availability, possibly as an adaptive response to low-light conditions.

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Bacterioplankton abundance and productivity at the ice-edge zone of McMurdo Sound, Antarctica

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The ice edge is a transition zone from land fast ice or dense pack ice to open water. These are regions of intense biological activity (see reviews by Smith and Nelson 1986; Smith 1987; Sullivan and Ainley 1987). The ice edge has been extensively studied in the Weddell Sea, however, the McMurdo Sound ice edge has, for the most part, been neglected. Several hydrographic studies have suggested that there is a southerly net nontidal flow of water along the east side of McMurdo Sound and a northerly counter current along the western side of the sound (Barry 1988; Barry and Dayton 1988). This southerly flow typically transports *Phaeocystis* sp. from the Ross Sea into McMurdo Sound in mid to late December. This delivery of allochthonous phytoplanktonic biomass may account for the rich benthic faunal assemblage on the east side of McMurdo Sound (Dayton and Oliver 1977) and may sustain heterotrophic food chains throughout the aphotic austral winter (Rivkin in press).

Metazoan and protozoan zooplankton and the planktotrophic larvae of numerous antarctic benthic invertebrates have been identified from McMurdo Sound (Foster 1987, 1989). These grazers require sufficient nutritional resources for growth and development. High-latitude regions, such as McMurdo Sound, are characterized by highly seasonal yet persistently low phytoplankton biomass (Bunt and Lee 1970; Rivkin in press). Our study was a part of a multidisciplinary study of the ecology and nutrition of polar and temperate planktotrophic echinoderm larvae, and we measured the abundance and rates of production of potential autotrophic and heterotrophic prey. These and other invertebrate larvae from temperate and high-latitude regions appear to ingest both phytoplankton and bacterioplankton as potential food resources. Here, we report on the distribution of bacterioplankton and phytoplankton at the ice edge during the late austral spring and early summer, prior to the delivery of *Phaeocystis* sp. into McMurdo Sound.

Vertical profiles of planktonic biomass were collected during late October and late November 1989 at four stations along an east-west transect at the ice edge (figure 1). These samples were immediately returned to our field station for processing. Chlorophyll *a* was measured fluorometrically after extracting, in 90 percent acetone, the particulate material collected onto Whatman GF/F filters. Bacteria were preserved in glutaraldehyde (1 percent final concentration) and abundances were measured by counting cells stained with acridine orange using epifuorescence microscopy (Hobbie, Daley, and Jasper 1977).

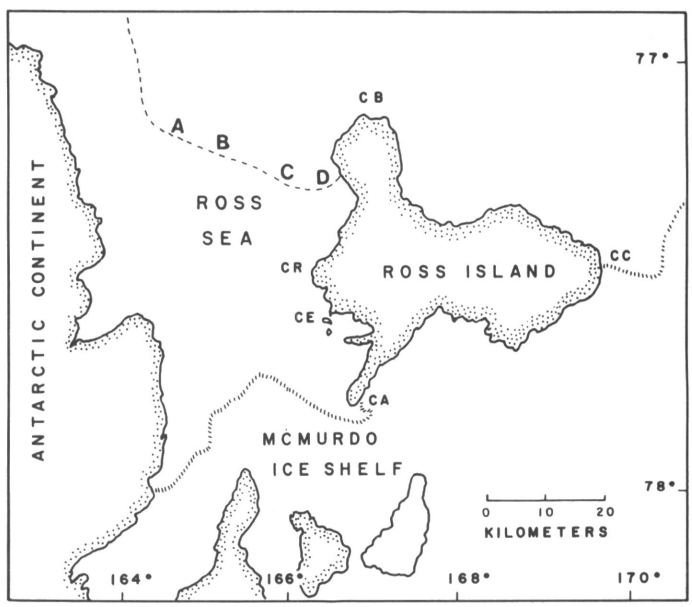

Figure 1. Map of McMurdo Sound, Antarctica, showing the location of the ice edge stations A, B, C, and D. (Other geographic features: CA denotes Cape Armitage, CB denotes Cape Bird, CC denotes Cape Crozier, CE denotes Cape Evans, and CR denotes Cape Royds.)

Bacterial production was determined by measuring the incorporation of methyl-tritiated thymidine (^{3}H-TdR; specific activity equals 40–60 curies per millimole thymidine) which was added at a final concentration of 5–8 nanomoles per liter. The incorporation of ^{3}H-TdR was related to bacterial growth by the logistic growth equation. The conversion factors equating substrate uptake to cells produced were determined frequently throughout the season (Rivkin et al. 1989).

Chlorophyll *a* was greater on the western than eastern side of the sound and greater in late October than late November (figure 2). Areal chlorophyll *a* concentrations ranged from 3 to 21 milligrams per square meter (integrated to 100 meters) and these were 5 to 100 times greater than measured during the same period in the sub-ice plankton community near McMurdo Station.

