Source: C. Benton

# Suisun Synthesis I Overview

*David Senn*
*March 8 2013*

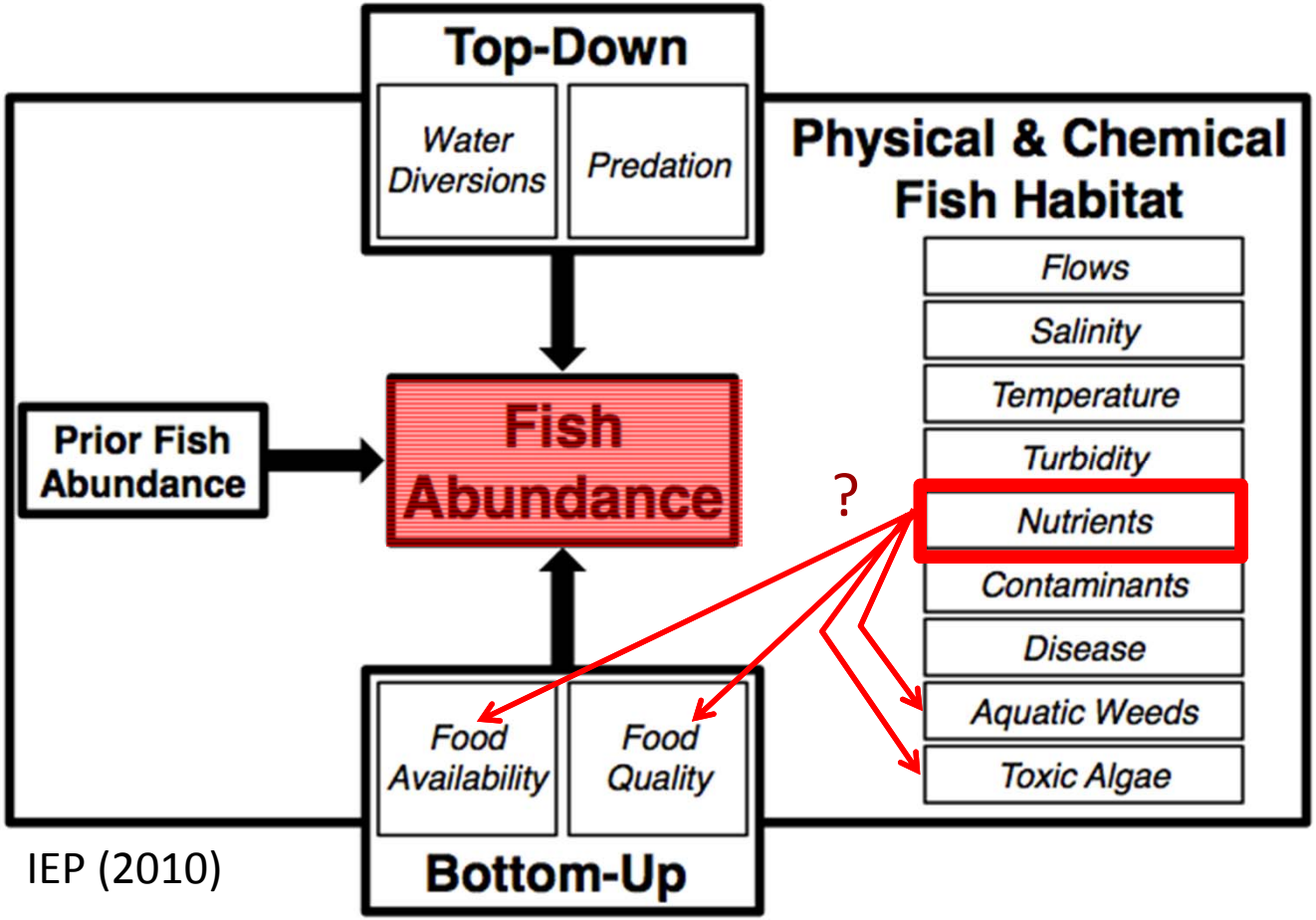
# Suisun Bay: evaluating potential impacts of nutrients

## Substantial impairment and complex/multiple drivers

- Pelagic Organism Decline (POD)
- Changes in phytoplankton and zooplankton abundance and composition
- Frequent *Microcystis* blooms
- Multiple stressors: what is the contribution from nutrients?

Wilkerson et al., 2006; Dugdale et al., 2007; Parker et al. 2012a,b; Dugdale et al 2012; Glibert et al 2011, 2012

# Suisun Bay: evaluating potential impacts of nutrients

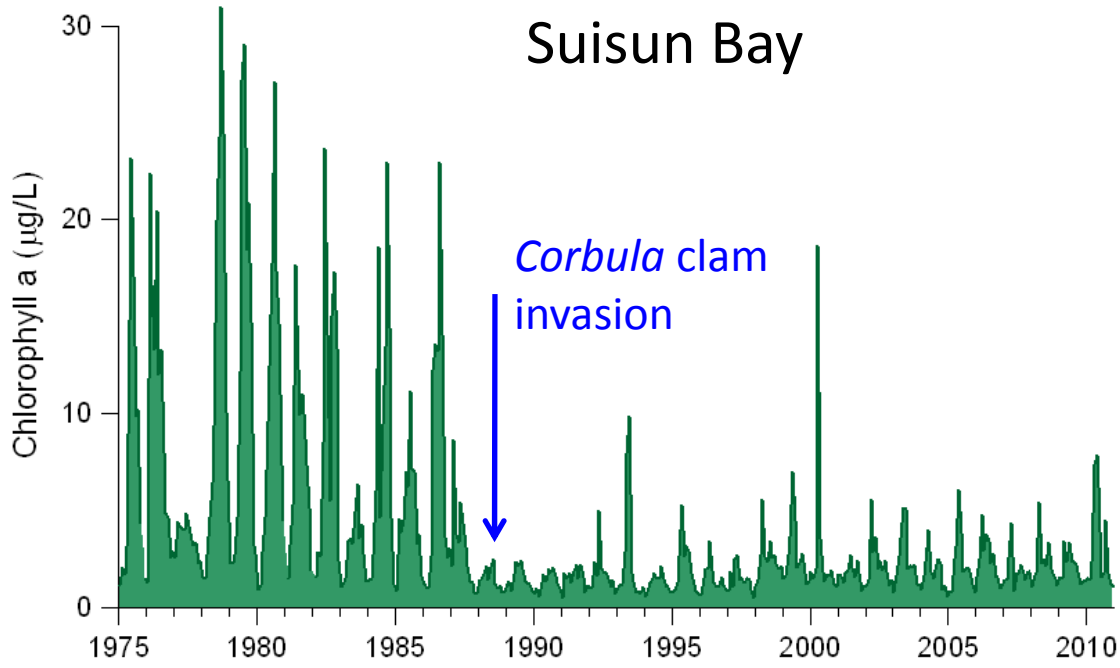



IEP (2010)

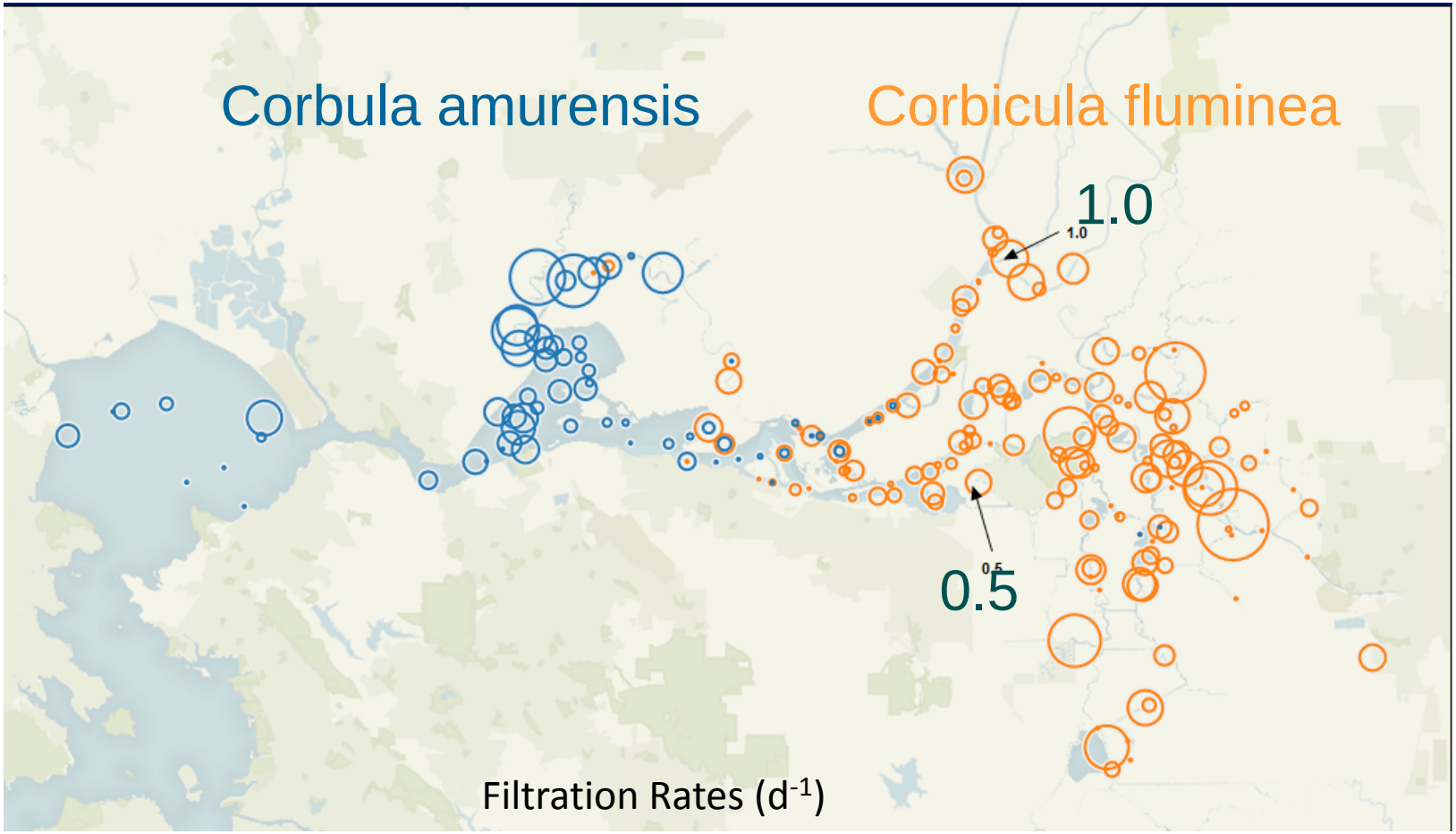
# Phytoplankton

**Abundance Drivers/stressors**

- Clams
- Light limitation
- Nutrients (NH4)
- Residence time



# Invasive clams can filter the entire water column every 1-2 days




Kimmerer et al. (2011)

