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Seasonal Variation in Particulate Organic Matter and its Constituent Fractions under the Ice covered sea near the Shelf, Antarctica

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Abstract

Particulate organic matter (POM) collected at a single station in the shelf waters of Princess Astrid coast (70°S : 11°E), Antarctica from May to December, 1986 was analyzed for chl a, POC and other constituent fractions at three discrete depths. Chl a concentration at all the 3 depths varied from 0.026 to 0.253 μgl^{-1} showing minimum values during August - September. POC values varied from 280 to 1058 μgl^{-1} while its constituent fractions such as particulate carbohydrates (PCHO), particulate proteins (PP) and particulate lipids (PL) varied from 14 to 193, 6 to 200 and 8 to 174 μgl^{-1}, respectively. Significant correlation existed between POC and chl a, PP and PL at 10m depth. This was in contrast to PCHO and chl a. The components studied showed seasonal variation suggesting that the sea ice microalgae and planktonic organisms contribute substantially to particulate organic carbon.

Introduction

Very little information is available on the biology of ice covered sea around the Antarctic continent (Bunt, i960; Littlepage, 1965; Wakatsuchi, 1982). In spite of this the Antarctic Ocean is considered most productive oceans in the world (Nienhuis, 1981) not only from the chlorophyll data but also from the compounds present in the water column (Bolter and Dawson, 1982). These compounds are of primary importance to maintain chemical and biological processes in the oceans (Leventer and Dunbar, 1985).

The particulate organic matter (POM) is an important source of food for the micro-organisms, filter feeders and deep water animals (McCave, 1975; Hanjo, 1978). The composition and concentrations of particulate organic matter reflects dynamic processes in water column such as primary production in surface waters, dissolution and degradation at depths and vertical and lateral transport of the particulate matter (Lal and Lerman, 1973; Biscaye and Eittreim, 1977; Bishop *et al.,* 1977, Bodungen *et al.,* 1986; Nelson *et al.,* 1987).

High particulate concentration under the ice covered water during early austral spring in the McMurdo sound has been related to the development of microalgal communities (Sullivan *et al.,* 1982). Tanoue et *al.,* (1982) reported that the average concentration of POM in the Pacific Sector of the Antarctic Ocean was half of those reported in the Northern Pacific Sea and Bering Sea.

In the present investigation seasonal changes in particulate matter and its constituent fractions such as carbohydrates, proteins and lipids have been described in relation to the organisms present in the water column and in the sea ice.

Materials and Methods

Monthly sampling was carried out from May to December, 1986 at a single station near the ice shelf (70°S, 11°E) at Princess Astrid coast, Dronning Maud Land, Antarctica.

The surface water in this part of Antarctica started to freeze by the middle of March forming thin layered sea ice that increased through winter with maximum thickness in November. Monthly sea ice and snow thicknesses have been recorded.

A bore hole water sampler having 1 litre capacity with thermometer installed in it was used through the drilled ice hole to collect water samples from the three discrete depths (namely 0, 10 and 30m). The water samples were filtered through pre-ignited Whatman glass fiber filter paper (4 mm dia., 1.2μm pore size). The suspended matter left on the filter paper was analyzed in triplicate for particulate organic carbon (POC), particulate carbohydrates (PCHO), particulate proteins (PP), particulate lipids (PL) and chlorophyll a (chl a). The POC, PL and chl a were analysed following the methods of Parsons et *al.* (1984). The PCHO and PP were determined as suggested by Hitchcock (1977) and Lowry et *al.* (1951) respectively.

The samples for phytoplankton, zooplankton and ice algae have been collected and analysed by using standard procedures. The details of these will be dealt with separately. However, part of this data has been used in the present study to correlate possible contribution from these parameters to the particulate organic carbon.

Results and discussion

The temperature of the seawater at all the three depths ranged from 1.5 to 2.4°C with minimum temperature in the month of August. The sea ice and snow thickness from May to December, 1986 ranged from 56 to 241 cm (maximum sea ice thickness during December) and from 5 to 103 cm (maximum snow cover during August) respectively (Fig. 1).

