BEST-BSIERP
Bering Sea PROJECT
UNDERSTANDING ECOSYSTEM PROCESSES IN THE BERING SEA 2007–2013

Origin and Fate of Nitrogen on the Eastern Bering Sea Shelf

FERTILIZER FOR AN ECOSYSTEM

The Bering Sea shelf is an exceptionally productive ecosystem, owing in large part to high concentrations of nutrients delivered to the shelf from the open Bering Sea. Nutrients entrained seasonally onto the shelf from the slope are thought of as "fertilizer" that leads to prolific spring phytoplankton blooms in marginal ice zones. The concentration of bio-available nutrient nitrogen (N) delivered to the shelf is particularly important, because its concentration in slope waters relative to other nutrients is below the physiological requirement of phytoplankton. The Bering Sea shelf is consequently a nitrogen-limited system, whose fertility is dependent on the amount of nitrogen fertilizer in shelf waters.

How We Did It

We investigated the origin of nitrogen and its cycling on the shelf from measurements of nutrient concentrations (specifically nitrate, nitrite, ammonia, and phosphate) and from corresponding measurements of the natural abundance stable isotope ratios ($^{15}N/^{14}N$) of discrete nitrogen pools in early spring shelf waters of 2007 and 2008 on the ice-covered shelf. By examining the stable isotope ratio measurements of the different types of samples in relation to each other we were able to start building a picture of the movement and transformations of nitrogen through the shelf water, sediment, and organisms.

Our observations revealed that, as expected, the annual resupply of nutrient N, in the form of nitrate, from the open Bering Sea contributes an important fraction of the

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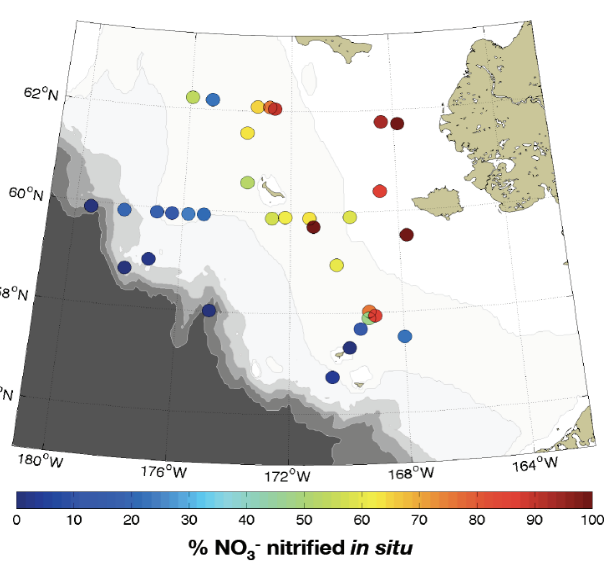
Fig. 1



The proportion of nutrient nitrate originating from the decomposition of shelf material rather than newly imported in waters from the slope, relative to the total nitrate.

The Big Picture

Given sufficient light and adequate nutrients, phytoplankton will thrive. The seasonal retreat of sea ice on the Bering shelf allows for sunlight to penetrate the sea surface, and phytoplankton begin to bloom in nutrient-rich waters. The size of the blooms is ultimately determined by the concentrations of nutrient nitrogen in the water, which occurs in lower concentration relative to other plant nutrients. We sought to determine the amount of nutrient N replenished seasonally to the shelf from the slope, and monitor the fate of this N once on the shelf. Our conclusions: Nitrogen sourced from decomposition in sediment is a dominant source of nutrient N for the spring bloom, increasingly so inshore.

NITROGEN SUPPLY FOR NEW PRODUCTION AND ITS RELATIONSHIP TO CLIMATIC CONDITIONS ON THE EASTERN BERING SEA SHELF
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"fertilizer" available for the spring bloom upon ice retreat, particularly so on the outer shelf and on the seaward portion of the middle shelf. Shoreward on the middle and inner shelf, however, nearly all of the N in the water column originates from mineralization *in situ* (Figure 1). Through this process, organic material accrued in sediments from the previous season's growth is decomposed in sediments during the dark winter, and released as inorganic nutrients back to the water column. In this way, the shallow continental shelf recycles and retains nutrients through the winter, and re-mobilizes these to the water column, thus fertilizing the spring bloom.

