Effect of wastewater treatment plant effluent on algal productivity in the Sacramento River Part 1: Grow-out and wastewater effluent addition experiments

Alex Parker, Richard Dugdale, Frances Wilkerson, Al Marchi, Jan Drexel-Davidson, Sarah Blaser, and Jim Fuller

Romberg Tiburon Center, SFSU
August 18, 2009
River Grow-Out Experiments

20-L enclosures were used to investigate the potential timing and magnitude of Sacramento River phytoplankton blooms by removing light limitation.

A. Does NH₄ inhibit NO₃ uptake?

B. Is there a difference in rates of phytoplankton N assimilation for NH₄ and NO₃?

C. Does NH₄ delay the initiation of phytoplankton blooms?
Phytoplankton will only assimilate NH$_4^+$ as long as NH$_4^+$ concentrations are found in excess of inhibitory concentrations.

Maximum specific NH$_4^+$ uptake rates by phytoplankton will be lower than maximum specific NO$_3^-$ uptake.

Initiation of phytoplankton increase will be delayed as a function of initial NH$_4^+$ concentration.

River Grow-Out Experiments

20-L enclosures were used to investigate the potential timing and magnitude of Sacramento River phytoplankton blooms by removing light limitation.
Phytoplankton will only assimilate NH$_4^+$ as long as NH$_4^+$ concentrations are found in excess of inhibitory concentrations.

March 2009 Enclosure Experiments
Phytoplankton will only assimilate NH₄ as long as NH₄ concentrations are found in excess of inhibitory concentrations.
Phytoplankton will only assimilate NH$_4$ as long as NH$_4$ concentrations are found in excess of inhibitory concentrations.

March 2009 Enclosure Experiments
Phytoplankton will only assimilate NH$_4$ as long as NH$_4$ concentrations are found in excess of inhibitory concentrations.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Treatment</th>
<th>Initial NH$_4$</th>
<th>Time to deplete NH$_4$</th>
<th>NO$_3$ uptake inhibition? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBD08-1</td>
<td>GRC</td>
<td>0.0 ± 0.1</td>
<td>&lt;24hr</td>
<td>N (?)</td>
</tr>
<tr>
<td>Jul 08</td>
<td>RM-44</td>
<td>9.1 ± 0.8</td>
<td>72hr</td>
<td>Y</td>
</tr>
<tr>
<td>WBD08-2</td>
<td>GRC</td>
<td>3.3</td>
<td>24hr</td>
<td>Y</td>
</tr>
<tr>
<td>Nov 08</td>
<td>RM-44</td>
<td>71.9</td>
<td>&gt;144hr</td>
<td>Y</td>
</tr>
<tr>
<td>WBD09-1</td>
<td>GRC</td>
<td>1.0 ± 0.4</td>
<td>24hr</td>
<td>Y</td>
</tr>
<tr>
<td>Mar 09</td>
<td>GRC+N3</td>
<td>1.5 ± 0.4</td>
<td>24hr</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>GRC+N4</td>
<td>12.1 ± 1.2</td>
<td>96hr</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>RM-44</td>
<td>12.5 ± 1.5</td>
<td>96hr</td>
<td>Y</td>
</tr>
<tr>
<td>WBD09-3</td>
<td>GRC</td>
<td>1.4 ± 0.6</td>
<td>24hr</td>
<td>Y</td>
</tr>
<tr>
<td>May 09</td>
<td>GRC+N3</td>
<td>1.5 ± 0.2</td>
<td>24hr</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>GRC+N4</td>
<td>6.8 ± 0.2</td>
<td>96hr</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>RM-44</td>
<td>9.5 ± 0.4</td>
<td>96hr</td>
<td>Y</td>
</tr>
</tbody>
</table>
Maximum specific NH$_4^+$ uptake rates by phytoplankton will be lower than maximum specific NO$_3^-$ uptake.
Initiation of phytoplankton increase will be delayed as a function of initial NH$_4$ concentration.

