Transport of nutrients from Sacramento River to Suisun and Grizzly Bays: Effects on River and Bay chlorophyll concentrations.

Dick Dugdale, Alex Parker,
Frances Wilkerson, Al Marchi

Outline

From newly acquired rates of ammonium, nitrate and carbon uptake we know that nitrate uptake is blocked by ammonium so that phytoplankton take up only ammonium below RM44

We can evaluate

a) effects of phytoplankton ammonium uptake on total river ammonium inventory

b) potential effects of added ammonium on river phytoplankton concentrations,

c) potential effects on Suisun Bay phytoplankton concentrations.

An example of regulatory measures that might be taken based on this new data on phytoplankton and nutrients in the river.

Questions

What is the effect of the phytoplankton on the downstream transport of ammonium?

What is the potential effect of inputs of ammonium to the river on production of chlorophyll?:

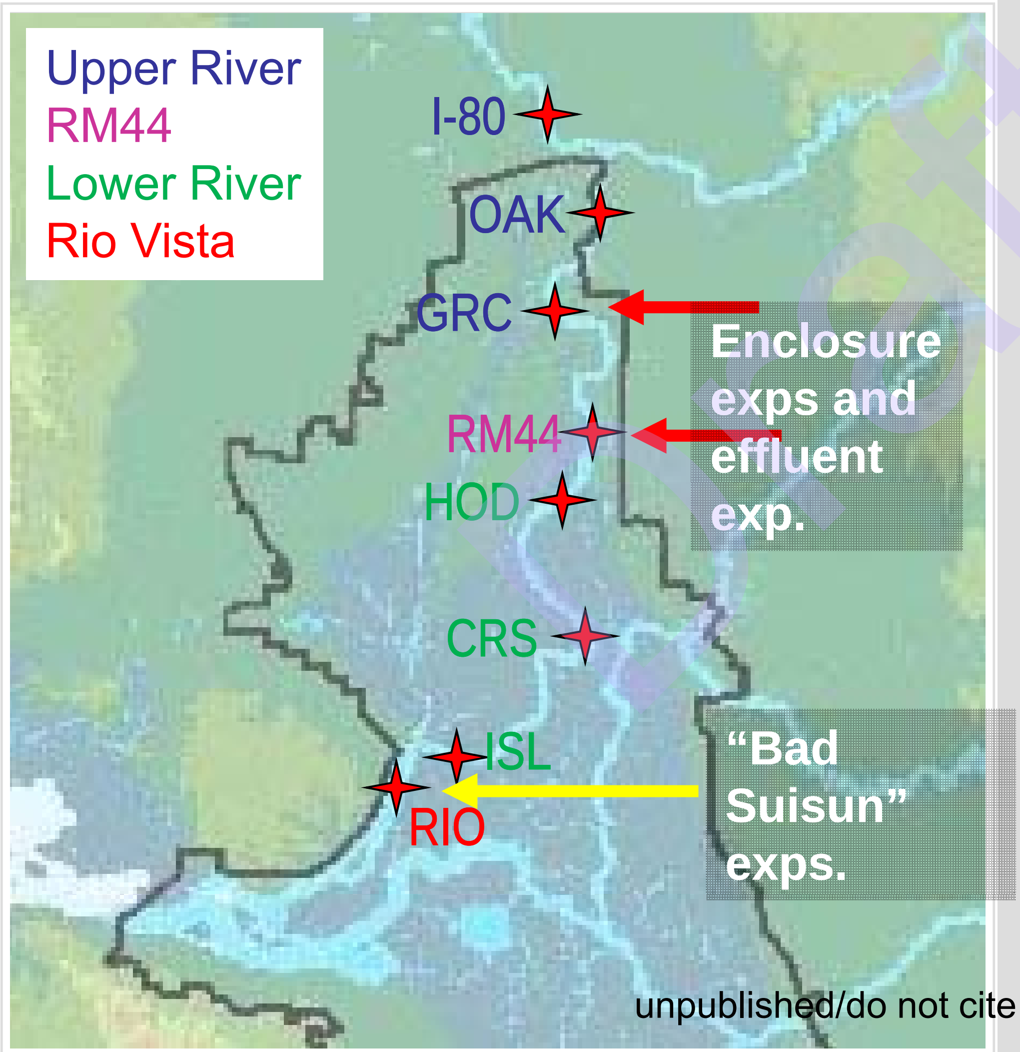
1) In the river?

2) in Suisun Bay?

What regulatory actions are available to mitigate these effects?

Study

Sampling Locations (8)



unpublished/do not cite

Sampling Times (5)

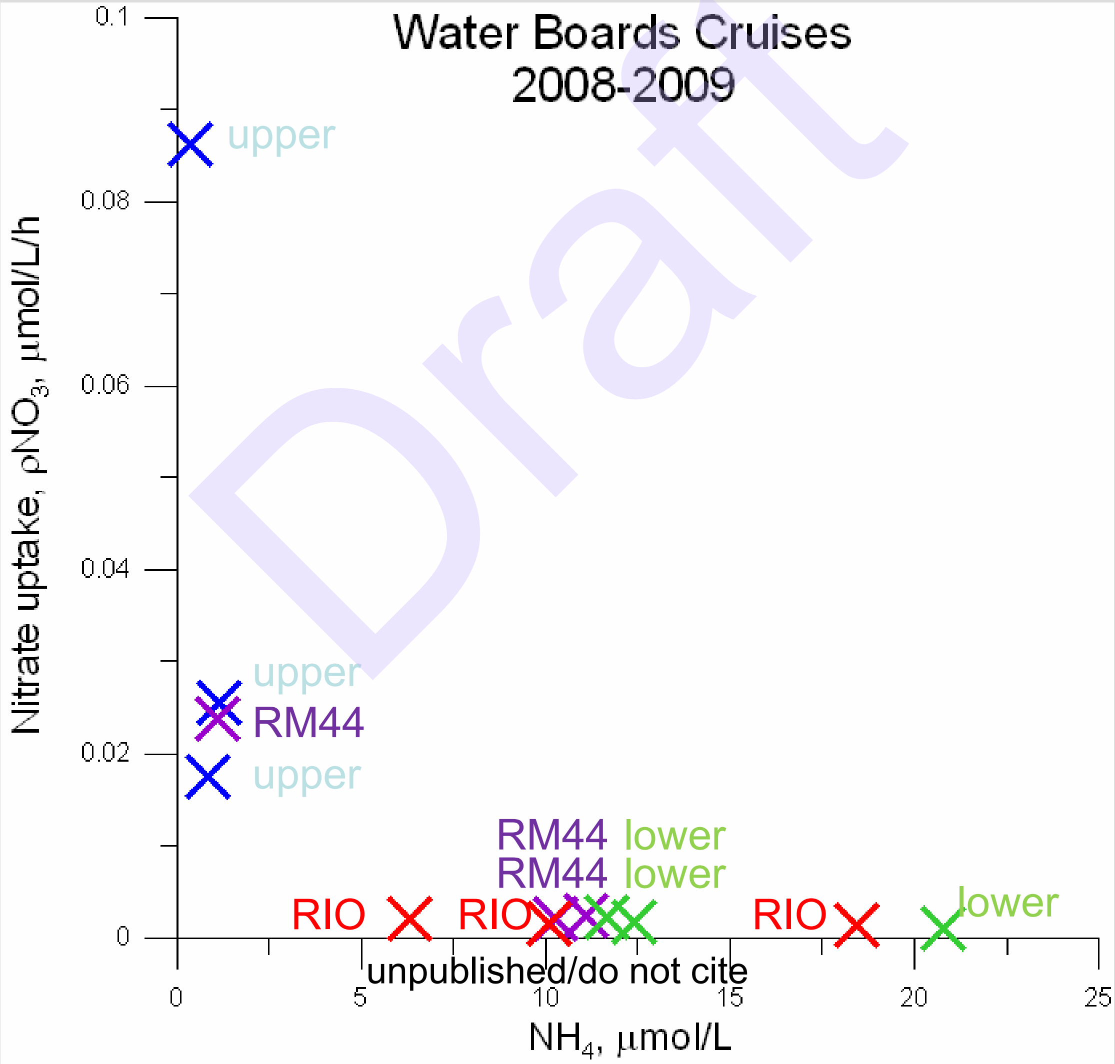
Cruise	Date
WB08-1	July 2008
WB08-2	November 2008
WB09-1	March 2009
WB09-2	April 2009
WB09-3	May 2009

