Development of Nutrient Water Quality Standards for Ohio Surface Waters

US EPA Nutrient TMDL Workshop, Feb 15 – 17, New Orleans

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Nutrient Pollution
Scope and Magnitude

• Nutrient over-enrichment is one of the top 5 causes of impairments to Ohio streams
• Many inland lakes were posted with advisories for harmful algal blooms during 2010
• Resurgence of anoxia in the Western Basin of Lake Erie, plus harmful algal blooms
Percentiles of IBI scores by Time Period

- Prior to 1985 <35% of waters were meeting CWA goal; 1 in 5 chronic or acute toxicity
- 2009 > 65% of water were meeting the CWA goal; toxicity rarely observed
- Achieved through regulation and investment
Outline of Ohio Criteria Development

• Observational study tracing effects of nutrients
  – Nutrients to benthic chlorophyll
    • as mediate by canopy cover
  – Benthic chlorophyll to dissolved oxygen
    • 24 hour range
    • absolute daily minimum
  – Dissolved oxygen to macroinvertebrates and fish
    • existing WQS for D.O.

• Identify change points/thresholds at each step
  – CART with bootstrapping, linear regression

• Reconcile thresholds with implementation
Change Point in Benthic Chlorophyll Over Nitrogen
Based on Residual Variation Following Regression to Canopy and Percent Ag Land Use

Bootstrap Statistics
Median = 0.44 mg/l
75th % = 1.09 mg/l
90th % = 1.56 mg/l

![Graph showing relationship between Dissolved Inorganic Nitrogen (mg/l) and Proportion per Bar. The graph includes a scatter plot with a trend line and a histogram of residuals.]
Change Points and Thresholds Identified in Nutrient Study of Ohio Rivers and Streams Drainage Areas $< 1000 \text{ mi}^2$

<table>
<thead>
<tr>
<th>Protection</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN</td>
<td>TP</td>
</tr>
<tr>
<td>(mg/l)</td>
<td>(mg/l)</td>
</tr>
<tr>
<td>0.44</td>
<td>0.04</td>
</tr>
<tr>
<td>1.0</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Now the Hard Part - Implementation

• Weight of evidence and independent application
  – How to balance the two
  – Reasonable potential

• Permits
  – Averaging period, seasonality, variance, dilution, antidegradation, WQBELs, TBELs

• TMDLs
  – Model selection, scope, allocations
Reasonable Potential

- Identifying a concentration that represents a potential for harm against a backdrop of noisy, multivariate relationships
  - Structural equation modeling
  - Logistic regression
    - requires large data sets - Ohio is fortunate in this regard
  - Quantile Regression
  - Threshold Indicator Taxa Analysis (TITAN*)

* Baker and King (2010)
Structural Representation Incorporating all Measured Variables

Photosynthetic Potential
- Canopy
- Agriculture
- Chlorophyll
- Pheophytin

Nitrogen

Phosphorus

Indirect Effects
- photo-potential
- 24h D.O.
- NH3
  - EPT Taxa: .085, .108, .085

24 h D.O. Range

NH3

Min. D.O.

% Urban

QHEI

Number of EPT Taxa

41% of variance explained

25

.29

.44
Biological Condition and Nutrient Concentration
Rivers and Streams

- Identified Thresholds
- Physical habitat quality
- Riparian quality
- Shading
- Land drainage
- Hydrology
- Precipitation
- Gradient
- Stream size

- Excellent
- Good
- Fair
- Poor

Increasing Nutrient Concentration

Forest Clearing

Intensive Land Use
Community Composition Along a Nutrient Gradient

TITAN* (Threshold Indicator Taxa Analysis)

- CP for taxon with decreasing abundance
- CP for taxon with increasing abundance

*Baker and King (2010)
Quantile Regression
EPT Taxa Richness and Total Phosphorus

