Cyanobacteria blooms promote low zooplankton diversity by decreasing phytoplankton richness

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Introduction

• Anthropogenic inputs of nitrogen and phosphorus pose threats to water quality, increasing the relative abundance of cyanobacteria and leading to cyanobacteria blooms in many instances (Schindler 1977, Lee et al 2015)
• Cyanobacteria negatively influence phytoplankton diversity (Watson et al 1997, Bouvy et al 2001) and phytoplankton diversity is positively related to zooplankton diversity (Stiebel et al 2012, Soininva and Luoto 2012)
• Cyanobacteria nutrition, toxicity, and morphology directly affect individual zooplankton growth and population abundances (Lampert 1987). The relationship between cyanobacteria and zooplankton diversity, however, is not well known (Fig. 1)
• Lake Champlain provides an interesting opportunity to study these relationships. The lake is highly heterogeneous with regions ranging from shallow and eutrophic (Figs. 2 & 3) to deep and mesotrophic

Diversity was measured as Shannon H’, Simpson D’, and species richness.

Lake Champlain is highly heterogeneous with regions ranging from shallow and eutrophic (Figs. 2 & 3) to deep and mesotrophic.

Results: All Sites

• Phytoplankton H' and richness decreased with increased cyanobacteria abundance at shallow (p < 0.01 for each) but not deep (p = 0.97, p = 0.59) sites (Fig. 5a and b).

Hypothesis 1

• Zooplankton H' increased with increased phytoplankton richness at shallow (p = 0.03), but not deep (p = 0.80) sites (Fig. 6a). Zooplankton richness did not increase with phytoplankton richness at shallow (p = 0.13) or deep (p = 0.34) sites (Fig. 6b).

Hypothesis 2

• Zooplankton H' decreased with increased cyanobacteria abundance at shallow (p = 0.03) sites, but increased H' at deep (p = 0.03) sites (Fig. 7a). Zooplankton richness was not affected by cyanobacteria abundance at shallow (p = 0.06) or deep (p = 0.07) sites (Fig. 7b).

Hypothesis 3

Discussion & Conclusions

Results: Shallow Sites

• Phytoplankton H’, D’ and richness were negatively related to cyanobacteria abundance (Table 2).
• Zooplankton H’, D’, and F were positively related to phytoplankton richness.
• Zooplankton H’, D’, and F were negatively related to cyanobacteria abundance

Hypothesis 2 (Table 2).

Cyanobacteria & Photoplankton Diversity

Cyanobacteria bloozms promote low zooplankton diversity by decreasing phytoplankton richness

Table 1.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Location</th>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Lake</td>
<td>Burlington, VT</td>
<td>50</td>
<td>20</td>
<td>July 2010</td>
</tr>
<tr>
<td>Otter Creek</td>
<td>South Hero, VT</td>
<td>10</td>
<td>20</td>
<td>July 2010</td>
</tr>
<tr>
<td>Isle La Motte (off Rouses Point)</td>
<td>South Hero, VT</td>
<td>10</td>
<td>20</td>
<td>July 2010</td>
</tr>
<tr>
<td>Port Henry Segment</td>
<td>South Hero, VT</td>
<td>7</td>
<td>20</td>
<td>July 2010</td>
</tr>
<tr>
<td>Malletts Bay</td>
<td>Burlington, VT</td>
<td>50</td>
<td>20</td>
<td>July 2010</td>
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<td>July 2010</td>
</tr>
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<td>South Lake A</td>
<td>Burlington, VT</td>
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<td>South Lake B</td>
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<td>Lake Champlain</td>
<td>Burlington, VT</td>
<td>50</td>
<td>20</td>
<td>July 2010</td>
</tr>
</tbody>
</table>

Results: All Sites

• Phytoplankton and zooplankton data from 2006-2010
• Samples collected by the Lake Champlain Long-Term Water Quality and Biological Monitoring Program for 15 lake sites (Fig. 4).
• Sites were categorized as deep or shallow (Tab. 1).
• Diversity was measured as Shannon H’, Simpson D’, Piellou J’ (evenness) and species richness.
• Generalized linear models were used to investigate relationships among cyanobacteria, phytoplankton diversity, and zooplankton diversity.

Methods

Hypotheses

Table 1. Lake Champlain’s sampling site characteristics.

Figure 1. Known and hypothesized relationships. Solid lines represent known direct relationships and dashed lines represent the hypothesis relationships.

Figure 2. Cyanobacteria bloom in Lake Champlain. Image: Burlington Free Press 2010

Figure 3. Phrytoplanckton Diversity

Figure 4. Map of Lake Champlain

Figure 5. Relationships between cyanobacteria abundance and phytoplankton diversity (A) and richness (B). Lines as in Figure 1.

Figure 6. Relationships between phytoplankton richness and zooplankton diversity (A) and richness (B). Lines as in Figure 5.

Figure 7. Relationships between cyanobacteria abundance and zooplankton diversity (A) and richness (B). Lines as in Figure 5.

Figure 8. Observed relationships between cyanobacteria, phytoplankton, and zooplankton diversity in shallow sites.

Next Steps

• Investigate how phytoplankton and zooplankton community composition relate to cyanobacteria abundance

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