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REVIEW

A Possible Collaboration with China on Marine Ecosystem Research in the East China Sea

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Abstract

The East China Sea is a productive sea. Its annual total fishery production including the Yellow Sea is about 9.2 million tons, about 10% of the world's total fishery production. For a sustainable development and wise use of natural resources in the East China Sea, cooperative international programs on marine ecosystem research among surrounding countries, China, Korea, Taiwan and Japan, are necessary. In this review paper, published papers and reports on the East China Sea are summarized and possible collaborative researches with the surrounding countries, especially with China, are sought.

Discipline: Fisheries
Additional key words: collaborative research, East China Sea, marine ecosystem

Introduction

The East China Sea is one of the largest marginal seas located in the western North Pacific between China and the Okinawa Island Arc. The East China Sea is also bounded on the south by the Taiwan Strait, northwest by the Yellow Sea and northeast by the Japan Sea (Fig. 1). The area is about 7.5×10^5 km^2 with an average water depth of 349 m. The East China Sea is characterized by a broad continental shelf, the Kuroshio, and high fresh water input from the Changjiang (Yangtze River). The continental shelf makes up about 70% of this area and it extends eastwards and ends at the deep Okinawa Trough just west of the Okinawa Island Arc[4]. The mean residence time of shelf water with respect to exchange across the shelf edge using Ra isotope is reported to be 2.3 years[19].

The annual total fishery production in the East China Sea (including the Yellow Sea) was about 9.2 million tons in 1997[9,14], about 10% of the world's total fishery production. The East China Sea serves as a spawning and nursing ground of many commercially important fishes such as yellow tails, Japanese jack mackerel and chub mackerel. This fertile sea is supported by high primary productivity as a result of rich nutrient supply from upwelling of the Kuroshio subsurface water and freshwater discharge from the continent[28]. The East China Sea also receives attention for acting as a net sink of atmospheric carbon dioxide[25].

The East China Sea ecosystem is built on the sensitive marine environment. The East China Sea is a physically dynamic coastal sea. Slight changes in the fresh water discharge from the Changjiang, the strength of Kuroshio frontal movement and the thickness of thermocline have an effect on the water mass structure. Consequently, nutrient supply may change and the ecosystem and fishery production are eventually affected. Cooperative international programs on marine ecosystem research with surrounding countries, especially with China, are necessary in order to deepen our understandings of the East China Sea ecosystem and to utilize marine resources intelligently. In this paper, published papers and reports on the East China Sea are summarized and possible collaborative researches with China are sought.

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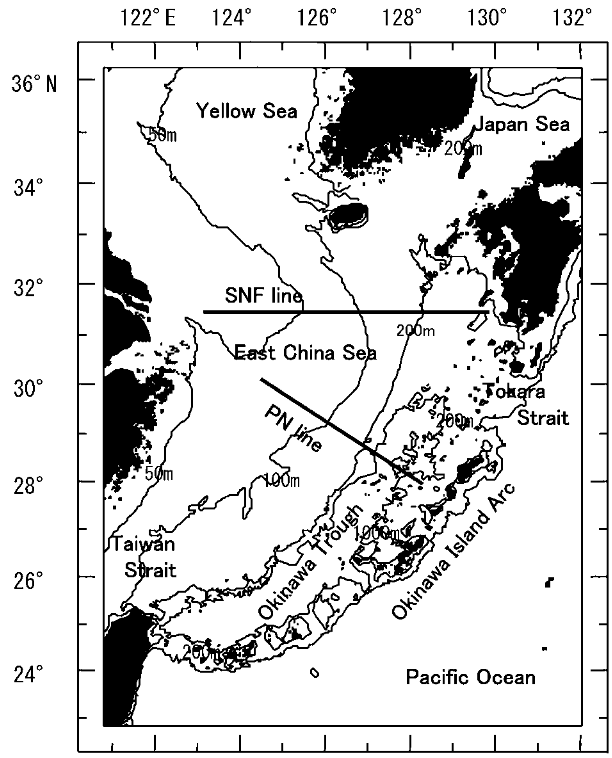

Fig. 1. Bottom topography of the East China Sea with the PN and SNF lines
The PN line is maintained by the Nagasaki Marine Observatory for oceanographic observations since the 1970s. The SNF line was intensively surveyed by Seikai National Fisheries Research Institute during the 1980s and 1990s.

