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NUTRIENTS DEPRESSION IN THE BLOOMING AREA OF PRYDZ BAY, ANTARCTICA

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Abstract: During the SIBEX cruise of R.V. KAIYO MARU to the Indian Sector of the Southern Ocean in 1983/84, nutrient depression in the phytoplankton blooming was observed in the innermost part of Prydz Bay (75°01.2′E, 69°01.4′S). The lowest concentrations of inorganic phosphate (0.30 μg-at/*l*), dissolved total phosphorus (1.06 μg-at/*l*), nitrate (10.5 μg-at/*l*) and silicate (8 μg-at/*l*) were observed, while the concentration of dissolved organic phosphorus (0.76 μg-at/*l*) as well as chlorophyll *a* (2.19 μg/*l*) was high. These low concentrations of inorganic nutrients would be attributable to the consumption by phytoplankton. However, phosphate and silicate seem to be consumed faster than nitrate is.

1. Introduction

As part of the Second International BIOMASS Experiment (SIBEX) cruise of the Japanese Fisheries Agency R.V. KAIYO MARU, a marine biological investigation was carried out off the Mac. Robertson Land and in Prydz Bay in the Indian sector of the Antarctic Ocean. The circulations and physical structure within Prydz Bay and adjacent sea have been discussed by ZVEREV (1959), GRIGOR'YEV (1967) and SMITH *et al.* (1984). However, information on the behavior of nutrient matters in relation to the phytoplankton blooming has been very limited.

In this paper, the authors discuss the distribution of temperature, salinity and inorganic nutrient matter in relation to that of standing stock of phytoplankton in Prydz Bay and adjacent sea. The distribution of dissolved organic phosphorus in Prydz Bay and its vicinity along 75°E is also discussed.

2. Materials and Methods

Serial observations were carried out at 24 stations in December (Leg I) and 33 stations in January–February (Leg II) in Prydz Bay and off the Mac. Robertson Land (Fig. 1). At the stations on meridional section along 75°E, water was sampled from 14–19 depths between the surface and down to the bottom, while at the other stations the water samples were collected from 18 fixed depths in the upper 2000 m. In this paper, however, only the data obtained in the upper 200 m are dealt with to discuss the nutrient status within a phytoplankton production layer.

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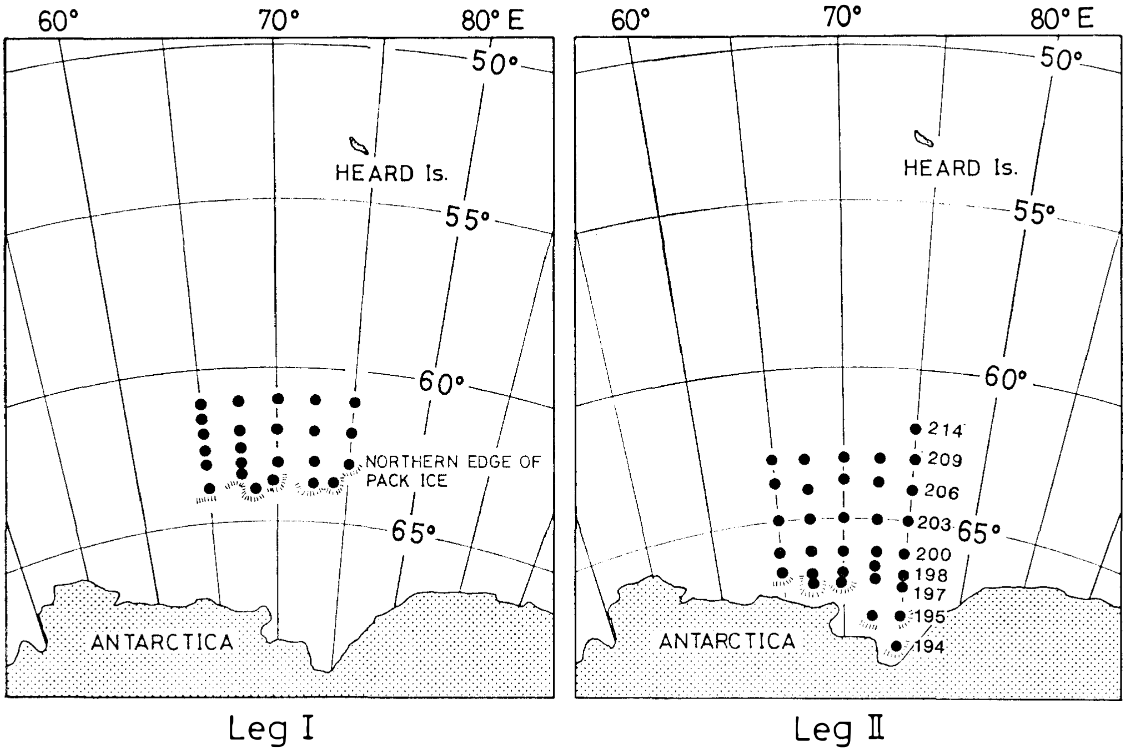

Fig. 1. Sampling stations occupied by R. V. KAIYO MARU, Japanese Fisheries Agency. Leg I covered the period between 11 and 24 December 1983, and Leg II between 19 January and 3 February 1984.

The salinity was determined with a salinometer of Auto Lab 60MK III and dissolved oxygen was determined by the Winkler's method. Each sample was chemically analyzed for the following inorganic nutrients; phosphate by phospho-molybdenum blue complex method (MURPHY and RILEY, 1962), silicate by silico-molybdenum yellow complex method (UNESCO, 1969) and nitrate by cadmium reduction method (GRASSHOFF, 1983). In addition to these, dissolved organic phosphorus was also determined after decomposition by ultraviolet irradiation (YANAGI *et al.*, 1983). This method can determine only dissolved organic mono-phosphate.

