DISTRIBUTION AND STANDING STOCK OF CHLOROPHYLL *a* IN THE ANTARCTIC OCEAN, FROM DECEMBER 1980 TO JANUARY 1981

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Abstract: Water samples for phytoplankton chlorophyll *a* and phaeopigments were collected by R. V. KAIYO MARU in her FIBEX cruise in the Indian sector of the Antarctic Ocean during a period from December 1980 to January 1981. Vertical distribution of chlorophyll in the eastern area showed quite different patterns from those of the western area. In the eastern area (December 1980), the chlorophyll maximum was usually found at the surface and the layer between 10 and 30 m depth. The highest value was 1.0 $\mu g/l$. While, in the western area (January 1981), the maximum was noticed in deeper layer between 50 and 125 m, and the highest value was 0.36 $\mu g/l$. The mean standing stock of chlorophyll in the water column was also high (28.3 mg/m^2) in the eastern and low (16.8 mg/m^2) in the western areas.

The amount of chlorophyll in the region of the present investigation was considerably lower than in the other oceans of the world, despite the fact that the concentration of dissolved nitrogen was identical.

1. Introduction

Standing stock of phytoplankton expressed as chlorophyll concentration has been discussed for the Antarctic Ocean by several authors. EL-SAYED (1970) described the phytoplankton standing stock, their primary productivity, and the environmental factors in the Atlantic and the Pacific sectors there. As for the Indian sector, chlorophyll concentration in the surface water has been observed during ten cruises of the icebreaker FUJI since 1965. The number of sampling stations in the area south of 60°S amounted to 330. Water samplings for chlorophyll determination were, however, limited to the surface layer. FUKUCHI (1980) used these data to compare the amounts of chlorophyll in the eastern Indian, western Indian, and the eastern Atlantic sectors. EL-SAYED and JITTS (1973) observed the chlorophyll distribution at nine stations in the Indian sector south of 60°S.

R. V. KAIYO MARU of the Fisheries Agency made two cruises in the Antarctic Ocean. The first one, pre-FIBEX cruise, was made in the eastern Indian sector (100°–120°E) during a period from December 1979 to March 1980. Distribution of chlorophyll *a* was observed at 35 stations from the surface to a depth of 200 m by YAMAGATA and FUKUI (1981). The second one, FIBEX cruise, was made in the Indian sector (30°–90°E) during a period from November 1980 to March 1981. In

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the present paper, the results obtained in the second cruise based on 787 water samples for chlorophyll *a* and phaeopigments collected at 52 stations are described, with special reference to the vertical distribution and standing stock of chlorophyll *a*.

2. Methods

The survey was made by the R. V. KAIYO MARU during the periods from December 11 to 26, 1980 in Area B and from January 16 to 30, 1981 in Area A (Fig. 1).

Water samples were taken by 2 *l* Nansen bottles except the surface layer. The samples were then filtered through Whatmam GF/C glass fiber filter (45 mm diameter) to measure phytoplankton chlorophyll *a* and phaeopigments. The filtrate was used afterward for nutrients analyses.

Phytoplankton pigments were extracted by 90% acetone and measured with a fluorometer (Hitachi UV-VIS 139 Spectrophotometer with fluorometry attachment), following the procedure of NISHIZAWA *et al.* (1971). Nitrate and nitrite nitrogen and phosphate phosphorus were analyzed by the method developed by STRICKLAND and PARSONS (1968). Ammonium nitrogen was determined by the procedure of MATSUNAGA and NISHIMURA (1974).

