

Vertical Distribution and Standing Stocks of Chlorophyll *a* in the Coastal Waters of the Antarctic Ocean*

Masao OHNO**, Yasushi FUKUDA*** and
Mitsuo FUKUCHI****

南極海沿岸域のクロロフィル *a* の垂直的分布と現存量*

大野正夫**・福田 靖***・福地光男****

要旨: 第26次南極地域観測隊では BIOMASS SIBEX II の計画の一環として、1984年12月から1985年2月にかけて東南極海沿岸域のクロロフィル *a* 量の垂直分布と現存量の調査が行われた。調査はブライド湾(70°05′-70°15′S, 23°50′-24°20′E)で12月と2月の2回、9定点で行われ、グネルス・バンク(68°00′-68°23′S, 30°00′-35°00′E)とリュツォ・ホルム湾(67°00′-68°00′S, 36°00′-38°00′E)では2月にそれぞれ7定点で行われた。

水温は -1.87°C から 2.1°C, 塩分は 32.63 から 34.63 の範囲内にあった。

ブライド湾では、12月には上層(0-50 m)でクロロフィル *a* 量は高い値を示し、0-200 m 水柱内のクロロフィル *a* 積算値は 230.0-410.7 mg/m² であった。2月には、その値は 95.1-207.2 mg/m² と減少していた。グネルス・バンクとリュツォ・ホルム湾のクロロフィル *a* 積算値は、それぞれ 41.9-116.5 mg/m² と 46.0-78.3 mg/m² であり、やはり上層で高い値を示したが、ブライド湾の値と比較して低い値であった。

Abstract: Japanese BIOMASS SIBEX II program was carried out partly by the 26th Japanese Antarctic Research Expedition from December 1984 to February 1985. The vertical distributions of chlorophyll *a*, phaeophytin and oceanographic parameters to a depth of 200 m were investigated in three areas; 9 stations in Breid Bay (70°05′-70°15′S, 23°50′-24°20′E), 7 stations off the Gunnerus Bank (68°00′-68°23′S, 30°00′-35°00′E) and 7 stations off Lützow-Holm Bay (67°00′-68°00′S, 36°00′-38°00′E) in the Antarctic coastal waters. Water temperature ranged from -1.87 to 2.1°C, and salinity ranged from 32.63 to 34.63. Salinity was 32.63-33.95 throughout the upper 0-50 m layer, in which chlorophyll *a* was abundant. In Breid Bay, integrated chlorophyll *a* stocks (0-200 m) decreased from 230.0-410.7 mg/m² in December to 95.1-207.2 mg/m² in February. In the waters across the Gunnerus Bank, integrated stocks ranged from 41.9 to 116.5 mg/m² in February. In the waters off Lützow-Holm Bay, the stocks remained between 46.0 and 78.3 mg/m². The phaeophytin content was large at almost all the stations.

1. Introduction

Measurements of chlorophyll *a* concentrations in the surface water of the Indian sector of the Antarctic Ocean have been carried out since 1965 as part of a marine bio-

* This paper was presented at "The Eighth Symposium of Polar Biology" (December 4-5, 1985).

** 高知大学海洋生物教育研究センター。Usa Marine Biological Institute, Kochi University, Usa-Inoshiri, Tosa 781-11.

*** 熊本大学教育学部生物教室。Biological Laboratory, Faculty of Education, Kumamoto University, Kurokami, Kumamoto 860.

**** 国立極地研究所。National Institute of Polar Research, 9-10, Kaga 1-chome Itabashi-ku, Tokyo 173.

logical program of the Japanese Antarctic Research Expedition (JARE). However, only a few reports are available on the vertical distribution of chlorophyll *a* in this region (YAMAGATA and FUKUI, 1981; KURODA and FUKUCHI, 1982; UNO, 1983; HAMADA *et al.*, 1985). To gain detailed information on the vertical distribution of chlorophyll *a* in the Antarctic coastal ecosystem, the present survey was conducted by the JARE-26, from December 1984 to February 1985, in conjunction with the international program of "Biological Investigations on Marine Antarctic Systems and Stocks (BIOMASS)".

In the coastal waters of pack ice and fast ice regions, the higher values of chlorophyll *a* concentrations were observed by TOMINAGA (1971), OHNO (1976), and FUKUCHI *et al.* (1984). SATOH *et al.* (1986), TANIMURA (1981), and WATANABE and NAKAJIMA (1982) reported that high chlorophyll *a* concentrations in the ice associated regions seemed to be contributed by ice algae released from sea ice.

The present paper describes the vertical distributions of chlorophyll *a* concentrations in Breid Bay, in the Gunnerus Bank and off Lützow-Holm Bay, East Antarctic coast during the 1984–85 summer.

2. Materials and Methods

The sampling stations in Breid Bay (December and February), Gunnerus Bank (February) and off Lützow-Holm Bay (February) are shown in Fig. 1. Surface water

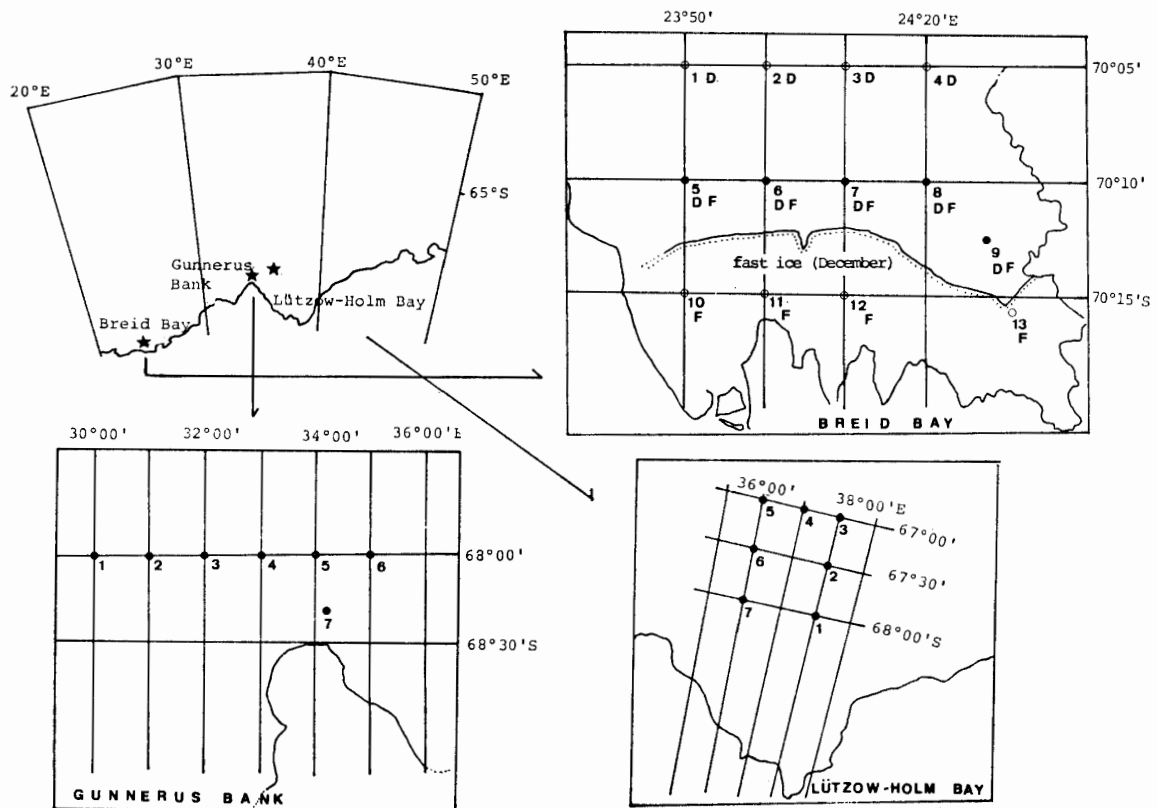


Fig. 1. Maps showing three survey areas of Breid Bay, Gunnerus Bank and Lützow-Holm Bay. Numerals indicate the station number of chlorophyll *a* measurement. In the map of Breid Bay, D and F denote stations occupied in December and in February, respectively.

