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Distribution and Biomass of Bacterioplankton in the Southern Bransfield Strait and Adjacent Areas; Relationships to Temperature, Inorganic Nutrients, and Phytoplankton Parameters in February 1993

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During the 6th KARP (Korean Antarctic Research Program) cruise in Feb. 1993, bacterial cell abundance and biomass were measured in Maxwell Bay and the southern Bransfield Strait area along 2 north-south transects spanning from near Brabant Island, Gerlache Strait, to the Drake Passage area. Samples were collected from a beach (Maxwell Bay), or from 3 depths in the surface (< 100 m) mixed layers (transect). Bacterial cell concentrations ranged 0.7-5x10^5 cells·ml^{-1}, showing correlations to temperature (r^2 = 0.43) and chlorophyll a (r^2 = 0.23). However, these correlations were weaker than those found in a temperate coastal region. Negative relationships were observed between the cell concentrations and inorganic nutrients, and the correlation was weak (NO_3, r^2 = 0.19; PO_4, r^2 = 0.08). Bacterial carbon biomass calculated from the cell concentrations ranged from ca. 2 to 10 ng·C·ml^{-1}, which are about 5-40% (transect samples) or 180% (Maxwell Bay samples) of the phytoplankton carbon biomass. The large variation (5-180%) of the relative biomass was due primarily to the changes of the phytoplankton biomass, instead of the bacterial biomass. For example, bacterial biomass did not vary much along the transects, while there was a tendency that phytoplankton biomass increased in the northern part of the transects. No clear trend of parallel fluctuations between the bacterial biomass and the phytoplankton biomass implies the uncoupling between the two.

Key words: bacterioplankton, cell abundance, carbon biomass, distribution

INTRODUCTION

Understanding of the Antarctic ecosystems recently became one of the major research objectives with the growing concerns about global environmental issues (Smith *et al.*, 1992). In order to study an ecosystem, one would first examine the structure and functions of the ecosystem components underlying the food chain. Over the past two decades, roles of planktonic bacteria have come close to our attention. Heterotrophic activities of bacterioplankton are now understood as an important process of the material cycle and energy flow in the marine food web (Azam *et al.*, 1983; Fuhrman, 1992).

Bacterioplankton in the Antarctic ecosystems would probably do the functions similar to those in other oceans, however environmental features, e.g., frigid temperature and ice melting, of the Antarctic seas may affect or modify the bacterial roles in this region. From a limited number of studies done in the Antarctic seas, structure and functions of the microbial compartment have begun to be documented (Fuhrman and Azam, 1980; Hodson *et al.*, 1981; Karl *et al.*, 1991).

Bacterial activities and biomass in the Antarctic seas, like in other oceans, vary with the changes of environmental or phytoplankton parameters (Karl *et al.*, 1991; and references therein). Among the parameters, primary production and standing stock (presented as chlorophyll amount or carbon biomass), and seawater temperature are known to affect the bacterial abundance and activity most significantly (Fuhrman *et al.*, 1980; Joint and Pom-

roy, 1987; Karl *et al.*, 1991). These parameters seem to control the bacterial dynamics in general, since heterotrophic bacteria ultimately derive their food from the primary productions, and temperature definitely affects biological activities. However, under certain circumstances, this paradigm turns into an apparent controversy; for example, bacterial biomass and activities in an Antarctic sea did not show a covariation with phytoplankton parameters (Karl *et al.*, 1991).

In order to understand the microbial role in an ecosystem, one would first need to examine the distribution patterns or biomass of bacteria in relation to other physicochemical or phytoplankton parameters. Abundance of bacteria in various regions of the Antarctic seas showed a broad range, in the order of from 10^4 to 10^6 cells·ml^{-1}, being almost comparable to the bacterial abundance in other world oceans (Fuhrman and Azam, 1980; Hodson *et al.*, 1981; Karl *et al.*, 1991; Kim, 1991). Bacterial heterotrophic activities or productions measured in Antarctic seas also showed a large variation over space and time (Fuhrman and Azam, 1980; Hodson *et al.*, 1981; Karl *et al.*, 1991; Bird and Karl, 1991; Kim, 1991). Micro- or meso-scale variation of environmental parameters would probably have caused the large variation. The environmental parameters that affect individual bacterial species would also change the community structure of the species composition (Lee and Fuhrman, 1991). Changes of species composition may subsequently result in the community-level changes of physiological or metabolic activities.

