# A Preliminary Report on Some Limnological Investigatons of Lakes in the Vicinity of Syowa Station by Japanese Antarctic Research Expedition in 1981 and 1985

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## 昭和基地周辺で行った湖沼調査予報(1981, 1985 年)

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**要旨：**環境モニタリング観測計画の一環として行われた，南極リュツォ・ホルム湾東岸露岩地帯の湖沼調査の結果のうち，湖の水温垂直分布について，第 26 次観測隊による観測を中心に，第 22 次観測隊の観測結果を加えて資料として示し，それ以前の若干の結果を併せて，その季節変動の特徴や年ごとの変動の一端を予察的に記述した．塩湖はそれぞれ特徴のある温度分布を示し，それらはいずれも大まかに季節的変動の大きい上部層と小さい下部層の二層構造を示し，化学成層に対応している．淡水湖は氷に覆われている間，典型的な逆列成層を示すことが確かめられた．

また，従来調査が行われなかったリュツォ・ホルム湾南部のルンドボークスヘッタおよびベルオッデンの湖水温，主化学成分の調査結果を示した．これらの湖は氷床に接していてその涵養を受けており，湖水の塩分濃度は極めて低く，1985/1986 年にはこの地域の淡水湖としては極めて低温の湖であった．ルンドボークスヘッタの湖は過去の観察，空中写真によると，夏期の湖氷の融解の程度の年ごとの変動が大きく，局地的な気候条件をよく反映することも指摘できる．

***Abstract:*** The characteristics of vertical water temperature distributions of several lakes which have been studied as part of the "monitoring of the environmental change project" in the Lützow-Holm Bay region are preliminarily reported, based mainly on the results obtained by the 26th Japanese Antarctic Research Expedition (JARE-26) in 1985/1986 and in part by JARE-22 in 1981, together with some other data. Selected lakes consist of saline and freshwater ones. Each saline lake has its characteristic temperature distributions, and seems to have two-layer structure which consists of the upper layer undergoing large seasonal fluctuations and the lower layer having rather stable temperature distributions. This structure corresponds to remarkable chemical stratification. The pattern of temperature distribution of each lake seems to have differed little for considerable years, but the absolute temperature value changes slightly from year to year. Freshwater lakes show typical inverse stratification

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when lakes are covered with an ice layer in winter, and fluctuation from year to year is very small. In addition, general features of two newly investigated lakes are reported. They are situated in ice-free areas in the southern part of the eastern coast of Lützow-Holm Bay, adjoining the ice sheet. Their waters show very low concentration of dissolved salts.

## 1. Introduction

Since 1957 with the commencement of the activities of the Japanese Antarctic Research Expedition (JARE), geochemical investigations of lakes around Syowa Station in Antarctica have been carried out intermittently. The results obtained showed the existence of various kinds of lakes in chemical composition and accordingly in physical properties. Since 1978, the research program has been concentrated mainly on the change of chemical composition of waters of selected lakes, as part of the "monitoring of the environmental change project" (hereafter "environmental monitoring"). The objectives of the program are to pursue the long-term change of chemical composition of water related to the change in climatic conditions and to monitor human impact on the natural environment. The results of chemical analysis of water samples obtained up to the 1982/1983 season were reported already(MURAYAMA *et al.*, 1981, 1984). However, other features of lakes such as water temperature profiles have not been sufficiently reported.

We describe preliminarily the results of water temperature measurements in the 1981 season (JARE-22) and the 1985/1986 season (JARE-26) in comparison with some results of the previous investigations, and general features of newly investigated lakes in 1985/1986, for the main purpose to record data at this stage. MURAYAMA is responsible for the 1985/1986 results, HIDAKA for the 1981 results, and YOSHIDA supported the 1981 investigation for preparation of this report on the basis of discussions among them.

## 2. Water Temperatures

There are many small lakes and pools in ice-free areas on the eastern coast of Lützow-Holm Bay. The chloride ion concentrations range from 1.3 mg/*l* to 210 g/*l* (MURAYAMA *et al.*, 1981). The lakes selected for the "environmental monitoring" are Lake Ô-ike, Lake Skallen Ôike, Lake Nurume, Lake Hunazoko and Mizukumi Stream. Mizukumi Stream is excluded from the present report, because it is a very shallow, artificially dammed pool and freezes completely during winter. Lake Ô-ike on West Ongul Island and Lake Skallen Ôike in the Skallen area are freshwater lakes fed by meltwater from snowdrift. Lake Nurume in the Langhovde area and Lake Hunazoko in the Skarvsnes area are saline lakes. In addition to these lakes, Lake Suribati in the Skarvsnes area was surveyed for "environmental monitoring" from 1985, because it is the largest saline lake in the Lützow-Holm Bay region.

Water temperature was measured with a thermister-thermometer through a 11-cm diameter hole bored with CRREL ice auger in a surface ice of a lake. Water sampling was conducted also through this hole. Location and some characteristics of each lake are given in Fig. 1 and Table 1, respectively.

