A Living Laboratory at Southern Illinois University: Remediation and Sustainable Science for Harmful Algal Blooms Following the 2016 Dredging of Campus Lake

Dr. Marj Brooks
Rachel Steiger

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- **Sierra Club, Shawnee Chapter**
SIU’s Campus Lake: A natural outdoor laboratory

Problems:
• High nutrients
• High temperatures
• Low oxygen

Solutions:
• Remove or trap nutrients
• Cool the water
• Aerate the water
• Exercise and improve water quality

When Ecosystems Thrive, People Thrive
Basic facts about Campus Lake

• 40 acre lake
• Contains 104,272,320 gallons of water
• Total volume refreshes ~1.75 years
• The shoreline under consideration was 12,900 feet long
• Campus lake has an income of nutrients from 23 storm drains
• It also had a savings account of decaying algae—enough wet compost to maintain hyper-eutrophic conditions for 50 years
2011 Sediment Depths

Sediments are not deep, however, build up of detritus was significant.
2015 Savings Account:

A conservative estimate of detritus was one cubic foot along the entire shoreline.
Stored nutrients in decaying algae and estimated time to flush Campus Lake naturally

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Best 1</th>
<th>Moderate 2</th>
<th>Worst 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated cubic feet of algae / linear foot of shoreline</td>
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</tr>
</tbody>
</table>

1. 12,900
2. 25,800
3. 38,700

1. 20.1
2. 40.3
3. 60.4

1. 3.0
2. 5.9
3. 8.9

1. 0.2
2. 0.3
3. 0.5

1. 10.3
2. 20.7
3. 31.0

18 years
36 years
54 years
2016 Southern Illinois University invested $400,000
Lowered lake level and dredged detritus
Detritus, “wet compost” deposited at shoreline
Buoyant starch & lipid content
Beginning 24 October 2016
Unstable organics above dry mud flat
Sierra Club Tackles the Compost
Completed Zones 1 & 2

Sierra Club Completed Zone 3 Up to Here
23,240 tons removed
Where did the spoils go?
Results: Benefits of dredging shown in water column
PO4 (mg/L)

1.00 - 1.99
0.50 - 0.99
0.20 - 0.49
0.00 - 0.19

Ideally 0.01 - 0.200 mg/L PO4

Data Range 0.07 - 1.27

Acceptable

June 2010
Hypolimnion PO4
PO4 (mg/L)

<table>
<thead>
<tr>
<th>Range</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00-1.99</td>
<td></td>
</tr>
<tr>
<td>0.50-0.99</td>
<td></td>
</tr>
<tr>
<td>0.15-0.49</td>
<td></td>
</tr>
<tr>
<td>0.00-0.19</td>
<td></td>
</tr>
</tbody>
</table>

Ideally 0.01 - 0.200 mg/L PO4

Data Range

No detect - 0.14 mg/L PO4

September 2017
Hypolimnion PO4

Acceptable
Ongoing concern: Income from storm drains
2013 Nitrate

All values below eutrophic, <1,875 mg NO₃/L
April 2016
Pre-dredge Nitrate

Legend
Campus Lake Nitrate (mg/L)

- 0.0 – 2.5
- 2.5 – 5
- 5.0 – 25
- 25 – 50
- 50 – 75
- 75 – 100
- 100 – 125

All values below eutrophic, <1,875 mg NO₃/L
All values below eutrophic, <1,875 mg NO$_3$/$L$.  

Legend

Campus Lake Nitrate (mg/L)

- 0-2.5
- 2.5 – 5
- 5 – 25
- 25 – 50
- 50 – 75
- 75 – 100
- 100 – 125
2013 Pre-dredge Phosphate

90% exceed eutrophic, >0.2 mg PO$_4$/L
April 2016
Pre-dredge Phosphate

60% exceed eutrophic, >0.2 mg PO$_4$/$L$,
3 culverts > 1 mg/L
July 2017 Post-dredge Phosphate

36% exceed eutrophic, >0.2 mg PO₄/L, Highest value 0.4 mg/L
Next steps: Inhibit CyanoHAB growth, limit N & P

• **Aerate**
  - In the water column, Lake contains 40 x more Fe and Ca than required to bind all PO₄

- ![Chemical structure of phosphate](image)

  - But that sequestration is seasonal

• **Cool**
  - One calorie cools 1 gram of H₂O by 1 °C
  - 540 calories of heat loss gram H₂O evaporation
  - Heat loss / one liter is can cool 180 L by 3 °C
  - 3 °C cooling from 27 to 24 °C can slow cyanobacterial growth by 25%.
Next steps: Inhibit CyanoHAB growth

• **Aerate**

- Cell counts dropped by 54% in 1 week, 16:8 h light:dark photoperiod, constant 30 °C
- Why?
- Aeration inhibits $N_2$ fixation

• **Wetlands & Swimming Areas**

- 2 x 9 m wetland can remove
- 2 kg $NO_3$ per day
- 125 kg of organic carbon → future detritus
Eco-Recreation Projects Underway:
Solar fountains, Pedal-powered water cannons

Kayaking beside a fountain in Barrie, Ontario (no photo credit. https://www.tripadvisor.ca/)

