

Chlorophyll-*a* Content in the Surface Water Observed During the Cruise of the FUJI to Antarctica in 1974-1975

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「ふじ」航路 (1974-1975) における表面水中のクロロフィル-*a* 量

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要旨: 1974年11月26日から1975年4月17日まで、第16次南極地域観測隊海洋生物・定常観測の一項目として「ふじ」の航路に沿って、表面海水のクロロフィル-*a*量を測定した。西太平洋では、クロロフィル-*a*量は0.05-0.19 mg/m³を示し、セレベス海、マラッカ海峡は西太平洋よりも高い値を示した。インド洋では、クロロフィル量は0.08-0.16 mg/m³を示したが、ケープタウン近海は1.08-5.21 mg/m³という非常に高い値であった。

南極海域もかなり高い値を示しているが、観測点により変動がはげしかった。流氷域に接した開水面では、1.04-2.01 mg/m³という高い値を示した。

Abstract: Chlorophyll-*a* determinations of sea water were conducted on board the FUJI during the cruise to Antarctica. The chlorophyll-*a* content was 0.05-0.19 mg/m³ in the western Pacific. In the Cerebes Sea, the content became higher than that in the western Pacific. The content was 0.08-0.16 mg/m³ in the Indian Ocean. The highest chlorophyll-*a* value (1.71 mg/m³) of surface water was obtained at Station 44 (51°8'S, 106°52'E) in the Antarctic Ocean. Outside the pack-ice region of the Antarctic Ocean the value was relatively low, but in the pack-ice region the value was high ranging from 1.04 to 2.01 mg/m³.

1. Introduction

The chlorophyll-*a* content is used as an indicator of the standing crop of water bodies. Therefore chlorophyll-*a* determination has been carried out since 1965 as part of the routine work in the marine biological program of the Japanese Antarctic Research Expedition, and some of the results have been published (HOSHIAI, 1968; TAKAHASHI, 1969; TOMINAGA, 1971; NISHIWAKI, 1972; HOSHINO, 1974). In 1963 ICHIMURA and FUKUSHIMA reported the chlorophyll-*a* content measured in 1960-1961 during the voyage of the research vessel SÔYA between Antarctica and Cape Town.

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The present paper deals with the horizontal distribution of chlorophyll-*a* in the surface water measured aboard the FUJI *en route* to and from Antarctica in 1974–1975.

2. Materials and Methods

Surface water was sampled twice a day from Tokyo to Fremantle and from Cape Town to Tokyo via Singapore, and three times a day in the Antarctic Ocean. A plastic bucket was used for sampling surface water. The sea water was filtered through a Millipore filter HA (47 mm). Then, the filter was ground in the mortar with a 92% aqueous acetone solution, and to extract chlorophyll-*a* the resultant suspension was kept in a 92% aqueous acetone solution for 12–24 hours in a dark refrigerator. Subsequently, it was centrifuged for 10 minutes at 3,000 rpm. The amount of chlorophyll-*a* was determined with a spectrophotometer, Hitachi 101 type.

The chlorophyll-*a* content was calculated according to the following formula:

$$\text{Chlorophyll-}a(\text{mg/m}^3) = (11.64 \cdot E_{663} - 2.16 \cdot E_{645} - 0.10 \cdot E_{630})F$$

$$F = \frac{\text{Volume of acetone (ml)}}{\text{Volume of filtrated water (l)}}$$

The water was sampled at the stations where the physical and chemical oceanographic observations were done, except for the pack-ice region along the Antarctic coast. Therefore the data of the sea water temperature and salinity shown in Table 1 were owing to Messrs. SUE and IMOTO, oceanographers of the JARE-16.

Table 1. Chlorophyll-*a* content along the route of the FUJI.

