Changes in photosynthetic metabolism of sea-ice microalgae during a spring bloom in McMurdo Sound

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Microalgae, primarily diatoms, bloom in the lower layers of coarse-grained congelation ice and platelet ice during the austral spring at McMurdo Sound, Antarctica (Bunt 1964; Palmisano and Sullivan 1983). Our purpose in the 1985–1986 field season was to examine changes in photosynthetic metabolism that occur during the development and decline of the spring bloom of sea-ice microalgae. We have proposed that sea-ice microalgae may serve as a model system for studying growth phase-related changes in physiology of natural populations of microalgae. Because they are physically trapped within the brine channels and pockets that permeate sea ice, a single community may be repetitively sampled throughout the bloom period.

Our seasonal study of photosynthetic metabolism included the following parameters:

- carbon assimilation into crude fractions of protein, lipids, carbohydrates, and small molecular weight metabolites;
- carbon assimilation into specific lipid fractions: neutral lipids, glycolipids, and phospholipids;
- identification of key lipid components by gas chromatography/mass spectrometry;
- photosynthesis/light relationships;
- release of extracellular organic carbon and
- analysis of pigment composition: chlorophylls, carotenoids, and breakdown products.

Detailed studies were conducted in November and December 1985 at two sites on sea ice in McMurdo Sound—Cape Armitage, an area near McMurdo Station where we have a 5-year data base, and near the Erebus Ice Tongue, a site away from the possible influence of McMurdo Station. We found little, if any, difference between these two communities. Standing crops of microalgae, as measured by chlorophyll *a* per square meter, increased steadily through November (figure 1). A peak in algal biomass of about 150 milligrams chlorophyll *a* per square meter was reached by 6 December. Subsequently, algal biomass decreased as the sea ice ablated, then leveled around 21 December as a minor secondary algal bloom was established.

An important finding from our research was that photosynthetic carbon-14 assimilation into specific lipid fractions (neutral lipids, glycolipids, and phospholipids) changed dramatically over the course of the bloom and its decline (figure 2). Early in the bloom in November, neutral lipids were dominant accounting for 54 to 77 percent of the total lipids labeled. In

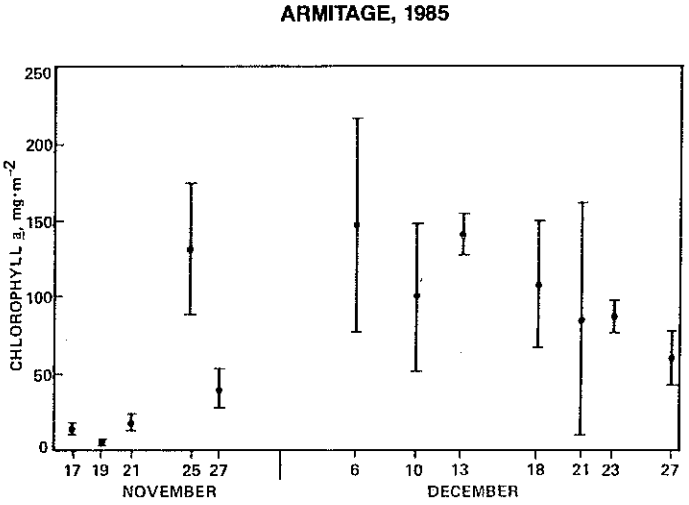

Figure 1. Changes in algal biomass as estimated by chlorophyll *a* per square meter during the spring bloom of sea ice microalgae in McMurdo Sound, November and December 1985. ("mg.m^{2}" denotes "milligrams per square meter.")

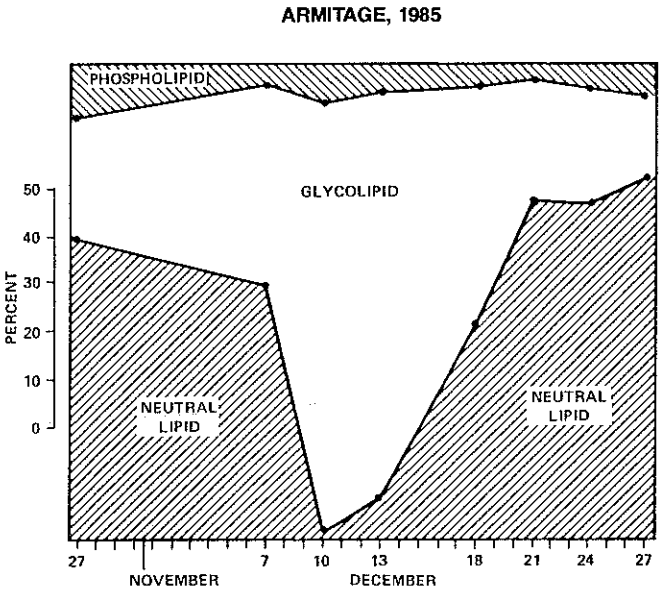

Figure 2. Percentage of total carbon-14-labeled lipids represented by three lipid fractions (neutral lipids, glycolipids, and phospholipids) during the 1985 of sea-ice microalgae. A percentage scale is shown at left.

