

The Importance of Separate Consideration of Anthropogenic NH₄ and NO₃ Inputs for Effective Management of Estuarine Cultural Eutrophication



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Background



Estuaries and nearshore communities worldwide are heavily impacted by anthropogenic nutrients, including nitrogen (N) loading as a result of wastewater treatment and fertilizer use. Current N conceptual models consider NH₄ and NO₃ as a single dissolved inorganic nitrogen (DIN) pool, assuming that the primary production response will be similar on both N substrates. We have been reevaluating this assumption in the San Francisco Estuary (SFE).

It is well established that:

- 1) Phytoplankton NH₄ and NO₃ uptake interactions occur.
- 2) Phytoplankton species may have evolved separate N assimilation mechanisms for NO₃ or NH₄.

Hypotheses

Differences in phytoplankton biomass observed in three SFE embayments (Suisun, San Pablo and Central Bays) are due, in part, to nitrogen substrate (NH₄ or NO₃) used for primary production.

NH₄ inhibition of phytoplankton NO₃ uptake is a feature of San Francisco phytoplankton ecology and will limit phytoplankton access to a significant portion of the total DIN pool.

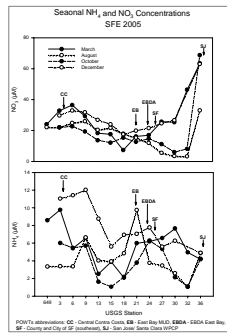
When access to NO₃ is possible, specific phytoplankton NO₃ uptake rates (VNO₃) will be higher than rates of NH₄ uptake in SFE.

Wastewater NH₄ and NO₃ Supply to the SFE

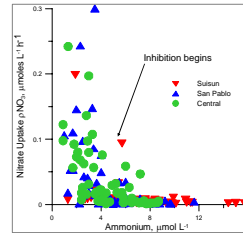
Name	Discharge (MGD)	type	location
San Jose/ Santa Clara WPCP (SJ)	167	Advanced Secondary	South Bay
East Bay MUD (EB)	120	Secondary	South Bay
City & County of San Francisco (Southwest) (SF)	85	Secondary	South Bay
EBA East Bay (EBDA)	77.1	Secondary	South Bay
Central Contra Costa (CC)	53.8	Secondary	Suisun Bay
Total POWT discharge SFE (47 plants)	718		

Five largest wastewater dischargers to SFE. Data for daily wastewater discharge, treatment level, and location in the SFE (Source: SFRWOB)

Secondary Wastewater Treatment discharges primarily NH₄. Advanced Secondary Treatment discharges primarily NO₃.



NH₄ inhibition of NO₃ Uptake



NH₄ has been known to inhibit phytoplankton NO₃ uptake in many marine systems (See Dortch, 1990).

In the San Francisco Estuary, NH₄ inhibition of NO₃ uptake occurs >3-4µM.

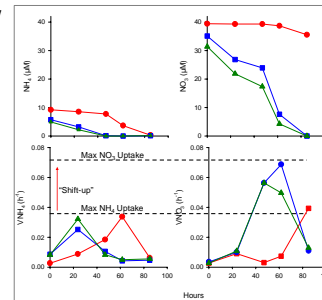
As a result, persistently high NH₄ reduces phytoplankton access to only ca. 20% of total DIN.

Differences in N Uptake by Phytoplankton in Response to NH₄ and NO₃ Supply

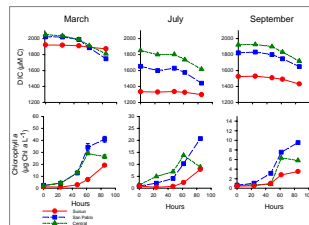
5-day "grow out" experiments show consistent sequence of N disappearance (top) and phytoplankton N uptake (bottom).

NH₄ inhibits access to NO₃ by phytoplankton. NO₃ uptake is delayed until NH₄ is reduced.

Once NO₃ uptake begins, phytoplankton NO₃ uptake is rapid and significantly higher than NH₄ uptake.



Phytoplankton Bloom Development



Enhanced phytoplankton N uptake is translated into higher growth.

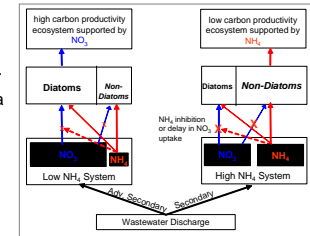
Higher rates of dissolved inorganic carbon use (top), greater chlorophyll increase (bottom), and greater phytoplankton cell numbers occur in treatments with significant NO₃ uptake (not shown).

Conceptual Model of Phytoplankton – DIN Interactions

Simplified conceptual model of two eutrophic systems (low versus high NH₄ systems) determined primarily from wastewater discharge practices.

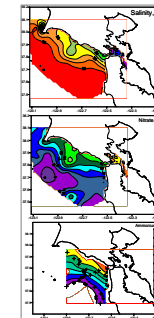
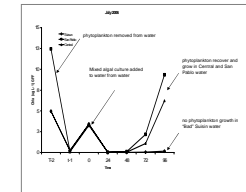
High NH₄ eutrophic systems lead to a non-diatom dominated system with lower primary production and biomass.

Low NH₄ eutrophic system supports diatom dominated phytoplankton community with high primary production and biomass.



Broader Implications for Management

Persistently high NH₄ in Suisun Bay may be a significant bottom-up control on phytoplankton growth. Coupled with known top-down controls, may have led to reduction in carbon supply to higher trophic levels.

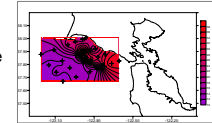


The San Francisco Bay outflow supplies nutrients, including significant NO₃ and NH₄, to the coastal ocean.

If NH₄ is not used within the estuary, inhibitory concentrations of NH₄ may reach the Marin Coast, influencing productivity dynamics and species composition.

Water resource models that consider only a single DIN pool may be oversimplified. Effective management of primary production response to cultural eutrophication may need to consider NH₄ and NO₃ separately.

We are investigating the influence of the SFE outflow on the Gulf of the Farallones with the Monterey Bay National Marine Sanctuary (R/V Fulmar).



Surface silicate concentrations in Feb 2007 show the influence of the SFE outflow on nutrient distribution outside of the Golden Gate Bridge.