Algal Blooms, Circulators, Waterfowl and Eutrophic Greenfield Lake, NC

Michael A. Mallin, Matthew R. McIver, Ellen J. Wambach, and Anna R. Robuck

Center for Marine Science
University of North Carolina at Wilmington
Wilmington, NC
910 962-2358
www.uncw.edu/cms/aelab/

Greenfield Lake

- Blackwater system, first dammed and filled as a mill pond in 1750
- Purchased for a city park in 1925
- Surface area 37 ha, average depth 1.2-1.5 m
- Total watershed is 1025 ha (2532 acres)
- One outfall, but 6+ inflowing streams
- Watershed is 37% impervious coverage
- 3 lake and 5 tributary stream stations sampled monthly to bimonthly by UNCW since 1998
A POLLUTED URBAN LAKE

- Recently (February 2014) proposed by NCDWR for inclusion on the NC 303(d) list due to excessive algal blooms
- Besides algal blooms, hosts periodic macrophyte growths that are treated by herbicides
- Most tributary streams have hypoxia problems
- Occasional fish kills in lake
- All stream stations have geometric mean fecal coliform counts exceeding 200 CFU/100 ml; periodic coliform issues in-lake as well
- Sediments in some areas polluted by excessive copper, lead, zinc and PAHs

2006-2013 WATER QUALITY AT GREENFIELD LAKE PARK
mean ± standard deviation (range) n = 168

- Ammonium-N: 53 ± 70 µg/L (5-410)
- Nitrate-N: 78 ± 107 µg/L (5-470)
- TN: 921 ± 784 µg/L (50-5,100)
- Orthophosphate-P: 27 ± 26 µg/L (10-180)
- TP: 96 ± 70 µg/L (10-420)
- Chlorophyll a: 34 ± 39 µg/L (1-303)
- BOD5: 3.6 ± 2.4 mg/L (1.0-16.0)
- Fecal coliforms: 1,090±6,270 (3-60,000)
So – what controls the algal blooms? To find out we performed NUTRIENT ADDITION BIOASSAYS

- We performed 5 nutrient addition bioassays at 3 stations in Greenfield Lake between September 1998 and August 1999
- Additions were nitrate at 100 μg-N/L, phosphate at 50 μg-P/L, and N+P combination; incubated for 3 days and sampled daily for 3 days for chlorophyll a
- N alone caused significant chlorophyll stimulation over control 11/15 experiments, N+P 12/15 experiments, P alone 1/15 experiments

RESULTS OF NUTRIENT ADDITION BIOASSAY, JUNE 1999

N Stimulates algal bloom formation
RESULTS OF NUTRIENT ADDITION
BIOASSAY, AUGUST 1999

N stimulates algal bloom formation

So – where does the P come from?
WATERFOWL CONTRIBUTIONS TO
GREENFIELD LAKE NUTRIENT LOAD

• We did weekly waterfowl surveys at 7 sites around the lake, August 2000-July 2001
• Maximum number of birds December-March
• Diving ducks, dabbling ducks, Muscovy ducks, geese, coots, cormorants, gulls, herons, grebes
• From bird counts and literature values of guano composition by species, we computed monthly waterfowl contributions to lake TN and TP
• Waterfowl contributed only 4% of lake TN but 26% of lake TP (21% of this by cormorants) annually—but cormorants feed in the river by day and roost at lake by night (and defecate “new” phosphorus into lake – called “translocation” of nutrients)
Guano on dock

Occasional fish kills, Feb 2006, July 2012

Greenfield thugs

Decaying algal bloom as a BOD source

Greenfield Lake bloom spring 2006, mainly green algae

Greenfield Lake *Anabaena spiroides* bloom June 1995

Note heterocytes and akinetes
Over the period 2006-2013 the chlorophyll $a$ – BOD5 correlation was highly significant ($r = 0.68$, $p < 0.0001$, $n = 168$ samples)

