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Seasonal changes of Antarctic marine bacterioplankton

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Abstract

During a one-year period the development of the Antarctic coastal seawater bacterioplankton was followed. Two field stations (surface and deep water = 20 m, respectively) were sampled daily in 1989 in "Terre Adélie area". The survey included physicochemical (temperature and particulate organic matter) and bacteriological (total and heterotrophic bacteria, bacterial production) measurements. Whereas bacterial parameters at the deep water station remained fairly constant, bacterial parameters in surface waters generally increased during the year obviously related to the formation of sea ice.

Introduction

In polar oceans influenced by seasonal variations in the ice cover, phytoplankton blooms in the ice-edge zones are the major source of the annual cycle of biogenic particle production (SMITH et al. 1987). The low water temperatures existing in these latitudes support the presence of large bacterial populations (BÖLTER and DAWSON 1982, SULLIVAN and PALMISANO 1984, DELILLE et al. 1988). The traditional understandings of high primary productivity in the southern ocean with a short, simple food chain from large diatoms to krill and further to whales have to be modified. More recent observations indicate that levels of phytoplankton are generally low over most of the Antarctic ocean (EL-SAYED 1984, COTA et al. 1990). Production and heterotrophic utilization of organic matter are closely related (BUCK and GARRINSON 1983, SULLIVAN et al. 1990). Bacteria may contribute significantly to the energy transfer in southern ocean waters (HANSON and LOWERY 1985). At present we have only a fragmentary picture of the temporal dynamics of Antarctic marine bacterioplankton. Most observations have been restricted to the spring-summer or late summer-early autumn periods. Previous work in the Kerguelen Archipelago has demonstrated strong and regular seasonal variations of subAntarctic bacterioplankton (DELILLE 1990). The purpose of this one-year study was to follow seasonal variations in the Antarctic seawater bacterial microflora possibly influenced by seasonal variations in the ice cover.

Material and methods

This study was conducted between January 1989 and February 1990 in the Géologie Archipelago (Adélie Land, 66°40'S; 140°01'E).

Subsurface seawater samples were collected with sterile glass bottles at 10 cm depth. Deep seawater samples were gained by pumping from a water depth of 20 m. Viable counts of aerobic heterotrophic bacteria were made applying the spread plate technique using ZoBell 2216 E medium (OPPENHEIMER and ZOBELL 1952). Inoculated plates were incubated for 21 days at 4 °C. Total bacteria were determined by the acridine orange direct count technique (AODC) with an Olympus epifluorescence microscope according to the method of HOBBIE et al. (1977). Frequency of dividing cells (FDC) was assessed using the method of HAGSTRÖM et al. (1979). Biovolumes were estimated using an ocular micrometer. The uptake of tritiated thymidine was measured according to the procedure of FUHRMAN and AZAM (1982). The uptake rate was determined in one hour incubations at a final concentration of 10 nM methyl-[^{3}H]-thymidine. Due to logistical problems, these studies were restricted to the first six months of the year. Particulate organic carbon (POC) was oxidized in an induction furnace equipped with an infra-red detector (LECO IR 212). Volumes of 2 - 4 l of seawater were filtered directly after sampling through precombusted glass fiber filters (Whatmann GF/F 25 mm diameter). Prior to analysis, filters were decalcified by treatment with 1M H_3PO_4 at 60 °C for 48 hours.

Results and discussion

The seawater temperature (Fig. 1) ranged from +0.5 °C in summer to -2.1 °C in winter. POC ranged from about 0.2 mg C l^{-1} to more than 1 mg C l^{-} in winter

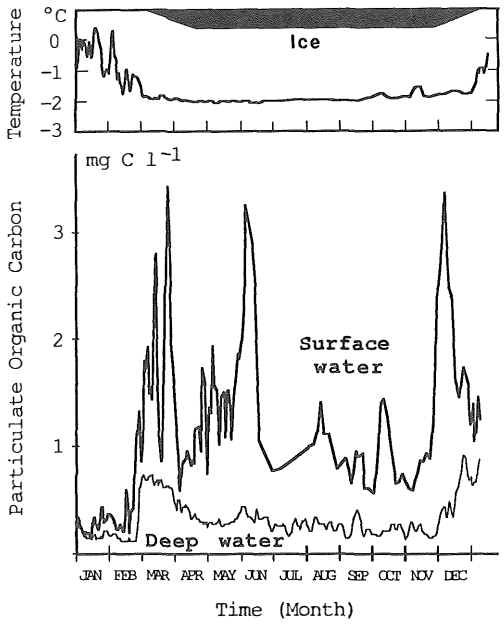

Fig. 1. Seasonal changes in temperature, ice covering and particulate organic carbon (POC) in seawater collected from surface and deep water (thick and thin line, respectively).

surface water. Three distinct peaks were observed in surface water after sea ice formation (March, June, November-December).

