Seasonal Changes of Nutrients on the Bering Sea Shelf: Implications on Primary Production and the Nitrogen Cycle

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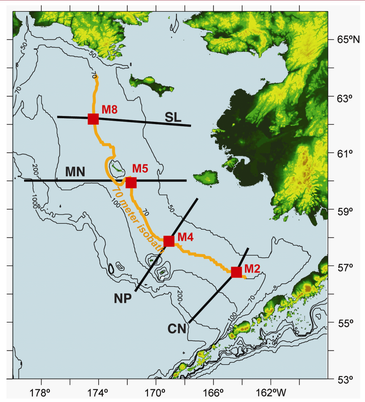
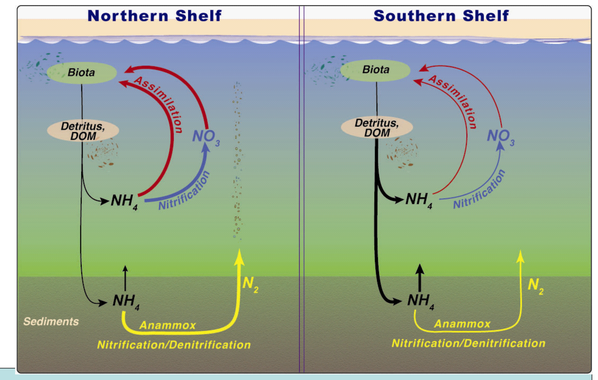


As part of the Bering Sea Ecosystem Study (BEST), along-shelf and cross-shelf transects were occupied multiple times in 2007 and 2008. The study area, repeat transects, and mooring sites are shown in the above map.

Season & Year	Cruise ID	Dates
Spring 2007	HLY0701	Apr 10 - May 11
Summer 2007	TN211	Sep 24 - Oct 11
Spring 2008	HLY0802	Mar 29 - May 6
Summer 2008	HLY0803	Jul 3 - Jul 31
Late Summer 2008	MEL0823	Aug 23 - Sep 11

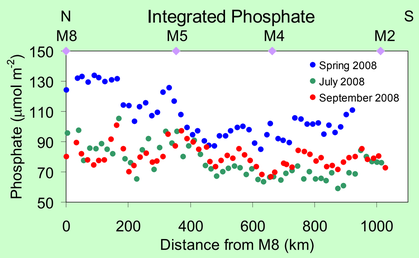
Results

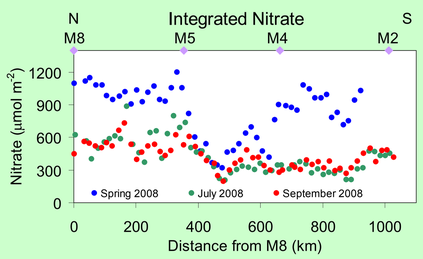
- Post-bloom conditions occurred over a large portion of the middle shelf in early spring:
  - Advection of post-bloom of inner-shelf water?
  - Early bloom associated with ice-melt event?
- Northern shelf dominated by processes that preclude the build-up of ammonium:
  - Production of phytoplankton and upper trophic levels
  - Denitrification and anammox
- Southern shelf dominated by ammonification with the fraction of ammonified production in the south (15-46%) similar to the mean value (30%) in the historical data
- Largest nitrogen deficit (denitrified water) was observed in spring



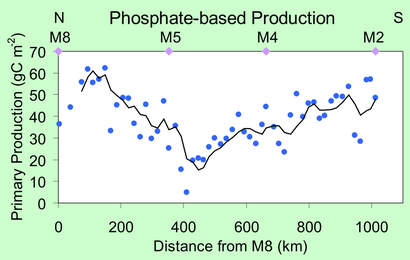
Estimates of New Primary Production in Spring

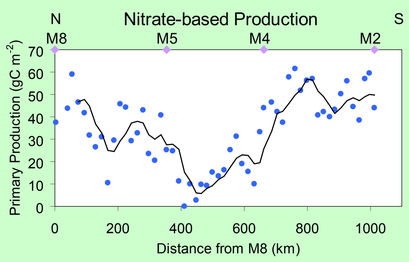
Estimates of primary production were made by (1) vertically integrating nitrate and phosphate at repeat hydrographic stations along the 70-m isobath in spring and summer, and (2) converting the seasonal drawdown of nutrients into carbon using a Redfield ratio of 1P-16N-106C. These estimates are valid for regions with low rates of advection.