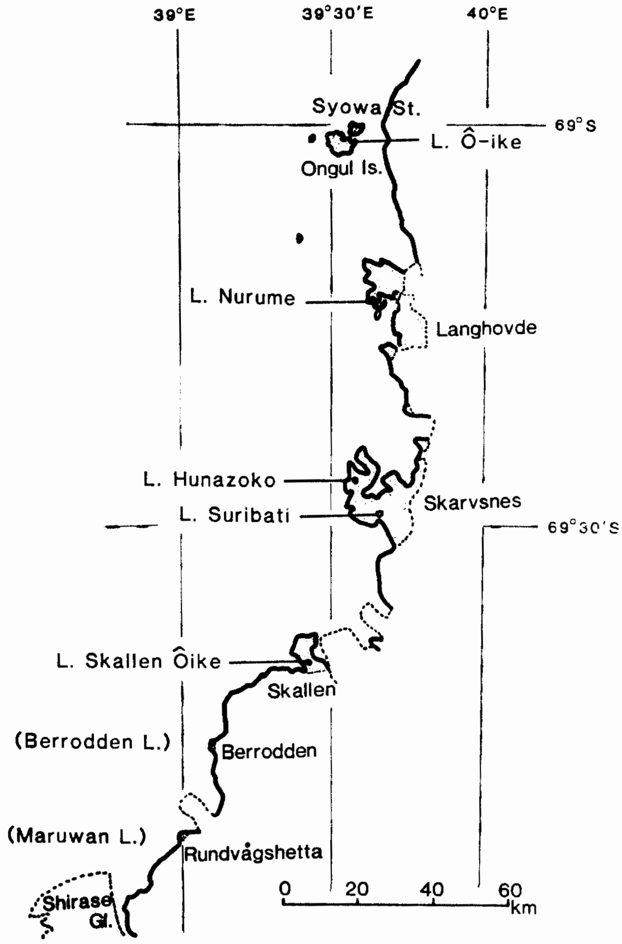


*Fig. 1. Map showing locations of lakes and ice-free areas on the eastern coast of Lützow-Holm Bay.*

*Table 1. Geographic characteristics of studied lakes.*

| Lake | Ô-ike | Nurume | Hunazoko | Suribati | Skallen Ôike |
|---|---|---|---|---|---|
| Location | West Ongul I. | Langhovde | Skarvsnes | Skarvsnes | Skallen |
| Distance from seashore (m) | 170 | 30 | 290 | 400 | 135 |
| Elevation of the lake surface above sea level (m) | 13 | $0^+$ | -23 | -33 | 10 |
| Depth of the lake (m) | 11.2 | 16.6 | 9.2 | 31.2 | 9.3 |
| Major diameter of the lake (m) | 370 | 305 | 675 | 1070 | 1180 |
| Minor diameter of the lake (m) | 215 | 155 | 250 | 780 | 275 |
| Area of the lake ($m^2 \times 10^4$) | 5.2 | 3.1 | 14.2 | 40.6 | 20.9 |

## 2.1. Lake Nurume

Figure 2a indicates seasonal fluctuations of vertical water temperature distributions in 1981, and Fig. 2b those in 1985, together with the distributions in October 1967, January 1974, May 1979 and September 1979 for comparison. Lake Nurume is covered with an ice layer up to 150 cm in thickness in winter, and the ice melts in January except in cool summers like the case of 1986 when only the ice along the lake margin thawed slightly.