The colorimetric analyses were done on board using two spectrophotometers of Shimadzu model UV-150-02 and Hirama model 6B. Chlorophyll *a* concentration was acetone-extracted and determined by fluorometric method using a Turner model 111 fluorometer (STRICKLAND and PARSONS, 1972).

Water samples for determination of dissolved total phosphorus were frozen on board and brought back to home laboratory and analyzed later by the wet combustion method of MENZEL and CORWIN (1965). Then, the concentration of dissolved organic poly-phosphate could be calculated as follows; dissolved total phosphorus−(dissolved inorganic phosphate+dissolved organic mono-phosphate).

3. Results

3.1. Surface distribution

The oceanographical observations on Leg I, which were carried out in December

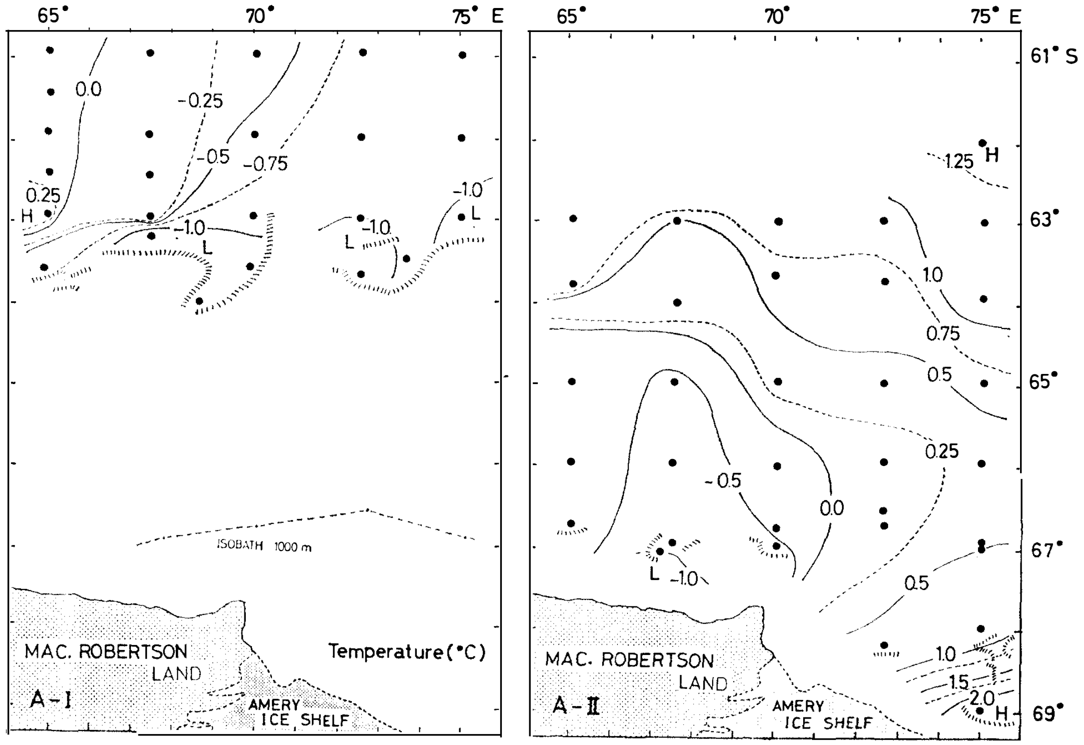

Fig. 2. (A) Horizontal distributions of water temperature in the surface waters. I & II denote Leg I in December and Leg II in January–February, respectively.

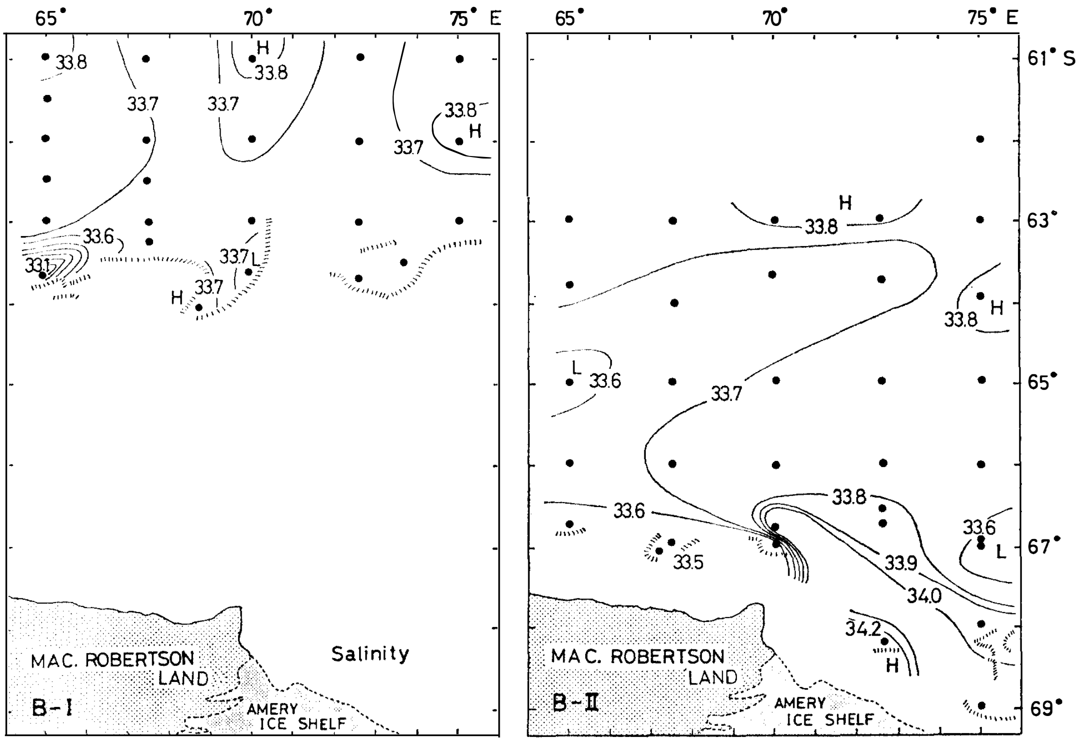

Fig. 2. (B) Salinity.

