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SEASONAL CHANGES OF WATER TEMPERATURE AND CHLOROPHYLL CONCENTRATION IN LAKE Ô-IKE

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Abstract: Seasonal observations of water temperature and chlorophyll concentration were carried out in Lake Ô-ike near Syowa Station, Antarctica, in 1987. Water sampling was begun at the end of March and continued to the next January almost every month. The lake surface was covered with ice during 10 months from March to December. The lake water was cooled through surface from March to August, but the bottom water remained above 3°C even at the coldest season. According to the results of chlorophyll measurement, the bloom of phytoplankton seemed to occur at two times in April and September mainly at lower layer reaching 0.80 and 1.82 mg/m^3, respectively.

1. Introduction

Limnological studies around Syowa Station have been carried out mainly from the geochemical viewpoint and have continued the chemical analysis of water as one of the items of environmental monitoring up to this time (HIGANO, 1977; MURAYAMA, 1977; MURAYAMA *et al.*, 1981). Biologically, floristic surveys of terrestrial and freshwater algae were made in ice-free areas extending over the east coast of Lützow-Holm Bay (AKIYAMA, 1968, 1974). Studies of algal standing crop and productivity were also carried out in some freshwater lakes at the ice-free areas of this region (TOMINAGA, 1977). But these studies were almost restricted to the summer season, and even though surveyed in winter, they were not always carried out systematically to pursue the seasonal variation of some items at some lakes throughout the year.

This paper deals with the seasonal variations of chlorophyll and water temperature of Lake Ô-ike measured during the wintering season of 1987.

2. Study Area and Methods

2.1. *Study area*

Lake Ô-ike lies in West Ongul Island, which is adjacent to the island where Syowa Station is located (Fig. 1). Although the lake is only about 2.5 km apart from the station, it is hardly disturbed by human activities, for the members of JARE seldom visit there except during survey period because of bad sea-ice condition in summer.

Surface area of the lake is about 59000 m^2, and elevation is about 12 m above sea level. The lake rapidly increases in depth from the shore, and the main part of the lake

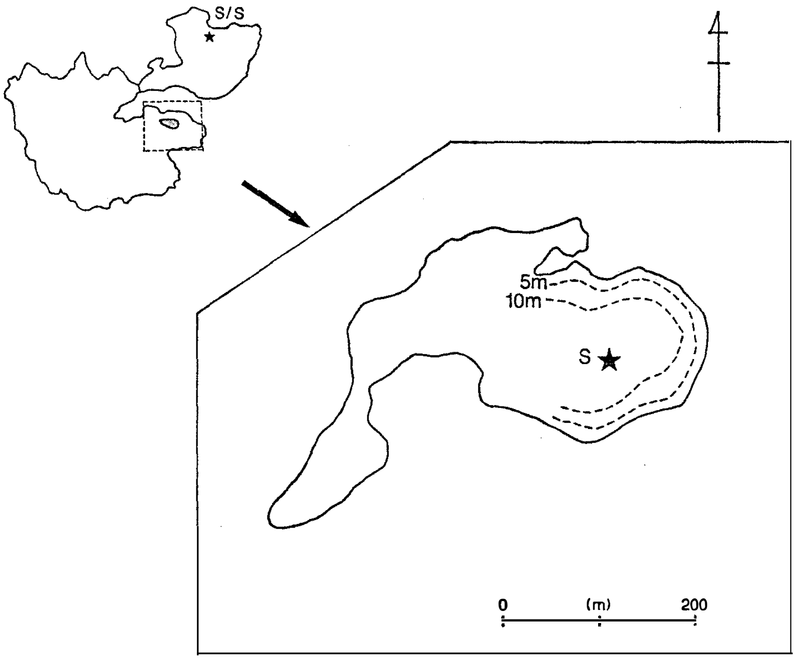

Fig. 1. Location of Lake Ô-ike and sampling station. S/S: Syowa Station; S: Sampling station.

is about 10 m in depth and forms almost a flat floor at the bottom. In the present survey, the maximum depth of 13 m was recorded at the center of the eastern part where the sampling station was settled (Fig. 1). The lake surface is covered with ice during the period from early March to mid-December. The lake water is supplied mainly by melted water in summer from the snowdrifts formed in winter on surrounding area of the lake. There is no outlet from the lake, and it seems that the lake water is discharged only by evaporation in summer.

