Suisun Synthesis I Overview

David Senn
March 8 2013

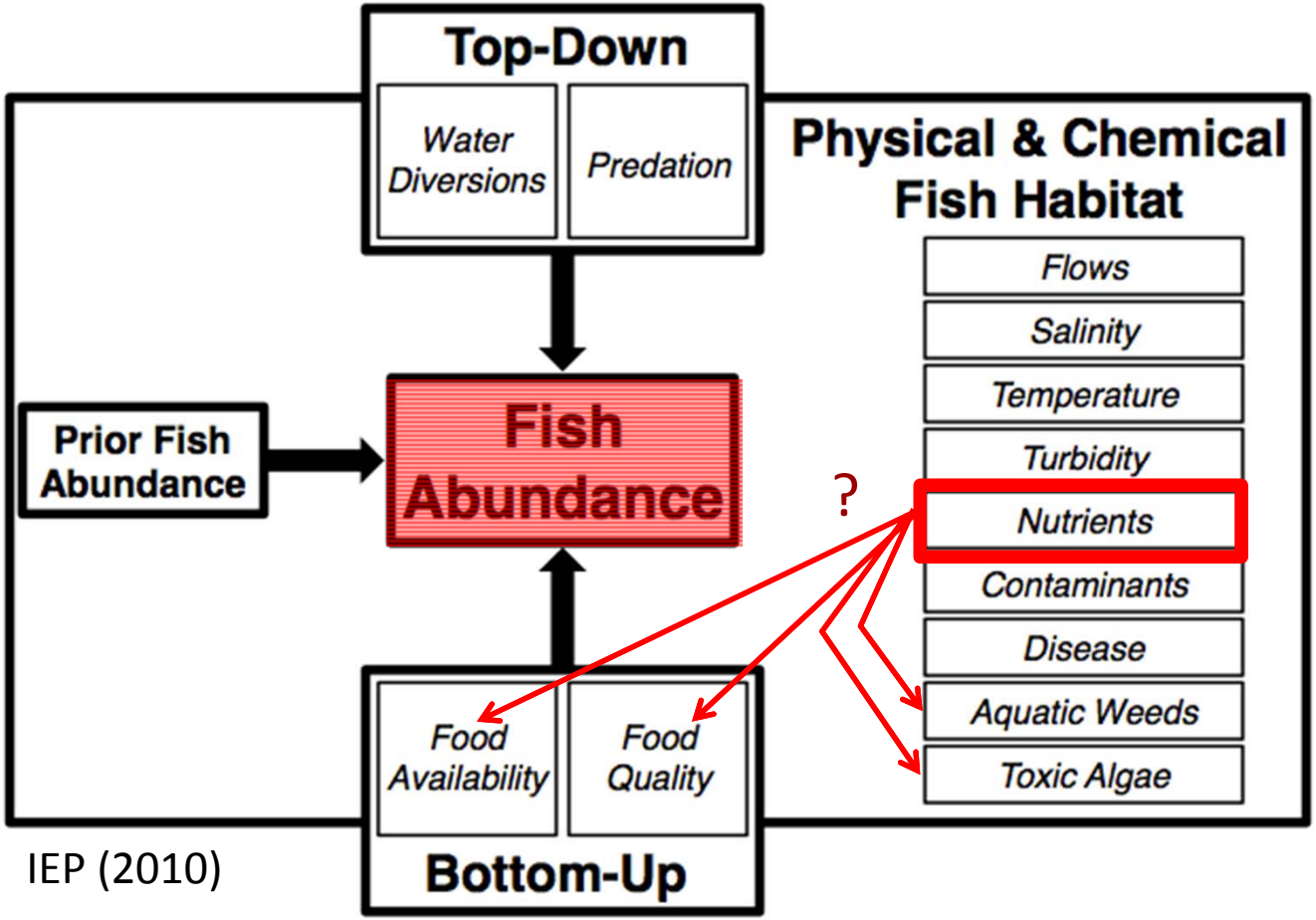
Suisun Bay: evaluating potential impacts of nutrients

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

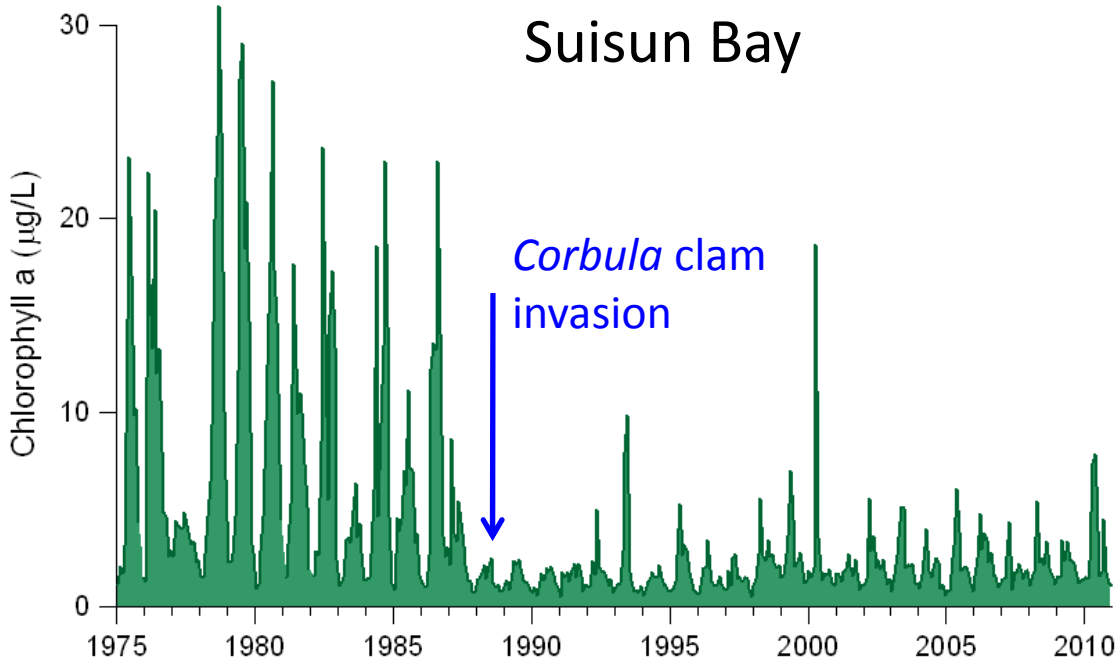


IEP (2010)

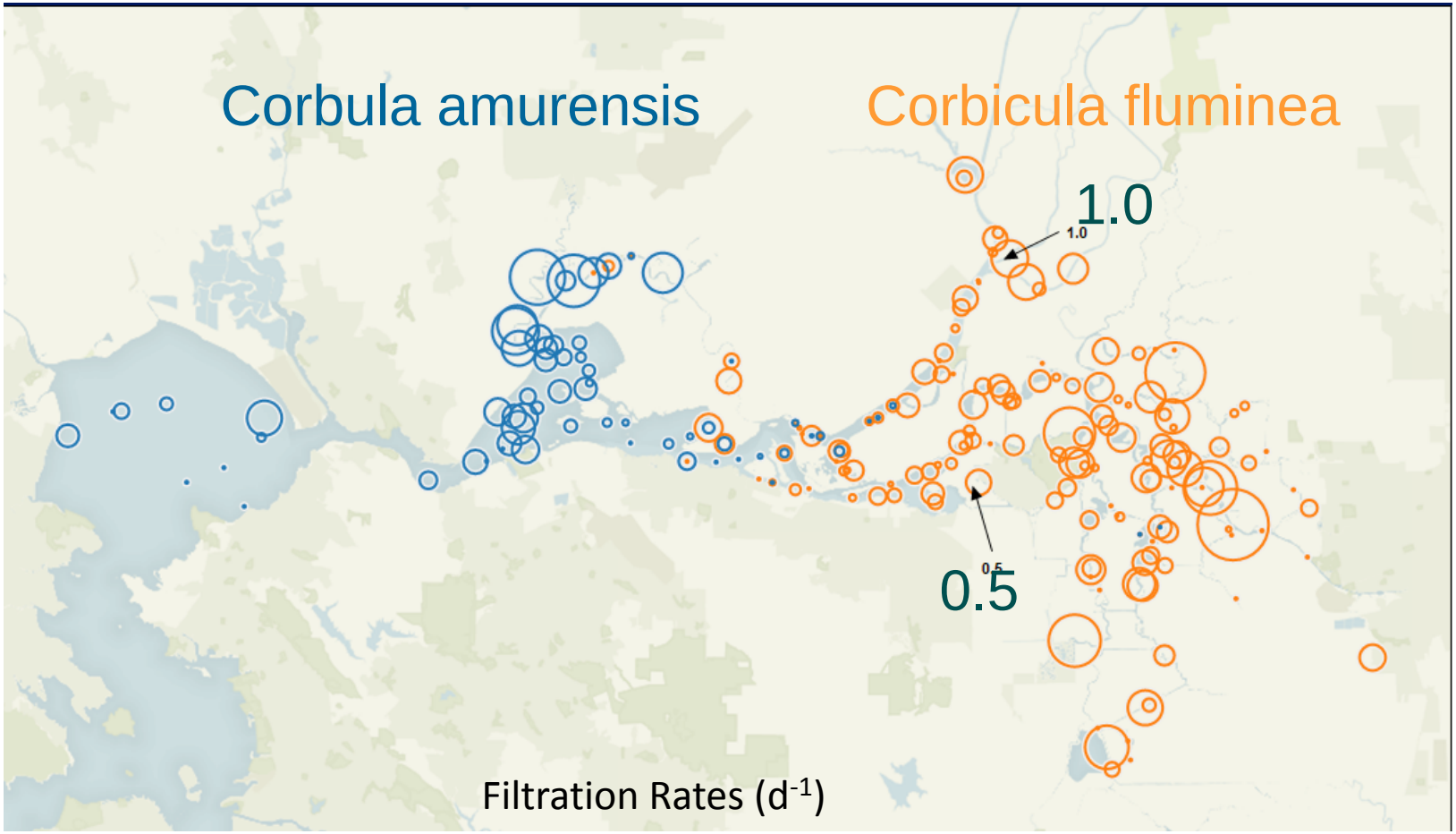
Phytoplankton

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)

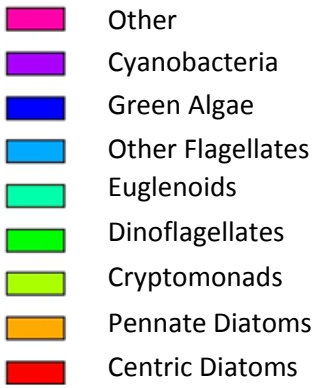
Phytoplankton

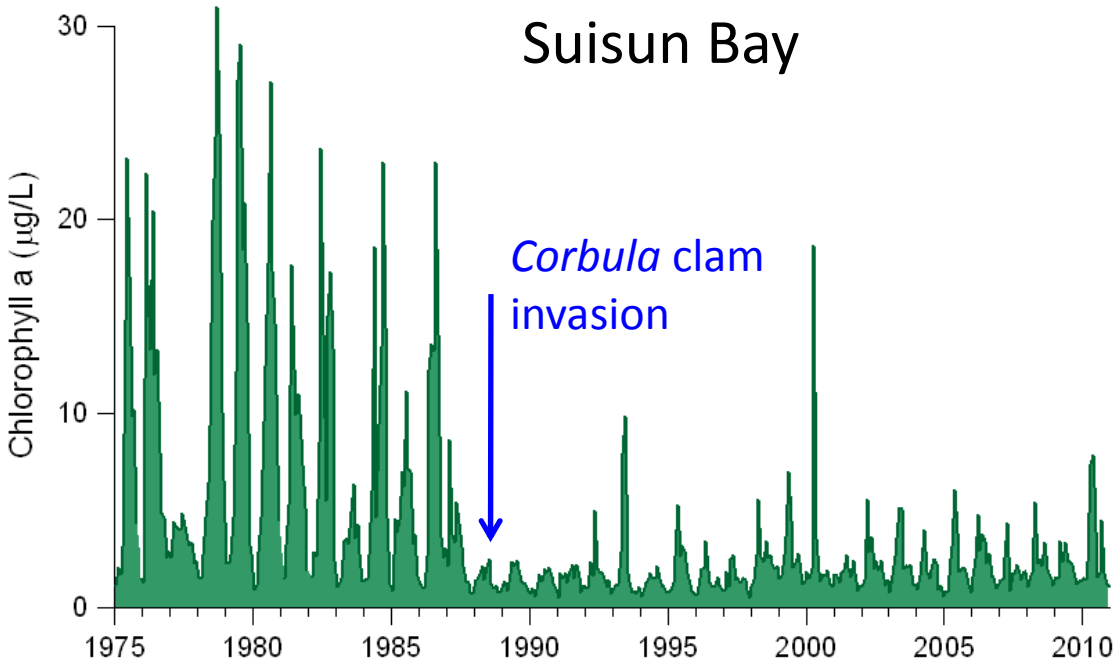
Abundance Drivers/stressors

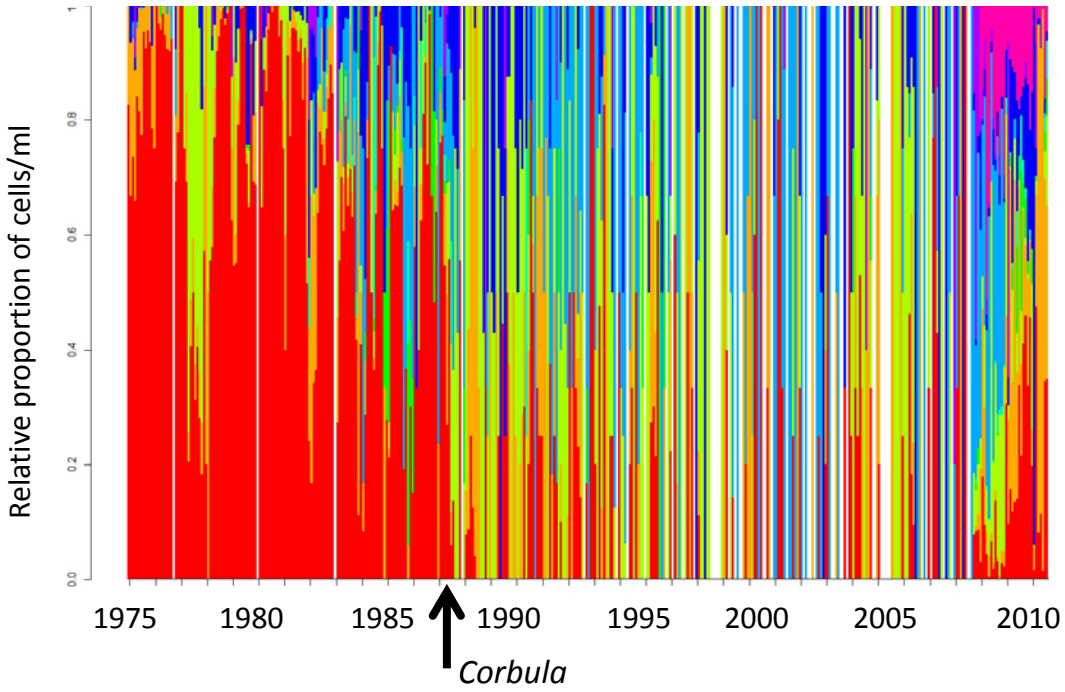
- Clams
- Light limitation
- Nutrients (NH4)
- Residence time

