D-1 Research on biogeochemical cycle in the East China Sea responding to the change in environmental loading from land

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1. Introduction

The Changjiang River is the major source of freshwater, sediments and nutrients that flow into the East China Sea, which is one of the most productive oceanic shelves in the world in terms of biodiversity and standing stocks. Human activity in the Changjiang catchment area, including industrialization, agriculture and water-resource development, such as the construction of the Three Gorges Dam, may affect the aquatic, elemental and energy cycles in the catchment area. Ultimately, the supply of freshwater, sediments and nutrients to the East China Sea will be altered and, therefore, the environmental assessment of ecosystem structure and function is essential for the conservation of marine environment in the East China Sea.

2. Objective

The objective of the project is to provide a scientific basis for management measures to protect the environment and biological resources of the East China Sea, through researches such as the evaluation of environmental capacity for pollution and the prediction of its effects on the ecosystem in the East China Sea.

3. Results and Discussion

3.1 Cruise Survey in the East China Sea

To understand the response of marine ecosystem to the environmental load (e.g. terrestrial suspended matter and macro nutrients) through the Changjiang River, cruise surveys were carried out in the continental shelf area of the East China Sea (124～128°E, 29°30' ~ 32°45'N, Fig 1) in June 2002, August 2003, and August 2004. In every survey, we observed well-developed pycnocline between the Continental Coastal Diluted Water (CCDW) and the East China Sea Bottom Water (ECSBW) on the wide area of continental shelf. Also we observed invasion of the Changjiang Diluted Water (CDW), which is classified as a part of the CCDW but contains high concentration of inorganic nitrogen, into the surface layer at the stations located in the west end of the studied area (124 ~ 125°E). However, the extent of spread of the low salinity water (CDW) toward the east, and the CDW influence on phytoplankton abundance & distribution differed depending on whether the cruise was carried out before (June 2002) or during (August 2003 and 2004) the flood season of the Changjiang River (Fig.2).

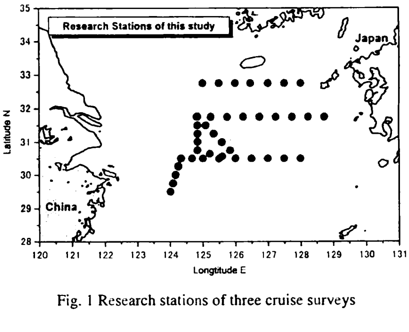

Fig. 1 Research stations of three cruise surveys

In June 2002 (before flood season), *Chaetoceros* and *Minidiscus comicus*, which are diatoms and generally observed in coastal environment, and *Synechococcus*, which is one of pico-sized algae and generally favors high nutrient environment, were predominant within the surface layer of CDW on 124°50'E. At the other adjacent stations located in the eastern side of 124°50'E, however, the CCDW and the Yellow Sea Coastal Current (YSCC) exceeded the CDW and higher abundance of phytoplankton was found around the pycnocline rather than within the surface layer (Fig. 3). In the stations beyond 126°E, cosmopolitan algal species in coastal environment disappeared, and oceanic algal species (e.g. Coccolithophorids and *Prochlorococcus*) became dominant.

In August 2003 and 2004 (more freshwater discharge from the Changjiang River occurred), the sea area affected by the CDW expanded, and it reached as far as 127 °E on the traverse line of 30°30'N (Fig. 2). In the lower layer, both the upwelling of the Kuroshio Subsurface Water (KSW) from the east and influence of the ECSBW from the south increased, and the strength of Yellow Sea Bottom Cold Water (YSBCW) decreased in the study area. With such a change in the balance of water masses, the nutrients were mainly supplied by the KSW, and phytoplankton accumulated near the pycnocline (Fig. 3). Coastal algae transported by the CDW reached even farther than nutrients, and accumulated just above pycnocline in each observation site. Effective uptake of these nutrients below the pycnocline enabled the coastal algal species to maintain their population, and to be distributed farther than the area where nutrients were transported through the CDW. It is suggested that the CDW is not only a transporter of nutrients discharged from the Changjiang