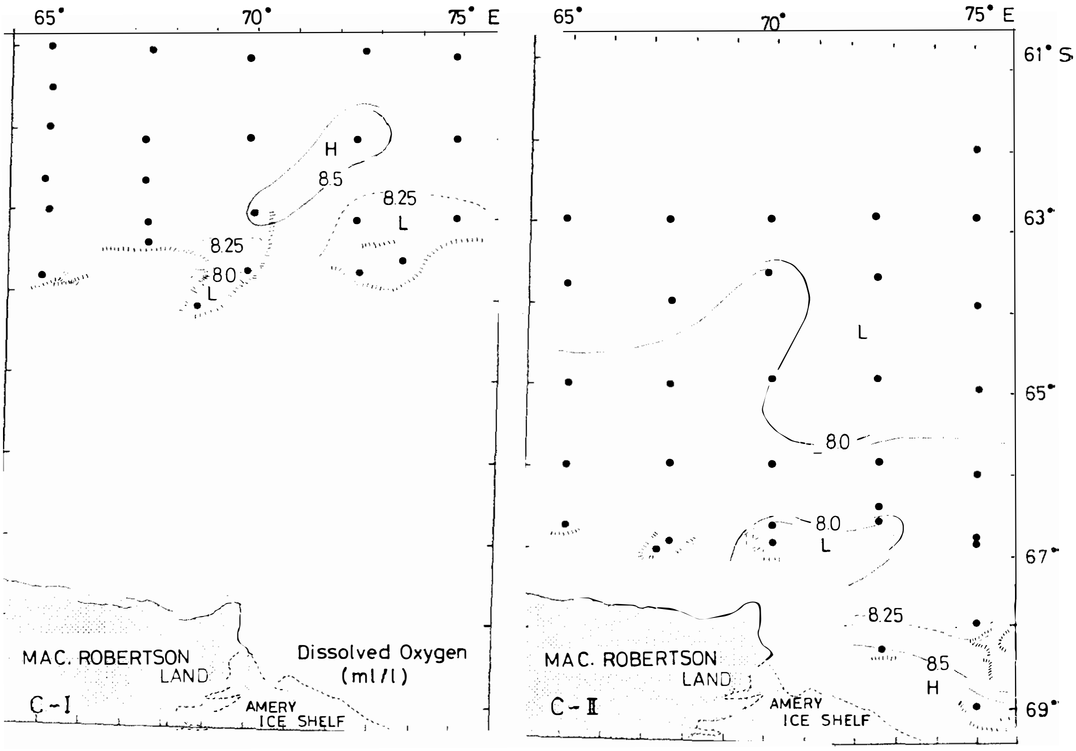

Fig. 2. (C) Dissolved oxygen.

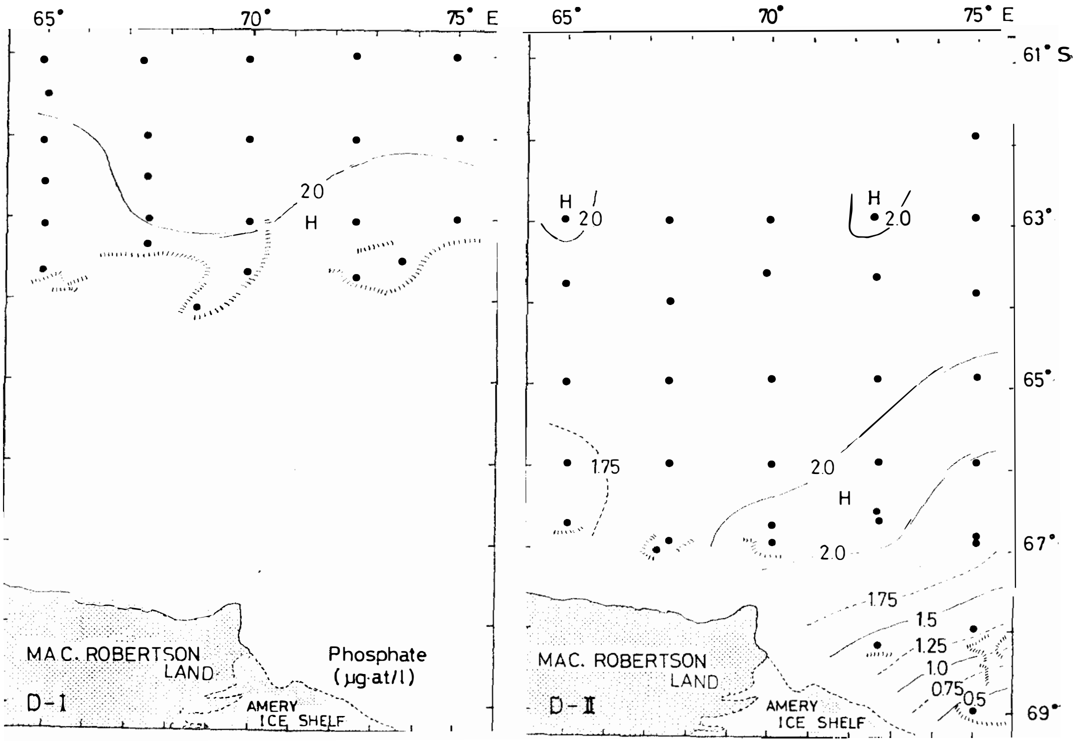

Fig. 2. (D) Phosphate.