<table>
<thead>
<tr>
<th></th>
<th>CEN</th>
<th>GRC</th>
<th>RM44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial NO$_3$ ($\mu$M)</td>
<td>22.7</td>
<td>12.8</td>
<td>12.6</td>
</tr>
<tr>
<td>Initial NH$_4$ ($\mu$M)</td>
<td>7.1</td>
<td>3.4</td>
<td>7.9</td>
</tr>
<tr>
<td>Initial DIN ($\mu$M)</td>
<td>29.8</td>
<td>16.2</td>
<td>84.5</td>
</tr>
<tr>
<td>Initiation Chl-a ($\mu$g L$^{-1}$)</td>
<td>4.3</td>
<td>1.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Time to NH$_4$ Depletion</td>
<td>24</td>
<td>72</td>
<td>&gt;168</td>
</tr>
</tbody>
</table>

November 2008
Initiation of phytoplankton increase will be delayed as a function of initial NH$_4$ concentration.
20-L enclosures were used to investigate the potential timing and magnitude of Sacramento River phytoplankton blooms by removing light limitation.

Phytoplankton will only assimilate NH$_4^+$ as long as NH$_4^+$ concentrations are found in excess of inhibitory concentrations. Maximum specific NH$_4^+$ uptake rates by phytoplankton will be lower than maximum specific NO$_3^-$ uptake. Initiation of phytoplankton increase will be delayed as a function of initial NH$_4^+$ concentration.
Serial addition experiments using SRWTP effluent and NH$_4$Cl were conducted in 6 hr incubations to investigate direct impact of wastewater and NH$_4$ on primary production and phytoplankton N uptake.

Questions that we can address with this approach:

A. Does SRWTP effluent or NH$_4$ inhibit NO$_3$ uptake?
B. Does SRWTP effluent or NH$_4$ inhibit NH$_4$ uptake?
C. Does SRWTP effluent or NH$_4$ inhibit C uptake (primary production)?
Wastewater / NH$_4$Cl Amendment Experiments

Serial addition experiments using SRWTP effluent and NH$_4$Cl were conducted in 6 hr incubations to investigate direct impact of wastewater and NH$_4$ on primary production and phytoplankton N uptake.

NO$_3$ uptake will be inhibited with NH$_4$ > 1 µM:
- For effluent
- For NH$_4$Cl

NH$_4$ uptake will increase at low concentrations and be inhibited at high NH$_4$:
- For effluent
- For NH$_4$Cl

Primary Production will be inhibited at high NH$_4$:
- For effluent
- For NH$_4$Cl
"Clean" NH₄ Addition Experiments

- C production may show some effect at elevated NH₄
- No effect observed for NH₄ uptake
- Clear inhibition of NO₃ uptake
Wastewater NH$_4^+$ Addition Experiments

![Graph showing the relationship between NH$_4^+$ concentration and VNO$_3$ and VNH$_4^+$](image)

- **Effluent**
- **NH$_4$Cl**

---

*Do Not Cite*
Serial addition experiments using SRWTP effluent and 
NH₄Cl were conducted in 6 hr incubations to investigate 
direct impact of wastewater and NH₄ on primary 
production and phytoplankton N uptake.

NO₃ uptake will be inhibited with NH₄ < 1 μM:
  For effluent
  For NH₄Cl

NH₄ uptake will increase at low concentrations and be inhibited 
at high NH₄:
  For effluent
  For NH₄Cl

Primary Production will be inhibited at high NH₄:
  For effluent
  For NH₄Cl
Summary

• NH₄ inhibition of NO₃ uptake holds everywhere

• Unlike Suisun and Rio Vista, chl-a accumulation is not delayed as a result of DIN composition.

• Effluent reduces C and NH₄ uptake (and NO₃ uptake) at concentrations >8 µM but NH₄Cl does not.