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
	1974						
1	Nov. 26	0800	32°–27' N	137°–44' E	22.7	34.514	0.35
2		1800	30–07	136–51	22.4	34.617	0.23
3	27	0800	27–11	136–47	23.8	34.706	0.20
4		1800	25–15	136–50	26.7	34.747	0.16
5	28	0800	22–32	134–35	27.1	34.555	0.09
6		1800	21–15	133–48	27.7	34.407	0.08
7	29	0800	18–45	132–41	27.5	—	0.07
8		1800	16–52	131–17	27.5	34.622	0.10
9	30	0800	14–17	129–54	28.5	34.440	0.10
10		1800	12–02	128–55.1	28.3	34.144	0.10
11	Dec. 1	0800	9–03	127–53	28.1	34.055	0.05

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
12	Dec. 1	1800	6°-53'N	126°-42'E	28.2	34.940	0.07
13	2	0800	4-27.5	124-36	28.0	34.259	0.07
14		1800	3-11.7	122-43.5	28.4	33.921	0.13
15	3	0800	1-34	120-38.5	28.4	33.253	0.33
16		1800	0-4.5 S	119-25	29.0	33.256	0.21
17	4	0800	3-6	118-35.5	28.9	33.179	0.26
18		1800	5-14.7	118-12.8	29.3	34.007	0.16
19	5	0800	7-34.5	116-27	29.2	34.187	0.18
20		1800	9-7.5	115-34	30.2	33.239	0.21
21	6	0800	11-54.2	115-5	29.1	34.344	0.14
22		1800	13-55.9	114-35	29.1	33.648	0.08
23	7	0800	16-45	114-2	26.8	34.615	0.10
24		1800	18-45	113-30	27.3	34.688	0.14
25	8	0800	21-19.7	113-11.5	24.7	34.853	0.14
26		1800	23-13	112-51	24.7	34.823	0.17
27	9	0800	25-42.6	112-22	21.8	35.166	0.13
28		1800	26-33.5	112-52	21.5	35.227	0.16
29	10	0800	29-50	113-55.3	20.3	35.401	0.16
30		1800	31-30.2	115-5.3	—	—	0.10
			Arrived at Fremantle				
	16		Left Fremantle				
31	17	0800	34-28	111-30.3	19.6	35.652	0.08
32		1300	34-46.1	111-24.8	—	—	0.11
33		1800	35-44.5	111-9.2	16.5	35.648	0.10
34	18	0800	38-43	110-23.5	12.8	34.912	0.12
35		1300	39-18.7	110-12.1	13.0	34.907	0.08
36		1800	40-14.7	109-58.9	12.5	34.907	0.18
37	19	0800	43-2	109-12	10.9	34.800	0.19
38		1300	43-19.1	109-18.9	—	—	0.31
39		1800	44-20	109-34	8.1	34.340	0.42
40	20	0800	47-14.9	109-22.2	8.6	34.458	0.41
41		1300	47-51	109-5.3	5.9	33.980	0.30
42		1800	48-47.5	108-36.9	5.8	33.905	0.28
43	21	0800	51-26	107-13	3.9	33.905	0.76
44		1300	51-8	106-52.1	3.5	33.979	1.71
45		1800	52-58.5	106-10.9	2.8	33.952	0.99
46	22	0800	55-28.4	103-38.5	2.9	34.021	0.33
47		1300	55-38.2	103-15.2	—	—	0.36
48	23	0800	58-19	98-23	0.6	33.945	0.32
49		1300	58-57.1	98-19.5	0.8	33.965	0.38

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
50	Dec. 23	1800	59°-45.2'S	97°-46.3'E	0.5	33.950	0.40
51	24	0800	61-38	92-35.5	0.6	34.080	0.45
52		1300	61-42.4	91-36.8	0.4	—	0.33
53		1800	62-2.9	89-43.5	0.1	34.068	0.43
54	25	0800	62-56.5	84-6.2	0.1	33.717	0.57
55		1300	63-10.9	82-19.9	-0.2	33.312	0.37
56		1800	63-32	80-41	0.4	33.569	0.66
57	26	0800	64-13.7	75-41.5	0.2	33.637	0.22
58		1300	64-53.2	74-6.8	0.3	33.653	0.19
59		1800	64-37	72-45	0.2	33.733	0.25
60	27	0800	63-41.5	67-19	0.8	33.618	0.11
61		1300	63-11.7	65-39	0.0	33.653	0.11
62		1800	63-23.6	63-27.9	2.2	33.751	0.19
63	28	0800	63-55.5	56-55	-0.4	33.810	0.15
64		1300	64-5.2	55-33.1	-0.3	33.885	0.10
65		1800	64-16	53-7	-0.2	33.928	0.13
66	29	0800	64-48.2	46-18.0	-0.7	33.889	0.12
67		1300	65-16.7	44-50.1	-0.7	33.671	0.10
68		1800	65-45.8	43-54	-1.7	33.770	0.09
In pack-ice region							
69	30	0800	66-23.6	43-15.5	-1.6	—	0.45
70		1300	66-27.5	43-13.8	-1.6	—	0.35
71		1800	66-34.9	43-14.0	-1.6	—	0.43
72	31	0800	66-41.2	43-10.5	-1.9	—	0.25
73		1300	66-48.1	43-1.8	-1.9	—	0.72
1975							
74	Jan. 1	1900	67-2.9	42-40.3	-1.9	—	0.35
75	2	0900	67-8.3	42-28	-1.9	—	0.45
76		1430	67-22.9	41-54.2	-1.9	—	0.25
77	3	1400	67-42.2	41-13	-1.9	—	0.58
78		1700	67-45.6	41-15.5	-1.9	—	0.37
79*		2330	67-51.5	41-21.9	-1.9	—	2.06
80*	4	0830	68-10.9	40-22.3	-1.4	—	0.43
81*		1015	68-18.6	39-52.4	-1.9	—	0.12
82*		1245	68-23.5	39-34.3	-1.9	—	0.20
83*		1900	68-29	38-45	-1.7	—	1.04
84	7	2200	68-37.7	38-47	-1.9	—	0.23
85	Feb. 20	1550	68-21.3	36-25.2	-1.2	—	0.20
86	21	0800	68-21	34-6.9	-1.6	—	0.71

