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SEASONAL CHANGES OF NUTRIENT CONCENTRATION IN LAKE Ô-IKE NEAR SYOWA STATION, ANTARCTICA

Yoshikuni OHYAMA[1], Kenji MORIMOTO[2] and Yukira MOCHIDA[3]

[1]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*
[2]*Tottori Higashi High School, 5-chome, Tatsukawa-cho, Tottori 680*
[3]*Biological Institute, Faculty of Science, Tohoku University, Aramaki, Aoba-ku, Sendai 980*

Abstract: Seasonal variation of nutrients (phosphate, silicate, nitrate, nitrite and ammonium) at various depths of Lake Ô-ike near Syowa Station, Antarctica was studied almost every month during the wintering season of 1987 (late March 1987 to mid-January 1988) Although concentrations of nutrients were generally low as in the case of the previous studies, it became clear that nitrate and ammonium increased considerably in the middle and bottom layers during the winter months. These increments may be attributed to degradation of dead planktonic and/or benthic algae and probably escaped observation in the former surveys. Phosphate could not be detected in the present survey, and nitrite was absent in the middle and bottom layers in the winter months

1. Introduction

Freshwater and saline lakes around Syowa Station, Antarctica have been studied mainly from the chemical aspect (*e. g.*, MATSUBAYA *et al.*, 1979; TORII *et al*, 1988), and the analysis of some lake waters has continued as one of the items for environmental monitoring up to this time (MURAYAMA *et al*, 1981, 1984). Biologically, floral surveys of freshwater algae were made in lakes, ponds and melt streams in the ice free areas extending over the east coast of Lutzow-Holm Bay (AKIYAMA, 1974). Standing crop and productivity of the freshwater algae were also determined in some lakes and ponds of this region (TOMINAGA, 1977). However, these former studies were almost restricted to the summer season so that the seasonal changes of nutrients and standing crop were not yet studied throughout the year in the lakes of this region.

In the previous paper, we reported the seasonal changes of water temperature and chlorophyll-*a* concentration in the wintering season of 1987 at Lake Ô-ike, a freshwater lake near Syowa Station (OHYAMA *et al*, 1990). This paper deals with the seasonal variation of nutrients (phosphate, silicate, nitrate, nitrite and ammoium) at various depths of Lake Ô-ike in the same season

2. Materials and Methods

The descriptions about Lake Ô-ike were already given in the previous paper (OHYAMA *et al*, 1990). The lake was not affected by human activities even though

it is located near the Station. Sampling of the lake water was conducted almost every month during the wintering season from late March 1987 to mid-January 1988, and made through the hole bored in the surface ice at almost the same point every time except for January. Water samples were taken by 1 *l* plastic sampler from six to seven layers at every 2 m depth from just beneath the surface ice. The water samples were carried back to the laboratory of the Station, and nutrients were determined by the methods of STRICKLAND and PARSONS (1972).

3. Results and Discussion

The lake surface started to freeze in early March, and was covered with ice till late December or early January. The surface ice reached its maximum thickness of 210 cm in late September, but disappeared completely in mid-January. The lake water was cooled from surface during autumn and winter months, so that the lake water showed a vertical temperature gradient in this period. The bottom water never cooled below 3°C even in the coldest month. Then a mixing of the lake water occurred after early spring, resulting in almost uniform temperatures (OHYAMA *et al.*, 1990).

In the present survey, the seasonal changes of each nutrient were pursued with more detailed sampling intervals than in the former ones. The following are the results obtained in the present survey, and are compared with the former ones.

Phosphate of the lake water was almost undetected in any season of the present survey. However, FUKUI *et al.* (1985) reported low concentration of phosphate in this lake ranging from 0.01 to 0.11 μg-at/l at different depths in the summer season. It is consistent with that TORII *et al.* (1988) summarized the distribution of nutrients in Antarctic lakes and ponds, and pointed out that concentrations of phosphate in freshwater lakes and the oxidative layers of meromictic lakes in Antarctica are generally low.

The concentration of phosphate is generally a limiting factor for algal proliferation in lakes of temperate regions (GOLTERMAN, 1975), and the same may be considered in the Antarctic region (TORII *et al.*, 1988). As already reported in the previous paper (OHYAMA *et al.*, 1990), planktonic algae increased in both autumn and spring as indicated by chlorophyll-*a* concentration of the lake water. At the same time, mat of blue green algae was found on the bottom floor with a considerable thickness as revealed by the sediment cores. Considering the above facts and the result of FUKUI *et al.* (1985), it is difficult to understand that phosphate was not detected in any layer throughout the year in the present survey. It is necessary to re-examine the concentration of phosphate in accordance with the seasonal changes of chlorophyll-*a* concentration, including the applied analytical method.