samples were taken with a plastic bucket. Samples from nine different layers (10, 20, 30, 50, 75, 100, 125, 150 and 200 m) were obtained with Van Dorn bottles. One liter of each sample was filtered through a membrane filter (0.45 μm). The pigments trapped on the filters were extracted with a 90% acetone solution. The amounts of chlorophyll *a* and phaeophytin were determined fluorometrically by the method of SAIJO and NISHIZAWA (1969), using a Shimadzu model RF-510 spectro-fluorometer. Values of *R* and *F_{ph}* were 9.3783 and 0.0478, respectively. The seawater temperature and salinity data referred to in this paper were owing to Messrs. IWANAMI and TOHJU, oceanographers of the JARE-26 (Hydrographic Department, Maritime Safety Agency).

3. Results

3.1. Oceanographic condition

Water temperature and salinity at each station of three survey areas are summarized in Appendix 1. In Breid Bay, water temperature and salinity ranged from -1.87 to 2.10°C and from 33.67 to 34.30, respectively, in December 1984. Water temperature higher than 0°C was observed in the upper layers (0–10 m) at 5 stations. Vertical gradient of salinity to the 200 m depth was not remarkable. In February, the water temperature and salinity were from -1.86 to 0.4°C and 32.63 to 34.25, respectively. Temperature remained at the values from -1.09 to 0.4°C in the upper layer (0–30 m) and salinity came to show lower values of 32.63–33.16 from the surface to the 30 m depth.

At the stations across the Gunnerus Bank, water temperature and salinity ranged from -1.84 to 0.60°C and from 33.30 to 34.43, respectively. In the region off Lützow-Holm Bay, water temperature and salinity ranged from -1.85 to 1.20°C and from 32.86 to 34.63, respectively, in February. High temperature and low salinity appeared in the layer above the 30 m depth.

3.2. Vertical distribution of chlorophyll *a* and phaeophytin

3.2.1. Breid Bay

Chlorophyll *a* observations were carried out two times; 27–30 December, 1984 and 8–11 February, 1985. Nine stations were occupied in each period. During the first survey, the fast ice remained over the southern half of the bay (see Fig. 1) but the fast ice flowed out from the bay by the time of the second survey.

The vertical distributions of chlorophyll *a* and phaeophytin measured in December are shown in Fig. 2. Chlorophyll *a* concentration was found to be higher within an upper 50 m layer. The maximum value was 6.58 mg/m^3 at the 20 m depth at Stn. 9 near the fast ice zone (Appendix 1). Surface waters contained slightly lesser amounts of chlorophyll *a* (1.62 – 4.99 mg/m^3) than those observed at the depths of 10–50 m. Maximum chlorophyll *a* concentrations at all the stations (2.57 – 6.58 mg/m^3) were found at subsurface depths (10–30 m). At greater depths, the concentrations decreased sharply, showing the values of 0.12 – 0.85 mg/m^3 at 200 m. Integrated chlorophyll *a* stocks in the water column (0–200 m) were 230.0 to 410.7 mg/m^2 in Breid Bay in December (Table 1). Vertical distributions of phaeophytin at all stations showed similar tendencies to those of chlorophyll *a*. In the deeper layers, phaeophytin concentrations remained at the level of 1.0 – 2.0 mg/m^3 , which were higher than chlorophyll *a*. Transparency was low (7–8 m) at the almost all the stations.

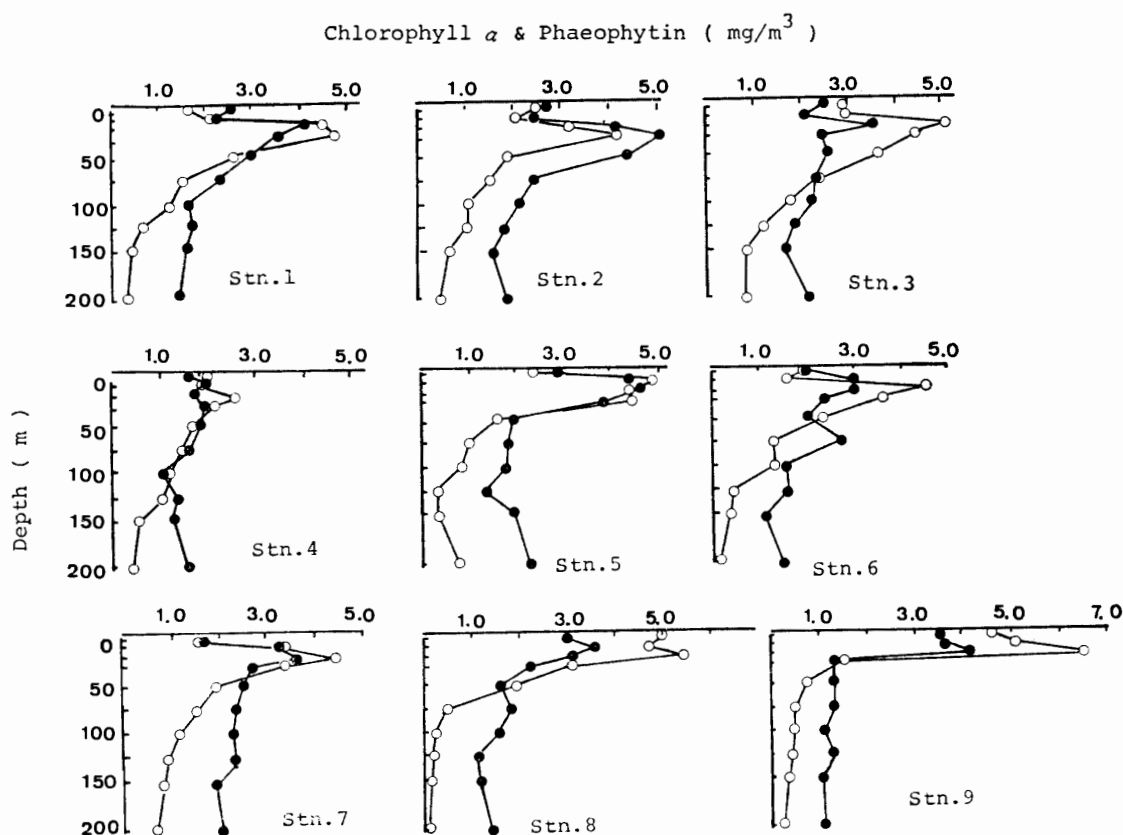


Fig. 2. Vertical distributions of chlorophyll *a* (○) and phaeophytin (●) at each station in Breid Bay, 27–30 December 1984.

