A Stream Algal Bioassessment
Incorporating the Biological Condition Gradient to Evaluate Tiered Aquatic Life Uses in Maine

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Stream Classes

% OF LINEAR MILES OF STATUTORY CLASSIFICATIONS

Class AA = 6%
Class A = 45%
Class B = 47%
Class C = 2%

(Class C ~8-10% for large rivers and urban streams)
Maine DEP’s Biological Monitoring Unit

- Determine if streams, rivers, and wetlands are attaining aquatic life criteria
- Provide water quality data for many other programs
- >25 years with stream macroinvertebrates.
- >10 years with stream and wetland algae, and wetland macroinvertebrates.

Leon Tsomides
Beth Connors
Jeanne DiFranco
Tom Danielson
Foundations of Algal Model

- Maine’s narrative aquatic life criteria
- U.S. Environmental Protection Agency’s Biological Condition Gradient (BCG)
# Aquatic Life Criteria

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class AA</td>
<td>as naturally occurs</td>
</tr>
<tr>
<td>Class A</td>
<td>support all aquatic species indigenous to the receiving water; no detrimental changes to the resident biological community</td>
</tr>
<tr>
<td>Class B</td>
<td>support all fish species indigenous to the receiving water; maintain the structure and function of the resident biological community</td>
</tr>
<tr>
<td>Class C</td>
<td></td>
</tr>
<tr>
<td>Non-attainment (NA) stream</td>
<td>does not meet minimum criteria</td>
</tr>
</tbody>
</table>
Biological Condition Gradient (BCG)

1. Native or natural condition
   - Minimal loss of species; some density changes may occur

2. Some replacement of sensitive species; functions fully maintained
   - Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

3. Tolerant species show increasing dominance; sensitive species are rare; functions altered
   - Severe alteration of structure and function

4. Natural
   - Degraded

5. Low Stressor Gradient
   - High Stressor Gradient

6. AA
   - A
   - B
   - C
   - NA
Class B Stream

Caddisflies
Mayflies
Stoneflies
Craneflies
Blackflies
Beetles
Midges
Non-Insects

Color Code
Sensitive
Intermediate
Tolerant

1 inch
Stream Algal Sample Locations

N=243
Range of Condition
Minimally Disturbed Reference Sites

- >95% of upstream watershed is forest & wetlands
- No point source discharges
- No dams
- No atypical source of pollution (e.g., iron mining)
Natural Substrate Samples
<table>
<thead>
<tr>
<th>Taxonomic Diversity</th>
<th>1999-2008 Stream Samples</th>
<th>Genera</th>
<th>Species/Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatoms</td>
<td>90</td>
<td>806</td>
<td></td>
</tr>
<tr>
<td>Green Algae</td>
<td>59</td>
<td>226</td>
<td></td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>51</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>Euglenoids</td>
<td>4</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Yellow-green Algae</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Dinoflagellates</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Red Algae</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Chrysophytes</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Weighted Average Optima

**Brachysira microcephala**

**Reimeria sinuata**

**Navicula gregaria**

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**Weighted Average Optima**

- **Brachysira microcephala**
- **Reimeria sinuata**
- **Navicula gregaria**

---

**Micrographs**

- Scale bar: 10.0 μm
### Weighted Average Optima

<table>
<thead>
<tr>
<th>Environmental Variable</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Watershed that is Forest or Wetland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent of Watershed that is Impervious Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Conductance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Weighted Average Optima

<table>
<thead>
<tr>
<th>Environmental Variable</th>
<th>Tabellaria flocculosa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Watershed that is Forest or Wetland</td>
<td>98%</td>
</tr>
<tr>
<td>Percent of Watershed that is Impervious Surface</td>
<td>1%</td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>22 μS/cm</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>331 ppb</td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>8 ppb</td>
</tr>
</tbody>
</table>
### Weighted Average Optima

<table>
<thead>
<tr>
<th>Environmental Variable</th>
<th>Tabellaria flocculosa</th>
<th>Nitzschia amphibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Watershed that is Forest or Wetland</td>
<td>98%</td>
<td>16%</td>
</tr>
<tr>
<td>Percent of Watershed that is Impervious Surface</td>
<td>1%</td>
<td>40%</td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>22 μS/cm</td>
<td>475 μS/cm</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>331 ppb</td>
<td>711 ppb</td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>8 ppb</td>
<td>39 ppb</td>
</tr>
</tbody>
</table>
PCA Identified Major Pattern in Species Optima