Hydrographic feature

The major water masses of the East China Sea are Changjiang Water, Kuroshio Water, Taiwan Current Water and Yellow Sea Water[26]. A large seasonal change of the hydrography in the shelf is well known[1,7,12,16]. The shelf water is well stratified in summer because of surface heating and low surface salinity and it is well mixed in winter because of surface cooling and winter storms.

The average annual river water discharge from the Changjiang, the main source of the Changjiang Water, is 921 km^3/y and the average annual suspended load is 478 × 10^8 t/y[15]. These inputs are about 9% and 7% of the total input of the world's rivers, respectively. The river water discharge shows a large seasonal variation and the discharge in summer reaches a maximum of 75,000 m^3/s[32]. In summer, a low salinity water mass of the Changjiang Water has been observed in a wide area of the shelf. Tanaka et al.[24] found a good correlation in summer between the average monthly Changjiang discharge and the surface water salinity at the PN line in the shelf. In winter, in contrast, the Changjiang Water is limited near the Chinese coast.

The Kuroshio, the western boundary current of the North Pacific Ocean, enters the East China Sea, east of Taiwan, flows northeastwards along the shelf edge with an average flow rate of 40 × 10^6 m^3/s and leaves for the Pacific through the Tokara Strait. The Kuroshio divides the continental shelf and the Okinawa Trough. Upwelling of the Kuroshio subsurface water can be seen along the continental slope. The Taiwan Current enters the East China Sea from the Taiwan Strait and flows northeastwards along the Chinese coasts. It is most visible in summer[10]. The Yellow Sea Water, a cold water mass formed in the Yellow Sea during winter, may extend to the south around 27°N[16]. It is still observed below the thermocline in the shelf in summer. These four water masses can be well observed from the satellite derived sea surface temperature image (Fig. 2).

Twenty-year variations of sea surface temperature in three representative areas are shown in Fig. 3. Although some warming trend is seen since the mid 1990s, an increase in the sea surface temperature corresponding to global warming is not evident.

Nutrients

Large spatial and seasonal variations of the nutrient concentrations are found, that roughly correspond to the water-mass distributions. Within the Kuroshio and the Okinawa Trough, NMO's (Nagasaki Marine Observatory) 30 years of data from the PN line indicate that nitrate and phosphate are mostly depleted all the year around in the surface waters. As for nutrients going landwards, the concentrations increase and seasonal variations become high[21]. In the shelf, the concentration becomes the highest in winter when strong vertical mixing brings the nutrient rich water to the surface. The concentration reaches as high as 5 μmole/L for nitrate and as high as 0.5 μmole/L for phosphate. In the slope, the maximum nutrient concentration is observed in spring-summer. The concentration is usually higher than the other areas mainly due to the intrusion of the nutrient rich intermediate water below the Kuroshio[21]. The atomic ratio of nitrate to phosphate (N/P) in this intermediate water is close to the Redfield ratio of 16. In the inner shelf, the nutrient concentrations are significantly influenced by the amount of the Changjiang discharge. Furthermore, the N/P ratio is greater than the Redfield ratio of 16 due to a nitrogen rich Changjiang discharge[27], in contrast to the intermediate water, implying that the primary production is limited by phosphate in this area.

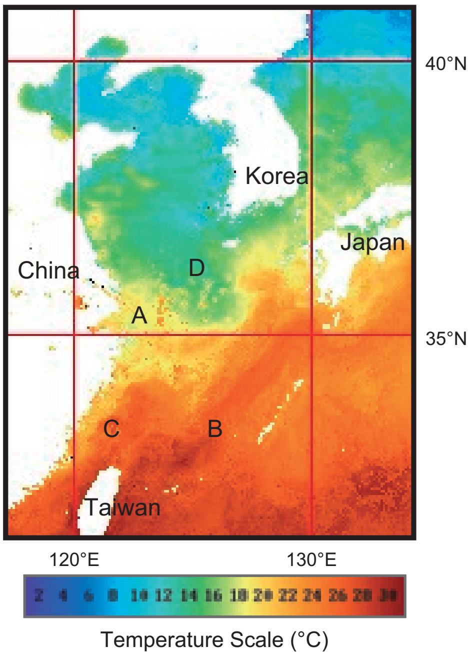

Fig. 2. Satellite (NOAA/AVHRR) derived 10-day composite sea surface temperature image in the East China Sea in May 2004