Table 1. Integrated chlorophyll *a* stocks (mg/m², 0–200 m) in the water column the at each station in the surver areas.

Breid Bay (December)		Breid Bay (February)		Gunnerus Bank (February)		Lützow-Holm Bay (February)	
Stn. No.	Stocks	Stn. No.	Stocks	Stn. No.	Stocks	Stn. No.	Stocks
1	324.4	10	184.8	1	116.5	1	55.0
2	293.7	11	207.2	2	87.9	2	46.0
3	410.7	12	137.7	3	41.9	3	58.1
4	243.3	13	141.7	4	46.8	4	78.3
5	288.8	5	135.7	5	53.0	5	75.2
6	282.4	6	95.1	6	46.6	6	60.7
7	311.6	7	153.9	7	62.5	7	43.4
8	251.1	8	144.7				
9	230.0	9	141.6				

The vertical distribution of chlorophyll *a* in February is given in Fig. 3. Chlorophyll *a* concentrations were 0.84–2.68 mg/m³ in the upper 20 m layer at all the stations. These values were lower than those in December. Chlorophyll *a* concentrations decreased sharply with the increase of depth. The maximum value was found at Stn. 11 near the ice shelf. Transparency became greater (8.0–12.0 m) than in December (Appendix 1).

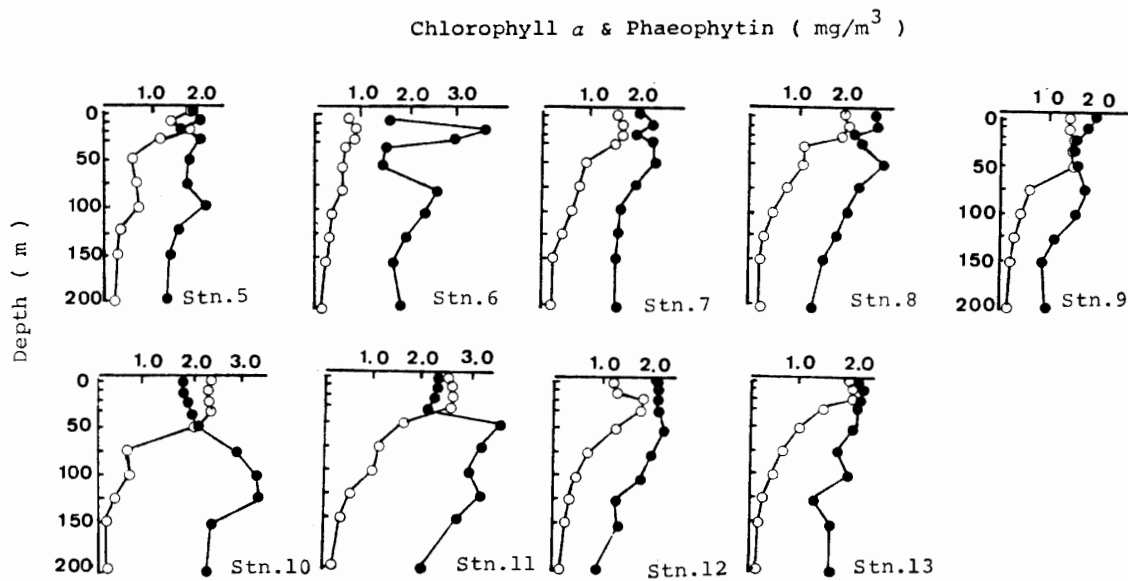


Fig. 3. Vertical distributions of chlorophyll *a* (○) and phaeophytin (●) at each station in Breid Bay, 8–11 February 1986.

Phaeophytin concentrations were higher than those of chlorophyll *a* in each layer at all the stations except for the upper layer of Stns. 11 and 12. Integrated chlorophyll *a* stocks became as lower as 95.1–207.2 mg/m².

3.2.2. Waters across Gunnerus Bank

The survey area was covered with pack ice during early summer, but became open in February. Six stations were occupied along 68°00'S of latitude and one station (Stn. 7) was near the fast ice zone (68°23'S) (Fig. 1).

The observation was carried out from 22 to 25 February 1985 (Fig. 4). Chlorophyll *a* concentrations ranged from 0.17–1.83 mg/m³ within the upper 50m depth at all the stations. The vertical gradient was small compared with that in Breid Bay. Phaeophytin concentration ranged from 0.86 to 2.28 mg/m³ in the upper 50m layer. Phaeophytin concentrations exceeded chlorophyll *a* values. Integrated chlorophyll *a* stocks ranged from 41.9–116.5 mg/m². The transparency ranged from 12.0m to 18.0m.

3.2.3. Off Lützow-Holm Bay

The survey area was situated at the entrance of Lützow-Holm Bay. Observations were carried out at seven stations in a region of 67°00'–68°00'S and 36°00'–38°00'E on 3–5 February, 1985 (Fig. 1). Generally, chlorophyll *a* concentrations were below 1.0 mg/m³ and vertical variation was small (Fig. 5). The maximum value was 1.37 mg/m³ at the depth of 50m at Stn. 4. Phaeophytin concentrations were always higher than those of chlorophyll *a*. Integrated chlorophyll *a* stocks in waters off Lützow-Holm Bay were 43.4–78.3 mg/m². These values were similar to those in the Gunnerus Bank. The transparency was also similar to that in the Gunnerus Bank, being 12.0–16.0m.

3.2.4. Pigment ratio distribution

The vertical distribution of the pigment ratio (Chl./Chl. + Phae. × 100) at all the stations of the three survey areas is given in Fig. 6. Higher pigment ratios generally mean active phytoplankton. Pigment ratios in the upper 50m layer in Breid Bay in December, exceeded 50%, but decreased gradually with the increase of depth. In

