RACER: Bacterial growth, abundance, and loss due to protozoan grazing during the 1989 spring bloom

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An understanding of the ecology of the nanoplankton (organisms in the size range of approximately 2–20 micrometers) and picoplankton (organisms less than approximately 1–2 micrometers) in aquatic systems is now recognized to be crucial for an understanding of the dynamics of the system as a whole. The Research on Antarctic Coastal Ecosystem Rates (RACER) program (Huntley et al. 1987) was initially designed to study ecosystem dynamics and their relationships to ocean physics. In that framework, we attempted to identify and quantify major routes of carbon flow in the system by measuring phytoplankton and bacterial community sizes and production rates, abundance, and distribution of metazoans, and the loss of particulate matter by solubilization, grazing, respiration, and sedimentation processes.

A major missing link in this initial RACER carbon budget was the transfer of bacterial and algal production to protozoan consumers. Earlier studies suggested that this is a potentially dominant pathway that has been overlooked in antarctic waters (Buck and Garrison 1983; Hewes, Holm-Hansen, and Sakshaug 1985; Taylor and Haberstroh 1988). Here, we present preliminary data from experiments designed to assess the importance of this link to microbiological dynamics in the Gerlache strait during early stages of the 1989 austral spring bloom.

Microbial community size and composition at each station of the four fast grids (Huntley et al., *Antarctic Journal*, this issue) were determined directly using epifluorescence microscopy (Porter and Feig 1980; Haas 1982). Each determination included bacterial abundance and cell size, heterotrophic nanoflagellate and ciliate abundance, and phytoplankton community abundance and composition. Between fast grids, predation and growth-rate experiments were conducted using the community dilution method (Landry and Hassett 1982). At the same time, feeding rates were determined directly using fluorescently labeled natural bacteria (Sherr, Sherr, and Fallon 1987). Alternatively, we also took advantage of the apparent lack of picophytoplankton in the waters near the Antarctic Peninsula (Letelier and Karl 1989) to measure clearance rates of protozoa by adding *Synechococcus* cells.

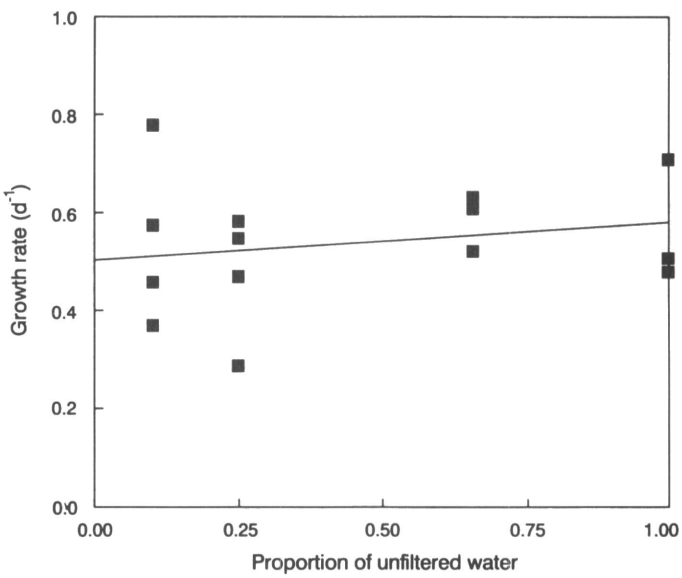
Despite the presence of a large and productive plankton community in many areas within the Gerlache Strait (Tien et al., *Antarctic Journal*, this issue), bacterial abundance was low at the beginning of the study period (beginning mean = 0.25×10^6 (range 0.15 to 0.45) cells per milliliter) and increased gradually during the development of the bloom (final mean = 0.35×10^6 (range 0.17 to 0.77) cells per milliliter). The geographic distribution of bacterial cell abundance did not correspond to the spatial patterns observed for total microbial biomass (Tien et al., *Antarctic Journal*, this issue) or phytoplankton (Holm-Hansen personal communication). This lack of a straightforward numerical relation between algae and bacteria confirms similar observations made during RACER I (Bird and Karl in press; Karl et al. in press).

