Proc. NIPR Symp. Polar Biol., 9, 125-130, 1996

DIFFERENCES IN DEVELOPMENT OF SUMMER PHYTOPLANKTON BLOOM UNDER FAST ICE AROUND SYOWA STATION, ANTARCTICA

Tsuneo ODATE[1]* and Mitsuo FUKUCHI[2]

[1]*Faculty of Bioresources, Mie University, 1515, Kamihama-cho, Tsu 514*
[2]*National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173*

Abstract: Temporal changes in phytoplankton abundance under Antarctic fast ice were investigated at three sites around Syowa Station from January 5 to February 6, 1992. One was located in the western part of Ongul Strait (Station A); the other two were in Kita-no-ura Cove (Stations B and C). Fast ice was thicker and snow coverage was heavier in the latter than in the former. During this period prominent blooms were observed at both areas when air temperature increased. Chlorophyll *a* abundance within the 5-30 m water column rapidly increased from January 12 to 17 and reached a maximum of 226 mg/m^2 at Station A. The increase was more gradual at Stations B and C than at Station A. The maximum abundances occurred on January 21-23 at Stations B and C, and corresponded to 65 and 53% of the maximum at Station A, respectively. The observed difference in bloom development seems to result from light availability, which was affected by ice and its condition.

1. Introduction

Primary production in polar ice regions is achieved by ice algae and phytoplankton, when incident irradiance increases in summer. Growth of ice algae usually precedes that of phytoplankton in time. When ice algal biomass declines in mid to late summer, phytoplankton production is a major food source for pelagic herbivores in the ecosystem under fast ice (SMITH and SAKSHAUG, 1990).

Around Syowa Station (69°00′S, 39°35′E), prominent phytoplankton blooms occur under fast ice in mid to late summer (HOSHIAI, 1969; FUKUCHI *et al.*, 1984; SATOH *et al.*, 1986; MATSUDA *et al.*, 1987). These studies showed that horizontal and vertical distributions of phytoplankton are not always homogenous. We consider that one of the causes of the uneven distribution of phytoplankton is light availability under fast ice since incident irradiance is greatly attenuated by sea ice and its condition (*i.e.*, its thickness and degree of snow cover and presence of ice algae, brine pockets, and air bubbles) (SMITH and SAKSHAUG, 1990). Consequently, the present study aims to reveal development of summer phytoplankton blooms under different fast ice conditions.

2. Materials and Methods

Samples of seawater under fast ice were taken at three sites around Syowa Station from January 5 to February 6, 1992 (Fig. 1). One of the sites was located in the

*Present address: Faculty of Fisheries, Hokkaido University, 1-1, Minato-cho 3-chome, Hakodate 041.

