Culver, M. E. and W. O. Smith. 1989. Effects of environmental variation on sinking rates of marine phytoplankton. *Journal of Phycology*, 25:262-270.
Karl, D. M., G. A. Knauer, and J. H. Martin. 1988. Downward flux of particulate organic matter in the ocean: A particle decomposition paradox. *Nature*, 332:438-441.
Karl, D. M. and V. L. Asper. 1990. RACER: Particle flux measurements during the 1989-1990 austral summer. *Antarctic Journal of the U.S.*, 25(5):167-169.
Karl, D. M., B. D. Tilbrook, and G. Tien. 1991. Seasonal coupling of organic matter production and particle flux in the western Bransfield Strait, Antarctica. *Deep-Sea Research*, 38:1,097-1,126.
Laws, E. A., P. K. Bienfang, D. A. Ziemann, and L. D. Conquest. 1988. Phytoplankton population dynamics and the fate of production during the spring bloom in Auke Bay, Alaska. *Limnology and Oceanography*, 33:57-65.
Nordhausen, W. and M. E. Huntley. 1990. RACER: Carbon egestion rates of *Euphausiasia superba*. *Antarctic Journal of the U.S.*, 25(5):161-162.
Smith, S. V., W. J. Kimmerer, and T. W. Walsh. 1986. Vertical flux and biogeochemical turnover regulate nutrient limitation of net organic production in the North Pacific Gyre. *Limnology and Oceanography*, 31: 161-167.
Smith, W. O. 1987. Phytoplankton dynamics in marginal ice zones. In M. Barnes (Ed.), *Oceanography and marine biology*. 25(annual review):11-38.
Vernet, M. and D. M. Karl. 1990. RACER: Phytoplankton growth and zooplankton grazing in the northern Gerlache Strait estimated from chlorophyll budgets. *Antarctic Journal of the U.S.*, 25(5):164-166.

Exocellular enzyme activities in Gerlache Strait, Antarctica

James R. Christian and David M. Karl

School of Ocean and Earth Science and Technology
University of Hawaii
Honolulu, Hawaii 96822

Most dissolved organic matter (DOM) in seawater consists of polymeric substances that must be hydrolyzed by exocellular enzymes before being assimilated by microorganisms. Techniques for measuring enzyme activities using fluorescent substrate analogs have been in use for several decades but have only recently been applied to marine plankton, and never, to our knowledge, in Antarctica.

During the 1991-1992 austral summer the Research on Antarctic Coastal Ecosystem Rates (RACER) cruise, activities of bacterial exocellular enzymes beta-glucosidase (BGase) and leucine aminopeptidase (LAPase) were measured in the Gerlache Strait. Two fast grids (30 to 40 stations sampled over approximately 72 hours) of surface water samples were taken, and four depth profiles (0 to 200 meters) at station A (64°11.7' S 61°19.5' W).

Because these experiments are conducted at saturating substrate concentration (Hoppe 1983) and the concentration of substrate *in situ* is not known, these results must be considered indices of potential activity rather than estimates of actual activities *in situ*. Enzyme activities are expressed as nanomoles of substrate analog (methylumbelliferyl-beta-glucoside or L-leucyl-beta-naphthylamine) hydrolyzed per liter per day at saturating substrate concentration.

It has been suggested that such potential activity measurements are an index of bacterial biomass rather than growth or activity (Billen et al. 1990). If this is correct, then the potential activities of the two enzymes should be strongly positively correlated. However, an important result of this work is that the activities of these two enzymes are uncoupled in space or time, or both. Across two fast grids of surface samples there is little correlation between the activities of the two enzymes (figure 1). In fast grid B (22 to 25 December) there is only a weak positive correlation between the two ($r^2 = 0.264$, but if the three outlier points, see figure 1a, are removed $r^2 = 0.695$). In fast grid C (27 to 30 December) there is no correlation at all ($r^2 = 0.156$).

Weak correlations beween BGase and LAPase suggest that enzyme activities are not a simple function of bacterial biomass. Our results from Hawaiian waters also show that while there is a positive correlation of enzyme activity with biomass, activity per unit biomass is highly variable.

