Project Report
Organic Matter Composition, Recycling Susceptibility, and the Effectiveness of the Biological Pump – An Evaluation Using NMR Spectra of Marine Plankton

The major goal of this project was to document inherent differences in the biochemical makeup of phytoplankton species, and the dependence of these differences on environmental conditions. The degree of organic matter biodegradation and recycling depends on the "reactivity" of compounds synthesized by the biota, which in turn is controlled by the structural characteristics of these compounds. Thus, abundance of a wide-range of organic compounds in seawater would lend itself to different susceptibility for biodegradation, which in turn is important for estimating the potential for rapid regeneration in the euphotic zone and thus the effectiveness of the biological pump. Specifically, C sequestration in the deep ocean (naturally or in response to Fe fertilization) is a function of the amount of C fixed by phytoplankton versus the C regenerated in the euphotic zone. If the regeneration efficiency is maximized, even at high C fixation rates, no net loss will result. A reduction in regeneration within the euphotic zone or decoupling of C from N and P regeneration will increase the effectiveness of the biological pump and C sequestration. Climate and C cycle models treat regeneration as a constant function of depth. If it is shown that regeneration efficiency significantly depends on taxa and/or environmental parameters (e.g. light or temperature), models could be refined and better predictability achieved.

The objective of our proposal was to address these questions by analyzing culture and field samples using ^{13}C and ^{31}P NMR spectroscopy. Samples were first analyzed by solid-state ^{13}C NMR spectroscopy, and then were analyzed for total P, total C and total N. Finally, samples were extracted and analyzed by solution ^{31}P NMR spectroscopy.

Culture Studies

A number of species were grown in culture either by us or for us in other labs. These species included: *Thalassiosira pseudonana* (CCMP 1335), *Symbiodinium* sp. (CCMP 832), *Emiliania huxleyi* (CCMP 2090), *Thalassiosira weissflogii* (CCMP 1051), *Dunaliella tertiolecta* (CCMP 1320), *Chaetoceros muelleri* (CCMP 1316), *Synechococcus* sp. (CCMP 2370), *Synechococcus* sp, *Prochlorococcus* sp., *Trichodesmium* sp. (IMS 101), *Ampera salina, and Imantonia rotunda.* These were grown under a variety of conditions, including low and high temperature stress (and controls), low and high P (and controls), and low and high light (and controls). Not all species were grown under all conditions.

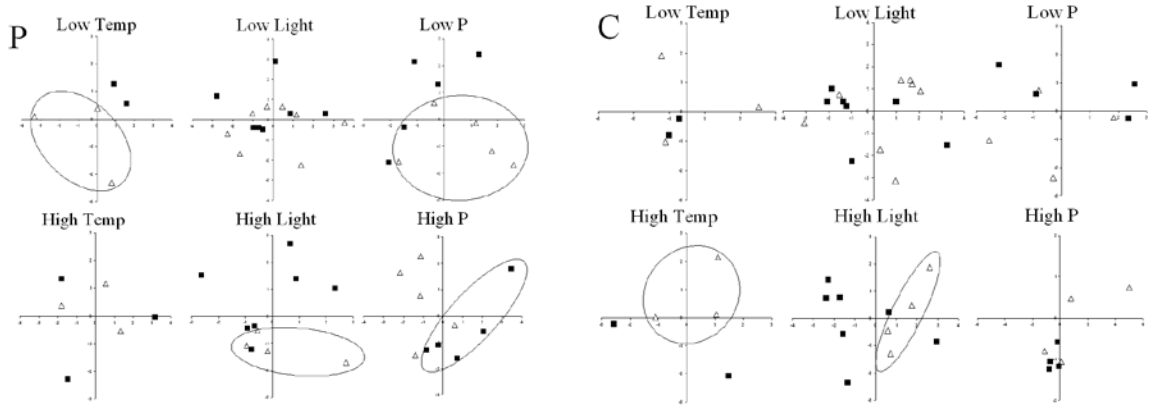

Fig. 1: Principle component analysis of ^{31}P and ^{13}C NMR spectra. Solid squares are controls; open triangles are treatments. Circles indicate significant differences between controls and treatments.