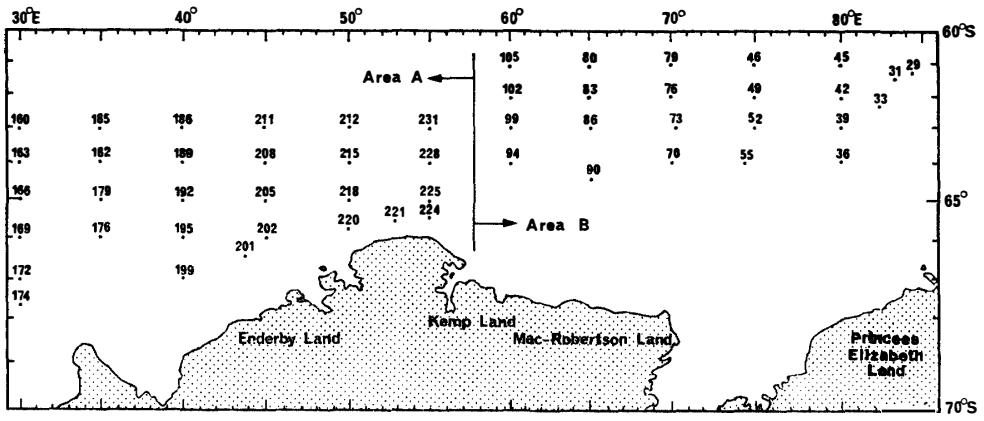

Fig. 1. Positions of sampling stations during the FIBEX cruise of R. V. KAIYO MARU.

3. Results

The vertical distribution of chlorophyll at each station in Area B (the eastern area, 61°–64°S, 60°–85°E) is shown in Fig. 2. Numerals below the station number indicate integrated value of chlorophyll *a* in the water column. The value of chlorophyll concentration in the surface layer varied within a range from 0.06 to 0.8 μg/*l*. Excluding Stn. 86, the values decreased slightly from the surface to the 10 m layer, and the maximum, 0.3–1.0 μg/*l*, was obtained between 30 and 50 m depths. Then it decreased sharply down to 0.05–0.1 μg/*l* in the 100 m layer, and became scarcely detectable at 200 m. The maximum of chlorophyll in the present cruise, about 1 μg/*l*, was obtained in the 50 m layer of Stn. 42. Chlorophyll concentration was high in the upper layers above 50 m. Four stations including Stn. 42 along the line of 80°E revealed large values of chlorophyll in the upper layers. However, there

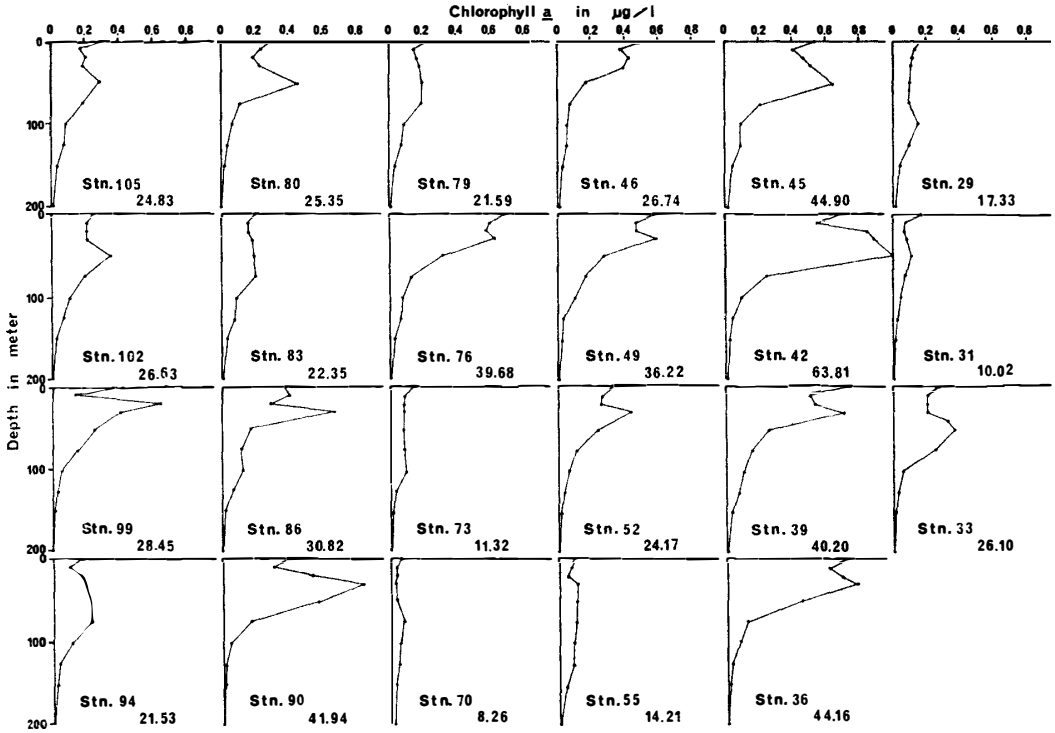

Fig. 2. Vertical distribution of chlorophyll a at each station in Area B. Standing stock of chlorophyll a in the water column is indicated below the station number in mg/m².

