Monitoring in Support of Numeric Nutrient Criteria

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Numeric Nutrient Criteria
Challenges of Implementation

Traditional Paradigm

- Establish protective standard based on well-defined dose-response relationships
- Facilitates implementation
  - Reasonable Potential
  - Independent Application
- Generally amenable to single number or simple algorithmic standard
- “To be acceptable to the public and useful in field situations, protection of aquatic organisms and their uses should be defined as prevention of unacceptable ...effects on... fish and benthic invertebrate assemblages in rivers and streams...” 1985 USEPA Guidelines on Numeric Criteria
Glossary

• Independent Application [policy]
  – chemical-specific, whole effluent, or biological measures can demonstrate non-attainment independently of each other

• Reasonable Potential [40 CFR 122.44 (d) (1) (i)]
  – NPDES limits are needed for pollutants discharged at a level with the reasonable potential to cause, or contribute to an excursion above a water quality standard (i.e. non-attainment)

• Protection of Downstream Uses
  – literal, WQS must protect downstream use
Independent Application, Reasonable Potential & Protection of Downstream Uses

• Basic organizing principal behind administrative and programmatic implementation of the CWA

• 30 year history, generally successful

• Predicated on well-defined dose-response relationships
Nutrient Enrichment in Rivers and Streams

Benchmarks, Thresholds & Change Points

Response or Change in Assemblage Structure

<table>
<thead>
<tr>
<th>Nutrient Form Most Frequently Reported in Literature</th>
<th>Concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN</td>
<td>0.001</td>
</tr>
<tr>
<td>SRP</td>
<td>0.010</td>
</tr>
<tr>
<td>TN</td>
<td>0.100</td>
</tr>
<tr>
<td>TP</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Algal Saturation: 7
Algae: 21
Invertebrates: 14
Fish: 7
Conceptual Framework

Environmental Gradient

Quality of Aquatic Life

CWA Goal

TP ~ 0.04 mg/l
TP ~ 0.10 mg/l
TP ~ 0.30 mg/l
NH3 = 1.0 mg/l

Response to Nutrient Enrichment

Probability of Impairment
TP 0.3 mg/l = 0.5

Probability of Impairment
NH3 1.0 mg/l > 0.95

Response to Conventional Pollutants (e.g., NH3)

Bright Red Line of IA and RP

Environmental Gradient
Conceptual Framework with Real Data
Headwater Stream in the ECBP of Ohio

![Graph showing the relationship between Ammonia-Nitrogen (mg/l) and IBI. The graph is divided into Acute and Chronic sections, with a protective line for Protect and Management areas.]

![Graph showing the relationship between Total Phosphorus (mg/l) and IBI. The graph is divided into Protect and Management sections, with protective lines.]

Acute  Chronic

Protect  Manage
Reasonable Potential, Independent Application, and Protection of Downstream Uses

A New Paradigm

• Waterbody needs to be positioned on the enrichment gradient
  – requires information from response variables

• Evaluation within the context of the watershed
  – robust monitoring design that includes biological measures
  – lakes have their own criteria; TMDL WLA for impaired lake may supersede stream NNC; DPVs ruled arbitrary for unimpaired lakes (Florida)

• Complexity precludes independent application of concentration-based criteria
  – complexity not an excuse for inaction
Develop Enrichment Indicators

- Step 1, Examine relationships between causal and response variables
- Step 2, Make sense of noisy, tenuous relationships
  - no silver bullet, at the end of the day, some BPJ is involved
- Step 3, Use resulting information to set benchmarks, thresholds, criteria

![Graph showing relationship between Dissolved Inorganic Nitrogen (mg/l) and Benthic Chlorophyll (mg/m²)]

![Graph showing relationship between 24 hrs D.O. Range (mg/l) and Benthic Chlorophyll (mg/m²)]
Change Points and Thresholds Identified in Nutrient Study of Ohio Rivers and Streams

Drainage Areas < 1000 mi²

<table>
<thead>
<tr>
<th>DIN  (mg/l)</th>
<th>TP   (mg/l)</th>
<th>Benthic Chl a (mg/m²)</th>
<th>24 hour DO Range (mg/l)</th>
<th>DO Min (mg/l)</th>
<th>Canopy (degree open)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.44</td>
<td>0.04</td>
<td>120</td>
<td>6</td>
<td>6</td>
<td>&lt;45</td>
</tr>
<tr>
<td>1.0</td>
<td>0.10</td>
<td>183</td>
<td>9</td>
<td>5</td>
<td>&lt;45</td>
</tr>
</tbody>
</table>