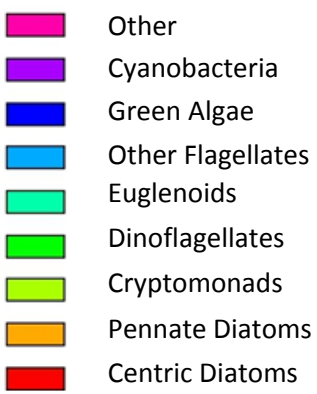
# Phytoplankton

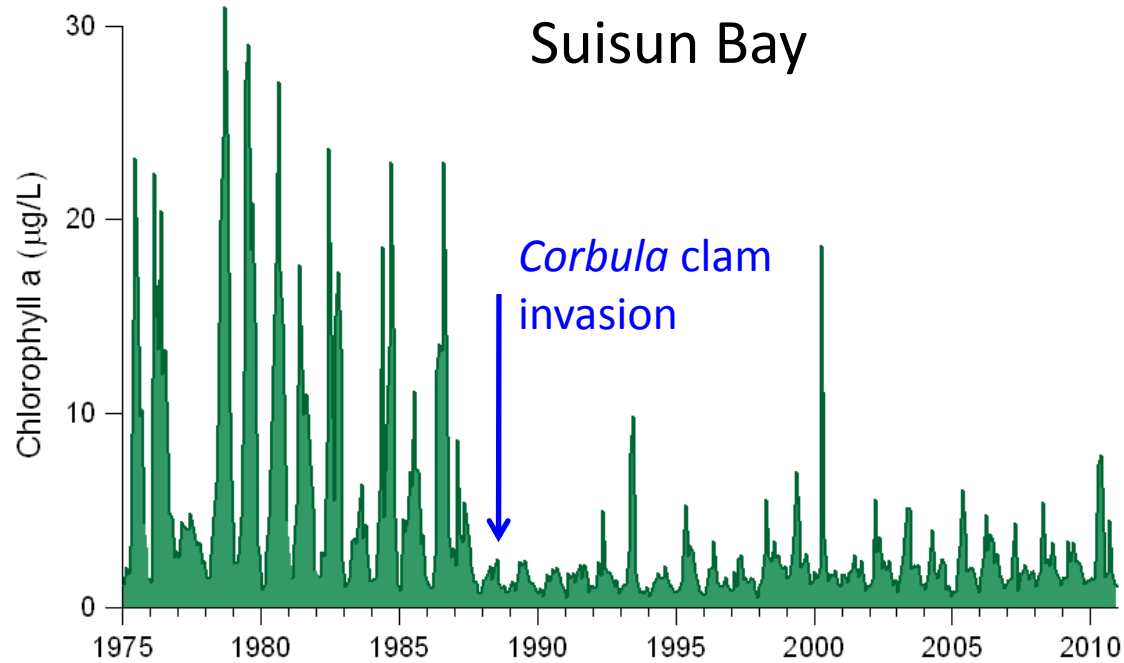
**Abundance Drivers/stressors**

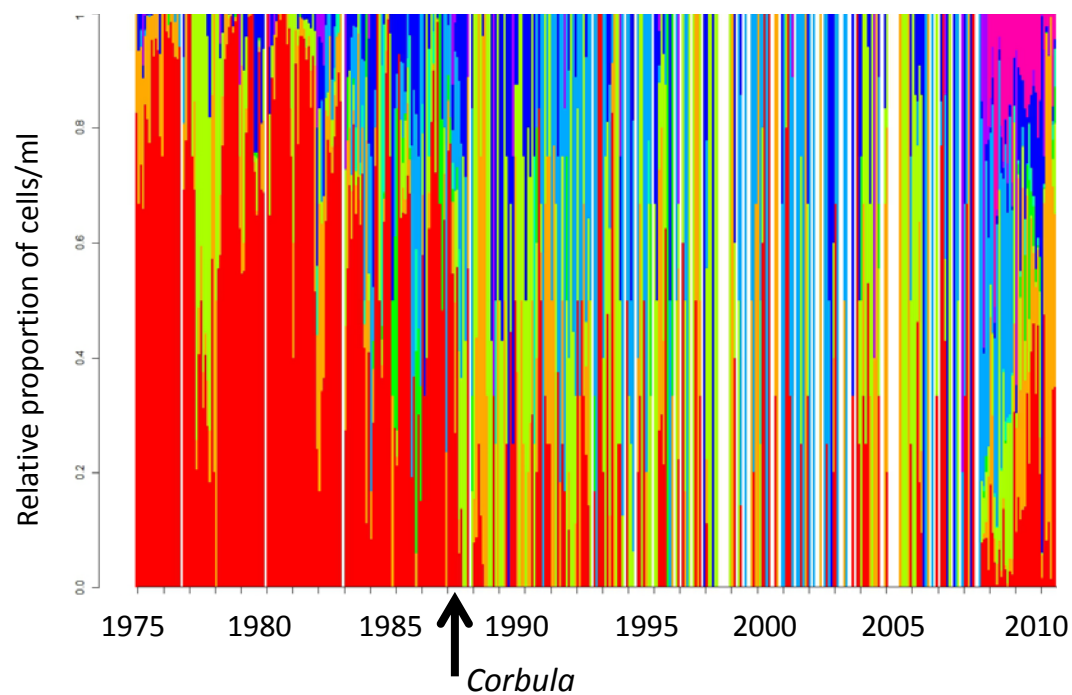
- Clams
- Light limitation
- Nutrients (NH4)
- Residence time

**Composition Drivers/stressors**

- Clams (size-selection)
- Nutrients
- other




Sources: J. Cloern, USGS; IEP/DWR; Senn et al, in prep

# Suisun Bay: evaluating potential impacts of nutrients

Potential pathways for nutrient-related impairment

- Low phytoplankton biomass related to elevated NH4
- Suboptimal phytoplankton assemblages related to
  - NH4:NO3, N:P, or high concentrations
- Direct NH4 toxicity to copepods

Wilkerson et al., 2006; Dugdale et al., 2007; Teh et al., 2011; Parker et al. 2012a,b; Glibert et al., 2012; Dugdale et al 2012

# Suisun Bay: evaluating potential impacts of nutrients

Synthesis I:

- NH4 and low phyto bioimass
- NH4 and copepods
- Ambient NH4 – sources, fate

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## Synthesis I:

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## Synthesis II

- N:P, NH4:NO3 on phytoplankton community composition
- Other foodweb effects

## Synthesis III

- Overview: multiple stressors

# Suisun Bay: evaluating potential impacts of nutrients

## Synthesis I:

- NH4 and low phyto bioimass
- NH4 and copepods
- Ambient NH4 – sources, fate

## Synthesis II

- N:P, NH4:NO3 on phytoplankton community composition
- 'Ecological stoichiometry'

## Synthesis III

- Overview: multiple stressors

Suisun Nutrient Science Plan:
- Priority management questions
- Priority science questions

Implement

Technical Workshop

External Science Review

# Suisun Synthesis I.

1. Synthesize the scientific literature on N utilization by marine and estuarine phytoplankton *(M Berg, AMS)*

2. NH4 inhibition of primary production: evaluate/synthesize results and interpretations of recent studies

   *(D Senn and T Jabusch, SFEI)*

3. Synthesize scientific literature on copepod ecology and changes in community composition and abundance in Suisun

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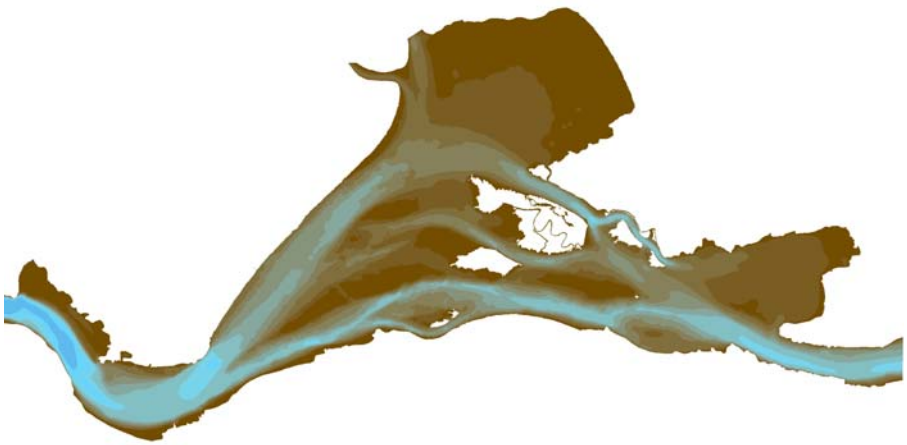
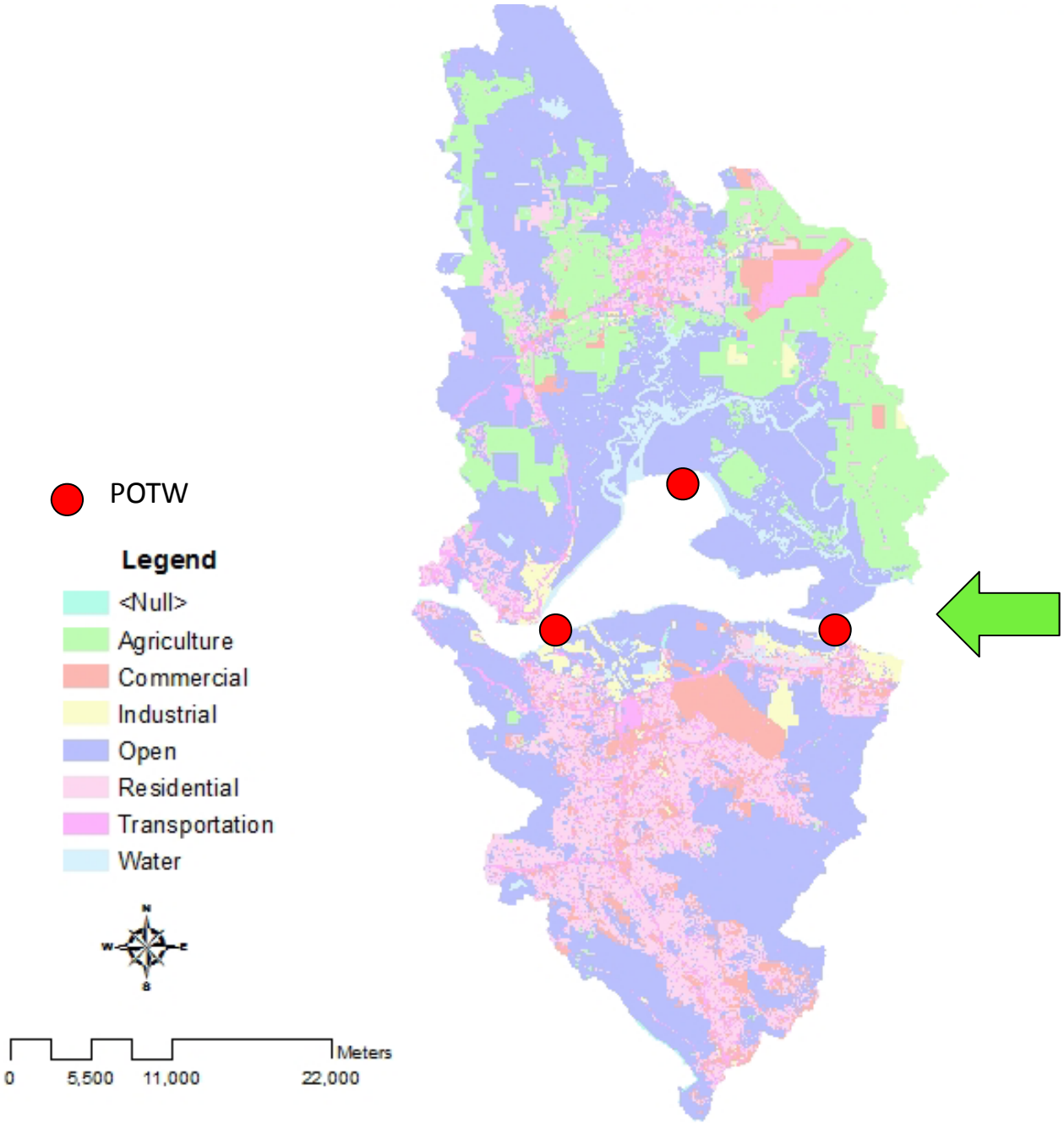
# NH4 in Suisun Bay