were no clear difference in the horizontal distribution of chlorophyll when the eastern part of this area is compared with the western part. The same tendency was noticed in the northern and southern parts.

The vertical distribution of chlorophyll at each station of Area A (the western area, 63°–68°S, 30°–55°E) is shown in Fig. 3. The collections in this area were made about one month later than those in Area B. The chlorophyll concentration in the surface layer was less than 0.2 $\mu g/l$ at almost all stations. Further, it also decreased slightly from the surface to the 10 m layer, but did not show the maximum in the 20 m and 30 m layers, unlike the case of Area B. Then, the concentration revealed a slight decrease, 0.1–0.4 $\mu g/l$, between 50 and 125 m depths. These maximum values were clearly smaller than those in Area B. However, the values in the deeper layers than these maximum layers were larger than those in Area B.

No clear difference was observed in the horizontal distribution of chlorophyll in the eastern and western parts. This tendency was the same between the northern and the southern parts.

The standing stock of chlorophyll varied within a range from 8.26 to 63.81 mg/m² in Area B, and 8.32 to 30.73 mg/m² in Area A, with the mean values 28.3 and 16.8 mg/m², respectively. No regional difference of standing stock in each area was observed, although somewhat higher values were found at four stations along the 80°E line and conversely small values were observed at four stations along the 40°E line.