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

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
- 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

   (W Kimmerer, SFSU-RTC)

4. NH4 loads and concentrations: seasonal and long-term trends, and NH4 fate *(E Novick and D Senn, SFEI)*

5. Identify next steps *(D Senn and E Novick, SFEI)*

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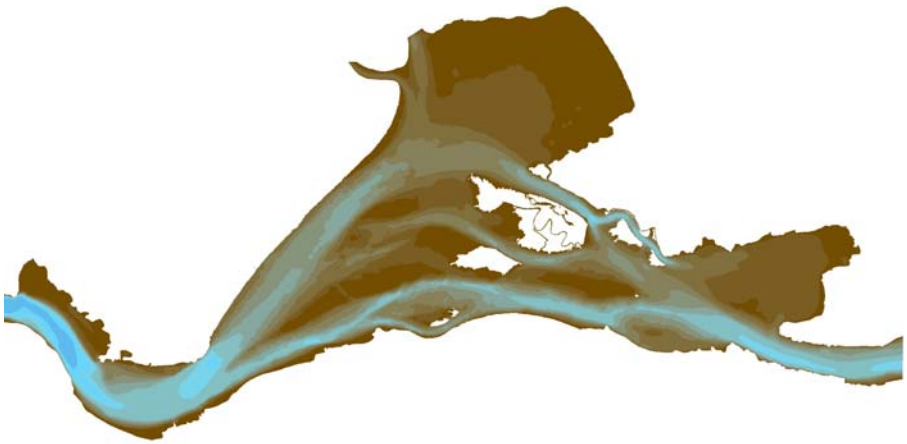
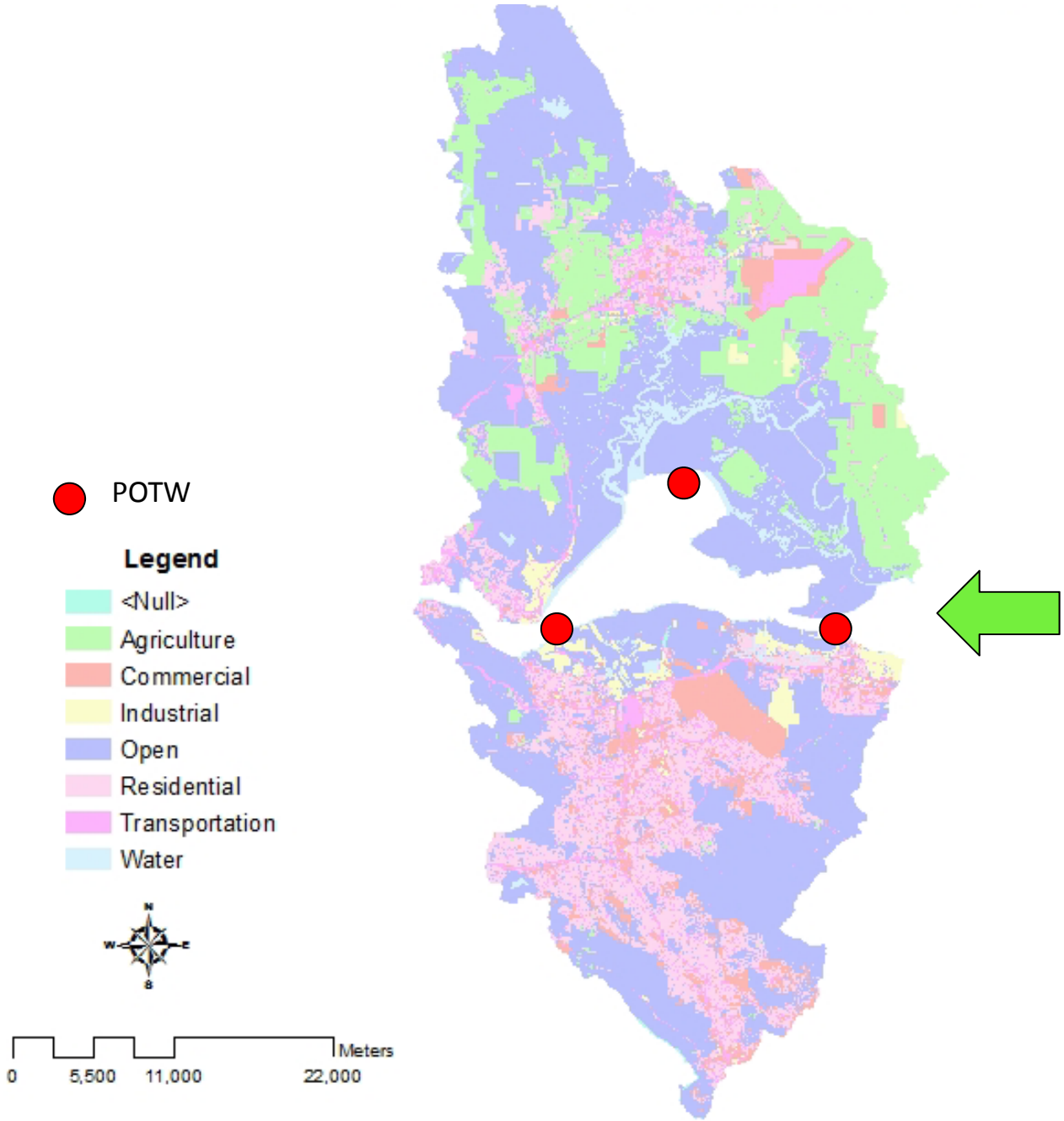
NH4 in Suisun Bay

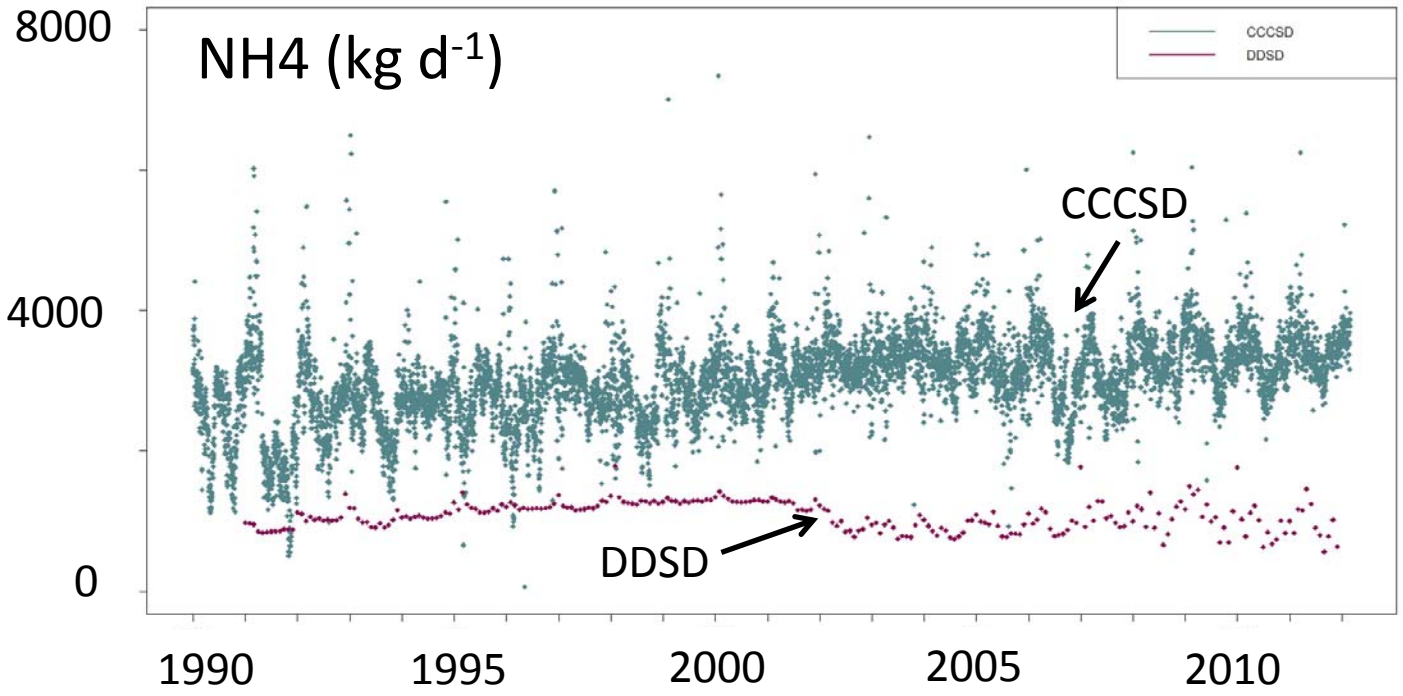
- Goals:
  - Develop improved understanding of sources, fate, and trends
  - Inform near-term management decisions on nutrient loads.
- Approach:
  - Analyzed ambient water quality data (1975-2012)
  - Estimated loads: Delta, POTWs, and stormwater
  - Mass balance/box-model