SANO *et al.* (1977) pointed out that the lake has the structure composed essen-

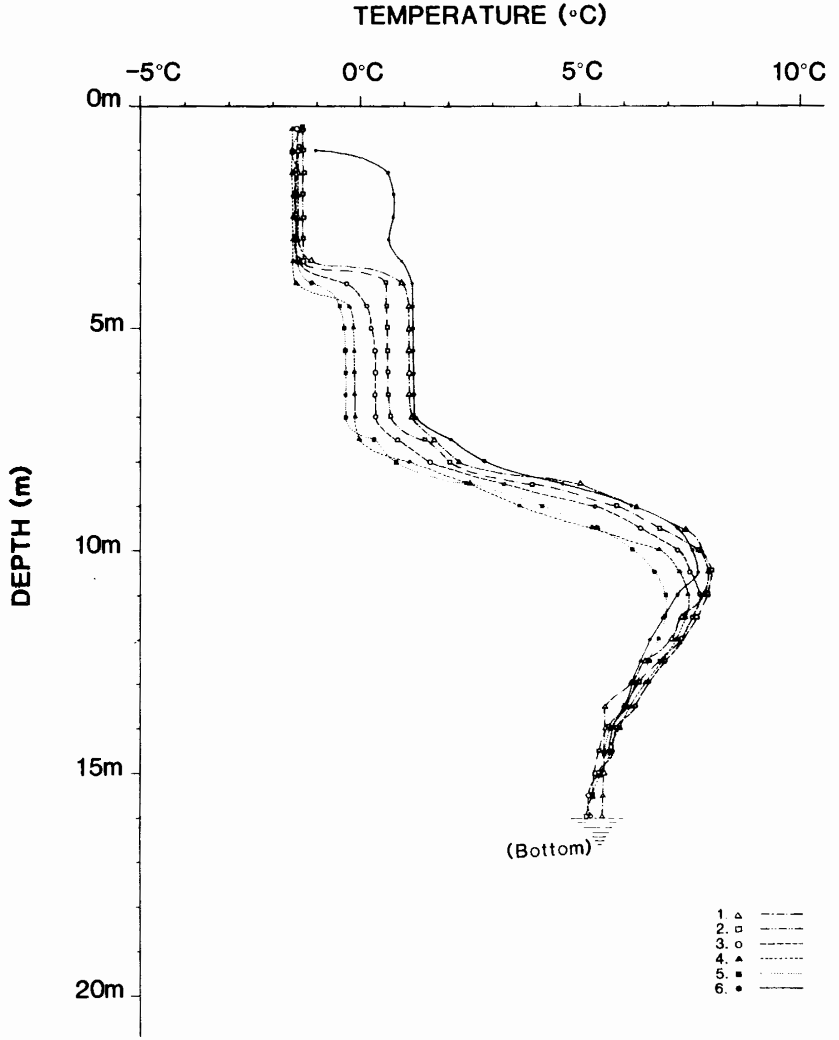


*Fig. 2a. Vertical water temperature distributions of Lake Nurume in 1981. 1: July, 2: August 11, 3: August 26, 4: September, 5: October, 6: November.*

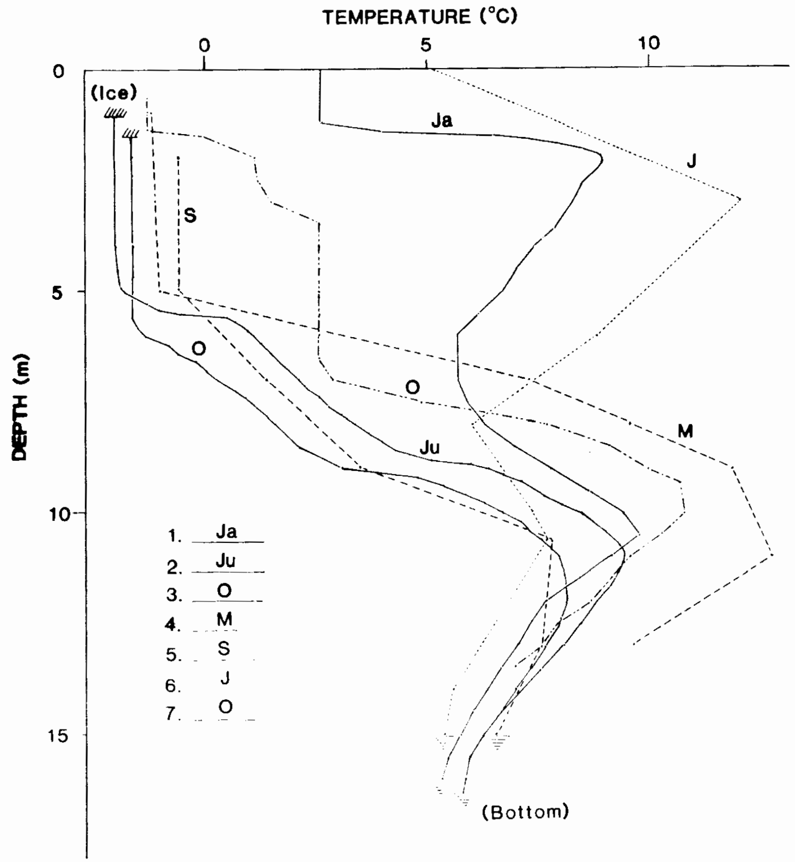


*Fig. 2b. Vertical water temperature distributions of Lake Nurume. 1: January 1985, 2: July 1985, 3: October 1985, 4: May 1979, 5: September 1979, 6: January 1974, 7: October 1967.*

tially of two water layers differing in chemical composition. The vertical distribution of water temperture reflects also such structure with characteristic chemical stratification.

It seems that the pattern of vertical water temperature distribution, particularly of the lower layer, has not changed substantially since its discovery in 1967 (YOSHIDA, 1970). The lower layer develops downwards from the depth of around 10 to 11 m where the maximum temperature occurs. A range of annual temperature fluctuation around the maximum temperature depth is estimated to be 1.7°C from the 1985 observation. In 1981 the range seems to be smaller than that in 1985. The 1979 observation (data extracted from MURAYAMA *et al.*, 1981) indicates at least the range of 5°C. Such large range and high temperature (+12.8°C) seem to be unusual, and the monitoring of water temperature should be continued.

The upper layer suffers a considerable seasonal change in vertical water temperature distribution, and its pattern differs to some extent from year to year. In 1985, temperature distribution in summer shows 1) 1.3 m thick surface layer subjected to mixing caused mainly by wind, 2) the formation of the upper maximum temperature with a conspicuous thermocline just below the surface layer, and 3) a gradual decrease to the upper minimum temperature of 5.8 °C. The observation in January 1974 seems to indicate a similar pattern though the graph was made based on sparser measurements.

In July 1985, the upper layer cooled down to −2.0°C which was the minimum temperature ever recorded in this lake. From July to October the convection layer developed to the depth of 5 m just under 1 to 1.5 m thick surface layer, and the temperature rose to the lower maximum layer at a rate of 2.2°C/m. This pattern resembles that in 1979 though the latter is based on sparser measurements.