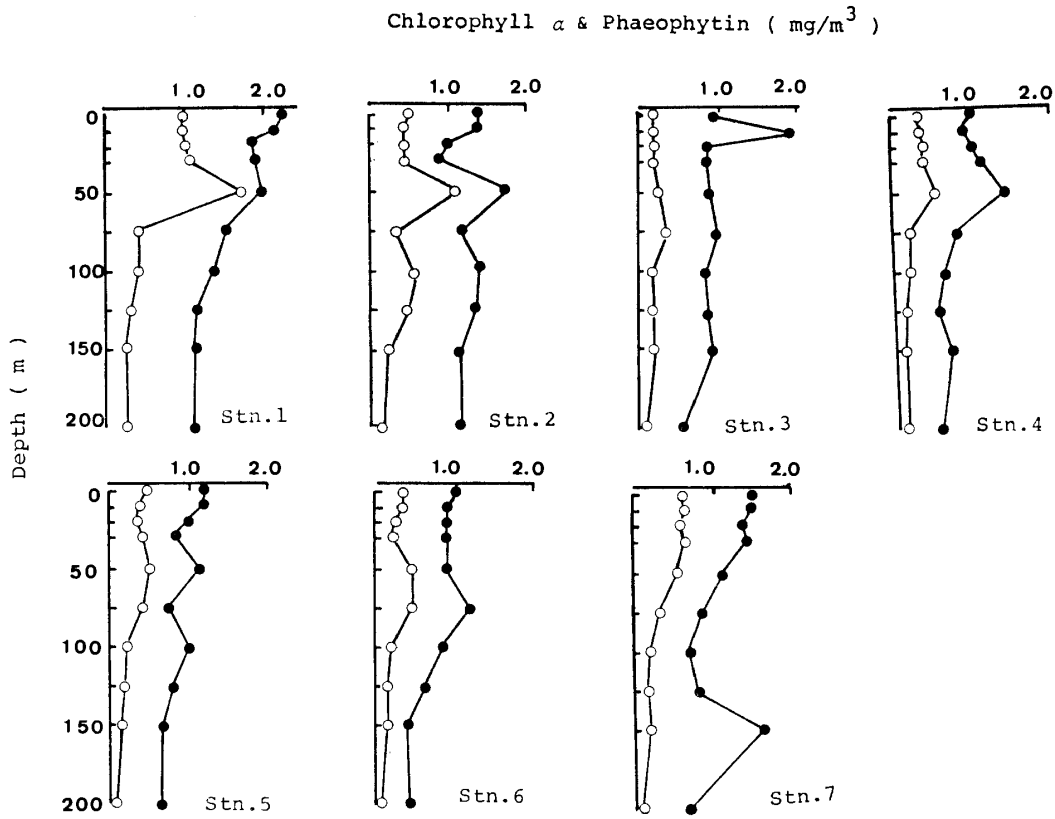


Fig. 4. Vertical distributions of chlorophyll a (\circ) and phaeophytin (\bullet) at each station off the Gunnerus Bank, 22–25 February 1985.

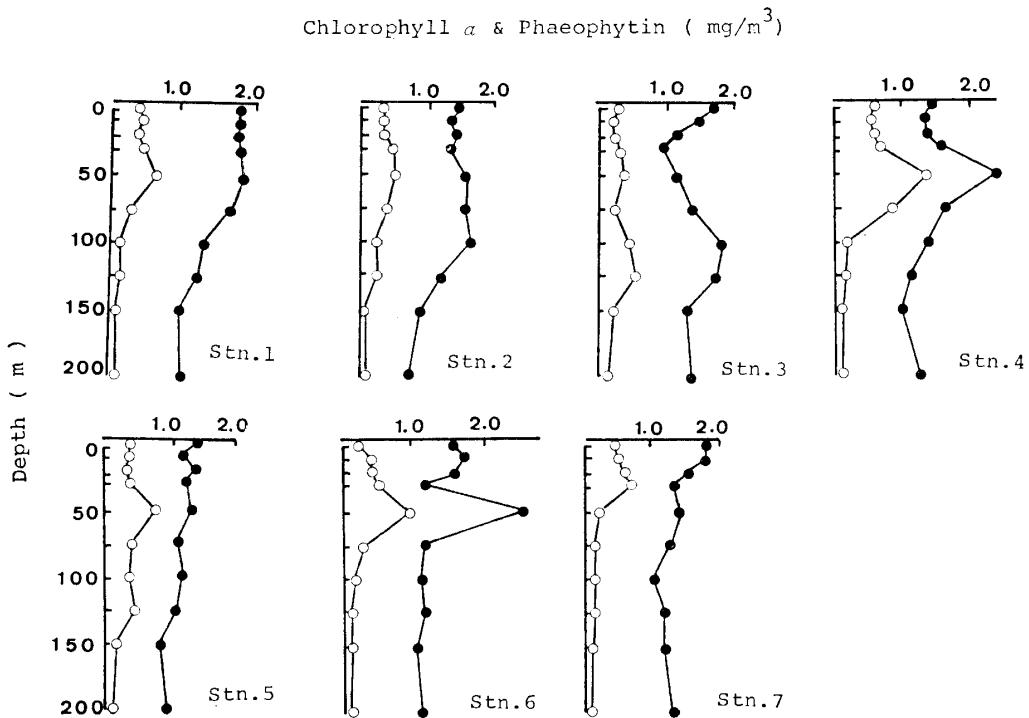


Fig. 5. Vertical distributions of chlorophyll a (\circ) and phaeophytin (\bullet) at each station off Lützow-Holm Bay, 3–5 February 1985.