Summary of mean data

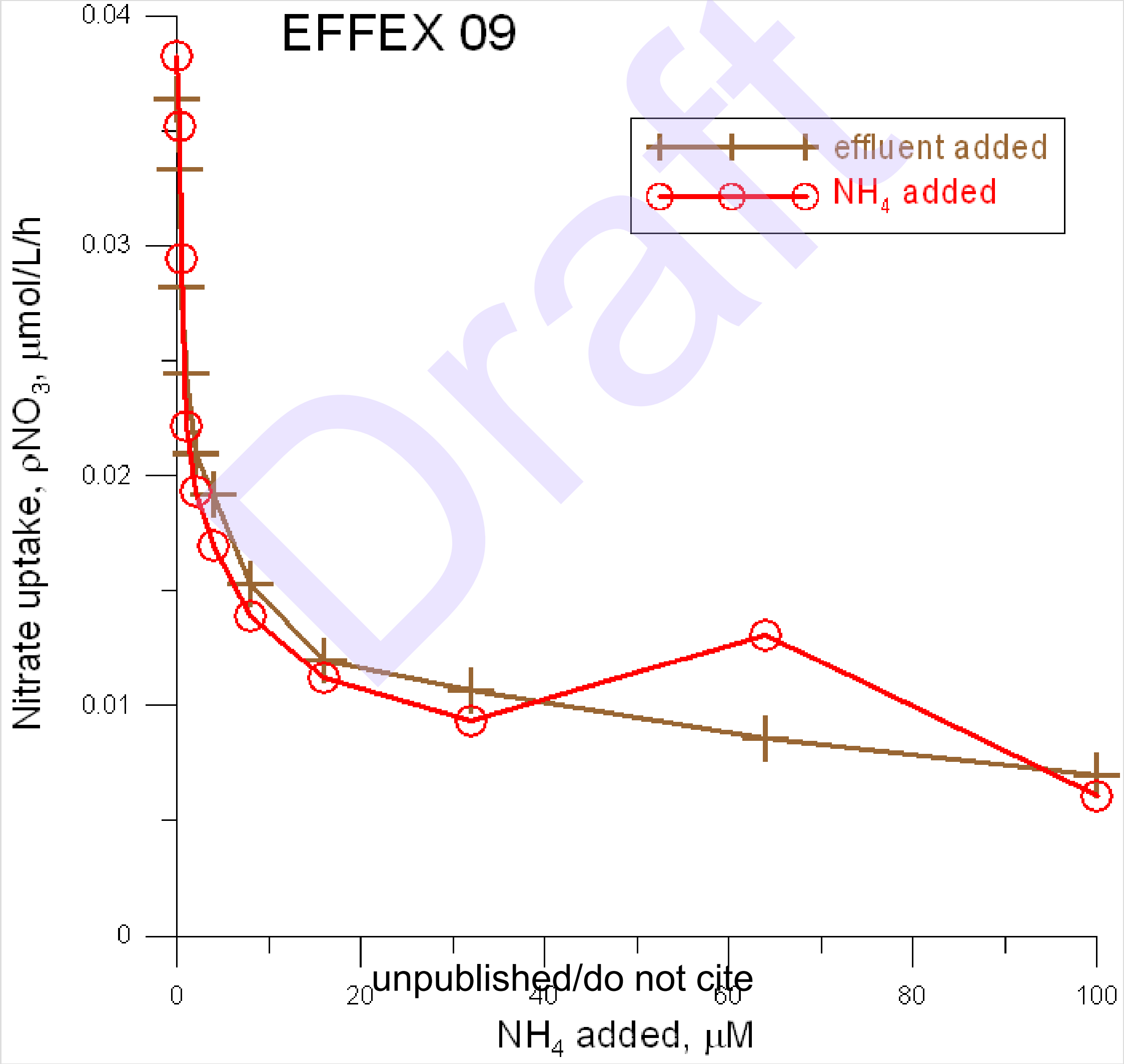
	Secchi m	NO3 uM	NH4 uM	Temp deg C	Chl ug/l
Upper	0.60	8.96	0.79	11.39	2.6
RM44	0.70	8.65	7.49	11.67	3.3
Lower	0.83	10.32	14.93	11.62	1.6
RV	0.57	21.24	11.61	11.81	1.5

	ρNO3 umol/l/h	VNO3 /h	ρNH4 umol/l/h	VNH4 /h	ρC umol/l/h	VC /h	f	Sum ρN umol/l/h	ρC/ sum ρN
Upper	0.0431	0.0062	0.0293	0.0037	0.3841	0.0047	0.53	0.0724	5.94
RM44	0.0095	0.0017	0.0485	0.0064	0.3681	0.0045	0.14	0.0579	6.97
Lower	0.0016	0.0002	0.0369	0.0048	0.3328	0.0035	0.04	0.0385	8.87
RV	0.0017	0.0003	0.0266	0.0050	0.2185	0.0028	0.06	0.0283	7.95