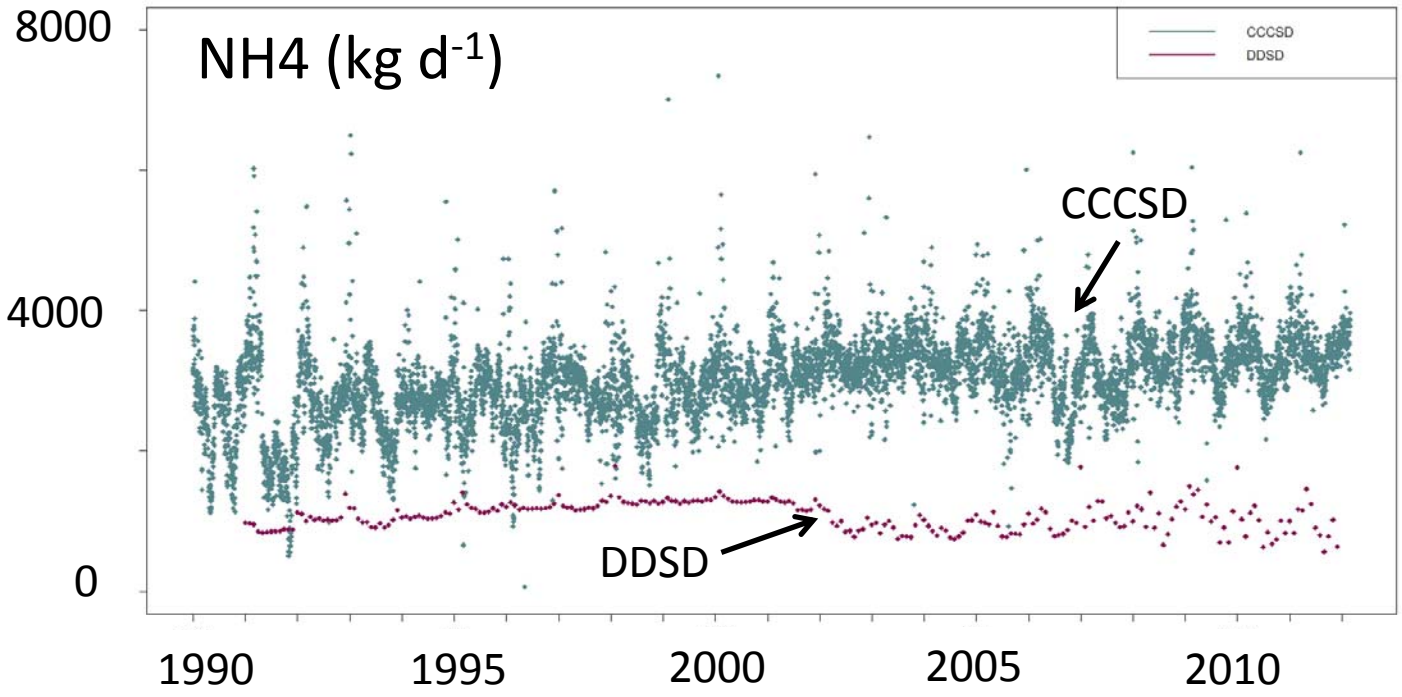
- Goals:
  - Develop improved understanding of sources, fate, and trends
  - Inform near-term management decisions on nutrient loads.
- Approach:
  - Analyzed ambient water quality data (1975-2012)
  - Estimated loads:  Delta, POTWs, and stormwater
  - Mass balance/box-model



