

Seasonal variability of primary production off Abashiri, the southern Okhotsk Sea¹

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Introduction

The Okhotsk Sea is the southernmost marginal sea that is ice-covered during winter; therefore, it is considered to be an area having sensitive environmental characteristics due to the influence of global warming. In order to detect such environmental changes, monitoring of oceanographic conditions is considered important. However, few monitoring studies have been made in the offshore area of the Okhotsk Sea due to difficulties making observations in the ice-cover season.

The Hokkaido National Fisheries Research Institute of the Fisheries Research Agency has been conducting monitoring surveys in the southern Okhotsk Sea since 2000. In this study, we report some results about oceanographic conditions on primary production from monitoring observations in the southern Okhotsk Sea.

Observations

Two observation lines (N-line and S-line) were set up in the area off Abashiri, in the southern Okhotsk Sea (Fig. 1). The oceanographic surveys along these lines were conducted in the non-ice seasons (generally April–October) 4–5 times a year. The routine surveys were CTD casts, vertical profiles of chlorophyll *a* and nutrients (nitrate, phosphate and silicate), and netplankton biomass collected with a NORPAC net. For detailed methods, see Saito *et al.* (1998) and Kasai *et al.* (2001). At some of the stations, daily primary production was measured with a simulated *in situ* incubation method using ¹³C as tracer (Yokouchi *et al.*, 2006).

Results and Discussion

During the survey periods, the observation area could be classified into two water masses. For example, the

T-S diagrams obtained in April, May, July and October of 2005 are shown in Figure 2. As the season progressed, two coastal stations showed characteristics of high temperature and high salinity corresponding to the characteristics of the Soya Warm Current. Therefore, the coastal stations should be considered under the influence of the Soya Warm Current. On the other hand, stations in the offshore area showed characteristics of low salinity in the surface layer, and a temperature minimum at around a salinity of 33 at about 200 m depth.

In this paper, we classify the study area according to two water masses: the Coastal Area and the Offshore Area. Because the oceanography of the Coastal Area has been well investigated for environmental conditions related to scallop culturing (Nishihama, 1994; Horii *et al.*, 1992; Shinada, 2006), we will report mainly on oceanographic conditions of the Offshore Area.

Seasonal changes in the vertical profiles of temperature and salinity in the Offshore Area are

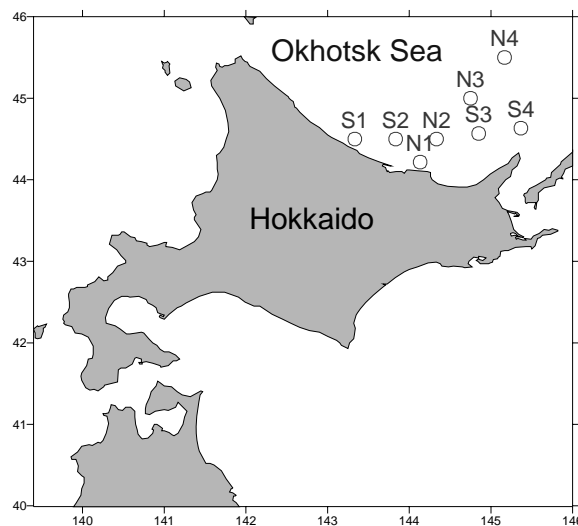


Fig. 1 Location of the N-line and the S-line.

¹ Some results from this study have also been submitted to the *Journal of Oceanography*.

shown in Figure 3. In April, the temperature profile remains constant vertically, but the water column becomes stratified by the salinity gradient. After May, the temperature in the surface layer increases through solar heating, and stratification of the water column progresses with the season. Because T-S characteristics in the deeper water hardly changed, a pycnocline developed remarkably around 20 m depth in summer and autumn.

Figure 4 shows the seasonal changes in vertical profiles of chlorophyll *a* mean concentration in the Offshore Area. In spring (April), a phytoplankton bloom was observed at the surface. In the summer and autumn, the maximum layer of chlorophyll *a* moved to the subsurface layer at around 20 m depth, forming a subsurface chlorophyll *a* maximum (SCM). The depth of the observed formation of SCM corresponds to the pycnocline (Fig. 3).