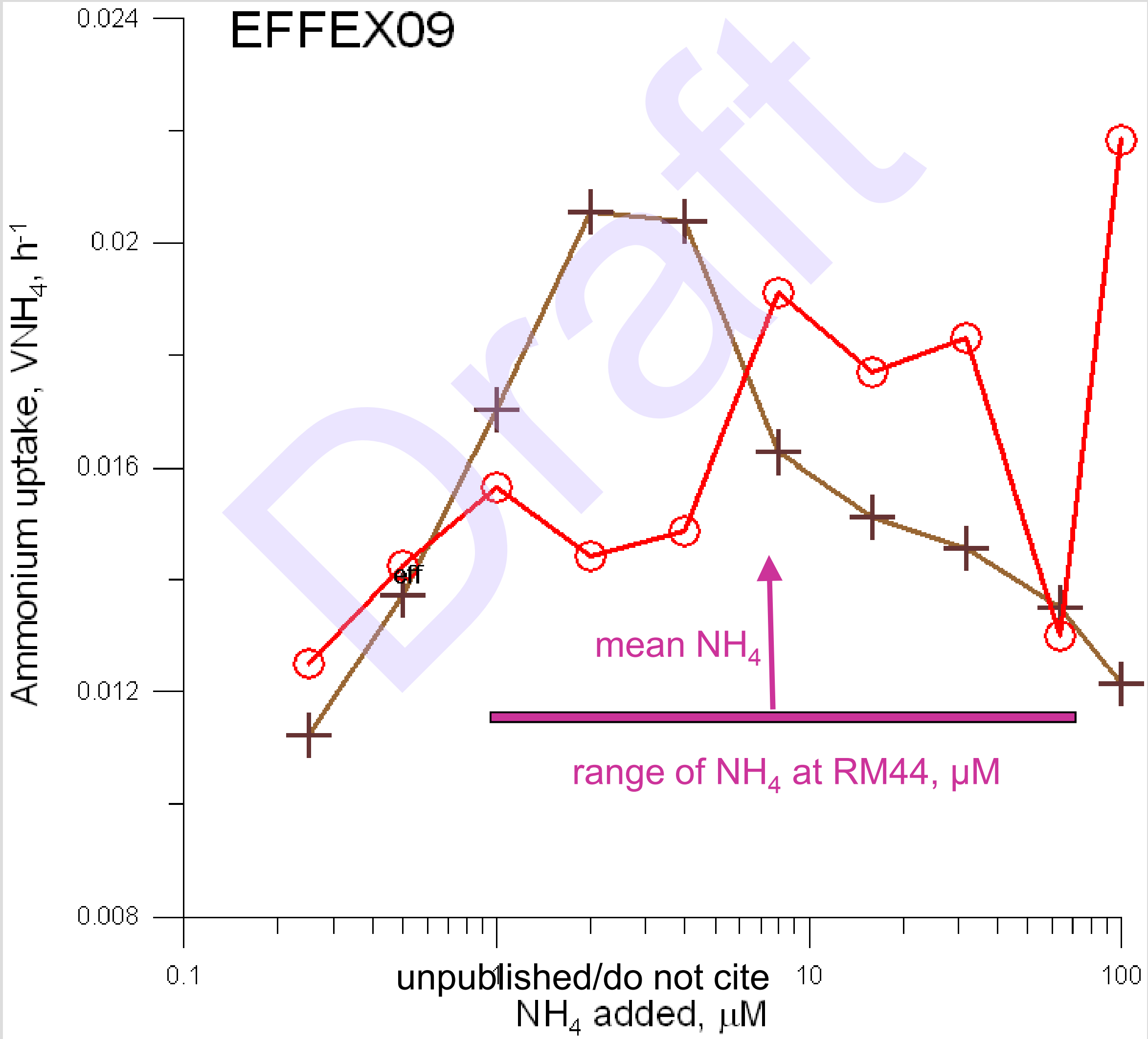
Nitrate uptake vs ammonium for all cruises shows with low nitrate uptake at high NH_4 concentrations



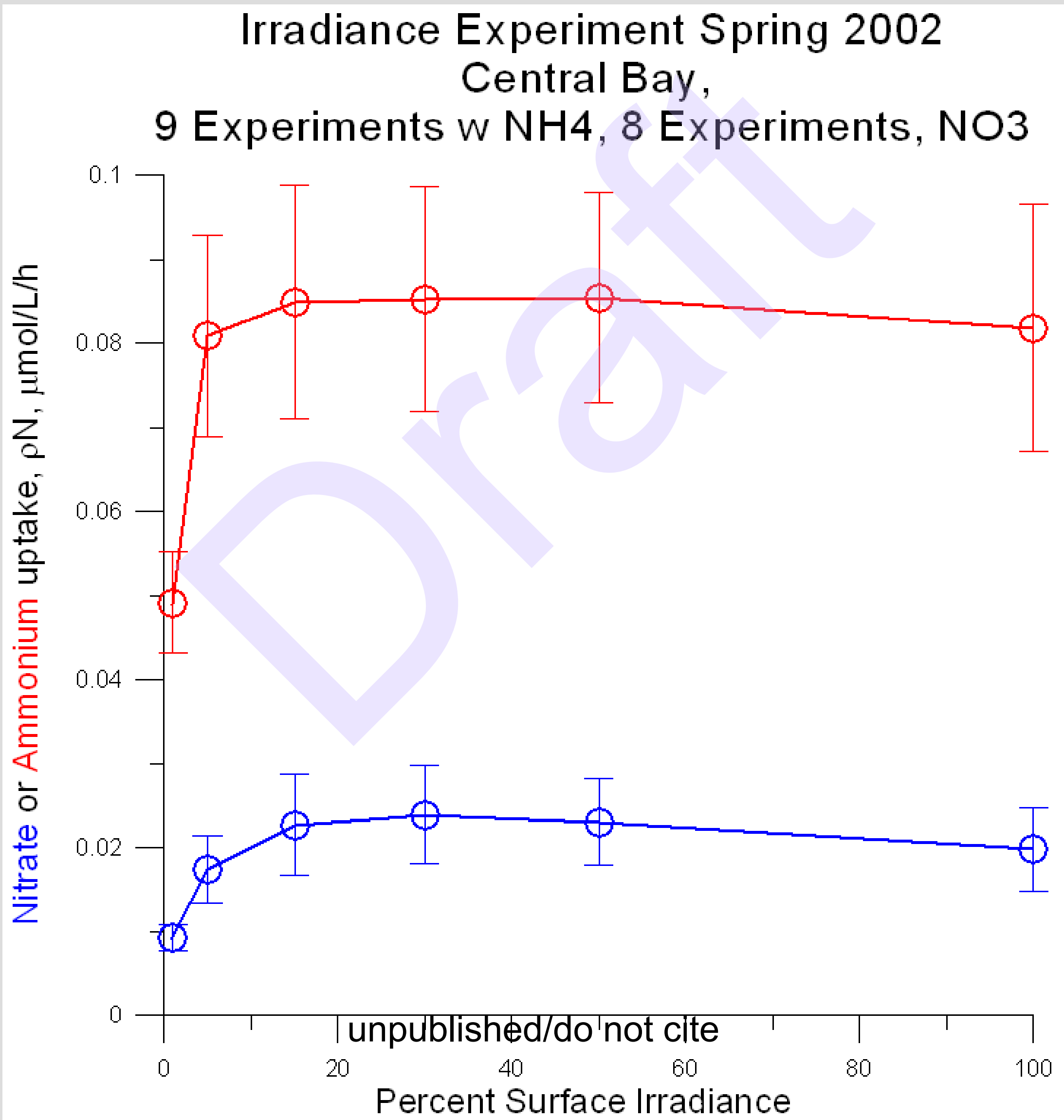
Effluent addition experiment also showed that nitrate uptake decreases with high NH_4 whether NH_4 is in effluent or alone