Suisun Bay Watershed and POTWs

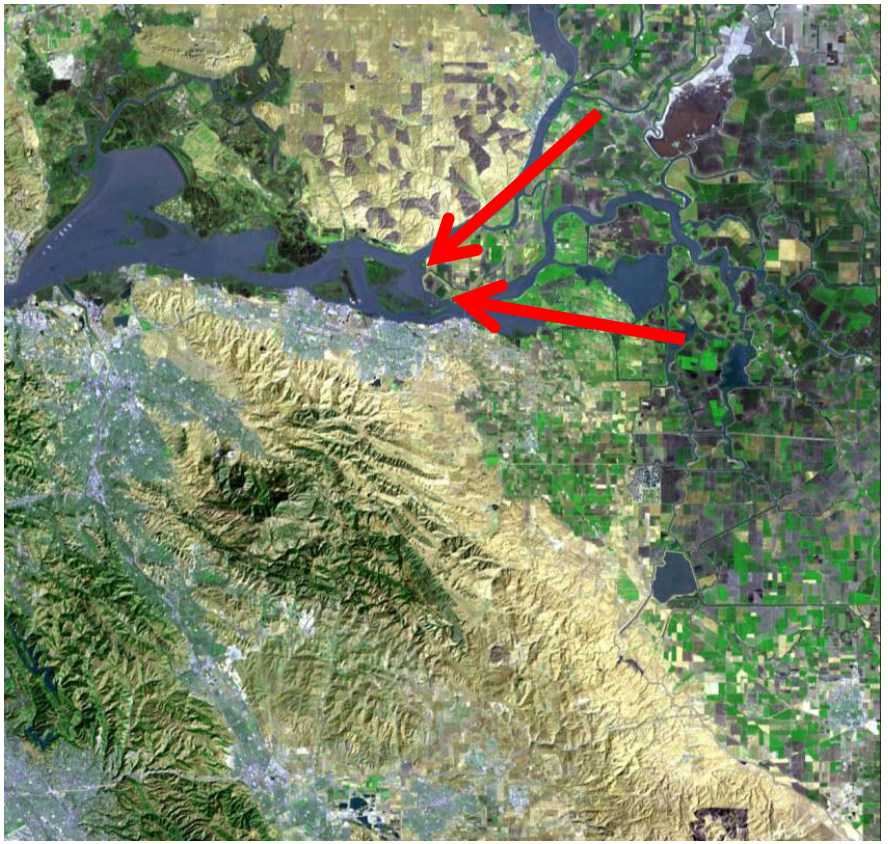


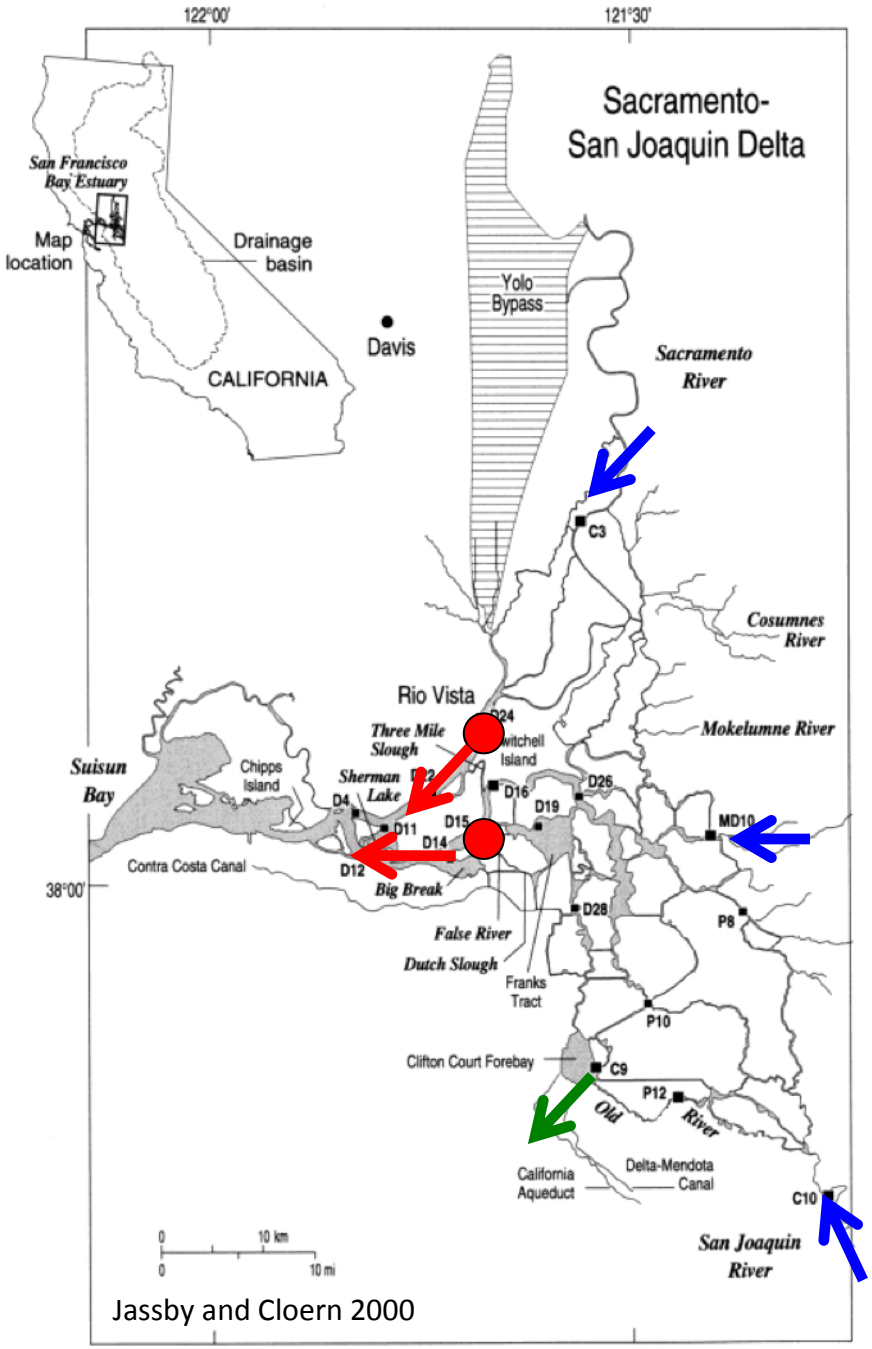
Suisun POTW loads



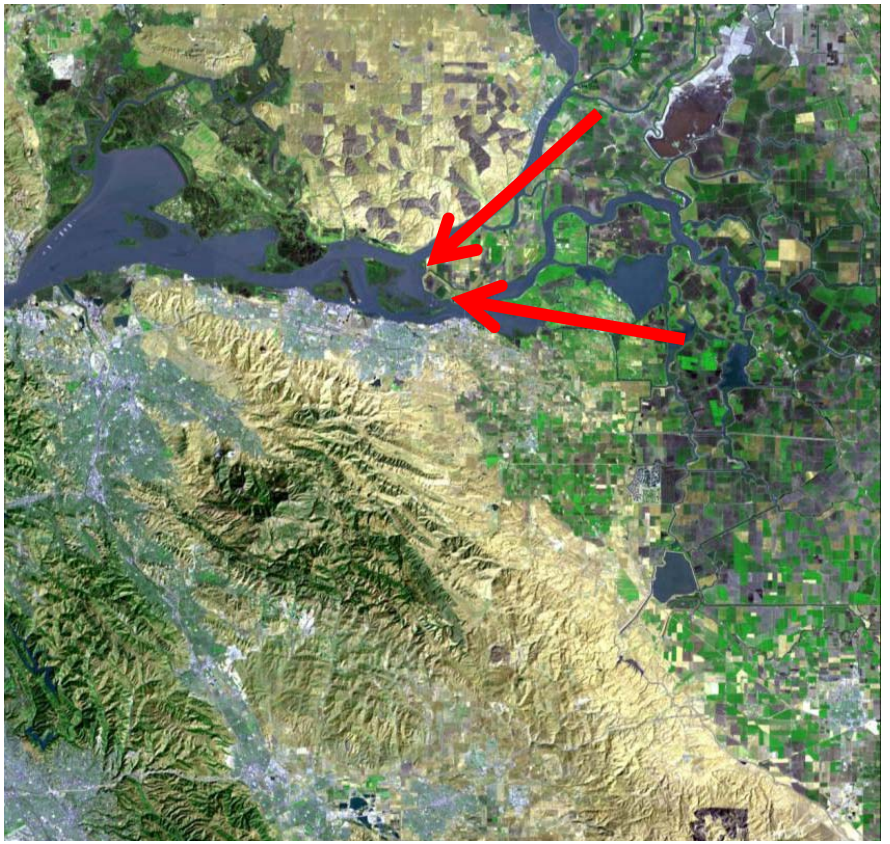
Loads from the Delta

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





Jassby and Cloern 2000

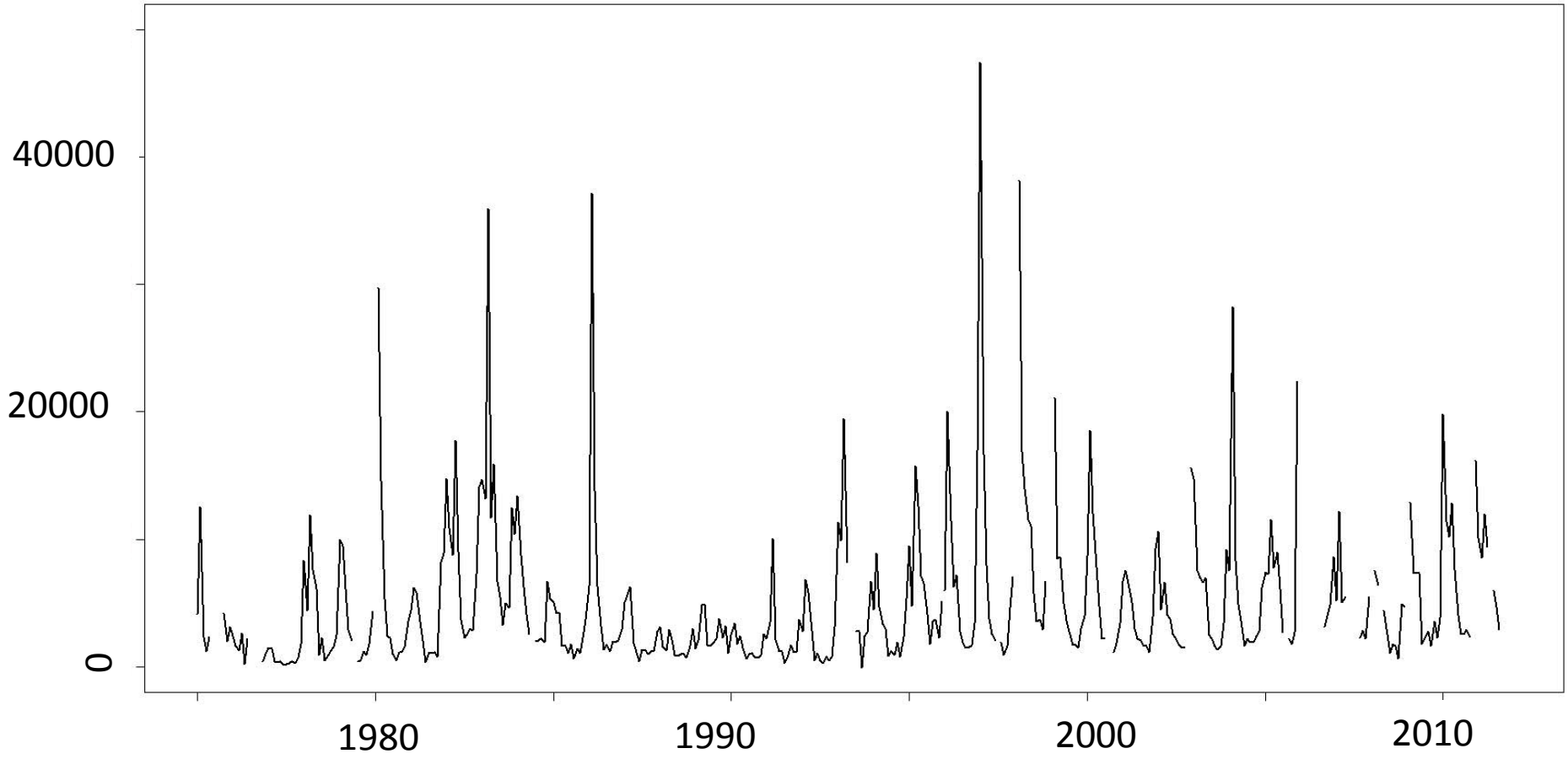


$$Load_{Suisun} = Q_{west} * [C]_{D16} + Q_{rio} * [C]_{D24}$$

- Long-term daily-averaged flows

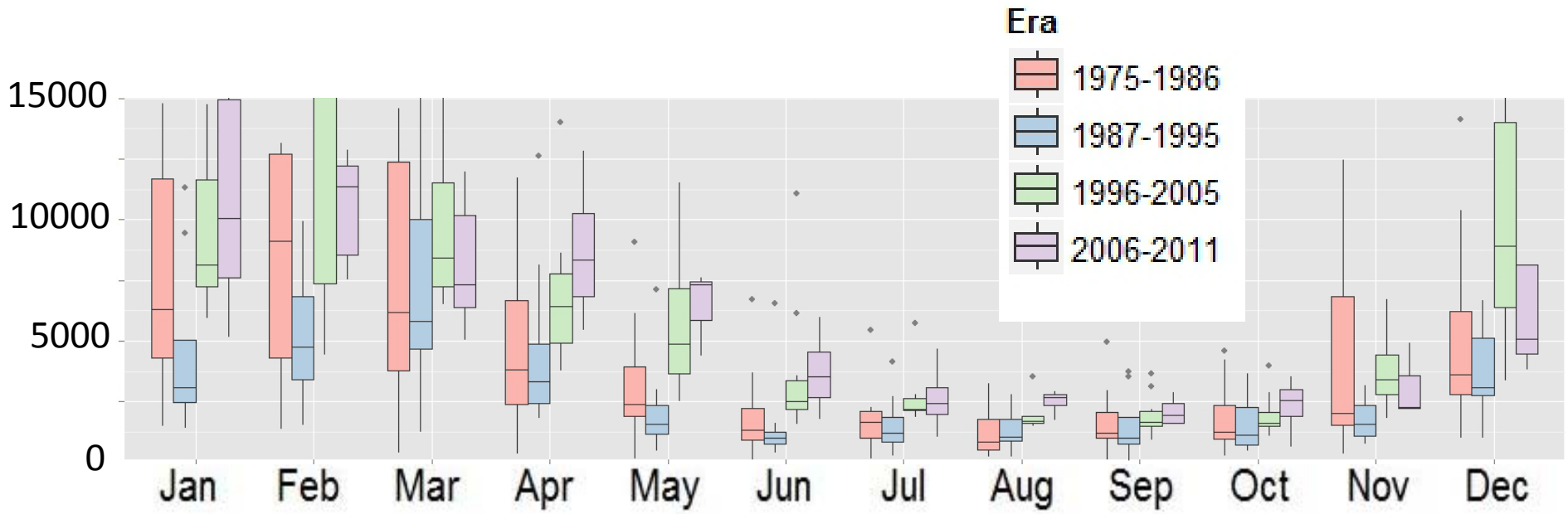
- Monthly concentration data at monitoring stations

