Some Observations on the Biological Productivity of Antarctic Waters

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ABSTRACT

Observations on chlorophyll *a,* particulate organic carbon (POC) and ATP from the Antarctic, waters showed that the chl *a* concentration in the inshore waters (mean 0.21 mg m^{-3}) were not significantly different from those of the open ocean waters of Antarctic (mean 0.215 mg m^{-3}). Vertical distribution of chl *a* was uniform in the euphotic zone. POG concentrations revealed that the area studied is fertile and there is regular input of organic material into the water column. A direct relationship was found between the bacterial counts and ATP content. A significant part of POC appears to exist as detritus, probably of phytoplankton and bacterioplankton origin.

Primary production ranged from 0.021 to 9.95 $mgCm^{-3}$ day^{-1}. The average rate, of fixation of particulate carbon was 3.72 mgC m^{-3} day^{-1} in the inshore waters and 0.95 $mgCm^{-3}$ day^{-1} in the open ocean waters of Antarctica. The areas with pack ice gave a production rate of 2.65 $mgCm^{-3}$ day^{-1}. Size fractionation showed that nannoplankton (<20μ) organisms form a very important component of phytoplankton. The data obtained have been discussed in relation to the season of observation and the availability of nutrients in the area of study.

INTRODUCTION

Cold water masses, originating in the Antarctic region and moving northward, are known to affect the hydrographical features of the southern Indian Ocean. These waters are characterized by very low temperature, high concentration of inorganic nutrients and are subjected to extreme seasonal changes in the total incident solar radiation falling on the sea surface. Consequently, the phytoplankton production is fairly restricted to a short period of summer in the year when it is intense. Under these conditions, plankton studies in these waters are of considerable importance for making an overall assessment of biological resources of the Antarctic Ocean.

Studies on the phytoplankton of Antarctic waters began several decades ago (Hendy, 1937; Hart, 1942). However, since 1960, the primary productivity of the Antarctic Ocean was investigated fairly extensively by several workers (Burkholder and Sieburth, 1961; Mandelli and Burkholder, 1966; Home, Fogg and Eagle, 1969; El Sayed, 1970). These studies included the pigment concentrations, rate of ^{14}C assimilation and photosynthetic indices. From these investigations, it can be deduced that the variations in these components are largely due to the light conditions, temperature of water and the stability of the water column. Knox (1970) made observations on the phytoplankton and zooplankton communities while Smith and Morris (1980) studied the nature of the metabolic products of phytoplankton in the Antarctic region. Deacon (1982) has attributed the characteristics of such an ecosystem to the circulation of water, winds and other physical conditions prevailing in the southern Indian Ocean.

In this communication, the data on primary productivity and on other ecosystem-related aspects, obtained during the First Indian Expedition to Antarctica (December 1981-February 1982) have been, presented.

MATERIAL AND METHODS

Oceanographic stations occupied during the Antarctic expedition are shown in Fig. 1. Water samples at these stations were collected from 0 m, 10 m, and 80 m depths (80 m depth nearly corresponded with the lower end of the euphotic zone) using PVC, GOFLOW (10 t) samplers. Carbon fixation was measured by the ^{14}C method. From each depth 125 ml of the water samples were incubated in duplicate with 5μci of $NaH^{14}C03$ for 24 hours under simulated *in situ* conditions. After the incubation, the samples were filtered through membrane filters (pore size 0.45 *μm)* and the radioactivity was measured using a liquid