The same general trends were observed for all bacterial parameters studied. Deep water values could be considered as fairly constant during the year. Data collected in summer surface waters were comparable to the corresponding data of deeper waters. After sea ice formation bacterial numbers generally increased. Total bacteria (Fig. 2) ranged from 1 x 10^4 cells ml^{-1} in summer in deep and

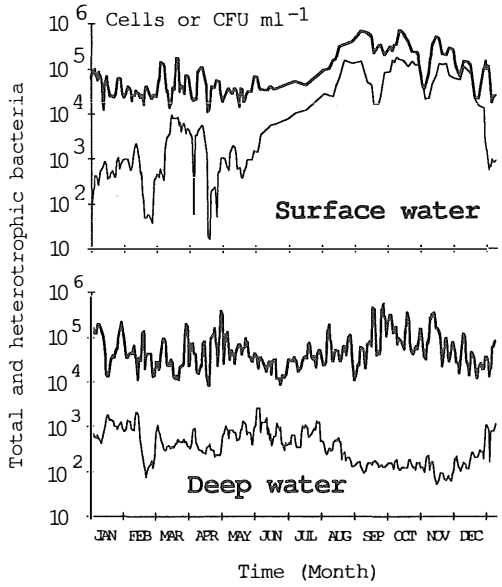

Fig. 2. Seasonal changes in total and heterotrophic bacterial populations (thick and thin line, respectively) of seawater collected from surface and deep waters.

surface samples to more than 5 x 10^6 cells ml^{-1} in late winter surface samples. At the same time heterotrophic bacteria ranged from about 10^2 cells ml^{-1} in summer to more than 10^5 cells ml^{-1} in late winter surface samples. Bacterial biovolumes (Fig. 3) ranged from about 0.1 μm^3 in summer to more than 0.3 μm^3 in winter surface waters. The highest FDC value (24 %) occurred in the surface seawater in late September. Seasonal changes observed in the ratio between bacteria associated with particles and free living bacteria paralleled those of heterotrophic bacteria. Bacterioplankton production displayed seasonal variations similar to those of the other bacterial parameters. At both depths, bacterial production in summer reached values close to 0.3 mg C $m^{-3}d^{-1}$. In contrast, thymidine incorporation exhibited a pronounced increase in surface water after sea ice formation. Production rates exceeded 10 mg C $m^{-3}d^{-1}$ during the winter maxima.

Variations in temperature comprised not more than 2.6 °C which could be considered as negligible. It can be concluded that temperature had only a limited influence on Artarctic bacterioplanktonic populations which must be characterized as psychrotrophic and not as true psychrophiles (INOUE and KOMAGATA 1976, DELILLE and PERRET 1989).

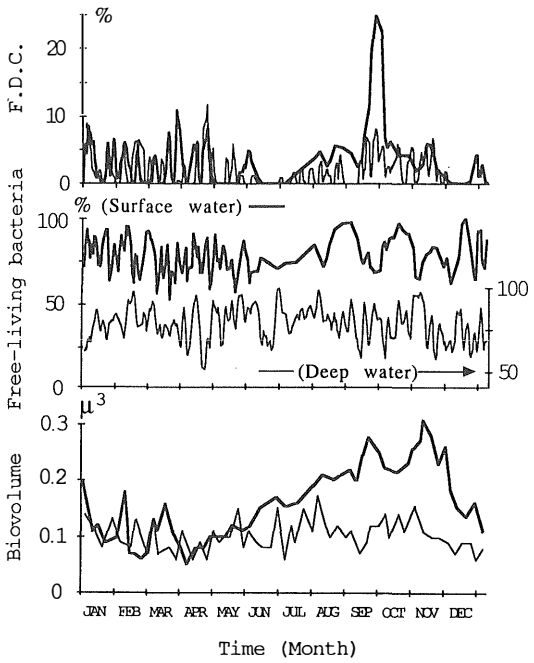

Fig. 3. Seasonal changes in frequency of dividing cells (FDC), percentage of free living bacteria and biovolume of bacterial populations collected from surface and deep seawater (thick and thin line, respectively).

Bacterial biomass estimates of summer surface waters and deep water samples, 1.1 mg C m^{-3} on average, are comparable to field data that are available for the Antarctic Ocean (HODSON et al. 1981, COTA et al. 1990). In contrast, bacterial biomass exceeded 20 mg C m^{-3} in surface seawater during the winter maxima. Variations at total bacterial numbers are less pronounced as compared to variations observed of heterotrophic bacteria. During winter growth-periods the quantitative difference between direct and viable counts showed a marked decline. Corresponding observations have been previously reported (DELILLE 1987, DELILLE and BOUVY 1989). The ratio between culturable bacteria and total bacterial numbers provides information concerning the composition and/or nutritional status of the population (CARON et al. 1989, DELILLE and BOUVY 1989). For all deep water samples and for summer surface water samples rates of bacterial production are comparable to the few field data that are available (COTA et al. 1990). In contrast, bacterial production was more than ten times higher in surface seawater during winter. Thus, the bacterial data clearly suggest that the winter surface supports considerably higher concentrations of "active" bacterioplankton as compared to the ice free seawater. Antarctic sea ice supports high concentrations of bacteria, diatoms, autotrophic flagellates, heterotrophic flagellates, ciliates and metazoans (GARRISON and BUCK 1989). When released from ice, the ice-bound organic matter may be regarded as an inoculum for the water column (ACKLEY et al. 1979, GARRISON et al. 1987, SMITH and CLEMENT 1990). The present data confirm this hypothesis. The relatively poor relationship between bacterial numbers and/or activities and POC on

the one hand, and the fairly good relationship between heterotrophic bacteria and total free living bacteria on the other hand may be an indication that particulate material plays only a minor role as nutrient supply for sea ice and winter bacterioplankton populations.

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