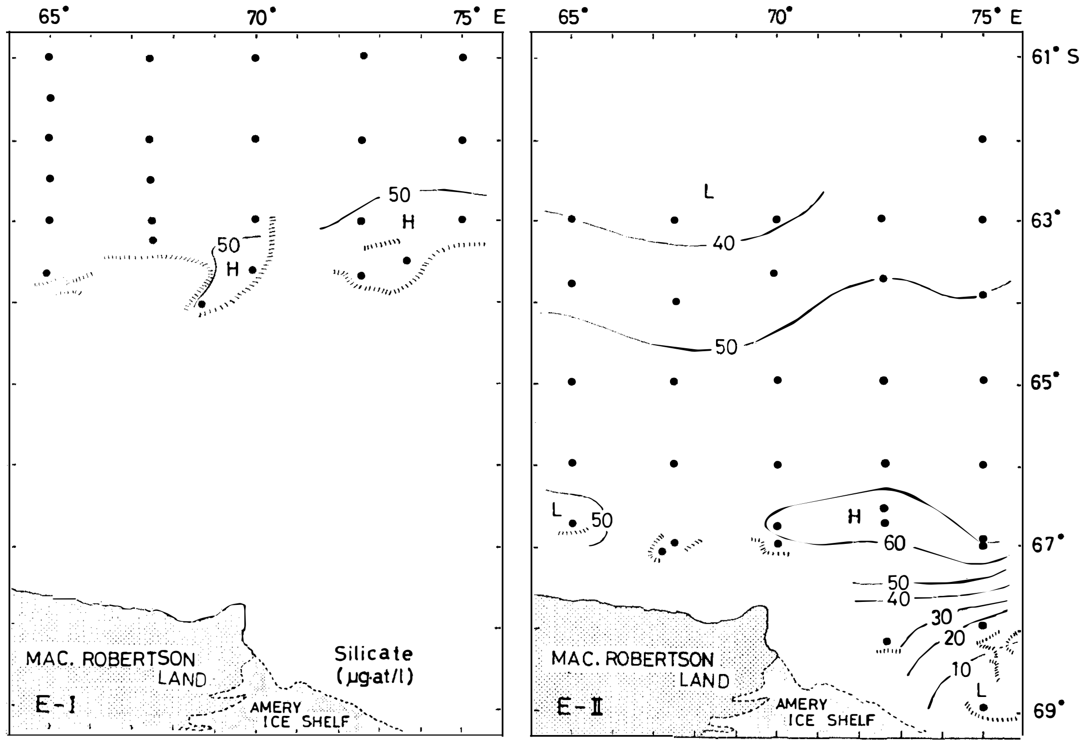

Fig. 2. (E) Silicate.

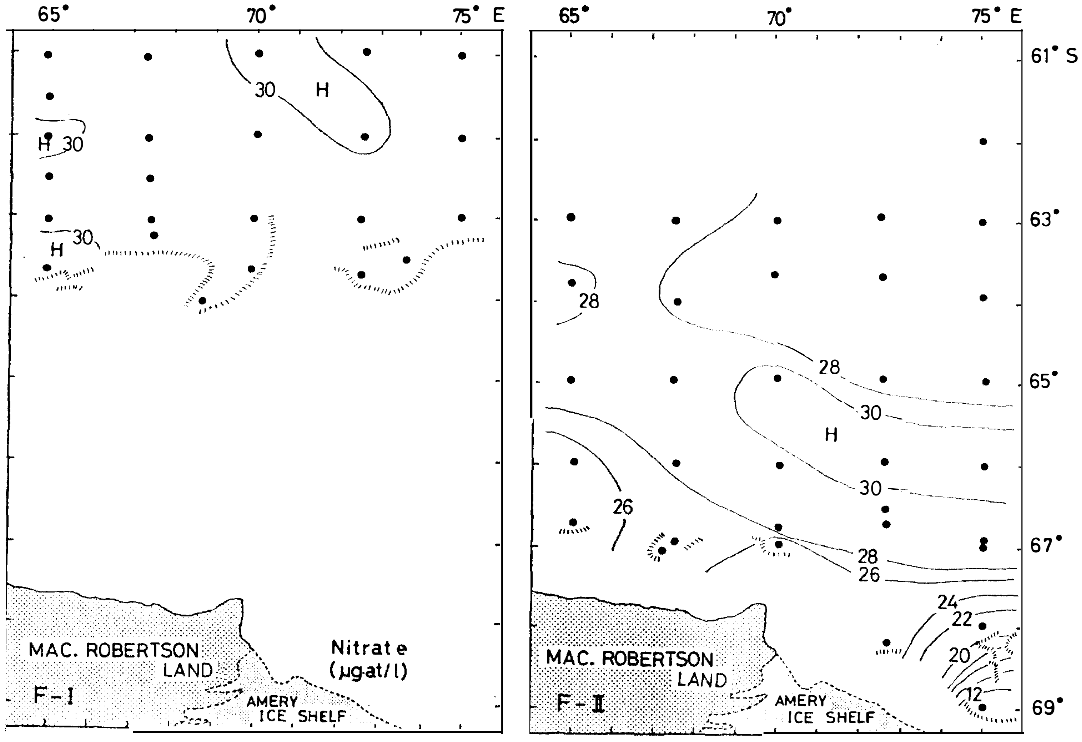

Fig. 2. (F) Nitrate.