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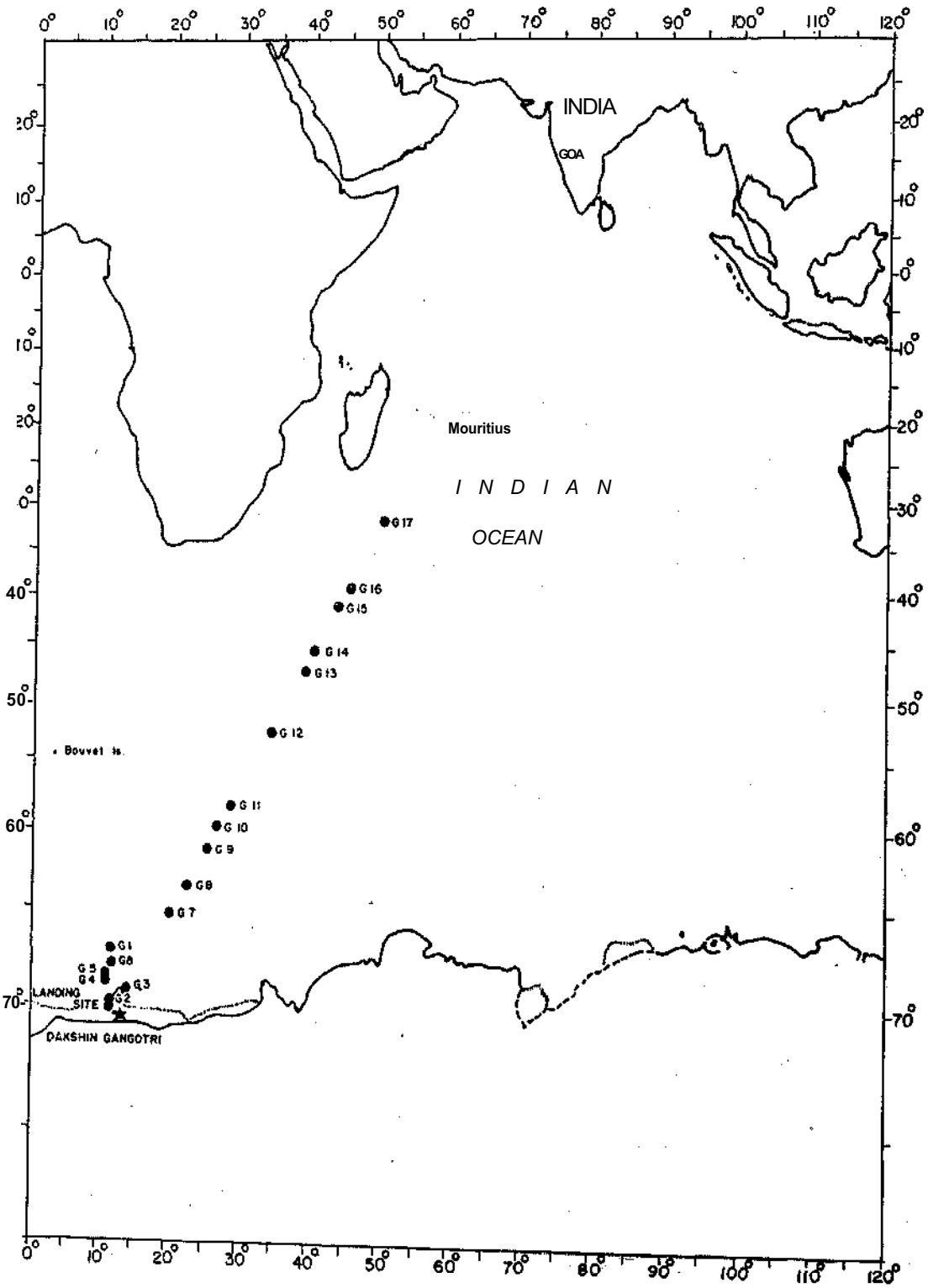

Fig 1: Stations worked during the First Indian Antarctic Expediton for the study of primary productivity and related aspects.

scintillation counting system. Chl *a* and phaeopigments were estimated by the fluorometric method and particulate organic carbon by the chromic acid digestion method (Strickland and Parsons, 1972). ATP was measured by the method described by Holm Hansen and Booth (1966). Phytoplankton carbon was calculated from chlorophyll *a* using a factor of 91.43 (Goes, 1983) and the bacterial carbon from the plate counts (Zobell, 1963). Detrital carbon was calculated from the estimates of particulate organic carbon, phytoplankton carbon and bacterial carbon.

RESULTS AND DISCUSSION

Minimum and maximum values of phytoplankton production and related aspects of the Antarctic ecosystem are presented in Tables 1 & 2 and the results have been shown in Figs. 2 & 3. The study period was the late Antarctic summer (January, 1982) when the ice was melting fast and the temperature of the surface water was going up. The temperature ranged from 1.90°C to 5.47°C and the thermal structure of the water column did not show any stratification upto 100 m (Rama Raju and Somayajulu, 1983).

TABLE 1

Minimum, maximum and mean values of primary production, chlorophyll a, phaeopigments, particulate organic carbon ATP, and nutrients at the surface of Antarctic waters.

