Use of Photopigments as a Descriptor of Phytoplankton Assemblages

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A Conceptual Framework for Illinois Lakes

- Watershed Characteristics
- Basin Morphometry
- Physical and Chemical Environment
- Biotic Response
- Local Meteorology
Why Phytoplankton?

• Respond directly to water quality variables
• Invertebrates of lakes and reservoirs have relatively fewer species
• Fish species tend to be stocked causing an artificial species distribution
Historical data

• 1983-2003
• IEPA Ambient Lakes Monitoring Program
• Annual monitoring involves approximately 50 lakes
• When sampled, collections are made five times:
  – once during spring turnover (April)
  – three times during summer when stratification may occur (June, July, August)
  – once during fall turnover (October)
Regionalization
Historic Environmental Analysis

Lake environments generally differ between regions.
Historic Environmental Analysis

ANOSIM reveals significant differences between regional aggregations of lakes

Sample Statistic (Global R) = 0.252, N = 151
Significance level of sample statistic = 0.01%

<table>
<thead>
<tr>
<th>Groups</th>
<th>R Statistic</th>
<th>Significance Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n, s</td>
<td>0.395</td>
<td>0.01</td>
</tr>
<tr>
<td>n, c</td>
<td>0.187</td>
<td>0.01</td>
</tr>
<tr>
<td>s, c</td>
<td>0.316</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Phytoplankton assemblages respond to their physical and chemical environment

**Historic Biotic Analysis**

*Phytoplankton Density*

3D Stress: 0.14

**region**
- ▲ n
- ▼ s
- □ c
Historic Biotic Analysis

ANOSIM reveals significant differences between regional aggregations of lakes

Sample Statistic (Global R)= 0.144, N = 151
Significance level of sample statistic= 0.01%

<table>
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<tr>
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<th>Significance Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n, s</td>
<td>0.300</td>
<td>0.02</td>
</tr>
<tr>
<td>n, c</td>
<td>0.071</td>
<td>0.03</td>
</tr>
<tr>
<td>s, c</td>
<td>0.208</td>
<td>0.20</td>
</tr>
</tbody>
</table>
IEPA Regions vs. N,C,S Regions
Conclusions from Historic Data

• Phytoplankton assemblages potentially useful as biocriteria

• Distinctions between lakes based on *a priori* classification can be made

• Regional differences sufficient to warrant alternative management strategies
Why Photopigments rather than Enumeration?

• Diverse assemblages of species characterized by characteristic pigments
• Economic considerations and relatively little expertise needed
• Time constraints

Research question

Do historical data from assemblage enumeration ‘mesh’ with current photopigment data?
# Photopigments indicative of taxonomic group

<table>
<thead>
<tr>
<th></th>
<th>Alloxanthin</th>
<th>β,β Carotene</th>
<th>Neoxanthin</th>
<th>Lutein</th>
<th>Zeaxanthin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cryptophyta</strong></td>
<td>Major</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Major</td>
</tr>
<tr>
<td><strong>Chlorophyceae</strong></td>
<td>X</td>
<td>Minor</td>
<td>Major</td>
<td>Major</td>
<td>Minor</td>
</tr>
<tr>
<td><strong>Cyanophyta</strong></td>
<td>X</td>
<td>Minor</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Prasinophyceae</strong></td>
<td>X</td>
<td>Minor</td>
<td>Major</td>
<td>Minor</td>
<td>X</td>
</tr>
<tr>
<td><strong>Rhodophyta</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Major</td>
</tr>
</tbody>
</table>

- Photopigment signature may be useful characterization of entire assemblage
A Conceptual Framework for Illinois Lakes

- Watershed Characteristics
- Basin Morphometry
- Physical and Chemical Environment
- Biotic Response
- Local Meteorology
**NLA Overview**

- 909 lakes in 48 states
- randomly selected
- 91 to be resampled
- sampling in summer 2007
- includes lakes of anthropogenic origin
- public or privately owned
- $A_o = 4$ hectares
- $Z_{max} > 1$ m
- $1000$ m$^2$ of open water

<table>
<thead>
<tr>
<th>Lake Size Category</th>
<th># of Lakes Selected</th>
<th>Total # of Lakes in the US</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-10 hectares (10-25 acres)</td>
<td>104</td>
<td>68559</td>
</tr>
<tr>
<td>10-20 hectares (25-50 acres)</td>
<td>185</td>
<td>24902</td>
</tr>
<tr>
<td>20-50 hectares (50-125 acres)</td>
<td>184</td>
<td>16488</td>
</tr>
<tr>
<td>50-100 hectares (125-250 acres)</td>
<td>172</td>
<td>6134</td>
</tr>
<tr>
<td>&gt;100 hectares (&gt; 250 acres)</td>
<td>264</td>
<td>7356</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>909</strong></td>
<td><strong>123439</strong></td>
</tr>
</tbody>
</table>
Illinois NLA Overview

Desktop evaluations of 93 lakes

Site visits at 58 lakes

Ultimately sampled 49 lakes
  - 6 Revisits

Lakes excluded from sampling
  - river backwaters
  - strip mine lakes
  - lakes with < 1000 m² open water
  - lakes with $Z_{\text{max}} < 1$ m
  - lakes with no water at time of sampling
Physiochemical Determinates

vertical profile (DO, temperature, pH)
Secchi disc transparency
depth-integrated sample (upper 2 m) at index station for water chemistry
surface water sample for supplemental study
HPLC Overview

• University of South Carolina, Estuarine Ecology Lab
  • *Supervision*: Jay Pinckney, Ph.D.