As a part of the 6th KARP (Korean Antarctic Research Program) cruise, a relatively narrow area in the southern Bransfield Strait was studied in two weeks. Bacterioplankton samples were collected from surface waters (< 100 m depth) along 2 parallel 200-km transects spanning from continental shelf to an open ocean (Drake Passage), crossing shelf break and island shelves. This study examined the abundance of bacteria and distribution of bacterial biomass in relation to temperature, inorganic nutrients, chlorophyll a, and phytoplankton biomass.

MATERIALS AND METHODS

Maxwell Bay samples (n=10) were collected from a pebble beach (62°14′ S, 58°45′ W) at depths < 1 m over a week, using clean plastic bottles. The two north-south transects and the sampling locations along the transects are presented in detail in Fig. 3 of Kang *et al.* (1994) in this volume. Transect samples were collected from 3 depths in the surface mixed layer, just above the thermocline determined from the CTD profile. Seawater samples were preserved immediately (in <30 min) with 1% (by vol) Formalin, and stored at < 4°C until the preparation of microscope slides.

Bacterial cell abundance was determined by DAPI direct count method (Porter and Feig, 1980). In brief, bacterial cells stained with 4′, 6-diamidino-2-phenylindole (final conc. 10 μg/ml) were collected on black-stained Nuclepore filters (0.2 μm pore-size; Costar, Cambridge, MA, USA). Cells on the Nuclepore filter discs were enumerated by epifluorescence microscopy. Bacterial carbon biomass was estimated from the cell count using the biomass conversion factor reported by Lee and Fuhrman (1987). Bacterial carbon biomass in the surface mixed layer was integrated from the 3 depths, and compared to that of the phytoplankton in the surface mixed layer. Methods for the estimation of the phytoplankton biomass are presented elsewhere in this volume (Kang *et al.*, 1994).

Chlorophyll a, nitrate, and phosphate concentrations were measured from the sampled seawater. Methods for the measurements are presented in detail elsewhere in this volume (Chung *et al.*, 1994). Relationships of the bacterial cell abundance to the other parameters, such as temperature, chlorophyll a, nitrate, and phosphate, were examined via the analysis of product-moment correlation coefficients (Sokal and Rohlf, 1981).

RESULTS AND DISCUSSION

Bacterial cell abundance showed a strong correlation to temperature (Fig. 1A). The correlation was significant at $P < 0.01$. The temperature dependency of bacterial abundance and activity was observed previously by others in areas other than Antarctic seas (Fuhrman *et al.*, 1980; Joint and Pomroy; 1987). Figure 1B presents the relationship obtained from a year-round study at a temperate coastal region, Long Island Sound, in 1986. The correlation from a coastal water (Fig. 1B) was

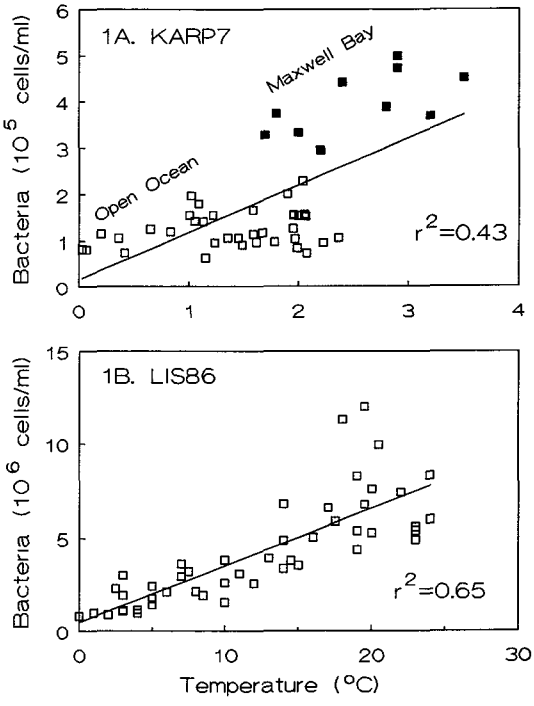

Fig. 1. Relationships between bacterial abundance and seawater temperature. Panel A presents the Antarctic samples (open squares for the open ocean transect samples; filled squares for the Maxwell Bay samples). Panel B presents year-round data from Long Island Sound in 1986. r^2 values are given in the panels (significant, $P < 0.01$).