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

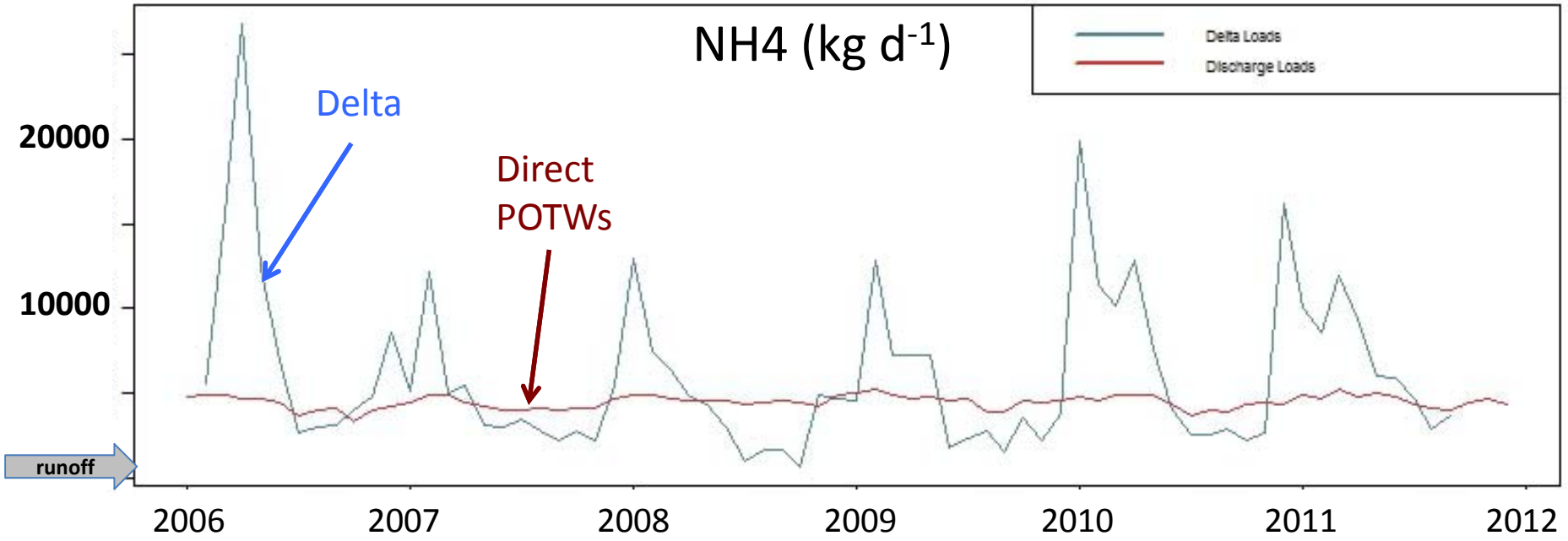


- Strong seasonality and interannual variability
- Increasing baseline

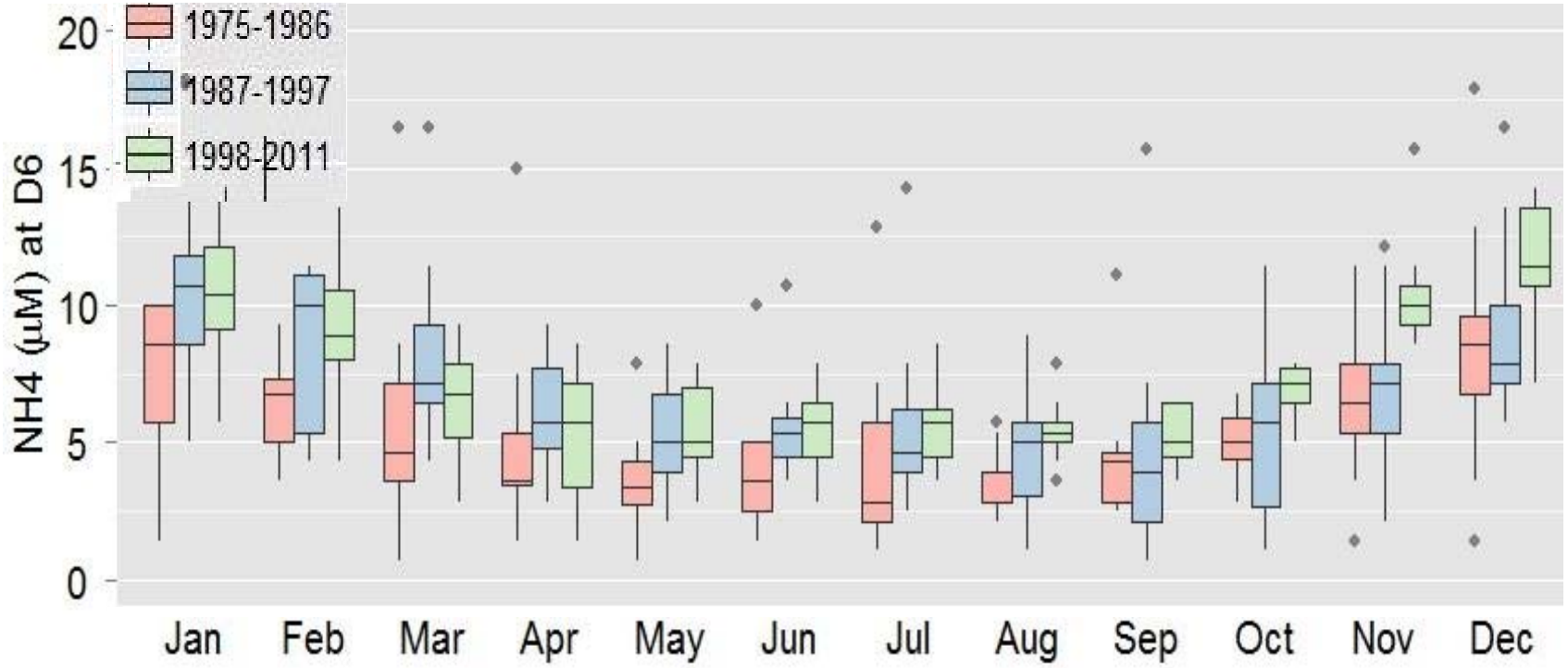
Delta NH4 loads to Suisun Bay (kg d^{-1})



- Large increases in April-May-June

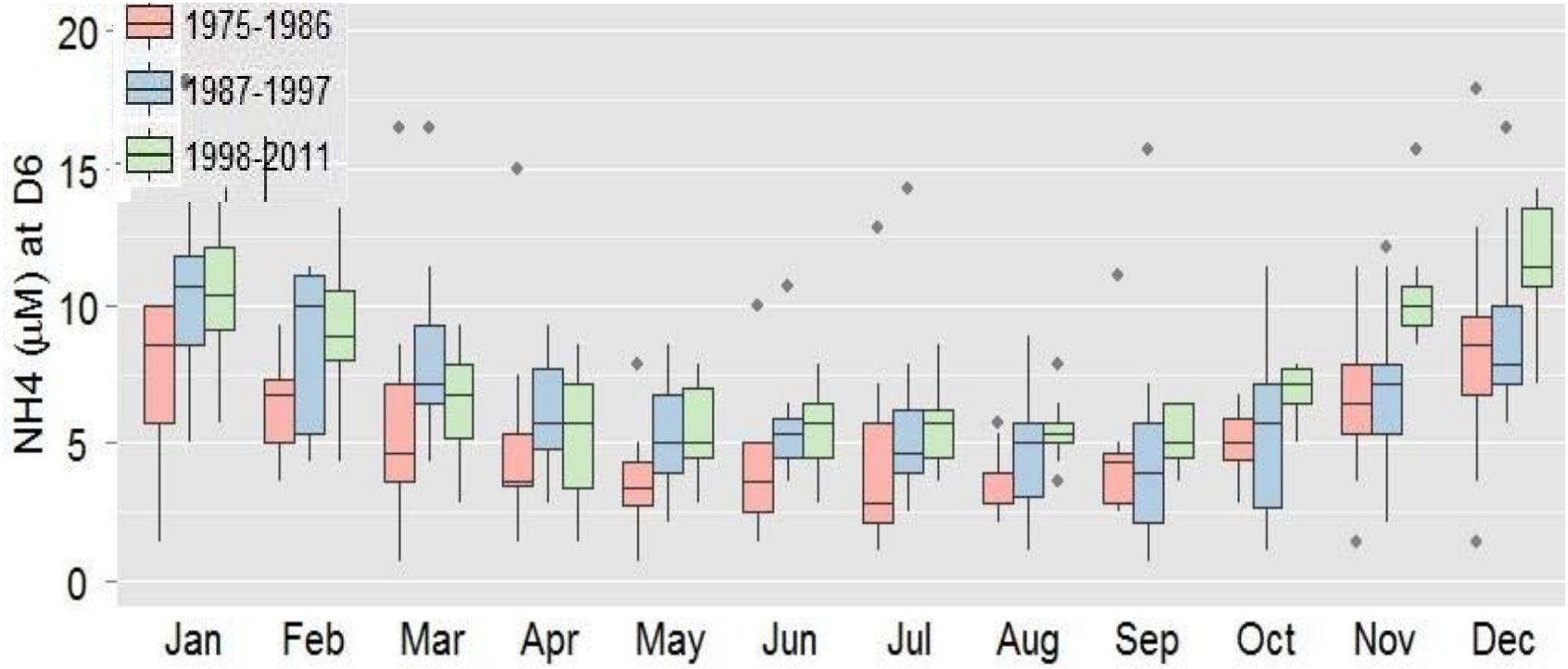

NH4 (kg d-1)
Delta Loads
Discharge Loads
Delta
Direct
POTWs
20000
10000
runoff
2006
2007
2008
2009
2010
2011
2012