# Suisun Bay Watershed and POTWs

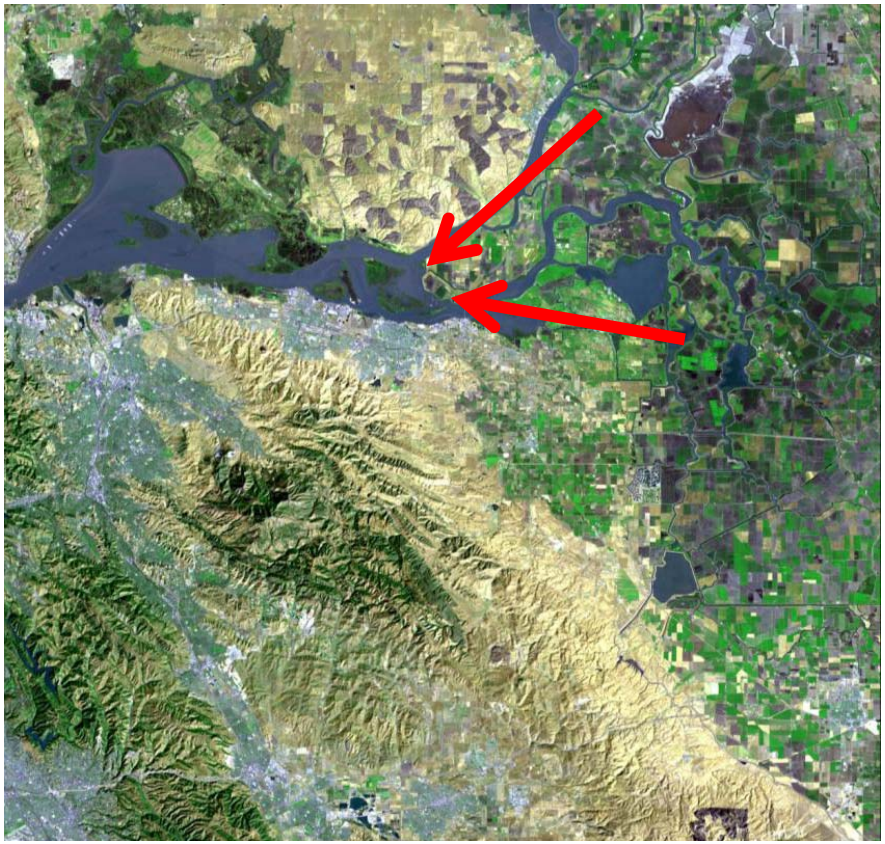


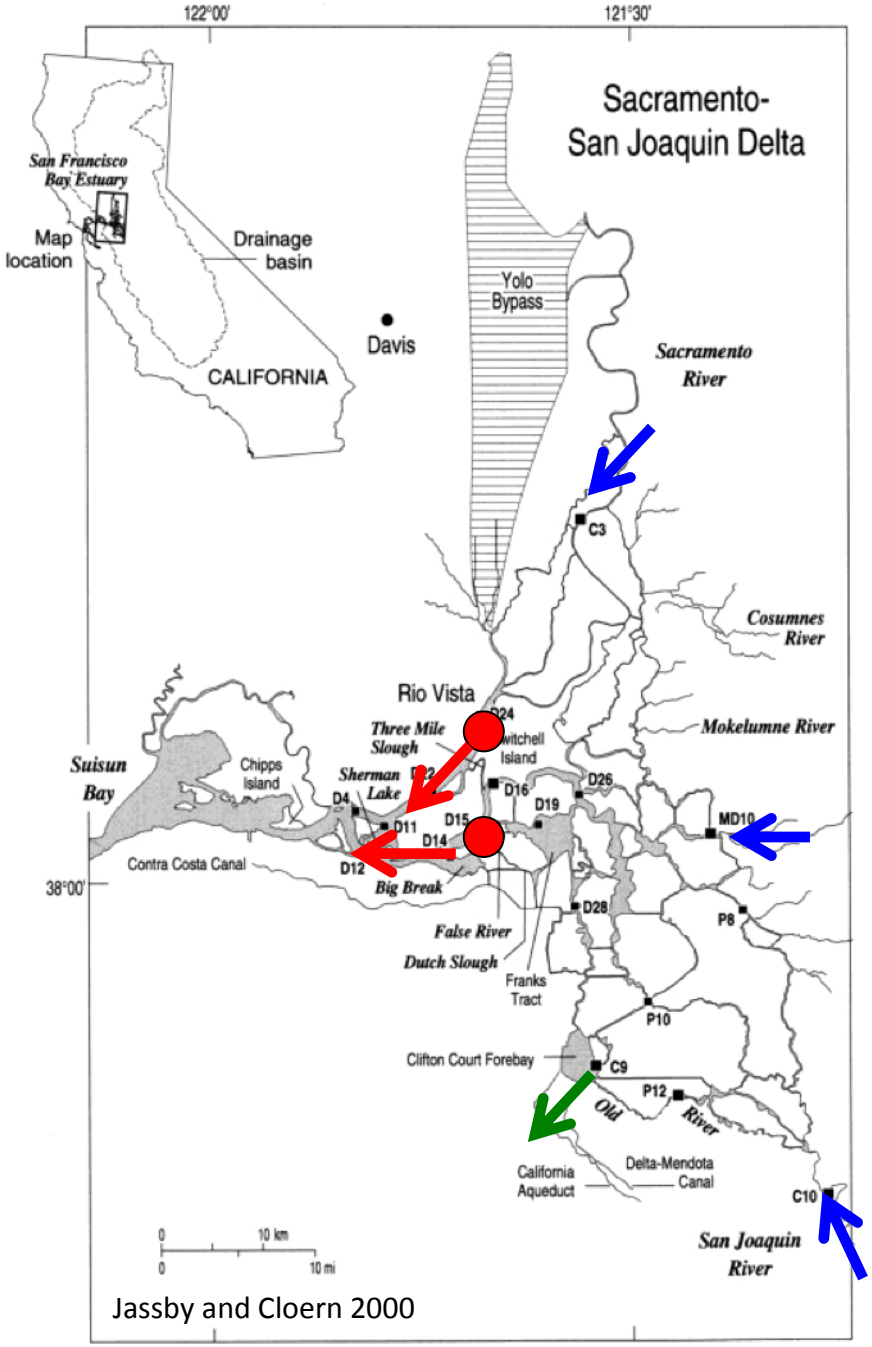
# Suisun POTW loads



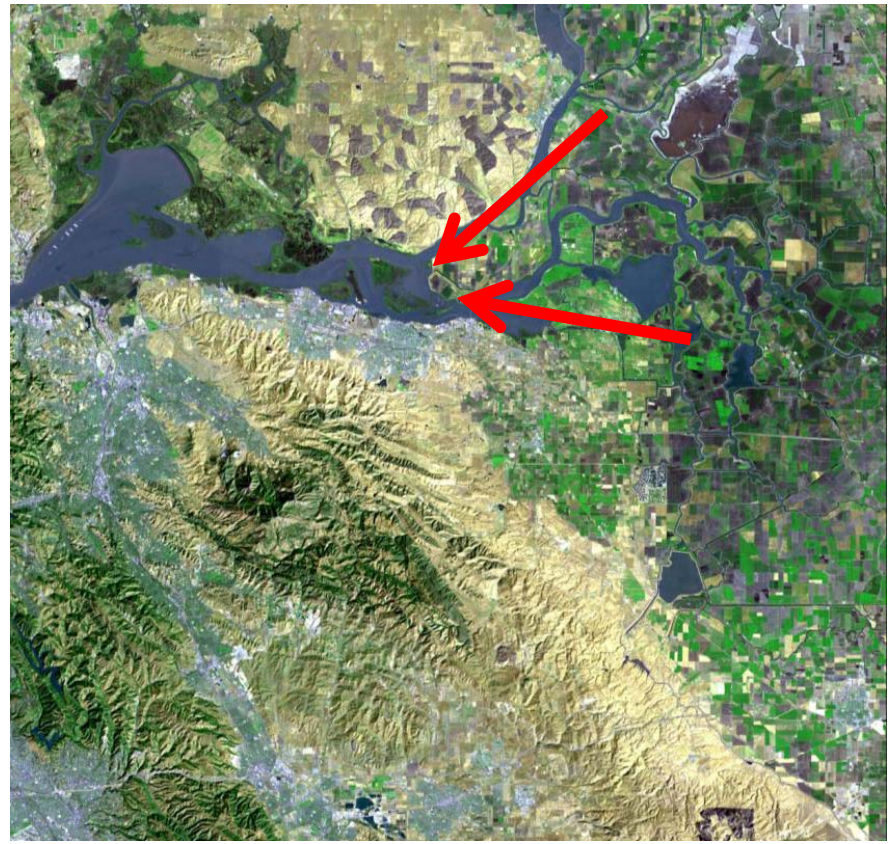
# Loads from the Delta

- Large interannual and seasonal variation
  - Flows
  - Concentrations
- Tides
- No long-term field studies for loads






Jassby and Cloern 2000

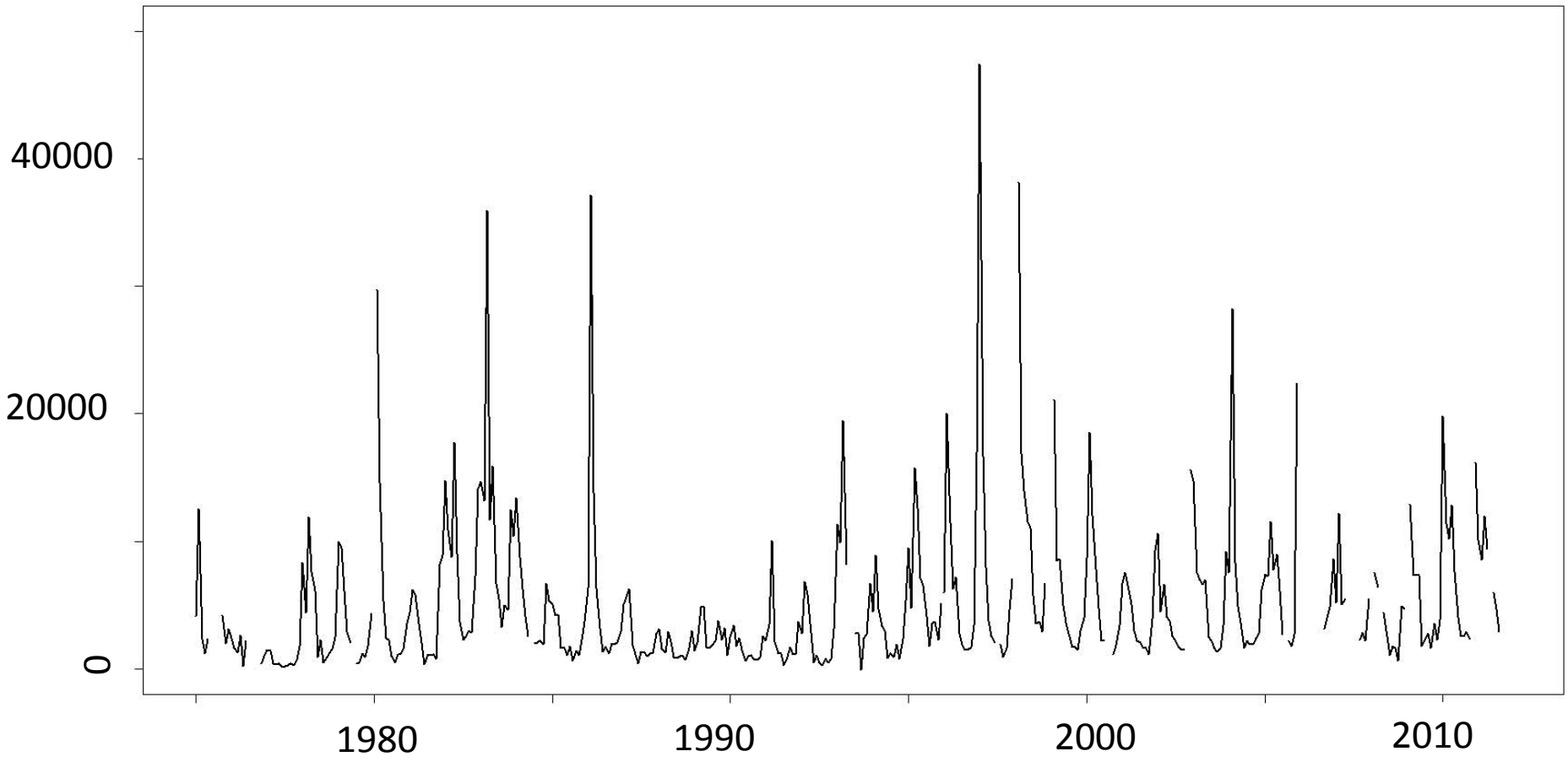


$$Load_{Suisun} = Q_{west} * [C]_{D16} + Q_{rio} * [C]_{D24}$$

- Long-term daily-averaged flows

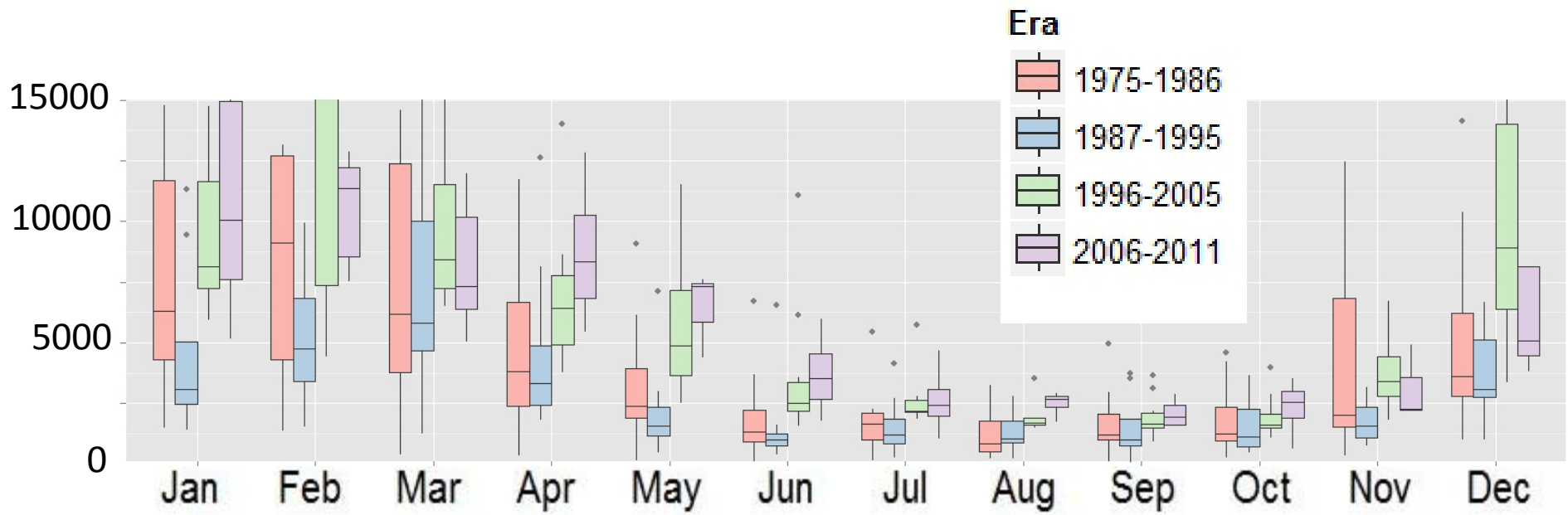
- Monthly concentration data at monitoring stations