	Min.	Max.	Mean	No. of .obs.
Primary production (mgC m^{-3} day^{1})	0.021	9.95	2.11	13
Chlorophyll *a* (mg m^{-3})	0.05	1.5	0.28	16
Phaeopigments (mg m^{-3})	0.0	0.66	0.10	16
Particulate organic carbon (mgC m^{-3})	126	811	328.12	16
Adinosine tri phosphate (live carbon) (mg m^{-3})	0.02	1.40	0.31	16
PO_43^- -P (μg-*at* l^{-1})	0.23	1.71	1.24	14
SiO_4^-Si (μg-*at* l^{-1})	1.1	106.8	35.21	14
NO_3^--N (μg-*at* l^{-1})	0.1	23.9	7.9	14
$N0_2^-$-N (μg-*at* l^{-1})	0.08	0.68	0.27	14

TABLE 2

Biomass values of the three major components of the ecosystem

St. No.	Surface ($mgCm^{-3}$)			Column (gCm^{-2})		
	Phytoplankton biomass	Bacterial biomass	Detrital component	Phytoplankton biomass	Bacterial biomass.	Detrital component
G 2	12.958	0.76	318.28	2.575	o.431	22.449
G 3	22.677	0.9	210.42	1.393	0.481	25.263
G 4	29.156	0.03	410.31	1.969	1.869	29.287
G 5	16.198	0.46	272.74	1.112	0.038	21.37
G 6	15.069	0.03	261.9	1.323	0.002	16.605
G 9	14.57	2.6	108.83	1.341	0.048	20.181
G11	67.05	0.062	285.89	5.811	0.291	19.883
G12	12.148	10.2	593.652	0.828	0.411	52.426
G14	7.775	0.0022	242.223	0.604	0.001	12.665
G15	4.49	0.0122	220.5	1.049	0.071	16.71
G17	14.57	0.0012	141.42	2.221	0.006	8.433