- Collective assessment of these measures plus information from biological communities can be used to position a water body along an enrichment gradient
- Rarefied as Trophic Index Criterion (TIC)
The Trophic Index as a Box Model
Positions Waterbody on an Enrichment Gradient

<table>
<thead>
<tr>
<th>Aquatic Life Condition</th>
<th>Attaining</th>
<th>Threatened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>• aquatic life uses fully Supported</td>
<td>• aquatic life uses fully supported or marginal</td>
</tr>
<tr>
<td></td>
<td>• TIC indicators within acceptable ranges (score 8-19)</td>
<td>• one or more TIC indicators elevated</td>
</tr>
<tr>
<td>Typical (WWH)</td>
<td></td>
<td>• local ameliorative conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• support for IA or RP (score 5-7)</td>
</tr>
<tr>
<td>Degraded</td>
<td>Impaired</td>
<td>Impaired</td>
</tr>
<tr>
<td></td>
<td>• aquatic life impaired</td>
<td>Nutrients are the Cause</td>
</tr>
<tr>
<td></td>
<td>• nutrients low</td>
<td>• nutrients low or high</td>
</tr>
<tr>
<td></td>
<td>• other indicators normal</td>
<td>• algal levels elevated</td>
</tr>
<tr>
<td></td>
<td><strong>Nutrients Not the Cause</strong></td>
<td>• DO swings evident</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• poor biological condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(score 0-4)</td>
</tr>
<tr>
<td>Toxic/Septic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Enrichment Gradient
# Draft Numeric Nutrient Criteria

**Ohio Wadeable Streams and Small Rivers**

<table>
<thead>
<tr>
<th>Aquatic Life Use and QHEI</th>
<th>TP (mg/l)</th>
<th>DIN (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceptional warmwater habitat and all QHEI scores</td>
<td>0.060</td>
<td>3.0</td>
</tr>
<tr>
<td>Warmwater habitat and QHEI score = 12 to 64</td>
<td>0.13</td>
<td>3.0</td>
</tr>
<tr>
<td>All other aquatic life uses and QHEI scores</td>
<td>0.30</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Application of Trophic Index Criterion

Waterbody Assessments and TMDL Development

- 2010 Monitoring
  - fish
  - macroinvertebrates
  - water quality
  - sestonic chlorophyll
  - benthic chlorophyll
  - continuous D.O.
  - habitat quality

- Great Miami River
  - 5371 mi² drainage area
  - High-intensity agriculture
  - Large urban population
Great Miami River
Sestonic Chlorophyll $a$ Concentrations

[Graph showing sestonic chlorophyll $a$ concentrations along the river mile.]

- 2010 Measured Values
- 75th percentile
- Van Nieuwenhuyse and Jones
- Remote sensing of GMR in 1999 (Shafique)

Sestonic Chlorophyll (ug/l)

River Mile
TIC Applied to Tributary Streams in the GMR

**Clear Creek**

- Phosphorus: Concentration (mg/l)
- Nitrogen: Concentration (mg/l)

**Wolf Creek**

- Phosphorus: Concentration (mg/l)
- Nitrogen: Concentration (mg/l)

**Bear Creek**

- Phosphorus: Concentration (mg/l)
- Nitrogen: Concentration (mg/l)

**Trophic Index Score**

- Springboro: pass through
- Brookville: organic + nutrient enrichment
- New Lebanon: assimilation without harm

- Concentration ranges: 0.01 to 1.00 mg/l
- River Mile ranges: 0 to 20
Summary and Conclusions

• Measurable changes to stream systems occur along a nutrient gradient
  – Implies system will respond to management
  – Monitor causal and response variables to determine waterbody position on enrichment gradient
    • phosphorus, nitrogen
    • chlorophyll, algae cover (e.g., Biggs)
    • dissolved oxygen, pH
    • assemblages (diatoms, macroinvertebrates or fish)
  – Complexity precludes independent application of chemical indicators
  – TIC encapsulates indicators, reduces to algorithm
    • Application is 2 parts heuristic, 1 part algorithmic