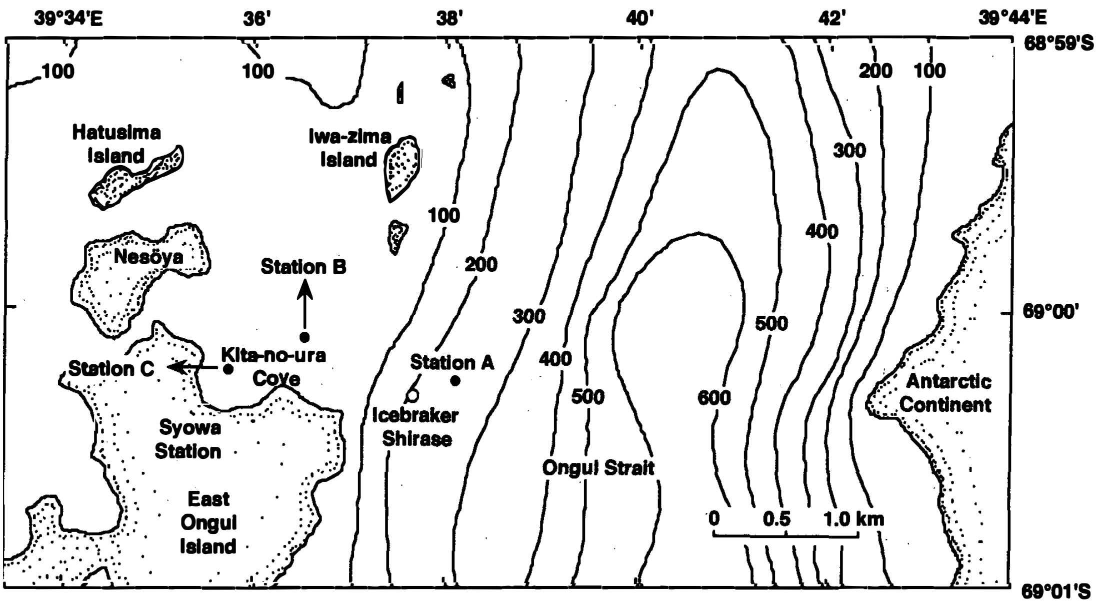

Fig. 1. Location of sampling sites. Station A was located in the western part of Ongul Strait, while Stations B and C were located in Kita-no-ura Cove. The icebreaker SHIRASE *was anchored at 69°00.3'S and 39°37.6'E (open circle). Submarine topography (depth in meter) is redrawn after* FUJIWARA *(1971).*

western part of Ongul Strait, Station A (sea depth was 219 m). The other two were in Kita-no-ura Cove, Stations B and C (sea depth was 33 m and 40 m, respectively). Data on air temperature, water temperature, and *in vivo* fluorescence were monitored every ten minutes with the Surface Water Monitoring System on the icebreaker SHIRASE (FUKUCHI and HATTORI, 1987), which was anchored near Station A (Fig. 1).

Seawater samples were collected using a Van Dorn bottle. An aliquot (100–200 m*l*) from the water sample was directly filtered through a Whatman GF/C glass fiber filter with vacuum pressure of less than 100 mm Hg. The filter was kept in a glass vial which contained 6 m*l* of N,N-dimethylformamide for extraction of chlorophyll *a* (Chl *a*) (SUZUKI and ISHIMARU, 1990), and stored in the dark at −20°C for 24 hours. Concentration of Chl *a* was determined by the fluorometric method using a Turner Design Fluorometer Model 10R (PARSONS *et al.*, 1984). The fluorometer was calibrated with pure Chl *a* (Sigma Chemical Co.).

3. Results

Sea surface in Ongul Strait and Kita-no-ura Cove was covered with fast ice over the sampling period. Fast ice was thicker in the latter (Station B, 2.7 m and Station C, 2.5 m) than in the former (Station A, 2 m). Coverage with snow on ice was heavier in the Kita-no-ura Cove than in the Ongul Strait area. Air temperature showed evident diel variation (Fig. 2a), reflecting the sun amplitude over a day. The mean air temperature increased from January 13, and reached the maximum of the mean air temperature of *ca.* 4.5°C on January 21–22. During the warming period (January 13–22), many puddles were formed, mainly in the Ongul Strait area where snow had almost disappeared. In contrast to air temperature, water temperature was fairly constant at *ca.*

