

Particulate organic matter in shelf waters of Prinsesse Astrid Kyst, Antarctica

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ABSTRACT. Particulate matter collected at a single station in waters off the ice shelf of Prinsesse Astrid Kyst (70°S, 11°E), Antarctica, during the austral summer January–February 1986 was analyzed for organic content. Phytoplankton biomass represented by chlorophyll *a* varied from 0.051 to 3.1 $\mu\text{g dm}^{-3}$. Values for constituent fractions ranged as follows: adenosine triphosphate 0.33 to 1.81 $\mu\text{g dm}^{-3}$, particulate organic carbon 305 to 1850 $\mu\text{g dm}^{-3}$, particulate carbohydrates 8 to 176 $\mu\text{g dm}^{-3}$, particulate proteins 22 to 132 $\mu\text{g dm}^{-3}$ and particulate lipids 8 to 209 $\mu\text{g dm}^{-3}$. Large variation in values suggested patchy distribution. The likely presence of degraded carbon argues in favour of an active microbial community in these waters

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Materials and methods

Sea-water samples were collected twice weekly, in 5-litre Niskin samplers, from a ship alongside the ice shelf (70°S, 11°E). Depth of the euphotic zone was calculated from Secchi disc readings. Three depths (surface just below sea ice, 10 m and 30 m) were sampled within the euphotic zone. Immediately after collection the water samples were filtered through pre-ignited Whatman GF/C glass fibre filters (47 mm diameter, 1.2 μm pore size). Suspended matter left on the filter papers was analyzed in triplicate for particulate organic carbon (POC), chlorophyll *a* (Chl *a*), adenosine triphosphate (ATP), particulate carbohydrates (PCHO), particulate proteins (PP) and particulate lipids (PL). POC and PL were analyzed as suggested by Parsons and others (1984), PCHO and PP respectively by the methods of Hitchcock (1977) and of Lowry and others (1951). Chl *a* was measured fluorometrically (Parsons and others 1984). To analyze ATP, water samples were filtered through sterilized Millipore filters (0.45 μm pore size) and estimated as photon emitted by the luciferin-luciferase system on an SAI photometer after extraction with hot tris buffer (Parsons and others 1984). ATP values were multiplied by a factor of 250 to estimate living carbon (Karl 1980, Vosjan and others 1987).

Introduction

In oceanic environments, suspended particulate organic matter (POM) is generally derived from primary production by phytoplankton (Deuser and others 1981). POM in shallow coastal and shelf waters, on the other hand, is influenced by terrestrial particles and resuspension of bottom sediments (Degens and Ittekkot 1985; Nelson and others 1987).

Attention has recently focused on larger particles (> 50 μm), generally collected by traps, to understand the origins, fate and composition of particulate organic material during its transport through the water column (Honjo 1978; Ittekkot and others 1984; Bodungen and others 1986; Nelson and others 1987). Some advances have also been made in understanding the distribution and composition of suspended POM collected by conventional sampling bottles (Copin-Montegut and Copin-Montegut 1983; Gordon and Cranford 1985; Dorth 1987; Saino and Hattori 1987).

These studies suggest that useful information on such dynamic water processes as primary production in the surface waters, and fate of suspended POM during vertical and lateral transport through the water column, can be obtained by studying the distribution and composition of suspended POM (Bishop and others 1977; Gordon and Cranford 1985; Harrison and others 1987; Saino and Hattori 1987).

Here preliminary data are presented on short-term variation in living carbon, phytoplankton biomass, POM, and carbohydrate, protein and lipid constituent fractions, during January and February (the austral summer) 1986 at a station near the Antarctic ice shelf.

Results

Nutrient concentrations were generally high through January to February (cf. Naqvi 1986). Nitrate, inorganic phosphate and silicate varied respectively from 19.6 to 20.9, 1.6 to 2.3 and 56.7 to 58.1 $\mu\text{mol dm}^{-3}$. This implies that phytoplankton growth was not limited by nutrient starvation.

