LTER Contributions to Understanding the Coastal Eutrophication Problem

Karen McGlathery, Virginia Coast Reserve, University of Virginia
Grand challenge: Altered biogeochemical cycles

Nutrient over-enrichment of the coastal zone

Period of explosive increase in coastal eutrophication

Total reactive N

Industrially fixed (mainly fertilizer)

N-fixing crops

Fossil fuel combustion

Galloway et al. 2003
Symptoms of eutrophication are prevalent in the nation’s estuaries. 67% of estuarine surface area shows signs of moderate-high impact.

Bricker et al. 1999
What are the consequences of eutrophication?
Coordinated network-level approach at coastal LTER sites
What controls the different responses to eutrophication?
What are the possible fates of watershed nutrients?

Why do different coastal systems respond differently to nutrient enrichment?
Virginia Coast Reserve: a coastal bay ecosystem

How do feedbacks from plant metabolism modulate the response to nutrient loading?
What is different about coastal bay ecosystems?

- watersheds are small
- little/no riverine input
- seafloor is in photic zone

BUT:

external nutrient loading rates are similar to deep estuaries
Benthic algae prevent release of inorganic nutrients to water column, and stimulate release of organic nutrients.
Competition with benthic microalgae makes denitrification an unimportant sink for N in coastal bays.

\[ \text{NH}_4^+ \rightarrow \text{NO}_3^- \rightarrow N_2 \]

Benthic microalgae

<table>
<thead>
<tr>
<th>Month</th>
<th>Mineralization</th>
<th>Benthic Microalgal Demand</th>
<th>Denitrification</th>
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<tbody>
<tr>
<td>June</td>
<td>4 mmol N m(^{-2}) d(^{-1})</td>
<td>8 mmol N m(^{-2}) d(^{-1})</td>
<td>0 mmol N m(^{-2}) d(^{-1})</td>
</tr>
<tr>
<td>August</td>
<td>6 mmol N m(^{-2}) d(^{-1})</td>
<td>10 mmol N m(^{-2}) d(^{-1})</td>
<td>2 mmol N m(^{-2}) d(^{-1})</td>
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<tr>
<td>November</td>
<td>8 mmol N m(^{-2}) d(^{-1})</td>
<td>12 mmol N m(^{-2}) d(^{-1})</td>
<td>4 mmol N m(^{-2}) d(^{-1})</td>
</tr>
<tr>
<td>May</td>
<td>5 mmol N m(^{-2}) d(^{-1})</td>
<td>8 mmol N m(^{-2}) d(^{-1})</td>
<td>2 mmol N m(^{-2}) d(^{-1})</td>
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Benthic plant assimilation is key to the fate and transport of N in coastal bays.

Primary producer assimilation is similar or equal to external nutrient loadings typical of coastal bays.

Pedersen et al. 2004
As the biological structure changes with eutrophication, how does the fate of nutrient inputs change?
As eutrophication proceeds, burial decreases.
Conceptual models:

Transfer to higher trophic levels declines and nutrient export increases.
PIE: Are salt marsh dominated estuarine systems less susceptible to eutrophication?
What is the capacity of the watershed to retain N?
Estuarine spatial complexity is related to water residence time.
Eutrophication simulated by $^{15}\text{NO}_3^-$ additions to 1st order tidal creek
Eutrophication simulated by $^{15}$NO$_3^-$ additions to 1$^{st}$ order tidal creek

Long residence time – phytoplankton dominate

Short residence time – benthic algae dominate
Food web structure, as dictated by water residence time, determines how N is processed and its fate within the system.
Phytoplankton blooms are limited to the head of the estuary where residence time is long. When coupled to land use change and watershed export models, model can be used to forecast algal blooms.
Summary

- LTER’s 3-tiered approach:
  - broad-scale long-term monitoring
  - process-based measurements
  - development of predictive models

- Comparative studies within network provide opportunities to understand regional and system-type differences
  - integration with regional efforts of NOAA, USGA, EPA

- Eutrophication models need to include the importance of biotic feedbacks and water residence time on nutrient cycling, and to capture dynamic events