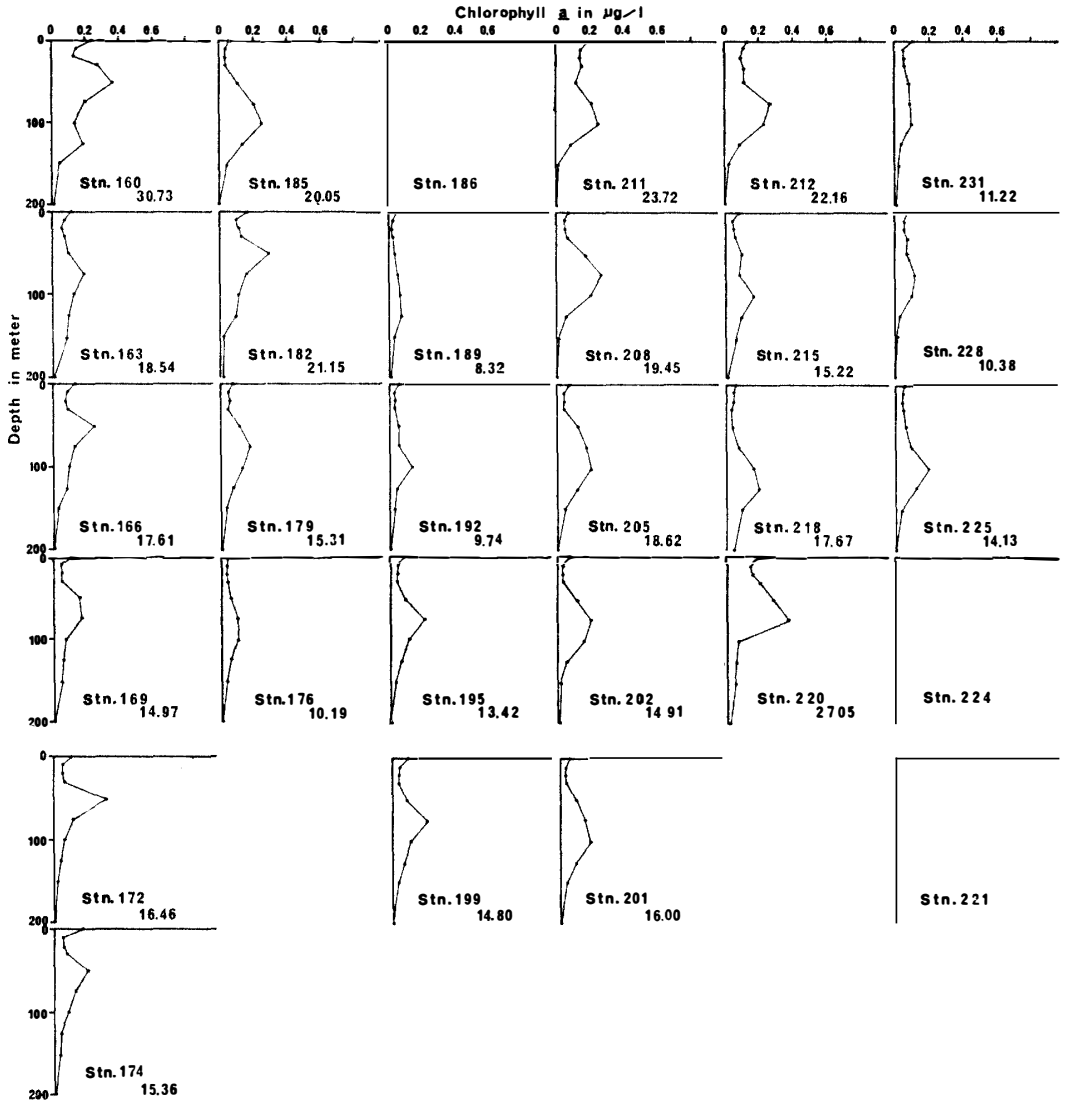

Fig. 3. Vertical distribution of chlorophyll a at each station in Area A. Standing stock of chlorophyll a in the water column is indicated below the station number in mg/m².

4. Discussion

The pattern of vertical distribution of chlorophyll was quite different in each area of the present investigation. The amount of standing stock in the water column was also different to a large extent there.

The mean value of chlorophyll concentration in the surface water of Area B was a little higher than the data reported by EL-SAYED and TURNER (1977), who made observation in the eastern half of Area B of the present investigation during the ELTANIN cruise 46 from November 1970 to January 1971. On the same cruise, EL-SAYED and JITTS (1973) observed the vertical distribution of chlorophyll, and averaging the values of six stations they found a clear maximum in 25 m layer. On the contrary, the surface maximum layer, which was more evident in Area B, was seen at all stations except one in each area of the present investigation.

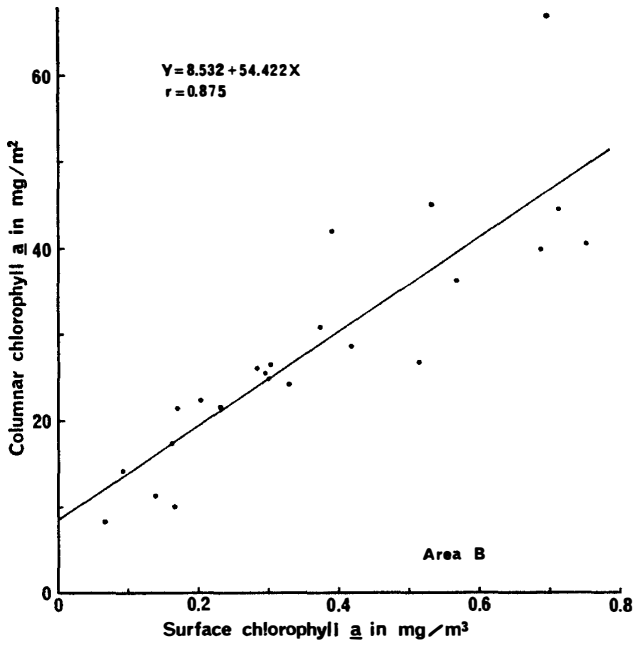

Fig. 4.

