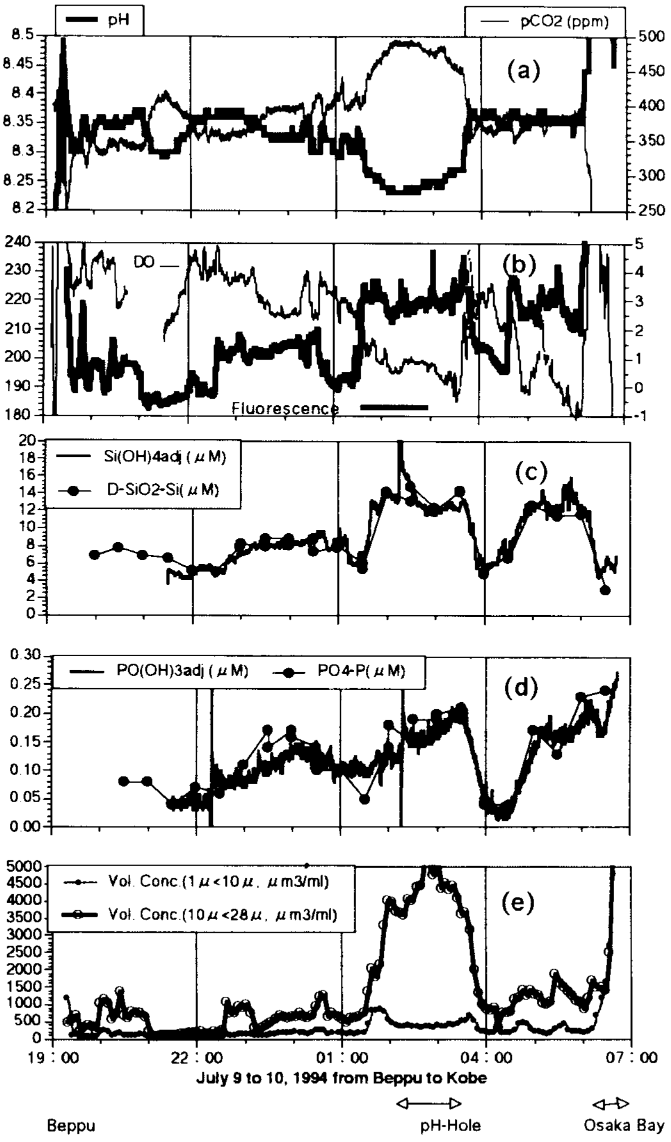

Fig.3 Distribution of (a) Dissolved pCO2 (thin line) and pH (thick line), (b) dissolved oxygen (thin line) and chlorophyll-fluorescence (thick line), (c) DSi: dissolved silica (d) DIP: phosphate, (e) volume concentration of medium-sized phytoplankton (circle) and small-sized phytoplankton (dot) measured by Lazer Bio-particle Counter in the July 9-10, 1994 Cruise of Sunflower2, Beppu (left) - Seto Inland Sea - Osaka (right).

3.Methods

In addition to the regular automated monitoring, manned investigations were performed research-oriented work. The development and evaluation of new sensing technologies were also performed. Taxonomy and counting of plankton were done by optical and fluorescence microscopes8). The measurements of the phytoplankton size spectra were done by Laser Bio-Particle Counter6). This apparatus counts the pulses of fluorescence from chlorophyll-containing particles excited by laser beam transmitted via a glass fiber. Assuming that the intensity of each pulse is proportional to the chlorophyll contained in each cell and that the amount of chlorophyll per unit of cell volume is essentially uniform, then the integration of pulses for a fixed time span, usually 5 minutes, yields the phytoplankton size spectrum. The partial pressure of CO_2 dissolved in the sea water was measured with a seawater CO_2 analyzer 7) with a bubble-type equilibrator to improve time response.

4. Results

In the observation performed in the midst of the spring bloom (March, 1994), Chlorophyll-a was relatively high and the dominant phytoplankton was diatom in most of the area. Level of pCO_2 were relatively lower and correlated inversely with the phytoplankton biomass reflecting the high photosynthetic intensity.