Seasonal and Long-term Variation in NH4



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

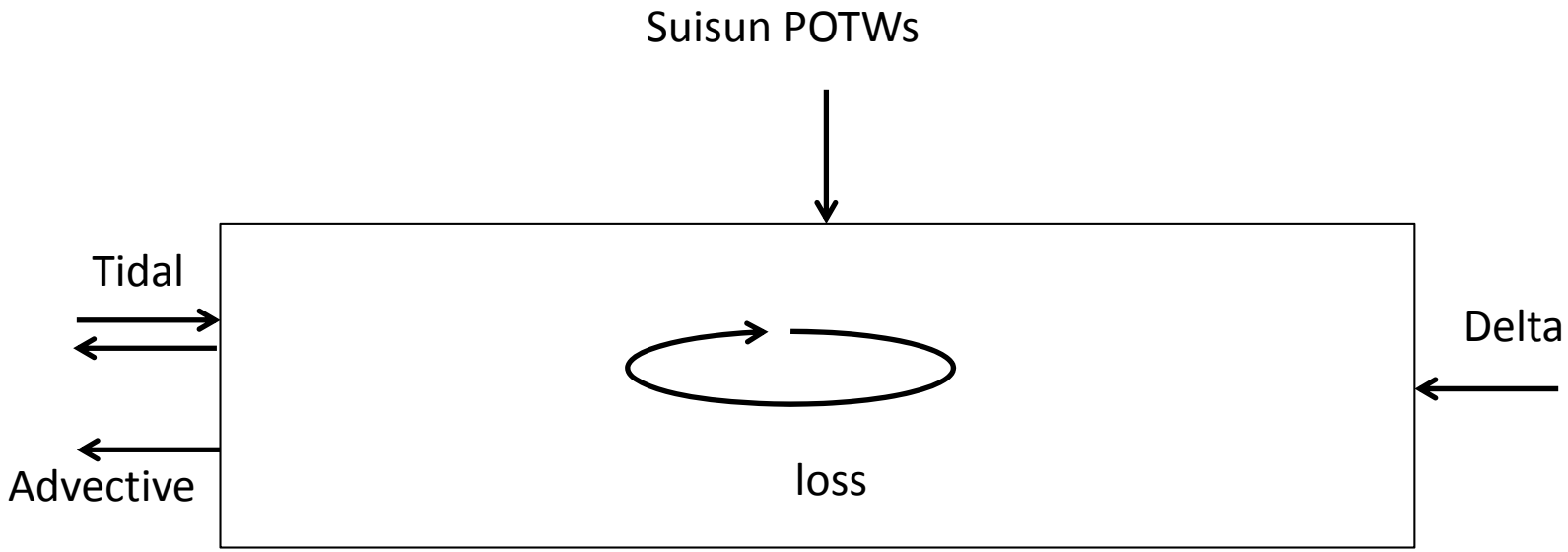
Seasonal and Long-term Variation in NH4



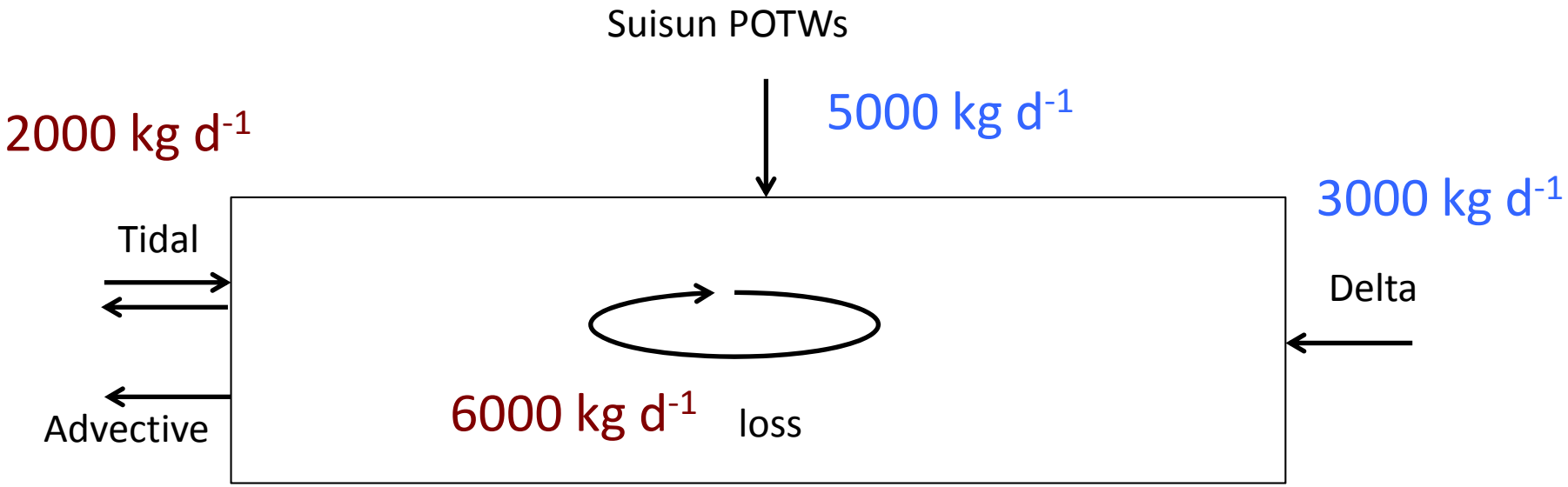
Thresholds

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

Spring-Summer NH4 Mass Balance

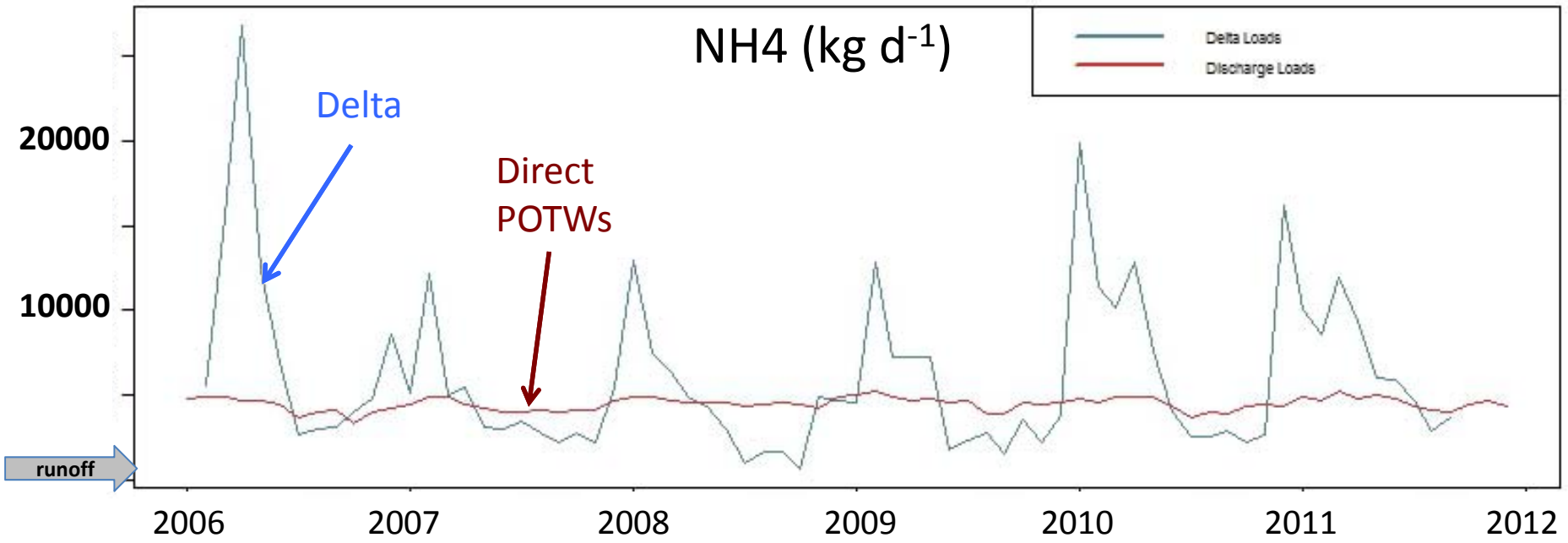


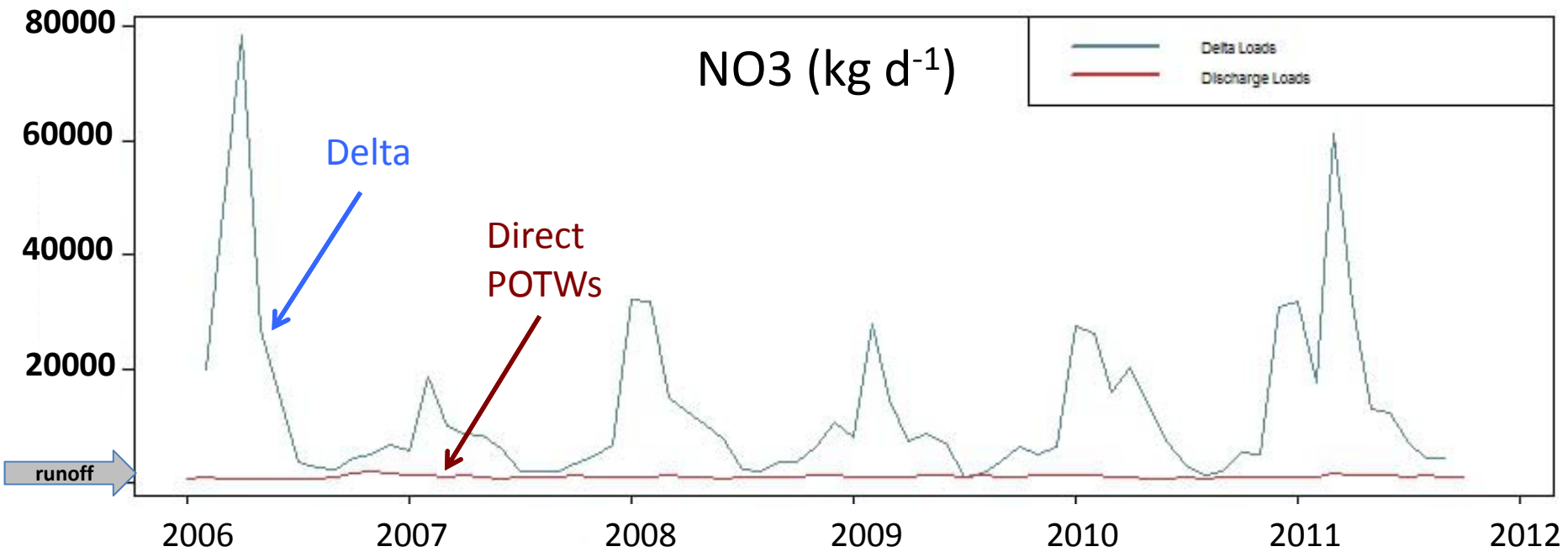
Spring-Summer NH4 Mass Balance



- *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

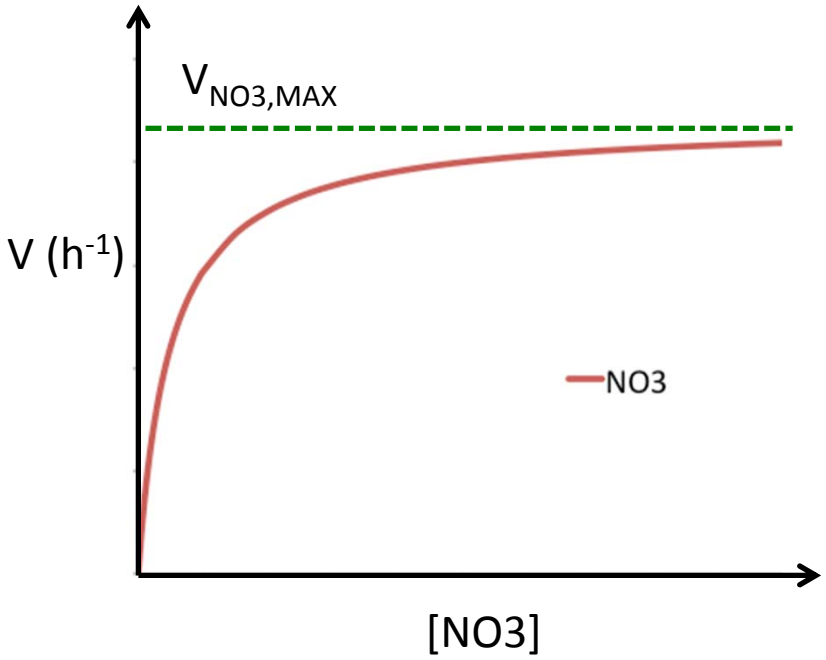
P.1 When NH4 > 1-4 µmol L^{-1}, nitrate uptake is inhibited

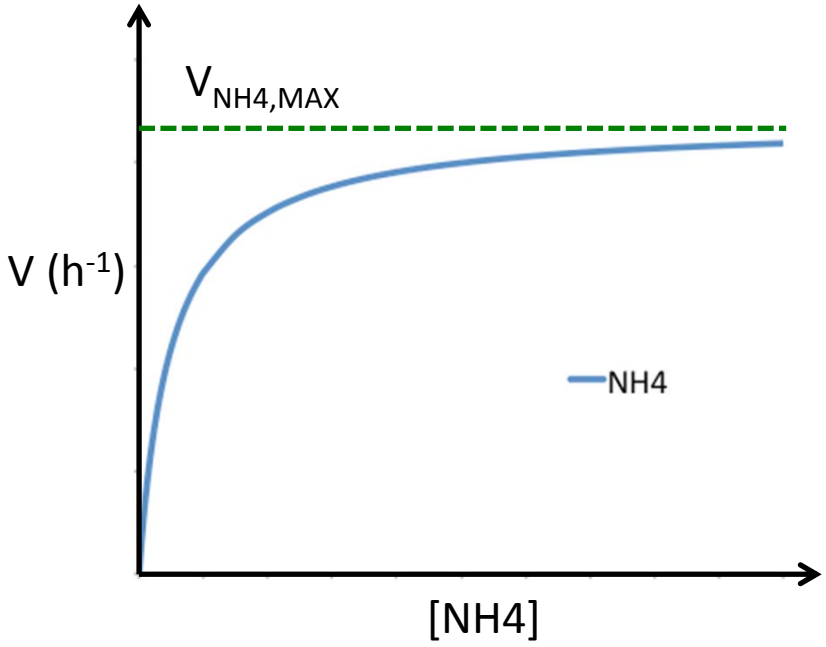
P.2 The rate of NO3 uptake is greater than the rate of NH4 uptake.

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

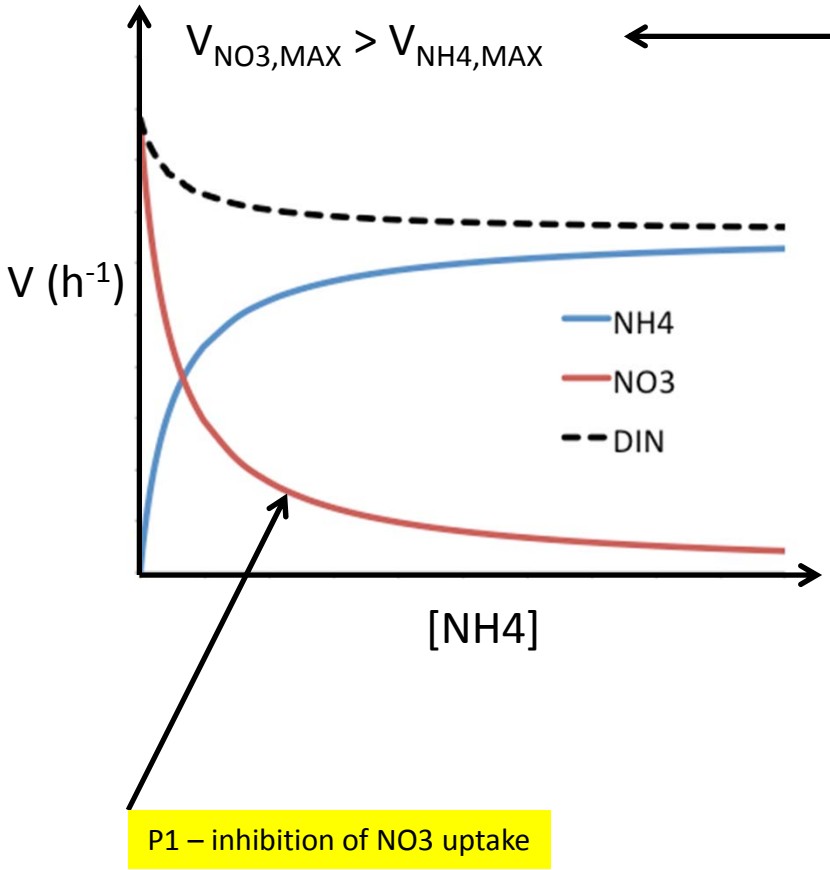
P.3 The lower rate of N uptake translates into lower rates of primary production.