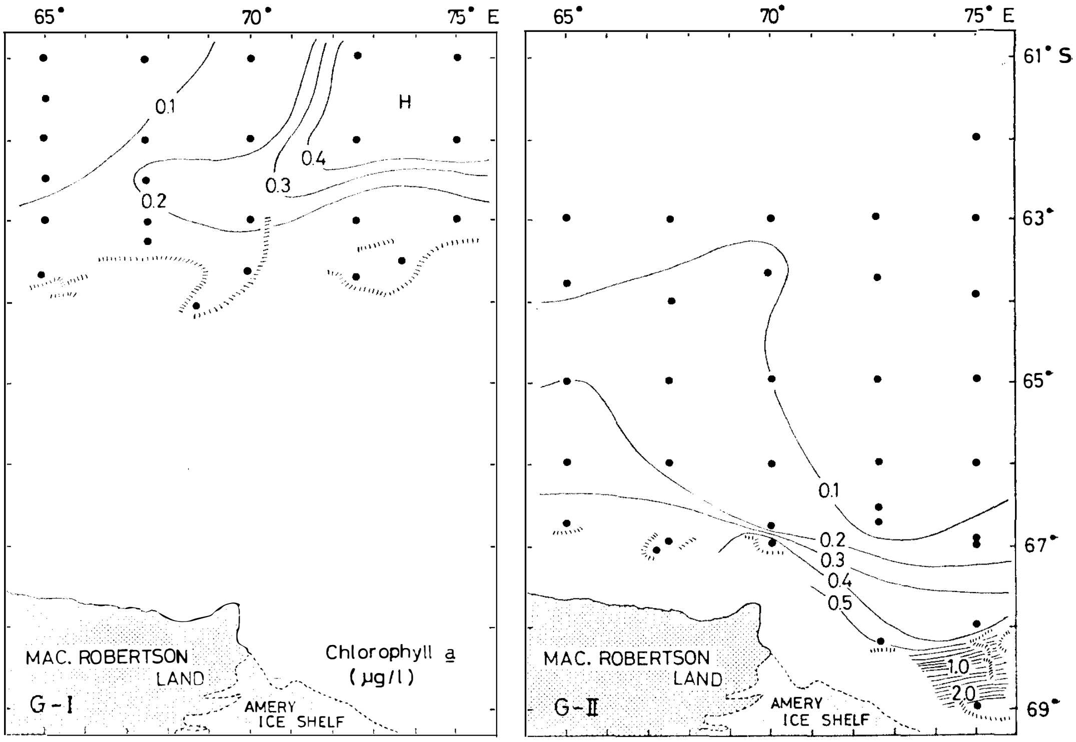

Fig. 2. (G) Chlorophyll a.

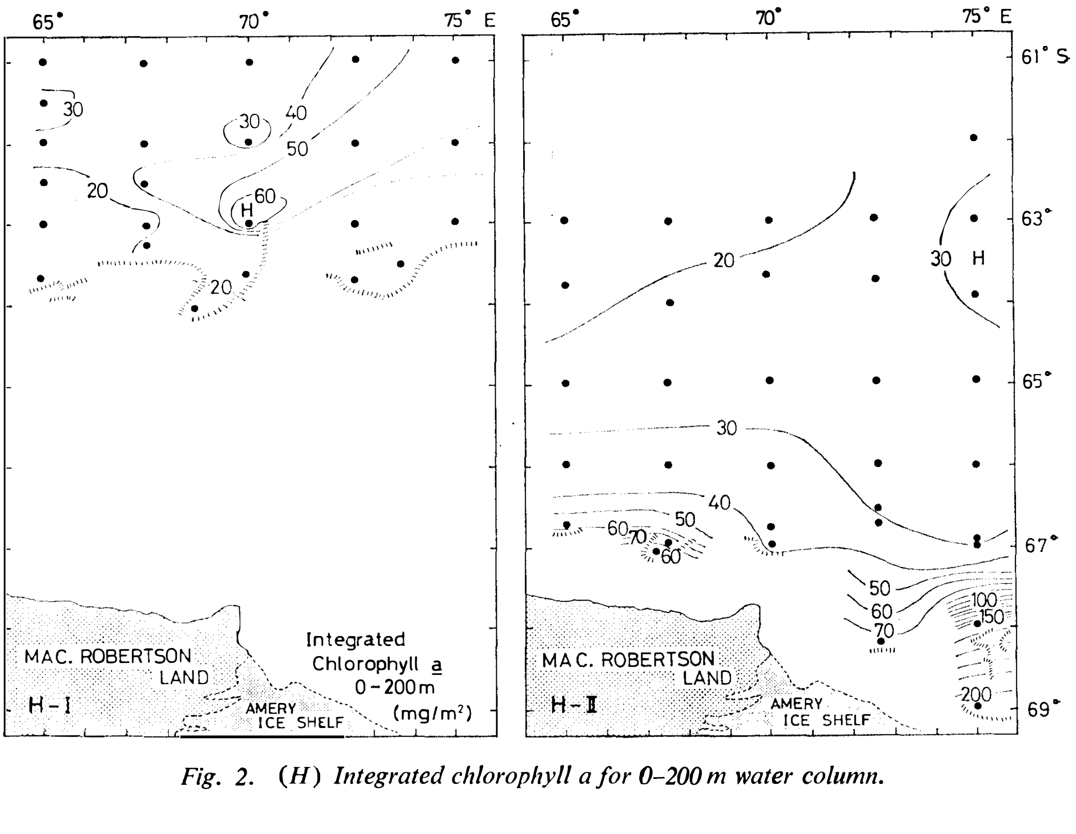

Fig. 2. (H) Integrated chlorophyll a for 0–200 m water column.

1983, were restricted within the north of the pack ice edge around 64°S, but those on Leg II in January and February 1984 could be carried out in farther south to 69°S. Surface distributions of water temperature, salinity, dissolved oxygen, phosphate, silicate and nitrate are shown in Fig. 2. In December, cold water below 0°C covered most part of stations and the temperature was below −1.0°C near the pack ice (Fig. 2: A-I). However, about one month later on Leg II, temperature increased 1°–2°C and that in Prydz Bay was higher than that at the northern stations (Fig. 2: A-II). The highest temperature, 2.2°C, was found at the southernmost station in Prydz Bay. Salinity was also higher on Leg II than on Leg I (Fig. 2: B-I and II).