The phytoplankton population in the seawater during June to September was dominated by a unicellular blue green algal form *(Synechocystis* sp), while remaining months diatom species *Thalassiothrix longissima, Amphiprora* sp and *Thalassiosira* sp were the most dominant forms. The absence of solar radiation during winter limits photosynthesis in certain groups of phytoplankton. However, blue green algal forms have a tendency to proliferate at very low light intensities due to specialized light harvesting pigments.

Microalgae living in the bottom of annual sea ice are uniquely adapted to ambient low light conditions. Total 24 species belonging to 13 genera have been recorded as a component of sea ice algal community. The diatoms were generally dominant whereas dinoflagellates were poorly represented especially during winter. The cell counts varied from 0.15 to 142 x 1Q^{4} with lowest counts in winter. The diatoms *Fragilaria* sp., *F. islandica* and *F. cylindrus* were the most commonly occurring forms.

The zooplankton communities were represented by the twelve taxonomic groups. Calonoid copepods were dominant in all the months averaging.24.98% followed by euphausid larvae, crustacean nauplii, radiolarian and foraminifera The minimum density of zooplankton population was 438 nos/100m^3 during July while maximum density of 2250 nos/100m^3 was recorded in December. In the month of August unusually high density of 1184 nos/l00m^3 was noticed with maximum population of copepods and euphausid larvae contributing 33.36 and 26.43% respectively. This could probably be due to the effect of transition period.

The chl a concentration at all the three depths ranged from 0.026 to 0.253 µg l^{-1} (Fig. 1). These values are relatively higher than the values reported

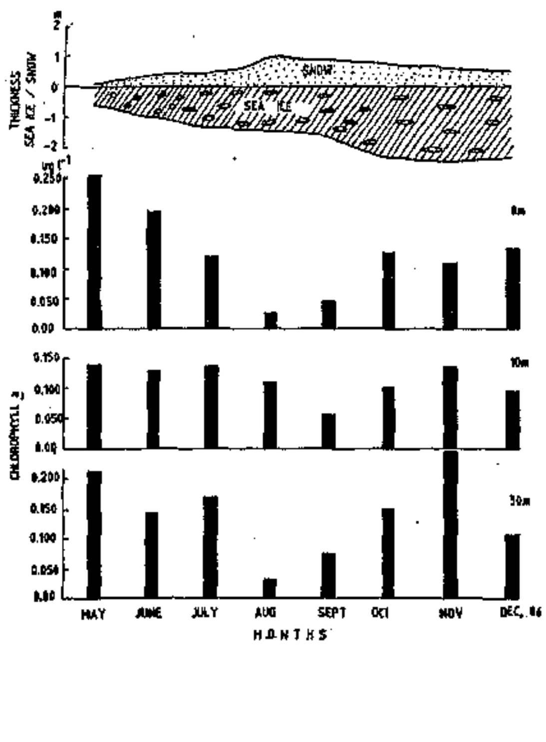

Fig. 1. Seasonal variation in chl a at different depths. (Snow cover and sea ice thickness during different months.)

by Fukuchi er *al.* (1985) which were $<0.1 \mu g l^{-1}$ from April to November at Lutzow-Holm Bay. In the present investigation chl a values were more than 0.1 μg^{-1} from May to July showing decrease during August-September, increasing steadily thereafter. Peak chl *a* concentration was noticed during May at 0 and 10m and during November at 30m depths while minimum concentration was in August at 0 and 30m and in September at 10m depth. Peak in chl a concentration may be due to contribution of sea ice microalgal species *Amphiprora* along with dominant phytoplankton species such as *Fragilaria* sp, *F. islandica* and *F. cylindrica* present in the water column. During November, peak chl a was noticed at 30m depth which was probably due to the effect of photoinhibition. Increase in chl *a* concentration from October onwards at all the three depths could be due to physiological response of the sea ice algae and phytoplankton to greater availability of light as suggested by Beardall and Morris (1976) and Falkwoski (1980).

