B-14 Studies on long term variation of ocean ecosystem/climate interactions based on the Odate collection (Abstract of the final Report)

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1. Introduction

The ocean has an important role to absorb carbon dioxide (the most serious greenhouse gas) through various biological processes. Phytoplankton synthesize carbon dioxide in the surface layer and are mainly consumed by zooplankton. The subsequent destination of the carbon depends on the species and ecology of the zooplankton. Small zooplankton distributing only shallow layer produce small fecal pellets and they usually degrade in the shallow layer. Therefore carbon dioxide is regenerated around the sea surface/atmosphere interface. Large zooplankton produce larger fecal pellets which quickly sink into the deep layer. Large plankton are also selectively consumed by large predators, such as fish, whales and sea birds. Large predators can extensively swim both horizontally and vertically, and their bodies sink rapidly after their death. In these processes, inter-specific relationships affect the potential effect of the ocean to absorb carbon dioxide into the deep layer. In order to monitor the relationships between climate change and biological processes, extensive zooplankton samples which have been collected over a long time period are necessary. Such zooplankton collections are quite rare in the world, and there is only one that has been collected in the western North Pacific, the Odate Collection.

2. Research objective

More than 20000 zooplankton samples called the Odate Collection have been collected off eastern Japan over a period of for more than 50 years since the 1950s. All of them have been assembled in Tohoku National Research Institute, and the report on long term variation of wet weight of these zooplankton was published by Dr. Kazuko Odate[1]. Since information on interspecific relationships of zooplankton is important to analyze long-term variation of ocean ecosystem in relation to climate change, the analysis of the long term variation species composition of zooplankton of the Odate Collection has been anticipated.

The research objectives of this study is to complete the data base of zooplankton species composition collected in western North Pacific (sub-theme 1), and to analyze variation pattern of physical oceanological processes using archives and newly designed modeling methods (sub-theme 2). Afterwards, these data on the physical processes and zooplankton composition will be utilized by other sub themes. Biological production processes will be analyzed in sub-theme 3, because it is thought that variation of zooplankton abundance is caused by that of primary production and the variation of primary production is caused by physical processes. The reason and mechanism of long-term variation of zooplankton community is analyzed in sub-theme 4. The goal of this study is toclarify the transport process of greenhouse gas into the deep sea through oceanic biological process of zooplankton.

3.Research Method

Zooplankton of the Odate Collection were collected obliquely from 150m depth using conical zooplankton net (0.33mm mesh size, 45cm mouth diameter). From more than 20000 samples, 2885 samples were selected for this study. 1527 samples out of all the samples were collected in the Oyashio region (water temperature at 100m depth was less than 5 °C) during 1960 and 2002. Other 1358 samples were collected in Kuroshio-Oyashio transition region (5°C< water temperature at 100m depth< 15°C) during spring and summer season (from April to September). Copepods were sorted from these samples, and classified into species, or into growth stages for some abundant species (e.g. *Eucalanus bungii*) and counted. Body length of 10 specimens of three dominant species (*Neocalanus plumchrus*, *N.flemingeri* and *N.cristatus*) from each zooplankton samples were measured. These data sets of species composition of copepods were combined with sampling information (e.g. sampling date, time) and oceanological information (e.g. water temperature).

4. Results

(1) Species composition data base from the Odate Collection

From the 1527 zooplankton samples collected in Oyashio region, 174 species of copepods were detected, and 236 copepods species were detected from 1358 samples collected in Kuroshio-Oyashio transition region. These data of copepods species composition and oceanological information were formed into tables of MS EXCEL files. Long term variation of species variability and order of dominant species were observed from this database. The database is planned to be open to the public being available for anyone who is researching on ocean ecosystems. In order to establish the database system using this dataset, we made a contact with the scientists of the British institute, the Sir Alister Hardy Foundation for Ocean Science, because they are also researching on long-term variation zooplankton composition, and they are constructing an on-line database system. The database system has been completed and it will be open to the public to be used by global ecosystem scientists in the world.

(2) Long term variation of Climate/Physical oceanography

The long term variations of vertical and horizontal structure of the northern North Pacific water were researched. Huge number of the sea surface temperature data sets collected since early 20th century was reanalyzed. From this research, the variation sea surface temperature of western North Pacific during all over the 20th century has been precisely observed. As the other view point, we analyzed the geophysical process, the tital cycle induced by the oscillation of earth's axis. The depth of isopycnal of 26.5-26.7 showed a strong relation between 18.6 year tidal cycle. This tidal cycle cause the intrusion of Okhotsk water to Oyashio region, and this physical oceanographical variation is thought to be related to biological variation. For example, the long term variation of body size of *Neocalanus cristatus*, one of the dominant species based on the data set of this project, clearly matched this 18.6 year cycle. The long term trends of distribution of picnocline and water mass of mid-water depth were observed from 1950s. Those trends are thought be related to increase trend of biomass of the species groups which were dominant during spring and summer season.

(3) Effect of biological production on the interaction between climate change and variation of ocean ecosystem

In order to assess the effect of vertical transport of carbon by the seasonal vertical migration of dominant zooplankton species especially *Neocalanus* spp., the information of vertical migration (e.g. range of depth, seasonal timing of descend and seasonal variation of feeding activity to the primary production) of various copepod species was researched. It is revealed that 4.3g Carbon $m^{-2}year^{-1}$ was transported by the seasonal vertical migration of *Neocalanus* spp. And 0.81g Carbon $m^{-2}year^{-1}$ was transported by *Eucalanus bungii*. In the subarctic North Pacific, 0.12Gt of carbon were transported annually to deepwater from the surface by the seasonal vertical migration of copepods species in total. Based on the data set of this project, biomass of *Neocalanus* species varied highly, therefore the estimation of vertical transportation by zooplankton migration should be varied highly, 1.2-8.0 Gt $year^{-1}$.