On the other hand, observations made from July to November in 1981 provided the results a little different from those in 1985. From July to October, a convection layer with constant temperature around −1.5°C existed from the surface down to the depth of 4 m, and the lower convection layer developed between the depths of 4.5 and 7 m, being separated by a small thermocline from the upper convection layer. In November, both the upper and the lower convection layers warmed by 2.2 and 1.5°C respectively, and the small thermocline disappeared, suggesting the beginning of rapid warming towards the midsummer. The vertical water temperature distribution in October 1967 resembles that in 1981, though it shows a little higher temperature.

### 2.2. Lake Hunazoko

Lake Hunazoko has no outlet streams, and so it is a highly saline lake which might have been separated from the sea due to a crustal uplift of the Skarvsnes area (YOSHIDA, 1970). The lake is usually covered with thin ice (up to 80 cm) in winter, but the ice melts completely in summer. In 1981, most of ice melted even in October.

Figure 3 shows the results of observations in 1973 and 1985 together with other sporadic results. In January 1985, a highly warmed layer of 22.6°C at 1.6 m in depth appeared under a thin mixing (convection) layer. From this depth the water temperature decreased markedly to −6°C at 4.5 m in depth, forming a kind of thermocline. Nearly constant temperatures occur in the layer below the depth of 6 m. The

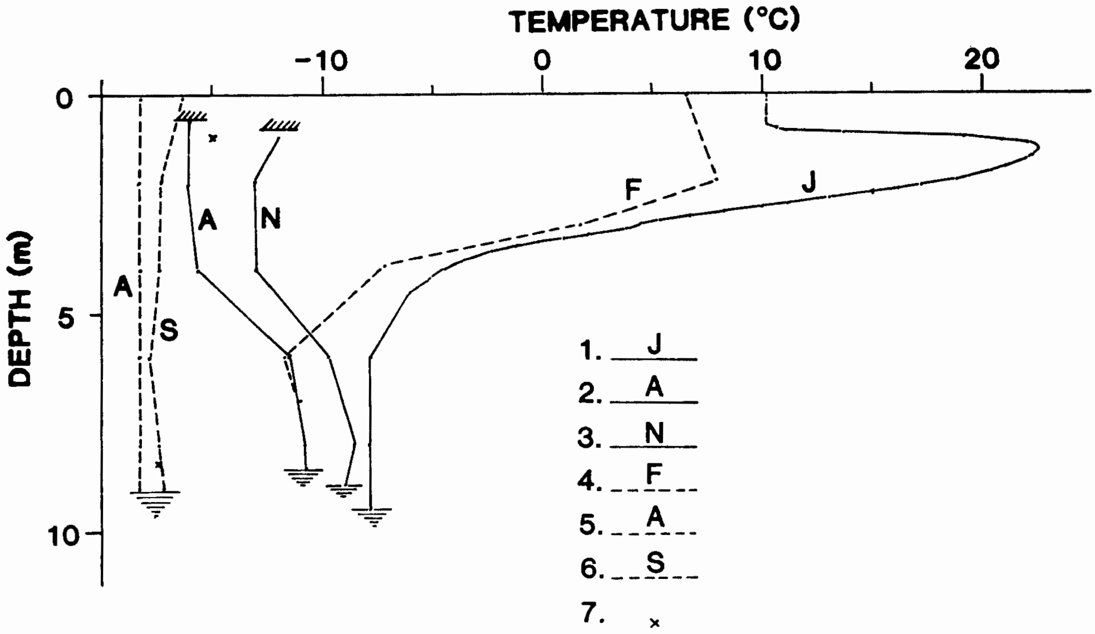


*Fig. 3. Vertical water temperature distributions of Lake Hunazoko. 1: January 1985, 2: August 1985, 3: November 1985, 4: February 1973, 5: August 1973, 6 : September 1973, 7: September 1979.*

observation in February 1973 seems to indicate a similar tendency though the measurements were rather sparse. On the other hand, the vertical water temperature distribution in the 1985 winter differs significantly from that in the 1973 winter. In 1985, the temperature of the lower layer seems not to have decreased to the usual (?) winter temperature level.

## 2.3. Lake Suribati

Lake Suribati is the deepest saline lake in the Lützow-Holm Bay region, as stated above. It had been a part of the sea and was later separated from the sea due to a crustal uplift as in the case of Lake Hunazoko (YOSHIDA, 1970). The lake is covered with a thin ice layer (up to 100 cm) in winter, and the ice melts completely in summer. Detailed temperature measurement was recorded only in 1985, as shown in Fig. 4. The measurement shows that below the depth of 10 m the water temperatures remain essentially unchanged throughout the year. The upper layer down to 4 m in depth undergoes large seasonal temperature fluctuations. The middle layer from 4 to 10 m in depth is separated by remarkable thermoclines from the upper layer in both summer and winter seasons. Plotting of sporadic data seems to indicate to some extent the same tendency in other years, though they suggest the existence of year-to-year changes. It is worthy of note that the cooling of the middle layer proceeded from August to November in 1985, probably due to retardation of cooling in comparison with the annual march of air temperature.