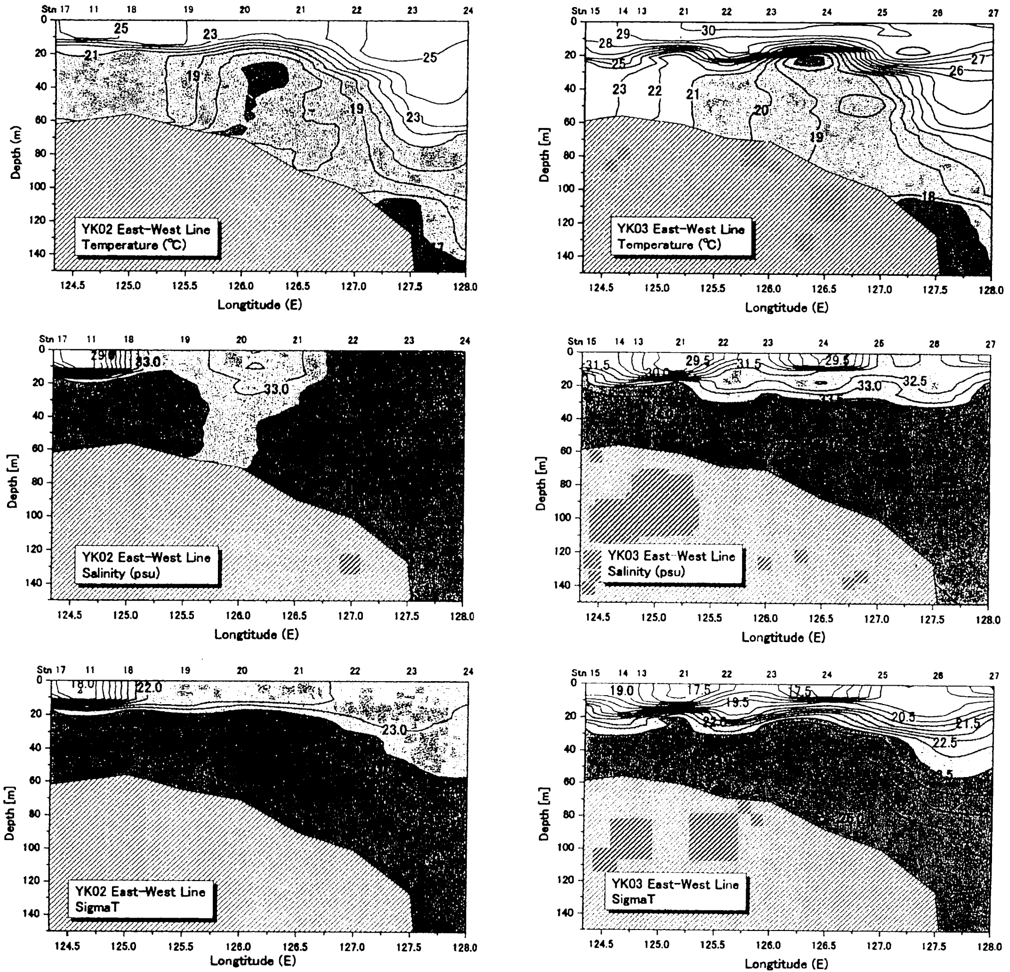

Fig. 2 Distribution of temperature, salinity and sigma T across the West-East section on 30°30'N in June 2002 (left) and August 2003 (right).

River but also that of coastal species of phytoplankton to the center of the continental shelf of the East China Sea.

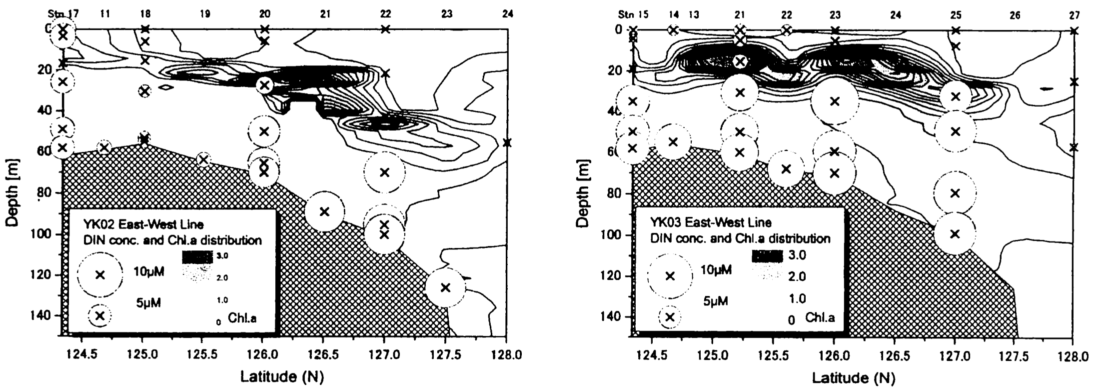

Fig. 3 Distribution of chlorophyll *a* (Chl.*a*) and dissolved inorganic nitrogen (DIN) concentrations across the West-East section on 30°30'N in June 2002 (left) and August 2003 (right).

