# Chlorophyll-*a* Contents in the Surface Water Observed During the Relief Voyage of FUJI to Syowa Station, Antarctica, in 1975-1976

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「ふじ」航路 (1975-1976) における表面海水中のクロロフィル-*a* 量

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**要旨**: 1975年11月から1976年4月まで，第17次南極地域観測隊の海洋生物観測の一環として，「ふじ」の航路に沿って表面海水中のクロロフィル-*a* 量の測定を行った．クロロフィル-*a* 量はプリンスオラフ海岸沖のパック・アイス中で最も高い値 (2.49 mg/m$^3$) が得られた．その他の海域では亜南極帯，マカッサール海峡，マラッカ海峡で高い値 (0.4－0.9 mg/m$^3$) を示した．今回は昭和基地沖の氷縁を離れてから最初の寄港地が，従来のケープタウンからモーリシャスのポートルイスに変更された．このため従来観測されなかった海域でのクロロフィル-*a* 量を測定することができた．

***Abstract***: During the relief voyage of FUJI to Syowa Station, Antarctica, from November 1975 to April 1976, the chlorophyll contents in surface water were measured twice a day as a routine shipboard oceanographic observation. The distribution of chlorophyll contents during the cruise did not show a marked difference from the past years. The maximum value (2.49 mg/m$^3$) was recorded in the pack-ice region in the Antarctic Ocean off Prince Olav Coast. High values more than 0.4 mg/m$^3$ were observed in such region as the Makassar Strait, Sub-Antarctic sea and the Malacca Strait. After leaving the ice edge off Syowa Station, the vessel sailed up to the north along about 33.5°E which is far east compared with the course of the previous voyages, which added new data in the series of chlorophyll observation.

## 1. Introduction

As one of the marine biological programs of the 17th Japanese Antarctic Research Expedition during the austral summer of 1975–76, the measurement of chlorophyll-*a* contents in the surface water was carried out on board the icebreaker FUJI in her relief voyage to Syowa Station, Antarctica. This measure-

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ment intends to collect the data for inferring a potential photosynthetic capacity of phytoplankton in the Antarctic Ocean and adjacent seas, and has been continued for the past ten years.

The vessel left Tokyo on November 25, calling after Fremantle, made resupply to Syowa, and returned Tokyo via Port Louis and Singapore. Since the first port of call after leaving the ice edge off Syowa Station was altered from Cape Town to Port Louis in the present cruise, this paper contains the data newly obtained in the southern Indian Ocean.

## 2. Method

Surface water was taken by a plastic bucket twice a day chiefly at 08:00 and 18:00 (local time) through the whole cruise. Water temperatures were also measured at the same time. The water samples were filtrated through a Millipore filter HA (47 mm) under reduced pressure. Chlorophyll was extracted from the filter which was immersed in 95 percent acetone solution and left in a dark refregirator for a day. After centrifugation, a supernatant was submitted to the spectrophotometric determination of chlorophyll. Chlorophyll-*a* was calculated with the following equation:

$$\text{Chlorophyll-}a\ (\text{mg/m}^3) = (11.64 \times D_{663} - 2.16 \times D_{645} - 0.10 \times D_{630}) \times \frac{\text{volume of 95\% acetone solution (ml)}}{\text{volume of filtrated sea water (l)}}$$

$D_{663}$, $D_{645}$, $D_{630}$, : optical density of acetone extract at wave length of 663, 645 and 630 nm, respectively.

## 3. Results and Discussion

The observation was started at the east of Luzon Island, Philippine, on the way from Tokyo to Fremantle, Western Australia. It was discontinued at the sea near Okinawa Island on the way from Singapore to Tokyo.

Chlorophyll contents and water temperatures are shown in Table 1. Fig. 1 shows the distribution of the chlorophyll contents along the route of the ice-breaker FUJI. The highest value was recorded in the pack-ice region in the Antarctic Ocean. The high level of chlorophyll was also observed in the Makassar Strait, Sub-Antarctic sea and the Malacca Strait.

