Interannual – interdecadal variations in plankton biomass and physical environment in the western North Pacific.

TAKASHIGE SUGIMOTO
Ocean research Institute, The University of Tokyo, 1-15-1, Minamidai, Nakano-Ku, Tokyo 164-8639, Japan; (sugimoto@ori.u-tkyo.ac.jp)

SUMMARY: Effects of climate regime shift, ENSO activities and winter monsoon on western boundary currents and upper ocean stratification, as well as their combined effects on plankton biomass and Japanese sardine population are described through analyses of historical time series data. The results are: 1) bidecadal scale variation in the atmospheric condition, coupled with the intensity of winter monsoon influences upper mixed layer depth and density stratification of the ocean, and the volume transport and the current path of the Kuroshio and Oyashio; 2) in the western subtropical North Pacific, weakening of winter cooling and vertical mixing associated with calm and warm winter during the early 1970s, increased surface chlorophyll concentrations in winter in the coastal and offshore water of the Kuroshio, which caused active spawning of mesozooplankton and better feeding condition for sardine larvae; 3) a remarkable weakening of southward intrusion of the Oyashio off the east of Japan during 1988-91 decreased plankton biomass in the Kuroshi-Oyashio transition region in late spring-early summer, and might have caused successive recruitment failures, inducing collapse of Japanese sardine population.

KEYWORD: Climate regime shift, ENSO, Asian monsoon, western North Pacific, plankton biomass, Japanese sardine

INTRODUCTION

Upper ocean circulation and density stratification in the western subtropical and subarctic North Pacific are controlled not only by variations in the westerly-trade wind pattern but also East Asian monsoon as shown schematically in Fig 1. El Nino events and climate regime shifts occur with several years and multi-decadal time intervals, respectively. Their influence on the regional climate and ocean environments in the mid latitude, with changes in seasonality of the westerly and the monsoon, affect the growth and the recruitment rates coupled with seasonal cycle of biological activities.

This paper intends to describe the facts from our recent observations on interannual-interdecadal scale variations in plankton biomass to clarify how long-term variations in fish stock and physical environment are linked together through variations in plankton biomass in the western North Pacific.

METHODS AND MATERIALS

The time series data of the meteorological indices and hydrographic observations involving chlorophyll concentration and zooplankton biomass to the south of Japan published by the Japanese Meteorological Agency (JMA) were used and a detailed data description is mentioned in Sugimoto and Tadokoro1). Latitude of the southern limit of the meandered path of the Kuroshio and the transparency data were collected from the Japan Oceanographic Data Center. Data for the southern limit of the Oyashio were obtained from the Hakodate Marine Meteorological Observatory. Time series data for fish catch of sardine and anchovy published by the Japanese Fisheries Agency were used for the present analysis.

RESULTS

The time series of the indices of meteorological conditions in winter are illustrated in Figure 2. Here, SOI is normalized anomaly of the southern oscillation index of Walker circulation, which relates to El Nino events. MOI is monsoon or intensity north wind index in winter in the Far Eastern region. NHZI is northern hemisphere zonal index or intensity of the eastward component of the westerly wind, i.e., straightness of the path of the westerly. The figure indicates the presence of a regime shifts around the year of 1977 and 1988. During the early 1970s and late 1980s, values of MOI anomaly were negative, indicating that winter monsoon was weak. In these period values of NHZI and SOI anomalies were both positive, indicating that activities of El Nino and meandering of the westerly were weak.
Figure 3 (a) shows the time series of the latitude of the southern limit of the first branch of the Oyashio intruding along the northeastern coast of Japan. It indicates that intensity of southward intrusion of the Oyashio was strong in 1980s. Fig.3 (b) shows the latitude of the trough of the Kuroshio path off the southern coast of Japan. It shows that the large and mid amplitude meander of the Kuroshio path persisted during late 1970s and during 1980s, respectively.

Figure 4(a) illustrates the time series of the chlorophyll concentration and the meso-zooplankton biomass (wet-weight) off the Kuroshio at 137°E in winter obtained by R/V Ryofu-Maru of JMA, respectively. Figure 4(b) shows those of the depth of the upper mixed layer in winter and summer. These figures indicate that mixed layer depth in winter in the decade of 1980s become more than 200m which caused too deep mixing in the upper ocean below the compensation depth to decrease phytoplankton and also zooplankton production. In El Nino (La Nina) years, winter monsoon is usually weak (strong) induces higher (lower) plankton production.

Figure 5(a) illustrates the time series of the yearly total landings of Japanese sardine and anchovy obtained in the water around Japan. The general trend of their stocks is considered to be similar with their landings. Landing of sardine rapidly increased in the decade of 1970s and became further more in the early and mid 1980s, although, landing of anchovy shows opposite trend in general. While, Figure 5(b) shows year-to-year variations in chlorophyll-a concentration converted from transparency data in the Kuroshio-Oyashio transition region off the east coast of the Japanese main island in spring and early summer.

DISCUSSION

Comparing Fig.5 (a) with Fig.4 (a), it is noticed that the timing of the population increase of Japanese sardine in the early 1970s corresponds to a relatively high level of chlorophyll concentration which might have caused higher production of meso-zooplankton eggs in the main spawning season and period i.e late winter and early spring in the coastal water of the Kuroshio off the southern coast of Japan.

Associated with the increase of Japanese sardines stock, their main spawning ground expanded to the frontal and upstream region of the Kuroshio south of Japan. In addition, their main spawning season advanced from March to February. During this period, sardine larvae were transported further down-stream in the Kuroshio Extension, and the wide area of the Kuroshio–Oyashio transition region become available for their feeding. Moreover, the high stock period of sardine during early and mid 1980s corresponded to the periods of intense southward intrusion of the Oyashio off the east coast of Japan. This situation caused high values of chlorophyll concentration as shown in Fig. 5(b) and might increased in meso-zooplankton biomass in the Kuroshio-Oyashio transition region in late spring and early summer.

During 1988-1991, there was a marked reduction in the southward intrusion of the Oyashio water into the western part of the Kuroshio-Oyashio transition region (Fig. 3a). In the late 1980s, chlorophyll concentrations in the transition water and the area of Oyashio water in this region decreased significantly (Fig.5b). As the level of zooplankton biomass in the Oyashio water is much higher than that in the transition region and the Kuroshio waters, this northward retreat of the Oyashio water in the late 1980s might decrease the mean biomass levels in the transition region drastically as well as the chlorophyll concentrations. This suggests that the poor feeding conditions for sardine juveniles may have been responsible for the successive recruitment failures during this period.

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REFERENCES