During winter months comparatively high chl a values were found which were due to the ability of some diatom species to increase its cell carbon quota in response to a simulated polar summer-winter transition (Palmisano and Sullivan, 1982). On the other hand some of the diatoms such as *Nitzchia* sp., *Amphiprora* sp. and *Thalassiosira* sp. get incorporated into the forming sea ice and release resting spores due to the variation in salinity and other related factors. These resting spores synthesise chl a during short term exposure to light and dark period (Doucette and Fryxell, 1983). The lowest values in August and September might be due to the maximum thickness of snow cover on the sea ice preventing sufficient light to penetrate through sea ice.

POC at all the three depths varied from 280 to 1058 μg l^{-1} (Fig. 2). It showed altogether different trend at 0m as compared to the other two depths. During May, maximum concentration of POC was recorded at 0m decreasing abruptly till July and remained almost steady till December. At 10m maximum values were recorded from May to July which tend to decrease till October. Similar pattern was also noticed at 30m except for the month of July when low value was recorded.

POC at all the three depths showed relationship with chl a until September and thereafter it showed increase in accordance with phytoplankton population having dominant *Thalassiothrix longissima, Amphiprora* sp. and *Thalassiosira* sp. in the water column. The correlation coefficient analysis showed significant correlation between POC and chl a at 10m (Table I). At 0m correlation coefficient was observed between POC and chl a ($r=0.85$, $N=8$, $P<0.001$) while at 30m no correlation with any of the parameters was observed. This-suggests that POC was lost by remineralization, ingestion and assimilation by the well developed zooplankton population whose density increased from 504 nos/100 m^3 to 1153 nos/100 m^3.

The particulate carbohydrates, proteins and lipids were the major components in the particulate organic matter and varied from 14 to 193, 6 to 200 and 8 to 174 μg l^{-1} respectively (Fig. 2). The sum of these three components constituted

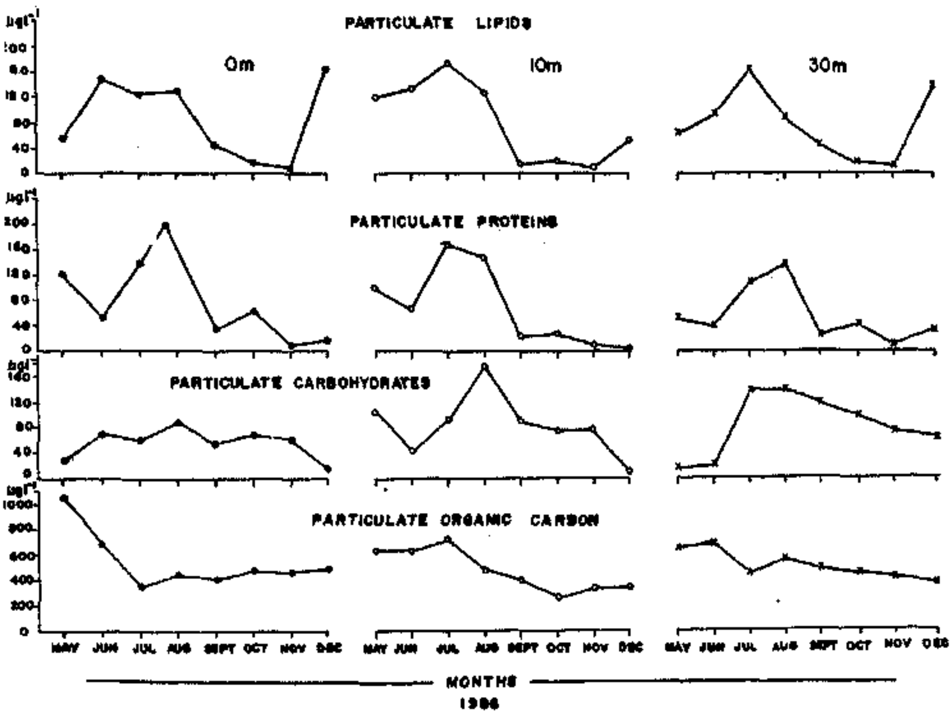

Fig. 2. Seasonal variation in POC, PCHO, PP and PL at different depths.