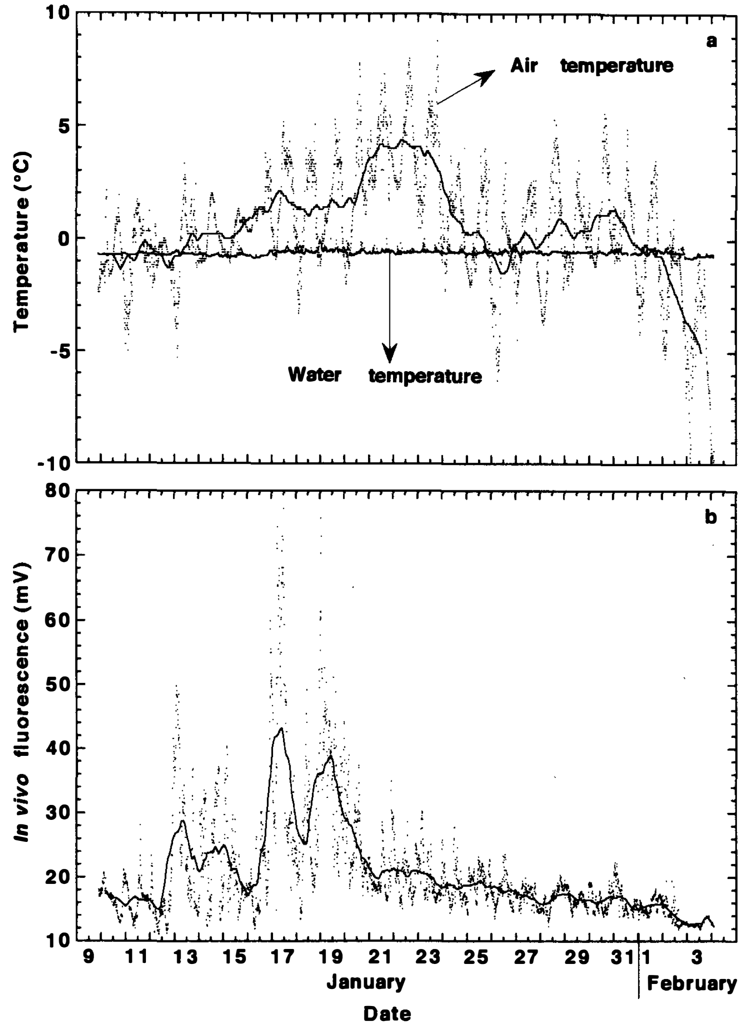

Fig. 2. Results of air and water temperature (a) and in vivo fluorescence (b), which were recorded by the Surface Water Monitoring System employed onto the icebreaker SHIRASE *(*FUKUCHI *and* HATTORI*, 1987). Solid lines denote the running mean within 24 hours. Calculation of the running mean of water temperature was not conducted.*

−0.6°C (Fig. 2a). Variation of *in vivo* fluorescence was large (Fig. 2b). The highest fluorescence was observed on January 17. Relatively high fluorescence was recorded on January 13–14, 17, and 19, when increase of air temperature was observed.

The vertical distribution of Chl *a* is shown in Fig. 3. The higher concentrations were usually observed in the upper layer at all stations. At the depth of 5 m, more than 8 *μg/l* Chl *a* was observed between January 15 and 26 in Ongul Strait (Station A). The highest concentration of 15.9 *μg/l* occurred at the depths of 5 and 10 m at Station A on January 17. On this day, the highest *in vivo* fluorescence was also recorded at the icebreaker SHIRASE (Fig. 2b). In Kita-no-ura Cove (Station B), more than 8 *μg/l* Chl *a* occurred at the depths of 5 and 10 m on January 22 and of 10 m on January 23. The highest Chl *a* at this station was 9.1 *μg/l* at 5 m on January 22. At another station in Kita-no-ura Cove (Station C), Chl *a* of more than 8 *μg/l* did not occur over the

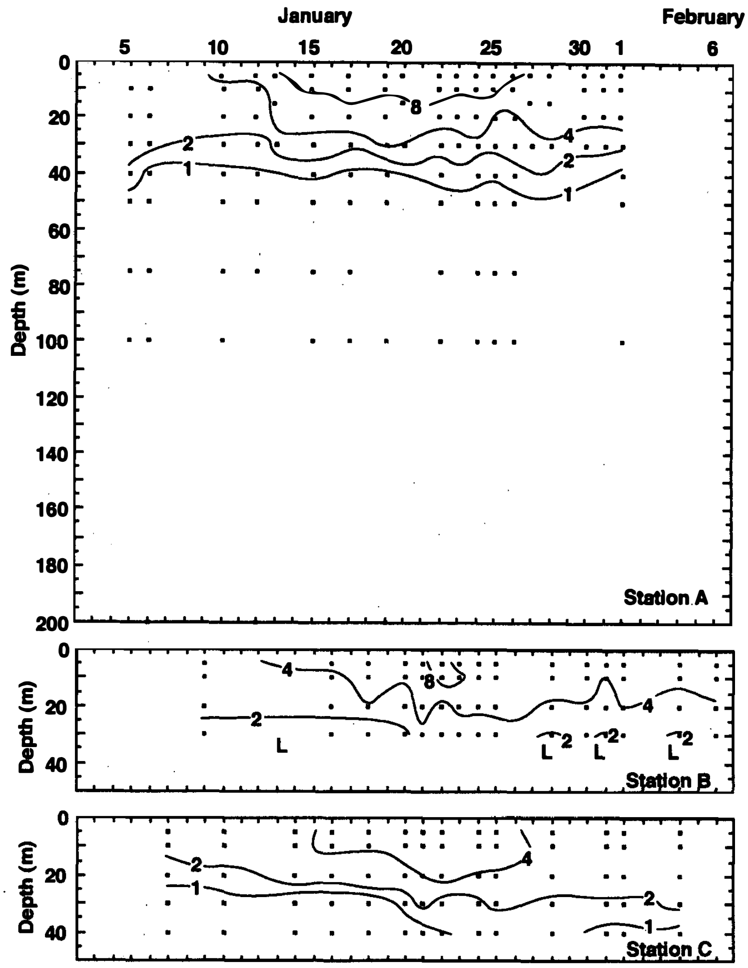

Fig. 3. Vertical distribution of chlorophyll a at three sites around Syowa Station (µg/l).