At all stations, the distribution of bacteria was vertically uniform within the upper 100 meters. Bacterial abundance and productivity increased over the season at all stations except station B. The heterotrophic activity (TdR incorporation and bacterial abundances) was substantially greater on the western side of the Sound, especially in late October (figure 3). The areal abundances of bacteria at the ice edge were 2×10^{12} to 7×10^{12} per square meter (integrated to 100 meters). This is similar to that reported for the sub-ice community during the austral spring in McMurdo Sound (Rivkin et al. 1989).

On an areal basis, phytoplankton biomass was 5 to 15 times greater than bacterial biomass. There was approximately 22 to

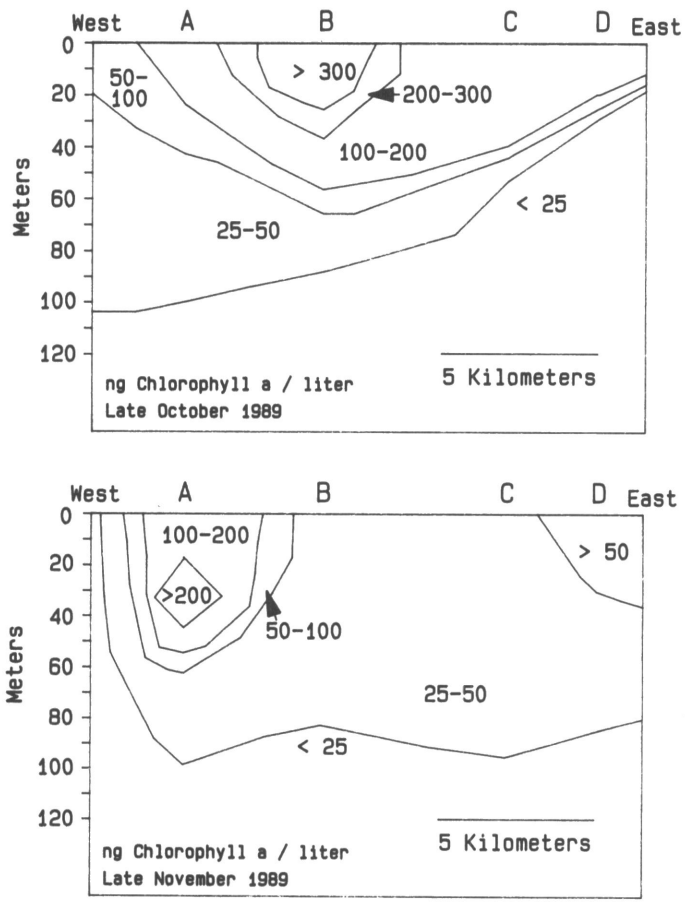

Figure 2. Two dimensional isopleths of chlorophyll *a* (nanograms per liter) during the last weeks of October (upper panel) and November (lower panel) 1989. During both sampling periods, chlorophyll *a* was greater on the western side of McMurdo Sound.

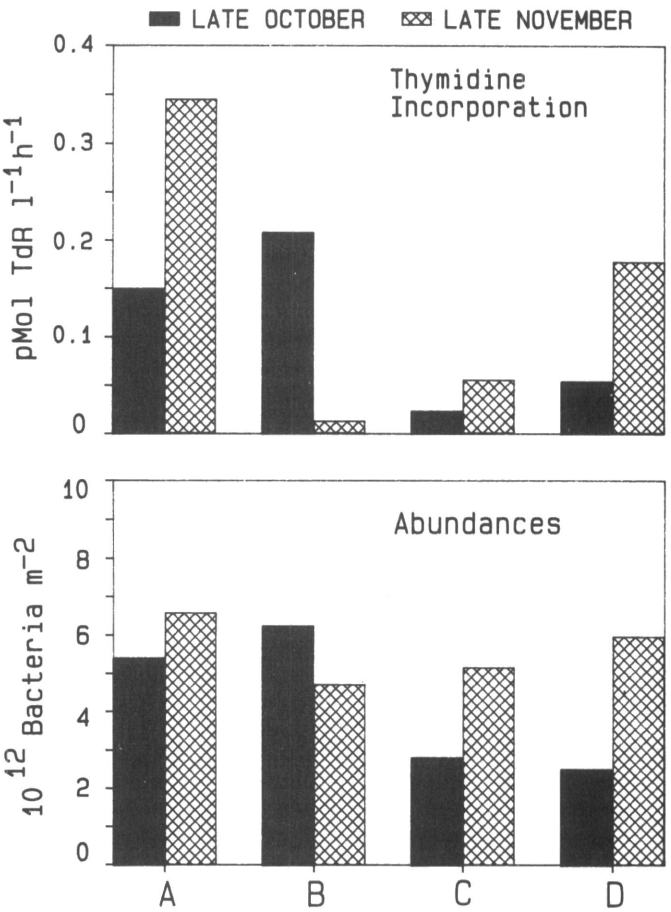

Figure 3. Upper panel: Tritiated thymidine incorporation rates (picomoles per liter per hour) for bacterioplankton collected at the ice edge during late October (solid bars) and late November (cross hatched bars) 1989. Samples were collected from 40 meters and bacterial distributions were vertically uniform at all stations. Lower panel: Areal bacterial abundances (cells per square meter; integrated to 100 meters) at the ice edge during late October (solid bars) and late November (cross hatched bars) 1989. Stations are denoted by the letters A-D. Please see figure 1 for the station locations. The average coefficient of variation for thymidine incorporation and bacterial abundances were less than 2 percent and approximately 15 percent, respectively. (pMole denotes picomole. l^{-1} h^{-1} denotes per liter per hour. m^{-2} denotes per square meter.)