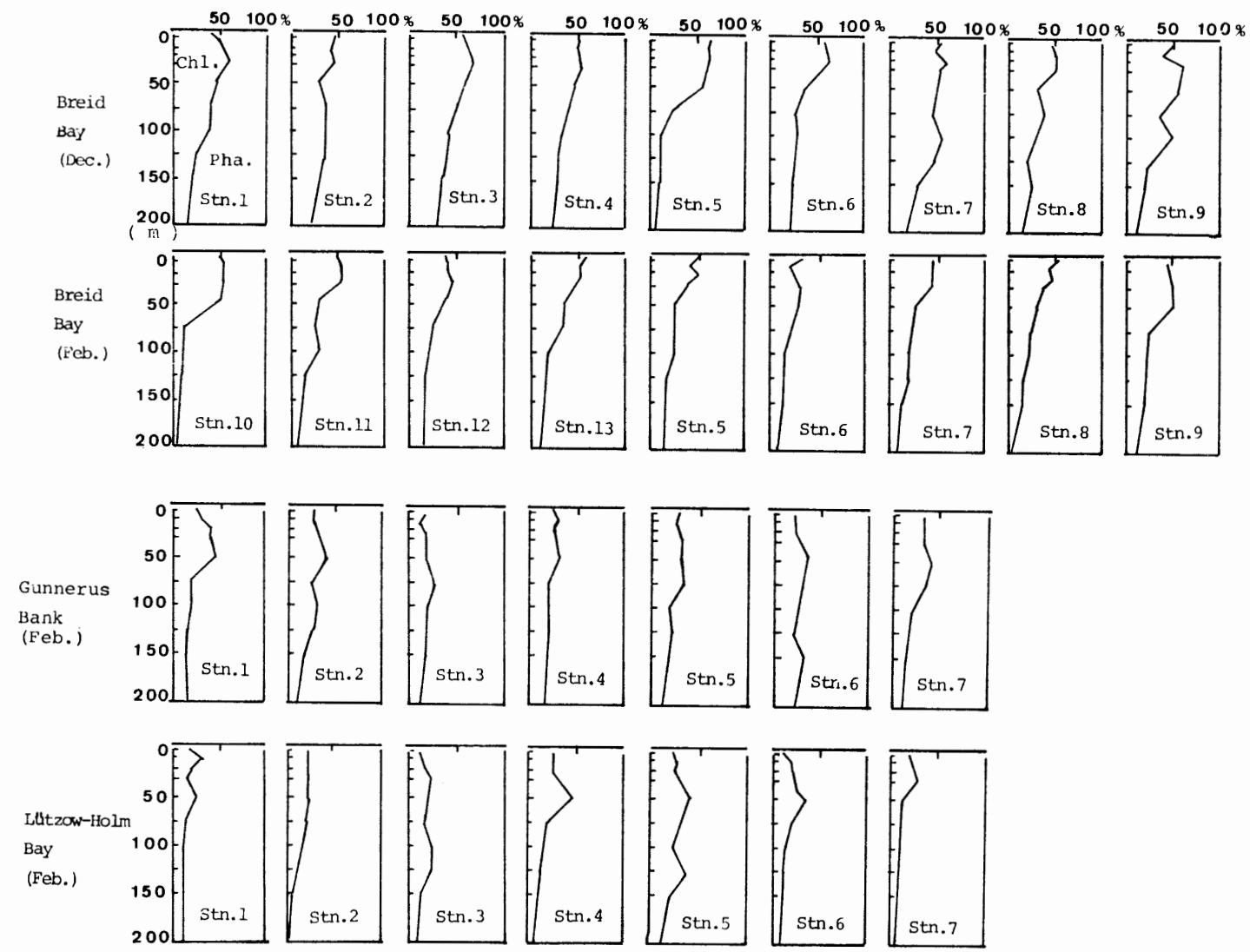


Fig. 6. Vertical change of pigment ratio (chlorophyll *a*/chlorophyll *a*+phaeophytin×100, %) at each station of three survey areas.

February, although the pigment ratio in the upper 30 m depth layer still remained approximately 50% in Breid Bay, it decreased in the deeper layers.

The pigment ratios in the Gunnerus Bank and off Lützow-Holm Bay were generally lower than those of Breid Bay. The vertical variation was small.

4. Discussion

Salinity of less than 33.00 was observed in upper 0–50 m at almost all the stations in Breid Bay in February, which was similar to the condition under the fast ice near Syowa Station in March and May (SATO *et al.*, 1986). Melting of the sea ice seemed to influence the condition of the upper water layer in the ice-associated coastal waters.

The values of transparency were 7.0–12.0 m in Breid Bay (December 27–30 and February 8–11), 12.0–18.0 m across the Gunnerus Bank (February 22–25) and off Lützow-Holm Bay (February 3–5). The values seem to be lower than those observed in the Southern Ocean. FUKASE (1961) reported that the transparency at the stations (66°17'–68°17'S, 33°41'–45°57'E) distant from the coast, ranged in 18.0–46.0 m on 22 January to 20 February 1969. From the results of these surveys, the values of transparency seem to be relevant to the biomass of the open sea or coastal waters.

The chlorophyll *a* concentrations and chlorophyll *a* standing stocks in Breid Bay were higher than those in the waters of the Gunnerus Bank and off Lützow-Holm Bay. Chlorophyll *a* concentration of the surface layer in the three areas was concurrently measured at 108 stations along the course of the SHIRASE (FUKUDA *et al.*, 1986). The chlorophyll *a* concentrations of the surface layer were considerably different from station to station. High chlorophyll *a* concentrations were observed near the fast ice region in Breid Bay. The values of chlorophyll *a* of the surface layer in the open water became lower in early February. Off Lützow-Holm Bay, the values of surface chlorophyll *a* ranged 1.08–1.95 mg/m³ between 2 and 3 January but 0.19–0.40 mg/m³ between 2 and 5 February. The present results and the above-mentioned surface data show the seasonal decrease in chlorophyll *a* from January to February. HAMADA *et al.* (1985) found the maximum chlorophyll *a* concentration of 3.85 mg/m³ at a 30 m depth in Breid Bay in mid-February 1984. The vertical distributions of chlorophyll *a* and phaeophytin were also similar to the present result.

The higher concentrations of chlorophyll *a* were reported in other regions close to pack ice and fast ice, Antarctic. In the open sea close to the pack ice zone near Lützow-Holm Bay, a high value of 2.06 mg/m³ was observed at the surface (OHNO, 1976). TOMINAGA (1971) observed the chlorophyll *a* concentrations as high as 73.8 mg/m³ in the Ongul Strait and EL-SAYED (1971) obtained a much higher value (190 mg/m³) in the ice free area near the fast ice region of the Weddell Sea.

A few reports have also been published on chlorophyll *a* concentrations beneath the fast ice of Lützow-Holm Bay (HOSHIAI, 1969; FUKUCHI *et al.*, 1984). In the 1981–83 survey, the highest chlorophyll *a* concentrations and stocks were observed in late January, being as much as 11.3 mg/m³ and 466.5 mg/m², 0–150 m, respectively (FUKUCHI *et al.*, 1984). The present result of highest value being 410.7 mg/m², 0–200 m at Stn. 4 in Breid Bay in December, is essentially the same as that reported by FUKUCHI *et al.* (1984).

Acknowledgments

We express our gratitude to Prof. S. KAWAGUCHI of National Institute of Polar Research (leaders of JARE-26) for his valuable advice. Thanks are also due to Messrs. K. IWANAMI and H. TOHJU (members of the JARE-26, Hydrographic Department, Maritime Safety Agency) for their cooperation in the present survey. The authors are indebted to Captain M. SATO of icebreaker SHIRASE and his officers and crew.

References

- EL-SAYED, S. Z. (1971): Observations on phytoplankton bloom in the Weddell Sea. *Biology of the Antarctic Seas IV*, ed. by G. A. LLANO and J. E. WALLEN. Washington, D.C., Am. Geophys. Union, 301–212 (Antarct. Res. Ser., Vol. 17).
- FUKASE, S. (1961): Oceanographical data of the fourth Japanese Antarctic Research Expedition. *Nankyoku Shiryo* (Antarct. Rec.), **13**, 17–28.
- FUKUCHI, M., TANIMURA, A. and OHTSUKA, H. (1984): Seasonal change of chlorophyll *a* under fast ice in Lützw-Holm Bay, Antarctica. *Mem. Natl Inst. Polar Res., Spec. Issue*, **32**, 51–59.
- FUKUDA, Y., OHNO, M., IWANAMI, K. and TOHJI, H. (1986): Chlorophyll *a* content in the surface and subsurface waters along the course of the SHIRASE to Antarctica in 1984–1985. *Nankyoku Shiryo* (Antarct. Rec.), **30**, 103–112.
- HAMADA, E., TANIGUCHI, A., OKAZAKI, M. and NAITO, Y. (1985): Report on the phytoplankton pigments measured during the JARE-25 cruise to Syowa Station, Antarctica, November 1983 to April 1984. *JARE Data Rep.*, **103**, (Mar. Biol., 7), 89 p.
- HOSHIAI, T. (1969): Syowa Kiti ni okeru kaihyōka no kurorofiru-a ryō to kankyō jōken no kisetsu henka (Seasonal variation of chlorophyll-*a* and hydrological conditions under sea ice at Syowa Station, Antarctica). *Nankyoku Shiryo* (Antarct. Rec.), **35**, 52–67.
- KURODA, K. and FUKUCHI, M. (1982): Vertical distribution of chlorophyll *a* in the Indian sector of Antarctic Ocean in 1972–1973. *Nankyoku Shiryo* (Antarct. Rec.), **74**, 127–142.
- OHNO, M. (1976): Chlorophyll-*a* content in the surface water observed during the cruise of the FUJI to Antarctica in 1974–1975. *Nankyoku Shiryo* (Antarct. Rec.), **57**, 106–114.
- SAIJO, Y. and NISHIZAWA, S. (1969): Excitation spectra in the fluorometric determination of chlorophyll-*a* and phaeophytin-*a*. *Mar. Biol.*, **2**, 135–136.
- SOTOH, 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 Shiryo* (Antarct. Rec.), **30**, 19–32.
- TANIMURA, A. (1981): Distribution of the surface chlorophyll *a* along the course of the FUJI to and from Antarctica in 1979–1980. *Nankyoku Shiryo* (Antarct. Rec.), **72**, 35–48.
- TOMINAGA, H. (1971): Chlorophyll *a* and phaeophytin contents in the surface water of the Antarctic Ocean through the Indian Ocean. *Nankyoku Shiryo* (Antarct. Rec.), **42**, 124–134.
- UNO, S. (1983): The relation between phytoplankton standing stock and water temperature in the Antarctic Ocean in summer, 1980–1981. *Mem. Natl Inst. Polar Res., Spec. Issue*, **27**, 37–49.
- WATANABE, K. and NAKAJIMA, Y. (1982): Vertical distribution of chlorophyll *a* along 45°E in the Southern Ocean, 1981. *Mem. Natl Inst. Polar Res., Spec. Issue*, **23**, 73–86.
- YAMAGATA, K. and FUKUI, F. (1981): Chlorophyll *a* content in the Indian sector of the Antarctic Ocean. *Nankyoku Shiryo* (Antarct. Rec.), **73**, 72–81.

