# Studies on long-term variation of ocean ecosystem/climate interactions based on the Odate collection: Outline of the Odate Project

*By Hiroya Sugisaki*

Recently, long-term variations and trends of global climate have been identified as serious problems affecting the biosphere, especially global warming problem. The ocean is thought to play an important role by absorbing 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, however, depends on the species and ecology of the zooplankton. Small zooplankton distributing in the shallow layer produce small fecal pellets, and they are usually degraded in the shallow layer. Therefore carbon dioxide is recycled within the sea/atmosphere interface layer of the ocean, and can potentially return to the atmosphere. On the other hand, large zooplankton produce large fecal pellets. Most of their bodies and feces quickly sink into the deep layer. Large plankton are also selectively consumed by large predators, such as fish and whales. These predators can swim extensively both horizontally and vertically, and their bodies sink to the deep layer rapidly after their death. Through these processes, inter-specific relationships affect the ocean ability to absorb carbon dioxide and transport it 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, however such zooplankton collections are quite rare in the world. In the North Atlantic Ocean, the CPR (Continuous Plankton Recorder) project has been carried out since 1946 (sample numbers are over 170,000), and precise atlases, including phytoplankton, are already published (Edinburgh Oceanographic Laboratory 1973; CPR Survey Team 2004). In the eastern North Pacific, the CalCOFI (California Cooperative Ocean Fisheries Investigations) project has continued since 1950. The original purpose of this project is to study the condition of the fishing grounds, and more than 60,000 samples of zooplankton were collected. The atlases of this dataset have been published since 1963, and the latest is No. 35 (Moser *et al*. 2002). Using these plankton samples, various works on long-term variability of zooplankton ecology have been published (*e.g*., Roemich and McGowan 1995; Edwards and Richardson 2004; Richardson and Schoeman 2004). In the western North Pacific, on the contrary, there are very few zooplankton sample sets collected systematically over a long period of time besides the Odate collection.

***What is the Odate collection?***

The Odate collection is a set of more than 20,000 formaline preserved zooplankton samples which are stocked at the Tohoku National Fisheries Research Institute (Japan). These samples were collected extensively over the western North Pacific since 1950 (Fig. 1). The Odate collection samples were mainly collected from along fixed sampling

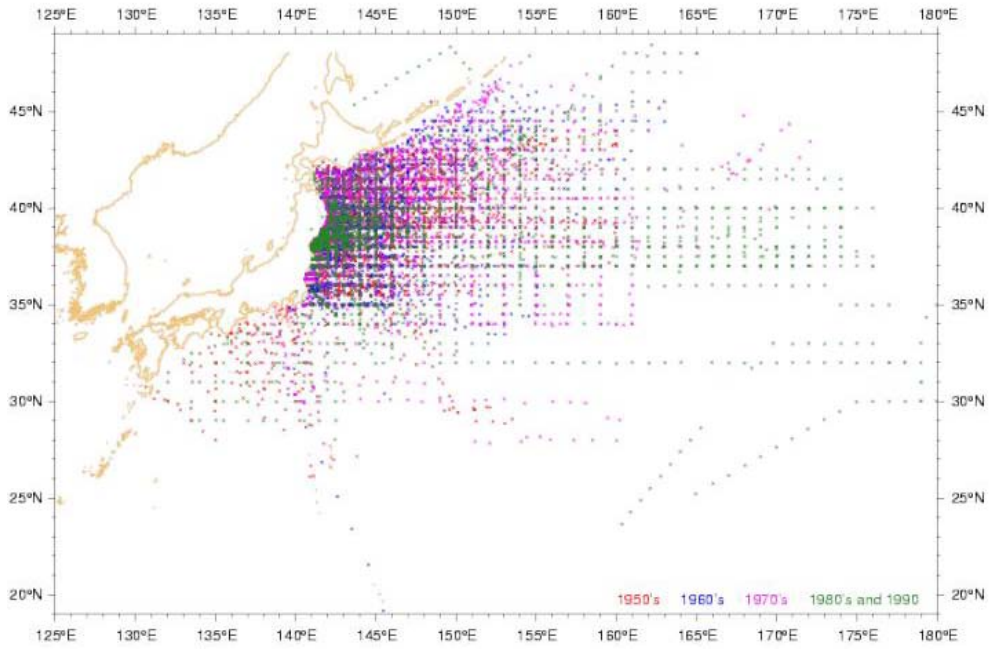


*Fig.1 Location of sampling stations of the Odate collection.*

lines for the purpose of routine monitoring of prey abundance in fisheries grounds and oceanic environment by national or prefecture institutes in northeastern Japan. Samples were usually collected either monthly or seasonally. Sampling gear used were conical standard plankton net systems called marutoku net and Norpac net. Both of them have 45 cm diameter and 0.33 mm mesh size. The net was towed vertically from 150 m depth layer to the surface.

