How long the road to recovery?

Factors determining the persistence of P loading in aquatic systems
Global View

• Eutrophication of surface waters
  ▫ Drinking water supplies
  ▫ Biological diversity
  ▫ Habitat

Smith and Schindler 2009
Wetlands at Risk

• In last 100 years, 50% of world’s wetlands lost to agriculture, urban development, draining for malaria

• Ramsar Convention (1971 in Iran) (Convention on Wetlands of International Importance)
  ▫ “...the conservation and wise use of all wetlands through local and national actions and international cooperation...”
Wetlands

- Store and purify water
- Recharge natural aquifers
- Retain nutrients in floodplains → control flooding
- Home to significant biodiversity
P Cycle Revisited (Wet Version)
INPUTS of P

• Atmospheric
  ▫ Deforestation
  ▫ Agricultural activity
  ▫ Urban development/ construction

• Surface runoff
  ▫ Erosion
  ▫ Land use change
INPUTS of P

- Agricultural origin
  - Fertilizers
  - Manure
  - Pesticides
  - Insecticides
INPUTS of P

• Urban
  ▫ Garbage/Waste
  ▫ Sewage*

• Industry
  ▫ Effluent from wastewater
  ▫ Mining operations

Volga River, Volgograd, Russia
Eutrophication

- **P sensitivity**
  - 10 ug P L\(^{-1}\) can support algal growth reducing water clarity
  - > 50 ug P L\(^{-1}\) $\rightarrow$ deoxygenation of waters and fishkills
- Excessive eutrophication preventable at <10 kg P ha\(^{-1}\) yr\(^{-1}\) (Smil 2002)
Eutrophication

- Bennett et al. 2001 inquire “Are there changes in the global P cycle that could increase impacts on freshwater systems?”
  - Is there increased storage of soil P?
- “What potential changes in the global climate can alter P cycling in freshwater systems?”
The Good News

- Survey 35 Lakes
  - Max P loads 3500-8 ug P/L and MRT from 0.2 – 56 years

Jeppesen et al. 2005
The Good News

- Re-oligotrophication is Possible! (10-15 years)

<table>
<thead>
<tr>
<th>Response variable</th>
<th>Shallow lakes (mean depth &lt;5 m or polymictic)</th>
<th>Deep lakes (others)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P response time to TP loading reduction</td>
<td>Typically 10–15 years</td>
<td>Typically 10–15 years</td>
</tr>
<tr>
<td>N response time to TN loading reduction</td>
<td>Typically &lt;5 years</td>
<td>Typically &lt;5 years</td>
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<tr>
<td>TP summer and annual</td>
<td>Decreased in most lakes</td>
<td>Decreased in all lakes</td>
</tr>
<tr>
<td>TN summer</td>
<td>Decreased in most lakes</td>
<td>No clear pattern</td>
</tr>
<tr>
<td>TN : TP summer</td>
<td>Increased in most lakes even in some lakes</td>
<td>Increased in most lakes</td>
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<td></td>
<td>with lower TN : TP in the inlet</td>
<td></td>
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<tr>
<td>SRP summer</td>
<td>Decreased in all lakes when TP decreased</td>
<td>Decreased in all but one lakes when TP decreased</td>
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<tr>
<td>SRP : TP summer</td>
<td>Decreased in all lakes when TP decreased</td>
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<td>DIN : SRP summer</td>
<td>Increased in most lakes</td>
<td>Increased in most lakes</td>
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<tr>
<td>Secchi depth summer</td>
<td>Increased in most lakes</td>
<td>Increased in most lakes</td>
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<tr>
<td>Chl a summer</td>
<td>Decreased in most lakes</td>
<td>Decreased in most lakes</td>
</tr>
<tr>
<td>Chl a : TP summer</td>
<td>Increased or no changes</td>
<td>Increased or no changes</td>
</tr>
<tr>
<td>Phytoplankton biovolume</td>
<td>Decreased in most lakes</td>
<td>Decreased in most lakes</td>
</tr>
<tr>
<td>Phytoplankton community changes</td>
<td>Higher importance of diatoms, cryptophytes and chrysophytes</td>
<td>Decline in cyanobacteria and greater importance of dinoflagellates and chrysophytes</td>
</tr>
</tbody>
</table>

Jeppesen et al. 2005
Factors Affecting Recovery

• Physical dynamics
  ▫ Phosphorus loads
  ▫ Retention time

  ▫ Tyne estuary:
    • Load = 1900 kg P/ha; MRT = 14 days
  ▫ Potomac estuary:
    • Load = 43 kg P/ha; MRT = 85 days

(Smil 2000; Metropolitan Washington Council of Governments, 2008)
Factors Affecting Recovery

- Internal loading
  - Iron
    - Fe:P > 2
  - "Scavenging" by Fe influenced
    - sulfides (FeS)
    - Fe-carbonate minerals

Hoffman et al. 2008
The Bad News

- Recovery isn’t “complete”
- Water quality is key however, alternative ecosystems result

What are the effects of changed ecosystem function?
Altered States

- High P and changes in species composition

Figure 1. Aerial view of a control and P-addition plot, Buena Vista marsh, March 2003. Bar segment = 20 cm.

Rejmankova et al. 2008
Altered States

• Disease risk?
  ▫ Positive correlation with P loading of wetlands and increased malaria incidence (Pope et al. 2003)

• Need to identify thresholds and feedbacks in interactions between nutrient loading and host-pathogen dynamics

\[ P \rightarrow \]
Where are Higher Risks?

- Must consider factors affecting recovery
  - Native P status
  - Human impact: Rate of loading
  - Geometry of water body: mean residence time
  - Mineralogy of lake/ wetland sediment
    - Fe concentration
    - Salinity (esp. sulfate salinity)
  - Biology trophic cascade; vegetation
Regionally Specific Concerns:

Tropical versus temperate lakes

- Higher temperatures, higher rates of metabolism → anoxic hypolimnion regardless of trophic activity (Marshall and Falconer 1972)
- Temperature and light virtually never limiting; addition of relatively small amounts of nutrients may greatly increase productivity
- Relative importance of N and P in eutrophication
Regionally Specific Questions:

Tropics

• Might tropical water bodies, surrounded by tropical soils with high fixing capacity be at lesser risk of eutrophication if storage is high?
• Greater eutrophication risk because of Fe-P associations and seasonal flooding? Erosion? Rapid land use change and human population growth?
• Is there greater human impact due to eutrophication because of disproportionate disease risk? Low availability of drinking water?
Regional Effects of Climate Change

• Shift of relative contribution of sources which can change P loads and retention time
• Changes in hydroperiod and fluctuation of aerobic and anaerobic conditions
Regional Patterns of Land Use Change

- **Deforestation:**
  - Interception and retention of water affects P movement into water bodies (flow rates)
  - Increased loads due to erosion, dust production
  - Pasture conversion/ livestock production increases waste flows
The Flip Side

- Terrestrial systems (P deficits for production)
- Aquatic systems (P surpluses for production)
Potential for Risk Assessment

- Information required
  - Map of water bodies
  - Surrounding land uses
  - Estimates of nutrient loads
  - Geometry and geochemistry
Discussion

Laguna Hedionda, Bolivia