Table I. Relationship between Particulate Organic Carbon and its constituent fractions at 10 m depth.

Parameters	Correlation coefficient r
POC	—
PCHO	0.16
CHI a	0.57 x
PP	0.76 xx
PL	0.89 xxx

x = P<0.10, xx = P<0.01, xxx = P<0.001

15.4 to 19.11% of POC and showed seasonal variation at different depths (Fig. 3). Particulate proteins was the major component of POC and particulate lipids was the second largest component of POC during winter. July-August being the coldest months of the year, the planktonic organisms living in the water column adapt to the lower temperature. Jorgensen (1968) studied the mechanism

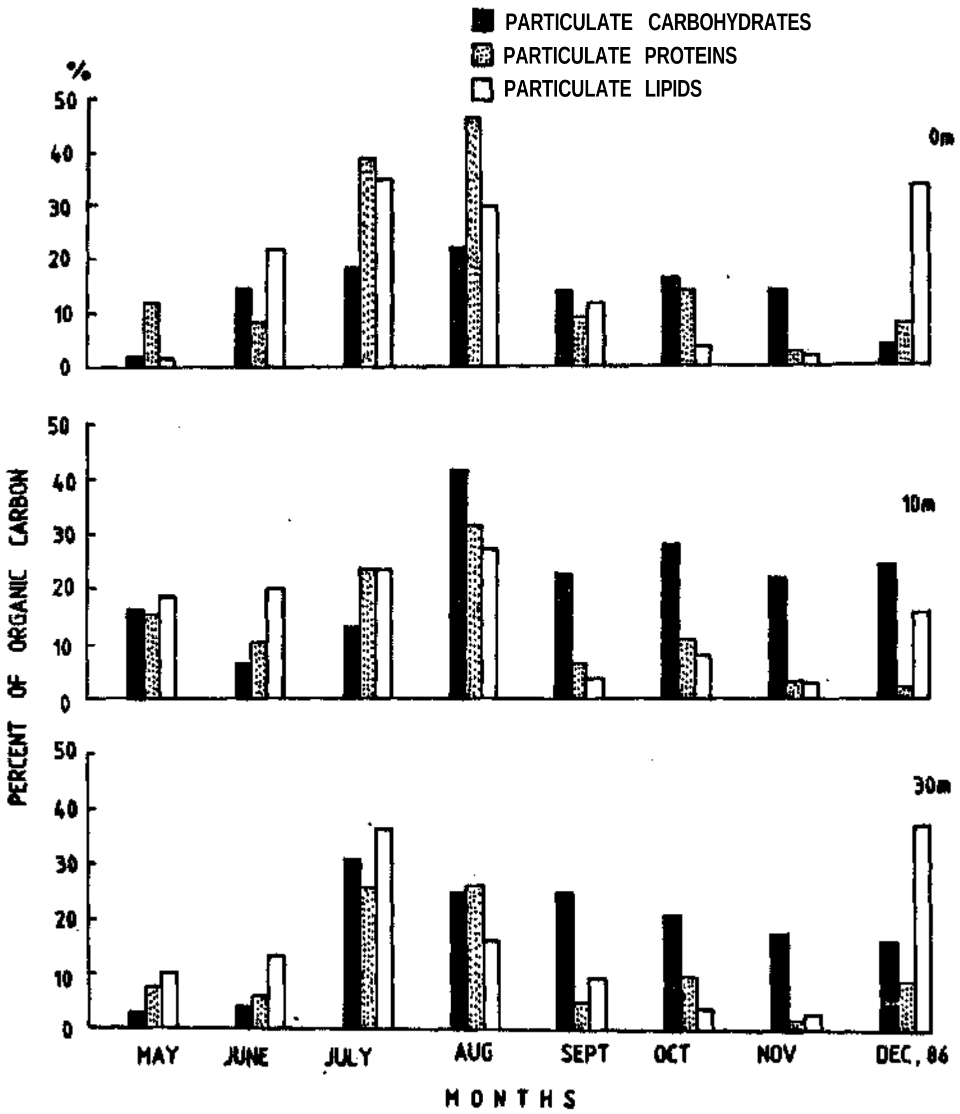

Fig. 3 *Contribution of PCHO, PP and PL to the % organic carbon.*

of temperature adaptation in *Skeletonema costatum* and found that the concentration of protein per cell increased with decreasing temperature. This physiological process may be occurring in the phytoplankton population present during the coldest months increasing their enzymatic protein concentration ultimately resulting in the protein rich particulate organic matter. The major contribution to POC from protein during' winter months also confirms this finding.

Particulate lipids was the second highest component of POC during the coldest months and showed peak in June at 0m and in July at 10 and 30m depths. Decrease in PL was noticed after winter suggesting its utilization by the planktonic organisms during the period of extensive growth. The contribution of PL to percent organic carbon ranged from 1.48 to 37.74% and these values are in accordance with the values reported by Kennicut *et al.* (1979). Lipid did not show any correlation with chl a and PCHO but correlation was demonstrated with POC at 10m depth ($r=0.89$, $P<0.001$).

Smith and Morris (1980) reported that 80% of carbon fixed by phytoplankton was incorporated into lipids material under the conditions of low light intensity and low water temperature in the Antarctic Ocean. The relatively high lipid during winter indicates that lipid synthesis in the phytoplankton must have been taking place under extreme conditions.