Watering with pedal power at the PermaPai agriculture project in Pai, Mae Hong Son province of northern Thailand (https://permapai.wordpress.com/2013/03/08/bicycle-pump-power/)
Prototypes: Solar fountains, Pedal water cannons
Potential Eco-Rec Project: Phone and “Fitbit” apps that link cardio directly to ... → lake health
Innovative aspects of Sustainable Eco-Recreation

- Methods to control harmful algae are well known but... Now, directly linked to human health
- Uses sustainable solar, wind, or human power
- Uses natural ecology, no chemicals
- Experiential learning incorporates theory and research into action
- Empowers students to learn, serve, and succeed
$400K investment yielded $1M donation from the Becker Family for Boathouse Renovation
Summary

- **Dredging results:** Water column P lowered by 90% to below 0.2 mg/L
- **Storm drain results:**
  - Decrease in P from storm drain from 90% to 34% of drains above eutrophic limit
  - Total storm drain input of P halved from 7 mg/L to 3.2 mg/L across the lake
- Intensive analysis underway

—Shameless plug

See Rachel Steiger’s poster
Questions?
Sigma plot of nutrients in water column over time.
Sustainable Eco-Recreation Designed by Students

Possible Projects:
• Fountain maze as an obstacle course for paddle boarders
• Shoreline swimming pool with wetland water treatment

Benefits:
• Renewable Energy
• Inter-disciplinary Experiential Education
• Career Building. Tiered funding tied to meeting deadlines, outreach, team-building
• Produce sustainable answers to a worldwide environmental problem
• New Patents and Products → Think Burton snowboards.
Nutrient levels in some areas of the lake were ~10 to ~60 times higher than concentrations that support moderate algal growth in lakes.

### 2013 Data

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Summer (µg/L)</th>
<th>Late Fall (µg/L)</th>
<th>Limit between &quot;Low&quot; to &quot;Moderate&quot; nutrients as NO₃, PO₄, or NH₃ (µg/L)</th>
<th>How many multiples of limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrate</strong> (NO₃)</td>
<td>500</td>
<td>11,000</td>
<td>1,356</td>
<td>8</td>
</tr>
<tr>
<td><strong>Phosphate</strong> (PO₄)</td>
<td>521</td>
<td>1,825</td>
<td>31</td>
<td>58</td>
</tr>
<tr>
<td><strong>Ammonia</strong> (NH₃)</td>
<td>900</td>
<td>250</td>
<td>119</td>
<td>8</td>
</tr>
</tbody>
</table>
Wetlands. Each day, a 2 x 9 m wetland can:

- Prevent wet compost
  - Remove 12 kg (27 pounds) of organic carbon
  - Remove 2 kg (4 ½ pounds) of nitrate
- Great habitat for young fish
- Only harvesting plants removes phosphorus

Eco-Recreation Projects: Solar fountains, Pedal water canons

Kayaking through a fountain in Barrie, Ontario (https://www.tripadvisor.ca/)

Watering with pedal power at PermaPai agriculture project in Pai, Mae Hong Son province, Thailand (https://permapai.wordpress.com/2013/03/08/bicycle-pump-power/)
Eco-Rec Projects: Obstacle course

Kayaking or paddling through a obstacle course of fountains → aerate & cool

Water cannons battles over wetlands using pedal power → aerate, cool, & remove nutrients
The science: Benefits of cooling and aeration

When aerated day and night with an aquarium bubbler, cyanobacteria cannot use nitrogen from the air. Cell counts dropped 54% after one week at 30 °C (86 °F) (M. Brooks, unpublished data).

Blue arrow shows that cyanobacteria have a 35% growth rate at cool temperatures where healthy algae grow at 90% of their maximal rate (Paerl et al. 2016. Harmful Algae 54:213-222).

540 calories of heat are lost when 1 gram of water evaporates

For every liter evaporated, 540,000 calories of heat is lost. That’s enough to cool two 40-gallon aquariums from 86 to 71 °F.

540 calories of heat is lost when 1 gram of water evaporates.

\[ y = -0.0872x + 15.939 \]

\[ R^2 = 0.99, \ P = 0.002 \]
June 2010
Ground Water PO$_4$

PO$_4$ (mg/L)

- **>1.0**
- **0.51-1.0**
- **0.26-0.50**
- **0.00-0.25**

Data Range

0.18 - 2.75 mg/L PO$_4$
Nutrient hotspots around Campus Lake

2010 Data

### June 2010 Storm Drain Inputs

<table>
<thead>
<tr>
<th>PO$_4$ (mg/L)</th>
<th>Range</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.40</td>
<td></td>
<td></td>
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<tr>
<td>0.20 - 0.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10 - 0.19</td>
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<td></td>
</tr>
<tr>
<td>0.05 - 0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00 - 0.049</td>
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</tr>
</tbody>
</table>

**Data Range:** 0.06 - 0.47 mg/L PO$_4$

**Ideally:** 0.01 - 0.20 mg/L PO$_4$
<table>
<thead>
<tr>
<th>% Increase</th>
<th>Phosphorus Percent Increase</th>
<th>Data Range (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;300%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150-300%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-150%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-50-0%</td>
<td></td>
<td></td>
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<tr>
<td>&lt;50%</td>
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Storm Drain Increases from 2004 to 2010