# Delta NH4 loads to Suisun Bay (kg $d^{-1}$)

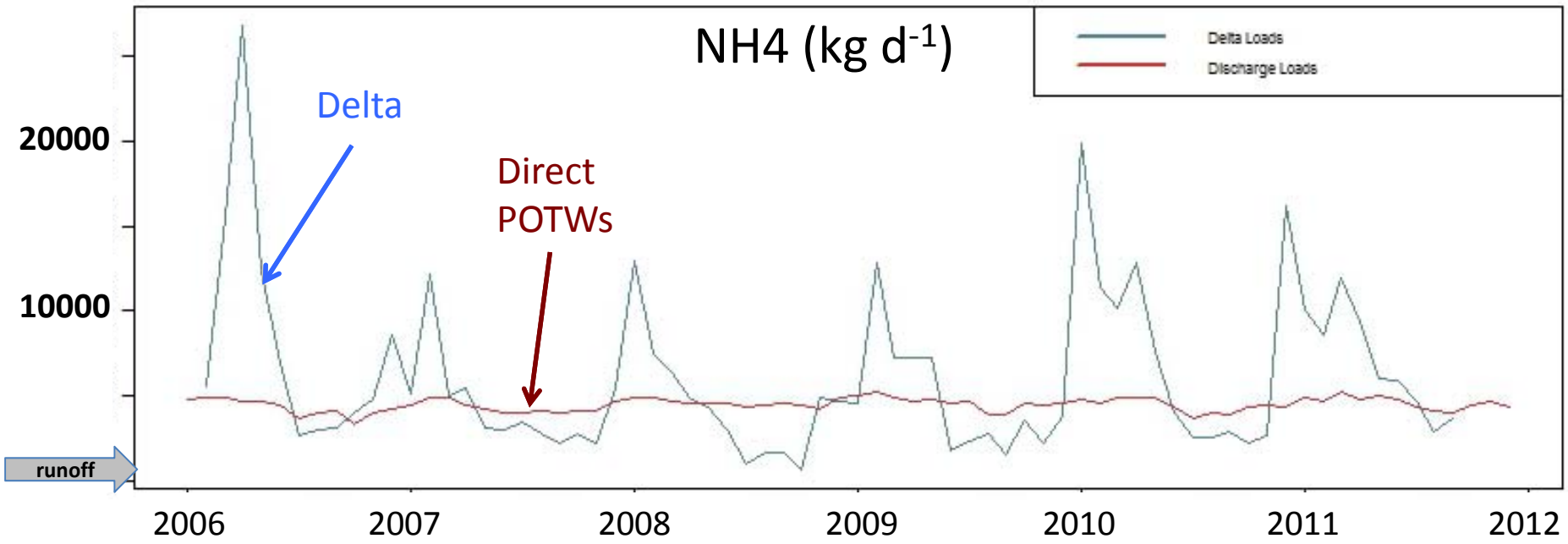



- Strong seasonality and interannual variability
- Increasing baseline

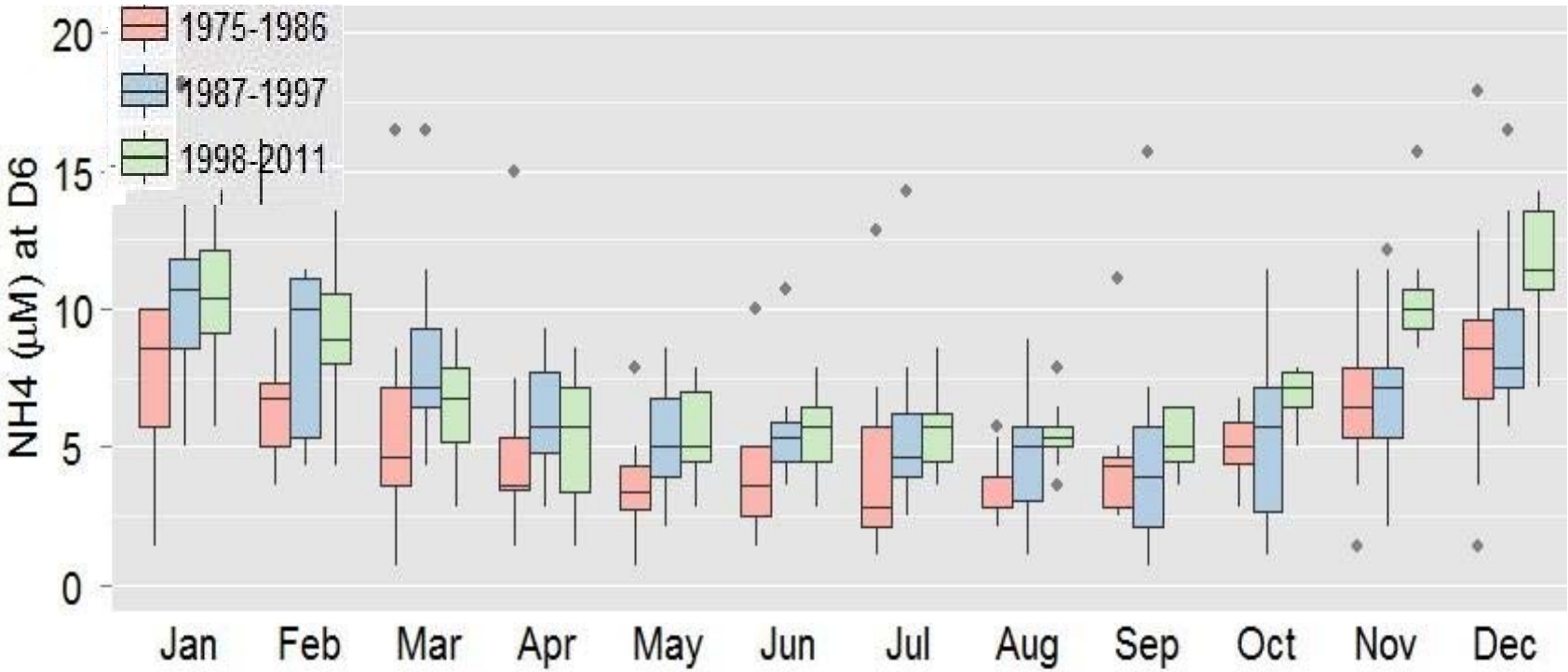
# Delta NH4 loads to Suisun Bay (kg $d^{-1}$)




- Large increases in April-May-June

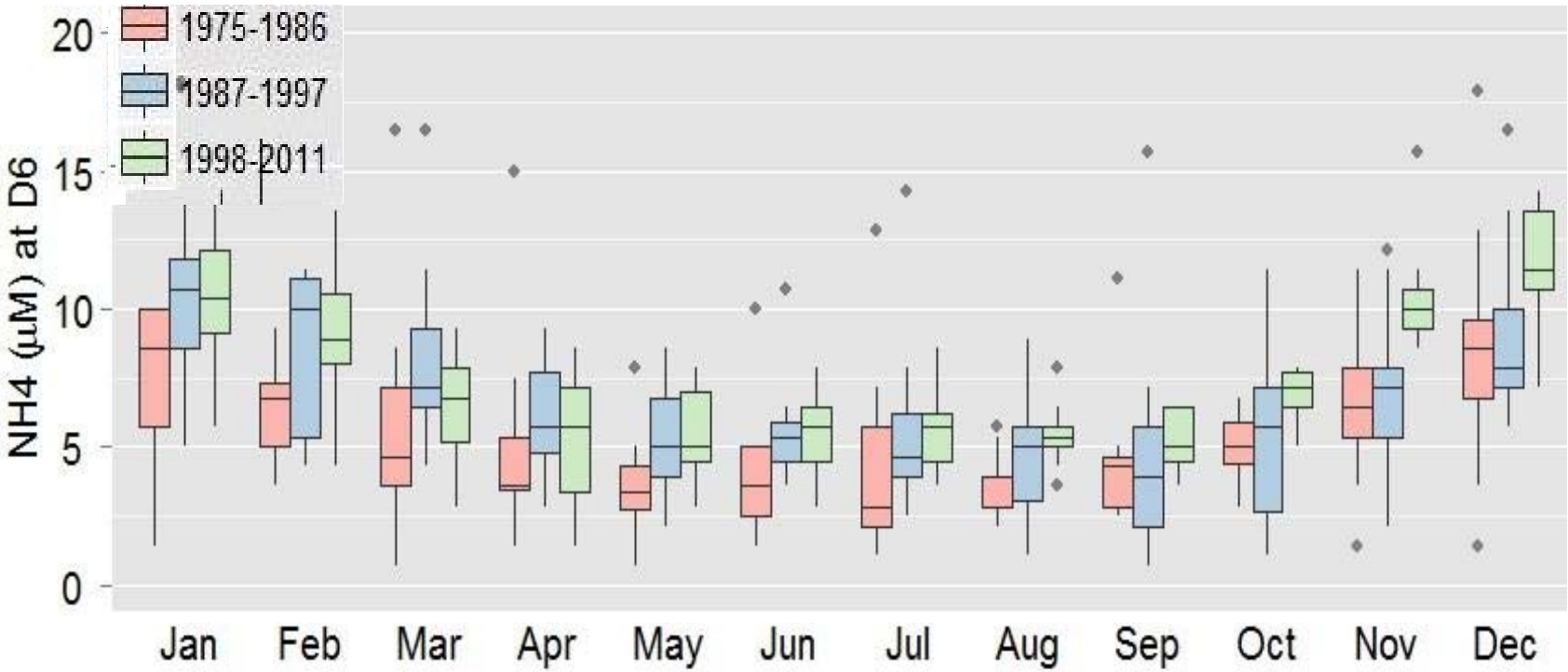

NH4 (kg d-1)
Delta Loads
Discharge Loads
Delta
Direct
POTWs
20000
10000
runoff
2006
2007
2008
2009
2010
2011
2012

# Seasonal and Long-term Variation in NH4




- Increases observed at all sites and during all months
- 50% increase in spring and fall

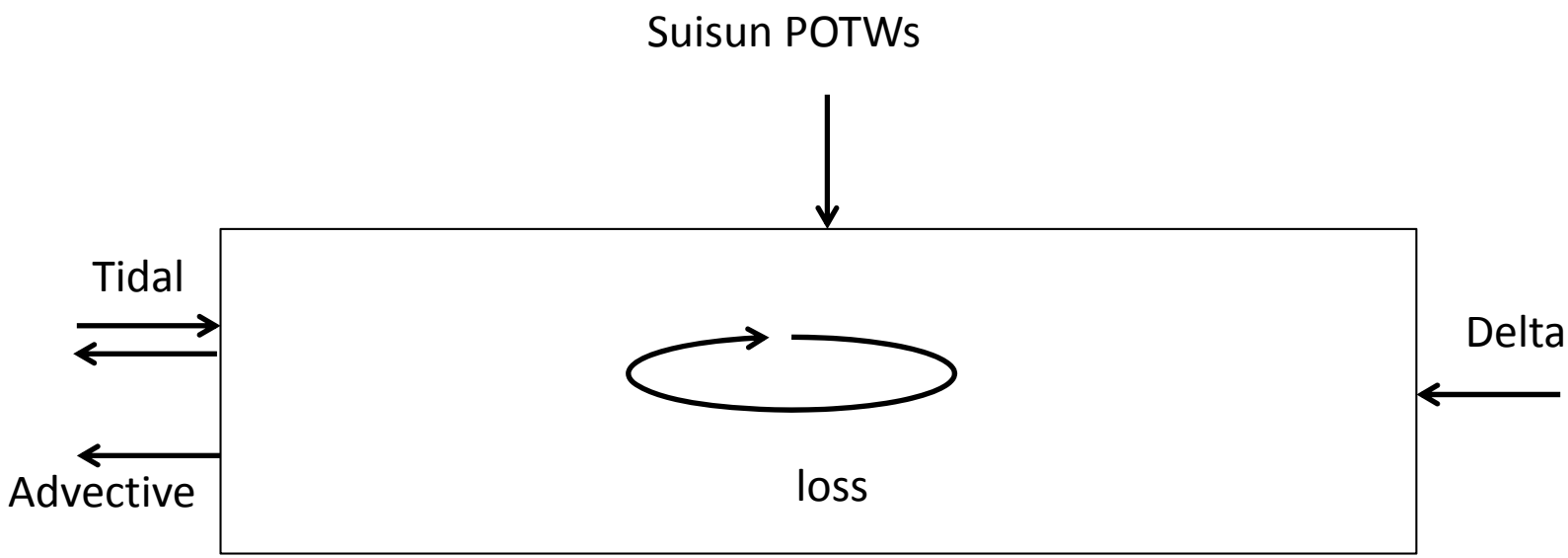
# Seasonal and Long-term Variation in NH4