The details of chlorophyll distribution were as follows:

**From Tokyo to Fremantle :**

Two stations in this leg showed relatively high value of chlorophyll contents; one was in the north of Makassar Strait with the concentration of 0.52 mg/m$^3$, and the other in the Indian Ocean with 0.43 mg/m$^3$. The high level of chlorophyll

*Table 1. Chlorophyll-a contents and water temperatures obtained during the relief voyage of* FUJI *to Syowa Station, Antarctica, in 1975–76.*

| Station No. | Date | Time (L.T.) | Latitude | Longitude | Chlorophyll-*a* (mg/m³) | Water temp. (°C) |
|---|---|---|---|---|---|---|
| 1 | Nov. 30 | 08 00 | 13° 19′ N | 130° 21′ E | 0.09 | 28.3 |
| 2 | | 17 30 | 11 58 | 128 33 | 0.06 | 28.7 |
| 3 | Dec. 2 | 08 00 | 3 40 | 123 37 | 0.13 | 28.8 |
| 4 | | 18 00 | 2 27 | 121 57 | 0.19 | 29.2 |
| 5 | 3 | 08 00 | 0 54 | 119 52 | 0.52 | 28.5 |
| 6 | 4 | 08 00 | 3 58 S | 118 28 | 0.10 | 29.1 |
| 7 | | 18 00 | 6 12 | 117 37 | 0.10 | 29.1 |
| 8 | 5 | 08 00 | 9 00 | 115 38 | 0.08 | 29.0 |
| 9 | | 18 00 | 10 23 | 114 32 | 0.17 | 29.2 |
| 10 | 6 | 08 00 | 12 11 | 112 49 | 0.43 | 28.6 |
| 11 | | 18 00 | 13 54 | 112 40 | 0.13 | 28.1 |
| 12 | 7 | 08 00 | 16 06 | 111 38 | 0.08 | 27.9 |
| 13 | | 18 00 | 17 57 | 110 29 | 0.08 | 27.6 |
| 14 | 8 | 08 00 | 20 29 | 110 47 | 0.11 | 24.5 |
| 15 | | 18 00 | 22 15 | 111 09 | 0.08 | 23.7 |
| 16 | 9 | 08 00 | 24 45 | 111 57 | 0.10 | 24.3 |
| 17 | | 18 00 | 26 33 | 112 38 | 0.18 | 23.1 |
| Fremantle | | | | | | |
| 18 | 16 | 18 00 | 32 25 | 114 27 | 0.19 | 20.3 |
| 19 | 17 | 08 00 | 34 10 | 111 58 | 0.08 | 18.5 |
| 20 | | 18 00 | 35 15 | 110 45 | 0.07 | 17.3 |
| 21 | 18 | 08 00 | 37 33 | 109 02 | 0.29 | 14.4 |
| 22 | | 18 00 | 39 14 | 109 00 | 0.26 | 13.8 |
| 23 | 19 | 08 00 | 42 04 | 109 00 | 0.28 | 11.9 |
| 24 | | 18 00 | 43 04 | 109 01 | 0.45 | 11.2 |
| 25 | 20 | 08 00 | 45 47 | 109 12 | 0.52 | 8.6 |
| 26 | | 18 00 | 47 06 | 108 39 | 0.41 | 8.3 |
| 27 | 21 | 08 00 | 49 06 | 106 40 | 0.29 | 5.6 |
| 28 | | 18 00 | 50 14 | 105 29 | 0.35 | 5.2 |
| 29 | 22 | 08 00 | 52 23 | 103 04 | 0.77 | 4.3 |
| 30 | | 18 00 | 54 11 | 102 21 | 0.29 | 2.4 |
| 31 | 23 | 08 00 | 56 58 | 101 45 | 0.57 | 1.3 |
| 32 | | 18 00 | 57 51 | 99 54 | 0.49 | 1.1 |
| 33 | 24 | 08 00 | 59 41 | 95 44 | 0.89 | 0.9 |
| 34 | | 18 00 | 60 47 | 92 50 | 0.74 | −0.2 |
| 35 | 25 | 08 00 | 62 28 | 88 29 | 0.39 | −0.2 |
| 36 | | 18 00 | 62 46 | 83 59 | 0.28 | −0.8 |
| 37 | 26 | 08 00 | 62 05 | 79 48 | 0.13 | 0.0 |
| 38 | | 81 00 | 62 47 | 75 39 | 0.38 | −0.2 |