Reasonable Potential?
Logistic Regression

Probability of an ICI Score < WWH as a Function of Total Phosphorus Concentrations
Available historic data, 1981-2009. Data culled for NH3>0.1. Drainage area < 500mi².
Streams with good to excellent habitat quality have less potential for impairment due to phosphorus concentrations exceeding background levels.
## Matrix of Reasonable Potential Thresholds

<table>
<thead>
<tr>
<th></th>
<th>ICI</th>
<th>EPT</th>
<th>IBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN (quantile)</td>
<td>3.2</td>
<td>3.1</td>
<td>2.91 mg/l</td>
</tr>
<tr>
<td>DIN (logistic)</td>
<td>NS</td>
<td>NS</td>
<td>Varies by QHEI$^1$</td>
</tr>
<tr>
<td>TP (logistic)</td>
<td>Varies by QHEI$^2$</td>
<td>Varies by QHEI$^3$</td>
<td>Varies by QHEI$^4$</td>
</tr>
<tr>
<td>TP (quantile)</td>
<td>0.31</td>
<td>0.13</td>
<td>0.159 mg/l</td>
</tr>
</tbody>
</table>

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1 For QHEI < median, probability of non-attainment > 0.5 when DIN $> \sim 2.1$ mg/l; when QHEI > 74, probability of non-attainment > 0.5 when DIN $> \sim 9.5$ mg/l;  
2 For QHEI < median, probability of non-attainment > 0.5 when TP $> \sim 0.6 - 3.0$ mg/l  
3 For QHEI < median, probability of non-attainment > 0.5 when TP $> \sim 0.3$ mg/l  
4 For QHEI < median, probability of non-attainment > 0.5 when TP $> \sim 0.159$ mg/l; when QHEI > 74, probability of non-attainment > 0.5 when TP $> \sim 0.457$ mg/l
Weight of Evidence Implementation of Draft Water Quality Standards
Integrating Multiple Benchmarks & Thresholds into a Single Numeric Scale - The Trophic Index Criterion

<table>
<thead>
<tr>
<th>Causal Link or Rationale for Nutrient WQS</th>
<th>TP</th>
<th>DIN</th>
<th>Chl a</th>
<th>24 H &amp; Min D.O.</th>
<th>Fish &amp; Bugs</th>
<th>TIC</th>
<th>Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients to Chlorophyll</td>
<td>≤0.04</td>
<td>≤0.44</td>
<td>≤120</td>
<td>≤6 range &gt;5 min</td>
<td>≥50</td>
<td>19</td>
<td>Acceptable (8 - 19)</td>
</tr>
<tr>
<td>Chl a &amp; D.O. to Aquatic Life</td>
<td>&gt;0.1</td>
<td>&lt;1.0</td>
<td>&gt;182</td>
<td>&gt;7 range &gt;4 min</td>
<td>&gt;38</td>
<td>7</td>
<td>Threatened (4 - 7)</td>
</tr>
<tr>
<td>Logistic &amp; Quantile Regression</td>
<td>&gt;0.3</td>
<td>&gt;3.0</td>
<td>&gt;320</td>
<td>&gt;9 range &gt;4 min</td>
<td>36</td>
<td>1</td>
<td>Impaired (0 - 3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Respective sub-scores</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>19</td>
<td></td>
<td>Acceptable</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td></td>
<td>Threatened</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Impaired</td>
</tr>
</tbody>
</table>
Summary and Conclusions

• Measurable changes to stream systems occur along a nutrient gradient—Complexity of relationship precludes adoption of a single numeric criterion and independent application
  – Exceeding a threshold or change point does not equate to impairment
  – Necessitates inclusion of response indicators (e.g., benthic chlorophyll, dissolved oxygen) in standard
Final Thoughts

• Significant restoration of surface waters has occurred since the 1980s
  – Toxins and organic matter
  – Regulation
  – Funding

• Remaining problems are comparatively intractable
  – Nonpoint
  – Habitat, flow
  – Non-toxic (e.g., nutrients)
  – Less funding
  – Little or no regulation
Nutrient Loads - In Large Part a Landscape Issue