Why We Did It

The concentration of N fertilizer relative to phosphorus, another nutrient, decreases dramatically inshore and northward, because bioavailable N is converted to unavailable N_2 gas by denitrifying bacteria in sediment. So-called "denitrifiers" actually "breathe" nitrate when oxygen runs out in order to decompose organic material. This is paradoxical, in a sense, because the more fertile the shelf as a result of the amount of nitrogen fertilizer in the water, the more this bioavailable nitrogen gets used up during the decomposition of dead algal material by denitrifying bacteria in sediments. This removes the nitrogen fertilizer from sediments and from water above the sediments, converting this usable nitrate into unusable N_2 gas! This conundrum motivates our research, to try to understand how much fertilizer N is "breathed" to unusable N_2 gas during decomposition in sediments rather than re-released to the water column to fertilize subsequent algal blooms.

We also found that phytoplankton and their predators had a much higher $\delta^{15}N$, the $^{15}N/^{14}N$ ratio, in the ice-covered portions of the shelf than those from areas of open water (Fig. 2). Algae growing under sea ice obtained nitrogen in the form of ammonium rather than nitrate, which gave them a distinctively higher $\delta^{15}N$ than open-water algae. Zooplankton feeding on ice-associated algae similarly adopted a higher $\delta^{15}N$ than those feeding on open-water algae. Because this distinct spatial pattern in the $\delta^{15}N$ of algae is transferred to their predators, it may prove useful for tracing the diet and movements of animals on and off the ice-covered shelf.

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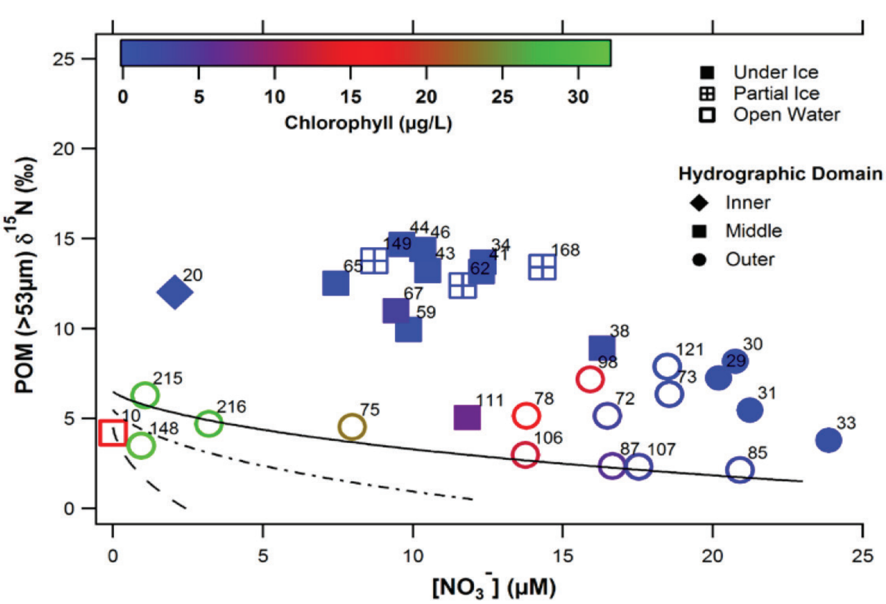
Fig. 2



$^{15}N/^{14}N$ ratio ($\delta^{15}N$) of POM (Particulate Organic Material = algal material) in the water column of the Bering Sea shelf vs. nitrate concentration, in relation to relative sea ice cover. Phytoplanktonic algae growing under sea ice have a distinctively greater $\delta^{15}N$ than open-water algae. Numbers correspond to those of individual shelf stations. Lines delineate the expected $^{15}N/^{14}N$ of POM derived solely from the partial assimilation of nitrate at the inner, middle and outer shelf.