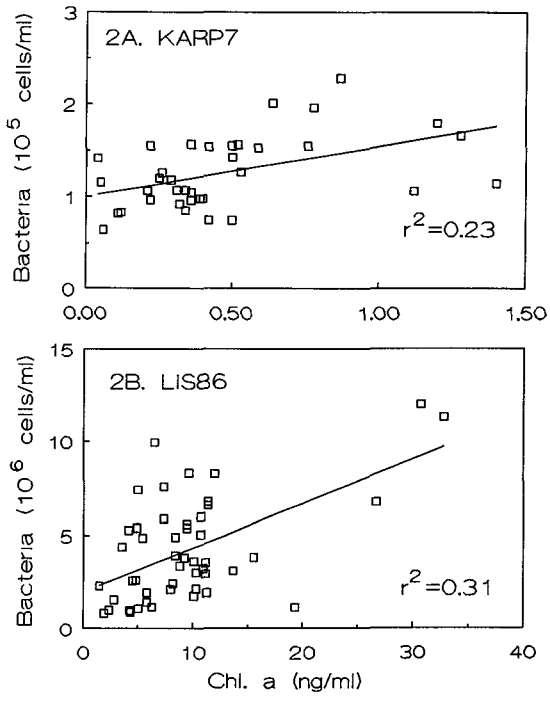

Fig. 2. Relationships between bacterial abundance and chlorophyll a concentration. Panel A presents the Antarctic samples. Panel B presents year-round data from Long Island Sound in 1986. r^2 values are given in the panels (significant, $P < 0.01$).

stronger than that from the Antarctic seas (Fig. 1A), while both of the correlations are significant at $P < 0.01$.

The narrow temperature range in Fig. 1A (0-3.5 °C) as compared to the temperature range of Fig. 1B (0-25°C) may have caused the slightly weaker correlation in Fig. 1A, which could be regarded as a statistical artifact. However, the temperature-abundance correlation becomes further weaker at an even lower temperature range. Temperature of the open ocean samples (open squares in Fig. 1A) ranged 0-2.5°C. Interestingly, when the Maxwell Bay samples in Fig. 1A were excluded from the correlation analysis, the open ocean samples showed no significant correlation ($r^2 = 0.06$) to temperature. Bacterial abundance does seem to be related to temperature, however the abundance did not vary significantly with temperature of a very low level. Biological activities may not vary substantially when temperatures are very low, and this may result in the rather constant cell abundances.

Figure 2 shows the relationships between the bacterial abundance and photosynthetic pigment, chlorophyll a. Again, there were significant correlations ($P < 0.01$) between the two parameters in both the Antarctic samples (Fig. 2A) and the 1986 Long Island Sound samples (Fig. 2B). Since heterotrophic bacteria derive their food from the primary production, bacterial abundance and activity would be closely related to the photosynthetic pigment. Chlorophyll dependency of bacterial abundance and activity was reported previously in other ecosystems and Antarctic seas as well (Fuhrman *et al.*, 1980; Karl *et al.*, 1991). It is noteworthy that the correlations of bacterial abundance to chlorophyll a (Fig. 2) are weaker than those to temperature (Fig. 1), despite the seemingly immediate interactions between the food source (presented by the pigment) and the consumer (bacteria).

Both nitrate and phosphate concentrations were

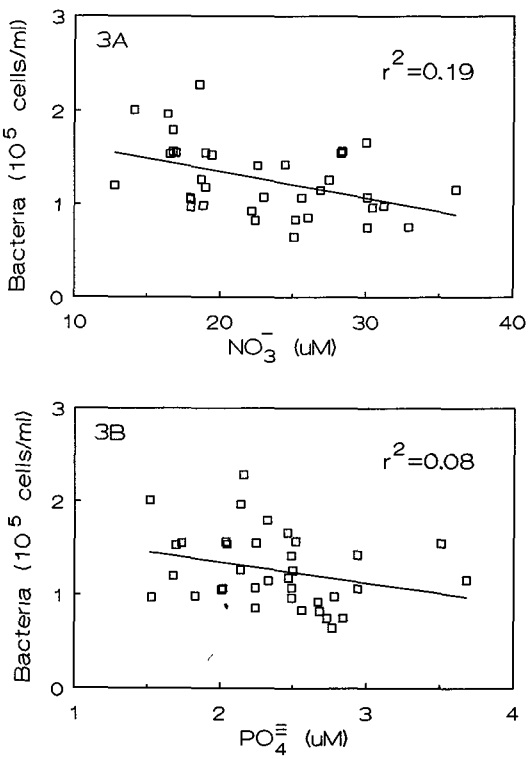

Fig. 3. Relationships between bacterial abundance and inorganic nutrients. Panel A and B present NO_3 and PO_4, respectively. r^2 values are given in the panels (panel A; significant, $P < 0.01$). Correlation to PO_4 is the only one not significant at $P < 0.05$.