- Axis 1 represents 86% of variance
- Rescaled axis to 1 (most sensitive) to 100
- Grouped taxa into Sensitive (<32.2), Intermediate (32.2-60), and Tolerant (>60).
Candidate Metrics

**FROM LITERATURE** (Examples)
- Relative abundance
  - motile diatoms
  - polysaprobic diatoms
  - eutraphentic diatoms
  - low oxygen diatoms
  - salt tolerant diatoms
  - dominant species
- Total Richness
- Shannon-Wiener Diversity Index

**NOVEL** (Examples)
- Relative richness
  - Sensitive taxa
  - Tolerant taxa
  - *Brachysira, Eunotia, Tabellaria, and Anomoneis* (BETA)
  - Bacillariaceae, Catenulaceae, Rhoicospheniaceae, and Surirellaceae (BCRS)
- Relative biovolume
  - Sensitive taxa
  - Tolerant taxa
Algal Metrics

- Spearman rank correlation ($\rho$) = -0.81 (P<0.001)

- Mann-Whitney U test statistic = 865
  - $\chi^2$ approximation = 37.830 with 1 df (P<0.001)
Materials given to biologists

- Summary variables and metrics for each sample (n=230)
- Taxa lists with abundances, relative abundances, tolerances, etc. for each sample
- Samples identified by random number
- Only biological data provided
- Report with metric graphs and descriptions
Example of Graphs Provided to Biologists
Relative Richness of Sensitive, Intermediate, and Tolerant Algae
Class Assignments

• Biologists independently evaluated samples (blind)
  ▪ Maine class (A, B, C, NA)
  ▪ BCG Tier (1-6)

• Biologists later compared results and made consensus assignments.
Biologist Class Assignments

• 105 Class A, 46 Class B, 46 Class C, and 33 non-attainment.
  ▪ 53% unanimous
  ▪ 22% 4 vs. 1 (differed by one class)
  ▪ 20% 3 vs. 2 (differed by one class)
  ▪ 5% differed by more than one class
Discriminant Analysis Model

- Predicts group membership (i.e., A, B, C, NA) based on linear combination of metrics.
- 230 samples
  - 150 used to build the model (training set)
  - 80 used to test the model (test set)
- Metrics selected with backward stepwise selection.
- Identified and removed metrics with high within-group correlations ($r>0.70$).
95% Correct Model Performance with Training Data (n=150)  
(Row percents with number of samples in parentheses)

<table>
<thead>
<tr>
<th>Algal LDM Predicted Class</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a priori</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class A</td>
<td>97%</td>
<td>3%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>(67)</td>
<td>(2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class B</td>
<td>3%</td>
<td>90%</td>
<td>7%</td>
<td>--</td>
</tr>
<tr>
<td>(1)</td>
<td>(27)</td>
<td>(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class C</td>
<td>--</td>
<td>--</td>
<td>93%</td>
<td>7%</td>
</tr>
<tr>
<td>(2)</td>
<td>(28)</td>
<td>(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>100%</td>
</tr>
<tr>
<td>(21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
91% Correct Model Performance with Validation Data (n=80)
(Row percents with number of samples in parentheses)

<table>
<thead>
<tr>
<th>Algal LDM Predicted Class</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a priori</strong> Class A</td>
<td>97%</td>
<td>3%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>a priori</strong> Class B</td>
<td>13%</td>
<td>81%</td>
<td>6%</td>
<td>--</td>
</tr>
<tr>
<td><strong>a priori</strong> Class C</td>
<td>--</td>
<td>13%</td>
<td>88%</td>
<td>--</td>
</tr>
<tr>
<td><strong>a priori</strong> NA</td>
<td>--</td>
<td>--</td>
<td>9%</td>
<td>91%</td>
</tr>
</tbody>
</table>

(Numbers in parentheses represent the number of samples.
Watershed Assessment
Pleasant River, Windham

Assigned Goal is Class B

- Stream sample
- Wetland sample

Direction of flow
BCG is a Crosswalk

Assigned Goal is Class B

Wetland Bugs: A
Wetland Bugs: A/B
Bugs: B
Algae: B
Algae: B
Bugs: B
Algae: C
Bugs: B

· Stream sample
· Wetland sample
BCG Helps Targets Resources

Target Resources
Here to Reduce Nutrient Enrichment

Algae: C
Bugs: B
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  ▪ U.S. Environmental Protection Agency
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  ▪ Chris Halsted
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  ▪ Manomet Center for Conservation Sciences

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  ▪ Dr. Francis Drummond
  ▪ Dr. Susan Brawley
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