At the start of sampling on 4 January, Chl *a* was high (1.33 $\mu\text{g dm}^{-3}$) at the surface (Figure 1A); it decreased thereafter to 0.06 $\mu\text{g dm}^{-3}$ on 21 January, then rose from 24 January to a maximum of 3.10 $\mu\text{g dm}^{-3}$ on 1 February. Thereafter surface values decreased to a minimum of 0.72 $\mu\text{g dm}^{-3}$ on 12 February, when sampling ended. Concentrations generally decreased with depth in the upper 10 m, and were often but not always higher at 30 m. Vertical

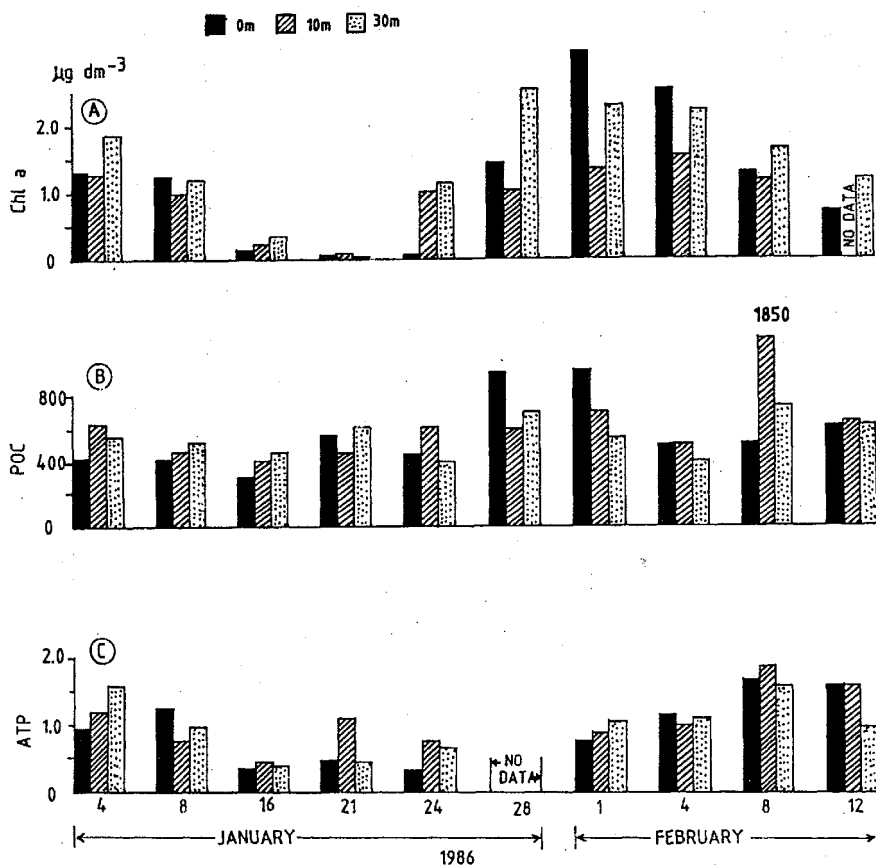


Fig. 1. Short-term variations in (A) chlorophyll a, (B) particulate organic carbon, (C) adenosine triphosphate, in the upper 30 m water column.

hauls of a plankton net showed the presence of *Fragilaria*, *Nitzschia*, *Thalassiosira*, *Biddulphia* and *Eucampia* spp., and unidentified unicellular flagellates in the water column.

POC distribution followed a similar pattern (Figure 1B). During the entire sampling period POC concentrations ranged from 305 to 956 $\mu\text{g C dm}^{-3}$ at the surface, 407 to 1850 at 10 m and 407 to 733 at 30 m. In general they were low from 4 to 24 January, increased from 28 January to 1 February, and thereafter reverted to former levels. With some exceptions, POC showed small decrease as the depth increased; however, strong depth gradients were conspicuously absent.