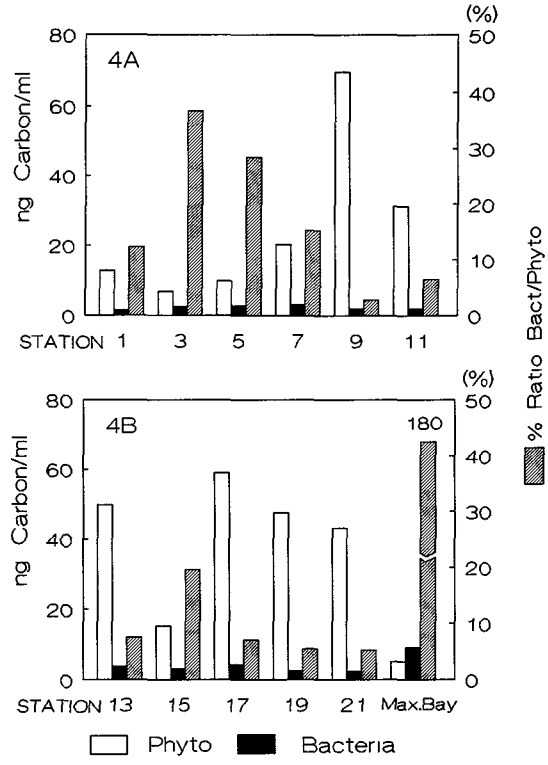

Fig. 4. Distributions of bacterial biomass (filled bar) and phytoplankton biomass (open bar). Ratio of bacterial biomass to phytoplankton biomass (shaded bar) is presented as percentage (%) with the scale at right-side Y axis. Panel A shows the transect 1 samples. Panel B shows the transect 2 and Maxwell Bay samples. Stations 1 and 13 are Gerlache Strait side (South), and stations 11 and 21 are Drake Passage side (North).

negatively related to bacterial abundance (Fig. 3). However, the correlation to the phosphate concentration was not significant. Fuhrman *et al.* (1980) also reported that nitrate concentration was negatively related to bacterial abundance and activity, and primary production. This negative relationship could be interpreted in general as a result of phytoplankton dynamics; active consumption of the inorganic nutrient by primary producers lowers the concentration of the inorganic nutrient, and leads to the increase of the bacterial abundance and activity, and primary production. The reason phosphate was not significantly correlated is currently unclear. It needs further investigations.

Bacterial carbon biomass of the open ocean transect samples were relatively constant along the transects (Fig. 4). Bacterial biomass of Maxwell Bay samples was ca. 3-4 times higher than the bacterial biomass measured in the open ocean (Fig. 4B). Being compared to the variation of the bacterial carbon biomass (2-10 ng·C·ml^{-1}), phytoplankton carbon biomass showed a larger (> 10 fold) variation (5-70 ng·C·ml^{-1}). In addition, bacterial biomass did not covary with the phytoplankton biomass, i.e., there was no significant correlation between the two biomasses. No simultaneous change of the bacterial biomass and phytoplankton biomass implies the 'time lag' or 'phase out' between the two. Due to lack of data from rate measurements (e.g., productions) and the relatively short study period, it is currently unclear why the uncoupling would occur. Similar observations of the uncoupling were made by others (Karl *et al.*, 1991; Bird and Karl, 1991) in the area close to the current one. One can only speculate the possible reasons

presently, however Bird and Karl (1991) suggested that a differential effect of temperature on the activities of the two organismal groups, bacteria and planktonic algae, may produce the time lag between their dynamics. Different community structures of species composition may result in different behaviors or responses to some extent under different environmental conditions (Lee and Fuhrman, 1991).

Unlike the open ocean where bacterial carbon biomass was only 5-40% of phytoplankton biomass, samples from Maxwell Bay showed the bacterial biomass consistently higher than the phytoplankton biomass, being almost twice of the phytoplankton biomass (Fig. 4B). Maxwell Bay data presented in Fig. 4B are means of 10 observations made over a week. The consistently high biomass of bacterioplankton despite the low phytoplankton biomass implies a different or additional source of organic material, for example, a detrital food chain in Antarctic coastal waters seasonally developed during the austral summer (Ahn *et al.*, 1994).