| Station No. | Date | Time (L.T.) | Latitude | Longitude | Chlorophyll-*a* (mg/m³) | Water temp. (°C) |
|---|---|---|---|---|---|---|
| 39 | Dec. 27 | 08 00 | 63° 51′S | 69° 31′E | 0.18 | −0.7 |
| 40 | | 18 00 | 64 38 | 65 05 | 0.26 | −0.6 |
| 41 | 28 | 08 00 | 65 11 | 60 05 | 0.29 | −1.0 |
| 42 | | 18 00 | 64 56 | 58 01 | 0.74 | −0.4 |
| 43 | 29 | 08 00 | 64 42 | 52 05 | 0.19 | −0.7 |
| 44 | | 18 00 | 64 58 | 48 37 | 0.35 | −0.2 |
| 45 | 30 | 08 00 | 66 09 | 43 02 | 0.25 | −0.9 |
| 46 | | 18 00 | 67 32 | 40 23 | 2.49 | −1.4 |
| Ice edge off Syowa Station | | | | | | |
| 47 | Feb. 25 | 08 00 | 67 34 | 33 25 | 0.23 | −0.4 |
| 48 | | 18 00 | 67 39 | 33 21 | 0.24 | −0.2 |
| 49 | 26 | 08 00 | 66 08 | 33 41 | 0.12 | 0.2 |
| 50 | | 18 00 | 65 03 | 33 46 | 0.17 | 1.0 |
| 51 | 27 | 08 00 | 63 05 | 33 34 | 0.02 | 1.8 |
| 52 | | 18 00 | 62 21 | 33 29 | 0.03 | 2.1 |
| 53 | 28 | 08 00 | 60 19 | 33 32 | 0.36 | 2.5 |
| 54 | | 18 00 | 59 36 | 33 45 | 0.21 | 2.8 |
| 55 | 29 | 08 00 | 57 44 | 33 45 | 0.49 | 2.4 |
| 56 | | 18 00 | 56 45 | 34 37 | 0.47 | 3.0 |
| 57 | Mar. 1 | 08 00 | 54 24 | 36 55 | 0.17 | 3.8 |
| 58 | | 18 00 | 52 50 | 38 23 | 0.18 | 4.4 |
| 59 | 2 | 08 00 | 50 39 | 40 19 | 0.19 | 4.3 |
| 60 | | 18 00 | 49 33 | 41 16 | 0.20 | 5.3 |
| 61 | 3 | 08 00 | 46 58 | 42 33 | 0.16 | 8.0 |
| 62 | | 18 00 | 45 32 | 43 26 | 0.10 | 9.6 |
| 63 | 4 | 08 00 | 43 06 | 45 03 | 0.13 | 10.2 |
| 64 | | 18 00 | 41 45 | 45 54 | 0.18 | 12.9 |
| 65 | 5 | 08 00 | 39 14 | 47 40 | 0.10 | 20.2 |
| 66 | | 18 00 | 37 27 | 48 47 | 0.08 | 21.0 |
| 67 | 6 | 08 00 | 35 00 | 50 16 | 0.01 | 22.0 |
| 68 | | 18 00 | 33 42 | 50 55 | 0.07 | 23.0 |
| 69 | 7 | 08 00 | 31 26 | 51 57 | 0.06 | 24.7 |
| 70 | | 18 00 | 29 53 | 52 49 | 0.09 | 25.6 |
| 71 | 8 | 08 00 | 27 19 | 54 02 | 0.15 | 26.4 |
| 72 | | 18 00 | 26 12 | 54 11 | 0.16 | 26.8 |
| 73 | 9 | 08 00 | 23 31 | 54 14 | 0.07 | 26.6 |
| 74 | | 18 00 | 22 05 | 55 31 | 0.08 | 27.6 |
| Port Louis | | | | | | |
| 75 | 17 | 18 00 | 19 07 | 59 44 | 0.07 | 27.6 |
| 76 | 18 | 08 00 | 17 44 | 60 53 | 0.07 | 27.0 |