55 milligrams bacterial carbon per square meter (assuming 8.3 femtograms carbon per cell; Fuhrman and Azam 1980) compared with approximately 120 to 800 milligrams phytoplankton carbon per square meter (assuming a 40-to-1 carbon-to-chlorophyll *a* ratio; Geider and Platt 1986).

Concurrent with an increase in bacterial and autotrophic production during the early summer, the planktotrophic echinoderm larva *Odontaster validus* collected from the ice edge appeared to develop a functional gut (Basch personal communication). Feeding in these larvae may be temporally phased to coincide with the development of the microbial community.

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The fate of bacterial production in McMurdo Sound in the austral spring

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The abundance of bacteria in the plankton under the annual sea ice in McMurdo Sound is low and increases slowly by five- to tenfold over the austral spring (Kottmeier, McGrath Grossi, and Sullivan 1987; Rivkin in press). Several explanations for this can be postulated (Pace 1988; Wright, Coffin, and Lebo 1987). First, bacterial growth may be limited by low temperatures (Pomeroy and Deibel 1986; Wright and Coffin 1983) or by substrate availability (Kirchman, Ducklow, and Mitchell 1982; Wright and Coffin 1984) and, hence, they may be growing very slowly. Second, rates of bacterial production may be balanced by loss rates (Pace 1988). The primary loss processes are bacterivory by proto- and meta-zooplankton and/or viral lysis (Pace 1988; Proctor and Fuhrman 1990).

As part of a project examining the nutrition of planktotrophic echinoderm larvae in antarctic and temperate regions, we measured the abundance and production of potential prey for the larvae. Because phytoplankton biomass and primary production are very low during the austral spring (Rivkin in press), bacteria may provide an important food source for these grazers. To assess the relative importance of bacteria as larval food, it is necessary to know not only the abundance of potential prey but also the rate at which prey biomass is produced. This is particularly true for organisms with generation times on the order of hours or days. Here, we report bacterial division rates during the austral spring, and we calculate the potential loss to bacterivores at our field site located 8 kilometers north of Hut Point, near McMurdo Station.

The water column depth at the field site was 40 meters and was well mixed (Rivkin unpublished data). Bacterial abundances were uniform over the water column for the entire season (figure 1). Bacterial samples were collected from the mid-point of the water column (20 meters) to measure division

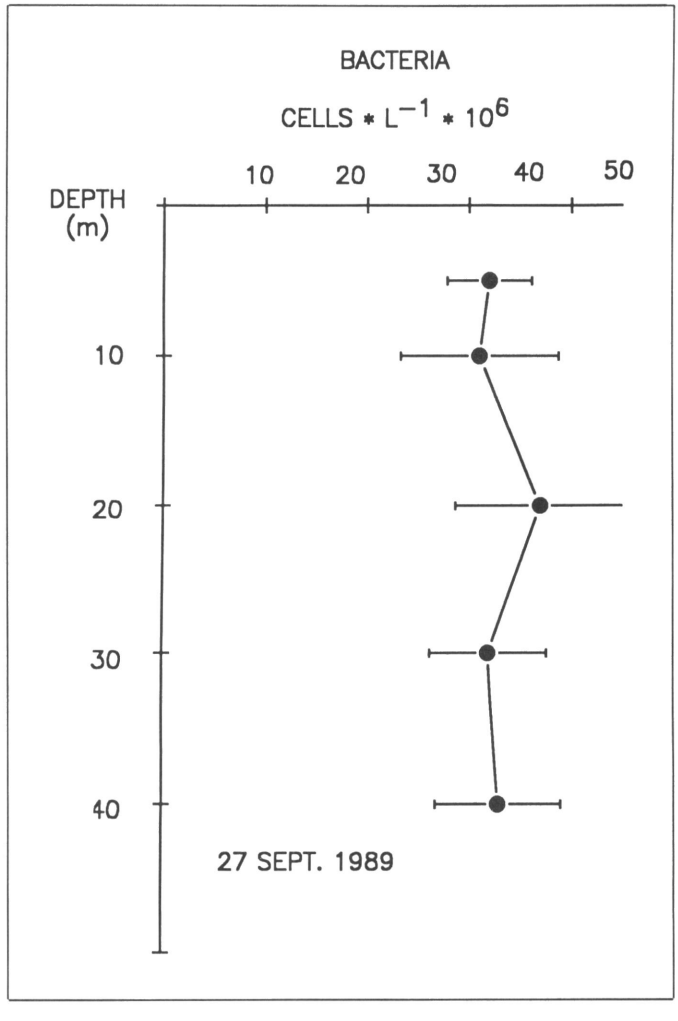

Figure 1. Representative vertical profile of bacteria (cells per liter × 10^6) at our field site in McMurdo Sound. Error bars are ± one standard error (s). (m denotes meter.)