To clarify the transport process of terrestrial matter on the continental shelf of the East China Sea, we determined $\delta^{13}C$ values of the suspended matter and surface sediment samples taken near the mouth of the Changjiang River, in its adjacent sea area, and on the continental shelf of the East China Sea from summer to autumn in the past 10 surveys from 1997 to 2003 including above surveys. The sediment load from the Changjiang River mostly deposits near the mouth of the Changjiang River in summer. The $\delta^{13}C$ value of suspended matter near the bottom in autumn was lower than that in summer, which indicates influx of terrestrial matter to the continental shelf in autumn (Fig. 4). In autumn the $\delta^{13}C$ value of suspended matter near the bottom was very low on the outer shelf and it was comparable to that around the Changjiang estuary. It is suggested that terrestrial matter originated from the Changjiang River is transported across the continental shelf to the outer shelf in autumn due to no low $\delta^{13}C$ of surface sediment on the outer shelf. It is considered that the transport process of the terrestrial matter in autumn is caused by the change of the current direction on the continental shelf of the Eat China Sea due to the beginning of the northerly monsoon burst.

3.2. Sediment Discharge Variation during the Last 50 Years Recorded in Marine Sediments

The accumulation rates of delta front to prodelta regions of the Changjiang (Yangtze) delta have clearly decreased for the last 10-20

Table 1. Accumulation rates of three core sites

	surface Pb-210	Cs-137 (bottom: Pb-210)
Y5 core WD 14.5m	2.0 cm/y	2.8-2.9 cm/y
Y6 core WD 19.7m	2.2 cm/y	3.5 cm/y (2.4-4.5)cm/y
Y7 core WD 26.8m	1.8 cm/y	4.3-6.6 cm/y (4.3 cm/y)

WD: water depth

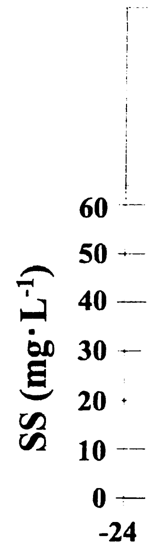

Fig. 4 Relatic

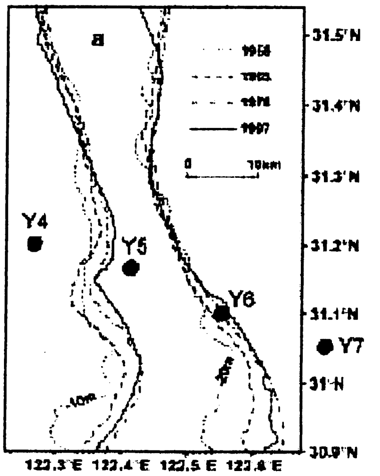

Fig. 5 Core locations for Y-4 to Y-7 and bathymetry changes from 1958 to 1997

years in response to the decrease of sediment discharge due to dam construction in the drainage basin of the Changjiang. Sediment cores taken from the delta front show low accumulation rates for the upper part of the cores and high accumulation rates for the lower part measured by a Pb-210 method, and high accumulation rates for average rates for the last 40 years estimated by Cs-137 concentration. These recent reduction in accumulation will be resulted from the decrease of sediment discharge since about 1985 due to small dam construction mainly in the upper reaches. Recent reduction of accumulation rates in Changjiang offshore is more obvious offshoreward.

3.3 Integrated ecosystem model in the East China Sea

1) Estimation of Pollutant Load from the Changjiang River

An efficient approach to estimate the river discharge using mainly satellite data is developed and described. The proposed method, which focuses on the measurement of water-surface width coupled with river width-stage and stage-discharge relationships, is applied to the Changjiang river with good results. Furthermore, pollutant load from the Changjiang river are estimated based on satellite derived discharge data and the relationship among the discharge and pollutant loads (SS, COD, DIN, TN, TP).