Classic uptake kinetics (Michaelis-Menten)



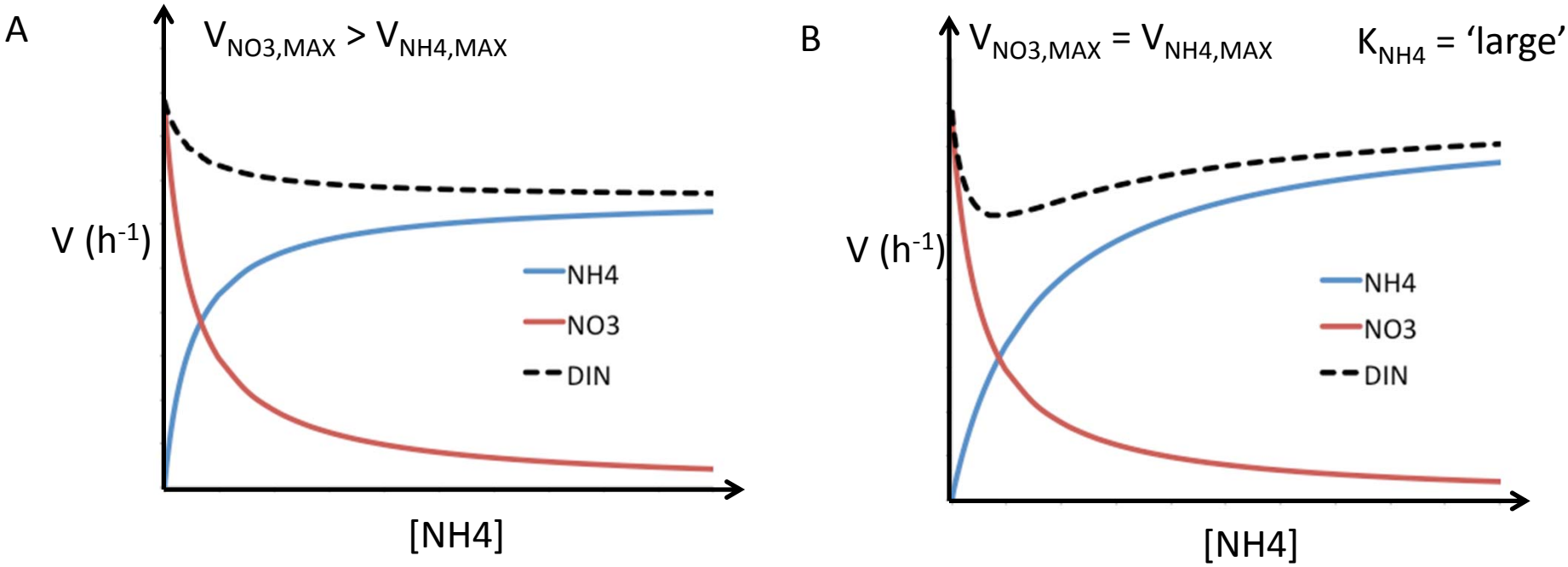


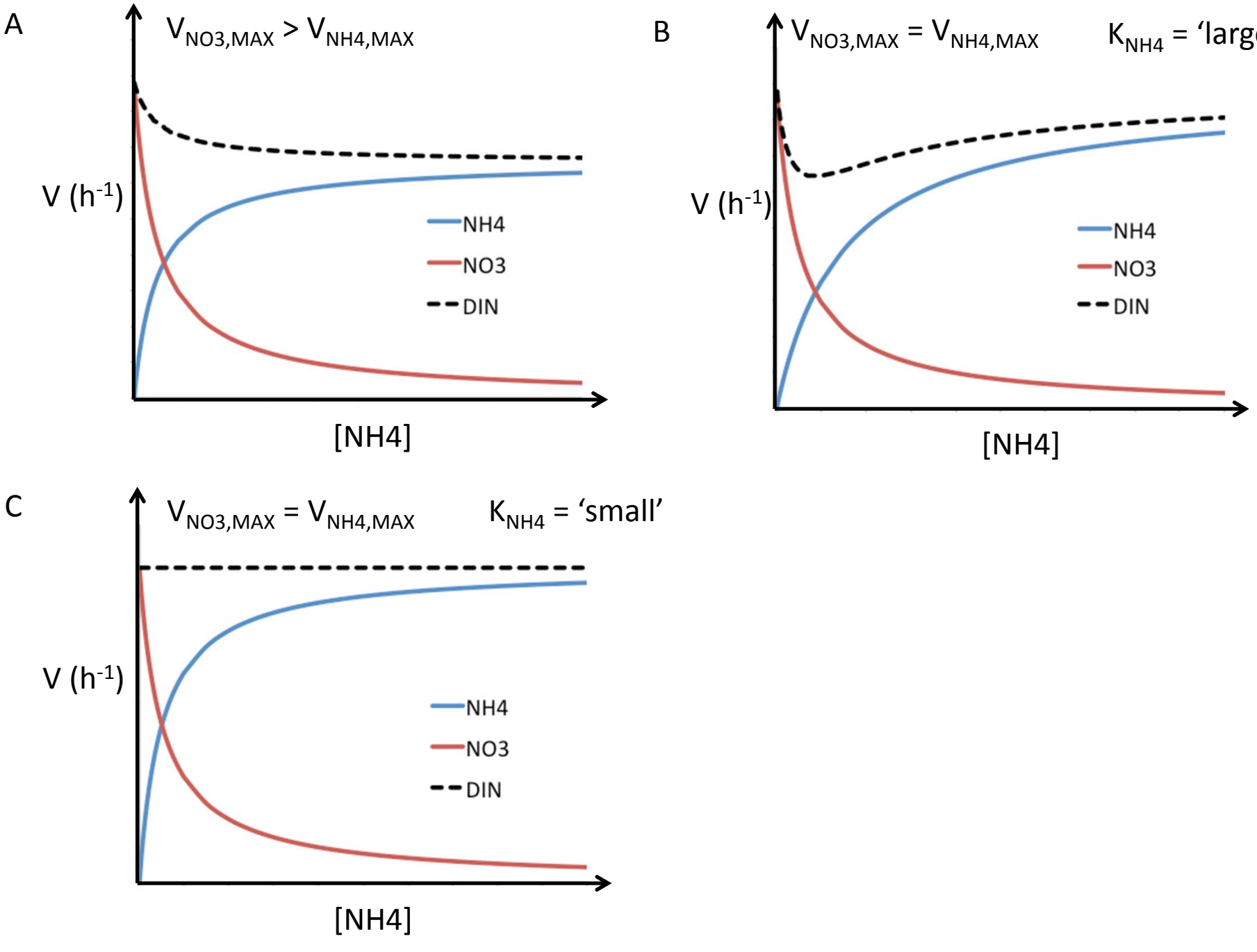
A



P2 – NO3 uptake slower than 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*

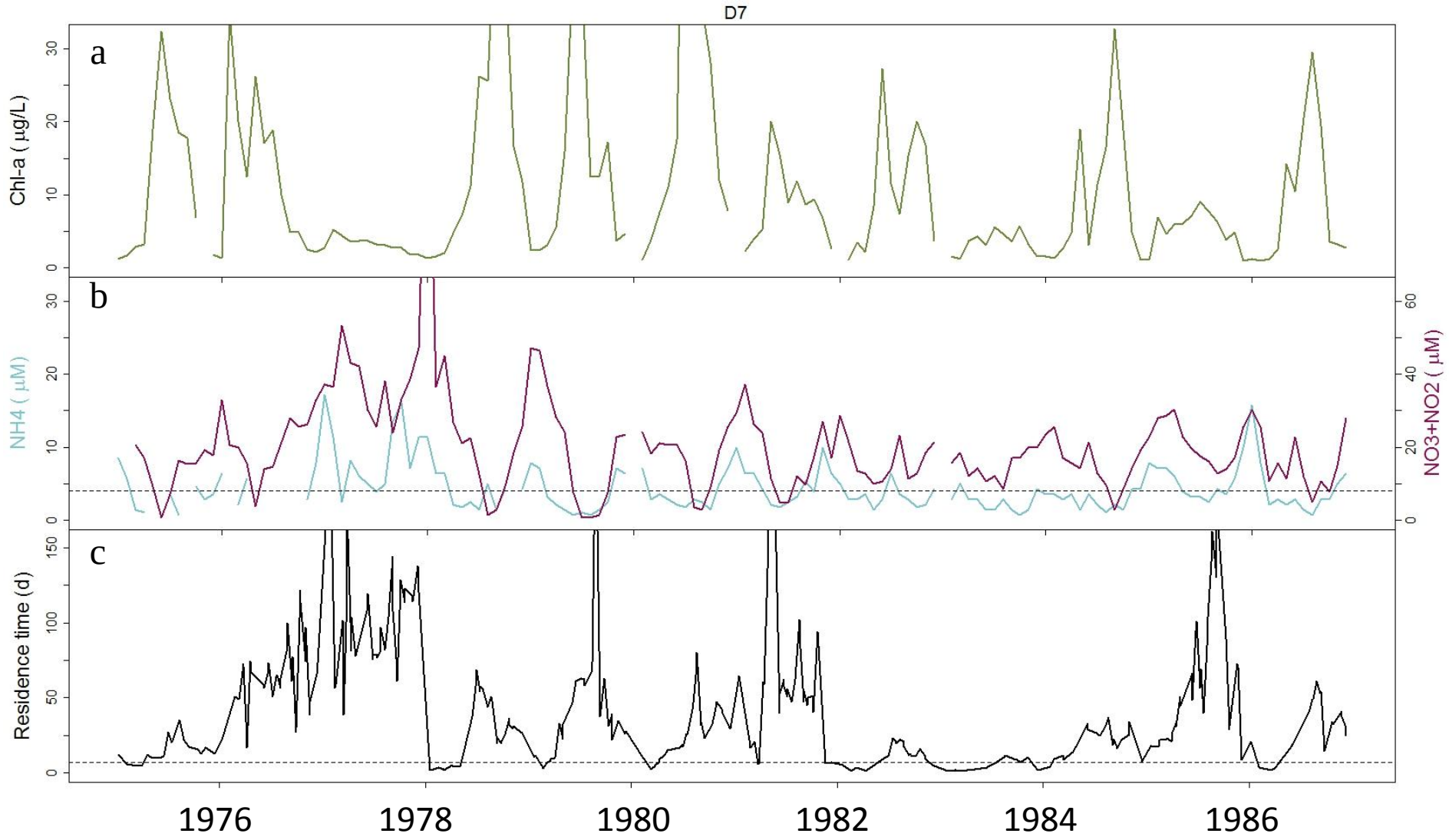
NH4-inhibition Hypothesis

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*

- *Remains a plausible hypothesis*

System Behavior pre-1987 (pre-clam invasion)



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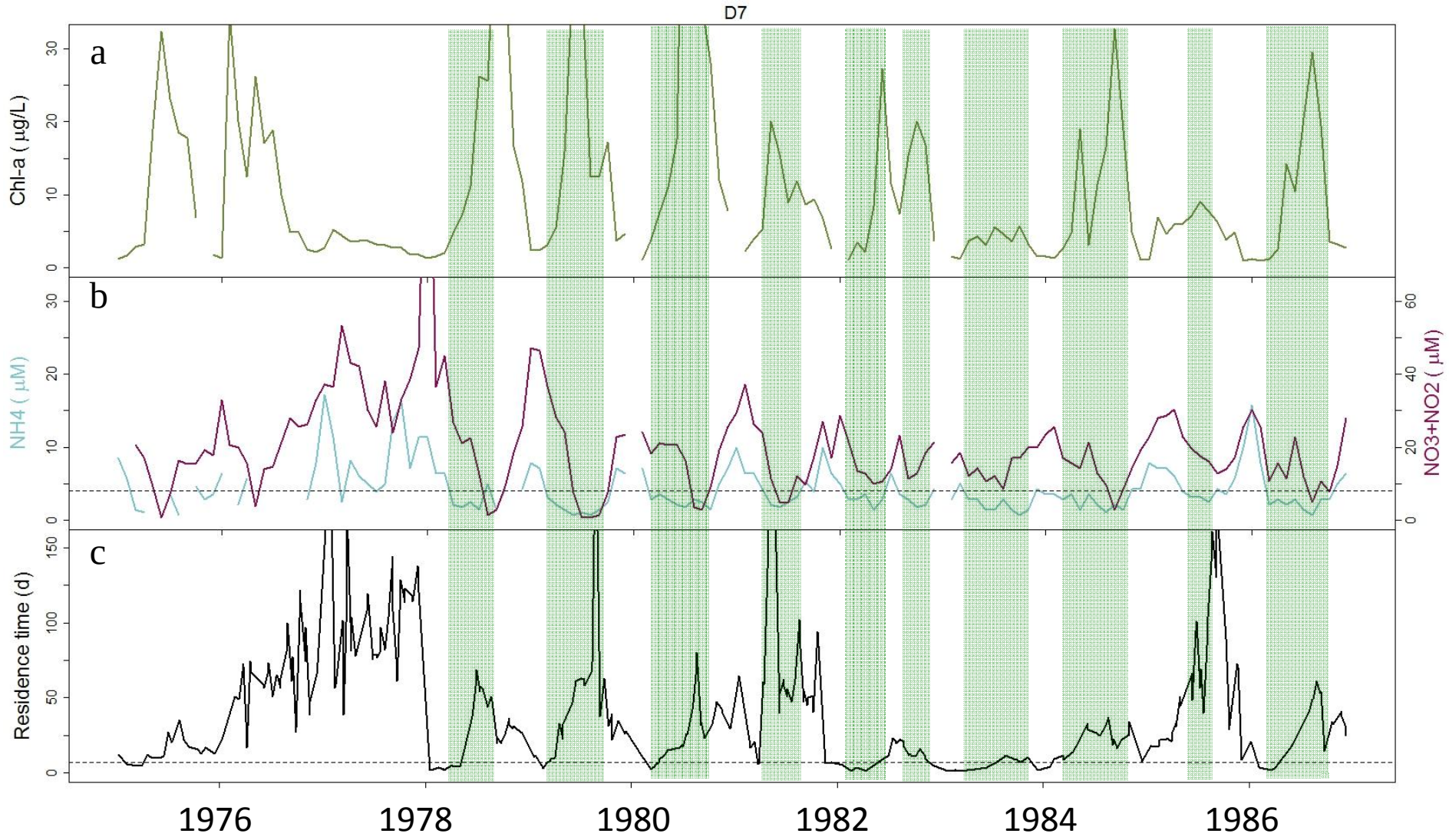
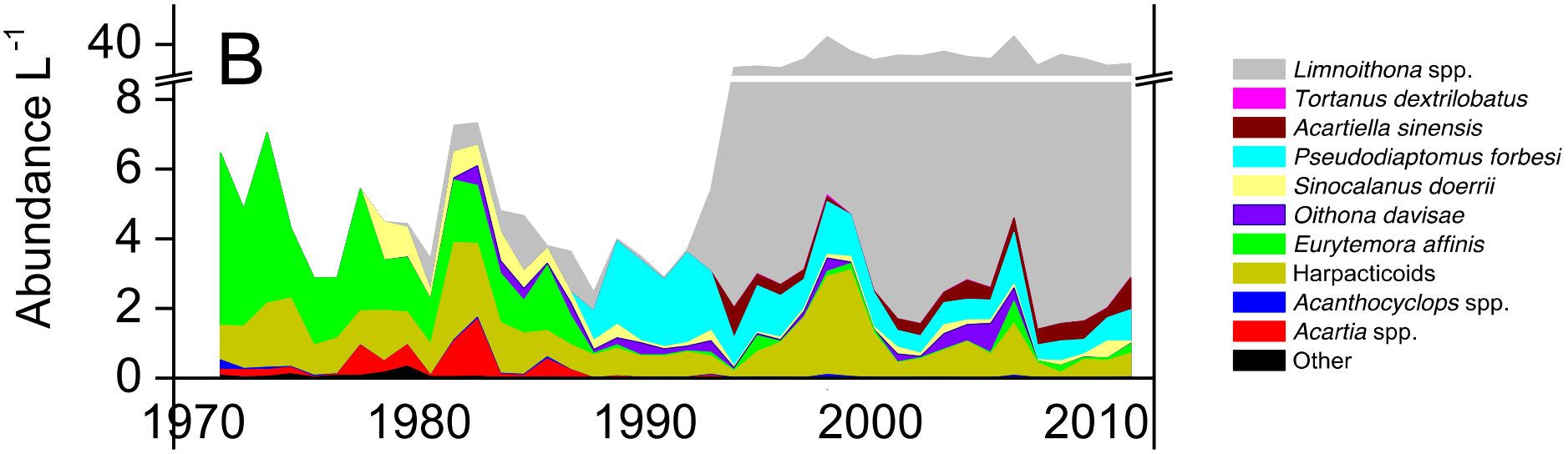