A: Changjiang Water, B: Kuroshio Water, C: Taiwan Current Water, D: Yellow Sea Water. This satellite image was provided by Agriculture, Forestry and Fisheries Research Information Center.

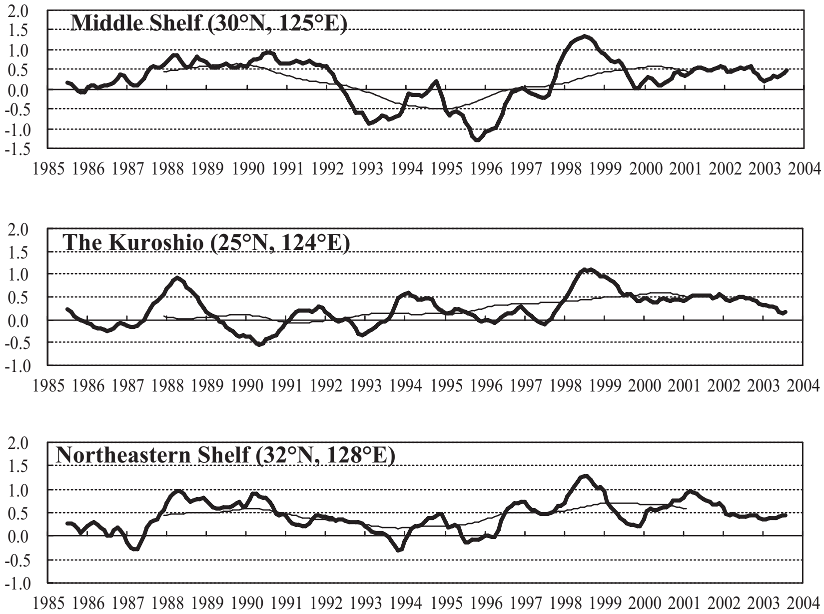

Fig. 3. Twenty-year variations of monthly mean sea surface temperature anomalies (ºC) in three representative areas

A thin line shows the 5-year running mean, while a thick line shows the one-year running mean. The temperature data were obtained by Japan Fisheries Information Service Center.

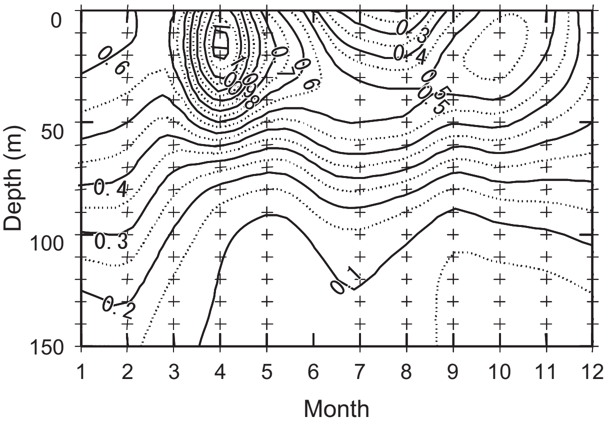

Fig. 4. Vertical profiles of the monthly chlorophyll a concentrations (µg/L) in the northern East China Sea compiled from SNF line and the JODC database