2.2. *Methods*

The survey was carried out from late March, 1987 to January, 1988 at intervals of almost every month. Water sampling and temperature measurements were made through a hole bored in the surface ice at the same point every time during March to December. Since the surface ice had disappeared in January, they were made on a boat at almost the same point. The hole was bored by an electric ice auger about 10 cm in diameter. Water samples were taken at the layers of every 2 m from just beneath the ice using a 1 *l* plastic bottle. Water temperature was also measured by a hand held thermistor at each sampling depth.

The amount of chlorophyll-*a* was determined by the fluorometric method (STRICKLAND and PARSONS, 1972) with the acetone extracts from residues of 500 m*l* filtration. Dissolved oxygen was also determined by Winkler method after the fixation of water at sampling site.

3. Results and Discussion

The present survey was started at the end of March after confirmation that the surface water had already frozen over in thickness of 7 to 10 cm in mid-March. The thickness of surface ice increased gradually with the lapse of time and reached the maximum of 210 cm on September 30. Then it decreased gradually, but still remained 120 cm on December 4. The ice had disappeared completely after 6 weeks, when the survey was made on January 16. Seasonal changes of the ice thickness are indicated in Fig. 2 together with the fluctuation of air temperature, and seasonal changes of water temperature measured at each depth of water sampling.

The water temperature was not measured until the end of March in the present survey, but Fig. 2 shows a tendency that the lake water was cooled by cold air from the surface, indicating lower value in upper layer and higher in bottom from April to August with decreasing air temperature.

As for rapid increase of water temperature after September, solar radiation seems to play an important role together with a moderate cooling rate due to no further decrease of air temperature. Since the surface-ice frozen in a slow cooling rate under natural condition is very transparent without bubbles, sunlight may easily reach into the