(Received April 7, 1987)

Appendix 1.

Data on water temperature ($^{\circ}\text{C}$), salinity, transparency (m), chlorophyll *a* (mg/m^3) and phaeophytin (mg/m^3) observed at each station in three areas; Breid Bay, across Gummerus Bank, and off Lützow-Holm Bay, from December 1984 to February 1985.

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. ($^{\circ}\text{C}$)	Salinity	Chl. <i>a</i> (mg/m^3)	Phaeop.
Breid Bay							
Stn. 1 1330 m (8.0 m)	Dec. 29, 1984 1110-1130	70 $^{\circ}$ 05'S 23 $^{\circ}$ 51'E	0	0.5	33.95	1.68	2.61
			10	1.23	33.67	2.10	2.25
			20	-0.34	34.10	4.59	4.11
			30	-1.16	34.16	4.80	3.54
			50	-1.55	34.20	2.58	2.94
			75	-1.75	34.19	1.48	2.35
			100	-1.73	34.21	1.21	1.83
			125	-1.75	34.24	0.65	1.86
			150	-1.70	34.26	0.40	1.55
Stn. 2 1625 m (8.0 m)	Dec. 29 0900-0920	70 $^{\circ}$ 05'S 23 $^{\circ}$ 59'E	0	1.7	33.86	2.47	2.70
			10	1.42	33.93	2.09	2.48
			20	-0.63	34.15	3.14	4.12
			30	-1.27	34.17	4.13	5.00
			50	-1.59	34.18	1.87	4.38
			75	-1.68	34.19	1.50	2.41
			100	-1.70	34.21	1.06	2.16
			125	-1.75	34.22	0.98	1.78
			150	-1.75	34.24	0.65	1.56
Stn. 3 1774 m	Dec. 30 1045-1114	70 $^{\circ}$ 05'S 24 $^{\circ}$ 09'E	0	1.6	33.95	2.82	2.43
			10	0.88	34.02	2.94	2.04
			20	-1.19	34.13	5.10	3.59
			30	-1.47	34.14	4.40	2.41
			50	-1.47	34.16	3.66	2.52
			75	-1.61	34.17	2.35	2.32
			100	-1.67	34.19	1.71	2.20
			125	-1.76	34.21	1.17	1.78
			150	-1.72	34.22	0.78	1.61
Stn. 4 789 m (11.0 m)	Dec. 30 1238-1304	70 $^{\circ}$ 04'S 24 $^{\circ}$ 20'E	0	-0.2	34.14	2.09	1.75
			10	-0.77	34.10	2.01	2.06
			20	-1.25	34.12	2.57	1.89
			30	-1.39	34.13	2.17	1.92
			50	-1.57	34.21	1.90	1.91
			75	-1.68	34.17	1.43	1.75
			100	-1.78	34.18	1.21	1.14
			125	-1.73	34.20	1.14	1.24
			150	-1.73	34.20	0.51	1.22
200	-1.77	34.28	0.35	1.80			

Appendix 1. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Breid Bay			0	1.9	33.97	2.40	2.98
Stn. 5	Dec. 27, 1984	70°08'S	10	0.49	34.01	4.84	4.44
269 m	1128-1200	23°50'E	20	-1.00	34.13	4.48	4.72
(7.0 m)			30	-1.21	34.15	4.48	3.84
			50	-1.54	34.18	1.66	1.97
			75	-1.86	34.21	1.02	1.87
			100	-1.86	34.22	0.85	1.79
			125	-1.84	34.24	0.37	1.35
			150	-1.85	34.23	0.35	2.00
			200	-1.87	34.24	0.85	2.29
Stn. 6	Dec. 27	70°09'S	0	2.1	33.89	1.98	1.98
307 m	0925-0956	23°58'E	10	1.00	—	1.68	3.08
(7.0 m)			20	-0.24	34.09	4.56	3.12
			30	-1.07	34.14	3.62	2.46
			50	-1.61	34.19	2.37	2.04
			75	-1.74	34.20	1.32	2.76
			100	-1.81	34.21	1.38	1.51
			125	—	—	0.45	1.58
			150	-1.77	34.26	0.31	1.16
			200	-1.81	34.28	0.13	1.45
Stn. 7	Dec. 27	70°08'S	0	0.5	34.13	1.62	1.65
318 m	1417-1448	24°08'E	10	-0.39	34.11	3.42	3.36
(7.0 m)			20	-1.02	34.14	4.50	3.57
			30	-1.19	34.15	3.39	2.91
			50	-1.44	34.18	1.99	2.31
			75	-1.68	34.19	1.59	2.14
			100	-1.72	34.21	1.16	2.30
			125	-1.75	34.22	0.90	2.35
			150	-1.79	34.23	0.81	1.94
			200	-1.79	34.26	0.68	2.05
Stn. 8	Dec. 29	70°10'S	0	0.5	34.06	4.99	3.09
284 m	1355-1419	24°19'E	10	-0.61	34.13	4.71	3.62
(8.0 m)			20	-1.44	34.18	5.48	3.23
			30	-1.66	34.19	3.11	2.24
			50	-1.81	34.20	1.94	1.65
			75	-1.84	34.21	0.49	1.87
			100	-1.83	34.22	0.25	1.63
			125	-1.86	34.23	0.19	1.19
			150	-1.79	34.25	0.14	1.22
			200	-1.82	34.29	0.12	1.40
Stn. 9	Dec. 30	70°12'S	0	0.4	34.18	4.62	3.34
320 m	1451-1513	24°27'E	10	-1.16	34.16	5.12	3.62
(7.0 m)			20	-1.71	34.20	6.58	4.13
			30	-1.82	34.24	1.46	1.28
			50	-1.83	34.21	0.73	1.34
			75	-1.86	34.22	0.50	1.33
			100	-1.86	34.22	0.49	1.17
			125	-1.78	34.24	0.45	1.29
			150	-1.80	34.25	0.36	1.08
			200	-1.82	34.29	0.26	1.10