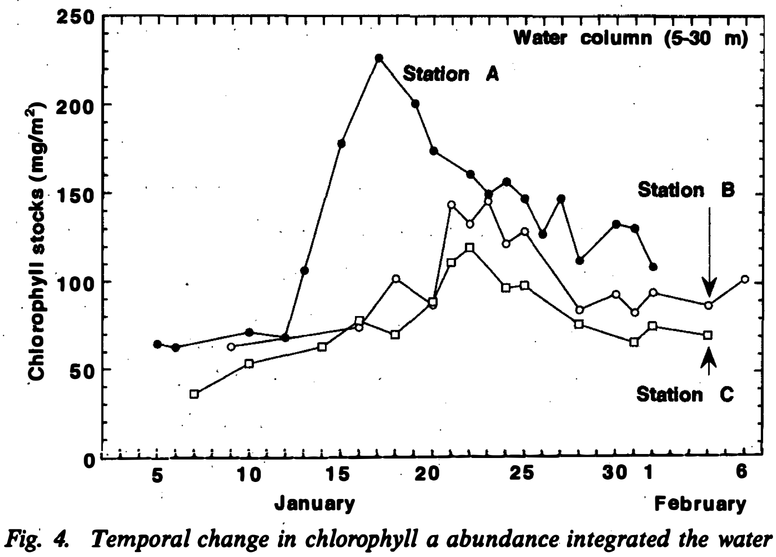

Fig. 4. Temporal change in chlorophyll a abundance integrated the water column between the depths of 5 and 30 m at three sites around Syowa Station.

sampling period and the highest concentration of 6.3 $\mu g/l$ was recorded at the depth of 10 m on January 20.

Figure 4 shows temporal changes in Chl *a* abundance integrated within the water columns (5–30 m). In Ongul Strait, Chl *a* abundance was 63–71 mg/m² on January 5–12 and increased rapidly from January 12 to 17 (closed circles in Fig. 4). In Kita-no-ura Cove, the temporal change was similar between Stations B and C, where the initial abundances were *ca.* 50 mg/m² and increased gradually by January 21–23. The maximum abundance occurred on January 17 in Ongul Strait (226 mg/m²), similar to *in vivo* fluorescence (Fig. 2), and on January 21–23 in Kita-no-ura Cove (146 mg/m² at Station B and 120 mg/m² at Station C).

4. Discussion

The present results showed that prominent blooms of phytoplankton occurred under the Antarctic fast ice around Syowa Station during a short period in summer. Usually one peak bloom occurs between middle January and middle February (HOSHIAI, 1969; FUKUCHI *et al.*, 1984; SATOH *et al.*, 1986; MATSUDA *et al.*, 1987). During the summer of 1992, the peak phytoplankton bloom was observed on January 17 at Station A, on January 22 at Station B, and on January 20 at Station C, being consistent with the former studies. The maximum concentration of Chl *a* of 15.9 $\mu g/l$ recorded at Station A is about 1.5 times higher than the previously reported maximum value (FUKUCHI *et al.*, 1984). On the other hand, the maximum values at Stations B and C coincide with the former values (HOSHIAI, 1969; SATOH *et al.*, 1986).

HOSHIAI (1969) reported that phytoplankton abundance under fast ice varied following the seasonal change of solar radiation. Although we did not measure solar radiation, its seasonal variation was well represented by air temperature (SATOH *et al.*, 1986). Both in Ongul Strait and Kita-no-ura Cove, development of phytoplankton bloom occurred from January 13 to 22, during which air temperature increased, implying that growth of phytoplankton was controlled by light intensity under fast ice.

We have further demonstrated that development of phytoplankton bloom in Ongul Strait was evidently different from that in Kita-no-ura Cove, although the spatial distance was less than two kilometers. Increase of phytoplankton abundance was first observed in Ongul Strait, where thickness of fast ice and depth of snow on ice were less than in Kita-no-ura Cove. Moreover, rapid increase of phytoplankton abundance in Ongul Strait occurred during the warming period, when snow on ice disappeared. Since thick fast ice and heavy snow increase the attenuation of incident irradiance (SMITH and SAKSHAUG, 1990), the observed difference in development of blooms seems to result from light availability under fast ice. Yearly difference in magnitude of phytoplankton bloom under fast ice was due to snow cover (SATOH *et al.*, 1986). Similar to phytoplankton blooms in water columns, light intensity attenuated by fast ice and snow is one of the critical factors controlling the growth of ice algae (HOSHIAI, 1985; SULLIVAN *et al.*, 1985; GOSSELIN *et al.*, 1990; WATANABE *et al.*, 1990).