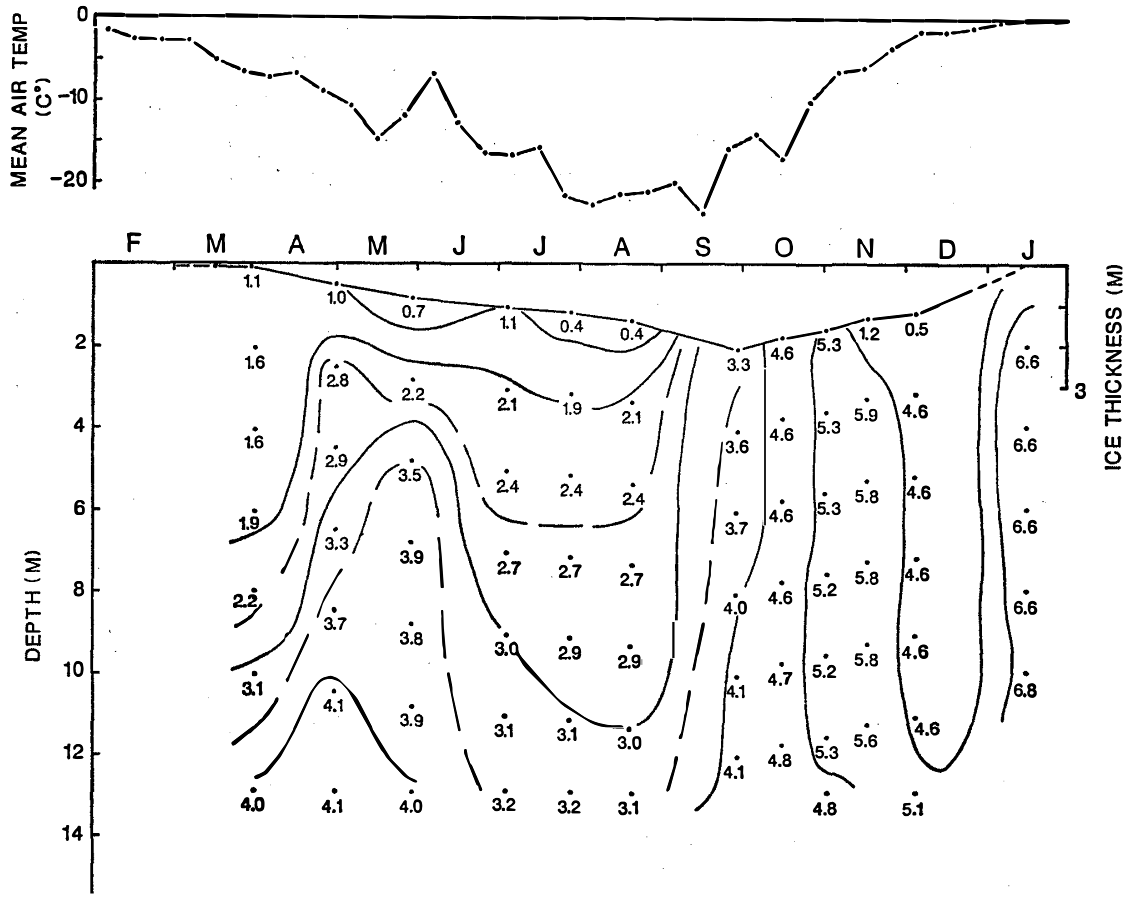

Fig. 2. Seasonal changes of mean air temperature and water temperature of Lake Ô-ike. The thickness of surface ice is also inserted. Each numeral indicates water temperature in centigrade.

lake water. There is no snow cover on the surface-ice blown by wind, and snowdrift on the ice is restricted to a small area of the northeastern corner by dominant wind direction. Albedo of the surface ice was determined at wavelength from 400 to 1100 nm in early December. Surface of the ice was somewhat disturbed by thin, whitish crust-ice formed from meltwater due to strong daylight and night cooling. The albedo of this ice was about 60 percent in visible range and about 40 percent in infrared around 1050 nm. When the crust was removed, the albedo decreased to 40 to 45 percent in visible range and 20 percent in infrared, respectively (T. YAMANOUCHI, unpublished data). It might, therefore, be expected that radiation exerted a comparatively large influence on the increment of water temperature due to the low value of Albedo, though spring radiation was much lower than in summer. The lake water once warmed is hard to cool due to the isolation from cold air by surface ice.

The water temperature of middle layer showed comparatively high value in May, whereas it decreased temporally in December. In the former case, the stable surface-ice grown to about 50 cm in thickness may prevent water mixing by wind besides the direct contact to cold air, and cooling rate of water moderates until the further decrease of air temperature in the coldest season. Heat source of this period seems to be latent heat of bedrock absorbed during summer rather than solar radiation because of short daylight. In the latter case, since the surface ice is thawing rapidly to a great extent, the temperature seems to decrease temporally by a supply of cold melted water.

