Is there suppression of algal production in Suisun Bay?

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Funded by CALFED and State Water Contractors
(Stop work order- data collected –work in progress)
Background: spring bloom in Suisun observed only when ambient ammonium (NH$_4$) low and uptake of nitrate (NO$_3$) by phytoplankton is high. For chlorophyll accumulation, need to access NO$_3$.

Possible mechanism: NH$_4$ inhibits phytoplankton access to NO$_3$

Wilkerson et al., 2006: Dugdale et al. 2007
Influence on Pelagic Food Web?

- Phytoplankton are important in the pelagic food web and POD
- A number of factors affect phytoplankton quantity and quality
  - Our question: what is the role of NH$_4$ in addition to these other factors
- Our approach is to remove other factors-such as light and benthic grazing and look at potential of phytoplankton for production and chlorophyll accumulation. Use enclosures/grow outs.
Grow Out/Productivity Indicators: used to investigate whether NH₄ delays the initiation of phytoplankton blooms

20-L cubitainers filled with surface water, maintained at 50% surface light, sampled for 5-7 days. This removes any light limitation and benthic grazing.

Questions addressed:
1. Given ideal conditions can chlorophyll accumulate as phytoplankton drawdown all available N?
2. Does NH₄ limit access to NO₃, and delay the time for chlorophyll accumulation?
Seven BS cruises (2007-8) to compare Suisun Bay with Central SF Bay and Rio Vista.

Data shown today- mostly grow out data of chlorophyll nitrate & ammonium (NO₃ & NH₄ uptake) (C uptake/fixation)

**NOTE:** concentration units used are µM, relevant level for phytoplankton physiology

1.5 µM = 0.02mg N/L = 0.02ppm
Central Bay Grow Outs (“healthy” controls)

Central Bay used as a “healthy” control in which: chlorophyll accumulates on a time scale of 48h

- First NH$_4$ is drawn down to zero
- Then NO$_3$ can be accessed and is drawn down to zero
- Greatest chlorophyll accumulation when NO$_3$ used.
- Carbon uptake tracks NO$_3$ uptake, and both show increased rates

Time scale is critical for chlorophyll accumulation. In nature, need favorable light and water column stability. If time scale is drawn out there is a decreased chance for favorable light conditions.

These are used to assess time scale and phytoplankton condition from other parts of SFB.
Central Bay Grow Out from BS3: June 2007

- Chlorophyll accumulation by 48h, matches DIN depletion
- NH$_4$ drawdown, then NO$_3$ drawdown completed by 72h
- Maximal NO$_3$ uptake > NH$_4$ uptake, C fixation tracks NO$_3$

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How do Suisun Bay phytoplankton compare?
How do Rio Vista phytoplankton compare?

For each BS cruise/grow out, the time scale of chlorophyll accumulation and nutrient drawdown, will be shown.
For some also the nutrient and C uptake rates-available but we have a lot of data to analyze…. 

If the data is similar to Central Bay, with chl accumulation (and N draw down) by 48 hours

(X) Poor performer-chl accumulation delayed, some chlorophyll accumulation by 96 hours

X Bad performer-no chlorophyll accumulation (or N draw down) by 96 hours
Susiun Bay Grow Outs: Example, June 2007

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<table>
<thead>
<tr>
<th></th>
<th>CENTRAL</th>
<th>BS1</th>
<th>BS2</th>
<th>BS3</th>
<th>BS4</th>
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<td>Y</td>
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<td>N</td>
<td>N</td>
<td>N</td>
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<td>Initial NH₄, µM</td>
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<td>3.8</td>
<td>3.9</td>
<td>8.7</td>
<td>4.4</td>
<td>6.6</td>
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*Suisun Bay* phytoplankton when given optimal conditions in grow outs show suppressed response vs. *Central Bay*.
- a delay in chlorophyll accumulation
- inability to drawdown all NH₄ by 48h

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Example of Rio Vista Grow Outs: June 2007

Init \(NH_4^+ = 9 \mu M\)

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# Rio Vista Grow Out Summary

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<td><strong>Chl accuml = N drawdown</strong></td>
<td>Y</td>
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<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
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<td><strong>Initial NH₄, µM</strong></td>
<td>14.6</td>
<td>7.5</td>
<td>9.0</td>
<td>7.0</td>
<td>16.2</td>
<td>15.4</td>
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Rio Vista phytoplankton when given optimal conditions in grow outs show more suppressed response than Suisun Bay.