Appendix 1. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Breid Bay			0	0.4	32.73	2.31	1.76
Stn. 10	Feb. 10, 1985	70°14'S	10	-0.66	32.71	2.26	1.88
226 m	1745-1807	23°49'E	20	-0.66	32.71	2.26	1.96
(10.5 m)			30	-0.67	32.72	2.30	1.86
			50	-0.63	32.76	2.01	2.04
			75	-1.33	33.78	0.58	2.92
			100	-1.68	34.04	0.65	3.30
			125	-1.81	34.16	0.39	3.32
			150	-1.86	34.15	0.15	2.28
			200	-1.83	34.20	0.11	2.24
Stn. 11	Feb. 11	70°14'S	0	-0.6	32.67	2.54	2.50
240 m	0756-0820	24°01'E	10	-0.78	32.63	2.68	2.38
(10.5 m)			20	-0.77	32.64	2.67	2.28
			30	-0.77	32.64	2.66	2.16
			50	-0.62	32.82	1.65	4.04
			75	-1.47	33.94	1.15	3.32
			100	-1.67	34.08	1.04	1.93
			125	-1.75	34.13	0.51	3.32
			150	-1.79	34.17	0.32	2.72
			200	-1.78	34.25	0.13	2.00
Stn. 12	Feb. 11	70°15'S	0	-1.0	32.66	1.21	2.19
212 m	0932-0956	24°07'E	10	-1.11	32.63	1.35	2.19
(8.5 m)			20	-0.71	32.67	1.82	2.15
			30	-0.60	32.70	1.79	2.20
			50	-0.67	32.88	1.28	2.23
			75	-1.45	33.94	0.70	2.02
			100	-1.63	34.05	0.45	1.72
			125	-1.70	34.11	0.23	1.26
			150	-1.67	34.15	0.18	1.27
			200	-1.78	34.22	0.12	0.86
Stn. 13	Feb. 10	70°16'S	0	-0.6	32.73	2.03	2.47
251 m	1342-1405	24°32'E	10	-0.55	32.73	2.18	2.50
(9.5 m)			20	-0.54	32.73	2.10	2.40
			30	-0.59	32.73	1.40	2.20
			50	-0.59	32.73	1.07	2.49
			75	-1.73	34.02	0.70	1.86
			100	-1.77	34.07	0.43	2.32
			125	-1.74	34.08	0.24	1.28
			150	-1.76	34.11	0.17	1.45
			200	-1.79	—	0.16	1.46
Stn. 5	Feb. 8	70°09'S	0	-0.5	32.76	1.79	1.80
293 m	0950-1012	23°47'E	10	-0.50	32.71	1.34	2.00
(12.0 m)			20	-0.52	32.74	1.64	1.66
			30	-0.85	33.13	1.17	2.03
			50	-1.32	33.81	0.57	1.74
			75	-1.41	33.92	0.55	1.71
			100	-1.51	34.08	0.70	2.11
			125	-1.60	34.13	0.32	1.57
			150	-1.66	34.18	0.26	1.34
			200	-1.70	34.22	0.19	1.28

Appendix 1. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Breid Bay			0	-0.6	32.70	0.76	1.62
Stn. 6	Feb. 8, 1985	70°09'S	10	-0.59	32.73	0.92	3.58
275 m	0753-0814	24°01'E	20	-0.62	32.83	0.84	2.91
(10.0 m)			30	-0.89	33.16	0.63	1.50
			50	-1.34	33.82	0.62	1.48
			75	-1.56	34.03	0.64	2.59
			100	-1.65	34.11	0.38	2.35
			125	-1.64	34.16	0.33	1.90
			150	-1.69	34.18	0.28	1.66
			200	-1.72	34.23	0.22	1.80
Stn. 7	Feb. 9	70°10'S	0	-0.5	32.76	1.58	2.13
266 m	0842-0905	24°11'E	10	-0.42	32.74	1.65	2.31
(9.0 m)			20	-0.43	32.74	1.65	2.07
			30	-0.44	32.74	1.50	2.01
			50	-0.72	32.95	0.91	2.63
			75	-1.51	33.97	0.76	2.69
			100	-1.63	34.08	0.60	2.03
			125	-1.75	34.12	0.41	1.69
			150	-1.76	34.13	0.25	1.65
			200	-1.77	34.21	0.17	1.50
Stn. 8	Feb. 9	70°12'S	0	-0.7	32.68	1.96	2.64
307 m	1045-1108	24°21'E	10	-0.68	32.63	2.04	2.65
(8.0 m)			20	-0.55	32.67	1.92	2.23
			30	-0.43	32.88	1.14	2.31
			50	-1.16	33.62	1.14	2.71
			75	-1.60	34.04	0.81	2.27
			100	-1.60	34.10	0.48	2.01
			125	-1.66	34.13	0.30	1.83
			150	-1.67	34.15	0.27	1.51
			200	-1.69	34.18	0.26	1.29
Stn. 9	Feb. 11	70°14'S	0	-0.8	32.67	1.44	2.02
280 m	1319-1341	24°26'E	10	-1.04	32.64	1.49	1.84
(10.0 m)			20	-1.06	32.65	1.53	1.64
			30	-1.09	32.65	1.55	1.53
			50	-0.89	33.04	1.53	1.50
			75	-1.64	34.02	0.62	1.75
			100	-1.65	34.06	0.43	1.56
			125	-1.74	34.11	0.27	1.12
			150	-1.72	34.13	0.22	0.89
			200	-1.76	34.20	0.19	0.96
Lützow-Holm Bay			0	1.0	33.59	0.39	1.91
Stn. 1	Feb. 3	68°00'S	10	0.90	33.57	0.46	1.91
3090 m	0918-0944	38°02'E	20	0.90	33.57	0.44	1.93
			30	0.35	33.66	0.48	1.98
			50	-0.77	33.85	0.62	1.90
			75	-1.60	34.18	0.29	1.84
			100	-1.72	34.25	0.16	1.40
			125	-1.77	34.28	0.15	1.30
			150	-1.79	34.30	0.11	1.04
			200	-1.70	34.34	0.12	1.09