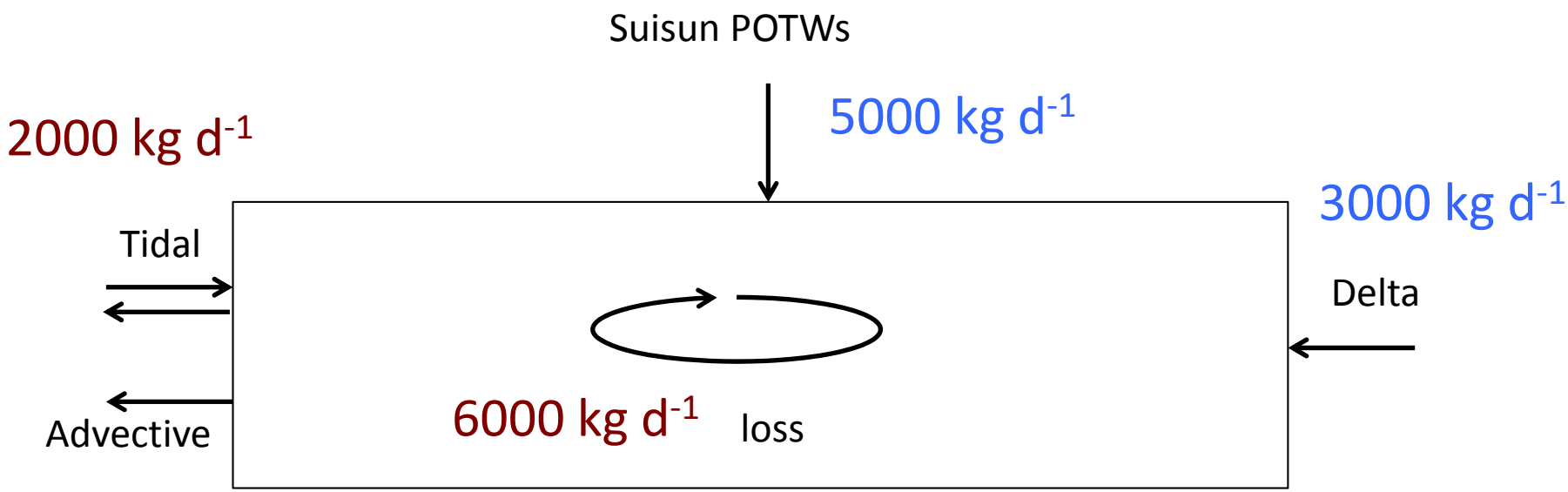

*Thresholds*

| | Season | Period | Exceed |
|---|---|---|---|
| 4 uM | April-Oct | 1998-2011 | 50-90% |
| 26 uM | year-round | 1998-2011 | 0% |

# Spring-Summer NH4 Mass Balance

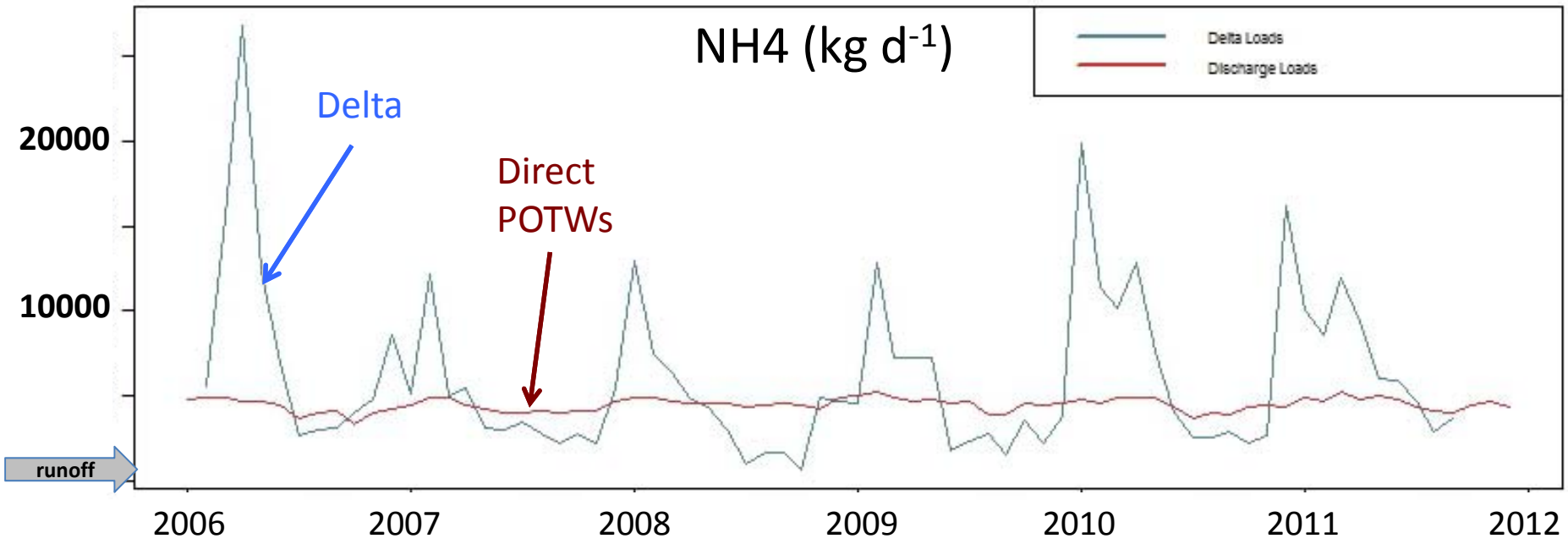


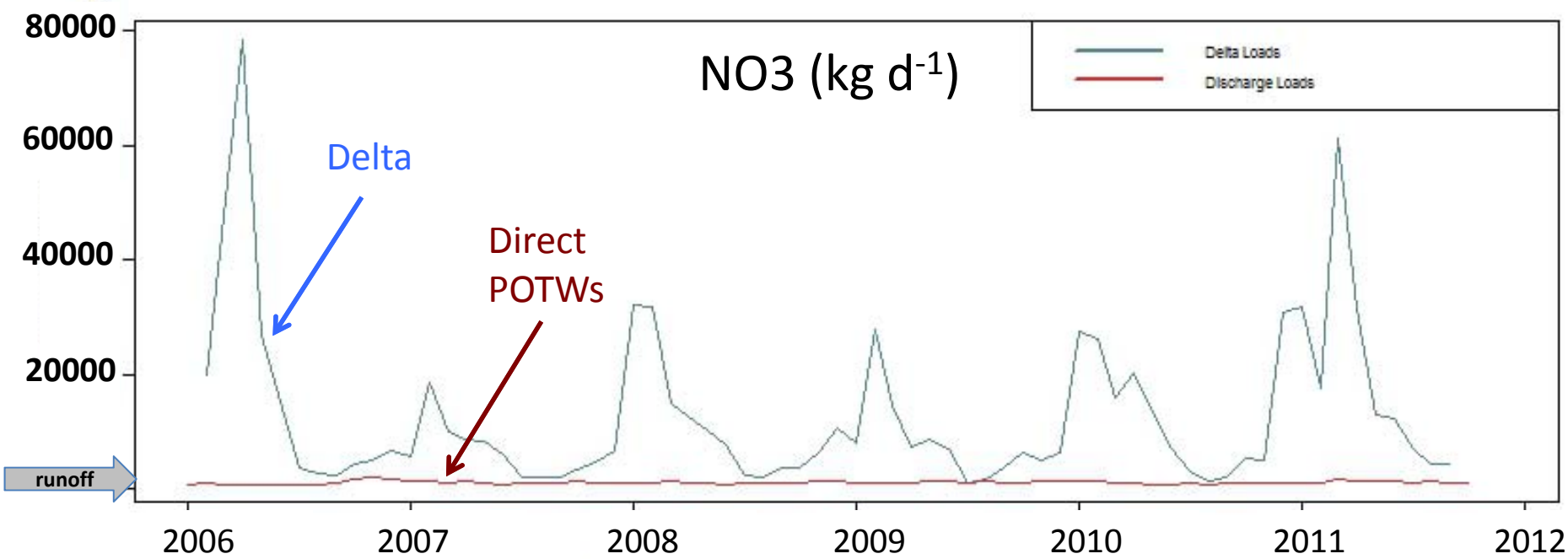
# Spring-Summer NH4 Mass Balance




- *Assimilative Capacity*: NH4 loss is a dominant process…75%

- Acceptable loads:
  - modeling
  - field investigations


NH4 (kg d-1)
Delta Loads
Discharge Loads
Delta
Direct
POTWs
20000
10000
runoff
2006
2007
2008
2009
2010
2011
2012


NO3 (kg d-1)
Delta Loads
Discharge Loads
Delta
Direct
POTWs
80000
60000
40000
20000
runoff
2006
2007
2008
2009
2010
2011
2012

# Suisun NH4 loads, concentration, fate: Summary

- Substantial NH4 concentration increase over past 4 decades
  - 4 uM threshold exceeded 50-90% of the time
  - 26 uM threshold seldom/never exceeded
- Increased loads:
  - Delta Loads have nearly doubled in some critical months
- Major source(s) of NH4 loads varies seasonally
  - Winter = Delta
  - Summer = Suisun POTWs
- ~75% of NH4 loads are “lost” within Suisun Bay

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# NH4-inhibition Hypothesis

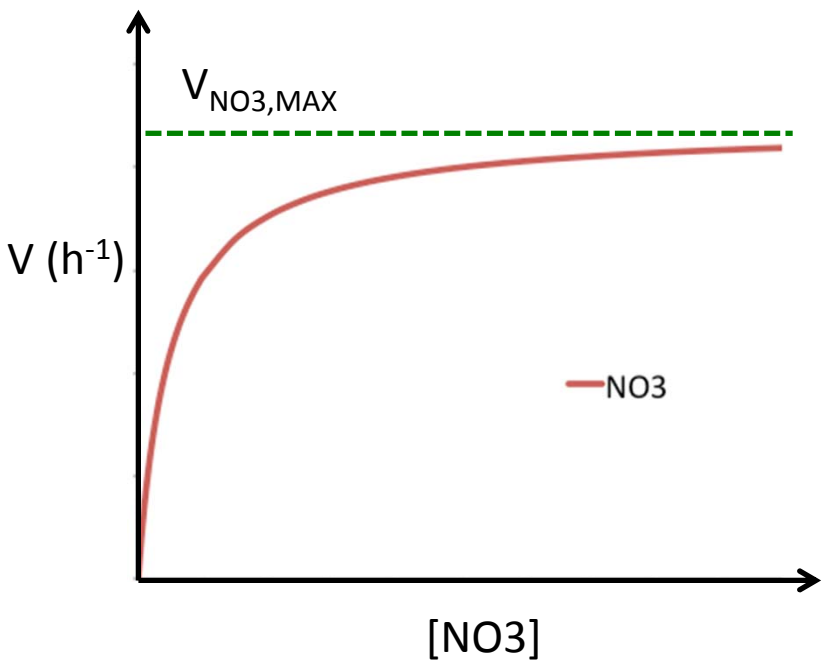
**P.1** When NH4 > 1-4 µmol $L^{-1}$, nitrate uptake is inhibited

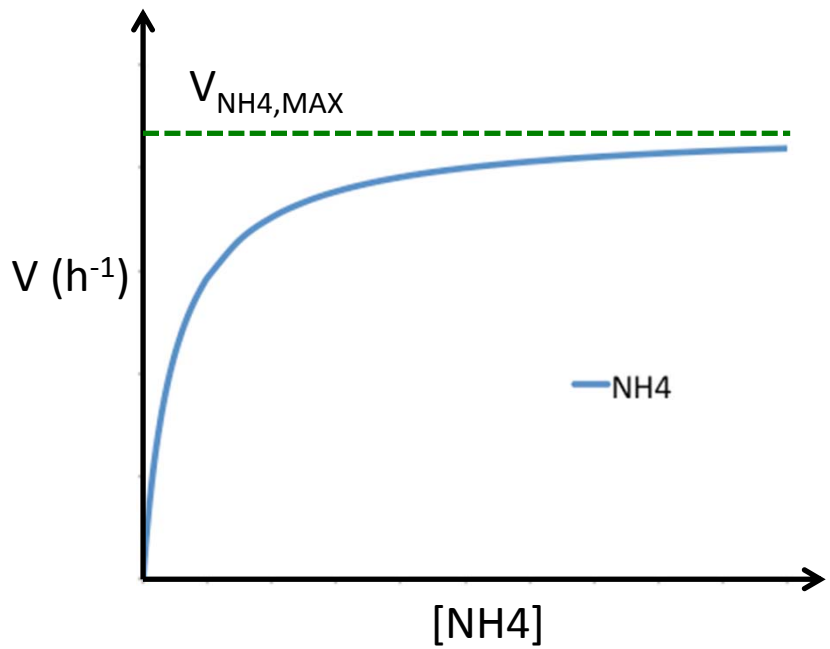
**P.2** The rate of NO3 uptake is greater than the rate of NH4 uptake.