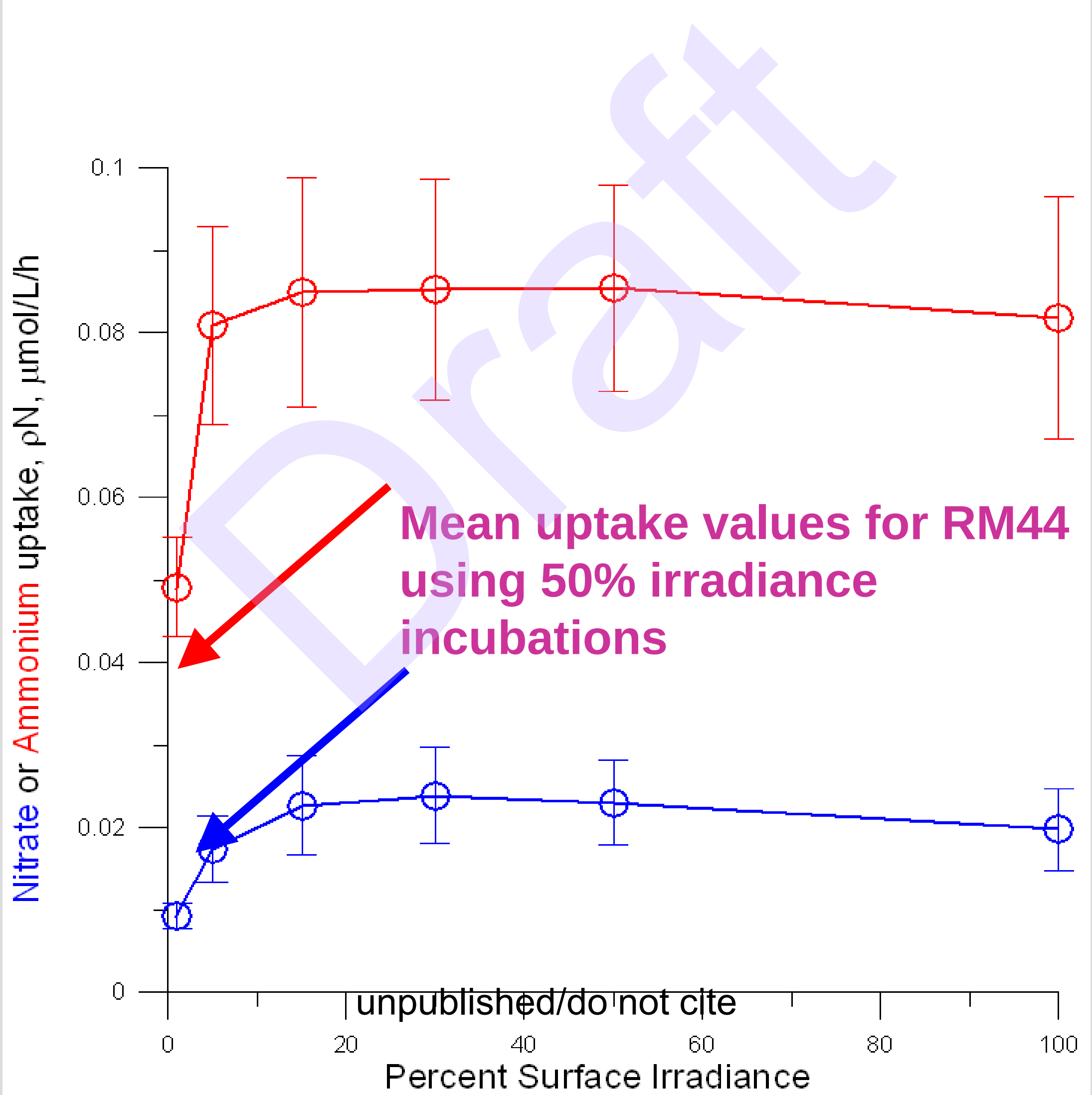
NH_4 uptake declines with increasing NH_4 from effluent in the concentration range of RM44