In 2005 the City of Wilmington had 4 Solarbee solar-powered mixers (SB 10000v12 units) installed in the main section of the lake to improve water quality. To help remove nuisance macrophyte growth the City added a total of 1,700 sterile grass carp to the lake (1,000 in 2005, 500 in 2006 and 200 in 2007). Additionally, an ongoing nuisance aquatic macrophyte monitoring program was added (done by Cape Fear River Watch) with spot herbicide control by City staff and contractors added in 2007.
Has water quality changed with rehabilitation measures? Changes in average parameter concentrations through time periods, 2000-2005 (147 samples) vs 2006-2013 (168 samples)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DO</td>
<td>7.1±3.5</td>
<td>7.5±3.1</td>
<td>NSD</td>
</tr>
<tr>
<td>Ammonium</td>
<td>106±212</td>
<td>53±70</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Nitrate</td>
<td>82±113</td>
<td>78±107</td>
<td>NSD</td>
</tr>
<tr>
<td>TN</td>
<td>1,047±1,195</td>
<td>921±784</td>
<td>NSD</td>
</tr>
<tr>
<td>TP</td>
<td>145±425</td>
<td>96±70</td>
<td>NSD</td>
</tr>
<tr>
<td>Chlor a</td>
<td>19±29</td>
<td>34±39</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>BOD5</td>
<td>3.0±2.1</td>
<td>3.6±2.4</td>
<td>NSD</td>
</tr>
</tbody>
</table>

While there has been no notable increase in inorganic nutrient concentrations, the frequency of phytoplankton blooms as chlorophyll a exceeding 40 µg/L has approximately tripled since Solarbee installation, herbicide treatments and grass carp additions. Blue-green algal blooms have been documented in 2005, 2006, 2011 and 2014.

July 22, 2011 blue-green algal bloom
Greenfield Lake
(Anabaena sp.)
SUMMARY

• Greenfield Lake is generally phosphorus-sufficient, with about 26% of the annual P load contributed by waterfowl, mainly cormorants. Much of it is likely “new’ P from river fish eaten and deposited as feces in or near the lake by roosting birds.

• Lake phytoplankton production is N limited, and lake nitrate concentrations are highest in the upper lake nearest the inputs (non-point inputs).

• The lake hosts large surface and water column algal blooms, some of which consist of N-fixing blue-green algae (such as Anabaena spiroides), other blooms have been green algae (Mougeotia, Spirogyra)

• Biochemical oxygen demand (BOD) is highly correlated with chlorophyll a concentrations; thus algal blooms are a cause of hypoxia

SUMMARY CONTINUED

• Addition of Solarbee mixers has not increased average dissolved oxygen concentrations in Greenfield Lake, but frequency of DO violations has decreased from 27% to 20%.

• Ammonium has significantly decreased, but nitrate concentrations have not changed

• Chlorophyll a concentrations have significantly increased since Solarbee installation, grass carp additions and herbicide applications from 11% violations (16/147) from 2000-2005 up to 31% violations (52/168) from 2005-2013

• This increase has led to NCDWR (in 2014) proposing Greenfield Lake to be added to the NC 303(d) list

• To reduce algal bloom frequency this watershed requires a management plan designed to a) determine principal source tributaries, and 2) reduce non-point source runoff of nutrients in targeted tributaries
Sometimes lake rehabilitation can have unintended consequences!

Acknowledgements
For funding I would like to thank the City of Wilmington and the University of North Carolina Wilmington.

For field and laboratory assistance I would like to thank Jesse Cook, Dylan Elks, Scott Ensign, Jen Hardin, Jenny Johnson, Matthew McIver, Doug Parsons, Rena Turner, Brad Shroeder and Heather Wells. For facilitation I thank Dave Mayes of Wilmington Stormwater Services.

More information is available on the Aquatic Ecology Laboratory website www.uncw.edu/cms/aelab/