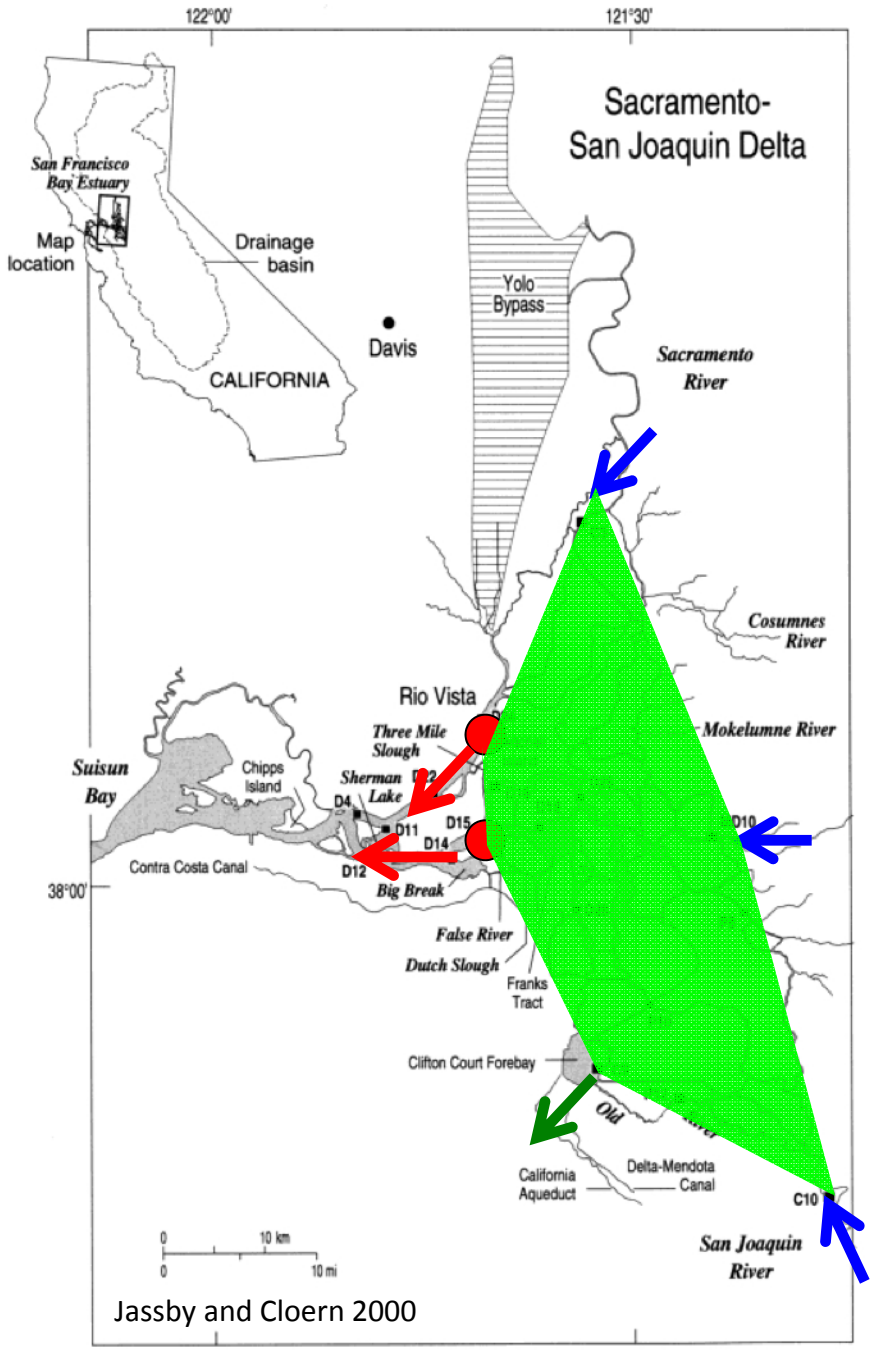
Recommendations

- 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

Copepod Ecology



- Key links in the foodweb between microplankton and fish.
- Declines in abundance, biomass, and composition and the underlying causes of these changes are of key concern
- Likely causes of change:
  - introduced species, some of which are not suitable as food
  - Food limitation – Clam grazing on phytoplankton (Corbula)
  - Grazing on copepod juveniles by clams
  - Contaminants (including nutrients) can't be ruled out



Quantifying N and P loads and transformations in the Delta

Funder: IEP

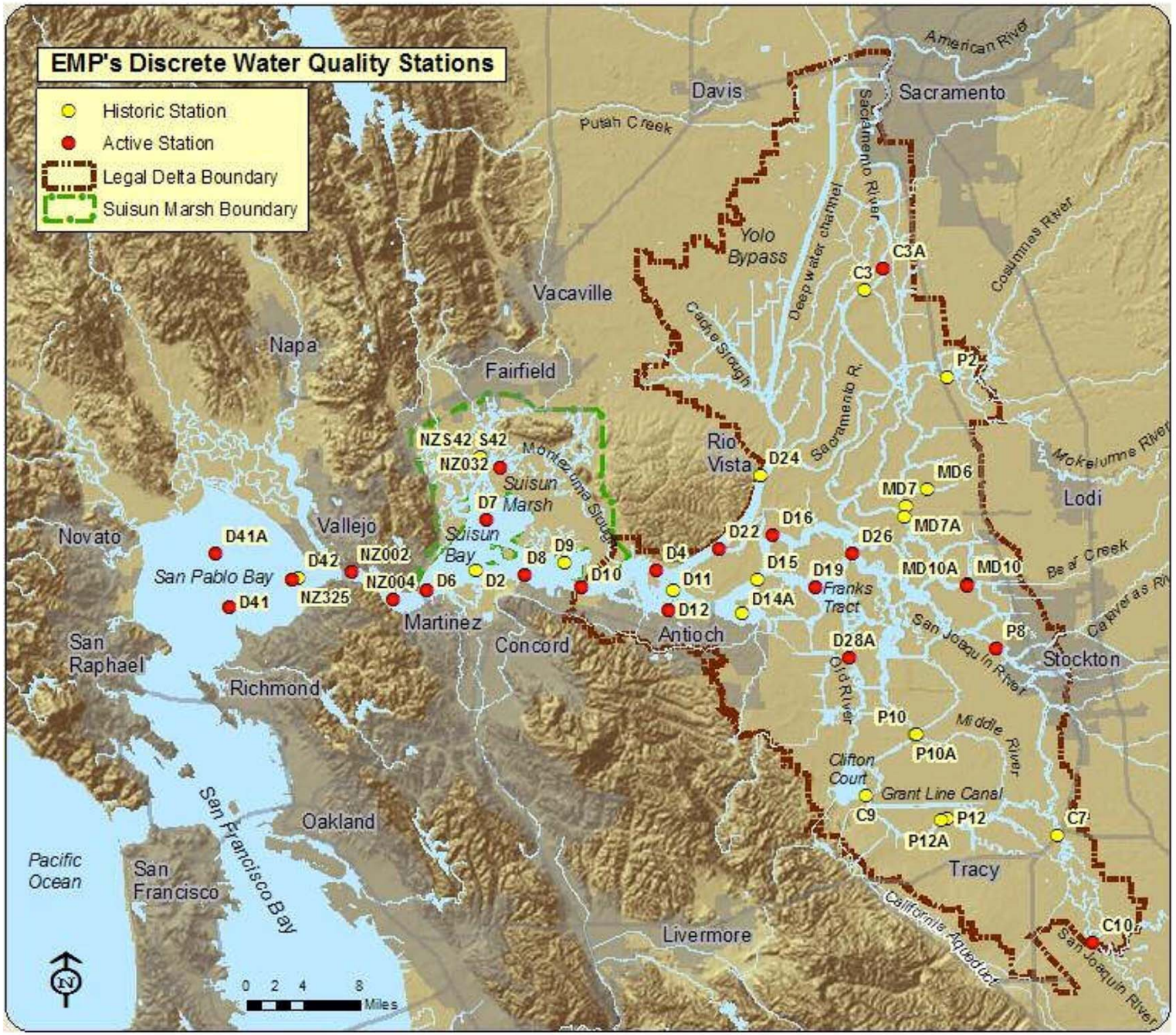
Collaboration: SFEI, RMA, USGS

Approach…

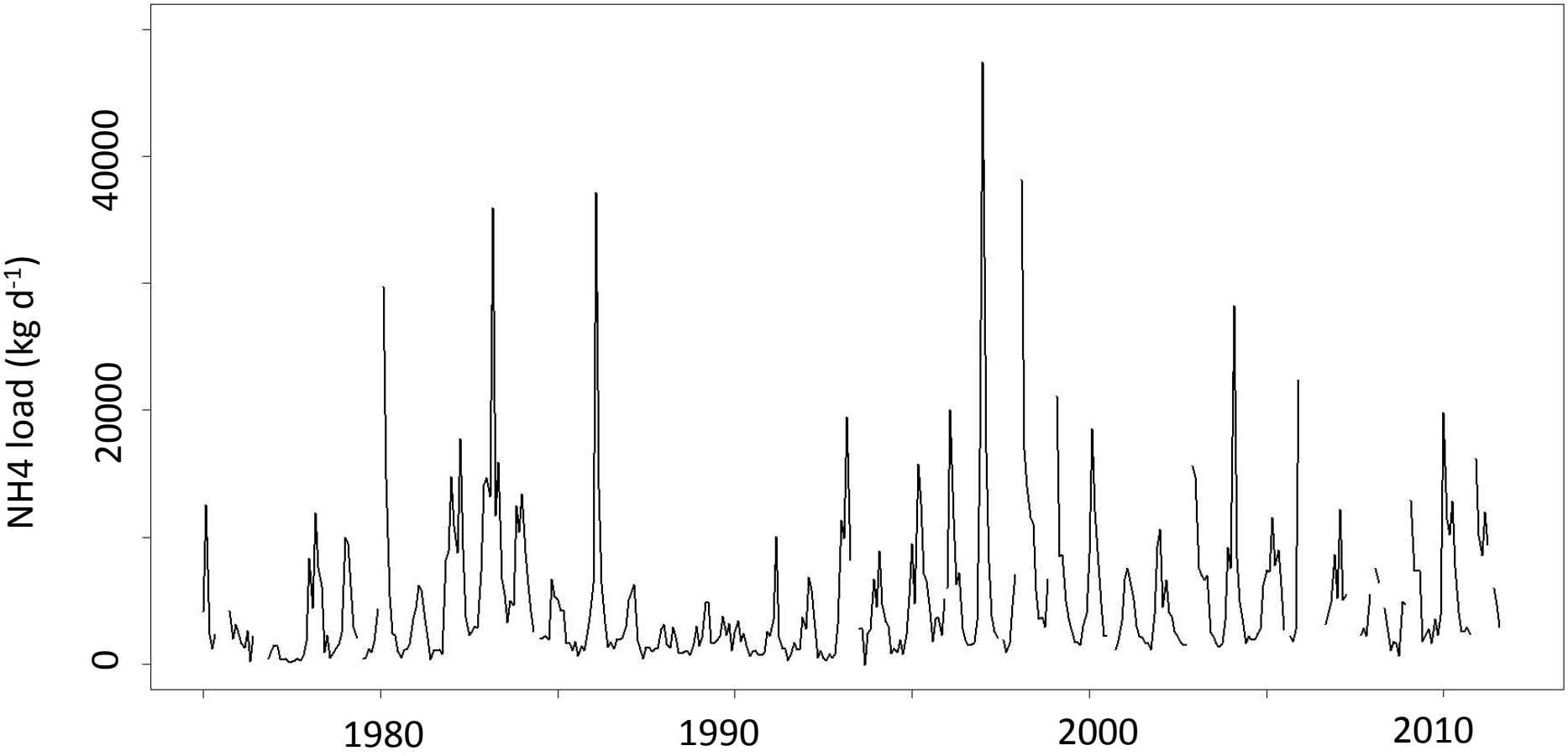
1. Spatial and temporal analysis of DWR/IEP nutrient data
2. Use monitoring data and flow estimates to quantify loads into and out of Delta
3. Calibrate hydrologic/WQ model (DSM2-QUAL)
4. Use simulation modeling to quantify transformation rates under varying conditions