Long-term variation of biomass (total wet weight) of this sample set was analyzed by Dr. Kazuko Odate, formerly of the Tohoku National Fisheries Research Institute, from the 1950s to the early 1990s, and this sample set is called the Odate collection. Decadal oscillations of zooplankton biomass (wet weight) were clearly observed by Dr. Odate (Fig. 2). Most of these samples are still available for identification of species, because the preserved condition is fairly good. Therefore, we planned a research project re-investigating zooplankton species composition in order to analyze long-term variation of the oceanic ecosystem and mechanisms of ecosystem variation affected by climate shift using the Odate collection.

***Species composition analysis***

Information from the total wet weight of zooplankton is not sufficient to assess the biological processes occurring in the oceanic ecosystem. From the total biomass we cannot deduce what has happened in the oceanic ecosystem in relation to climate change. It is probable that the effect of the climate shift is different between warm-water species, and cold-water species, between large and small species, and between gelatinous and crustacean species, *etc*. In the study area of the Odate collection, there are both cold current (Oyashio) and warm current (Kuroshio) systems, and therefore the species composition shows large variation. So, it is necessary to analyze the species composition of the zooplankton. During the species identification procedure, copepods have been sorted out and identified into species using the latest information on copepod classification. Classification has been conducted by Dr. Hiroshi Itoh (Suidosha Co. Ltd.). Adults and larvae of all species were distinguished. Besides, copepodite larval stages (I-V) of dominant copepods in the Oyashio region (*Neocalanus*, *Eucalanus*, *Calanus* and *Metridia* species) were precisely identified. The total number of each classified species and life stage category were calculated.

***What has happened to the zooplankton community in the second half of the 20th century?***

The study area was divided into three regions according to Odate (1994): the Oyashio cold current region (water temperature at 100 m depth <5ºC), the Kuroshio warm current region (water temperature at 100 m depth >15ºC), and the Kuroshio-Oyashio mixed region (5ºC< water

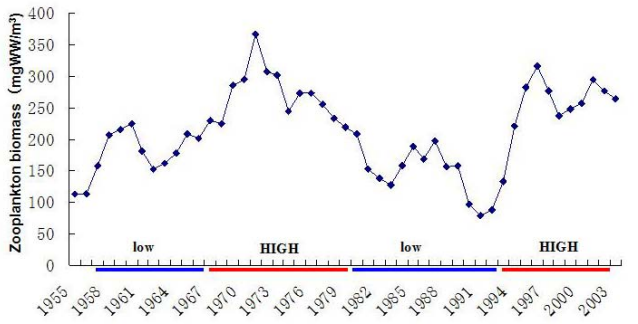


*Fig. 2 Long-term variation of zooplankton biomass collected in the Oyashio region; revised from Odate (1994).*

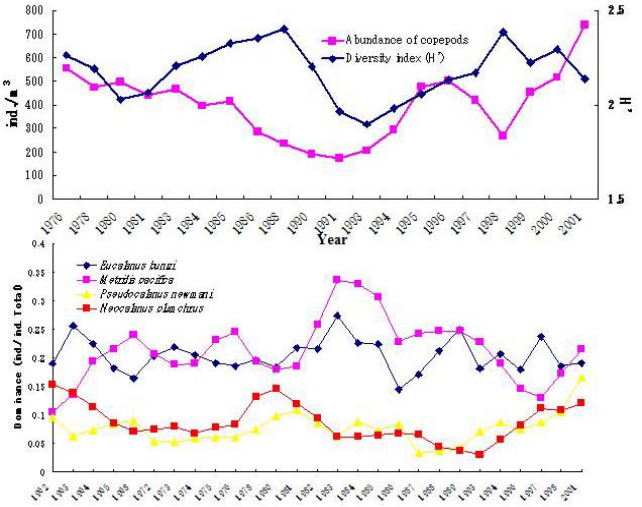


*Fig. 3 (Top) Long-term variations of abundance of total copepods and their species diversity (Shanon-Wienner's diversity index, H') during summer season (June-Aug); (Bottom) Long-term variation of dominance ratio of 4 dominant species (*Eucalanus bungi, Metridia pacifica, Neocalanus plumchrus *and* Pseudocalanus newmani*).*

temperature at 100 m depth <15ºC). Here, we briefly introduce a preliminary report on the long-term variability of the copepod composition collected in the Oyashio region as an example of this study, because the species identification analysis for this area has been completed. Odate (1994) reported that in the Oyashio region, the species composition is relatively simple compared with the other sea areas, and the zooplankton biomass is high and their long-term variation was clearly observed. In this study, 1527 samples collected from 1960 to 2002 in the Oyashio region have been investigated and 206 species of copepods detected. Over the 40-year period, the five most dominant species were *Eucalanus bungii*, *Metridia pacifica*, *Neocalanus plumchrus*, *Pseudocalanus newmani*, *Oithona similis*, and they dominated more than 70% of the total abundance of copepods. The long-term variability of

species diversity and total abundance were clearly observed. It seems that there are decadal oscillations with high diversity and low abundance of total copepods during the 1980s (Fig. 3a). Decadal variation is also observed in the abundance of each dominant copepod. During the 1980s, *Metridia pacifica* was dominant, while the abundance of *Neocalanus plumchrus* was low compared to other decades (Fig. 3b). The abundance of most of these species clearly shows decadal oscillations. The abundance of some species was high during the 1980s and some were low. The depression of some dominant species, such as *Neocalanus plumchrus*, might be a factor leading to the low abundance and high species diversity during the 1980s.