* In the open sea of pack-ice region.

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
87	Feb. 21	1600	67°-46.7'S	34°-22.9'E	-1.4	—	0.21
88	23	1800	67-21	31-22.6	-0.1	—	0.21
Left pack-ice region							
89	24	0800	67-68	23-19.3	0.4	33.991	0.09
90		1300	67-8	22-6	0.4	33.931	0.14
91		1800	67-4.2	19-37	0.4	33.772	0.09
92	25	0800	66-57.3	12-42	0.4	33.830	0.14
93		1300	66-57.3	11-47.9	0.6	33.837	0.15
94		1800	66-56.7	9-20.8	1.2	34.149	0.14
95	26	0800	67-25.6	4-6	1.2	34.508	0.12
96		1300	67-26.6	2-4	1.2	34.485	0.15
97		1800	67-17.1	0-45.1	1.2	34.441	0.11
98	27	0800	66-12.7	4-54.3	1.6	34.372	0.16
99		1300	65-50.8	4-55.2W	1.6	—	0.21
100		1800	65-1	4-50	1.6	34.318	0.28
101	28	0800	62-38	4-33	1.4	34.193	0.13
102		1300	61-48	4-25	1.3	34.172	0.09
103		1800	60-58	4-3	1.5	34.086	0.12
104	Mar. 1	0800	58-42	3-8	1.7	34.990	0.19
105		1300	58-18.2	2-30.2	1.6	33.822	0.24
106		1800	57-34	1-18	1.8	33.800	0.22
107	2	0800	55-24	1-48 E	1.8	33.704	0.18
108		1300	54-58	2-23.2	1.9	33.449	0.17
109		1800	54-17	3-18	1.6	33.652	0.47
110	3	0800	51-44	5-44	3.4	33.693	0.58
111		1300	50-44	6-39	4.6	33.738	0.74
112		1800	49-45	7-33	5.1	33.751	0.54
113	4	0800	46-59	9-53	7.8	33.822	0.44
114		1300	45-54	10-28	8.4	33.866	0.43
115		1800	44-50	11-4	8.9	33.913	0.33
116	5	0800	41-54	12-43	17.8	35.500	0.38
117		1300	40-50	13-17	18.6	35.542	0.47
118		1800	39-49	13-59	18.2	35.423	0.46
119	6	0800	37-21	15-53	20.8	35.516	0.25
120		1300	36-35	16-35	20.6	35.475	0.25
121		1800	35-44	17-7	21.1	—	0.39
122	7	0700	33-51.5	18-22.1	14.8	—	5.08
Arrived at Cape Town							
Left Cape Town							
123	15 16	0800	34-37	23-35	16.8	35.173	1.08

