The SNAP in a Nutshell

• A method to accurately ascribe nutrient over-enrichment as a cause of impairment to rivers and streams

• benchmarks from multiple measures are arrayed in a box model
  – fish and macroinvertebrates
  – dissolved oxygen
  – benthic chlorophyll

• further analysis is guided by decision trees to arrive at appropriate management action
Ohio Nutrient Study - Bivariate Representation

- Benthic Chl a (mg/l)
- 24 DO Range (mg/l)
- DIN (mg/l)
- Minimum DO (mg/l)
- 24 h DO Range (mg/l)
- EPT Taxa Richness
Change Point Analysis

Dissolved Inorganic Nitrogen (mg/l) vs. Benthic Chlorophyll (mg/m²)

24 hrs D.O. Range (mg/l) vs. Benthic Chlorophyll (mg/m²)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change Points</th>
<th>Affects</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>0.04 mg/l</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>DIN</td>
<td>0.44 mg/l</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>Benthic Chlorophyll</td>
<td>200 mg/m²</td>
<td>D.O. &amp; Macros</td>
</tr>
<tr>
<td>24-Hour D.O. Max - Min</td>
<td>6.5 mg/l</td>
<td>Fish &amp; Macros</td>
</tr>
</tbody>
</table>
Characteristics of a Robust Numeric Criterion
Balancing Error Rates

Assuming a cutoff value of 3
False positive rate = 2/39 = 0.05;
True positive rate = 17/22 = 0.77
Indicator Performance Against Bio-indicator (IBI, ICI or EPT)

what you hope for in a numeric criterion

24 h D.O. Range

False positive rate

True positive rate

Chlorophyll

1:1 line = 50/50 chance occurrence

24-hour D.O. Range

EPT Richness

False positive rate

0.0 0.2 0.4 0.6 0.8 1.0

25 20 15 10 5 0

0.0 0.2 0.4 0.6 0.8 1.0

24 20 15 10 5 0

24 - hour D.O. Range

EPT Richness
# The Box Model

<table>
<thead>
<tr>
<th><strong>STEP 1</strong></th>
<th><strong>STEP 2</strong></th>
<th><strong>STEP 3</strong></th>
<th><strong>STEP 4</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Criteria</td>
<td>DO Swing $^2$</td>
<td>Benthic Chlorophyll $^3$</td>
<td>Preliminary Assessment: Trophic Condition Status of Evaluated Segment or Waterbody</td>
</tr>
<tr>
<td>All indices attaining or in non-significant departure $^1$</td>
<td>Normal (≤6.5 mg/l)</td>
<td>Low to moderate (≤320 mg/m$^2$)</td>
<td>Attaining use / Not threatened</td>
</tr>
<tr>
<td></td>
<td>Wide (&gt;6.5 mg/l)</td>
<td>High (&gt;320 mg/m$^2$)</td>
<td>Attaining use, but may be threatened</td>
</tr>
<tr>
<td>Non-attaining (one or more indices below non-significant departure)</td>
<td>Normal or low swings (≤6.5 mg/l)</td>
<td>Low to moderate (≤320 mg/m$^2$)</td>
<td>Impaired, but cause(s) other than nutrients</td>
</tr>
<tr>
<td></td>
<td>Wide swings (&gt;6.5 mg/l)</td>
<td>High (&gt;320 mg/m$^2$)</td>
<td>Impaired; likely nutrient over-enrichment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low to moderate</td>
<td>Impaired; Nutrient over-enrichment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate to High</td>
<td></td>
</tr>
</tbody>
</table>
When is a Waterbody Threatened by Enrichment?
Flow Chart A

• Nutrient enrichment alters biological condition incrementally
  – small changes accrue along gradient of enrichment
  – predictable in general sense; unpredictable in specific cases

• Flow Chart A asks three broad questions:
  – is the biology stable/improving over time, or is it deteriorating?
    • deteriorating condition indicates present level of enrichment unsustainable
  – is the observed biological condition expected given conditions unrelated to nutrient enrichment?
    • habitat quality
    • landscape features
  – are nutrients assimilated and enrichment localized?
Flow Chart A  
(Abbreviated Version)

**Possible Actions**
- Continue to work through management plan
- Evaluate fate and impact of load to downstream waters
- Increase monitoring frequency
- Permit limits or adaptive management plan
- List as threatened
Adaptive Management

Following is a conceptual diagram of the Ohio nutrient adaptive management (AM) process.

**SNAP:**
Assess Water Body Condition

Evaluate Potential Management Alternatives
- Nutrient load reduction?
- Habitat restoration?
- Other?
- Predicted to materially improve biological conditions?

Develop AM Plan
Implement AM Plan
Allow time for actions to show effect
Post-implementation monitoring

If nutrient-caused impairment
Chlorophyll a = 113 mg/m²; D.O. range = 8.2 mg/l; D.O. minimum = 1.0 mg/l
TP = 0.028 mg/l; DIN = 0.090; N:P ~ 7.1
IBI = 40; MIWb = 7.24; EPT = 9; ICI = NA

* mostly

Wide D.O. Swing Unrelated* to Nutrient Enrichment

Bullskin Creek
Chlorophyll a = 435 mg/m²; D.O. range = 4.0 mg/l; D.O. minimum = 6.8 mg/l
TP = 0.050 mg/l; DIN = 1.178; N:P ~ 52.1
IBI = 55; EPT = 32
What if Flow Chart A Evaluates to Threatened?

- Threatened evaluation ends at one of two management nodes
  - if the waterbody is being actively managed for nutrients, then continue to work iteratively through plan
    - e.g., Little Miami River
  - if no active management, then waterbody may be listed as threatened on 303d list
    - requires TMDL, NPDES action
    - NPDES
      - adaptive management (WWTP optimization, BNR)
      - alternative endpoints (D.O., benthic chlorophyll)
      - numeric limits (generous compliance schedule; stepwise)
Advantages & Disadvantages of SNAP

- Sets a high bar for attributing impairment to WWTPs
  - False positives expensive
- Applied during low-flow, critical condition
  - works within existing regulatory infrastructure
  - does not address low frequency, high magnitude load events
    - Nutrient Reduction Strategy
    - eutrophication from diffuse sources is often manifest during CC
      - over-application of manure or fertilizer
- Retains primacy of biocriteria for determining impairment
- Not a numeric criterion
### Nutrient Targets

**Box Model Evaluates to Impaired or Threatened**

<table>
<thead>
<tr>
<th>Total Phosphorus</th>
<th>Dissolved Inorganic Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.44</td>
</tr>
<tr>
<td>&lt;0.04</td>
<td>Reference or Ambient</td>
</tr>
<tr>
<td>0.04 &lt; 0.08</td>
<td>Enriched</td>
</tr>
<tr>
<td>0.08 &lt; 0.13</td>
<td>Working Landscapes</td>
</tr>
<tr>
<td>0.13 &lt; 0.30</td>
<td>Tile Drained or Manure</td>
</tr>
<tr>
<td>&gt;0.30</td>
<td>Effluent Dominated</td>
</tr>
</tbody>
</table>
Questions