In the observation in July, 1994 (Fig.3), DIP (dissolved inorganic phosphorus) and DSi (dissolved silica) had been lowered in most of Seto Inland Sea reflecting the termination of spring bloom. However, two areas were of particular characteristics. In the area 1/3 from the right end of the figure, pH was lower than the surrounding area by 0.2 pH unit. We call it pH-hole area. Consistently with the low pH, dissolved pCO_2 was higher. It even exceeded the atmospheric pCO_2 level. Both of DIP and DSi were also higher. These facts imply the remineralization of organic matter in the sediment and consequent upper supply by vertical mixing. In Osaka Bay (right hand side), DIP was higher whereas DSi was lower unlike the pH-hole area.

From the phytoplankton taxonomy and Fig.3(e), it is seen that the small-sized cyanobakteria (*synechococcus*) dominated in the most of area. It is consistent with the low levels of DIP and DIN. On the other hand, medium to large sized diatoms appreared in pH-hole and dinoflagellates appeared in Osaka Bay, reflecting the residual (DIN, DIP, DSi) and (DIN, DIP), respectively.

Thus a criteria on the characteristics of the seas appear after the spring bloom terminates. For the more comprehensive illustration, data sets of Fig.3 were plotted in the other form, the phytoplankton biomass on DSi-DIP diagram (Fig.4).

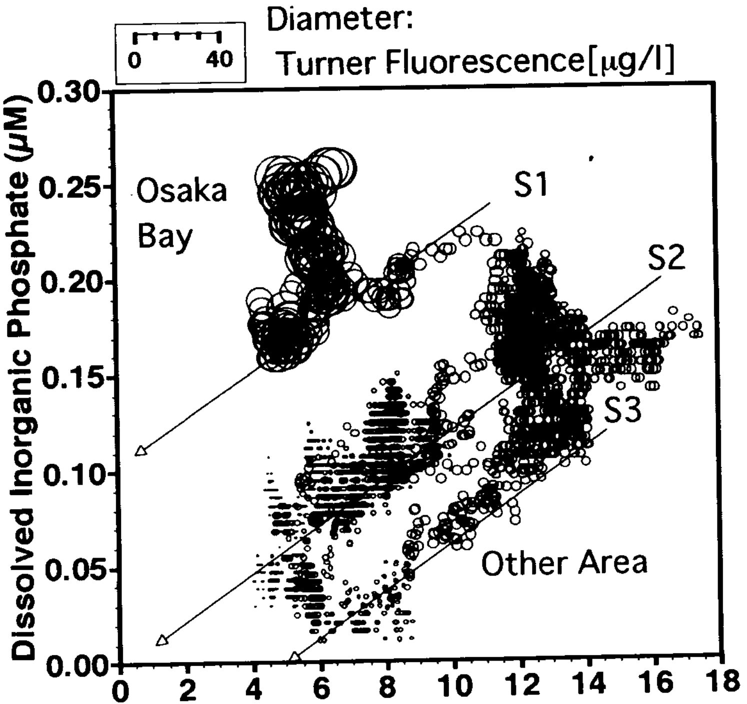

Fig.4 Phytoplankton bimass concentration measured by Turner Design fluorometer (shown by the diameter of the circles) plotted on the DSi (horizontal) and DIP (vertical) axes based on the same datasets of Fig.2. S1, S2, and S2 denotes the water qualities which the water masses possessed before spring bloom.

The lines that start from the points S1, S2, and S3 are the assumed trajectories along which DIP and DSi are uptaken in the course of phytoplankton blooms. In the most area, the process of nutrient decrease is shown by the trajectry from S2 or S3, *i.e.*, all nutrient species are depleted or certain amount of DSi remains in summer. On the other hand, the trajectory from S1 account for the Osaka Bay, where DIP (and DIN) remains after the termination of spring bloom. Such a high (N,P)/Si ratio, presumably due to the anthropogenic N and P loading, would favors dinoflagellates and actually the results of taxonomy shows the dominance of dinoflagellates and small sized flagellates.

5. Conclusions and remarks

From the time series investigation using the ferry as a platform, three types of seasonal cycles of (DIN, DIP, DSi, phytoplankton species composition) are defined. The point of assessing the anthropogenic impacts are based on the consideration that the increase of DIN and DIP basically comes from the human activities and Si comes from natural weathering. Type (a) is characterized by the less anthropogenically affected area, where DIN, DIP are depleted and DSi remains after the termination of diatom-based blooms. The other two types are thought to be