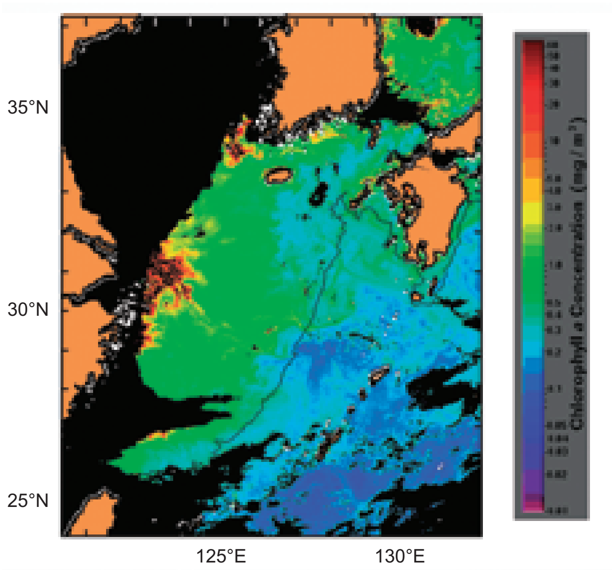

Fig. 5. Satellite derived chlorophyll a image in the East China on May 3, 2000

Black color indicates no data because of cloud cover. This SeaWiFS satellite image was provided by NASDA/EORC.

Plankton biomass and production

Available chlorophyll a data from 1974 to 1990 obtained from the SNF line and the JODC (Japan Oceanographic Data Center) database in the East China Sea was compiled monthly and plotted in Fig. 4[31]. A spring bloom is clearly observed in April. The chlorophyll a concentration becomes high in the surface mixed layer and reaches more than 1.1 μg/L in April. The weak maximum is also visible in October. The 20-years of data at the SNF line indicates a higher surface chlorophyll a concentration near the Chinese coast and an eastward decrease of the concentration[11]. This decreasing trend is similar to the nutrient distribution and the Changjiang discharge may be a key player to control the phytoplankton biomass and production. A satellite derived chlorophyll a image in the East China Sea on May 3, 2000 is shown in Fig. 5 as an example of chlorophyll a distribution. High concentration of chlorophyll a (red color) is observed near the Changjiang mouth.

Spatial and seasonal variability of phytoplankton composition has been documented. Furuya et al.[3] reported that phytoplankton composition is rather uniform vertically and the dominant species are diatoms in the shelf in spring with a relative abundance of more than 50% based on their intensive studies at the PN line. On the other hand, they also report that cyanobacteria and prochlorophyta dominate in summer accounting for as much as 63% of chlorophyll a and phytoplankton composition changes with water depth.

The primary productivity is also variable spatially and seasonally. In the inner shelf, the variation is the largest reflecting the nutrient supply from the Changjiang and light availability. The value of more than 1,500 mgC/m^2/y has been reported in summer when the Changjiang discharge is large[2,5]. In winter, on the other hand, the productivity is much lower than other areas because of less availability of light induced by high turbidity as a result of vigorous vertical mixing and resuspension of bottom sediments. In the rest of the East China Sea, the productivity decreases going to the Kuroshio and its variation is small. Based on our recent studies, the average primary productivity of 300 mgC/m^2/y in the shelf is obtained, that is higher than the Seto Inland Sea[30], but is comparable to other very productive estuaries and continental shelves reported in the world[18].

The zooplankton biomass is, in general, higher in the western part of the shelf[13]. Copepod is by far the most abundant, followed by Salps, Chaetognath and Appendicularia. The abundance of the latter three are quite variable spatially and seasonally, believed to be reflecting changes in temperature, salinity, light intensity and nutrient supply. The 10-year observations from 1981 to 1991 at the SNF line indicate a decreasing trend of the zooplankton biomass (Fig. 6). Future research is certainly needed to find a cause of this decrease and the relation to other environmental changes.

Recent studies by Suzuki[22] showed a high population of picoplankton, nanoplankton and microplankton in the shelf. They were in the order of 1×10^9, 1×10^6 and $1 \times 10^3 – 1 \times 10^5$ cells/L. Pico and nanoplankton are common everywhere in the shelf, but the abundance of microplankton was strongly salinity dependent.