• Samples are filtered/frozen, pretreated, lyophilized, and extracted

• Photopigments present are separated and identified based on retention time
  • Depends upon interactions (polarity and size) of the sample in the mobile phase with the stationary phase

• Pigment peak areas are quantified and concentrations calculated
Environmental Variables Kept

• Some variables eliminated to reduce covariation and stress

Kept variables normalized

• Hardness
• HCO$_3^-$
• FDS & VDS
• Secchi Depth
• Meterable Variables: DO, pH, and Temp

$log_e$ transformed and normalized

• CO$_3^-$
• Nutrients: TON, TP, SRP, sulfates, NH$_4^+$-N
• FSS & VSS
• Proportion of Water Column Oxygenated
Current Environmental Analysis

ANOSIM reveals significant differences between regional aggregations of lakes based on physiochemical variates

Sample Statistic (Global R) = 0.287, N = 55
Significance level of sample statistic = 0.01%

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<tr>
<td>n, s</td>
<td>0.423</td>
<td>0.01</td>
</tr>
<tr>
<td>n, c</td>
<td>0.341</td>
<td>0.07</td>
</tr>
<tr>
<td>s, c</td>
<td>0.194</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Current Biotic Analysis

Standardise Samples by Total
Transform: Fourth root
Resemblance: S17 Bray Curtis similarity

Region
- Central
- Northern
- Southern

3D Stress: 0.1
Current Biotic Analysis

ANOSIM reveals significant differences between regional aggregations of lakes based on physiochemical variates

Sample Statistic (Global R) = 0.133, N = 55
Significance level of sample statistic = 0.04%

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<th>R Statistic</th>
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</thead>
<tbody>
<tr>
<td>n, s</td>
<td>0.168</td>
<td>.11</td>
</tr>
<tr>
<td>n, c</td>
<td>0.238</td>
<td>0.04</td>
</tr>
<tr>
<td>s, c</td>
<td>0.037</td>
<td>1.68</td>
</tr>
</tbody>
</table>
Does regionalization based on historic data mesh with current data?
What’s Next?

Continue to develop the concept of reference conditions for Illinois lakes and reservoirs

- Exploratory analyses to determine factor(s) that best exhibit gradient
- NLA data
- Additional sampling (2008 and beyond…….)

Considerations and concerns for future design

- Physical and chemical data are multivariate
  - No single lake/reservoir may best define “reference”
- Watershed features may be equally important
- Random sampling relative to time
Acknowledgements

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Illinois Environmental Protection Agency
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James L. Pinckney, University of South Carolina, Estuarine Ecology Lab

Logistical Support
Gregg Good, Teri Holland, Tara Lambert, Jeff Mitzelfeldt

All statistical analyses performed using Primer, V.6.1.3
Clockwise from far left: Daniel Hiatt, Jason Allen, Charles Pederson, Ph.D., TJ Evans, Dan Jablonski (a.k.a., “other Dan”), Jessica Rasmussen (not pictured)
Evaluation of lake/reservoir condition gradient
Evaluation of lake/reservoir condition

undisturbed (reference) versus disturbed

strong response

weak response

reference degraded

reference degraded

METRIC

reference

degraded

degraded

LAKE CONDITION
Additional Variables to be Explored

Potentially informative variates
characteristics of watershed
basin morphometry
surface area
exotic species
The NLA and Illinois “enhancements”

- Official collaboration with IEPA (10/2006) on NLA
- All sampling as part of the National Lakes Assessment (NLA)
  - 17 Panel 1 Lakes in Illinois
    - Split samples collected
      - contract labs
      - analyses by EIU Fisheries and Aquatics Research Lab
  - 33 Additional lakes to be sampled
    - Stratification to ensure statewide representation
    - Stratification to ensure representation of gradient of origin and perceived conditions
    - Analyses by EIU Fisheries and Aquatics Research Lab
  - All lakes sampled for determination of water column mercury
Why Bioassessment?

Benefits of biocriteria when coupled with routine assessment of physical or chemical conditions:

- Sensitive to changes in environmental quality
- Respond to environmental conditions which often may not be detectable via routine analyses
- Integrate changes in environmental quality over time
Indices of Biotic Integrity

• **Widespread use in lotic systems**
  – Typically based on fish or macroinvertebrates
  – Generally numerical based on community attributes
  – Applicable for assessing overall habitat quality

• **Application for lentic habitats less well-developed**
  – Recent efforts utilizing reservoir fish assemblages
  – Macroinvertebrates and zooplankton in New England
  – Some incorporation of phytoplankton in northern glacial lakes
Phytoplankton Data

• 100+ lakes and reservoirs

• 20+ years

• 378 species of phytoplankton (126 genera)
What is the reference condition?