The seasonal variation of chlorophyll-*a* is indicated in Fig. 3. The amount of chlorophyll-*a* in lake water increased both in the end of April and of September, respectively. The increment in April was comparatively moderate, but spread over the water column. On the other hand, that in September was remarkable, but apparently was

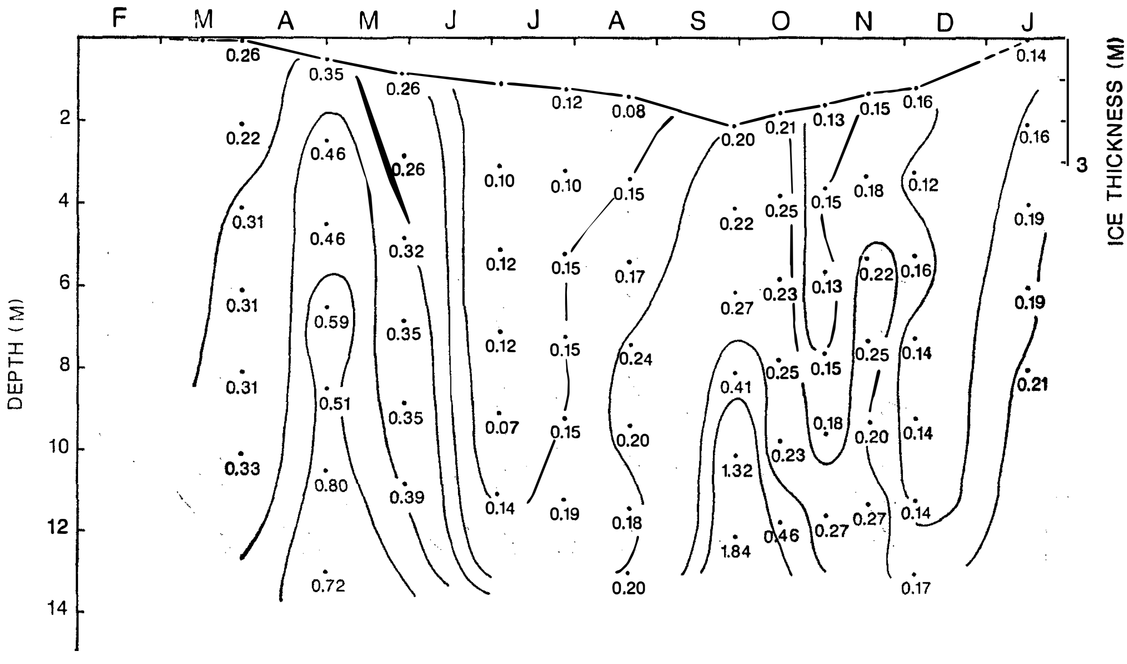

Fig. 3. Seasonal fluctuation of chlorophyll-a in lake water. Each numeral indicates concentration in mg/m³.

restricted to the bottom layer. The standing stocks of both watei columns, however, were almost the same value, indicating 6.71 in April and 6.48 mg/m^2 in September, respectively, on condition that the depths were 12 and 10 m, respectively, because of difference of the ice thickness at each time.

Heath (1988) studied the primary production in Watts Lake, Vestfold Hills, Antarctica, and showed that phytoplankton production peaked in autumn and spring with a maximum rate in September, then declined in summer, whereas benthic algal production peaked in summer. Production strategies differed, with more efficient phytoplankton adapted to growth at low light, while benthic production increased with increasing light in summer. He also estimated an annual production, and benthic production occupied about half value compared to that of phytoplankton.

Phytoplankton in Lake Ô-ike, as indicated by chlorophyll-*a* concentration, increased in April and September, and decreased in summer like Watts Lake. As to benthic algae, the present survey brought no information about standing stock. But bottom core samples obtained at 6 points ranging from center to shore were exclusively composed of algal mats or deposit of algal remains at least 40 to 50 cm in thickness. These samples seemed to be blue-green algae in appearance. Since benthic algae seem, therefore, to exist in rather large quantity, it is necessary to take them into consideration for studies on primary production and standing stock of algae in this lake.