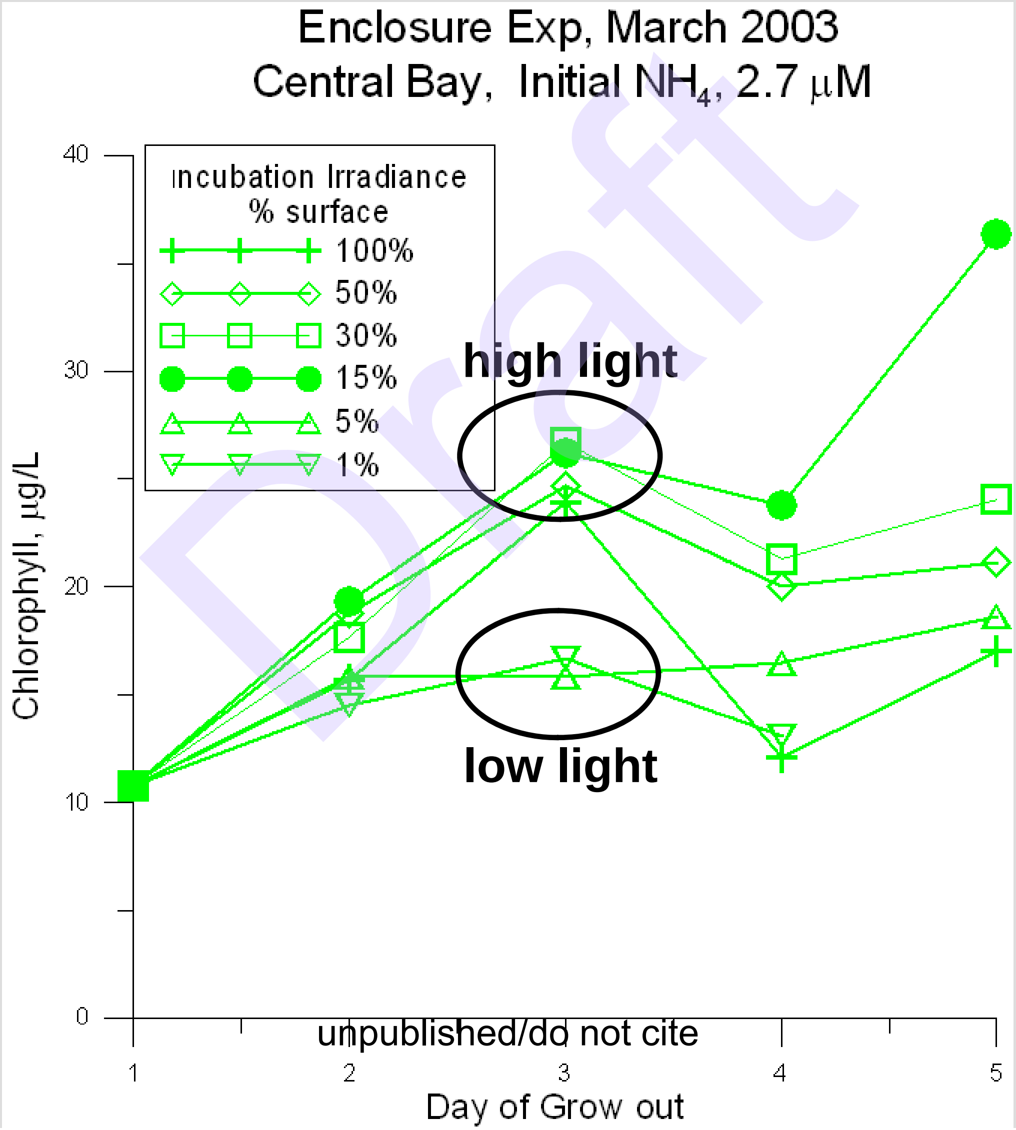
Light is important for N uptake-rapid decrease in NH_4 uptake at low light



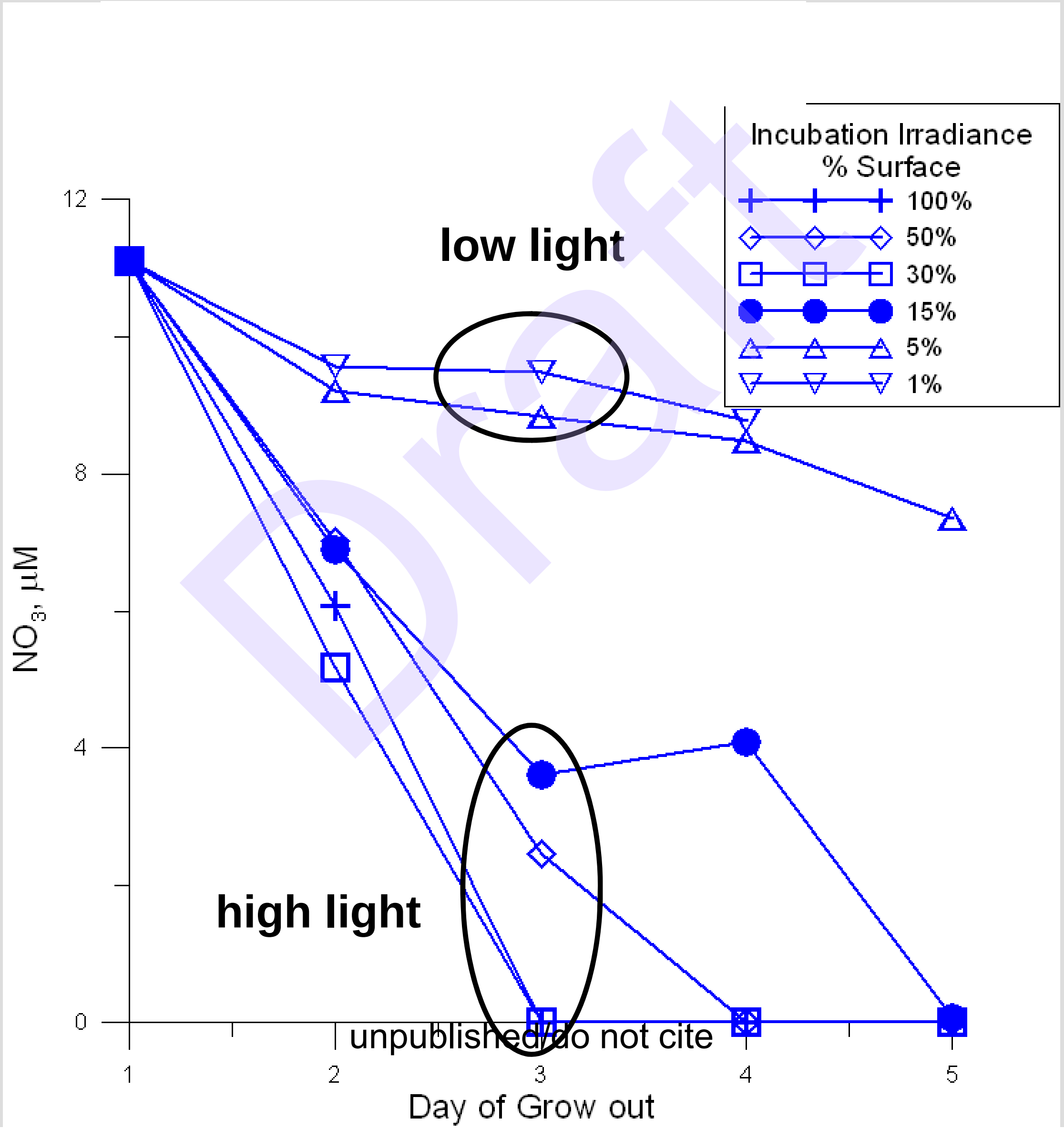
Mean uptake rates for RM44 correspond to uptake rates at low irradiances in Central Bay suggesting severe light limitation in the river