The' detrital component in POC was lower during July-August while during rest of the months it was high. This could be related to the low phytoplankton and sea ice microalgal population during winter and high and diverse planktonic population during rest of the year. The dead microalgae, phytoplankton cells and the faecal pelletes, exuviae and corpses of zooplankton take longer time to degenerate at lower temperature (Smetacek, 1980).

In the present investigation, it is evident that when sea is covered with thick sea ice fpr nine months of the year, the sea ice microalgae and diverse planktonic organisms contribute substantially to POM.

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References

BEARDALL. J. AND MORRIS, I. (1976): The concept of light intensity adaptation in marine phytoplankton: some experiments with *Phaeodactylum criconrutum, Mar. Bio.,* 37, 377-387.

BiSCAYE, P.E. AND EITTREIM, S.L. (1977): Suspended particulate loads and transport in the nepheloid layer of the abyssal Atlantic Ocean. *Mar. Geol.,* 23, 155-172

BISHOP, J.K.B., EDMOND, J.M., KOTTEN, P.P., BECON M.P. AND SILKAR, W.B. (1977): The chemistry, biology and vertical flux of particulate matter from the upper 400 m of the Equatorial Atlantic Ocean. *Deep* Sea *Res.,* 24, 511-548.

BODUNGEN, B.V., SMETACEK, V., TILZER, M.M. AND ZEITZSCHEL, B. (1986): Primary production and sedimentation during spring in the Antarctic Peninsula region. *Deep Sea Res.,* 33, 177-194.

BOLTER, M. AND DAWSON, R. (1982): Heterotrophic utilization of biochemical components in Antarctic waters. *Neth. J. Sea Res.,* 16, 315-332.

BUNT, J.S. (1960): Introductory studies of hydrology and plankton at Mawson. June 1956 to February 1957. *ANARE, Sci. Rep. Sor.,* B. 3, 1-135.

DOUCETTE, G.J. AND FRYXELL, G.A. (1983): *Thallassiosira antarctica:* Vegetative and resting stage chemical composition of an ice related marine diatom. Mar. *Bio.* 78, 1-6.

FALKOWSKI, P.G., (1980): *Primary productivity in the sea.* Plenum, New York.