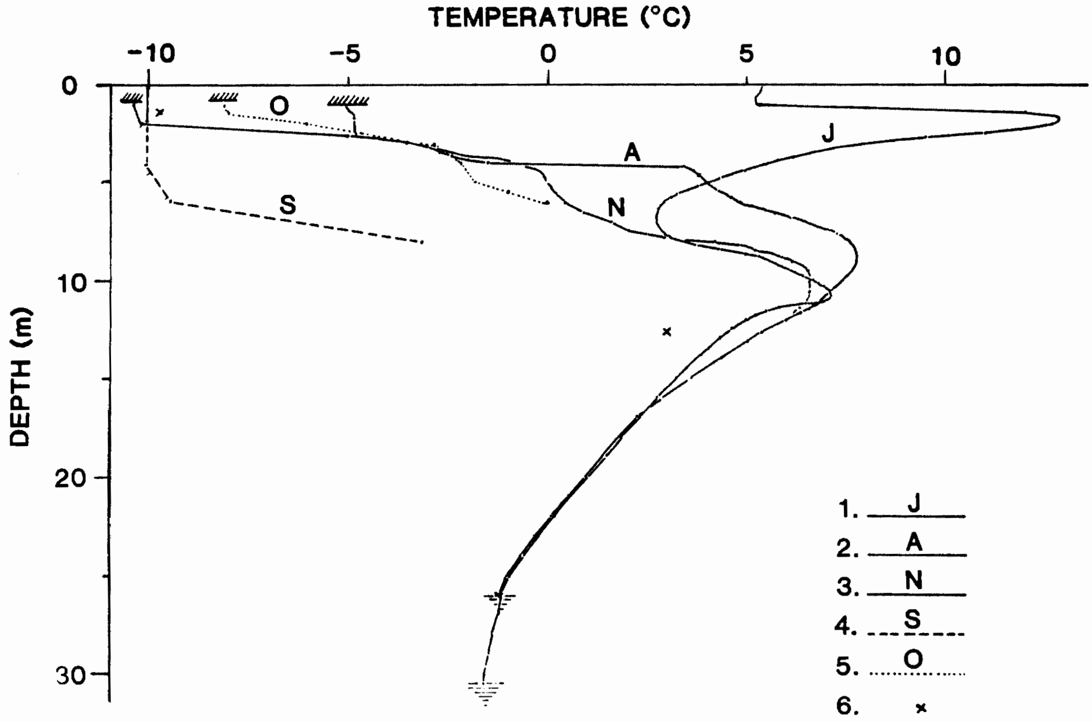


*Fig. 4. Vertical water temperature distributions of Lake Suribati. 1: January 1985, 2: August 1985, 3: November 1985, 4: September 1973, 5: October 1967, 6: October 1981.*

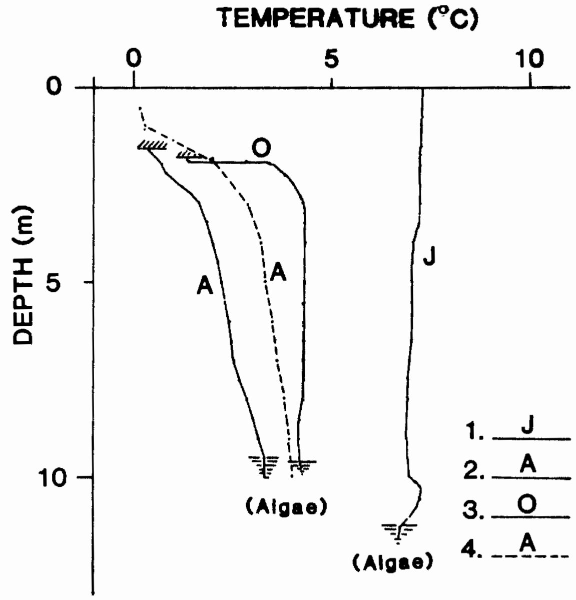


*Fig. 5a. Vertical water temperature distributions of Lake Ô-ike. 1: January 1985, 2: August 1985, 3: October 1985, 4: August 1981.*

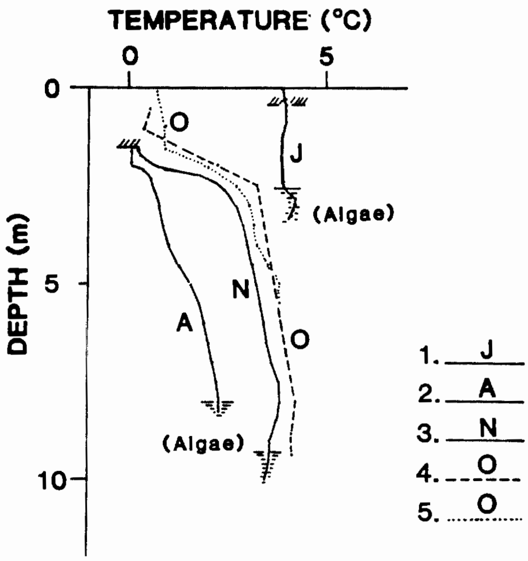


*Fig. 5b. Vertical water temperature distributions of Lake Skallen Ôike 1: January 1985, 2: August 1985, 3: November 1985, 4: October 1981, 5: October 1967.*

## 2.4. Lakes Ô-ike and Skallen Ôike

Lakes Ô-ike On West Ongul Island and Skallen Ôike in the Skallen area are freshwater lakes which are fed by meltwater from snowdrift and have outlet streams. Lake Ô-ike is covered with an ice layer up to 180 cm in winter and the ice melts completely in midsummer. On the other hand, Lake Skallen Ôike is covered with an ice layer up to 150 cm in thickness in winter, and even in summer the ice often covers some 50 to 70% of area of the lake surface. The difference seems to be caused at least in part by abundant snow accumulation on Lake Skallen Ôike in winter on the basis of the 1967 observation.

