Eutrophication, Cyanobacteria, and Floating Wetlands
Quantification and remediation

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Global rise of cyanobacterial blooms

Although cyanobacterial blooms have been known since ancient times (BOX 1), several studies indicate that they are currently increasing globally. For example, analysis of cyanobacterial pigments in sediment cores from over 100 lakes in North America and Europe shows that cyanobacteria have increased substantially in almost 60% of the lakes since the industrial revolution, that cyanobacterial abundance has increased disproportionately relative to other phytoplankton and that this increase has accelerated since 1945 (REF.26). This trend is likely to continue in the next decades. A recent study used climate change projections from five global circulation models as input for a coupled water quantity and quality model of the USA28. The model predicts that, in the USA, the mean number of days with harmful cyanobacterial blooms will increase from about 7 days per year per waterbody under current conditions to 18–39 days in 2090. The expansion of cyanobacterial blooms and their economic and societal

Huisman et al. 2018
Bloom Quantification
What to measure and how to measure it

Sampling and Laboratory

EPA Buoy: Summer 2015-Present
EPA Buoy in-vivo fluorescence

2015

2016

2017

2018

Turbidity (NFU) & Chlor (RFU)

Phycocyanin (RFU)
Cyanobacteria (Cells / mL)
Abundance Estimation Using Sedgewick Rafter Counting Chamber (Catherine et al. SOP 1. 3.3)
Can we trust turbidity?

**Laboratory Measurements**
- Turbidity (NTU) & Chlor (RFU)
- EPA Buoy
- Phycocyanin (RFU)

**Internal Agreement**
- Lab. Turb vs Cell Count
- EPA Turb vs Phyco.

**Comparison of EPA vs Lab. Measurements**
- EPA turb. vs Cell count*
- EPA Turb vs Lab. Turb*

Cells/ml = (Turb\_EPA - 2.19) * 40,000

*1 day offset
Theory

Oligotrophic State I
Clear with Submerged vegetation

Eutrophic State II
Turbid with algal growth

Top-down Control

Bottom-up Control

International Institute for Sustainable Design
Experimental Lakes Area: Ontario, Canada
Assimilative Factor and Alternative Equilibria

- Nutrient Loading
- Biotic Factors: Species composition, Trophic interaction
- Alternate Equilibria
- Nutrient Concentration
- Water Quality

Long Lake Michigan, from: Trophic Downgrading of Planet Earth
Estes et al. (2011)

Alternate Equilibria in Shallow Lakes
Scheffer et al. (1993)
Reducing Phosphorus to Curb Lake Eutrophication is a Success

David W. Schindler, Stephen R. Carpenter, Steven C. Chapra, Robert E. Hecky, and Diane M. Orsiel

ABSTRACT: As human populations increase and land-use intensities, toxic and unsightly nuisance blooms of algae are becoming larger and more frequent in freshwater lakes. In most cases, the blooms are predominantly blue-green algae (Cyanobacteria), which are favored by low ratios of nitrogen to phosphorus. In the past half century, aquatic scientists have devoted much effort to understanding the causes of such blooms and how they can be prevented or reduced. Here we review the evidence, finding that numerous long-term studies of lake ecosystems in Europe and North America show that controlling algal blooms and other symptoms of eutrophication depends on reducing inputs of a single nutrient—phosphorus. In contrast, small-scale experiments of short duration, where nutrients are added rather than removed, often give spurious and confusing results that bear little relevance to solving the problem of cyanobacteria blooms in lakes.

Table 1 Characteristics of some major ecosystem state shifts and their causes

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>State I</th>
<th>State II</th>
<th>Events inducing shift from I to II</th>
<th>Events inducing shift from II to I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakes</td>
<td>Clear with submerged vegetation</td>
<td>Turbid with phytoplankton</td>
<td>Killing of plants by herbicide Killing of Daphnia by pesticide</td>
<td>Killing of fish Low water level</td>
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</tbody>
</table>

Scheffer, Carpenter 2001

Ecological Thresholds: The Key to Successful Environmental Management or an Important Concept with No Practical Application?