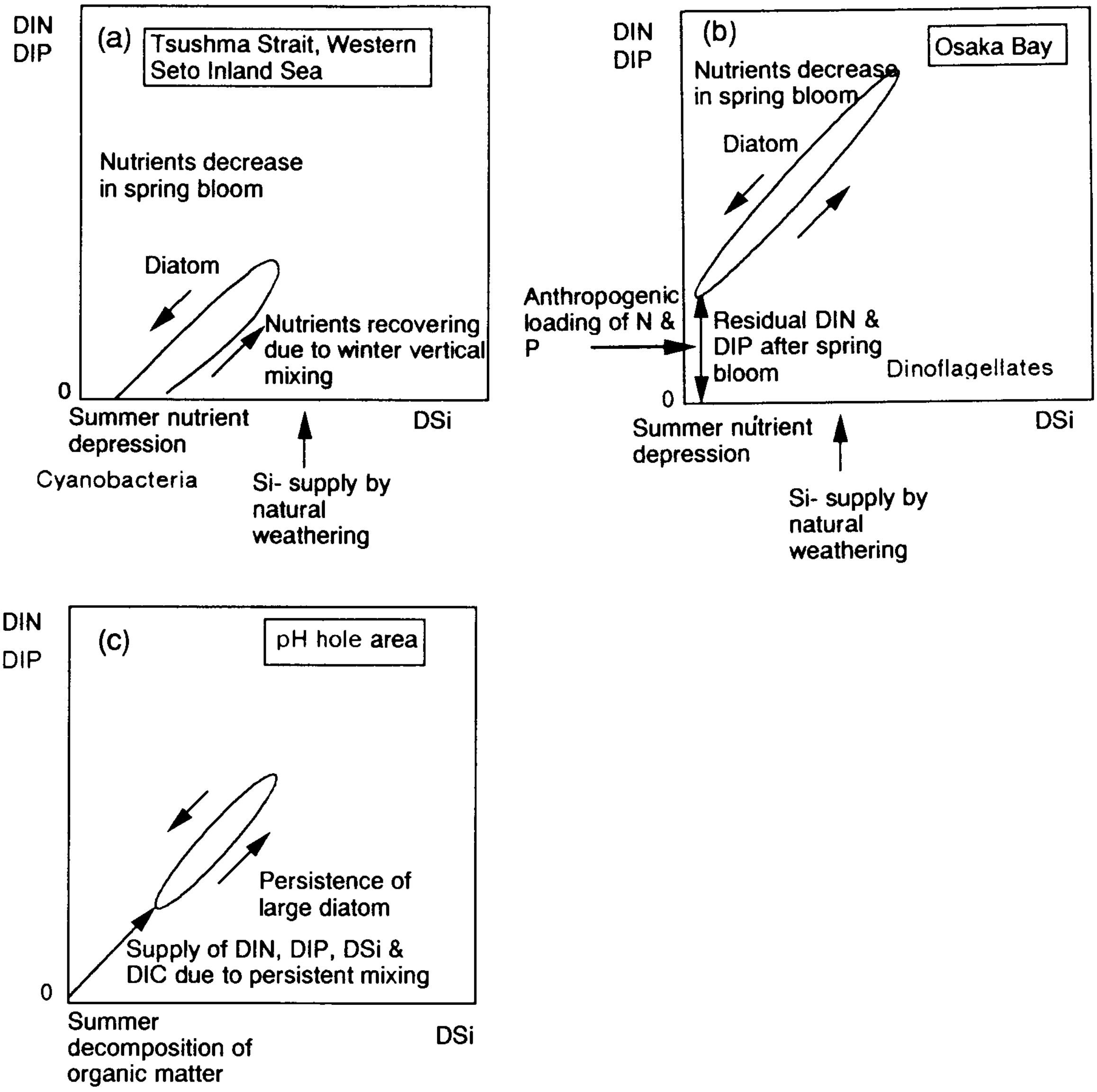

Fig.5 Three categories of the yearly cycle of DIN and DIP (dissolved inorganic nitrogen and phosphorus, vertical axis), DSi (dissolved inorganic silica, horizontal axis), and the dominant phytoplankton species in each phase of blooms.

resulted from anthropogenic factors. In Type (b), residual DIN and DIP favors dinoflagellates after the diatom-based spring bloom terminates. In Type (c), the remineralization of organic matters at the sea bottom raises the concentration of DIN, DIP, DIC/pCO2 and lowers pH. The continental shelf sea such as the Tsushima Strait still falls into the category (a), where N and P are depleted prior to Si in summer. However, the increase of human activities on the Asian continent such may cause the gradual shift from (a) to (b). Therefore it is of high priority to continue monitoring and *in situ* measurements such as those carried out in this program.

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