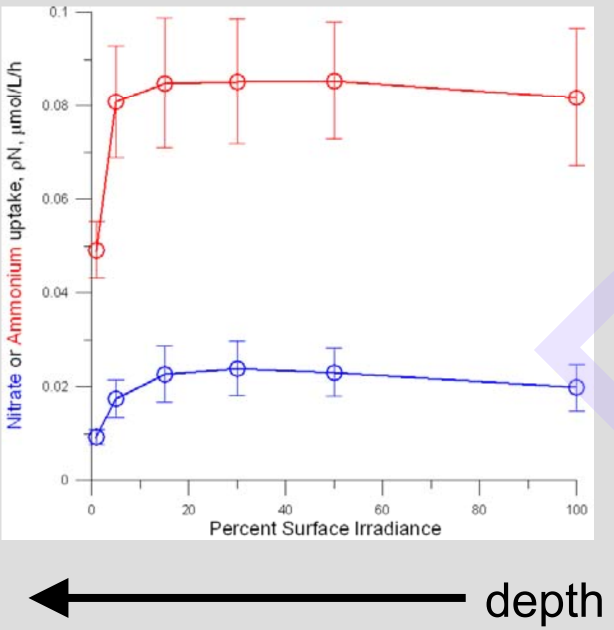
Chlorophyll does not accumulate at low light (light levels of 1-5% of surface irradiance)



Nitrate draw down does not occur at low light (light levels of 1-5% of surface irradiance)



These experiments were used to obtain a uptake vs light (= depth) relationship so that depth integrated values can be calculated from a single light (=depth) value, typically 50% as used in our river study



To get a euphotic zone depth integrated uptake rate use the irradiance experiments and convert the % of surface irradiance to an equivalent depth using a Secchi depth/extinction coefficient relationship

Then the data for uptake vs light is converted to an uptake vs depth and a trapezoid integration applied.

Then can calculate the ratio of the integrated value to the 50% light level

Ratio of uptake integrated for whole euphotic zone to the uptake at 50% surface irradiance can now be used to convert any 50% uptake value to a depth integrated value using Secchi (or k)

Secchi m	Depth of 1% light m	ρNO3 int/ ρNO3 50%	ρNH4 int/ ρNH4 50%
0.5	1.3	1.05 +/-.09	1.21 +/-.08
1	2.6	2.08 +/-.17	2.41 +/-.21

For RM44

Secchi = 0.5m

ρNH4 int: ρNH4 50% from table for Secchi of 0.5 m = 1.21

Mean NH_4 uptake at 50% light level for RM44,

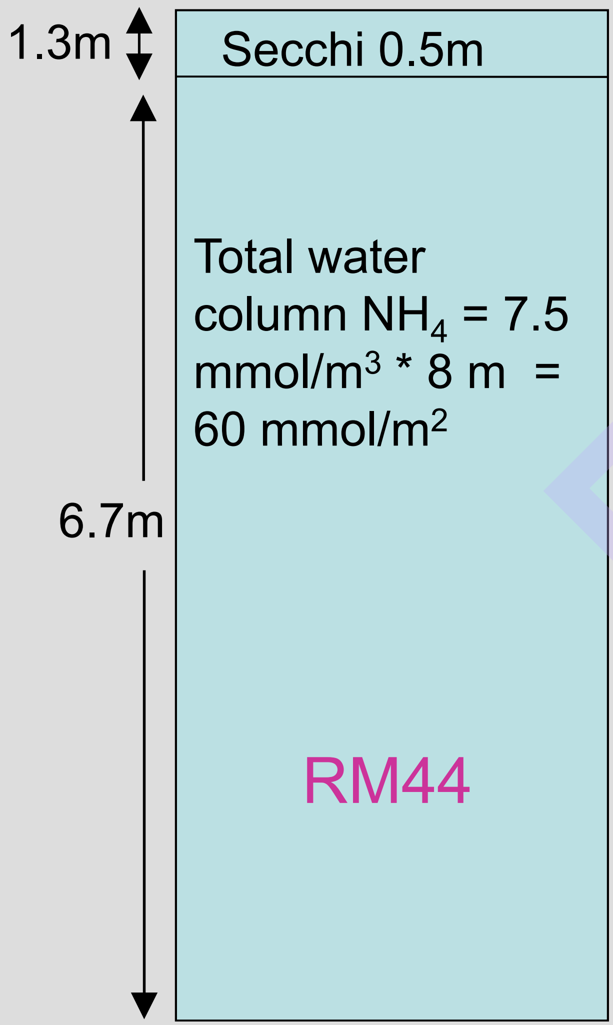
ρNH4 = 0.0485 umol/L/h = mmol/m3/h

The euphotic zone integrated value

= 0.0485 * 1.21 * 24 = 1.41 mmol/m2/d

This euphotic zone depth wll be compared with the total NH_4 content of the entire water column (i.e. /m2), i.e. the mixed layer

The result is a classical Sverdrup Critical Depth condition where the mixed layer depth is deeper than the euphotic zone depth



ρNH_4 = 1.41 $mmol/m^2/d$ for euphotic zone

ρNH4 for total water column (8 m) after mixing (euphotic zone uptake with aphotic zone uptake) =

ρNH4 = 1.41 / 8 m = 0.18 $mmol/m^3/d$

= 0.18 μmol/L/d

Phytoplankton NH_4 uptake per day as % of total water column NH_4 = 1.41/60 = 2.4%/day

<u>Conclusion:</u> Phytoplankton uptake in water column is negligible and so biological drawdown of NH_4 will not impact the river concentration of NH_4 that flows downstream to Suisun except with very low flow rates and high residence time

The NH_4 from RM44 that reaches Suisun Bay can be estimated assuming 4 day travel time

	NH_4	NH_4 uptake for 8m water column	NH_4 draw down over 4 days	NH_4 at Suisun Bay (i.e. after 4 days)
	µmol/L	$mmol/m^3/d$	$mmol/m^3$	µmol/L
WB09-1	10.25	0.13	0.51	9.14
WB09-2	1.11	0.31	1.24	0
WB09-3	11.11	0.17	0.69	10.42