Ratios of POC to Chl *a* were low during 4 to 8 January and very high from 16 to 24 January (Figure 2), decreasing later to former levels. This ratio followed the trend of Chl *a* (Figures 1 and 2).

Variations in content of ATP were also evident (Figure 1C), ranging from 0.33 to 1.81 $\mu\text{g dm}^{-3}$. As for Chl *a*, a subsurface ATP maximum was seen at 10 or 30 m. ATP and Chl *a* maxima generally but not always coincided. ATP values used as an index of living carbon (ATP \times 250) indicated wide variation (18–80%) through the study period (Table 1).

Relative composition of POC as PCHO, PP and PL was also evaluated (Figure 3). PCHO, PP and PL concen-

trations ranged respectively from 8 to 176, 22 to 132 and 8 to 209 $\mu\text{g dm}^{-3}$. Together these compounds contributed from 8.26 to 58.61% of organic carbon (Figure 4). PCHO and PP values were high on 4 January, decreasing to 24 January. PL by contrast was high from 21 to 28 January and decreased from 2 to 12 February. Low PL was generally accompanied by higher PCHO and PP. In general, during the period of high phytoplankton biomass, PL was a minor constituent of organic matter, compared with PCHO and PP.

In summary, no particular pattern could be discerned in the vertical distribution of these compounds in the upper 30 m water column, especially PP and PL (Figure 3). However, PCHO concentrations were generally high at the surface and decreased in the upper 10 m during 4 to 24 January, showing small increase below this depth: from 28 January onwards PCHO generally decreased from the surface to 30 m.

Discussion

From these limited data, some generalization can be made on short-term summer variation of phytoplankton biomass, living carbon, organic matter and its constituents.

Though sampling at four-day intervals has provided useful information on variations in plankton biomass, including seasonal build-up, for the future we recommend

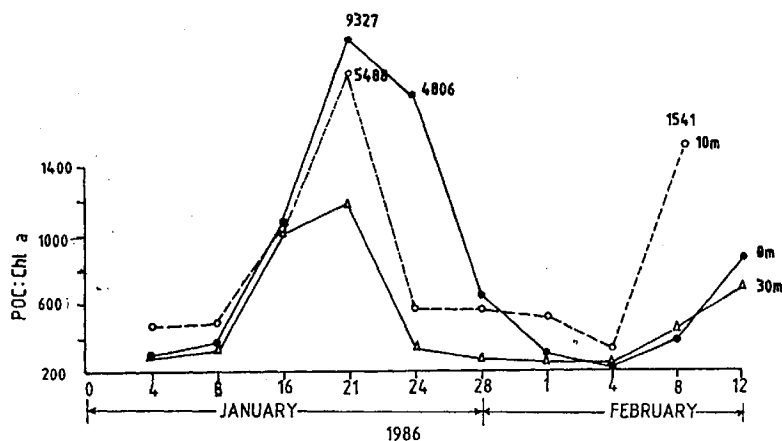


Fig. 2. Variations in ratio of particulate organic carbon to chlorophyll *a* in the upper 30 m water column.

more frequent sampling, that would provide detail of day-to-day variations of the kind described by Bodungen and others (1986) and El-Sayed and Tomo (1987).

Such nutrients as inorganic phosphate, nitrate and silicate were abundant at this station and are unlikely to have limited phytoplankton growth; other factors including light intensity, temperature and physiological state of the algae are more likely to have exerted controlling influences.

Chl *a* concentrations were often but not always higher at 30 m than at the surface, suggesting that phytoplankton accumulated at this depth. El-Sayed and Tomo (1987) and Liebezeit (1984) also observed accumulation of Chl *a* at about 20–25 m, which Liebezeit ascribed to inhibitory effect of surface radiation and perhaps in-situ growth of phytoplankton. High Chl *a* was generally associated with high POC. The concentrations of POC observed here (305 to 1850 $\mu\text{g dm}^{-3}$) are similar to those reported for surface waters from other coastal and shelf environments (Karl 1980; Pocklington and Mackinnon 1982; Harrison and others 1987; Bhosle and others 1988).