Water with the dissolved oxygen content of 7.9–8.5 m*l*/*l* was distributed widely on both legs. High contents more than 8.5 m*l*/*l* were restricted to the area of 70°–72.5°E, 62°–63°S on Leg I and at the southernmost station in Prydz Bay on Leg II (Fig. 2: C-I and II). Concentrations of phosphate (about 2.0 μg-at/*l*), silicate (50 μg-at/*l*) and nitrate (30 μg-at/*l*) were relatively high at all stations on Leg I, while the concentrations were very low at the southernmost station in Prydz Bay. The lowest concentrations of phosphate, silicate and nitrate in Prydz Bay were 0.30 μg-at/*l*, 8 μg-at/*l* and 10.5 μg-at/*l*, respectively (Fig. 2: D–F).

Chlorophyll *a* concentration on Leg I was below 0.2 μg/*l* near the pack ice but higher than 0.4 μg/*l* at the northern stations (Fig. 2: G-I). On the contrary, on Leg II, the chlorophyll *a* increased toward south and the maximum concentration (2.00 μg/*l*) was found at the southernmost station in Prydz Bay (Fig. 2: G-II). Integrated chlorophyll *a* stocks through the upper 200-m water column were distributed similarly to surface chlorophyll distributions and the maximum stock was calculated to be 200 mg/m^2 at Stn. 194.

3.2. *Vertical distribution*

Meridional vertical section of physical and chemical parameters along 75°E observed on Leg II is shown in Fig. 3. The water temperature higher than 0°C was observed in a stratum from the surface to 40 m and the pycnocline existed between 30 and 50 m. At Stns. 194 and 195, the levels of phosphate, silicate and nitrate in the upper 50 m were remarkably lower than at the other northern stations. Concentration of chlorophyll *a* in the upper 100 m at the former two stations was high, exceeding 1.0 μg/*l*, and the maximum concentration (3.06 μg/*l*) was measured in the 20 m layer at Stn. 194.

Vertical distribution of the concentration of total dissolved phosphorus and its composition with inorganic, organic mono- and poly-phosphate at the selected five stations along 75°E are shown in Fig. 4. Vertical gradient in the distribution of the dissolved total phosphorus at northern four stations (Stns. 214, 206, 200 and 195) was small. At the southernmost station (Stn. 194), the gradient was large; the concentration increased from 1.0 μg-at/*l* above 30m, with the maximum value of 2.3 μg-at/*l* at 50m, to $>$2.0 μg-at/*l* below 75 m. The percentage contribution of inorganic phosphate, organic mono- and poly-phosphate at three stations (Stns. 200, 206 and 214) decreased in this order and ranged from 85 to 94% from 1 to 9%, and from 1 to 10%, respectively. High percentage of dissolved organic phosphorus (sum of monos- and poly-phosphate), more than 70%, was found in the upper 10 m at Stn. 194.

(a)