diatoms, carbon may be stored in the neutral lipid fraction which is comprised primarily of triglycerides. (Nichols et al. in press). As the bloom declined after 6 December, the glycolipid fraction became dominant (70 to 97 percent of the total lipids) primarily due to a decrease in neutral lipids. After a secondary sea-ice algal bloom became established in late December, initial proportions of the three lipid fractions were reestablished. The phospholipid fraction, which includes membrane components, remained constant and low (less than 10 percent of the total lipids) throughout the bloom. To further characterize these lipid fractions, detailed analyses of the lipid biochemistry of sea ice microalgae are currently being performed in the laboratories of David C. White and Peter D. Nichols.

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Photosynthesis by antarctic microalgae

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In the Antarctic, temperature is low (-1.8° C) but constant, and inorganic nutrient concentrations are usually high enough to preclude nutrient limitation. The annual sea ice attenuates a significant proportion of the incident insolation (Sullivan et al. 1983), thus light intensities will regulate the physiology, growth, and ultimately the seasonal succession within microalgal communities. Microalgae inhabit the benthic, planktonic, and the sub-ice epontic environments. The algae within each of these environments experience distinctly different photic regimes. For example, ice (epontic) algae are typically exposed to relatively "high" but constant irradiances. Daily variations in light fields can arise from diel changes in incident insolation and cloud cover. Phytoplankton experience these daily variations, as well as those resulting from vertical movement due to positive buoyancy, sinking, or tidal mixing within the euphotic zone. Thus, phytoplankton may be exposed to relatively large and rapid variations in irradiance. Benthic algae are similar to the ice algae in so far as being exposed to relatively constant albeit "low" irradiance. The average irradiances to which ice algae are exposed are higher than phytoplankton which in turn are higher than benthic algae. The biosynthetic pathways, photosynthesis-irradiance relationships and division rates may be different for microalgae adapted to different photic regimes (Harris 1978; Morris 1981; Prezelin 1981). Reported herein are the irradiance-dependent rates of photosynthesis for individual species of microalgae isolated from epontic, planktonic, and benthic environments. By using high-resolution, single-species techniques (Rivkin and Seliger 1981; Rivkin et al. 1982; Rivkin and Voytek in preparation), the photosynthetic characteristics of algae isolated from natural populations can be examined with almost the same precision as in unialgal laboratory cultures.

During the 1985 austral spring, ice algal and plankton samples were collected at our seasonal field station in McMurdo Sound which was located about 25 kilometers north of Cape Armitage and 9 kilometers west of Tent Island. Phytoplankton were sampled through a 1-meter diameter hole in the 1.5- to 2-meter-thick annual sea ice using a 0.5-meter diameter, 20-micrometer aperture plankton net or a 10-liter Niskin bottle. Ice algae were collected with a 7.5-centimeter diameter SIPRE auger. Benthic algae were collected in 18–22 meters of water off Cape Armitage from the sponge spicule mat and adjacent spicule free areas by scuba divers. Species-specific rates of photosynthesis were measured as previously described (Rivkin and Seliger 1981; Rivkin and Voytek in press).

The photosynthesis irradiance relationships were measured for six species of microalgae isolated from benthic, planktonic, and epontic environments. Microalgae isolated from these different environments had distinct photosynthetic characteristics (table and figure). The benthic algae had a lower saturation irradiance (Isat) and greater initial slope of the light limited region of the P vs. I curve ( ) than the other algae examined (figure A). The Isat of 6 microEinsteins per square meter per second among the lowest ever measured (Platt et al. 1983; Palmisano et al. 1985a, 1985b). Photosynthesis by *Trachynesis aspera* (figure, block A) was sharply photoinhibited above approximately 6–10 microEinsteins per square meter per second. In contrast, carbon uptake by the other benthic alga (*Amphora antarctica*) was photoinhibited above 30 microEinsteins per square meter per second. The Isat of the planktonic microalgae was much higher (more than 50 microEinsteins per square meter per second) and was usually not photoinhibited (table and figure B). An exception to this was *A. kufferathii;* however, this alga (figure, block B) may not be truly planktonic since it was isolated from both the plankton and the sub-ice epontic communities. The photosynthetic characteristics of *A. kufferathii* were similar when isolated from both the epontic and planktonic environments (table). Photosynthesis by the two ice