An analysis of NMO's 30 years of phytoplankton

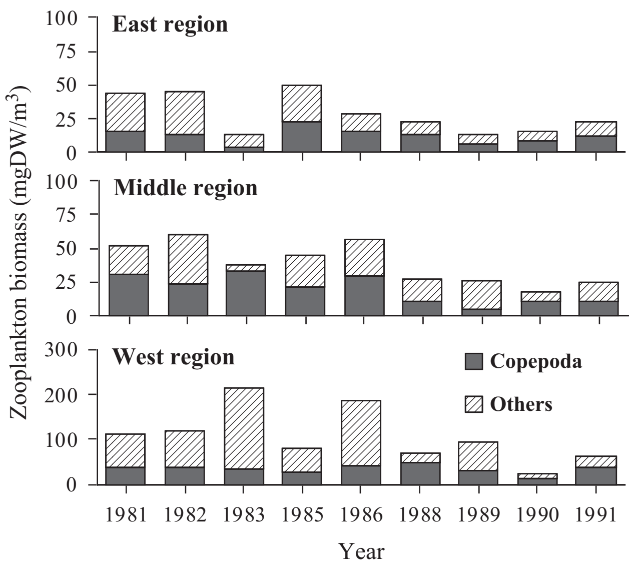

Fig. 6. Zooplankton biomass at the SNF line from 1981 to 1991

and zooplankton data revealed that the diatom and zooplankton biomass have a long-term trend of a sine-wave pattern. However, the pattern is not synchronized and there seems a large time lag on the peaks[17]. Moreover, the diatom biomass was positively correlated with the thickness of the surface mixed layer. These results indicate that a nutrient supply from the depths can promote the phytoplankton production but the fixed carbon may not be efficiently transported to zooplankton and higher trophic level organisms. There should be other environmental factors controlling the carbon flow. Future research is also necessary to understand the carbon cycle in this area.

Suspended particulate matter

A seasonal change in the transport of suspended particulate matter (SPM) in the East China Sea is large mainly because of the water mixing induced by monsoon wind. SPM is, in general, transported from the coast to the shelf edge and its transport is the largest in fall. However, in summer, the direction of the transport is reported to be reversed[29].

High turbid water is constantly seen near the bottom in a wide area of the shelf[20,23]. This bottom turbid layer is developed most strongly in summer to fall and coincides with seasonal changes in SPM load from the Changjiang[6]. Sediment trap experiments revealed that the vertical flux of SPM in the shelf was related to the Changjiang discharge, primary productivity and development of the bottom turbid layer, but the highest flux in the Okinawa Trough was observed in winter when the Changjiang discharge and the primary productivity is low[8]. This finding infers that winter mixing plays an important role on the movement of SPM. The SPM, including lithogenic and biogenic materials deposited on the shelf bottom in summer, may be resuspended, transported and settled down to the deep sea, the eventual sink of particles, in winter. Additional work is needed to quantify the particle flux from the shelf to the deep sea. Better understandings of the particle flux in the continental margin will contribute to synthesize the global carbon flux and cycle and to clarify the role of the continental shelf as a sink of atmospheric carbon dioxide.

Possible collaboration with China

In the past, we had a joint research with China under the theme of "Kuroshio Exploitation and Utilization Research" from 1986 to 1998 funded mainly by the Science and Technology Agency of Japan. During that period, many scientists were exchanged and collaborative cruises were carried out. Symposiums were also held to discuss findings obtained from the joint research. As a result, our knowledge on the East China Sea has been enriched and many scientific papers have been published. However, it is still far from sufficient to predict a change and/or shift of the marine ecosystem in response to environmental changes.

For a sustainable development and wise use of marine resources in the East China Sea, an advancement of scientific knowledge is required. There are still many unknowns. Continuous environmental monitoring is the first step to gain an entire picture of the changing environment of the East China Sea. China has a large exclusive economic zone in the East China Sea and Chinese contribution on environmental monitoring is expected. Furthermore, continuing industrialization in China may alter the amount of freshwater discharge and pollutant transfer to the East China Sea. Chinese information is essential to deepen our understandings of the East China Sea ecosystem. Standardization of sampling equipments and/or inter-calibration of analytical techniques is necessary to produce and share reliable data. The collaboration can be started from these activities.

The East China Sea is politically and economically an area that the two nations are concerned about. The scientific advancement in this research will not be achieved without collaboration with China.

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