Abundance of the postulated major predators on bacteria, the heterotrophic nanoflagellates, was also low at the start of the study (mean = 560 cells per milliliter) and consisted of large-bodied species that were ingesting small phytoplankton (centric diatoms and cryptomonads) in addition to bacteria. By the end of the study, a month later, the heterotrophic nanoflagellate community had grown tenfold in abundance and now contained many choanoflagellates, specialists in bacterial predation previously identified as a major component of ice-edge communities (Buck and Garrison 1983).

The ciliate community also grew rapidly in abundance over the course of the RACER II cruise. The community was dominated by large-bodied, naked ciliates that were feeding on the abundant, 12–20-micrometer diameter centric diatoms. The ciliates appeared to be surprisingly versatile feeders, however. Individual cells were seen to contain large (10–30 micrometers) centric and pennate diatoms and 4-micrometer *Phaeocystis* cells in addition to the recently ingested fluorescently labeled bacteria (>1 micrometer).

During the early part of November, there was little evidence that grazing had an impact on bacterial biomass and productivity (figure). Bacterial community growth rate showed no response to sample dilution (*sensu* Landry and Hassett 1982), despite the sizable growth rate observed (mean = 0.54 per day). Experimental evidence relating the effect of container size on growth rate provided support for the dilution protocol, suggesting that the apparent discrepancy between growth and grazing loss was genuine. If this result is confirmed following examination of the results from our direct feeding experiments, we must look beyond protozoan grazing for other factors which might be controlling bacterial abundance.

Finally, incubation experiments indicated that the bacteria probably depend directly on contemporaneous primary production for growth at this time of year. Dark incubations of



Exponential growth rate of Gerlache Strait bacteria at different dilutions during 30-hour incubations, 7–8 November 1989. If there was a strong effect of grazers on the bacteria, then growth rates at higher dilutions (to the left on the graph) should be greater than rates where grazers were undiluted (to the right). For these data there was no effect of dilution on growth rate, suggesting that grazing was not controlling population size at this sampling period. (d^{-1} denotes per day.)

unamended water led to slow decline in bacterial abundance, whereas growth was rapid in lighted controls. Using these results in combination with data derived from the radioisotope uptake experiments, we hope to determine whether the current notion that bacterial population size is determined by nutrient supply rate, and production by grazing loss rate, is applicable to antarctic bacteria.

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RACER: Fine-scale and mesoscale zooplankton studies during the spring bloom, 1989

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By comparison to other nearshore areas of the Antarctic Peninsula, the Gerlache Strait can support unusually large standing stocks of macrozooplankton, including krill (Hopkins 1985; Brinton and Townsend in press; Huntley and Escritor in press). Huntley and Brinton (in press) postulated that a persistent physical circulation mechanism might be responsible for retaining an abundant population of *Euphausia superba* larvae in the northern Gerlache Strait during summer and early fall. The best estimates of mesoscale circulation in the region, however, can be inferred only from geostrophic calculations based on coarse hydrographic sampling (Niiler, Amos, and Hu in press). Furthermore, the reproduction, development, and growth of zooplankton populations in the Gerlache Strait during spring has never been observed in detail.

Macrozooplankton studies during the 1989 Research on Antarctic Coastal Ecosystem Rates (RACER) were designed to address two key questions:

- Do abundant zooplankton populations accumulate in the Gerlache Strait purely as a result of physical circulation? or
- Do they originate there by virtue of high rates of local reproduction, development and survival in the spring?

To answer these questions effectively, our study required that physical oceanographic measurements be made in conjunction with our observations of macrozooplankton populations. Physical oceanography included assessment of water-mass structure based on frequent and comparatively high-resolution hydrographic surveys throughout the northern Gerlache Strait and western Bransfield Strait (Amos, Jacobs, and Hu, *Antarctic Journal,* this issue), and direct measurements of upper water-column mesoscale circulation obtained from ARGOS-linked Lagrangian drifters (Niiler, Illeman, and Hu, *Antarctic Journal,* this issue).

Macrozooplankton studies were aimed at obtaining information on the vertical and horizontal distribution of species with the highest possible resolution in time and space. Two principal pieces of sampling equipment were used: a "fast net" and a multiple opening and closing net and environmental sensing system (MOCNESS). The fast net is a 1-meter diam-