Peter M. Groffman, Jill S. Baron, Tamara Bllett, Arthur J. Gold, Iris Goodman, Lance H. Gunderson, Barbara M. Levinson, Margaret A. Palmer, Hans W. Paerl, Garry D. Peterson, N. LeRoy Poff, David W. Rejeski, James F. Reynolds, Monica G. Turner, Kathleen C. Weathers, and John Wiens
The missing link: Floating wetlands provide habitat for zooplankton.
Hypothesis

Refugia (plant roots) → Reduced Predation → Large Bodied Zooplankton → Enhanced Grazing → Cyanobacteria (HAB)
**Wetland Design**

**Why?**
- History: Before urban development, the Charles River was a major tributary to the Charles River. The area was characterized by a complex habitat, supporting a diversity of species including shellfish, migratory birds, and anaerobic fish.
- Ecological feedback loops exist, which maintain the balance of aquatic ecosystems.

**Challenges**
- Nutrient runoff from urban areas and agricultural practices can lead to eutrophication, causing algal blooms that deplete oxygen levels and harm aquatic life.
- Wetland vegetation can help mitigate these effects by filtering pollutants and providing habitat for native species.

**Intervention**
- Floating wetland rafts can be used as floating islands, providing habitat for wildlife and helping to reduce nutrient runoff.

**Urban Condition**
- The urban area surrounding the wetland has a high population density and high levels of pollution, which can negatively impact the wetland ecosystem.

**Multiple Configurations**
- Wetland designs can be customized to fit specific site conditions, with multiple configurations possible to meet the needs of the ecosystem.

**SCENARIOS**
- Various wetland designs can be implemented, each tailored to specific site conditions and goals.

**Planting Strategy**
- **Goals** for plant selection include maximizing roots for habitat, creating a visually captivating design, and selecting varieties appropriate for the growing conditions.

**Research**
- Dynamic Modeling
- ZP Grazing Rates
- Bloom Quantification
- Water Quality Improvement
- Published Research
- Ecology, Water Quality
- Public Speaking
- Website, Pamphlet, Talks

**Public Education**
- Wetland Design
- Place Making
- Signs, Planting
Proposed Research and Anticipated Results

Field Experiment

Data Collection

Zooplankton
1. Species Abundance
2. Species mean body size
3. Total Herbivore Biomass

Bloom Quantification
1. Cell Counts
2. Chlor extraction (?)
3. Phycocyanin extraction (?)

Floating Wetland
1. E. coli
2. Plant growth and survival

Public Data Sets & Remote Sensing

Calculation
1. Algal Growth Rates
2. Peak Algal Biomass
3. Community Grazing Rates
4. Substrate specific grazing rates

Modeling
1. Predation and Competition
2. Critical Grazing Rate
3. Nutrient Concentration and Turbidity

Literature

Results
1. Wetland sizing criteria for water quality improvement
2. Improved bloom alert system
3. Improved long-term monitoring
Permitting and Progress

- Wetland Design Sizing and Location
  - Material Selection
    - Engineer Selection
      - Informational Meetings
        - Vendor Selection
          - Finalize Design
            - Engineered Drawings
              - Project Narrative
                - Permit Pre-submission
                  - Cambridge Con. Com.
                    - Army Corp Self Verification
                      - 10A Permit
                        - DCR Research Permit
                          - Permit Strategy
                            - Anchor Design
                              - Sasaki Design Review
                                - Finalize Design
                                  - Engineer Selection
                                    - Informational Meetings
                                      - Vendor Selection
                                        - Wetland Design Sizing and Location
Thank You!
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<tr>
<td>Cyanobacteria and eutrophication</td>
<td>Shapiro, 1980; Coakley &amp; Baker, 2014; Gragnani, Scheffer, &amp; Rinaldi, 1999; Jeppesen et al., 1997; Scheffer &amp; Van Nes, 2007; Smith, 2003</td>
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<td>Nutrients and Eutrophication</td>
<td>Schindler, Carpenter, Chapra, Hecky, &amp; Orihel, 2016</td>
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<td>Alternative Equilibrium</td>
<td>Bond et al., 2015; Scheffer &amp; Carpenter, 2003; Scheffer, Hosper, Meijer, Moss, &amp; Jeppesen, 1993; Yu et al., 2016</td>
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<td>Floating Wetlands</td>
<td>Location &amp; Island, 2005; McAndrew &amp; Ahn, 2017; Power, Matthews, &amp; Stewart, 2017; Shapiro, 1980; Urrutia-Cordero, Ekvall, &amp; Hansson, 2015</td>
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