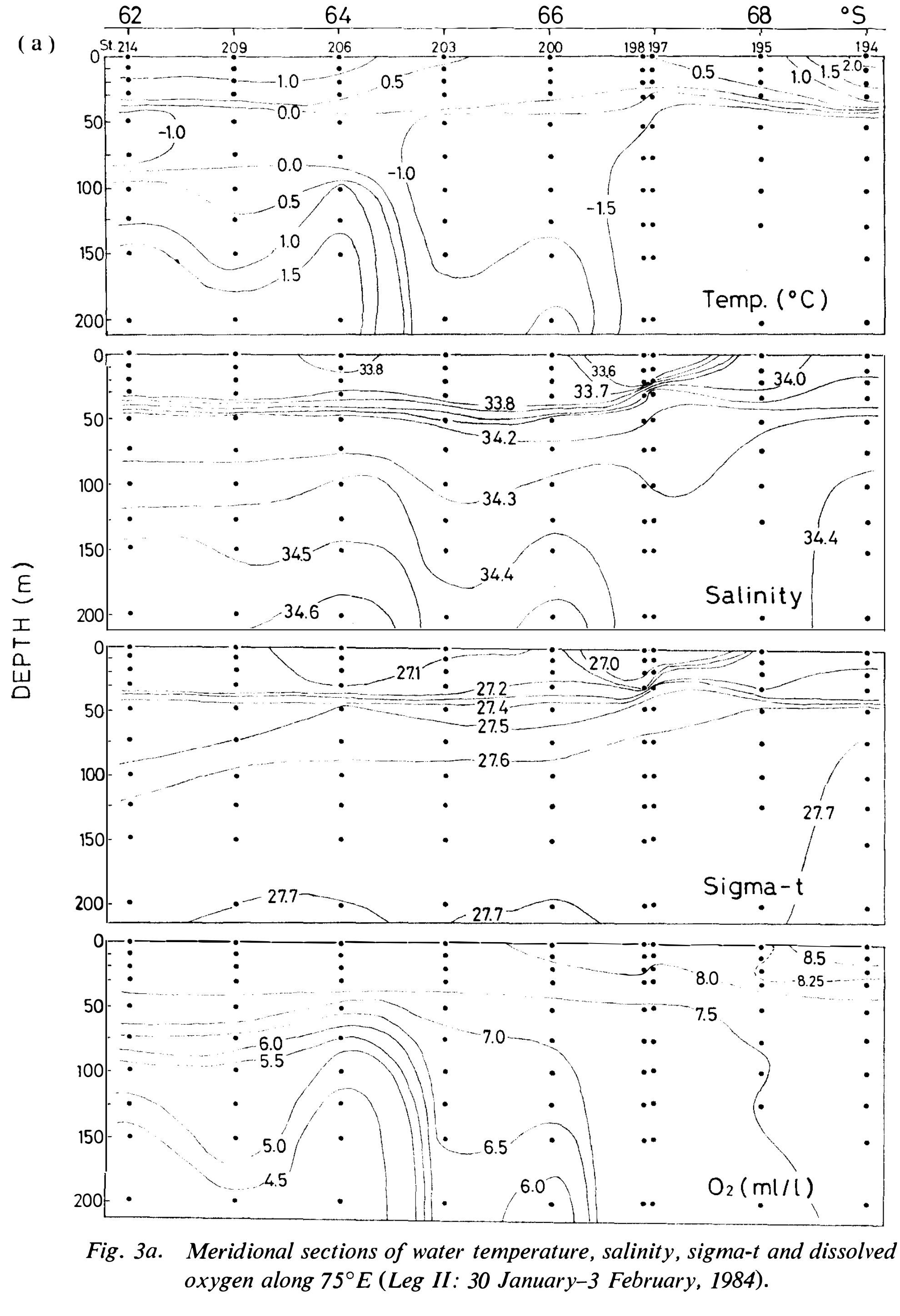

Fig. 3a. Meridional sections of water temperature, salinity, sigma-t and dissolved oxygen along 75°E (Leg II: 30 January–3 February, 1984).

4. Discussion

SMITH and NELSON (1985) reported a high integrated chlorophyll *a* stock (128.2 ± 91.7 mg/m², 0–150 m) in the receding ice-edge in the Ross Sea off the Victoria Land. FUKUCHI *et al.* (1984) observed the large integrated chlorophyll *a* stocks (466.5 mg/m², 0–150 m) from the fast ice area in the eastern part of Lützow-Holm Bay. The present

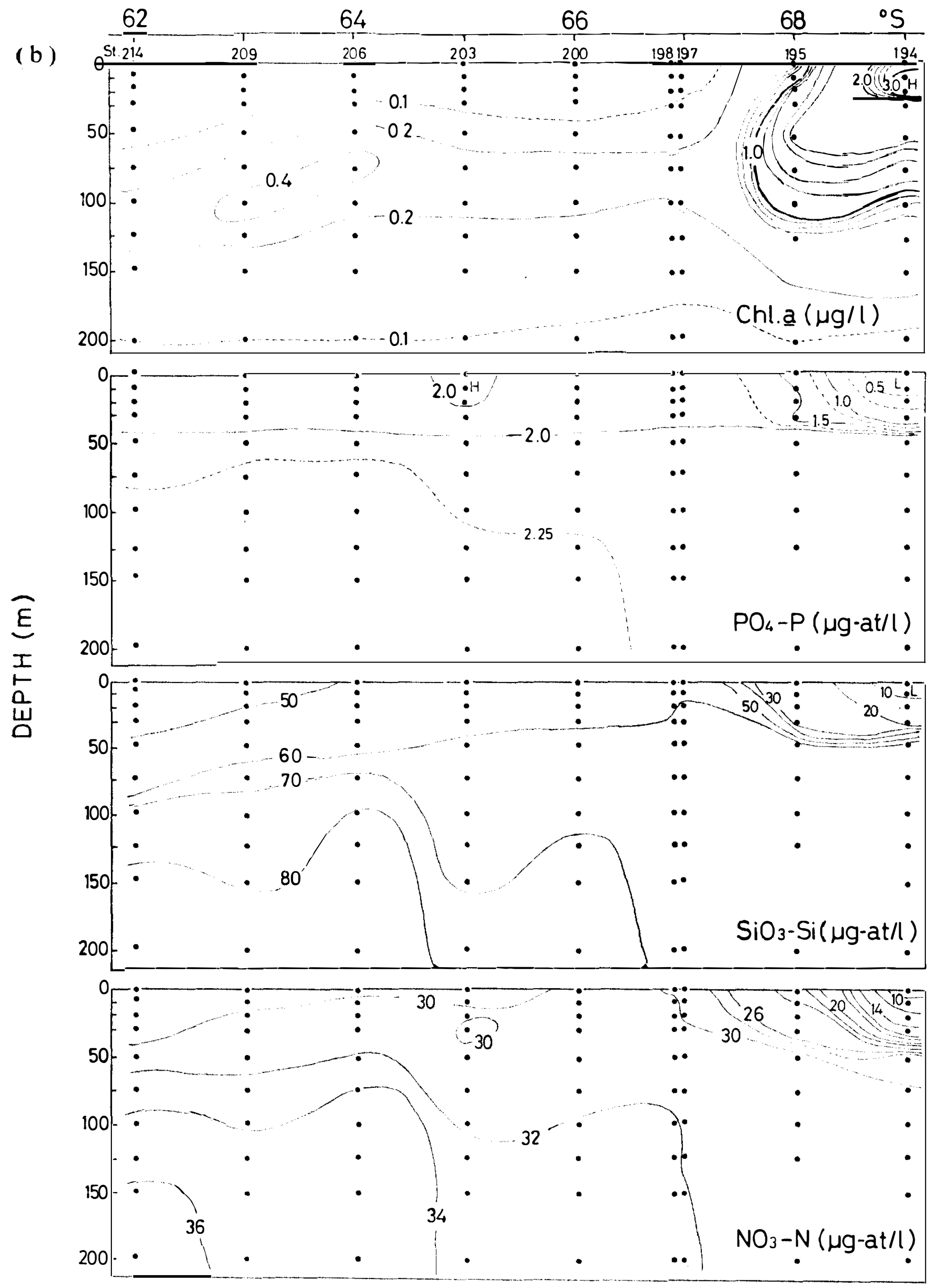

Fig. 3b. Meridional sections of chlorophyll a, phosphate, silicate and nitrate along 75°E (Leg II: 30 January–3 February, 1984).

data in Prydz Bay (200 mg/m², 0–200 m) are intermediate value of them.

The high concentrations of chlorophyll *a* (>2.0 μg/*l*) were observed in the upper layers shallower than 30 m at Stn. 194, while inorganic nutrients were depressed throughout the upper layers; <1.0 μg-at P/*l*, <20 μg-at Si/*l*, <16 μg-at N/*l*. Phytoplankton seemed to have consumed inorganic nutrients in the blooming process. The upper layer of 0–30 m at Stn. 194 is arbitrarily called "the blooming zone" in this work.