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
124	Mar. 16	1800	34°-10'S	26°-30'E	19.5	35.303	5.21
125	17	0800	32-48	29-54	24.7	35.462	0.21
126		1800	31-45	32-16	23.8	35.508	0.30
127	18	0800	30-14	35-8	23.8	35.548	0.23
128		1800	29-27	37-16	25.8	35.226	0.35
129	19	0800	28-21	40-16	25.7	35.336	0.23
130		1800	27-29.9	42-15	26.1	35.450	0.23
131	20	0800	26-14	44-51	24.8	35.148	0.31
132		1800	25-21	46-53	24.8	34.221	0.34
133	21	0800	24-08	49-33.8	26.5	35.109	0.13
134		1800	22-51.8	51-38.1	27.2	35.289	0.19
135	22	0800	21-17	54-17.8	26.8	35.389	0.11
136		1800	20-13.8	56-15	27.9	35.371	0.10
137	23	0800	18-51.9	59-13.5	26.5	35.357	0.16
138		1800	17-39.6	60-0	27.7	35.219	0.10
139	24	0800	15-56.6	63-31.2	28.0	35.790	0.12
140		1800	14-38.4	65-21.0	28.3	34.467	0.12
141	25	0800	13-0	67-33	28.1	33.950	0.12
142		1800	11-42	69-27	27.7	33.856	0.15
143	26	0800	9-10.6	71-12	28.1	34.050	0.13
144		1800	7-30.7	72-37.1	28.7	33.996	0.09
145	27	0800	5-51.6	75-27.2	28.4	34.088	0.18
146		1800	4-38.4	77-32.8	28.6	34.906	0.25
147	28	0800	2-54	80-24	28.6	35.069	0.23
148		1800	1-46.2	82-8.6	28.6	35.913	0.18
149	29	0800	0-22	84-26	28.9	34.683	0.13
150		1800	0-37.9N	86-12.5	28.9	34.670	0.15
151	30	0800	2-4	88-42	28.9	34.836	0.15
152		1800	3-7	90-19.5	29.7	34.480	0.23
153	31	0800	4-43	92-39.8	29.1	34.187	0.05
154		1800	5-48.4	94-20.7	29.4	32.174	0.10
155	Apr. 1	0800	5-44.9	96-45	29.2	32.649	0.15
156		1800	4-50	98-29.9	29.3	32.049	0.23
157	2	0800	3-33	100-16.1	29.6	31.512	0.32
158		1800	2-37	101-21.2	29.5	31.321	0.46
159	3	0800	1-11.5	103-33.5	29.0	31.709	0.90
			Arrived at Singapore				
			Left Singapore				
160		1800	2-15	105-4	29.6	32.128	0.31
161	10	0800	4-32.8	106-14.6	28.7	33.286	0.17

Station	Date	Time (Local)	Latitude	Longitude	Water temp. (°C)	Salinity (‰)	Chlorophyll- <i>a</i> (mg/m ³)
162	Apr. 10	1800	6°-9' N	107°-27.5' E	28.7	33.314	0.08
163	11	0800	8-23.1	109-0	28.6	33.570	0.28
164		1800	9-52.1	110-27.8	28.7	33.496	0.16
165	12	0800	11-51.5	112-38.1	28.5	33.177	0.15
166		1800	13-11.8	114-15.2	28.8	33.209	0.10
167	13	0800	15-8.6	116-15.2	28.2	33.351	0.19
168		1800	16-33.9	118-9.8	29.0	33.399	0.16
169	14	0800	18-44.5	120-27.5	28.4	33.478	0.14
170		1800	20-15.5	122-7.5	26.8	—	0.10
171	15	0800	22-37.4	123-29.2	25.8	—	0.08
172		1800	24-13	124-29	25.8	—	0.13
173	16	0800	25-28.9	127-13.7	23.0	—	0.13
174		1800	26-48.4	128-54.4	23.0	—	0.13
175	17	0800	29-7	131-11.7	23.9	—	0.45
176		1800	30-55.3	135-25.7	19.3	—	0.89

3. Results and Discussion

The horizontal distribution of surface water chlorophyll-*a* content is shown in Figs. 1 and 2. The outline of the distribution was as follows:

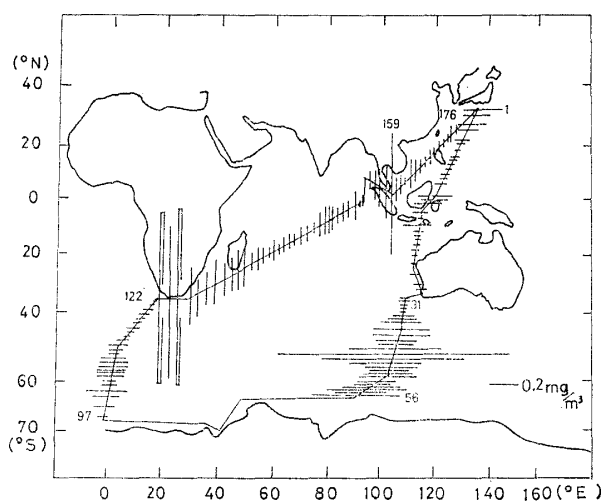


Fig. 1. Horizontal distribution of chlorophyll-*a* along the route of the FUJI from St. 1 to 56 and from St. 97 to 176.