2) Estimate the pollutant loads from the Changjiang river basin including the effect of land use change

In order to illustrate the relationship of land use change and pollutant loads from the Changjiang river basin, the land use change of this region was analyzed based on the land use data of 1990 and 2000 and land use change data during 1990 to 2000, which are derived from TM images of 1990 and 2000. The results show that the characteristics of land use change of the Changjiang river basin during 1990 to 2000 are: (a) arable land and forest land have been decreased by 417096 and 147491 ha respectively. areas of grassland, water body, built-up area and unused land have been increased by 4141, 69142, 468583, 22762 ha, respectively; (b) the decrease of arable land is obvious, among which most of them (63.6%) converted to built-up area, and 17.3% to water body, 12.4% to forest land, respectively; (3) built-up area were increased largely and most of them were converted from arable land (91%) and forest land reclamation (6%). The framework was also presented to estimate the pollutant load from the basin based on the land use data in the basin of the Jialingjiang river which is one of main tributaries in the Changjiang river.

3) Long-term variations in dissolved silicate flux from the Yangtze River into the East China Sea and impacts on estuarine ecosystem

The results indicate that the distribution of dissolved silicate concentration (DSiC) is controlled by the distribution of silicate rocks. DSiC was high in the upper stream and gradually decreased from Cuntan to Yichang; increased from Yichang to Datong. On average, the upper Yangtze River was a DSi sink, retaining 3.39×10^4 t/yr; the middle Yangtze River was a DSi source, emitting 2.85×10^4 t/yr; but Dongting Lake and Poyang Lake were major DSi sinks, retaining 5.59×10^4 and 2.51×10^4 t/yr. Seasonal variations in monthly DSiC and flux were controlled by variations in monthly runoff discharge. Monthly DSiC and flux increased during the flood season and decreased during the dry season, similar to the runoff discharge variation. The flood season flux reached 1.77×10^6 t, accounting for 74% of the yearly total. Inter-annual changes of DSiC and flux were strongly affacted by anthropogenic dam construction and fertilizer application. DSiC and flux showed a sharp decrease since 1950. The mean DSiC was 109.47, 91.09, and 77.56 μmol/L in the 1960s, 1970s and 1980s, respectively. The mean DSi fluxes for 1960s, 1970s and 1980s were 2.72, 2.23, and 2.13 × 10^6 t, respectively. Up to 2002, approximately 3.14 × 10^5 t of DSi flux (13.08% of the DSi) was fixated and 6.25 × 10^4 t (2.64% of the DSi) was silted within the 162 reservoirs. Reservoirs have become a significant sink of DSi in the Yangtze River Catchment. A sharply decrease of DSi flux and quickly increase of N and P fluxes into the East China Sea has enhanced eutrophication and caused frequent harmful algal blooms in the East China Sea.

4) Ecosystem Model in the East China Sea

The oceanographic structure in the East China Sea is strongly influenced by the complicated combination of the following four water masses, 1) Changjiang river diluted water which contains large amount of nutrients, 2) Kuroshio water which is rich in nutrients, 3) Yellow sea water and 4) continental coastal diluted water which are poor in nutrients. It was found that the distributions of nutrients in the East China Sea are strongly controlled by this oceanographic structure and the distributions of phytoplankton are therefore determined by the nutrients distributions and the oceanographic structure. Long term simulation was conducted by using the three-dimensional numerical model which contained the daily data of fresh water and sediment fluxes from the Changjiang river, daily distributions of precipitation on the sea surface in the East China Sea obtained from TRMM satellite-data, daily distributions of wind stress and meteorological data obtained from GCM model (ECMWF). Simulation results compared with field observation data （obtained in the continental shelf of the East China Sea (124° ~ 128°E, 29.5 ~ 32°N) in June 2002） indicated excellent agreement and the oceanographic structure in the East China Sea composed with different water masses were well reproduced by this numerical model. Simulated results indicated clearly that freshwater from the Changjiang river during 1998 flood period had reached to Kyushu island in Japan.

It is estimated that the water resources demand along the Changjiang river will increase due to the economic development and south to north water transport project. Based on the scenario of water demand increase (3000 m3/s), significant salinity intrusion to the Changjiang river is predicted during the winter period (January – March).

Ecosystem model based on element cycle has been developed in the East China Sea. Relationship of the pollutant loads (SS, COD, TP, TN and DIN) with the discharge, such as $L=aQ^b$, has been established for the Changjiang river by using data of 1987,1988 and the data base of the field survey in 1998 and 1999. The long–term prediction of the ecosystem change in the East China Sea becomes possible by using these pollutant loads. Predicted distribution of Chl-a explaines very well the qualitative nature of the observed Chl-a distribution by satellite data. It was found that improvement of pollution loads estimation from other rivers besides the Changjiang river was essential for better agreement.