POC/Chl *a* ratios fluctuated widely from 198 to 9327. These values are very high in comparison with typical values of 35 observed for phytoplankton and those reported from the Weddell Sea (~31.8) and Ross Sea (~138) (Nelson and others 1988). However, values ranging from > 250 to 1270 have also been reported from the oceanic waters of the Indian and the Pacific sectors of the Southern Ocean (Grall and Jacques 1982; Tanoue and others 1982,

Treguer and others 1988); the latter also reported more than 50% of organic detritus in their samples collected from the Indian sector of the Southern Ocean. We were collecting much closer to the coast, and our high and varying values might have arisen at least in part from included terrestrial matter.

Our use of 0.45 μm filters in estimating ATP (instead of the more generally used 0.2 or 0.22 μm filters, which were not available to us) almost certainly lost us a proportion of biologically important microorganisms. Furthermore, Vosjan and others (1987) have recently reported that tris-buffer extraction gives large scatter and somewhat overestimates ATP. For these reasons we regard our values of ATP as approximate and open to further interpretation. In general, though not always, there was close correspondence between ATP and Chl *a* values (Figure 1). Divergences may have been due to extraction of ATP from fragments of copepod, eggs, faecal pellets and other large organic particles (Vosjan and others 1987).

Organic matter in the coastal and shelf environments is both allochthonous from terrestrial material and autochthonous from in-situ aquatic production (Degens and Ittekkot 1985; Nelson and others 1987). Terrestrial material comes seasonally from sub-glacial sedimentation, ice-rafting, or material trapped in ice from the land. There are no rivers or streams, and sediment from meltwater is minimal along most of the Antarctic coastline (Dunbar and others 1985). The detritus we studied during January and February included some terrestrial elements but was

Table 1 Short-term variation in living carbon and detrital carbon in the upper 30 m water column.

| Sample depth (m) | Total living carbon (ATP x 250) | | | % detrital carbon | | |
|------------------|------------------------------------|-------|-------|-------------------|-------|-------|
| | 0 | 10 | 30 | 0 | 10 | 30 |
| January | | | | | | |
| 4 | 237.5 | 330.0 | 400.0 | 41.93 | 52.45 | 29.70 |
| 8 | 312.5 | 187.5 | 240.0 | 23.97 | 61.60 | 54.63 |
| 16 | 87.5 | 112.5 | 95.0 | 71.33 | 72.35 | 78.74 |
| 21 | 120.0 | 277.5 | 115.0 | 78.91 | 35.53 | 81.14 |
| 24 | 82.5 | 190.0 | 152.5 | 81.68 | 68.87 | 62.45 |
| February | | | | | | |
| 1 | 187.5 | 217.5 | 267.5 | 80.38 | 69.01 | 53.47 |
| 4 | 292.5 | 257.5 | 277.5 | 42.41 | 49.41 | 31.81 |
| 8 | 420.0 | 452.0 | 400.0 | 17.48 | 75.54 | 45.43 |
| 12 | 397.5 | 402.5 | 227.5 | 35.98 | 38.17 | 63.94 |