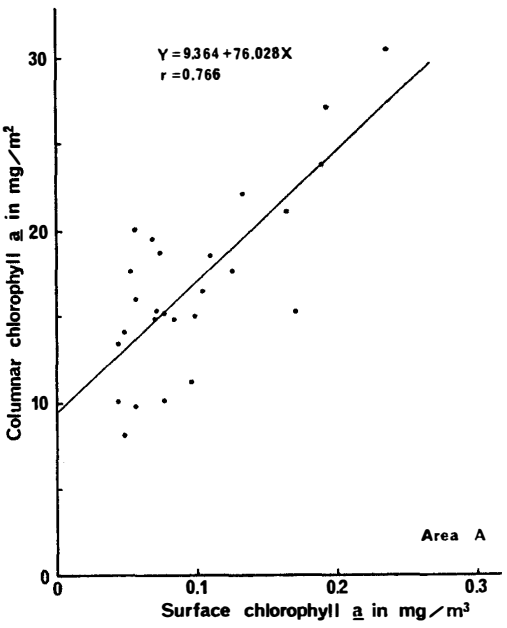

Fig. 5.

Figs. 4 and 5. Relations between chlorophyll a concentration at the surface and its standing stock in the water column in Area B (Fig. 4) and Area A (Fig. 5).

The relation between chlorophyll at the surface and that in the water column in Area B is shown in Fig. 4. The concentration of chlorophyll in the surface water corresponded to the standing stock of chlorophyll in the water column, with a correlation coefficient 0.875. The extrapolated value to 0 point of the surface chlorophyll was 8.532 mg/m^2, which is influenced by the large values of the secondary maximum layer between 30 and 50 m depths.

The same relationship in Area A is shown in Fig. 5. The correlation coefficient, 0.766, is clearly lower than that of Area B. The extrapolated value to 0 point of the surface chlorophyll was 9.364 which is similar to the figure of Area B. However, the regression coefficient of Area A is obviously higher than that of Area B. This is presumably caused by the existence of the deeper maximum layer.

In a restricted area, it is probably feasible to estimate the standing stock of chlorophyll in the water column from the chlorophyll concentration in the surface water. LORENZEN (1970) indicated a good relation of surface and euphotic zone with somewhat higher correlation coefficient in the Atlantic and Pacific Oceans.

Although the maximum concentration of entire samples was obtained as 1 μg/l, the mean value of chlorophyll in the surface water of Areas B and A was 0.35 and 0.11 μg/l, respectively. These values are rather low as compared with the nutrient concentrations in their environment. In Area B, nitrate nitrogen was measured in a range from 20 to 26 μg-at/l at the surface and 26 to 32 μg-at/l in the 200 m layer. In Area A, it was found within a narrow range of 24 to 26 μg-at/l at the surface and 29 to 32 μg-at/l in the 200 m layer. The difference of nitrate concentration between the two areas may be partly due to the presence of phytoplankton. However, the difference of total nitrogen (dissolved inorganic, dissolved organic plus estimated