Appendix I. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Lützow-Holm Bay			0	1.2	33.74	0.33	1.46
Stn. 2	Feb. 3, 1985	67°31'S	10	0.87	33.74	0.32	1.33
4132 m	1329-1351	37°59'E	20	0.63	33.75	0.35	1.43
(12.5 m)			30	0.56	33.78	0.37	1.26
			50	-0.14	33.92	0.45	1.54
			75	-1.54	34.20	0.35	1.55
			100	-1.70	34.27	0.20	1.64
			125	-1.77	34.30	0.20	1.22
			150	-1.80	34.31	0.05	0.89
			200	-1.66	34.35	0.04	0.67
Stn. 3	Feb. 4	67°00'S	0	1.0	33.67	0.26	1.67
4150 m	0757-0824	38°00'E	10	0.98	33.65	0.19	1.46
(16.0 m)			20	0.84	33.74	0.22	1.15
			30	0.36	33.83	0.31	0.96
			50	-1.43	34.13	0.33	1.14
			75	-1.12	34.31	0.23	1.36
			100	-0.07	34.44	0.48	1.86
			125	-0.74	34.54	0.54	1.72
			150	-0.97	34.57	0.22	1.27
			200	-1.31	34.63	0.10	1.37
Stn. 4	Feb. 4	67°00'S	0	0.9	33.64	0.58	1.44
4250 m	1105-1132	37°02'E	10	0.87	33.61	0.52	1.35
(12.0 m)			20	0.74	33.61	0.56	1.42
			30	0.61	33.61	0.66	1.53
			50	-1.56	34.14	1.37	2.41
			75	-1.76	34.23	0.39	1.68
			100	-1.85	34.28	0.19	1.41
			125	-1.82	34.30	0.13	1.16
			150	-1.80	34.32	0.10	0.98
			200	-1.15	34.36	0.08	1.25
Stn. 5	Feb. 4	67°01'S	0	1.0	33.70	0.39	1.40
4290 m	1616-1702	36°00'E	10	0.90	33.69	0.38	1.14
(13.0 m)			20	0.85	33.73	0.34	1.32
			30	0.67	33.74	0.41	1.23
			50	-1.36	34.14	0.76	1.27
			75	-1.62	34.27	0.41	1.02
			100	-1.79	34.31	0.34	1.14
			125	-1.37	34.36	0.46	1.01
			150	-1.11	34.39	0.17	0.78
			200	-1.55	34.56	0.08	0.90
Stn. 6	Feb. 5	67°31'S	0	1.2	33.48	0.23	1.68
3017 m	0851-0914	36°00'E	10	1.12	33.45	0.41	1.76
(12.0 m)			20	1.02	33.48	0.43	1.64
			30	0.45	33.58	0.51	1.19
			50	-1.54	34.09	0.98	2.72
			75	-1.73	34.20	0.31	1.29
			100	-1.78	34.25	0.15	1.16
			125	-1.78	34.28	0.13	1.24
			150	-1.80	34.28	0.11	1.08
			200	-1.81	34.30	0.10	1.12

Appendix 1. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Lützw-Holm Bay			0	0.5	32.86	0.46	1.73
Stn. 7	Feb. 5, 1985	68°00'S	10	0.36	33.05	0.50	1.76
3082 m	1223-1243	35°58'E	20	-0.21	33.46	0.59	1.56
(15.0 m)			30	-1.00	33.73	0.69	1.32
			50	-1.81	34.04	0.22	1.40
			75	-1.78	34.09	0.13	1.24
			100	-1.71	34.16	0.12	1.04
			125	-1.74	34.21	0.10	1.21
			150	-1.75	34.24	0.10	1.26
			200	-1.81	34.28	0.11	1.29
Gunnerus Bank			0	0.4	33.81	1.00	2.28
Stn. 1	Feb. 22	67°59'S	10	0.33	33.78	1.09	2.17
3693 m	0800-0828	30°04'E	20	0.34	33.78	1.09	1.80
(12.0 m)			30	0.35	33.79	1.10	1.89
			50	0.32	33.79	1.83	2.00
			75	0.37	34.33	0.46	1.56
			100	-1.76	34.36	0.45	1.41
			125	-1.72	34.37	0.35	1.20
			150	-1.07	34.43	0.27	1.22
			200	0.50	34.58	0.27	1.23
Stn. 2	Feb. 23	68°00'S	0	0.4	33.76	0.52	1.30
3230 m	1238-1304	31°03'E	10	0.30	33.75	0.43	1.30
(14.0 m)			20	0.30	33.74	0.44	1.05
			30	0.31	33.74	0.46	0.90
			50	-1.45	34.24	1.12	1.71
			75	-1.76	34.32	0.30	1.10
			100	-1.71	34.71	0.57	1.35
			125	-1.66	34.37	0.44	1.30
			150	-1.78	34.36	0.22	1.16
			200	-1.06	34.43	0.12	1.15
Stn. 3	Feb. 23	68°01'S	0	0.4	33.87	0.22	0.93
787 m	1649-1717	32°01'E	10	0.31	33.83	0.18	1.90
(16.0 m)			20	0.29	33.83	0.18	0.86
			30	0.33	33.83	0.17	0.86
			50	0.20	33.83	0.25	0.90
			75	-1.73	34.27	0.38	0.98
			100	-1.77	34.31	0.19	0.94
			125	-1.74	34.34	0.17	0.88
			150	-1.77	34.35	0.21	0.94
			200	-1.22	34.41	0.09	0.69
Stn. 4	Feb. 24	68°00'S	0	0.2	33.83	0.38	1.02
561 m	1407-1436	33°00'E	10	0.05	33.81	0.38	0.91
(17.0 m)			20	0.01	33.83	0.34	1.02
			30	-0.02	33.81	0.40	1.10
			50	-1.36	34.12	0.54	1.40
			75	-1.77	34.28	0.21	0.77
			100	-1.82	34.30	0.18	0.65
			125	-1.78	34.30	0.11	0.53
			150	-1.76	34.33	0.12	0.70
			200	-1.68	34.36	0.10	0.53

Appendix 1. (Continued)

Area Station No. Sea depth (Transparency)	Date and Time (LT)	Location	Depth (m)	Water temp. (°C)	Salinity	Chl. <i>a</i> (mg/m ³)	Phaeop.
Gunnerus Bank			0	-0.2	33.32	0.48	1.23
Stn. 5	Feb. 24, 1985	67°59'S	10	-0.37	33.30	0.42	1.28
865 m	1102-1128	34°00'E	20	-0.25	33.36	0.37	1.00
(16.0 m)			30	-0.03	33.45	0.42	0.88
			50	-1.48	33.98	0.50	1.13
			75	-1.68	34.12	0.38	0.76
			100	-1.70	34.16	0.19	0.99
			125	-1.69	34.17	0.19	0.80
			150	-1.73	34.19	0.12	0.70
			200	-1.78	34.25	0.08	0.66
Stn. 6	Feb. 24	68°00'S	0	0.5	33.69	0.26	1.03
2719 m	0801-0831	35°01'E	10	0.43	33.64	0.26	0.90
(14.0 m)			20	0.44	33.64	0.24	0.91
			30	0.46	33.64	0.23	0.89
			50	0.04	33.77	0.43	0.89
			75	-1.70	34.20	0.45	1.20
			100	-1.77	34.25	0.19	0.86
			125	-1.79	34.26	0.13	0.62
			150	-1.83	34.28	0.15	0.40
			200	-1.83	34.31	0.09	0.45
Stn. 7	Feb. 25	68°23'S	0	-0.4	33.39	0.64	1.49
297 m	1808-1835	34°13'E	10	-0.33	33.47	0.66	1.48
(18.0 m)			20	-0.17	33.55	0.59	1.35
			30	-0.18	33.68	0.65	1.44
			50	-1.49	33.93	0.56	1.09
			75	-1.72	34.11	0.32	1.83
			100	-1.72	34.18	0.19	0.70
			125	-1.72	34.21	0.14	0.79
			150	-1.74	34.24	0.18	1.17
			200	-1.73	34.27	0.09	0.64