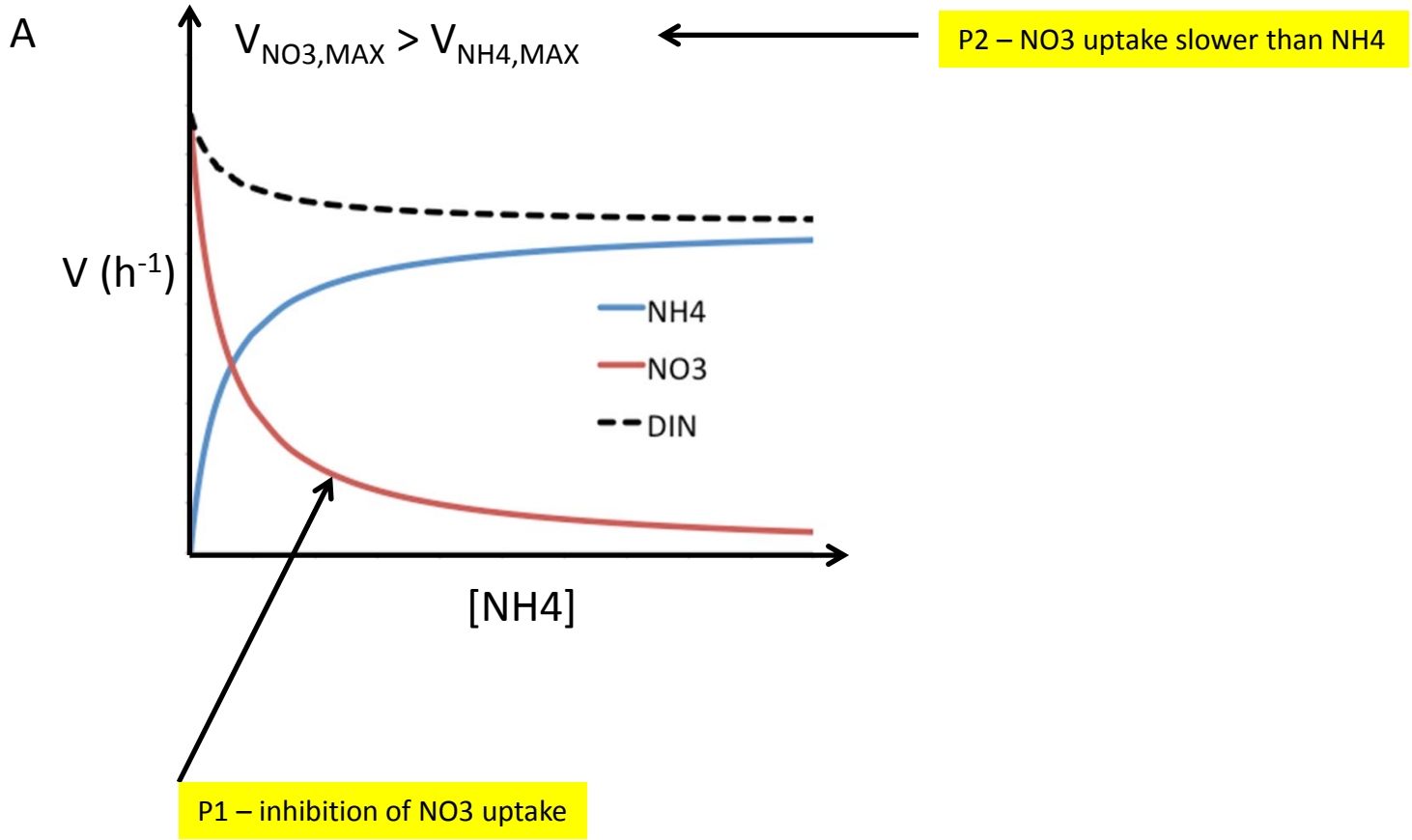
- when NO3 uptake is suppressed, and only NH4 is being taken up by phytoplankton, the overall rate of N uptake is lower

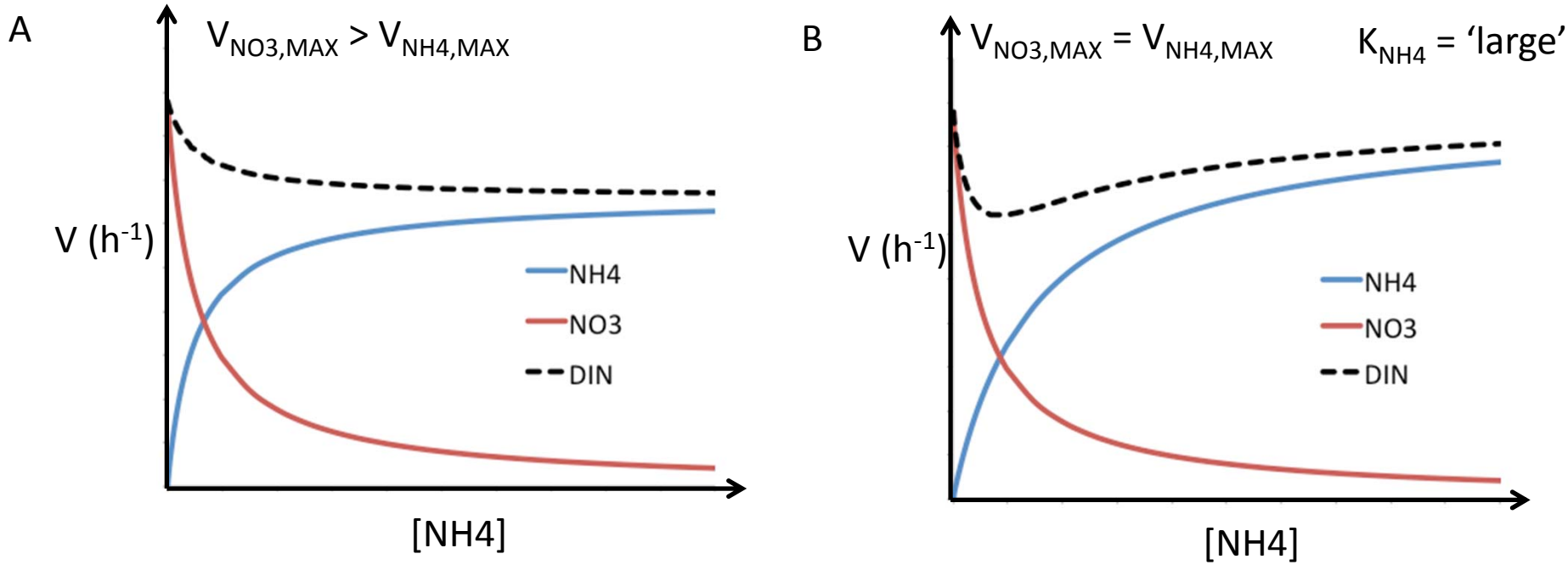
**P.3** The lower rate of N uptake translates into lower rates of primary production.

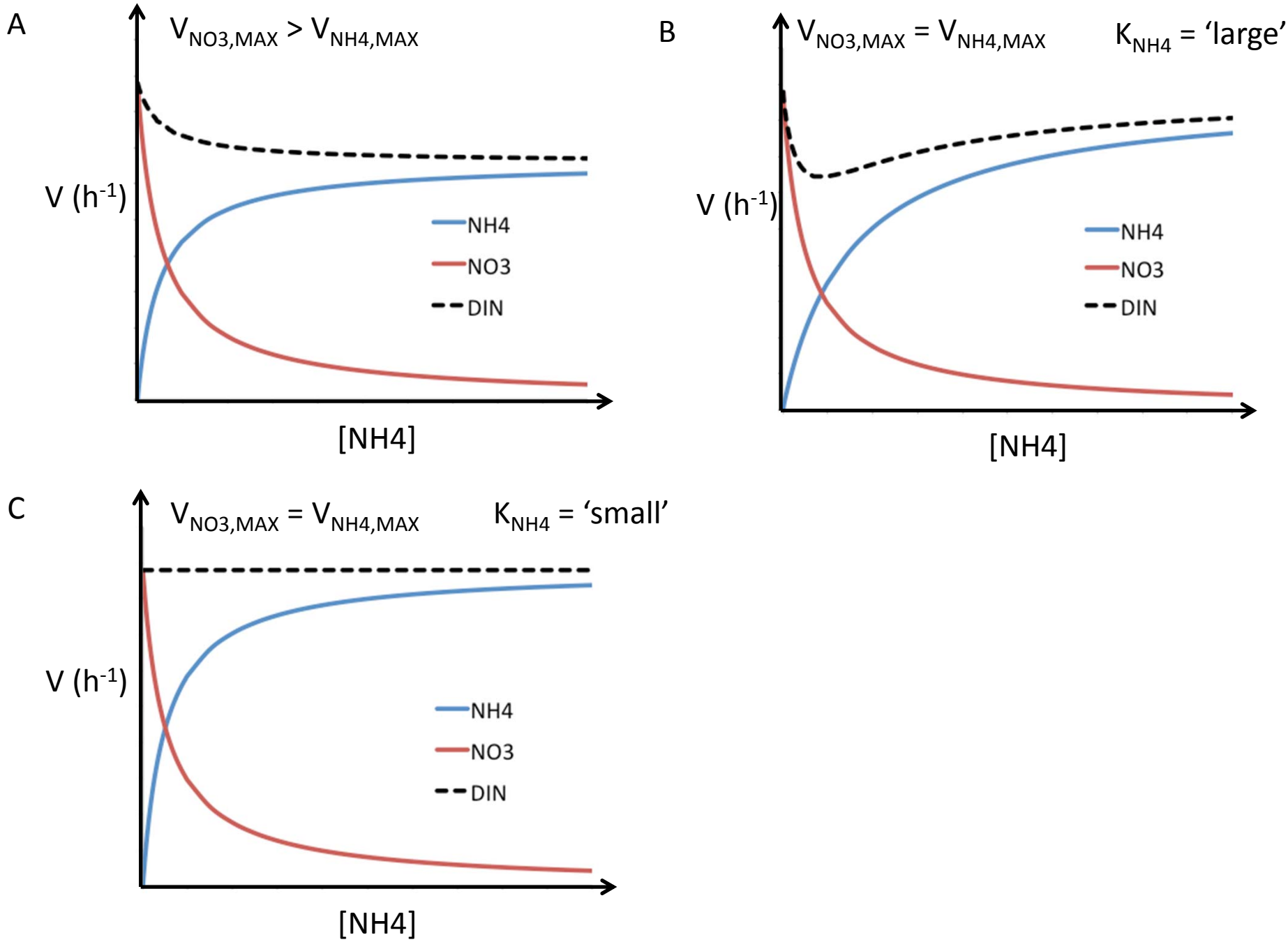
# Classic uptake kinetics (Michaelis-Menten)