Vertical water temperature distributions in both lakes show typical inverse stratification as a shallow frozen lake throughout the most part of the year. The difference in summer temperatures between these lakes may reflect the absence and presence of lake ice in summer (Figs. 5a and 5b).

## 3. Some Characteristics of "Berrodden Lake" and "Maruwan Lake"

Limnological investigations were not been conducted in ice-free areas south of the Skallen area on the eastern coast of Lützow-Holm Bay before 1985. In the 1985/1986 season one of the authors (MURAYAMA) carried out for the first time geochemical investigations of "Berrodden Lake" in Berrodden and "Maruwan Lake" (both are tentative place-names) in 1985/1986 season which are situated in the region south of the Skallen area (Fig.1 and Table 2).

Sampling of water and water temperature measurement were carried out with a KITAHARA-II type sampler and EST-II type thermister-thermometer through a hole of 11 cm in diameter bored into lake ice at the center of a lake. Collected water samples consisting of two bottles of water (each one liter) from one sampling depth were naturally frozen. The sample in one bottle was melted at Syowa Station for pH and electric conductivity measurements. The sample in another bottle was brought back to Japan in a frozen state for other chemical analyses. Sodium, potassium, calcium and magnesium were analyzed with atomic absorption spectrophotometry. Chloride ion and sulfate ion were measured with colorimetry using mercury (II) thiocyanate (460 nm) and barium chromate (370 nm), respectively.

Both lakes are situated at the margins of ice-free areas, adjoining the edge of the ice sheet (Figs. 6a and 6b). They are nourished by meltwater from the ice sheet surface in summer. Therefore, concentration of dissolved salt is very low, as in the cases of

*Table 2. Geographic characteristics of lakes in Berrodden and Rundvågshetta.*

| Lake | Berrodden Lake* | Maruwan Lake* |
|---|---|---|
| Location | Berrodden | Rundvågshetta |
| Distance from seashore (m) | 200 | 300 |
| Elevation of the lake surface above sea level (m) | 24 | 8 |
| Depth of the lake (sampling site) (m) | 8.2 | 23.7 |
| Major diameter (m) | 530 | 770 |
| Minor diameter (m) | 205 | 370 |
| Area of the lake ($m^2 \times 10^4$) | 4.9 | 22 |

*Tentative place-name.