FUKUCHI, M., TANIMURA, A. AND OHTSUKA, H. (1985): Marine biological and oceanographical investigation in Lutzow-Holm Bay, Antarctica. *4th SCAR Symp. Antarctic Biol. Antarctic nutrient cycle and food webs* (eds. SIEGRIED, W.R., CONDY P.R. AND LAWS, R.M.), 52-59.

HANJO, S. (1978): Sedimentation of materials in the Sargasso Sea at a 5367 m depth station J. *Mar. Res.,* 36, 469-482.

HITCHCOCK, G.L. (1977): The concentration of particulate carbohydrates in a region of the West Africa upwelling zone during March, 1974. *Deep Sea Res.,* 5 (24), 83-93.

KENNICUTT II, M.C., WARNER, R.A. AND EL-SAYED, J.Z. (1979): Chemical and microbial characterization of particulate organic matter in Scotia Sea and northern Weddell Sea *Antarctic J. U.S.A.,* XIV (5): 156-157.

LAL, D. AND LERMAN, A. (1973): Dissolution and behaviour of particulate biogenic matter in the ocean. Some theoretical consideration. J. *Geophysical Res.,* 78: 7100-7111.

LEVENTER, A.R. AND DUNBAR, R.B. (1985): Supsended particulate matter in Antarctic coastal waters. *Antarctic J. U.S.A.,* XIX (5), 100-102.

LITTLEPAGE, J.L. (1965): Oceanographic investigation in McMurdo Sound. Antarctica In : *Antarctic Res Ser.* 5 *Biology of Antarctic Seas.* II. G.A. LLANO (ed.) American Geophysical Union, Washington D.C. pp. 1-37.

LOWRY, O.H., ROSENBROUGH, N.J., FARR, A.L. AND RANDALL, R.J. (1951): Protein measurement with Folin-phenol reagent. J. *Biol. Chem.,* 193, 265-275.

McCAVE, I.N. (1975): Vertical flux of particles in the ocean. *Deep Sea Res.,* 22, 491-502.

NELSON, J.R., BEERS, J.R., EPPLEY, R.W., JACKSON, G.A., MCCARTHY, J.J. AND SOUTER, A. (1987): A particle flux study in the Santa Monica, San Pedro Basin off Los Angeles : Particulate flux primary production and Transmissometer study. *Continent. Shelf Res., 7,* 307-328.

NrENHUls, P.H. (198.1): Distribution of organic matter in living marine organisms. In *Mar. Organic Chew.,* DUURSMA, E.K. AND DAWSON, R. (Eds.), Amsterdam, Elsevier, 31-69.

PALM.SANO, A.C. AND SULLIVAN, C.W. (1982): Physiology of sea ice diatoms: I Response of three polar diatoms to a simulated summer-winter transition. J. *Phyol,* 18, (489-498.

PARSONS, T.R., MATAI, Y. AND LALLI, CM. (1984). *A Manual of Chemical and Biological Methods tor Seawater Analysis,* Pergamon Press, Oxford, 63-104.

SMETACEK, V.S. (1980); Zooplankton standing stock copepod faecal pellates and particulate detritus in Kiel Bight. *Estuarine and coastal Mar. Sci.,* 11, 477-490.

SMITH, A.E. AND MORRIS, I. (1980); Pathways of carbon assimilation in phytoplankton from the Antarctic Ocean. *Limnol. Oceanogr.,* 25, 865-872.

SULLIVAN, C.W., PALMISANO, A.C., KOTTMEIER, S., MCGRAET-GROSS, S. AND MOE, R. (1982): Development of sea ice microalgal community in McMurdo Sound. *Antarctic J. USA.,* 17 (57), 155-157.

TANOUE, HANDA, E.N. AND KATO, M. (1982): Horizontal and vertical distribution of particulate organic matter in the Pacific sector of the Antarctic ocean. *Trans. Tokyo Univ. Fish.,* 5, 65-83.

WAKATSUCHI, M., (1982); Seasonal variation in water structure under fast ice near Syowa Station, Antarctica, 1976. *Antarctic* -Res., 74, 85-108.