| Station No. | Date | Time (L.T.) | Latitude | Longitude | Chlorophyll-*a* (mg/m³) | Water temp. (°C) |
|---|---|---|---|---|---|---|
| 77 | Mar. 18 | 18 00 | 16° 24′ S | 62° 15′E | 0.09 | 28.5 |
| 78 | 19 | 08 00 | 14 48 | 64 10 | 0.11 | 28.7 |
| 79 | | 18 00 | 13 52 | 65 24 | 0.15 | 28.3 |
| 80 | 20 | 08 00 | 11 28 | 65 52 | 0.11 | 28.3 |
| 81 | | 18 00 | 10 36 | 67 18 | 0.11 | 28.5 |
| 82 | 21 | 08 00 | 9 14 | 69 37 | 0.11 | 28.8 |
| 83 | | 18 00 | 9 00 | 71 40 | 0.12 | 28.8 |
| 84 | 22 | 08 00 | 7 16 | 72 50 | 0.13 | 27.8 |
| 85 | | 18 00 | 6 23 | 74 14 | 0.13 | 28.5 |
| 86 | 23 | 08 00 | 5 04 | 76 14 | 0.09 | 28.5 |
| 87 | | 18 00 | 4 05 | 78 20 | 0.09 | 28.5 |
| 88 | 24 | 08 00 | 2 30 | 80 55 | 0.10 | 28.5 |
| 89 | | 18 00 | 1 23 | 82 54 | 0.09 | 28.7 |
| 90 | 25 | 08 00 | 0 08N | 85 22 | 0.12 | 28.8 |
| 91 | | 18 00 | 1 04 | 87 08 | 0.07 | 29.0 |
| 92 | 26 | 08 00 | 2 23 | 89 32 | 0.10 | 29.2 |
| 93 | | 18 00 | 3 28 | 91 05 | 0.07 | 29.3 |
| 94 | 27 | 08 00 | 5 03 | 93 17 | 0.15 | 28.8 |
| 95 | | 18 00 | 6 09 | 94 54 | 0.22 | 29.3 |
| 96 | 28 | 08 00 | 6 03 | 97 26 | 0.24 | 29.3 |
| 97 | | 18 00 | 5 08 | 98 29 | 0.16 | 29.9 |
| 98 | 29 | 08 00 | 3 45 | 100 13 | 0.30 | 29.1 |
| 99 | | 18 00 | 2 44 | 101 11 | 0.35 | 28.9 |
| 100 | 30 | 08 00 | 1 36 | 102 51 | 0.43 | 28.6 |
| Singapore | | | | | | |
| 101 | Apr. 7 | 18 00 | 2 21 | 105 06 | 0.08 | 29.2 |
| 102 | 8 | 08 00 | 5 15 | 106 51 | 0.10 | 27.9 |
| 103 | | 18 00 | 7 26 | 108 15 | 0.07 | 28.8 |
| 104 | 9 | 08 00 | 10 08 | 110 42 | 0.12 | 28.0 |
| 105 | | 18 00 | 11 47 | 112 30 | 0.10 | 28.9 |
| 106 | 10 | 08 00 | 14 14 | 115 11 | 0.11 | 27.8 |
| 107 | | 18 00 | 16 11 | 116 55 | 0.07 | 28.5 |
| 108 | 11 | 08 00 | 18 52 | 119 24 | 0.12 | 25.6 |
| 109 | | 18 00 | 20 21 | 120 47 | 0.25 | 25.1 |
| 110 | 12 | 08 00 | 22 15 | 122 29 | 0.08 | 27.5 |
| 111 | | 18 00 | 24 13 | 123 23 | 0.08 | 24.3 |
| 112 | 13 | 08 00 | 26 01 | 125 16 | 0.14 | 24.5 |
| 113 | | 18 00 | 27 02 | 126 41 | 0.07 | 24.4 |

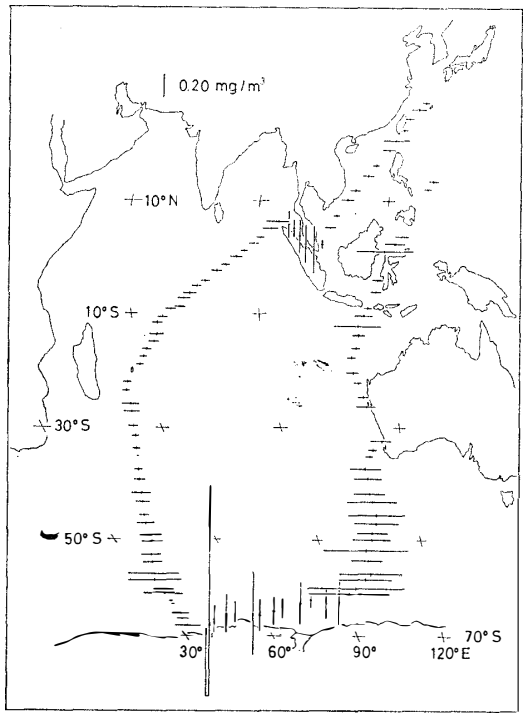


*Fig. 1. The distribution of chlorophyll-a along the route of* FUJI.

in the former sea area has been reported in the previous observations (HOSHIAI, 1968; HOSHINO, 1974). It is, however, the first time that such a high concentration was recorded in the Indian Ocean, although the high concentration more than 0.30 mg/m³ was reported around the Lombok Strait (TOMINAGA, 1971).