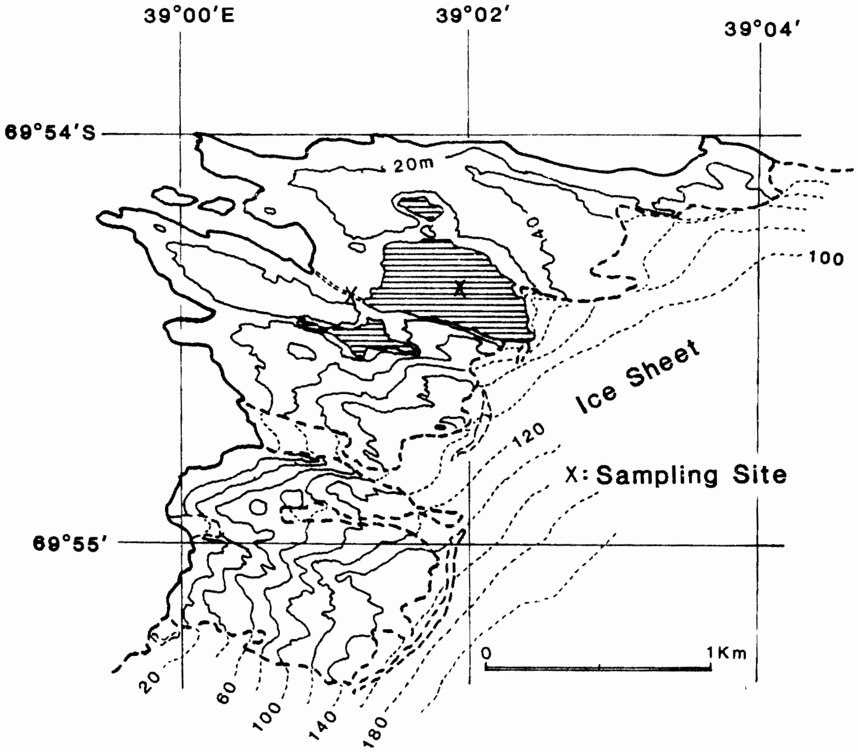


*Fig. 6 a. Map of Rundvågshetta and sampling sites.*

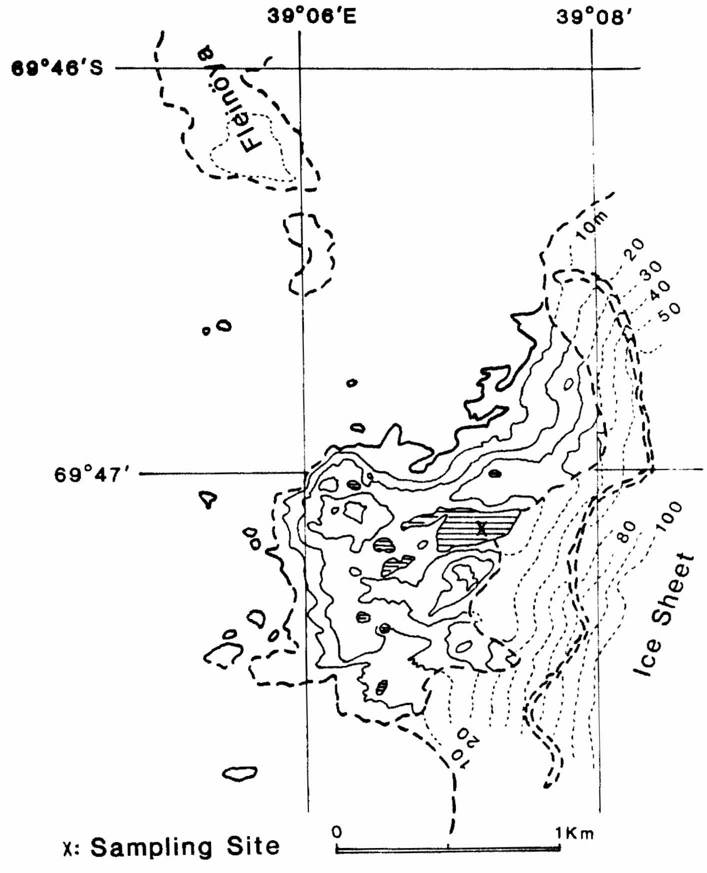


*Fig. 6 b. Map of Berrodden and the sampling site.*

*Table 3a. Limnological features of Maruwan Lake*.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date of sampling | October 20, 1985 | | | | | | |
| Air temperature (°C) | -9.1 | | | | | | |
| Thickness of lake ice (m) | 2.05 | | | | | | |
| Sampling depth (m) | 2.1 | 5.0 | 10.0 | 15.0 | 20.0 | 23.7 (bottom) | |
| Water temperature (°C) | 0.10 | 0.84 | 0.84 | 0.84 | 0.85 | 0.88 | |
| pH | 6.79 | 6.78 | 6.79 | 6.82 | 6.82 | 6.78 | |
| Electric conductivity ($\mu$S) | 15.1 | 18.1 | 18.9 | 17.1 | 16.9 | 20.0 | |
| $Na^+$ (mg/$l$) | 1.1 | 1.2 | 1.3 | 1.2 | 1.2 | 1.9 | |
| $K^+$ (mg/$l$) | 0.14 | 0.16 | 0.16 | 0.17 | 0.16 | 0.67 | |
| $Ca^{2+}$ (mg/$l$) | 0.50 | 0.55 | 0.60 | 0.55 | 0.57 | 0.14 | |
| $Mg^{2+}$ (mg/$l$) | 0.27 | 0.33 | 0.33 | 0.32 | 0.32 | 0.32 | |
| $Cl^-$ (mg/$l$) | 2.1 | 2.1 | 2.3 | 2.1 | 2.1 | 2.4 | |
| $SO^{2-}$ (mg/$l$) | 0.5 | 0.6 | 1.3 | 1.3 | 1.1 | 1.9 | |
| Date of sampling | January 24, 1986 | | | | | | |
| Air temperature (°C) | +0.9 | | | | | | |
| Thickness of lake ice (m) | 1.60 | | | | | | |
| Sampling depth (m) | 2.0 | 5.0 | 10.0 | 15.0 | 20.0 | 23.6 (bottom) | over flow |
| Water temperature (°C) | 1.75 | 3.13 | 3.13 | 3.13 | 3.13 | 3.13 | 1.20 |
| pH | 6.63 | 6.70 | 6.67 | 6.81 | 6.84 | 6.92 | 6.68 |
| Electric conductivity ($\mu$S) | 14.3 | 17.6 | 17.1 | 15.7 | 16.1 | 18.8 | 13.6 |
| $Na^+$ (mg/$l$) | 1.0 | 1.3 | 1.3 | 1.3 | 1.2 | 2.2 | 2.2 |
| $K^+$ (mg/$l$) | 0.17 | 0.21 | 0.20 | 0.19 | 0.20 | 0.92 | 0.19 |
| $Ca^{2+}$ (mg/$l$) | 0.50 | 0.54 | 0.56 | 0.56 | 0.54 | 0.13 | 0.46 |
| $Mg^{2+}$ (mg/$l$) | 0.27 | 0.37 | 0.35 | 0.34 | 0.33 | 0.37 | 0.29 |
| $Cl^-$ (mg/$l$) | 1.9 | 2.4 | 2.1 | 2.1 | 2.0 | 3.9 | 1.6 |
| $SO^{2-}$ (mg/$l$) | 1.2 | 1.1 | 1.0 | 1.1 | 1.2 | 3.6 | 1.1 |

*Tentative place-name.

