Using structural and functional indicators to develop numeric nutrient criteria for Utah’s wadeable streams

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Key Concept: Indicators versus Criteria

Which Path Forward?

**Nutrient Indicators**
- Identify sites with nutrient related problems
- Allows resource prioritization
- Triggers monitoring response by DWQ

**OR**

**Nutrient Criteria**
- CWA Requirement
- Provides regulatory certainty
- Less flexible and difficult to change
Why use multiple indicators?

- Pristine
- Functional Response
- Structural Response
- Impairment

Eutrophication
Indicators

- **Functional Indicators**
  - Stream Metabolism
  - Nutrient Limitation
    - Organic Matter Storage
    - Decomposition Rates
- **Compositional Indicators**
  - Macroinvertebrates
  - Diatoms
- **Statewide Snapshot**
Whole Stream Metabolism

\[ \Delta \text{DO} = \text{GPP} - \text{ER} \pm K \]

- Measures daily production & consumption of oxygen
### Nutrient Group Thresholds

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN (mg/L)</td>
<td>Low &lt; 0.24</td>
<td>Medium &lt; 1.28</td>
<td>High</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>Low &lt; 0.02</td>
<td>Medium &lt; 0.09</td>
<td>High</td>
</tr>
</tbody>
</table>

### Stream Metabolism

**Nutrient Metabolism**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>TN Group</th>
<th>TP Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPP gO₂/m²/day</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>ER gO₂/m²/day</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

**Legend**

- **a** indicates a significant difference from low.
- **b** indicates a significant difference from medium.
- **c** indicates a significant difference from high.
- Nutrients increase rates of GPP and ER
- High rates of GPP and ER lead to more minimum DO impairments
- Direct tie to aquatic life uses
Nutrient Limitation

- Adding the limiting nutrient will have the greatest affect on algal growth
- Nutrient Diffusing Substrates (NDS)
- Control, N, P, & N + P
- Analyze algal growth under different nutrient additions
A) Mean Chl a growth rate per treatment

B) Mean Chl a growth rate per treatment, relative to control
### Nutrient Limitation Results

<table>
<thead>
<tr>
<th>Site</th>
<th>None</th>
<th>N</th>
<th>P</th>
<th>N&amp;P</th>
<th>N1</th>
<th>P2</th>
<th>P1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moderate Impact</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High Impact</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- 80% of reference sites have some form of Nitrogen limitation
- 6 of 7 High Impact sites are not limited by nutrients
- No limitation likely to occur > 0.42 mg/L TN and > 0.08 mg/L TP
Organic Matter Storage

- Standing stock of all organic matter
  - Autotrophs, heterotrophs & detritus
- Analysis in progress
Decomposition

- Heterotrophic response to nutrients
  - Invertebrates excluded
- Leaf packs and wood veneers
- measured at 0, 3 & 6 weeks
  - Analysis in progress
Indicators

- Functional Indicators
  - Stream Metabolism
  - Nutrient Limitation
    - Organic Matter Storage
    - Decomposition Rates
- Compositional Indicators
  - Macroinvertebrates
  - Diatoms
- Statewide Snapshot
Taxonomic Indicator Threshold Analysis
-TITAN-
- Uses individual taxon responses instead of community metrics/composition
- Identifies and categorizes taxa into two categories
  - Negative responders (sensitive)
  - Positive responders (tolerant)
- Ideal for developing numeric criteria

Respond negatively to increasing nutrients

Respond positively to increasing nutrients

TN (mg/l)

0 0.5 1 1.5 2 2.5 3

0 5 10 15 20 25 30 35
Multiple Lines of Evidence TN

TITAN-Sensitive inverts - 0.18 mg/L
TITAN-All significant inverts – 0.40 mg/L
TITAN-Tolerant inverts – 0.41 mg/L
O/E biologic impairments – 0.43 mg/L

Stream Metabolism 0.24 & 1.28 mg/L
Nutrient Limitation - 0.42 mg/L
TITAN-Sensitive inverts - 0.011 mg/L
TITAN-All significant inverts – 0.015 mg/L
TITAN-Tolerant inverts – 1.8 mg/L
Diatom TITAN – 0.045 mg/L
O/E biologic impairments – 0.045 mg/L
Stream Metabolism 0.02 & 0.09 mg/L
Nutrient Limitation - 0.08 mg/L
Indicators

- Functional Indicators
  - Stream Metabolism
  - Nutrient Limitation
    - Organic Matter Storage
    - Decomposition Rates
  - Compositional Indicators
    - Macroinvertebrates
    - Diatoms
- Statewide Snapshot
What does this mean for Utah’s streams?

What’s the Number ???

<table>
<thead>
<tr>
<th>Possible Criteria (mg/L)</th>
<th>Percent Impaired</th>
<th>Stream Miles Impaired</th>
<th>Impaired Stream Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min 0.24</td>
<td>50%</td>
<td>~6700</td>
<td>Too Low??</td>
</tr>
<tr>
<td>Medium 0.45</td>
<td>30%</td>
<td>~4000</td>
<td>Maybe??</td>
</tr>
<tr>
<td>Max 1.2</td>
<td>10%</td>
<td>~1300</td>
<td>Too High??</td>
</tr>
<tr>
<td><strong>TP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min 0.011</td>
<td>60%</td>
<td>~8000</td>
<td>Too Low??</td>
</tr>
<tr>
<td>Medium 0.045</td>
<td>25%</td>
<td>~3400</td>
<td>Maybe??</td>
</tr>
<tr>
<td>Max 0.08</td>
<td>10%</td>
<td>~1300</td>
<td>Too High??</td>
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</table>
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Phased Implementation: One Possible Scenario

- Apply numeric nutrient **criteria** to all category 1 antidegradation waters
  - Cat 1 are mostly high elevation waters on USFS land
  - Immediate protection of high quality waters

- Apply numeric nutrient **indicators** to all other waterbodies
  - Make certain nutrients are cause of impairments in multi stressor waterbodies
  - Consider economic impacts in nutrient reduction strategies
  - Consider appropriate uses and best attainable conditions
  - Allows time for additional investigations
Questions?

- Special Thanks
  - Utah DWQ
    - Emilie Flemer
    - Suzan Tahir
    - Jared Terry
    - Emily Bartusek
    - Kate Tipple
    - Alex Anderson
    - Ben Holcomb
  - USU
    - Michelle Baker
    - Bethany Neilson
    - Andrew Hobson
Nutrient Indicator Ecological Study

Study Design

Probe & Water Chemistry

Compositional & Functional Measurements

Reference Sites

Probe & Water Chemistry

POTW

Mixing Zone

Treatment Sites
Thresholds determined by nonparametric deviance reduction among binary response data of O:E impairment indicator.
Site Locations

- 9 POTWs
- 17 Reference Sites
Indicator Pathway

Numeric Indicators

N  P

Response Indicators

Primary Production | Compositional Indicators | Functional Indicators

Identify potential nutrient-related problems

Convene Stakeholders

Immediate Nutrient Reduction

Develop long-term reduction strategies

Promulgate Indicators

Numeric Criteria
Negative responding taxa
All significant taxa
Positive responding taxa
Types of Indicators

**Numeric Indicators**

- N
- P

**Response Indicators**

- Primary Production
- Compositional Indicators
- Functional Indicators

- In stream/lake concentrations of nitrogen and phosphorus that suggest nutrient impairment

- Biological or Ecological responses that confirm or reject suggested impairment

**DWQ would only promulgate numeric nutrient criteria when numeric AND response indicators suggest an impairment**