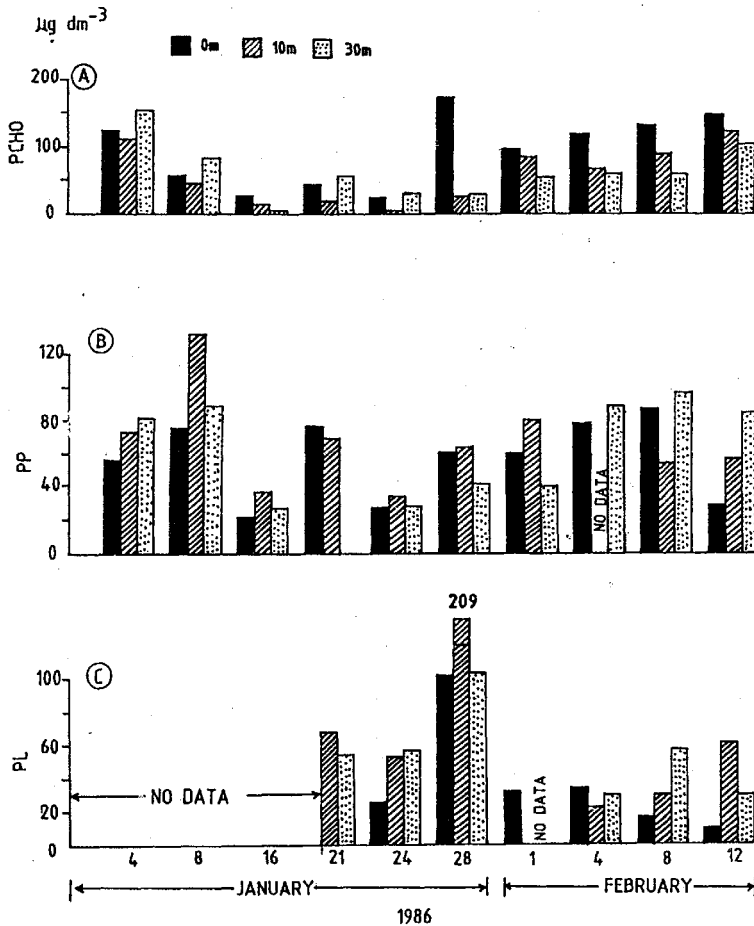


Fig. 3. Variations in (A) particulate carbohydrates, (B) particulate proteins and particulate lipids, in the upper 30 m water column.

mostly from dead phytoplankton and heterotrophic organisms. The wide variations in suspended living carbon that we measured are likely to have been based mainly on autochthonous materials, with some influences from land. More organic material may have been released from decaying sea ice, and possibly from a nearby concentration of penguins at Old Lazarev station.

The constituent fractions of organic matter including PCHO, PP and PL varied with time and depth, though concentrations reported in the present study are similar to those from other polar studies (Jeffrey and Bottino 1967; Bolter and Dawson 1982; Harrison and others 1987). Usually these constituents decreased with depth, due either to loss during descent by remineralization, ingestion and assimilation by aquatic organisms, or to dilution by input of re-suspended and terrestrial particles that are poorer in these compounds. The steep decrease with depth of PCHO, especially from 28 January to 12 February (Figure 3), suggests preferential utilization of PCHO over PP and PL. Handa and Yanagi (1969) regard the PCHO of reserved particulate material and phytoplankton (Handa and Yanagi 1969; Hitchcock 1977; Tanoue and Handa 1987) in the euphotic zone to be used preferentially by sinking diatoms and heterotrophic organisms, as compared with PP and PL.

The relative contribution of these compounds as per-

centages of organic matter varied during the period of sampling. Relative content of carbohydrates, proteins and lipids are known to be influenced by the nutrient status of the community (Morris 1981); thus nutrient-deficient cultures or natural populations of phytoplankton show variations in the concentrations of these compounds. In our study nutrients were abundant and unlikely to account for the observed variations. On the other hand, Hecky and others (1973) found pronounced differences in these compounds for various fresh and brackish water diatom species. The species composition of the phytoplankton indeed varied during the period of our observations, and the variations we recorded in these compounds may have reflected changes in the composition of the phytoplankton.