- Longer delay in chlorophyll accumulation
- Chlorophyll accumulation does not match N drawdown
- Unlike Suisun, NH₄ rarely drawn down to zero
Does the ambient NH$_4$ play a role?

Central Bay and Suisun can take up NO$_3$, Rio Vista with more NH$_4$ shows less capacity. Higher ambient NH$_4$, and consequent low NO$_3$ uptake extends the time for N draw down and chlorophyll accumulation.

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Another approach – look at ability to use NO$_3$ – f-ratio

One way to look at productivity state is to use concept from oceanography that determines the percent NO$_3$ uptake relative to the total DIN uptake (f-ratio = $\rho$NO$_3$ / $\rho$NO$_3$ + $\rho$NH$_4$).

Two productivity patterns;
- low f-ratio, low NO$_3$ uptake-based production with low C uptake ($\rho$C) and chlorophyll vs
- higher f-ratio, NO$_3$ based production with high C uptake and chlorophyll.
Suisun and Rio Vista are poor performers with low f-ratio

The low f-ratio productivity pattern occurs in Suisun and Rio Vista. Little use of NO₃, low C uptake and chlorophyll accumulation

<table>
<thead>
<tr>
<th></th>
<th>NO₃</th>
<th>NH₄</th>
<th>Chl</th>
<th>C Uptake</th>
<th>NO₃ Uptake</th>
<th>NH₄ Uptake</th>
<th>f-ratio</th>
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<tr>
<td></td>
<td>µM</td>
<td>µM</td>
<td>µg/L</td>
<td>µmol/L/h</td>
<td>µmol/L/h</td>
<td>µmol/L/h</td>
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<td>Central</td>
<td>10.6</td>
<td>0.72</td>
<td>20.4</td>
<td>15.194</td>
<td>0.652</td>
<td>0.147</td>
<td>0.82</td>
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<td>Suisun</td>
<td>36.8</td>
<td>4.36</td>
<td>3.1</td>
<td>0.994</td>
<td>0.031</td>
<td>0.125</td>
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<td>Rio Vista</td>
<td>25.8</td>
<td>11.68</td>
<td>1.6</td>
<td>0.394</td>
<td>0.008</td>
<td>0.048</td>
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What about the river?
Initial conditions..... transect data from 2009

<table>
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<tr>
<th></th>
<th>NO₃</th>
<th>NH₄</th>
<th>Chl</th>
<th>C Uptake</th>
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<tr>
<td></td>
<td>µM</td>
<td>µM</td>
<td>µg/L</td>
<td>µmol/L/h</td>
<td>µmol/L/h</td>
<td>µmol/L/h</td>
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<td><strong>GRC</strong></td>
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<td>0.84</td>
<td>4.6</td>
<td>0.376</td>
<td>0.037</td>
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<td><strong>RM44</strong></td>
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<td>0.283</td>
<td>0.009</td>
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<td>0.16</td>
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Interestingly the river rates show low C uptake and N uptake but Garcia Bend is using NO₃ to fuel production (f-ratio =0.5) vs River Mile 44 which is using mostly NH₄, and has very low f-ratio like Suisun.

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However, in grow outs the river phytoplankton can accumulate chlorophyll.

Garcia Bend

River Mile 44

Behavior upstream appears to be different. When given optimal conditions in grow outs, chlorophyll accumulates like Central Bay (draw down all DIN) with slightly longer time scale (72h vs 48h in Central Bay).
Questions addressed using the grow outs during the BS Project:

1. Given ideal conditions can chlorophyll accumulate as phytoplankton draw down all available N?
2. Does NH$_4$ limit access to NO$_3$ and delay the time for chlorophyll accumulation?

Chlorophyll accumulation over 48h can occur in Central Bay with complete drawdown to zero of first NH$_4$, then NO$_3$.

Suisun and Rio Vista are poor performers and barely start to accumulate chlorophyll after 48h that may be associated with higher ambient NH$_4$, low f-ratios and less use of NO$_3$ and delays the time for chlorophyll accumulation to at least 96h or longer.

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Consequence for phytoplankton biomass and the POD?

This extended time scale for chlorophyll accumulation in Suisun and Rio Vista grow outs suggests that in situ there is a decreased chance for the algae to have sufficient water stability and available light for growth. NH$_4$ is likely a bottom up factor to the POD.

Is there suppression of algal production in Suisun Bay?

Yes- algal production (and nutrient drawdown) in Suisun Bay is suppressed, but more so at Rio Vista and this can be linked to their availability to use nitrogen on appropriate time scales.