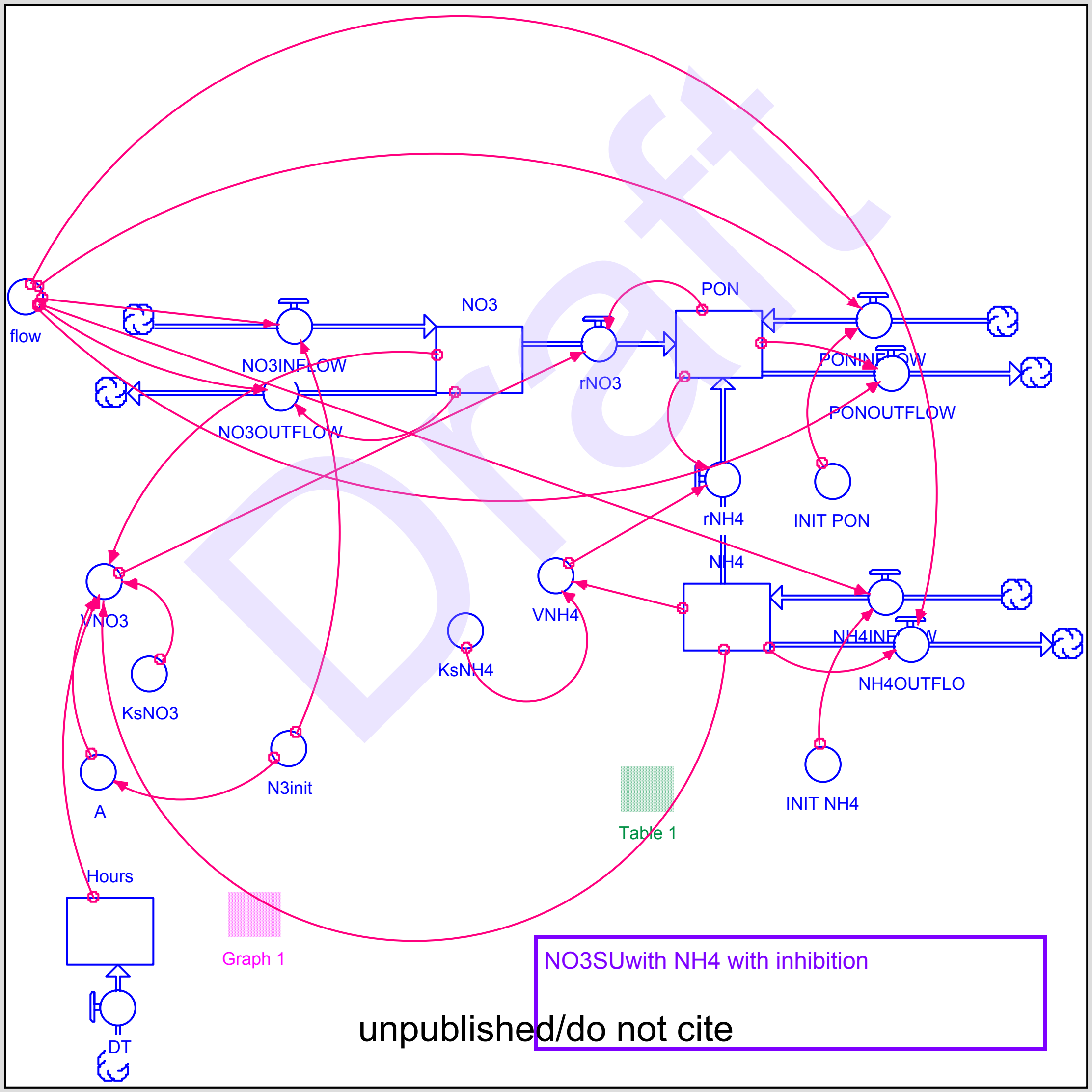
Can calculate the permissible NH_4 concentrations at RM44 to meet a target of 1 or 4 µmol/L at Suisun Bay

	NH_4 draw down over 4 days	**NH_4 at RM44 to meet 4 µmol/L target at Suisun**	**NH_4 at RM44 to meet 1 µmol/L target at Suisun**
	mmol/m³	**µmol/L**	**µmol/L**
WB09-1	0.51	4.51	1.51
WB09-2	1.24	5.24	2.24
WB09-3	0.69	4.69	1.69

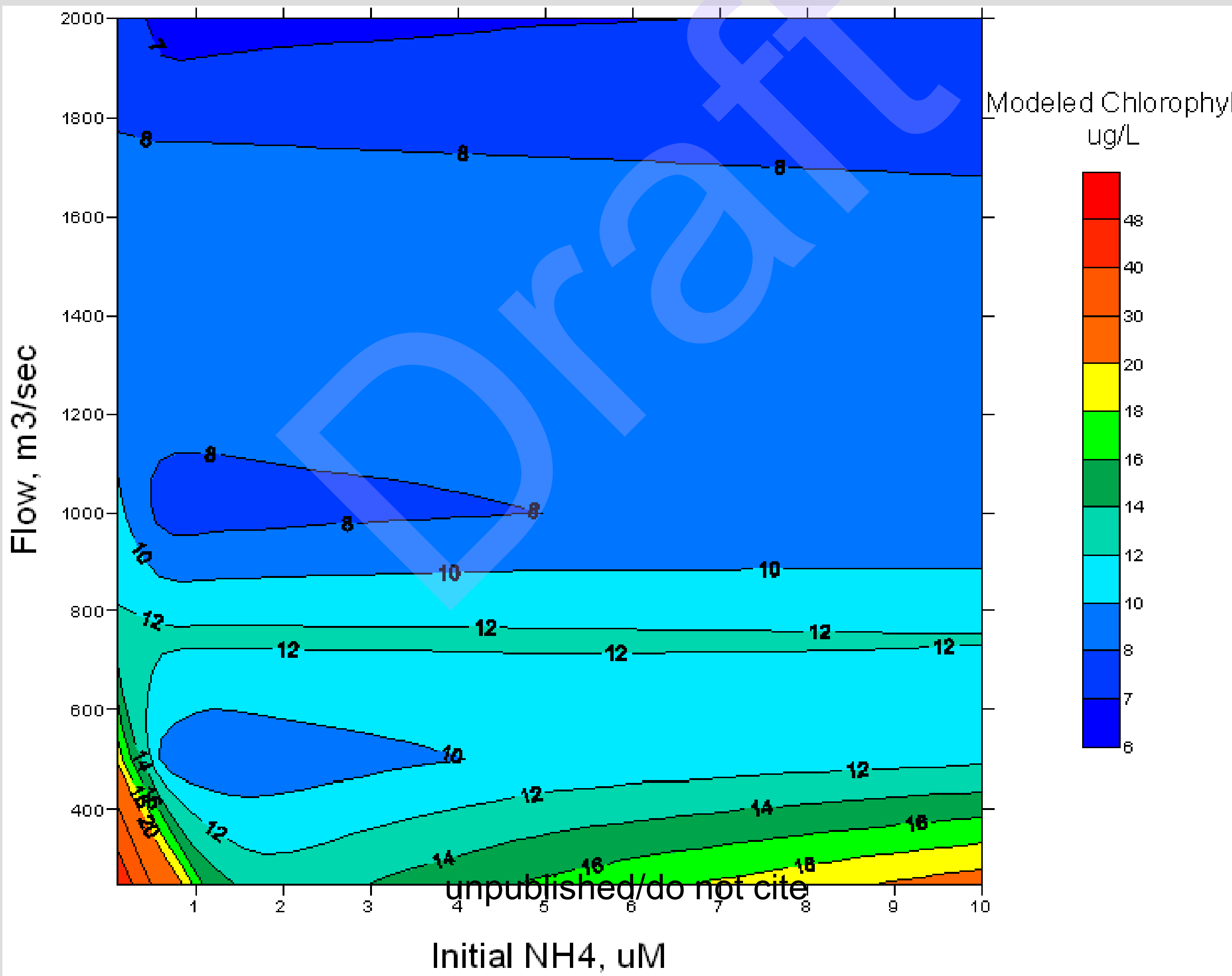
This example assumes

- Secchi depth of 0.5m
- flow rate that results in 4 day travel time between RM44 and Suisun
- no transformations such as nitrification
- no additional NH_4 inputs as water moves downstream