We are now analyzing the mechanisms of this long-term variation of the copepod community. We especially wish to examine the effects of climate oscillation, top-down control and tidal oscillation. As for climate oscillation, the timing of shifts of well-known climate oscillations, *e.g*., PDO (Pacific Decadal Oscillation) or AO (Arctic Oscillation), seemed to roughly match with the timing of the phase change of zooplankton abundances. Dr. Sanae Chiba (project member) suggested the hypothesis that cold winters and hot summers during the 1980s led to the short productive season for some dominant cold-water species (Chiba, 2005). As for top-down control, Dr. Kazuaki Tadokoro (project member) reported that the feeding pressure of Japanese sardine on *Neocalanus* species had been high during the 1980s. During that time, stock size of Japanese sardine off the Pacific side of Japan was estimated at over 15 million metric tons (estimated stock size in 2004 was only 110 thousand tons). Since sardine prey on *Neocalanus* copepods efficiently, high feeding pressure on *Neocalanus* by sardine might have occurred during the 1980s. Tadokoro *et. al*. (2005) estimated that Japanese sardine could consume 32-138% of the daily production of *Neocalanus* species during summer off the northern part of Japan. This top-down control may explain the reason of depression of the abundance of *Neocalanus*. Dr. Ichiro Yasuda (project member) has been doing research on the basin scale physical oceanographical mechanism in relation to the abundance of zooplankton (Yasuda, 2005). The 18.6-year cycle oscillation of the earth axis induces an oscillation in the strength of tidal mixing. This tidal cycle causes an intrusion of Okhotsk water into the Oyashio region, and this physical oceanographical variation is thought to be related to the biological variation. The strong intrusion of low-nutrient water from the Okhostk region may cause the low primary production and low abundance of large copepods such as *Neocalanus* species.

Consequently, long-term variability of the copepod community is clearly observed from this research of species composition data set. Details of the mechanism of the long-term variation of the copepods community in relation to physical and biological effects will be published by the members of this project elsewhere.

***Work in progress***

Now we are analyzing the species composition of more than 3000 samples from the Odate collection sampled in the Oyashio-Kuroshio mixed region and the Kuroshio Extension area. These areas are warmer than the Oyashio region, so species diversity is much higher. The mechanism of long-term variation in the plankton community will be examined in detail (especially the trends of global warming, climate oscillation, tidal oscillation, predation by sardine, *etc*.) as well as that of the Oyashio region. The mechanism of long-term variation of oceanic zooplankton communities of both subarctic and subtropical current systems in the western North Pacific will be synthetically examined.

The database of the species composition made by this project (more than 5000 samples collected from 1960-2002 in the western North Pacific) will be open to the public through the internet site after all species identification is completed. We hope that this data set will be useful for research on the global ecosystem as a resource available to all.

***Importance of continuous field monitoring research***

There are still a large amount of zooplankton samples and datasets that have been kept unused in various institutes in Japan, because they were collected for temporal purposes, *e.g*., the condition of fishery grounds or environment factors at that time. On the other hand, as interest in the information of long-term variation of the ocean ecosystem becomes stronger because we need to estimate the effects of long-term climate change such as regime shift and global warming effect, we have to accumulate ecological data of the ocean over a long period. 50 years' accumulation of the Odate data is not enough to research on a more than 50-year cycle of some fish abundance (*e.g*., sardine, herring and so on) or estimate the trend of global warming to the 22$^{nd}$ century. However, due to competition from other research with more immediate benefits, it is difficult to maintain the funding to continue the current field monitoring research, because instantaneous prominent results cannot be expected. But we should not quit. We have to realize the importance of continuous field monitoring research for the science of the next generation.

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## Hokkaido University Fisheries & Oceanographic Database CD-ROM


Since 1957, Hokkaido University has carried out regular oceanographic and fishery surveys with the fisheries training vessels *Oshoro maru* (PICES Press Vol. 9(1): 25-28) and *Hokusei maru* (PICES Press Vol. 10(2): 25-28). Biological and environmental data collected on these surveys are published annually in the "*Data Record of Oceanographic Observations and Exploratory Fishing*". The Hokkaido University has collaborated closely with the Japan Oceanographic Data Center (JODC) to assemble close to 50 years of these data in a Long-Term Fisheries and Oceanographic Data Base (HUFO-DAT). Volume 1 contains hydrographic station data, nutrients, oxygen, zooplankton wet weight, and chlorophyll-*a* concentration. Volume 2, currently in preparation, will include experimental fishing and associated biological data. To obtain a copy of HUFO-DAT Vol. 1, please contact one of the following sources:

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