Seasonal change of silicate concentration is indicated in Fig. 1. These values were comparatively low in late March and August, but were high (over 30 μg-at/l) in late April and during the period from November to January. In this lake, the silicate concentrations determined formerly ranged from 13.1 to 31.3 μg-at/l (MURAYAMA *et al.*, 1981), of which the maximum value occurred in April at 2 m depth. This is similar to those in the same season of the present survey. In comparison with

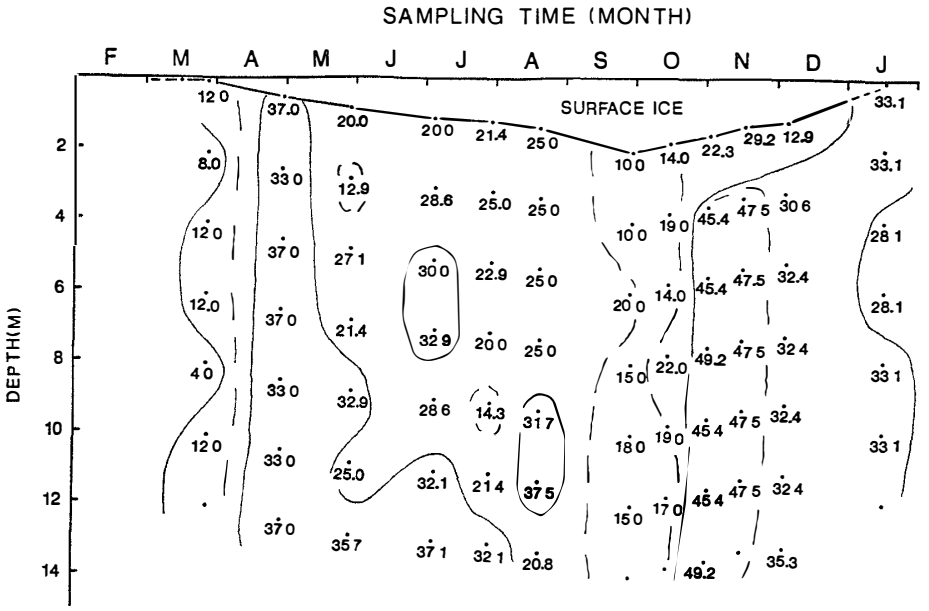

Fig 1 Seasonal change of silicate concentration in Lake Ô-ike with vertical distribution. Each numeral indicates the concentration in μg-at/l

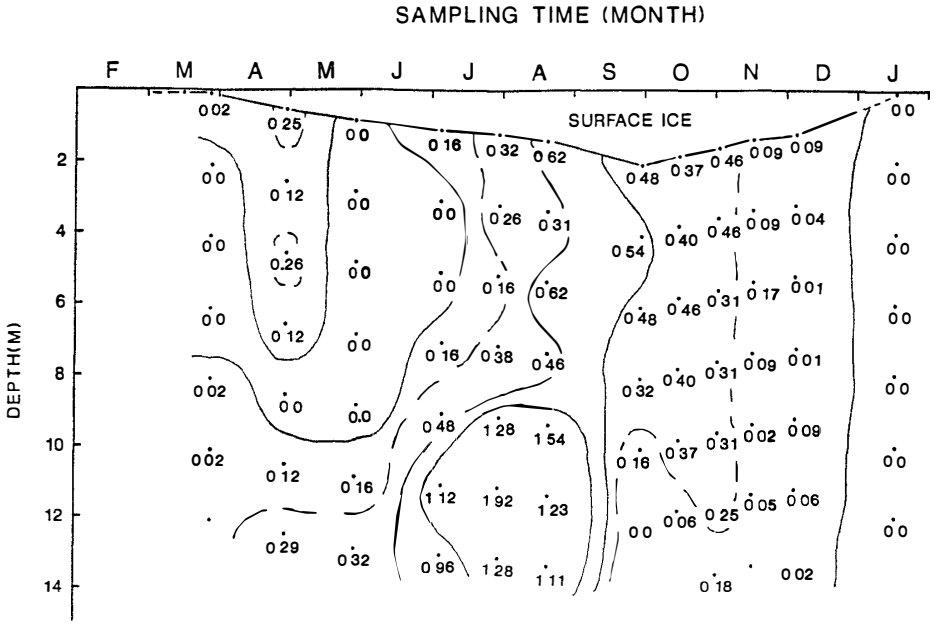

Fig 2. Seasonal change of nitrate concentration in Lake Ô-ike with vertical distribution. Each numeral indicates the concentration in μg-at/l

the former values referring to season and depth (MURAYAMA *et al*, 1981; 1984), the present values showed a small difference in surface layers throughout the whole season. However, after November much high values were observed in the middle and bottom layers of the present survey, although the data of the former surveys were scarce.