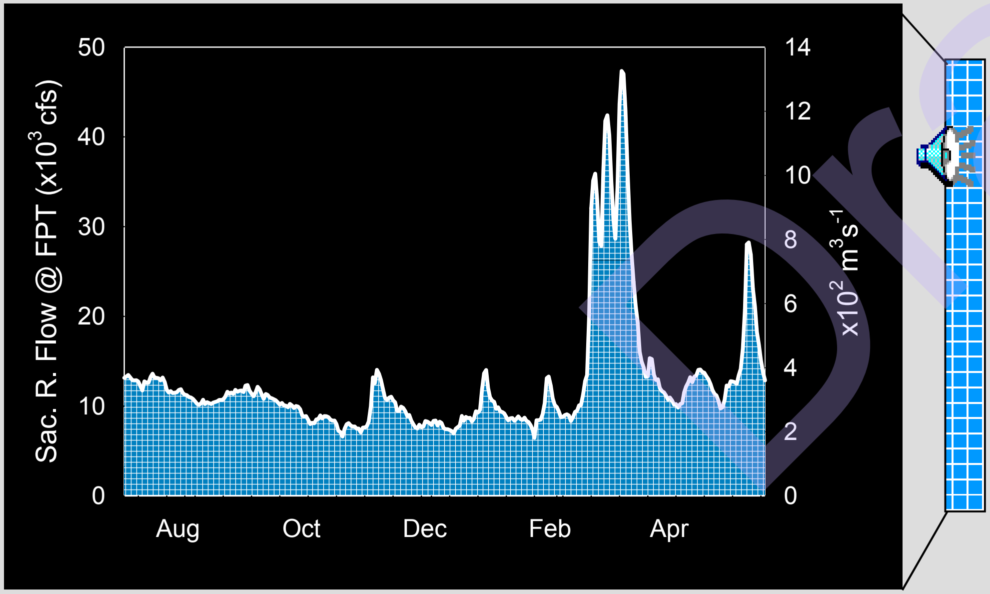
Model to incorporate NH_4 inhibition of NO_3 uptake that calculates a time series of variables in a volume of water as it drifts downstream from RM44

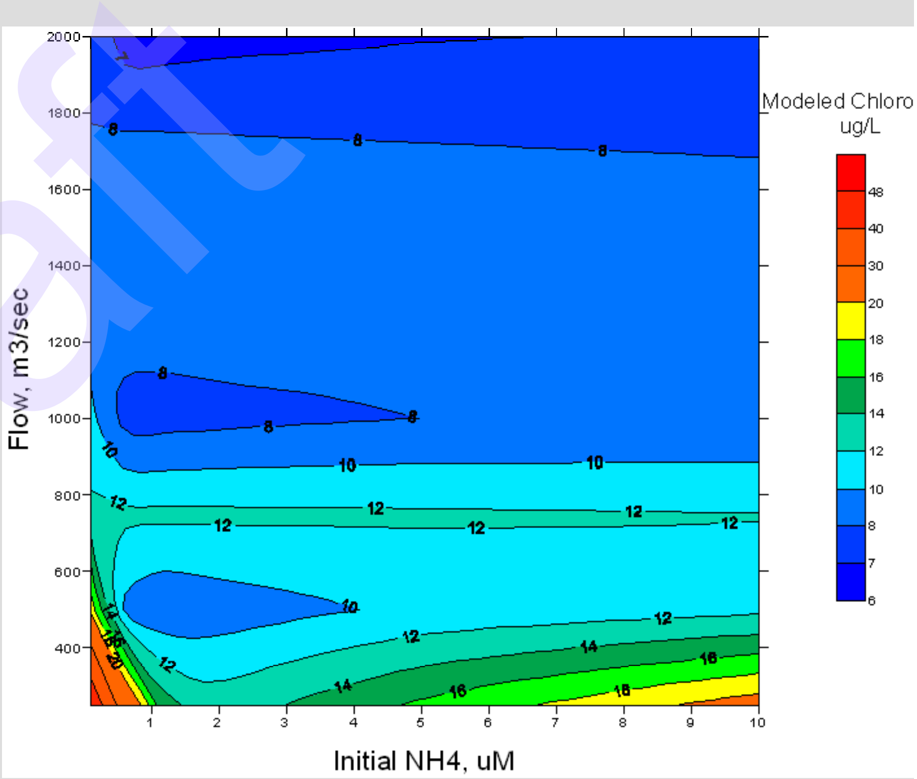


Model output for river 30 km downstream from RM44 shows high chlorophyll (> 20 µg/L) only accumulates with low NH_4 and low flow (when phytoplankton use NO_3) and high NH_4 and low flow when they use NH_4



River Flow can be low enough (e.g. 200 m^3/sec) where chlorophyll is modeled to accumulate with low NH_4





unpublished/do not cite

Conclusions

- The river is converted to an NH_4-only water body for phytoplankton by the effluent additions of NH_4.
- The measured rates of NH_4 uptake by phytoplankton within the river are very low, likely the result of a shallow euphotic zone and deep mixing.
- Euphotic zone NH_4 uptake rates are too low to significantly affect the downstream concentrations of NH_4. Inputs at RM44 will be experienced at the entrance to Suisun Bay largely unchanged.
- Modeling suggests that chlorophyll accumulation (blooms) within the river will only occur at low flow and low NH_4 concentrations.
- If there were no sinks in the river for NH_4 other than the phytoplankton uptake, maximum permissible concentrations of NH_4 at RM44 can be calculated for one set of flow and transparency as 1.5 and 4.5 μmol/L for targets at Suisun Bay of 1 and 4 μmol/L respectively.

Future Work

- Make ammonium uptake measurements in the euphotic zone with simulated light incubations
- Research consequences for the ecosystem of an ammonium-only nutrient uptake environment for phytoplankton
- Establish continuous monitoring stations along the river to correlate ammonium levels, sources and reveal other ammonium consuming processes
- Establish continuous monitoring of chlorophyll and phytoplankton for model validations