Together these compounds contributed 50% or less to the total of organic carbon, leaving half or more to be accounted for otherwise. Possible sources of error were contamination, analytical problems, or a presence of highly degraded residual carbon of terrestrial or detrital origin. Contamination is unlikely; great care was taken in the sampling. PCHO, PP and PL analyses followed standard methods which are unlikely to yield underestimations; the method used for organic carbon is known to overestimate carbon by about 20% (Parsons and others 1984). Correcting the values accordingly did not alter the

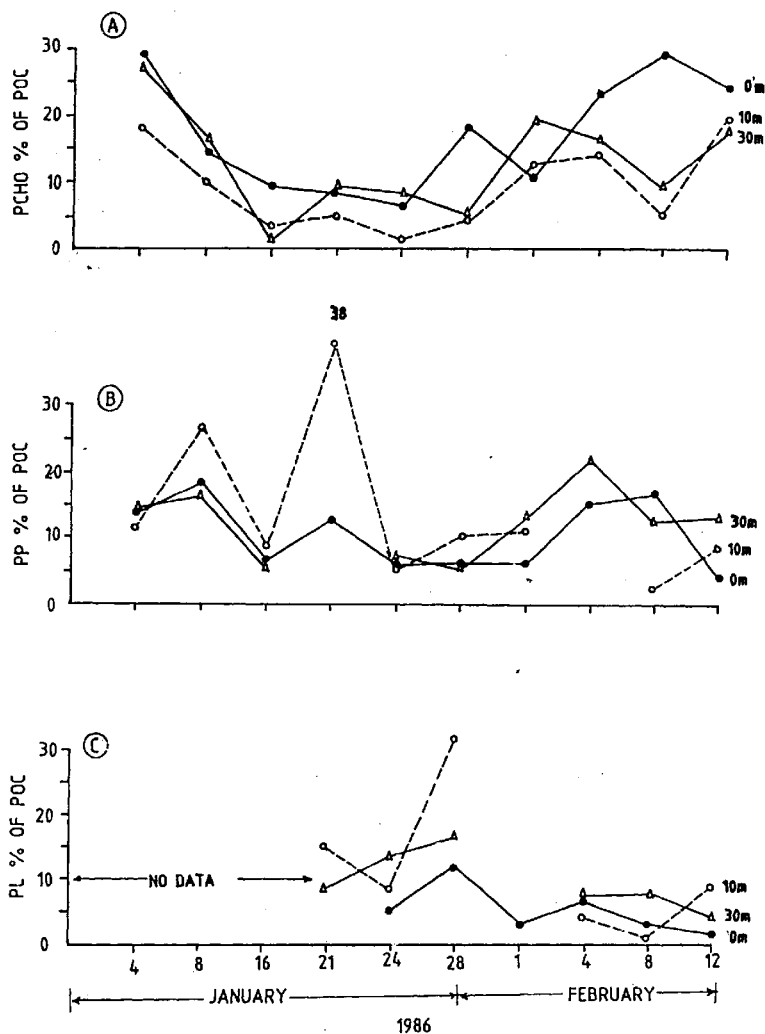


Fig. 4. Variation in the relative contribution of (A) particulate carbohydrates, (B) particulate proteins and (C) Particulate lipids in the upper 30 m water column.

pattern to any great extent. Thus the most probable source of error seems to be the presence of degraded carbon.

This argues the presence of an active microbial system in these waters and contributes to an on-going debate. Sorokin (1970) suggested that the low temperatures (-1° to 3°C) of polar waters inhibited the bacterial decomposition of organic matter; Gillespie and others (1976) and Tanoue and Handa (1982) reported that bacterial populations of Antarctic waters were sufficiently active to mineralize much of the organic matter present. We assume that low contributions of PCHO, PP and PL were probably due to the presence of highly degraded residual carbon, but our data are insufficient to identify the nature and sources of this carbon. Further analyses, including those of individual sugars, amino acids, biomarker lipids and lignin degradation products, are now needed to provide useful information on the nature and sources of organic matter in this interesting shelf environment.

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