HOSHIAI (1994) investigated the process and mechanism of patchy formation and decay of phytoplankton. The present study suggests that areal differences in ice thickness and snow coverage result in different developments of phytoplankton bloom under fast ice. The uneven distribution of the primary producer may govern the local trophic dynamics under the Antarctic fast ice. In the present study, however, underwater irradiance was not directly measured. And other environmental variables (*e.g.*, nutrient concentrations, salinity, and water temperature) are also required to discuss different developments of phytoplankton bloom under fast ice in detail. Further investigations are necessary to clarify these points.

Acknowledgments

The authors are indebted to the colleagues of JARE-33 for their cooperation during the samplings. A part of the present study was supported by a Grant-in-Aid for Scientific Research on Priority Areas from the Ministry of Education, Science and Culture in 1991 and 1993 (Grant Nos. 03248208 and 05760151 to T.O.).

References

FUJIWARA, K. (1971): Sounding and submarine topography of the glaciated continental shelf in Lützow-Holm Bay, East Antarctica. Nankyoku Shiryô (Antarct. Rec.), **41**, 81–103 (in Japanese with English abstract).

FUKUCHI, M., TANIMURA, A. and OHTSUKA, H. (1984): Seasonal change of chlorophyll *a* under fast ice in Lützow-Holm Bay, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **32**, 51–59.

FUKUCHI, M. and HATTORI, H. (1987): Surface water monitoring system installed on board the icebreaker SHIRASE. Proc. NIPR Symp. Polar Biol., **1**, 47–55.

GOSSELIN, M., LEGENDRE, L., THERRIAULT, J.-C. and DEMERS, S. (1990): Light and nutrient limitation of sea-ice microalgae (Hudson Bay, Canadian Arctic). J. Phycol., **26**, 220–232.

HOSHIAI, T. (1969): Seasonal variation of chlorophyll-*a* and hydrological conditions under sea ice at Syowa Station, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **35**, 52–67.

HOSHIAI, T. (1985): Autumnal proliferation of ice-algae in Antarctic sea-ice. Antarctic Nutrient Cycles and Food Webs, ed. by W. R. SIEGFRIED *et al.* Berlin, Springer, 89–92.

HOSHIAI, T. (1994): A review of the coastal marine ecosystem research at Syowa Station, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **38**, 243–251.

MATSUDA, O., ISHIKAWA, S. and KAWAGUCHI, K. (1987): Oceanographic and marine biological data based on the routine observations near Syowa Station between February 1984 and January 1985 (JARE-25). JARE Data Rep., **121** (Mar. Biol. 10), 21 p.

PARSONS, T.R., MAITA, Y. and LALLI, C.M. (1984): A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford, Pergamon Press, 173 p.

SATOH, H., WATANABE, K., KANDA, H. and TAKAHASHI, E. (1986): Seasonal changes of chlorophyll *a* standing stocks and oceanographic conditions under fast ice near Syowa Station, Antarctica in 1983/84. Nankyoku Shiryô (Antarct. Rec.), **30**, 19–32.

SMITH, W.O., JR. and SAKSHAUG, E. (1990): Polar phytoplankton. Polar Oceanography, Part B: Chemistry, Biology, and Geology, ed. by W.O. SMITH, Jr. San Diego, Academic Press, 477–525.

SULLIVAN, C.W., PALMISANO, A.C., KOTTMEIER, S., GROSSI, S.M. and MOE, R. (1985): The influence of light on growth and development of the sea-ice microbial community of McMurdo Sound. Antarctic Nutrient Cycles and Food Webs, ed. by W. R. SIEGFRIED *et al.* Berlin, Springer, 78–83.

SUZUKI, R. and ISHIMARU, T. (1990): An improved method for the determination of phytoplankton chlorophyll using N,N-dimethylformamide. Nippon Kaiyô Gakkaishi (J. Oceanogr. Soc. Jpn.), **46**, 190–194.

WATANABE, K., SATOH, H. and HOSHIAI, T. (1990): Seasonal variations in ice algal assemblages in the fast ice near Syowa Station in 1983/84. Antarctic Ecosystems: Ecological Change and Conservation, ed. by K. R. KERRY and G. HEMPEL. Heidelberg, Springer, 136–142.

(Received June 19, 1995; Revised manuscript accepted October 2, 1995)