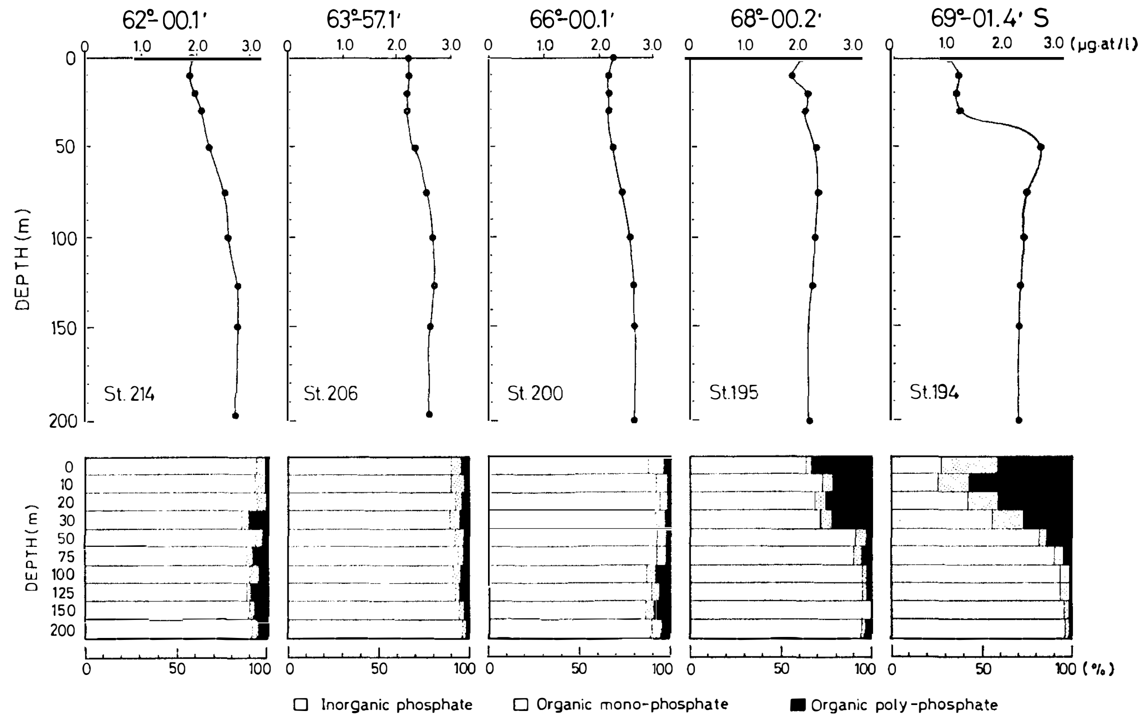

Fig. 4. Vertical distribution of the concentration of total dissolved phosphorus (upper) and the relative abundance of inorganic, organic mono- and organic poly-phosphate within the dissolved total phosphorus (lower) along 75°E (30 January–3 February, 1984).

The average nitrate to phosphate (N/P) ratio was found as high as 28.6 ± 5.9 (4 layers) in the upper 30 m at Stn. 194, where the blooming occurred. On the other hand, low ratio of 14.8 ± 0.7 (85 layers) was obtained from layers other than the blooming four layers. SAGI (1983) reported N/P ratios of 12 in the region of 100°–112°E, 59°–65°S, FUKUI and YAMAGATA (1981) presented 15.2 ± 0.6 in the area of 100°–120°E, 61°–65°S, and MAEDA *et al.* (1985) observed that the ratio in the surface water ranged from 13.7 to 20.7 in the Southern Ocean south of Australia. Although the present N/P ratio obtained from the non-blooming zone is equivalent to those reported values, the ratio obtained from the blooming zone is markedly higher than the reported values. This is attributed to relatively low phosphate concentration or preferential consumption of phosphate to nitrate by phytoplankton in the blooming zone. On the other hand, the value of silicate to phosphate ratio (Si : P) was in the present study not significantly different between the blooming zone and the non-blooming zone, the value being 25.4 ± 1.0 (4 layers) and 29.0 ± 3.9 (85 layers), respectively, and the ratios of phosphate, nitrate and silicate were 1 : 28.6 : 25.4 and 1 : 14.8 : 29.0, respectively. Such the identical Si/P ratios in and out of the blooming zone indicate that the rate of phosphate and silicate consumption by blooming phytoplankton was constant, while the consumption rate of nitrate was much slower as mentioned above.

AKIYAMA (1968) observed the high concentration of total phosphorus (>3.0 μg-at/*l*) in the Antarctic surface water south of 60°S. He also reported the average organic phosphorus concentration (1.5 μg-at/*l*) in the surface layer south of the Antarctic Convergence. Dissolved total phosphorus and dissolved organic phosphorus (mono- and poly-phosphate) obtained between 62° and 69°S along 75°E in the present vertical observation ranged from 1.06 to 2.75 μg-at/l and from 0.07 to 0.98 μg-at/l, respectively. Both values were considerably lower than those reported by AKIYAMA (1968).

While the lower dissolved total phosphorus than 1.5 μg-at/l was observed only in the blooming zone of Prydz Bay, the highest dissolved organic phosphorus (0.98 μg-at/l) was found at 10m in the blooming zone. Since the concentration of dissolved inorganic phosphate, the main constituent of total phosphorus (Fig. 4), in the upper 30m at this station was low (0.30–0.74 μg-at/l) as previously mentioned, the total phosphorus concentration became low there. Conclusively, it is suggested that the dissolved phosphate in an inorganic form was preferentially consumed in the course of the blooming of phytoplankton. Moreover, it can be assumed that the consumption of silicate in the blooming zone proceeds parallel with that of inorganic phosphate.

Acknowledgments

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