The lowest value of 0.06 mg/m³ was observed in the western Pacific and this value was slightly higher than those of the previous observations.

**From Fremantle to the ice edge off Syowa Station at about 68. 5°S :**

At the first station from Fremantle a slightly high value of chlorophyll was observed, but its contents soon decreased and continued to be low level until latitude 37°S. Then the chlorophyll contents began to increase and showed a peak around 45°S, attaining to the concentration of 0.52 mg/m³, while the surface temperature was 8.6°C. The chlorophyll contents fluctuated with relatively high values to the south, and they showed the next peak of 0.89 mg/m³ around 60°S, while the water temperature was 0.9°C. This was the second maximum after the highest value obtained in the ice area during this leg.

The vessel passed 60°S around 95°E and cruised toward west, where the chlorophyll contents were relatively high until longitude 85°E. Lower values appeared when advancing to the west. The highest concentration of 2.49 mg/m³ was recorded at 67°32′S, 40°23′E in the pack-ice off Prince Olav Coast on

December 30. Such a high value might be due to the influence of the ice algae which were released from broken algae-rich ice.

The fluctuation of chlorophyll contents in the present observation showed the same pattern as observed in the past five observations (HOSHIAI, 1968; TAKAHASHI, 1969; TOMINAGA, 1971; NISHIWAKI, 1972; HOSHINO, 1974); the chlorophyll contents remained at low level began to increase from the south of 37°S. However, the peaks of chlorophyll contents appeared between 37°S and 60°S in the present observation did not correspond with the past observations with reference to the latitudes or the water temperatures. The peaks in past observations did not also correspond with one another with reference to the latitudes or the water temperatures, although there were slight differences in the routes toward south and the time of observations. When the vessel proceeded to the west in the south of 60°S in the past years, the chlorophyll contents showed high level in the east of longitude 85°E, while low between longitude 40°E and 85°E with some exceptions.

**From the ice edge off Syowa Station to Port Louis:**

After leaving the ice edge, the observation was started in the north of Riiser-Larsen Peninsula. The vessel sailed toward north between 33°E and 34°E, and then turned to northeast around latitude 57°S for Port Louis, Mauritius. The chlorophyll contents decreased extremely in the sea area around 63°S, where the water temperatures were from 1.8° to 2.1°C. A peak value of 0.49 mg/m$^3$ was observed around latitude 58°S where the water temperature was 2.4°C. Then the chlorophyll contents showed the decreasing tendency toward north. The value of chlorophyll contents was about 0.16 mg/m$^3$ in average without much fluctuation until latitude 40°S, and decreased further in the north of 40°S.

In the past four years, after leaving the ice edge off Syowa Station, the vessel sailed toward west along the latitude of 65°S and reached in the meridian between 2°W and 10°E, and sailed to the north for Cape Town. In another case the vessel sailed straight for Cape Town from the ice edge at longitude 35°E. The chlorophyll contents in these observations fluctuated considerably in each case and did not show a consistent tendency with reference to the latitudes or the distribution of water temperatures, but they were always high between 35°S and 40°S off South Africa. Planktonic productivity in surface water might be influenced by the upwelling of water mass along continental slopes and the pouring of inland water supplying nutrient matters. Chlorophyll contents in surface water is, therefore, influenced by a distance from a continent. It is interesting that chlorophyll contents in past years were always high extending to the far offing of South Africa, while its value decreased rapidly off Fremantle

including the present result.

**From Port Louis to Tokyo via Singapore:**

The chlorophyll contents remained about 0.10 mg/m$^3$ in the Indian Ocean from north of Port Louis. They began to increase in the west of the Malacca Strait and showed high level in the strait, and attained to the maximum of 0.43 mg/m$^3$ in the eastern part of the strait. The chlorophyll contents measured in the Malacca Strait were always high throughout the past five years. The contents decreased rapidly after passing Singapore, and continued in low level through Singapore to Tokyo except one station between Luzon Island and Formosa Island.

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