Seasonal change of nitrate concentration is indicated in Fig. 2 The concentration increased rapidly over 1 μg-at/l in the lower layers during July and August. Then

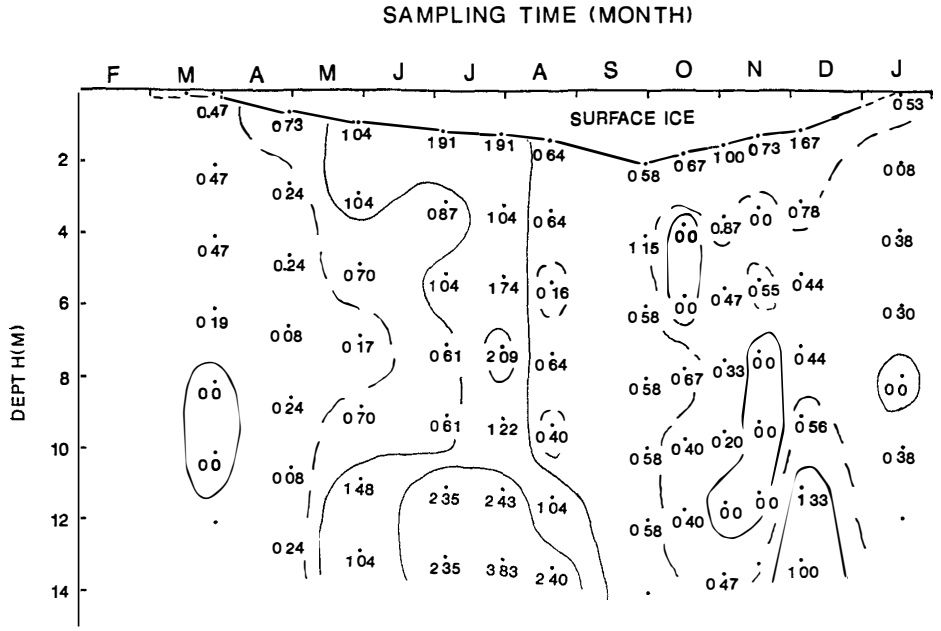

Fig 3 Seasonal change of ammonium concentration in Lake Ô-ike with vertical distribution Each numeral indicates the concentration in μg-at/l

the nitrate seemed to diffuse in the upper layers due to the circulation of lake water (OHYAMA *et al.*, 1990), and the concentration decreased to the original level of autumn by the next summer. MURAYAMA *et al.* (1981) reported the concentrations below 0.08 μg-at/l in the surface waters of the lake in summer. However, the high concentration of 1.19 μg-at/l was recorded in the water obtained at 9 m layer in August of 1981 (MURAYAMA *et al.*, 1984). This value is similar to the present one. But the concentrations sampled in March of that season showed higher values than the present ones in both surface and bottom layers (MURAYAMA *et al.*, 1984).

Frequently nitrite could not be detected in the present survey. Especially it was completely absent in the middle and bottom layers in the winter months. Its concentration attained 0.2 μg-at/l in the surface layers from October to December, but there was no characteristic seasonal change. The concentrations obtained in the former surveys were generally low (below 0 25 μg-at/l, MURAYAMA *et al.*, 1981) as in the present ones. TORII *et al* (1988) also pointed out that the concentration of nitrite is generally low in the coastal lakes of the Antarctic.

Seasonal change of ammonium concentration is indicated in Fig. 3. The values fluctuated considerably with season and depth even at the same sampling time. The characteristic change of the concentration throughout the season is that the values increase during the dark winter months especially in the bottom layers. The present values are similar to the former results (MURAYAMA *et al.*, 1981, 1984) except for the dark winter months

In the previous paper, we reported the slightly colored water which was sampled from the bottom layer in July and August. It was thought to be a cell suspension of dead planktonic algae with a phaeophytin pigment judging from the chlorophyll concentration. The bottom floor is also covered with a considerably thick mat of blue

green algae as previously stated. Since temperature of the bottom water never cooled below 3°C even in the coldest month (OHYAMA *et al*, 1990), the degradation of organic matter was supposed to occur at the lake bottom Also, it is thought that ammonium liberated from organically bound nitrogen is oxidized to nitrite, and then to nitrate Comparing the seasonal changes of ammonium and nitrate in the present survey, the concentration of ammonium in the bottom layers increased slightly earlier than that of nitrate (Figs 2 and 3) However, nitrite was not detected in the middle and bottom layers in the winter months when both ammonium and nitrate increased. Since nitrite is easily oxidized to nitrate in aerobic condition (GOLTERMAN, 1975), nitrite may be in low concentration and frequently not detected in the present survey

It has been pointed out that nutrient level is generally low in the freshwater lakes of the Antarctic (TORII *et al.*, 1988) As in the previous reports (MURAYAMA *et al*, 1981, 1984), the present survey also showed low concentration of the nutrients except for the increment of ammonium and nitrate during the winter months Since the former surveys were conducted only in the summer season or with sparse sampling frequency even in the wintering season, they probably failed to observe such increment for a short period as occurred in the middle and bottom layers of the present survey.

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