*Table 3b. Limnological features of Berrodden Lake*.*

| | | | | |
|---|---|---|---|---|
| Date of sampling | October 18, 1985 | | | |
| Air temperature (°C) | -13.0 | | | |
| Thickness of lake ice (m) | 3.05 | | | |
| Sampling depth (m) | 3.5 | 5.0 | 7.5 | 8.0 (bottom) |
| Water temperature (°C) | 0.09 | 0.10 | 0.10 | 0.10 |
| pH | 6.38 | 6.28 | 6.34 | 6.16 |
| Electric conductivity ($\mu$S) | 36.9 | 19.2 | 24.6 | 19.4 |
| $Na^+$ (mg/$l$) | 3.8 | 1.5 | 2.2 | 1.6 |
| $K^+$ (mg/$l$) | 0.12 | 0.075 | 0.094 | 0.35 |
| $Ca^{2+}$ (mg/$l$) | 0.59 | 0.57 | 0.60 | 0.24 |
| $Mg^{2+}$ (mg/$l$) | 0.36 | 0.23 | 0.29 | 0.17 |
| $Cl^-$ (mg/$l$) | 4.5 | 2.5 | 3.3 | 2.3 |
| $SO^{2-}$ (mg/$l$) | 2.8 | 1.8 | 1.8 | 4.7 |

*Tentative place-name.


*Fig. 7. Vertical airphotograph of Rundvågshetta. Nearly frozen Maruwan Lake can be seen on the left side of letter "M" (January 21, 1962).*

*Fig. 8. Oblique airphotograph of Rundvågshetta on February 10, 1975. The lake ice almost completely melted.*

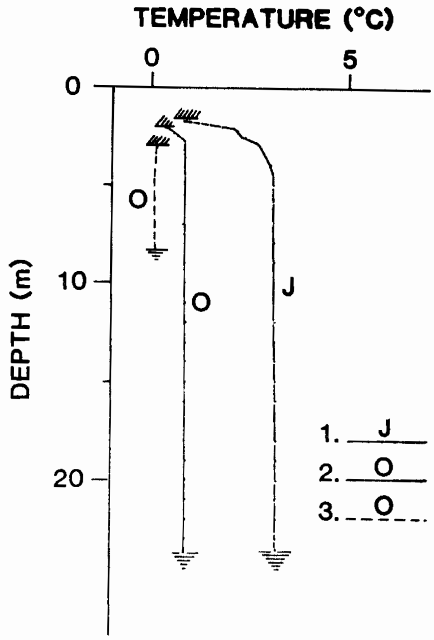


*Fig. 9. Vertical water temperature distributions of Maruwan Lake and Berrodden Lake. 1: January 1986 in Maruwan Lake, 2: Octoter 1986 in Maruwan Lake, 3: October 1985 in Berrodden.*

other lakes adjoining the ice sheet (MURAYAMA, 1977). It is noteworthy that the bottom water is significantly lower in calcium concentration than the upper water in both lakes, though the cause cannot be inferred at this stage (Tables 3a and 3b).

Berrodden Lake was covered with a 305-cm thick ice layer on October 18, 1985. This is the thickest lake ice ever known in the Lützow-Holm Bay region. The maximum thickness of one-year lake ice is estimated to be less than 200 cm in this region (YOSHIDA *et al.,* 1975). Therefore, this lake ice would be of multi-year. The water temperature was nearly freezing point throughout the column at the time of observation in October.

Maruwan Lake was visited on October 10, 1985 and January 24, 1986. Therefore, the seasonal comparison was possible to some extent. In January 1986, almost the whole lake surface was covered with ice. However, examination of air photographs and observation from a helicopter in the summer season indicate that the degree of meltimg of lake ice varies considerably from year to year. For instance, the melted area about 7% on January 21, 1962, 100% on February 10, 1975, and 40% on January 30, 1981 (*e.g.* Figs. 7 and 8).

The vertical water temperature distribution showed naturally inverse stratification even in summer in 1986. Temperature stratifications in October 1985 and January 1986 are well indicated by dense and precise measurements of temperatures (Fig.9).

Maruwan Lake seems to be an adequate site for "environment monitoring program", because 1) it is the deepest freshwater lake ever known in the Lützow-Holm Bay region, 2) it has a considerably large area (the fourth largest) and 3) it reflects climatological conditions relatively rapidly as is indicated by the variability of ice condition in spite of its position adjoining the ice sheet and its size.

## 4. Summary

1) Limnological investigations of several lakes as part of "environmental monitoring project" give the record of water temperature of these lakes. Every saline lake studied has a lower layer which shows a somewhat stable vertical temperature distribution and an upper layer which undergoes large seasonal temperature fluctuations. They have their respective characteristic pattern of vertical temperature distribution. There is some year-to-year change in the pattern, particularly in the upper layer. Freshwater lakes show inverse stratification when they are covered with an ice layer. A seasonal fluctuation pattern differs a little with lakes according to their physical situation, and there exists a slight change in the fluctuation pattern from year to year.

2) The general characteristics of two freshwater lakes are described briefly on the basis of the 1985/1986 field investigations. They show very low concentration of dissolved salt and low water temperature.

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