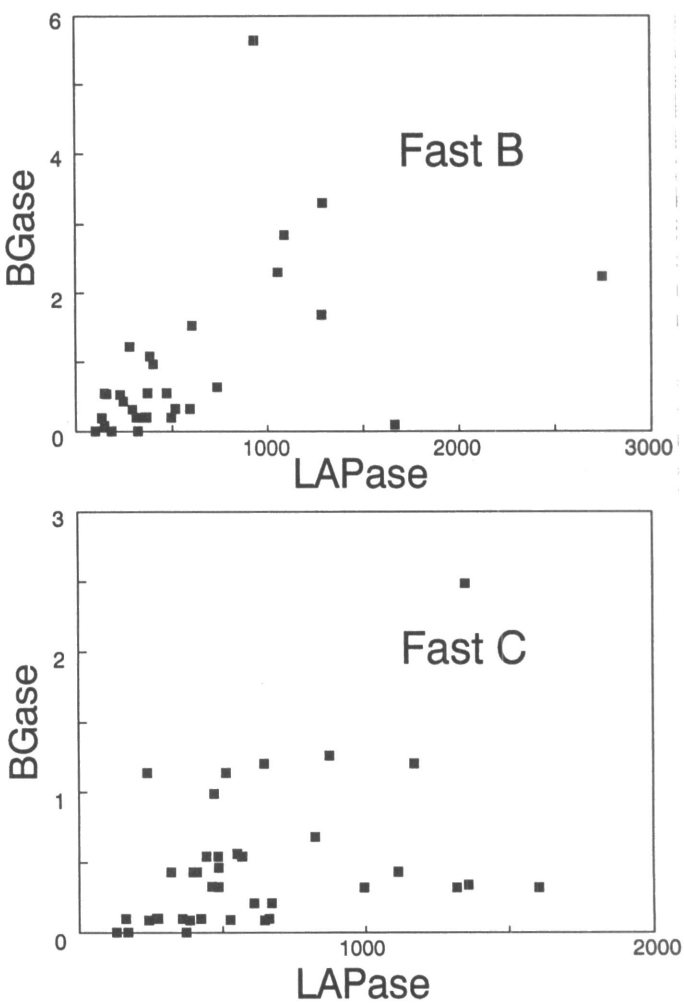

Figure 1. Relationship between the activities of beta-glucosidase (BGase) and leucine aminopeptidase (LAPase) on (top) fast grid B (22 to 25 December 1991) and (bottom) fast grid C (27 to 30 December 1991). Activities are in nanomoles per liter per day.

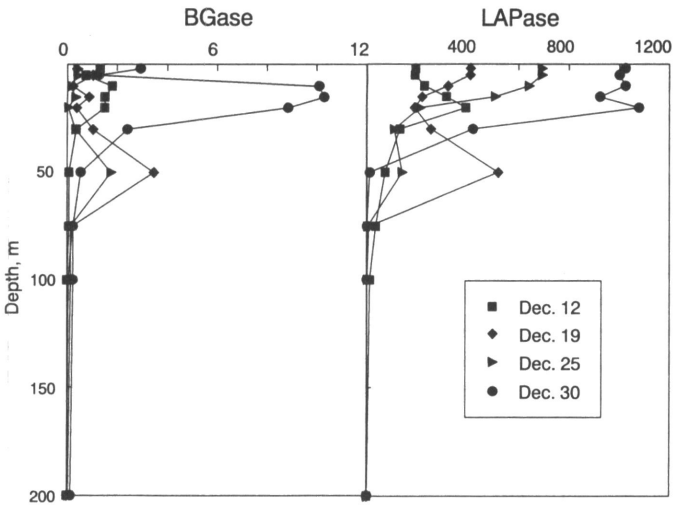

Figure 2. Depth profiles of (*a*) β-glucosidase and (*b*) leucine aminopeptidase (LAPase) activity at station A (64°11.7' S 61°19.5' W). Activities are in nanomoles per liter per day.

Size fractionation of leucine aminopeptidase (LAPase) activities at station A

Depth (m)	LAPase Activity (nmol l^{-1} d^{-1}) <1 um	Total	%<1 um
	2 Dec 1991		
2	185	191	97
5	152	189	81
10	182	228	80
15	287	316	91
20	396	394	101
30	116	131	89
50	88	72	121
75	21	34	61
100	0	12	-
200	0	0	-
	19 Dec 1991		
2	405	423	96
5	308	421	73
10	285	331	86
15	200	227	88
20	177	195	91
30	150	263	57
50	439	538	82
75	8	8	100
100	0	0	-
200	0	0	-

Size fractionation experiments show that most activity is associated with the bacterial size fraction (less than 1 micrometer; see table). However, activities in the unfiltered (202 micrometer screened) samples are usually somewhat greater than those in the less than 1 micrometer fraction. This is most likely due to bacteria attached to particles, but it is also possible that larger eukaryotic algae possess exoenzymes. In the profiles taken at station A on 12 and 19 December the fraction of LAPase activity in the less than 1 micrometer size fraction varied from 57 to 100 percent with a mean of 87 percent for samples from depths less than 100 meters. Size fractionation experiments with BGase were inconclusive due to low activities and correspondingly poor signal-to-noise ratios, but most activity was associated with the less than 1 micrometer size fraction.

The activities of these enzymes are extremely patchy in time and space. Four occupations of station A at intervals of 5 to 7 days show that these enzymes are part of a highly dynamic system (figure 2). On 19 December a large peak in the activities of both enzymes was observed at 50 meters, which was not present on 12 December. A trace of this peak remained on 25 December but had disappeared by 30 December, by which time an even larger peak appeared at less than 20 meters. This pattern is the same for both enzymes, although the overall correlation between the two over all four profiles is weak ($r^2 = 0.489$).

These preliminary results give a brief view into a complex and dynamic system. The profiles taken at station A show that the surface samples taken at the fast grid stations may miss much of the activity. This could alias the spatial pattern since the maximum activity sometimes occurs at or near the surface.

Although there is no single sampling depth at which one could reasonably expect to observe the greatest activity, activities tend to be greatest in the mixed layer (less than 20 meters). The event observed at station A on 19 to 25 December may be due to wind mixing of mixed layer water rich in living cells and organic matter below the euphotic zone where it was trapped when a new pycnocline formed. There were strong winds in Gerlache Strait during the week of 12 to 19 December. It might also be caused by rapid sinking of phytoplankton (Alldredge and Gottschalk 1989). Such events may be an important mechanism for removal from the euphotic zone of primary production in antarctic waters.

We thank the RACER program scientists, R/V *Polar Duke* crew and Antarctic Support Associates personnel for their assistance in sample collection. This research was supported by National Science Foundation grant DPP 88-18889. SOEST Contribution #3132.

References

Alldredge, A. L. and C. C. Gottschalk. 1989. Direct observations of the mass flocculation of diatom blooms: Characteristics, settling velocities and formation of diatom aggregates. *Deep-Sea Research*, 36:159-171.

Billen, G., C. Joiris, L. Meyer-Reil, and H. Lindeboom. 1990. Role of bacteria in the North Sea ecosystem. *Netherlands Journal of Sea Research*, 26:265-293.

Hoppe, H. G. 1983. Significance of exoenzymatic activities in the ecology of brackish water: Measurements by means of methylumbelliferyl substrates. *Marine Ecology Progress Series*, 11:299-308.