Nutrient Limitation in Chesapeake Bay: Analysis of long-term monitoring data & implications for water-quality management

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A watershed example: Synthesis and analysis of monitoring data from the Partnership to understand regional patterns and drivers of water-quality (e.g., nitrogen) trends.
An estuary example: Synthesis and analysis of monitoring data from the Partnership to understand patterns of and changes in nutrient limitation to algal growth.
Why does it matter?

Nutrient limitation has shown large spatial and seasonal variations in Chesapeake Bay, which have implications to nutrient reductions (Fisher et al. 1999, Kemp et al., 2005).
Recent signs of change from tidal water-quality data

1990-1994 Spring

2006-2010 Spring

Similar flow periods

Neither DIN/0.07 < 1
DIP/0.007 < 1
Both DIN/0.07 < 1 & DIP/0.007 < 1

Percent of samples
50% Light 31%
0.7% N 1.5%
48% P 52%
1.4% N&P 16%

Recent signs of change from tidal water-quality data
Hypothesis

Given the long-term efforts to reduce nutrients to the Bay and different trends in N and P loads, nutrient limitation patterns in the mainstem may have changed temporally and spatially.

Kemp et al. (2005)
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**Data of Bioassays for Nutrient Limitation**

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**Data of Tidal Water-quality Monitoring**
Goal 1: To develop empirical approaches to relate tidal monitoring data to bioassay-based nutrient limitation ("truth") in the concurrent period of 1992-2002*

Data of Bioassays for Nutrient Limitation in 1992-2002

11 years of samples (n = 800+) at 6 mainstem stations

Data aggregated to 72 nutrient limitation classes (6 stations x 12 months)

Kemp et al. (2005)
Data of Tidal Water-quality Monitoring in 1990-2018

Three decades of WQ samples at 21 mainstem stations

1992-2002 data aggregated to the size of bioassay classes (6 stations x 12 months)
Three empirical approaches were evaluated, and CART satisfactorily reproduced the bioassay-based classes

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<th>Approach</th>
<th>Variables</th>
<th>Decision Rules</th>
<th>Classification Rate</th>
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<tr>
<td>A1. Probability-based approach</td>
<td>DIN and DIP concentrations</td>
<td>N (low DIN ≥ 50%) P (low DIP ≥ 50%) NP (both ≥ 40%) NoR (else)</td>
<td>43% (31 matches / 72)</td>
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<td>A2. Nutrient index-based approach</td>
<td>DIN and DIP indices (based on concentrations)</td>
<td>N (N-index ≥ 0.5) P (P-index ≥ 0.5) NP (both ≥ 0.4) NoR (else)</td>
<td>57% (41 matches / 72)</td>
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<td>A3. Classification and Regression Trees (CART)</td>
<td>DIN, DIP, + more (e.g., WTEMP, N:P ratio, CHLA, Secchi, Salinity)</td>
<td>Data-driven (through CART)</td>
<td>89% (64/72; LOOCV); 99% (71/72; Full Data)</td>
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NoR: No responses to nutrient additions

Kemp et al. (2005)

CART
Goal 2: To apply the selected approach to monitoring data in more recent periods to predict nutrient limitation and explore potential changes in response to altered nutrient loading.*

Changes in estimated nutrient limitation between two decadal periods of similar hydrology

NoR: No responses to nutrient additions

less NoR more N
Changes in estimated nutrient limitation between two decadal periods of similar hydrology

NoR: No responses to nutrient additions

CB2.1 Sep P → N
DIN: -0.08 mg/L (p< 0.01)
DIP: +0.003 mg/L (p=0.066)
Changes in estimated nutrient limitation between two 2-yr periods of similar hydrology
Key Messages

1. The CART approach can satisfactorily reproduce the bioassay-based, mainstem nutrient limitation patterns.

❖ It can provide complementary information on nutrient limitation since it can utilize the CBP tidal monitoring data, expanding the spatial & temporal extent of assessments to guide water-quality management.

❖ New bioassays are useful for validating and updating the CART models.
Key Messages


❖ Long-term reductions in N load appear to have led to expanded areas with nutrient-limitation.

❖ Continued reductions are needed to achieve a less nutrient-saturated ecosystem.

❖ This study demonstrates the importance of the monitoring data from the CBP Partnership and the value of novel approaches for gaining insights from the available data sets.