(4) Long term variation of zooplankton communities and the process of transportation of organic matter through biological processes

Using the dataset of zooplankton established in this research project, the mechanism of long term variation of oceanic ecosystem induced by climate and geophysical processes. The coincidence of the climate regime shift and the timing shift of peak season of copepod production was observed. Duration of the peak season of copepod production was relatively short during mid '70s and late '80s because of cold winter and hot summer. On the other hands, water temperature was low after early '90s and preferable season for biological production was long. It was found that the biomass of *Neocalanus* spp. , dominant copepods in Oyashio region, was relatively low during '80s. The long term variation of the effect of intrusion of the oligotrophic Okhotsk Sea into the Oyashio sea area induced by tidal cycle in thought to be a part of the reason of the low abundance of *Neocalanus*, because the low nutrient concentration was

observed during '80s caused by dominant Okhotsk water in the mesopelagic layer. Another reason of low abundance of *Neocalanus* during '80s is thought to be the top-down control of predation by abundant pelagic fish, because the Pacific sardine had been quite abundant in the western North Pacific during mid '80s.

5. Discussion

The more than 40 year database of species composition zooplankton was established from 2885 samples of a part of the Odate Collection. This is the biggest and precise database of biological monitoring in the western North Pacific. From this data base, various patterns of long-term variation of zooplankton were observed. The most variations match climate regime-shift, and there may be a knock-on effect such as climate change affecting physical oceanography which affects biological production and subsequently species composition (Fig.1). We found some long term increase trend of biomass some cold water group of copepod species. It is consistent with that the cooling trend has been observed in the mid latitude (35-45°N) of western North Pacific[2]. Therefore, this trend may be an effect of earth warming condition.

Moreover we analyzed the process of the effect of physical oceanographical variation motivated by the tidal effect, since it is noticeable that the various variations of species composition and biomass have 20 year cycle. It is thought that the supply of nutrient was controlled by this oceanographical change.

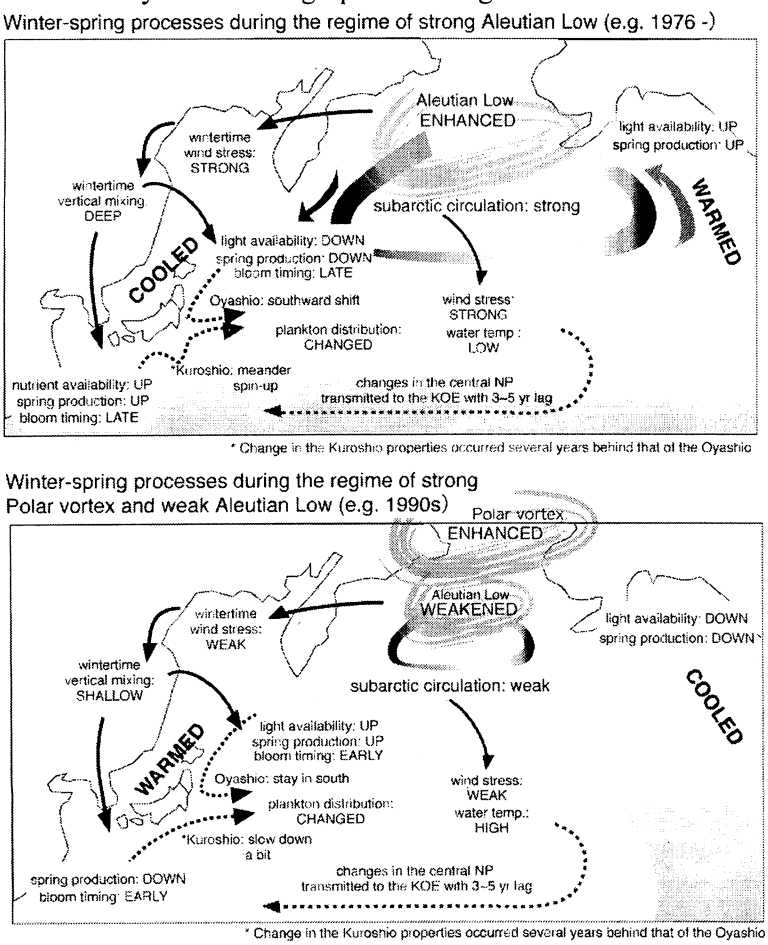

Fig.1 Schematic figures of the mechanisms of long-term variation of zooplankton community in relation to climate change.

We also assess the vertical transport of carbon by the seasonal vertical migration of dominant zooplankton species especially *Neocalanus* spp.. In the subarctic North Pacific, 0.12Gt of carbon were transported annually to deepwater from the surface by the seasonal vertical migration of copepods. According to the dataset of long term variation of zooplankton established by this project, the abundance of *Neocalanus* spp. had been varied and the differences between lowest and highest is 2.4 times during spring season and 6.7 times during summer season, and *Neocalanus* species has been increasing during spring in recent years. This increasing trend might be related with earth warming trend. Then the estimation of vertical transportation by zooplankton migration should be varied highly, 1.2-8.0Gt $year^{-1}$, because biomass of *Neocalanus* spp. varied. The research of long term variation of species composition and biomass of zooplankton was necessary to estimate the carbon transportation from the surface to deep layer of the Ocean.

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