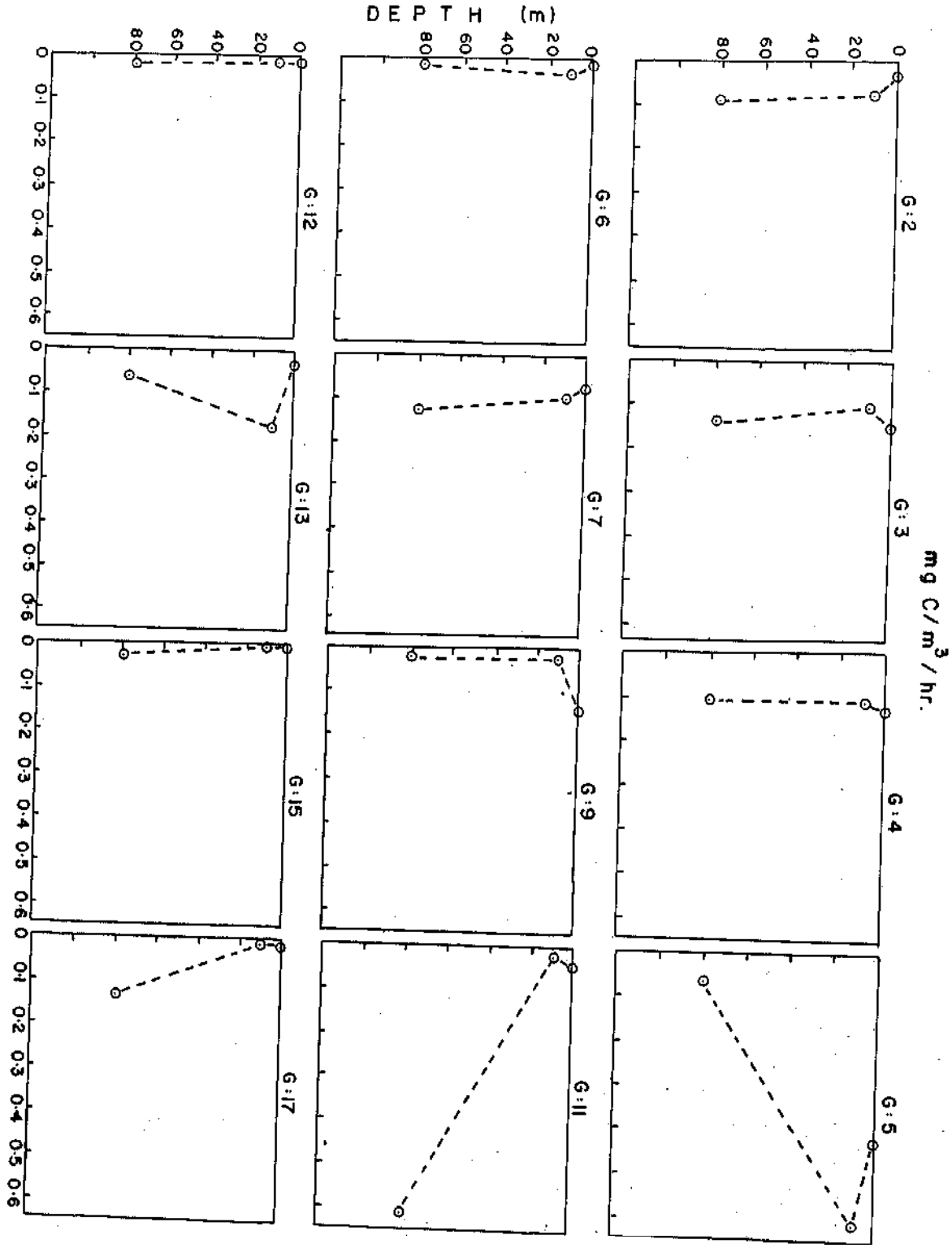

Fig. 2 : Vertical distribution of primary productivity in the water column at some stations during the Antarctic Expedition.

Phytoplankton biomass and rate of production:

Surface chl *a* values at most of the stations were high averaging 0.28 mg m -3 at the 16 stations which were worked. The highest surface chl *a* (1.5 mgm^{-3}) was at the station Gloccupied in the pack ice zone. In a similar study of the Indian Ocean-Antarctic Ocean Sector, Ichimura and Fukushima (1963), measured chl *a* at the surface and found that its concentration increased from the Indian Ocean to the Antarctic Ocean. They reported the chl *a* range from 0.15 to 0.6 mg m^{-3} . In the present study the chl *a* values agree with those (0.1-0.4 mg m^{-3}) measured by Jacques and Minas (1981) in the Indian Ocean sector of the Antarctic Ocean. Column distribution of chl *a* upto 80 m depth showed no significant difference with depth (Fig. 3).

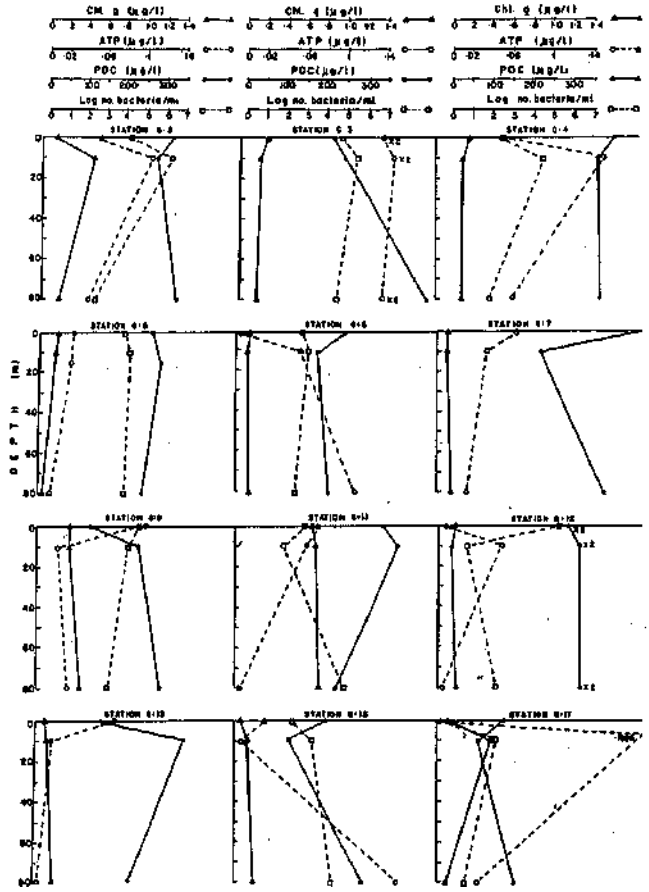

Fig. 3 : Chlorophyll *a,* ATP, particulate organic carbon and bacterial counts in the water column of some stations during the Antarctic Expedition.

Phaeopigments varied from non-detectable concentrations to 0.66 mg m^{-3} at the surface (average 0.1 mg m^{-3}) and showed a distribution pattern similar to that of chl *a.* Phaeopigments were always low in the entire water column as compared to chl *a.* This feature indicates that phytoplankton population is in a healthy state.

Very little information is available on the contribution made by nannoplankton (<20μ) to the primary production in this region. A comparison of chl *a* concentrations between the net plankton and nannoplankton showed that the biomass ratio between the two was nearly one. Thus nannoplankton appears to form a major group of phytoplankton in this region.