This portion of the research has been completed, and a manuscript is in preparation. As Fig. 1 indicates, there were more significant differences with P forms than with C forms. Low temperature stress produced significant differences in orthophosphate concentration, but no differences in C forms, while high temperature stress resulted in significant differences in C forms (lipids), but no differences in P forms. Low light did not produce significant differences in P or C forms, but high light significantly altered both P and C forms. Both low and high P affected P forms, particularly pyrophosphate and phospholipids, but had no affect on C forms.

Field Studies

We had three main collections of field samples for this study. The first was a compilation of sediment trap and plankton tow samples from throughout the world's oceans to look at spatial and temporal variability in organic matter composition. Bothe temporal and spatial variability were detected and results were published in a manuscript in Marine Chemistry.

The second was a series of plankton tows collected off Barrow Alaska under ice and at ice edge, plus core-top samples from the same region. Unfortunately, these samples were preserved in formalin, so we could not analyze them by ^{13}C NMR spectroscopy. However, we observed some interesting differences in P forms, which were directly related to differences in organisms from the ice-edge bloom Fig. 2). The manuscript for this work is in review in Global and Planetary Change.

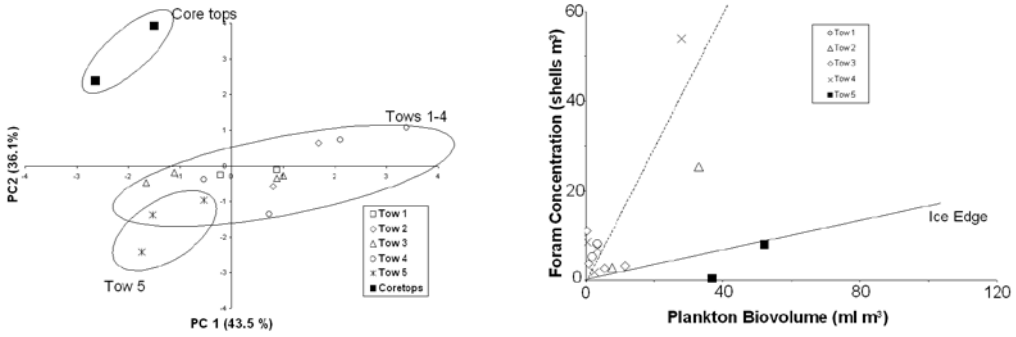

Figure 2: Principle component analysis of ^{31}P NMR spectra plankton tows and core top samples (left) from Alaska. Tow 5, at ice edge, had different species (right), resulting in different P forms from tows collected under ice.

The third set of field samples were collected in Monterey Bay in 2006. Samples were collected seasonally (in Feb., April, June and Sept.) from four mooring locations (C1, M0, M1 and M2). Samples collected were plankton tows and seawater, which was filtered through 1-μm mesh.

This portion of the research has been completed, and a manuscript is in preparation. When analyzed with all dates and locations together, plankton were significantly higher in total P, organic P, total C and total N than particulate samples and were significantly lower in orthophosphate and higher in monoesters. However, there were no differences in C forms. Analyzing plankton samples by date (with location as the replicate), there were no significant differences in P or C forms, but significant differences in the C:P and N:P ratios, which were both highest in February and lowest in September. Analyzing particulate samples by date (with location as the replicate), there were significant differences in total P, total C and total N. Total P was highest in September and lowest in June, while N and C were highest in June and lowest in February. There were no significant seasonal differences in particulate P forms, but there were differences in C forms, with proteins significantly higher in April than in February.

Publication and Education

The project supported a post doctoral fellow Dr. Barbara Cade-Menun and partially supported a graduate student (Karen McLaughlin). Several undergraduate students were involved in the project and had the opportunity to participate in and learn the process of scientific inquiry.

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