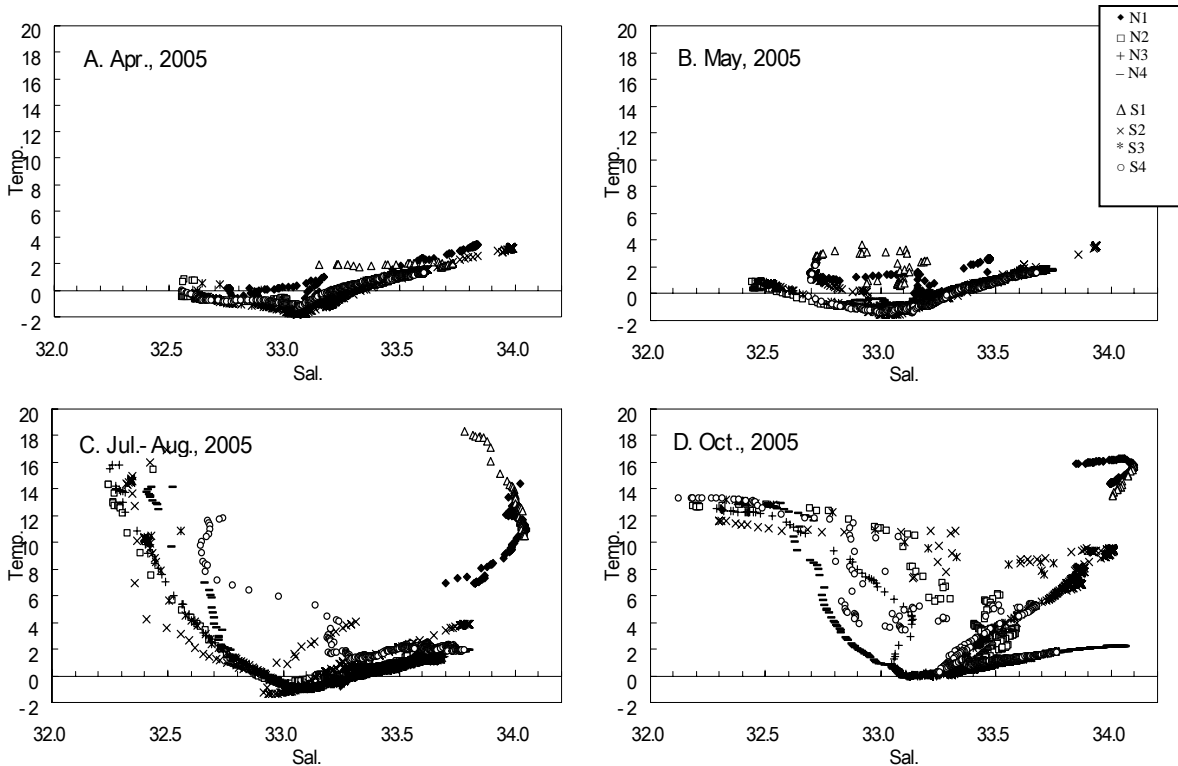


Fig. 2 T-S diagrams from 4 cruises conducted in 2005. (A) April, (B) May, (C) July–August, and (D) October. Temperature is in °C.

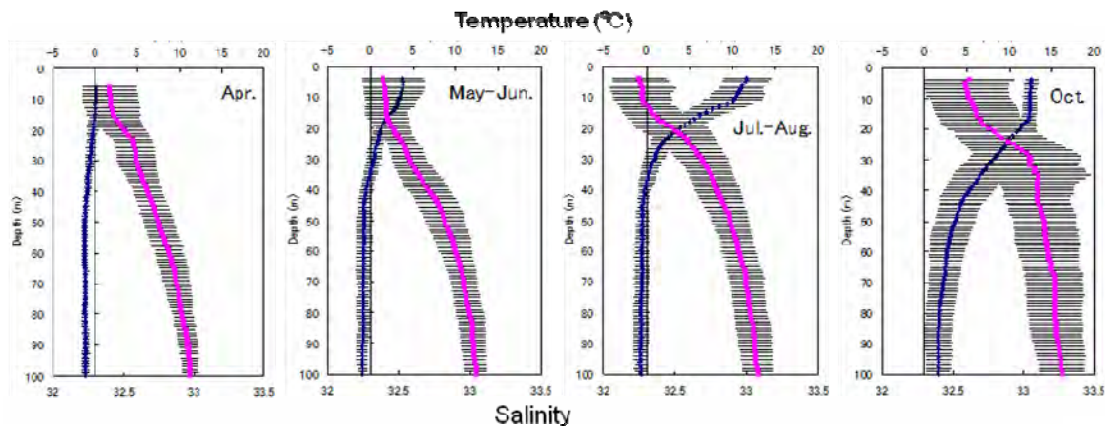


Fig. 3 Temporal changes in the vertical profiles of temperature (blue) and salinity (red) in the Offshore Area. Each value is the mean obtained from the observations between 2000–2006. Horizontal bars show the standard deviation obtained at each depth.

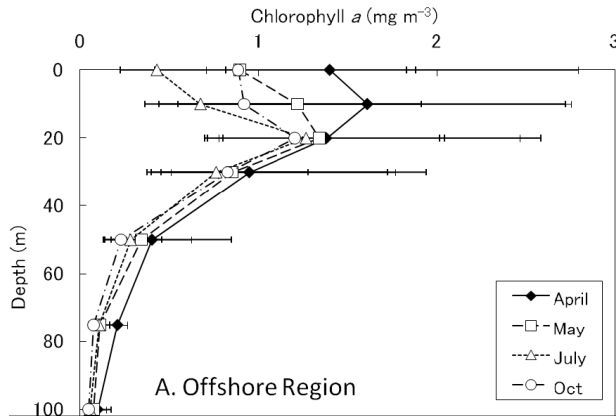


Fig. 4 Temporal change in the vertical profiles of chlorophyll *a* concentration. Each value is the mean obtained from the observations between 2000–2006. Horizontal bars show the standard deviation obtained at each depth.