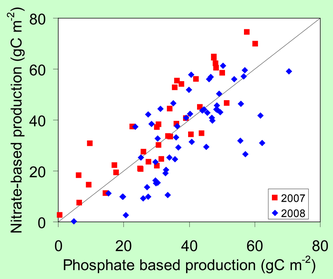
- Highest nutrient content was in the north for each cruise
- Anomalous conditions were observed in the center of the transect (between M4 and M5) including:
  - Very low nutrient content in spring
  - Low seasonality of nutrients
- In the south, seasonal changes were larger for nitrate than phosphate





- Calculated from the difference in integrated nutrients between the spring and summer BEST cruises
- Pre-bloom conditions at the southernmost stations were established from bottom water concentrations
- Very low production in the center of the transect – post bloom conditions between M4 and M5
- Production estimates from nitrate were higher in the south than in the north

Comparison of nutrient-based new production estimates in 2007 & 2008

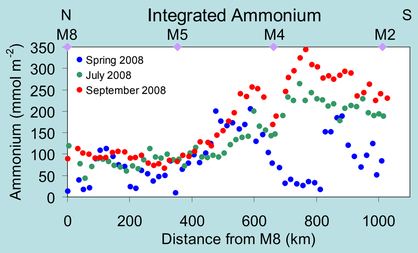


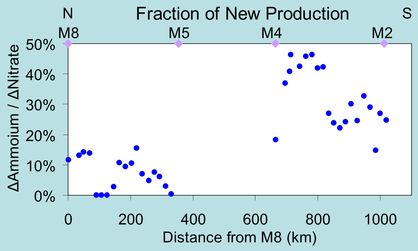
- Similar range of production: both nutrients, both years
- Similar in range to historical measurements on the middle shelf
- Instances with higher rates of phosphate-based production likely result from ammonium rather than nitrate being used as a primary nitrogen source, i.e. post-bloom production

Variability in the Marine Nitrogen Cycle

Subsequent to the seasonal drawdown of nitrate by phytoplankton, fixed nitrogen is distributed among phytoplankton, higher trophic levels, and pools of detrital and dissolved organic matter. Portions of these nitrogen pools may be converted into ammonium (ammonification), and thereafter into nitrate (nitrification) or lost as nitrogen gas (denitrification / anammox). In the Bering Sea, denitrification and anammox are restricted to the sediments; however, these processes impact the water column as remineralized nutrients with anomalous ratios diffuse out of the sediments. To gain a better understanding of the relative importance of these pathways, we examined the seasonal accumulation of ammonium (vertically integrated ammonium at each station on the 70-m isobath), and the extent to which nitrogen was "missing" from the water column.

Seasonal Accumulation of Ammonium

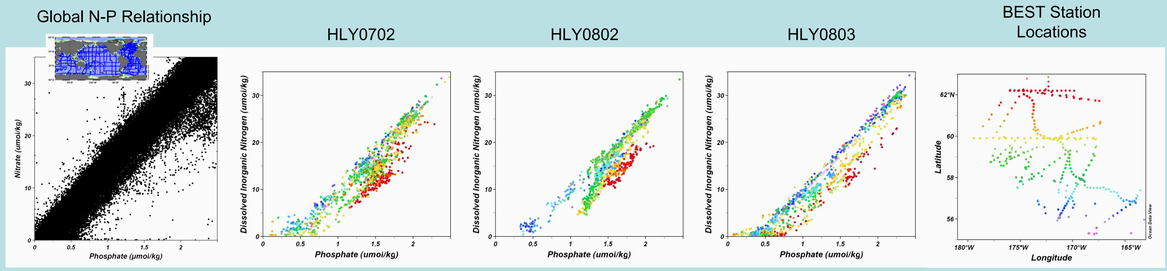




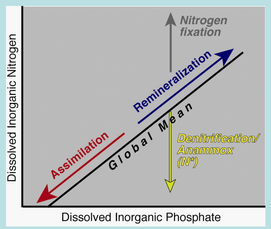
Integrated ammonium
- Spring: high ammonium in the center and at 850 km of the transect – post bloom conditions
- Summer: highest ammonium in the south
- Low seasonality of ammonium from 0-600 km

Fraction of Spring Production
- Ratio the seasonal changes of ammonium and nitrate
- Northern shelf: 0-15% of nitrate drawdown was ammonified
- Southern shelf: 15-46% of nitrate drawdown was ammonified

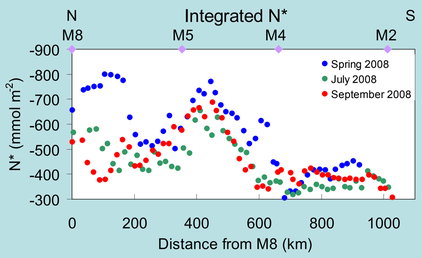
Examining Variability of Denitrification / Anammox Using Nutrient Relationships



Influence of N cycling on N-P ratios



- Primary production (i.e. assimilation) and remineralization change nutrient concentrations along the global relationship (nutrient ratios are constant)
- Denitrification / anammox are a nitrogen sink; data falls below the global mean - these deviations are negative and termed "N*"
- Nitrogen fixation is not prevalent in the Bering Sea
- N* calculations in the Bering Sea have been corrected for ammonium
- Estimates of N* do not account for unmeasured N pools, or sequestration of remineralized phosphate in the sediments



- N* was greatest in the north in all years, and all seasons
- Greatest seasonal variability of N* observed in the North
- The seasonal trend everywhere was opposite of what we expected!
- Was the shelf flushed with denitrified water in winter?

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