The vertical distribution of primary production (Fig. 2) bears a close resemblance with that of chl *a* (Fie. 3). The rates of production at 13 stations studied ranged from 0.021 to 9.95 $mgCm^{-3}$ day^{-1} , with an average of 2.11 $mgCm^{-3}$ day^{-1} .The station occupied in the pack ice zone (G1) showed a relatively high carbon assimilation rate (2.65 $mgCm^{-3}$ day^{-1}), as compared to the low rate reported earlier (El Sayed and Jitts, 1973). Jacques and Minas (1981) also reported low production rates varying from 2 to 7 $mgCm^{-3}$ day^{-1} in the Indian sector of the Antarctic Ocean and ascribed this low production to the lack of some trace elements. However, Brockel (1981) reported a higher production rate (Range : 1.1-19.0 $mgCm^{-3}$ day^{-1} ; mean 7.5 $mgCm^{-3}$ day^{-1}) for the western Antarctic Ocean. Thus, it appears that the Indian sector has a production rate somewhat lower than that of the Atlantic sector of the Antarctic Ocean.

The average production of net plankton was 2.11 $mgCm^{-3}$ day^{-1} and that of nannoplankton (<20μ) was 2.33 $mgCm^{-3}$ day^{-1}. This together, with the high nannoplankton biomass indicates that the nanno-plankton contributes almost to the entire primary production in this region. Similar is the case with the Western Antarctic Ocean where Brockel (1981) observed that the nannoplankton organisms with sizes smaller than 20μ were responsible for about 90% of the production. The average primary production rate in the coastal waters (st. G1-G6) was 3.72 $mgCmr^{3}$ day^{-1} .which was several times higher than that (0.95 $mgCm^{-3}$ day^{-1}) in the open ocean waters, even though the mean chl *a* concentrations were nearly the same. Inorganic nutrients, however, do not seem to be limiting both in coastal and oceanic waters. As pointed out by Jacques and Minas (1981),the low production in oceanic waters could perhaps be explained by the absence of some as yet unidentified trace elements necessary for vigorous phytoplankton growth.

Inorganic nutrients-nitrate, phosphate and silicate were high at all the stations sampled. Melting of ice at the beginning of the summer, the transport of nutrients from below the euphoric zone, bacterial regeneration of nutrients within the euphotic zone and the runoff of water from the Antarctic landmass appear to be the probable sources of high nutrients. Other studies (Jacques and Minas, 1981) also show that the nutrients in the Antarctic waters are always in excess of the phytoplankton requirements.

A comparison of chl *a,* phytoplankton carbon and POC concentrations (Tables 1 and 2; Fig. 3) shows that while the phytoplankton biomass is not very much different from the values obtained from the oligotrophic seas, the POC values are close to those observed in eutrophic coastal waters. This suggests that not only the major portion of POC is in the form of detritus, but it is produced at a rate faster than the phytoplankton. Seasonal changes in the environmental conditions in the polar zone are extreme and thus the period favourable for plant production is very short. With the onset of favourable conditions, phytoplankton production gets accelerated and in ice-free waters adjoining the continent, intense production of phytoplankton attaining bloom situations is very common (El Sayed, 1971). The rapid turnover rates for the Antarctic phytoplankton (El Sayed, 1970) also lend support to this observation. In the present study, algal blooms were observed close to the drift ice and in waters with a sub-zero temperature. Thus, excess plant material following successive blooms would find its way into the food chain as detritus and will remain there as surplus. This situation largely accounts for the high POC concentrations observed in the Antarctic Ocean during late summer.

The role of bacteria in the Antarctic food chain is a little known factor. Bacterial biomass varied from 0.002 to 1.869 gCm^{-2} in the column. At the surface, the range was from 0.0012 to 10.2 $mgCm^{-3}$ (Table 2). Although these values are somewhat lower as compared to the high turnover rates for the bacteria, their overall production is likely to be very substantial. In fact, Fuhrman & Azam (1980) estimated that the production of bacterioplankton in the Antarctic waters could be as high as 2.9 $mgCm^{-3}$ day^{-1}. These rates are of the similar order of magnitude as the rates of primary production observed in the present study and support the idea that bacterioplankton are a quantitatively important component of the Antarctic food-web. Such a production occurs largely at the expense of dissolved organic matter (Hodson, Azam, Carlucci, Fuhrman, Karl and Holm-Hansen, 1981; Fuhrman and Azam, 1980) and contributes substantially to the bacterial pathway of the food chain in the Antarctic and sub-Antarctic region during late summer.

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