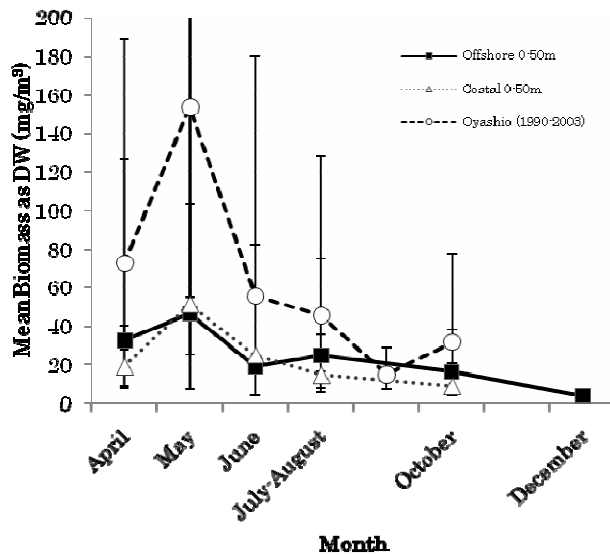


Fig. 5 Seasonal change of netplankton biomass as the mean dry weight (DW) concentration within the layer of 0–50 m depth. Vertical bars show the standard deviation obtained at each month.

Seasonal changes in the vertical profiles of nutrient concentrations (nitrate, phosphate and silicate) showed a similar trend. After April, the nutrient concentration in the surface layer decreased with season due to feeding by phytoplankton. The consumption of nutrients was observed in the layer shallower than 20 m depth, corresponding to the SCM. In summer and autumn, nitrate was at low level in the surface layer, limiting primary productivity. This suggests that the SCM was maintained using the nutrients supplied from the deeper layer through the pycnocline.

Netplankton biomass was highest in May in both the Offshore and Coastal areas (Fig. 5). A similar trend in seasonal variation of netplankton biomass was also observed in the Oyashio region; however, variability was much larger in the Oyashio region, compared to the small seasonal variation in the southern Okhotsk Sea. The seasonal change in species composition of netplankton samples is presently unknown. For future study, the temporal succession of species composition of not only zooplankton, but also phytoplankton, associated with movement between water masses, should be examined.

Using obtained data from this study, we can generally describe the seasonal change of daily primary production in the Offshore Area of the southern Okhotsk Sea (Fig. 6). Variability in primary production was seasonally small from spring to autumn; monthly mean production was about $500 \text{ mgC m}^{-2} \text{ day}^{-1}$. However, it is notable that we cannot capture data on primary productivity in the early spring; phytoplankton blooms have occurred in the ice-edge area accompanied by ice-melting (Mustapha and Saitoh, 2008). Primary production in summer was comparable to that in spring. Primary production in spring occurred mainly in the surface layer; on the other hand, production in summer was mainly in the SCM layer. This suggests that primary production during summer in the offshore Okhotsk Sea is just as important as that during spring in order to supply particulate organic matter to higher trophic levels in the offshore area.

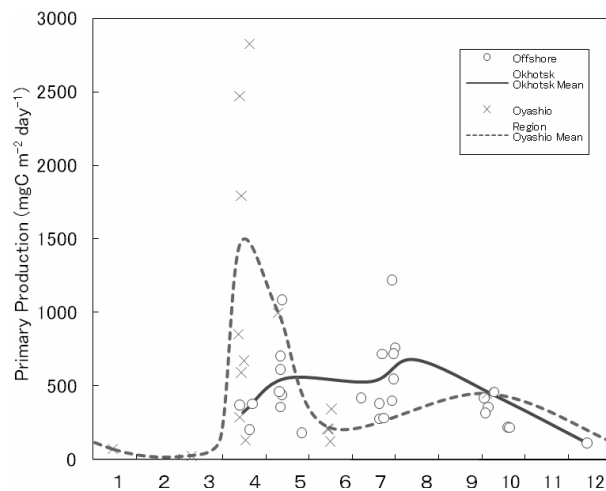


Fig. 6 Seasonal changes in daily primary production in the offshore area of the southern Okhotsk Sea and Oyashio region. Horizontal axis denotes months. Data in the Oyashio region was modified from Kasai (2000).

In this study, we have generally described the seasonal change of water column stability, nutrients, chlorophyll *a*, and primary production in the offshore area of the southern Okhotsk Sea. The importance of primary production at the SCM layer during summer and autumn can be indicated. In order to evaluate more precisely the primary productivity in the studied area, yearly monitoring of oceanographic conditions affecting primary productivity needs to be conducted. In the future, we can expect that a collaborative monitoring system with other laboratories and institutes will be established for evaluating and predicting the coastal ecosystem of the southern Okhotsk Sea in relation to global warming.

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