Relationships of the bacterial abundance and biomass to the other measured parameters in the Antarctic seas showed patterns similar to those observed in other marine environments. Correlation of the cell abundance to temperature was stronger than the correlation to chlorophyll a or phytoplankton biomass. However, the correlation to temperature became insignificant at very low temperatures. Uncoupling between the dynamics of bacterioplankton and phytoplankton is intriguing, and it needs further examinations. This study provides an overview for the bacterioplankton biomass and distributions, and their interactions to phytoplankton and related parameters in an Antarctic marine ecosystem.

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REFERENCES

Ahn, I.-Y., J.-S. Kang and S.-H. Kang. 1993. Primary food sources for shallow-water benthic fauna in Marian Cove, King George Island during an austral summer. *Korean J. Polar Res.* **4:** 67-72.

Azam, F., T. Fenchel, J.G. Gray, L.A. Meyer-Reil and T. Thingstad. 1983. The ecological role of water-column microbes in the sea. *Mar. Ecol. Prog. Ser.* **10:** 257-263.

Bird, D.F. and D.M. Karl. 1991. Spatial patterns of glutamate and thymidine assimilation in Bransfield Strait, Antarctica during and following the austral spring bloom. *Deep-sea Res.* **38:** 1057-1075.

Chung, C.S., G.H. Hong, D.-J. Kang, S.H. Kim, S.-H. Kang and M.-S. Suk. 1994. Distribution and dynamics of dissolved inorganic nutrients in the Bransfield Strait, Antarctica during austral summer 1993. *Korean J. Polar Res.* **4:** 1-10.

Fuhrman, J.A. 1992. Bacterioplankton roles in cycling of organic matter: The microbial food web. *In*, Falkowski, P.G. and A.D. Woodhead (eds.), Primary productivity and biogeochemical cycles in the sea. Plenum Press, New York. pp. 361-383.

Fuhrman, J.A. and F. Azam. 1980. Bacterioplankton secondary production estimates for coastal waters of British Columbia, Antarctica, and California. *Appl. Environ. Microbiol.* **39:** 1085-1095.

Fuhrman, J.A., J.W. Ammerman and F. Azam. 1980. Bacterioplankton in the coastal euphotic zone: Distribution, activity and possible relationships with phytoplankton. *Mar. Biol.* **60:** 201-207.

Hodson, R.E., F. Azam, A.F. Carlucci, J.A. Fuhrman, D.M. Karl and O. Holm-Hansen. 1981. Microbial uptake of dissolved organic matter in McMurdo Sound, Antarctica. *Mar. Biol.* **61:** 89-94.

Joint, I.R. and A.J. Pomroy. 1987. Activity of heterotrophic bacteria in the euphotic zone of the celtic sea. Mar. *Ecol. Prog. Ser.* **41:** 155-165.

Kang, S.-H., M.S. Suk, C.S. Chung, S.Y. Nam and C.Y. Kang. 1994. Phytoplankton populations in the western Bransfield Strait and the southern Drake Passage, Antarctica. *Korean J. Polar Res.* **4:** 29-43.

Karl, D.M., O. Holm-Hansen, G.T. Taylor, G. Tien and D.F. Bird. 1991. Microbial biomass and productivity in the western Bransfield Strait, Antarctica during 1986-87 austral summer. *Deep-Sea Res.* **38:** 1029-1055.

Kim, S.-J. 1991. Bacterial number, heterotrophy and extracellular enzyme activity in the Bransfield Strait. *Korean J. Polar Res.* **2:** 9-16.

Lee, S. and J.A. Fuhrman. 1987. Relationships between biovolume and biomass of naturally derived marine bacterioplankton. *Appl. Environ. Microbiol.* **53:** 1298-

1303.

Lee, S. and J.A. Fuhrman. 1991. Spatial and temporal variation of natural bacterioplankton assemblages studied by total genomic DNA cross-hybridization. *Limnol. Oceanogr.* **36:** 1277-1287.

Porter, K.G. and Y.S. Feig. 1980. The use of DAPI for identifying and counting aquatic microflora. *Limnol. Oceanogr.* **25:** 943-948.

Smith, R.C., B.B. Prézelin, K.S. Baker, R.R. Bidigare, N.P. Boucher, T. Coley, D. Karentz, S. MacIntyre, H.A. Matlick, D. Menzies, M. Ondrusek, Z. Wan and K.J. Waters. 1992. Ozone depletion: Ultraviolet radiation and phytoplankton biology in Antarctic waters. *Science* **255:** 952-959.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. W. H. Freeman, New York. 859 pp.