A
$V_{NO3,MAX} > V_{NH4,MAX}$
P2 – NO3 uptake slower than NH4
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]
P1 – inhibition of NO3 uptake


A
$V_{NO3,MAX} > V_{NH4,MAX}$
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]
B
$V_{NO3,MAX} = V_{NH4,MAX}$
$K_{NH4}$ = 'large'
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]


A
$V_{NO3,MAX} > V_{NH4,MAX}$
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]
B
$V_{NO3,MAX} = V_{NH4,MAX}$
$K_{NH4}$ = 'large'
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]
C
$V_{NO3,MAX} = V_{NH4,MAX}$
$K_{NH4}$ = 'small'
V ($h^{-1}$)
NH4
NO3
DIN
[NH4]

# NH4-inhibition Hypothesis

**P.1** When NH4 > 1-4 µmol $L^{-1}$, nitrate uptake is inhibited

- *well-supported by the scientific literature*
- *common across wide-range of phytoplankton species*

**P.2** Phytoplankton take up NH4 more slowly than N03

- *not well-supported by broader scientific literature*
- *science gap: few targeted studies*
- *some RTC studies support P2, but some contradictory or unclear results and further validation needed*

- *Remains a plausible hypothesis*

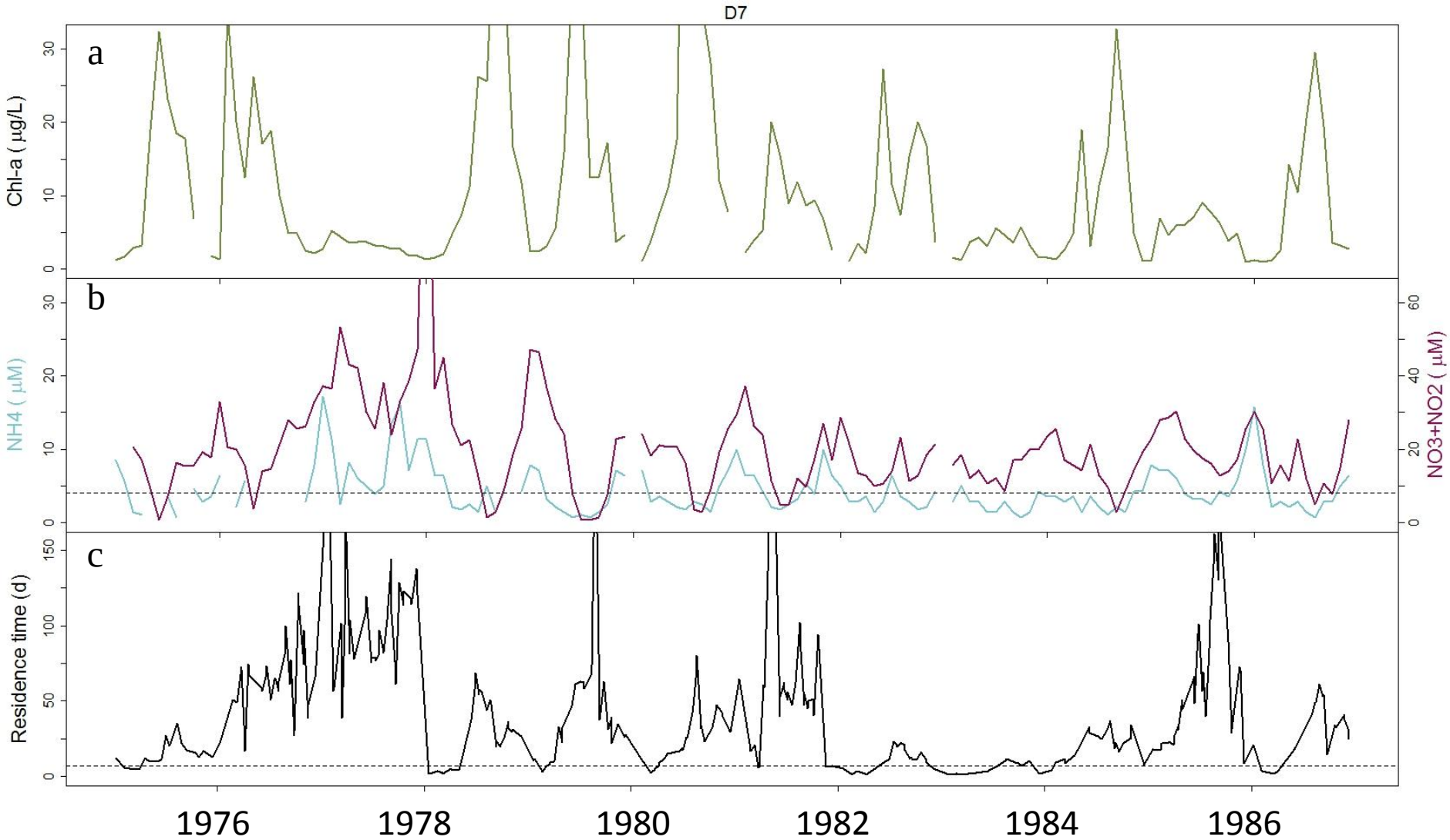
# NH4-inhibition Hypothesis

**P.3** The lower rate of N uptake translates into lower rates of primary production.

- *not well-supported by broader scientific literature*
- *multiple studies suggesting comparable growth rates on NO3 and NH4*
- *science gap: few targeted studies*
- *some results from RTC studies support P3*
  - *further validation needed*
  - *competing explanations tested*

- *<u>Remains a plausible hypothesis</u>*

# System Behavior pre-1987 (pre-clam invasion)



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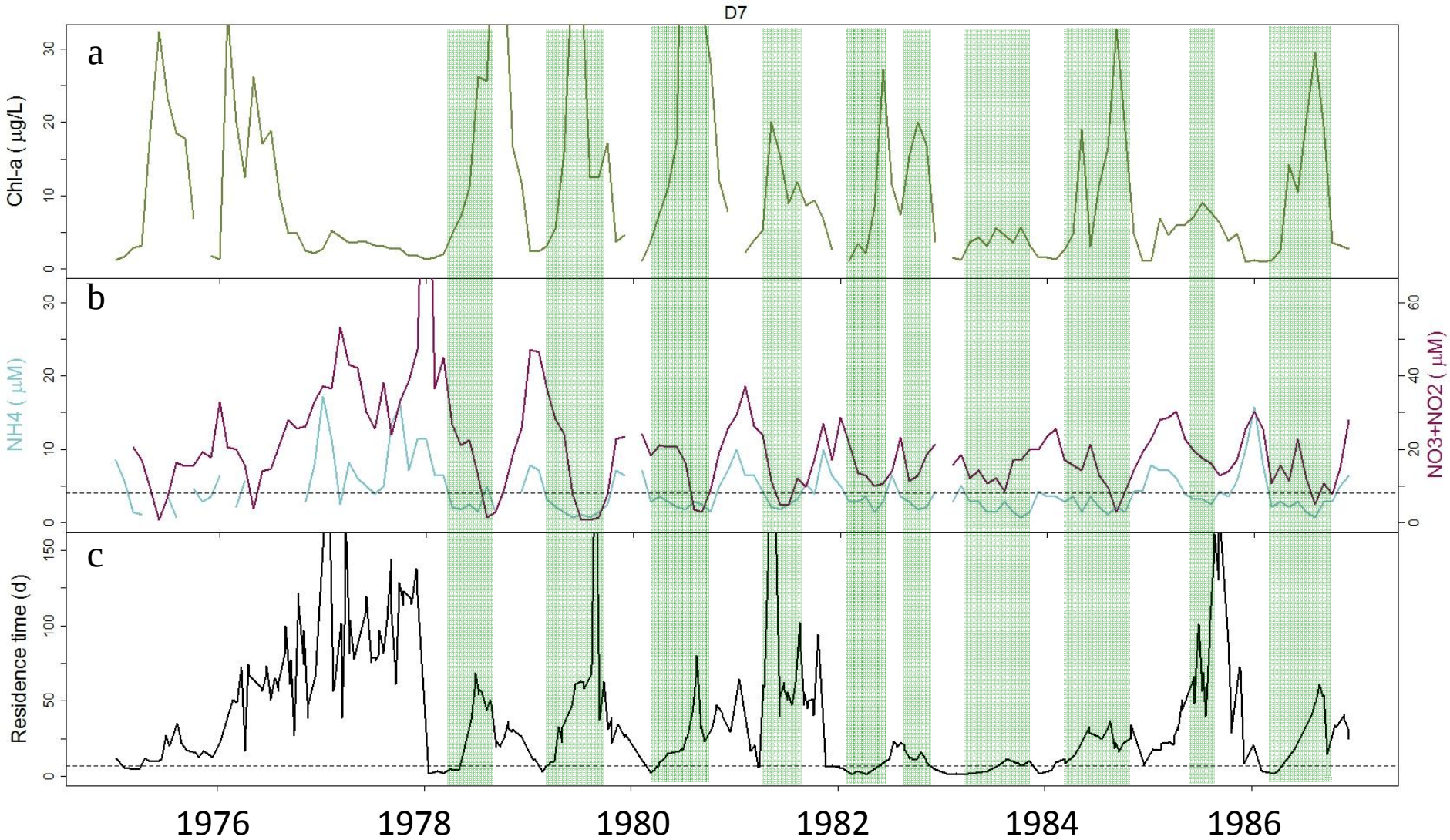

# Recommendations

- Need for well-controlled experiments…
  - Greater growth with NO3 than NH4?
  - test under a range of conditions (e.g., T, light, levels)
  - Experiments with phytoplankton mono-cultures from Suisun/SFB
- Test and rule-out/rule-in competing explanations and experimental artifacts
- Evaluate the potential environmental significance of process at the ecosystem scale (vs. clams, light limitation)
  - Modeling
- Science Plan and Workshop: Identify key science questions and experiments to test current uncertainties