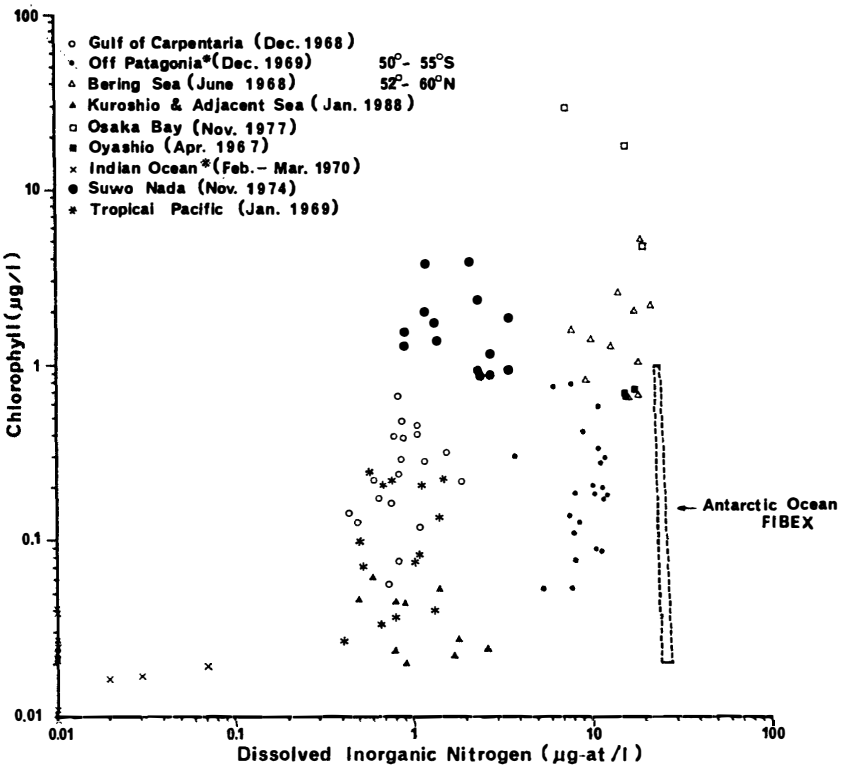

Fig. 6. Relations between chlorophyll a and dissolved inorganic nitrogen in the euphotic zone in nine different sea areas. The figures for the offing of Patagonia and Indian Ocean do not include ammonium nitrogen. ■: *Data Record of Oceanographic Observations and Exploratory Fishing, No. 12, Hokkaido Univ. (1968);* △ & ▲: *Data Record of Oceanographic Observations and Exploratory Fishing, No. 13, Hokkaido Univ. (1969);* ○ & ∗: *Data Record of Oceanographic Observations and Exploratory Fishing, No. 14, Hokkaido Univ. (1970);* · & ×: *Showa 44-nendo KAIYO MARU Chôsa Kôkai Hôkokusho, Fisheries Agency (1971);* □ & ●: *UNO (unpublished data).*

particulate nitrogen based on the volume of seston in Coulter Counter® measurements) between the two areas was still noticed. Phosphate phosphorus was rather high as compared with nitrate nitrogen, since the nitrogen/phosphate ratio by atom was lower than 14 in almost all samples.

The relation between the phytoplankton standing stock and the dissolved inorganic nitrogen concentration in the euphotic zone of nine sea areas is shown in Fig. 6. The data of nitrogen from the offing of Patagonia and the Indian Ocean do not include the value of ammonium nitrogen. A positive but indistinct correlation between chlorophyll and the concentration of dissolved inorganic nitrogen is noticed in the figure. The higher values of chlorophyll concentration correspond to the higher concentration of nitrogen, and the lower chlorophyll values were found to correspond to the lower nitrogen values. These sea areas excluding the Indian Ocean could be divided into two groups. The one is the higher nitrogen group including Osaka Bay, Bering Sea, Oyashio region, and off Patagonia region. The other is the lower nitrogen group including Suwo Nada, Gulf of Carpentaria, Trop-

ical Pacific Ocean, and Kuroshio and adjacent regions. It is considered that the chlorophyll concentration in each sea area was affected fairly well by the distance from the land. The chlorophyll concentration was high in most of coastal areas, low in most of oceanic areas. This may indicate the presence of some uncertain effect on the growth of phytoplankton by organic substances from the land.

The importance of soil-extract enrichment of sea water to the growth of phytoplankton has been stressed by PRINGSHEIM (1912) and many other investigators. HELLEBUST and LEWIN (1977) showed the uptake of organic substances by diatom. While, PRAKASH and RASHID (1968) pointed out that the positive effect of humic substances from land on dinoflagellates growth was independent of nutrient concentration. Furthermore, SWIFT (1980) described in the chapter of South Polar Seas that "inorganic nutrient levels are relatively high, so that the low levels or lack of Vitamin B_{12} in some samples may have limited the growth rate of the diatoms".

In the Antarctic Ocean, nitrogen concentration did not differ significantly from the area observed previously with a range from 23 to 29 μg-at/l, while chlorophyll concentration varied in a wide range from 0.03 to 1.0 μg/l. These values of chlorophyll are excessively low in contrast to the nitrogen levels in the surrounding waters. The mean distance from these areas to Antarctica is nearly the same as the distance from the Bering Sea to Alaska. However, the Antarctic Continent is almost entirely covered with ice containing little organic substances. Thus, the supply of organic nutrient from the Antarctic Continent to the coastal waters should be limited to the minimal level.

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