The amount of chlorophyll-*a* decreased as a matter of course during austral winter from June to August. Slightly colored water was sampled in July and August at bottom layer. It was thought to be a cell suspension of phytoplankton, but chlorophyll-*a* concentration showed lower value. Since core samples mentioned above were composed of algal mats or deposit of algal remains at least 40 to 50 cm in thickness and inorganic

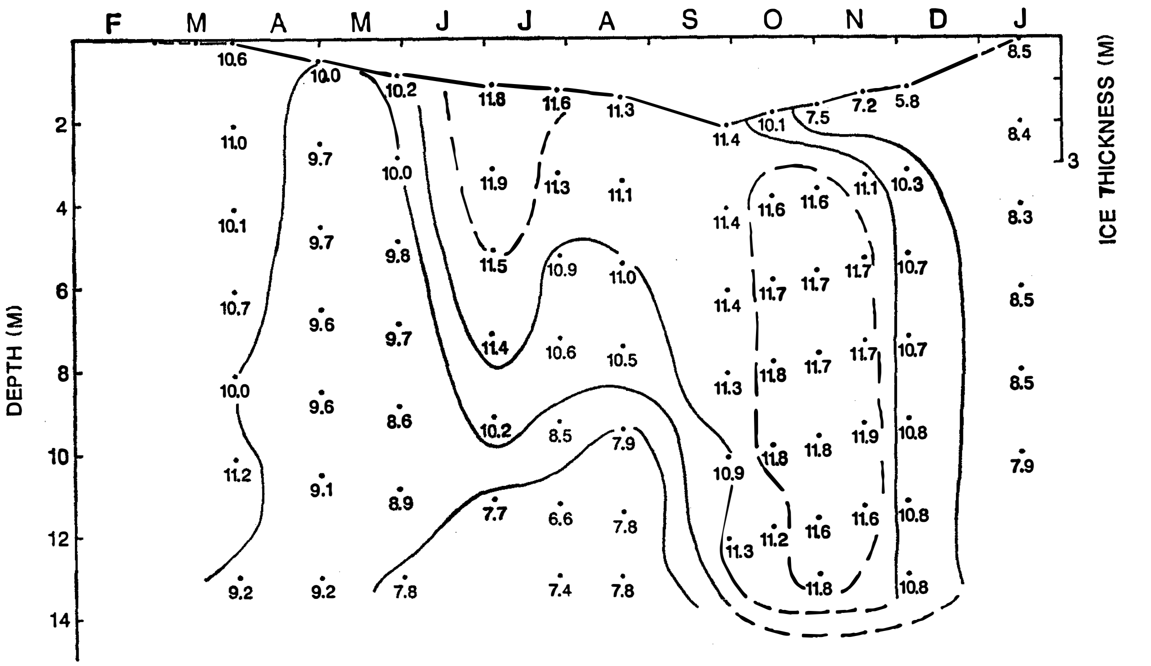

Fig. 4. Seasonal fluctuation of dissolved oxygen in lake water. Each numeral indicates concentration in ml/l.

matters like silt were not observed on the bottom surface, the colored waters taken in July and August seemed to be dead-cell suspension of phytoplankton.

Seasonal changes of dissolved oxygen is indicated in Fig. 4. The concentration of dissolved oxygen showed low value at bottom layer during the winter season. This low level might be due to the degradation process of dead cells mentioned above. The low concentrations were also observed just beneath the surface ice from November to December, and this low level seemed to be diluted by the melted water from surface ice. On the other hand, the high value was observed in almost the whole layer extending September to December. This high level was not inconceivable from photosynthetic activities including benthic algae, whereas the high concentration was also observed in upper and middle layers from June to August. Vertical profile of the concentration indicated that the oxygen was supplied from the lake surface, but in this season the surface was entirely covered with the ice more than 1 m in thickness. Ice-associated algae frequently observed in sea ice were not present in this lake ice. Even though present, it was dark winter and photosynthetic activity was not expected. The oxygen may be liberated into the lake water in the process of ice formation, but it is difficult to explain the quantitative relationship of dissolved oxygen and liberated oxygen. In this stage, it is impossible to elucidate the high concentration of surface layer in winter, and it is necessary to continue successive surveys.

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