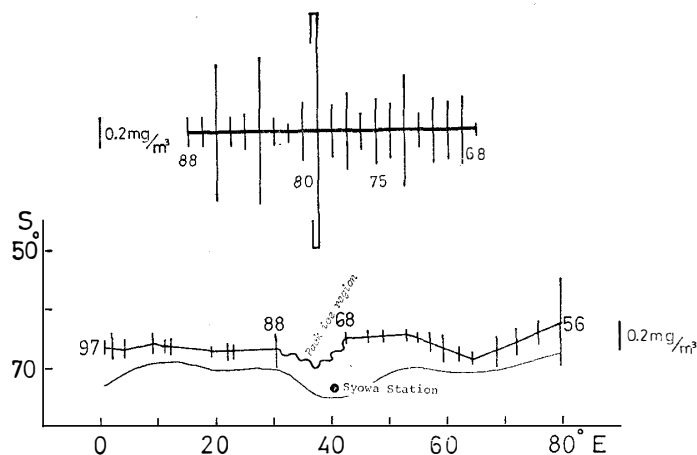


Fig. 2. Horizontal distribution of chlorophyll-*a* along the Antarctic coast (St. 56–St. 97).

The Western Pacific and South China Sea

The chlorophyll-*a* content was 0.05–0.19 mg/m³ in the western Pacific. It was 0.20–0.89 mg/m³ at the stations located southwest of Japan. In the Cerebes Sea, the chlorophyll-*a* concentration became slightly higher than in the western Pacific. In the Malacca Strait an increase of concentration (0.15–0.90 mg/m³) was observed. These data closely resembled the results obtained along the similar course by the previous workers mentioned above.

Indian Ocean

In the northern part of the Indian Ocean (St. 21–29), chlorophyll-*a* concentration was 0.08–0.16 mg/m³ and the similar value was observed also in the central part (0.09–0.15 mg/m³). The chlorophyll-*a* values in the western area near Madagascar were higher (0.34–0.44 mg/m³) than those in the northern and central areas of the ocean. Extremely high values were observed outside the Cape Town harbor (1.08–5.21 mg/m³), where TAKAHASHI (1969) and HOSHINO (1974) recorded 2.51 mg/m³ and 7.8 mg/m³ respectively.

Subantarctic and Antarctic Ocean

From Fremantle to St. 35 (39°18'S, 110°12'E), concentration of chlorophyll-*a* was low (0.08–0.12 mg/m³), but it increased gradually toward St. 56 (64°32'S, 80°41'E). The highest value of concentration in surface water was observed at St. 44 (51°8'S, 106°52'E) in the subantarctic zone. It was reported that chlorophyll-*a* concentration decreased at subtropical and Antarctic Convergences (HOSHIAI, 1969, etc.). The same tendency was recognized in the present work.

In the Antarctic Ocean, concentration of chlorophyll-*a* was relatively low

(0.09–0.25 mg/m³) outside the pack-ice region (64°65'S, 74°34'E). The highest concentration of chlorophyll-*a* was observed in the region close to pack-ice and decreased toward the central part of the open water. Particularly in the pack-ice region the sampled surface water contained sludge of ice colored by micro-organisms and high concentration of chlorophyll-*a* was observed. Therefore, along the Antarctic coast the value of chlorophyll-*a* varied regionally as shown in Fig. 2. In the coastal water of Antarctica (St. 79 and St. 82), even in the ice free part, the concentration was high ranging from 1.04 to 2.01 mg/m³. TOMINAGA (1971) observed concentration 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.

On the way from the Antarctic Ocean to Cape Town, the latitudinal variation of chlorophyll-*a* was similar to that from Fremantle to Antarctica, although the concentration on the former route was higher than the latter.

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