Simplified Lake Eutrophication Modeling: Using the Ecoregion-based model MINLEAP

Steven Heiskary,
Environmental Research Scientist
Minnesota Pollution Control Agency
MINLEAP - Development and Acknowledgements

- “Minnesota Lake Eutrophication Analysis Procedure”
- Developed by Bruce Wilson and Dr. William Walker Jr. (1989), published in Lake and Reserv. Manage. 5(2): 11-22 “Development of Lake Assessment Methods Based on Aquatic Ecoregion Concept”
- BASIC originally (Wilson), recent Windows version - (Wade Gillingham, MPCA)
Overview

Session I

- General modeling concepts;
- Ecoregion framework and MINLEAP;
- MINLEAP background and subroutines;
- Application of MINLEAP

Session II

- Loading and using MINLEAP
- Case Studies;
Lake Eutrophication Modeling
(Drawn from Wilson, 1990)

- Predictive techniques to assess common lake problems;
- Foundation is reasonable estimation of water and nutrient budgets or loading;
- Lakes often exhibit similarities in response to nutrient loading;
- Most techniques based on cross-sectional studies -- e.g., ecoregion reference lakes;
Typical Empirical Model Network

- Inflow TP
- Mean Depth
- Residence

In-lake Total P

Chlorophyll-a

Secchi
MINLEAP Development

- Based on ecoregion framework -- considers regional patterns in geomorphology, soils, landuse, and climatic characteristics;
- Uses average precip., evap., and runoff;
- Canfield and Bachmann (1981) is the sedimentation model used;
- TP, Chl-a, and Secchi models based on MN reference lakes;
Ecoregion Reference Lakes

- Northern Minnesota Wetlands

- Northern Lakes and Forests

- North Central Hardwood Forests

- Red River Valley

- Northern Glaciated Plains

- Western Corn Belt Plains

- Driftless Area

- N = 30
  Z = 6.3 m
  A = 318 ha

- N = 36
  Z = 6.6 m
  A = 364 ha

- N = 8
  Z = 1.6 m
  A = 218 ha

- N = 11
  Z = 2.5 m
  A = 107 ha
### Distribution of Phosphorus by Lake Mixing Status and Ecoregion

**D** = Dimictic, **I** = Intermittent, **P** = Polymictic

<table>
<thead>
<tr>
<th>Mixing Status:</th>
<th>NLF</th>
<th>NCHF</th>
<th>WCBP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>I</td>
<td>P</td>
</tr>
<tr>
<td>Percentile value for [TP]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 %</td>
<td>37</td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td>75 %</td>
<td>29</td>
<td>35</td>
<td>39</td>
</tr>
<tr>
<td>50 %</td>
<td>20</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>25 %</td>
<td>13</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>10 %</td>
<td>9</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td># of obs.</td>
<td>257</td>
<td>87</td>
<td>199</td>
</tr>
</tbody>
</table>
TP and Chl-a

ECOREGION REFERENCE LAKES
Mean summer concentrations

Log Total Phosphorus ppb vs Log Chlorophyll a ppb
Chlorophyll-a and Secchi

Summer-mean Secchi vs. Chlorophyll-a (log-log).
Based on ecoregion reference lakes.

\[ y = -0.57x + 0.87 \]

\[ R^2 = 0.82 \]
Algal Bloom Frequency

Chlorophyll-a Bloom Frequency as a Function of Summer Mean. Based on a single season of data (Walker, 1985).
### MN Lake P Criteria

**Heiskary and Wilson, 1988**

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Most Sensitive Use</th>
<th>P Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northern Lakes and Forests</strong></td>
<td>drinking water supply</td>
<td>&lt; 15 µg/L</td>
</tr>
<tr>
<td></td>
<td>cold water fishery</td>
<td>&lt; 15 µg/L</td>
</tr>
<tr>
<td></td>
<td>primary contact recreation</td>
<td>&lt; 30 µg/L</td>
</tr>
<tr>
<td></td>
<td>and aethetics</td>
<td></td>
</tr>
<tr>
<td><strong>North Central Hardwood Forests</strong></td>
<td>drinking water supply</td>
<td>&lt; 30 µg/L</td>
</tr>
<tr>
<td></td>
<td>primary contact recreation</td>
<td>&lt; 40 µg/L</td>
</tr>
<tr>
<td></td>
<td>and aethetics</td>
<td></td>
</tr>
<tr>
<td><strong>Western Corn Belt Plains</strong></td>
<td>drinking water supply</td>
<td>&lt; 40 µg/L</td>
</tr>
<tr>
<td></td>
<td>primary contact recreation</td>
<td>&lt; 40 µg/L</td>
</tr>
<tr>
<td></td>
<td>(full support)</td>
<td>&lt; 90 µg/L</td>
</tr>
<tr>
<td></td>
<td>(partial support)</td>
<td></td>
</tr>
<tr>
<td><strong>Northern Glaciated Plains</strong></td>
<td>primary contact recreation</td>
<td>&lt; 90 µg/L</td>
</tr>
<tr>
<td></td>
<td>and aethetics</td>
<td></td>
</tr>
</tbody>
</table>
Model Statistics

- **Error**: Difference between observed and predicted mean value (e.g. standard error);
- **Variability**: Considers spatial and temporal fluctuations in concentration about mean;
- **T-test**: If absolute value is < 2 the observed mean is not significantly different than predicted (95 % confidence). Useful for identifying problem lakes.
Vighi and Chiaudani
“Background P”

- Based on MEI -- ratio between TDS and Z, used to estimate fishery yields;
- Regression based on 53 lakes with negligible anthropogenic P loading;
- MEI = alk (meq/L)/ Z;
- Lakes within the predicted [P] +/- C.I. approach background P;
- May not work well on ‘naturally eutrophic’
Applications

- How is lake doing given its ecoregion and morphometric considerations;
- Estimates water and nutrient budget;
- Assesses inter-relationship of TP, Chl-a, and Secchi -- compared to reference;
- Estimates background P (chl-a and Secchi);
- One basis for goal setting;
Goal Setting

<table>
<thead>
<tr>
<th>1995 mean</th>
<th>Long-term</th>
<th>MIN-LEAP</th>
<th>Vighi-</th>
<th>BATHTUB</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 ± 3</td>
<td>40 ± 4</td>
<td>31</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

Lake Minnewaska Summer-Mean P (ppb)

- recent summer-mean TP comparable to predicted - at or near “background TP”
- Goal - TP < 30 μg/L (criteria for NCHF ecoregion < 40 μg/L)
- Below 30 μg/L nuisance blooms <5% of summer; 40 μg/L TP - blooms ~ 30%
Model Performance

**Good**
- Dimictic - NLF, NCHF;
- No large upstream lakes;
- Watershed char. similar to norm for ecoregion;

**Poor**
- Polymictic WCBP, NGP
- high internal recycle, high turbidity;
- Seepage lakes
- Chains of lakes -- upstream sedimentation;
MINLEAP Predicted vs Observed
Confidence interval = mean std. error of observed data.
Conclusions and Recommendations

- Simple model - first cut analysis;
- Rough estimate of nutrient and water budgets;
- Tool to flag lakes that may deserve additional study -- relative to others in ecoregion;
- Basis for communicating lake response and estimating response to change in load;
- One basis for goal setting -- along with Vighi, P criteria, observed data, and related;