IEP Project: Nutrient loads and transformations in the Delta

David Senn
March 8 2013


EMP's Discrete Water Quality Stations
Historic Station
Active Station
Legal Delta Boundary
Suisun Marsh Boundary
Davis
Sacramento
American River
Putah Creek
Sacramento River
Deep water channel
Yolo Bypass
Vacaville
C3A
C3
Cosumnes River
Napa
Cache Slough
Fairfield
P2
Sacramento R.
NZS42
S42
NZ032
Montezuma Slough
Suisun Marsh
Rio Vista
D24
Mokelumne River
MD6
MD7
Lodi
D7
MD7A
D16
Vallejo
Suisun Bay
D22
D26
Novato
D41A
D42
NZ002
D9
D8
D4
D15
D19
MD10A
MD10
Bear Creek
San Pablo Bay
NZ004
D6
D2
D10
D11
Franks Tract
D41
NZ325
D14A
D12
Martinez
Concord
Antioch
San Joaquin River
P8
Stockton
San Raphael
D28A
Old River
Richmond
P10
Middle River
P10A
Clifton Court
Grant Line Canal
C9
P12
C7
P12A
Oakland
Tracy
Pacific Ocean
San Francisco
San Francisco Bay
California Aqueduct
Livermore
C10
0 2 4 8
Miles
N

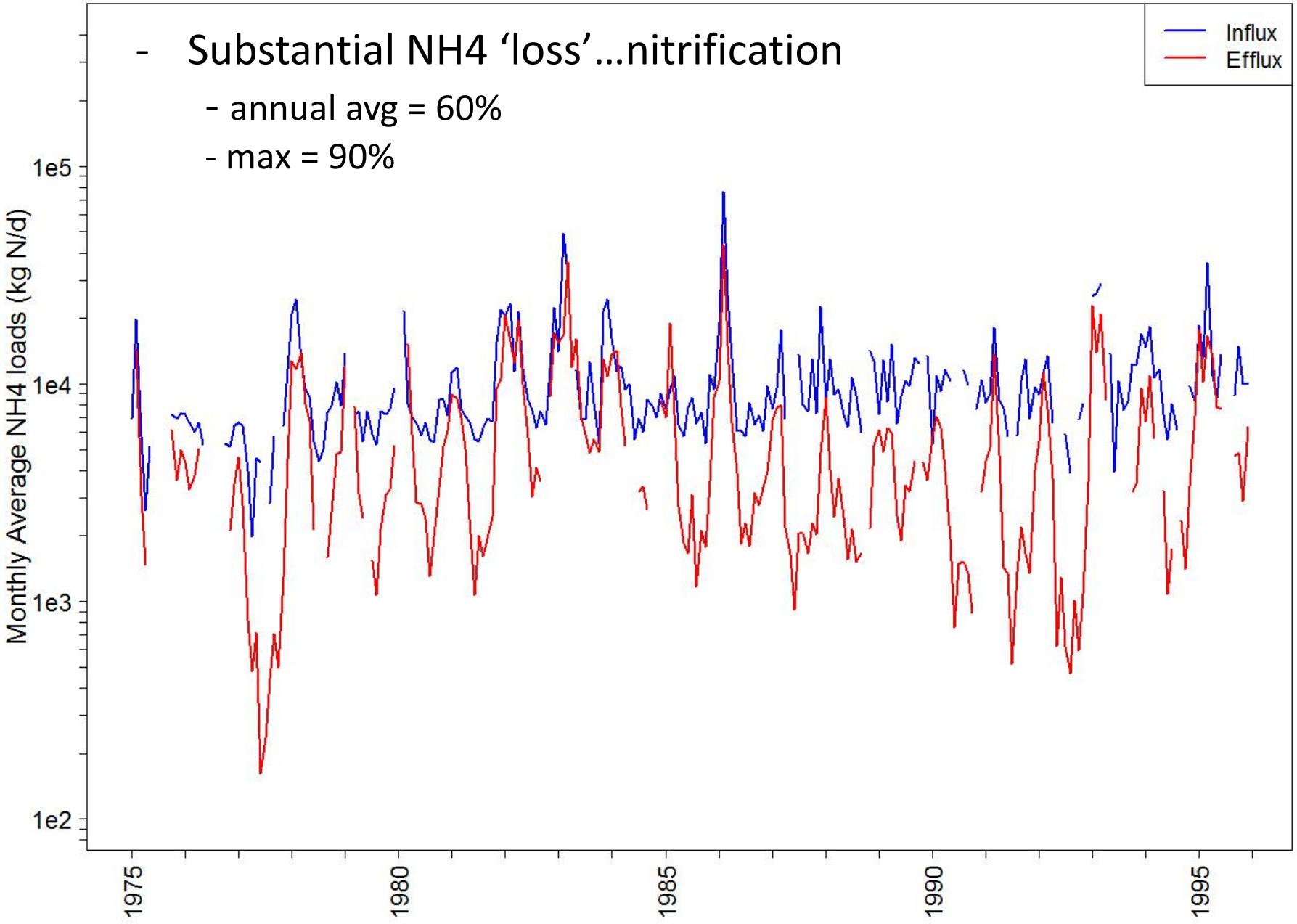
Delta NH4 loads to Suisun Bay (kg d^{-1})



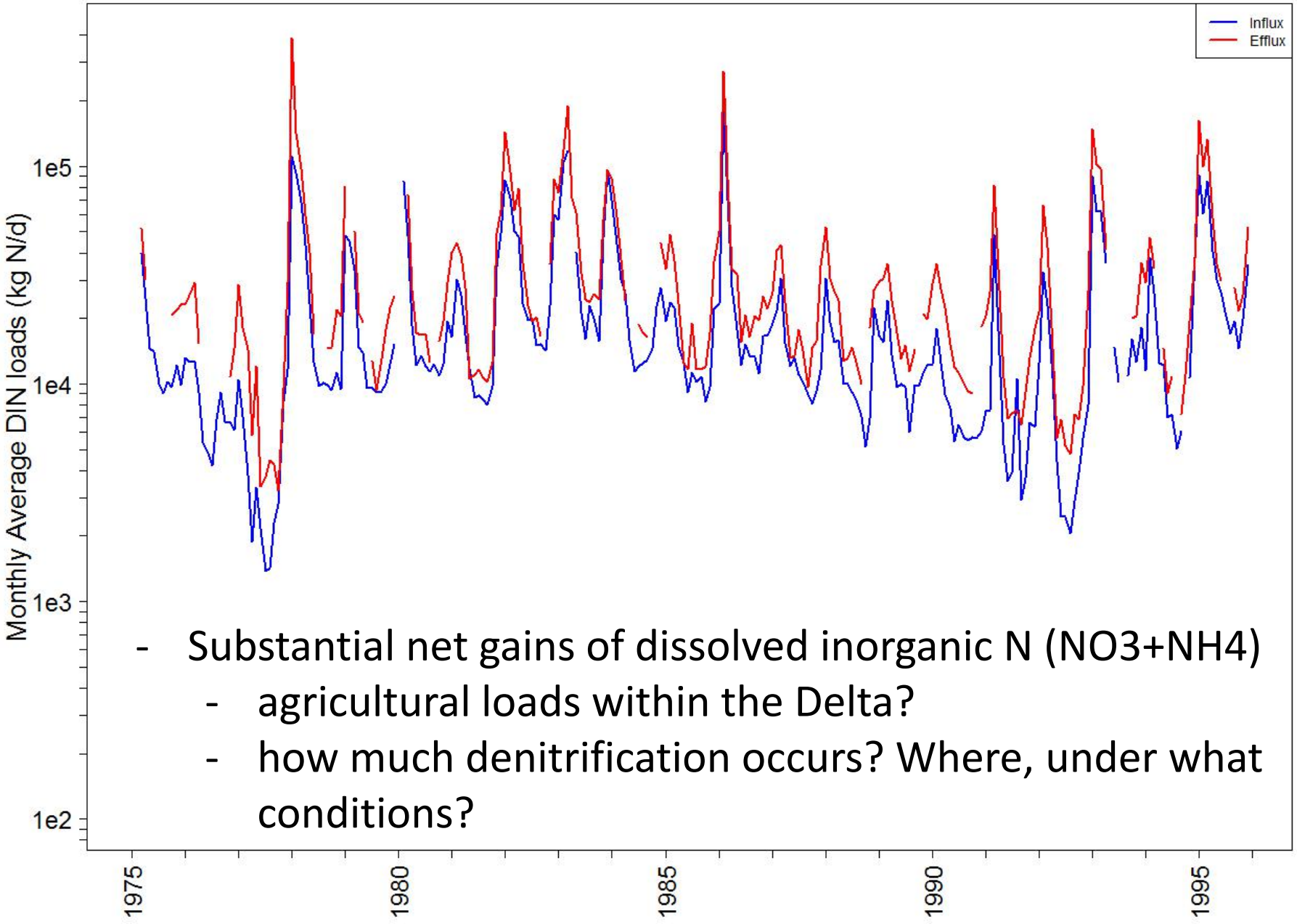
- Strong seasonality and interannual variability
- Increasing baseline

NH4 Budget: Delta

- Substantial NH4 'loss'…nitrification
  - annual avg = 60%
  - max = 90%

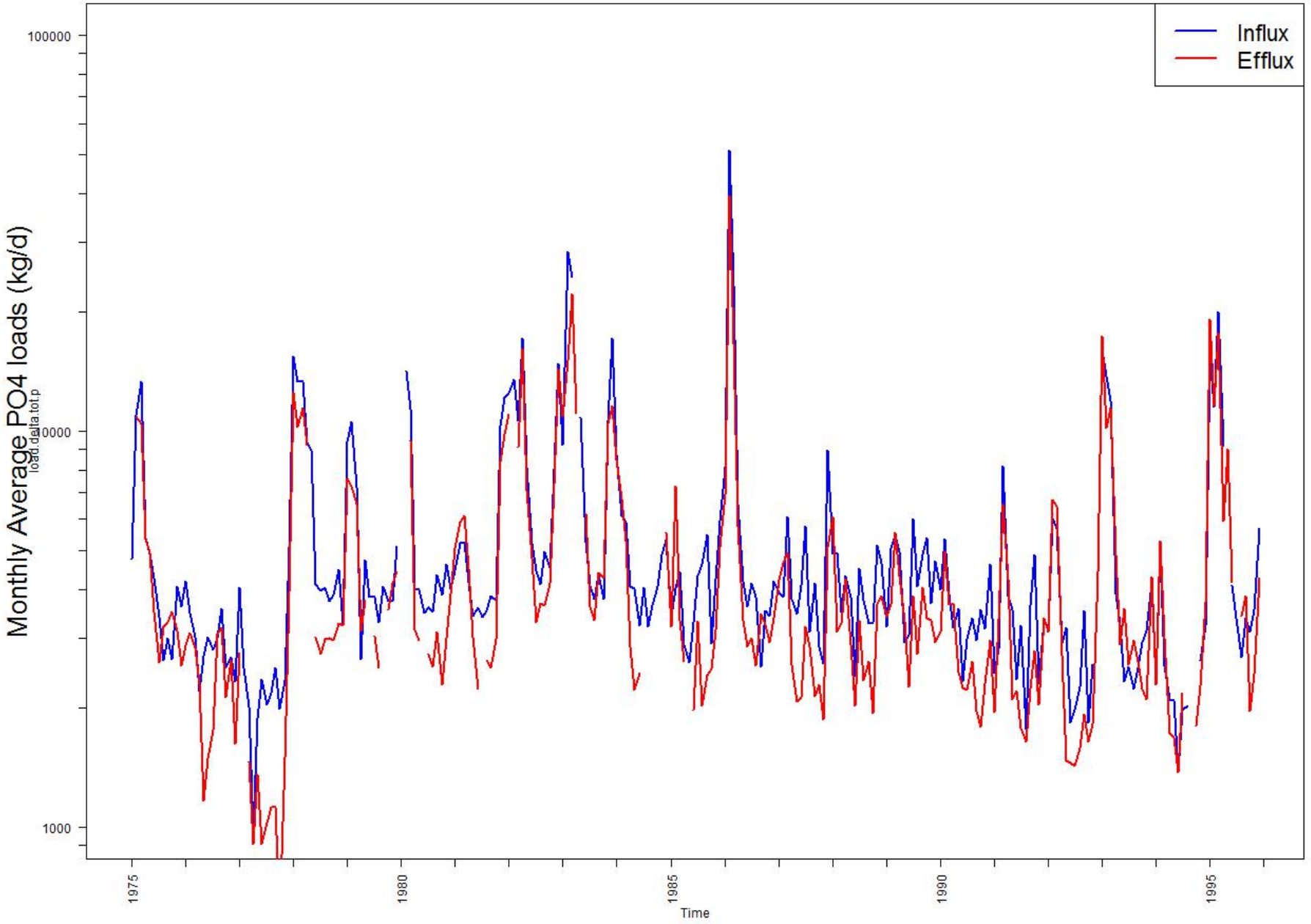


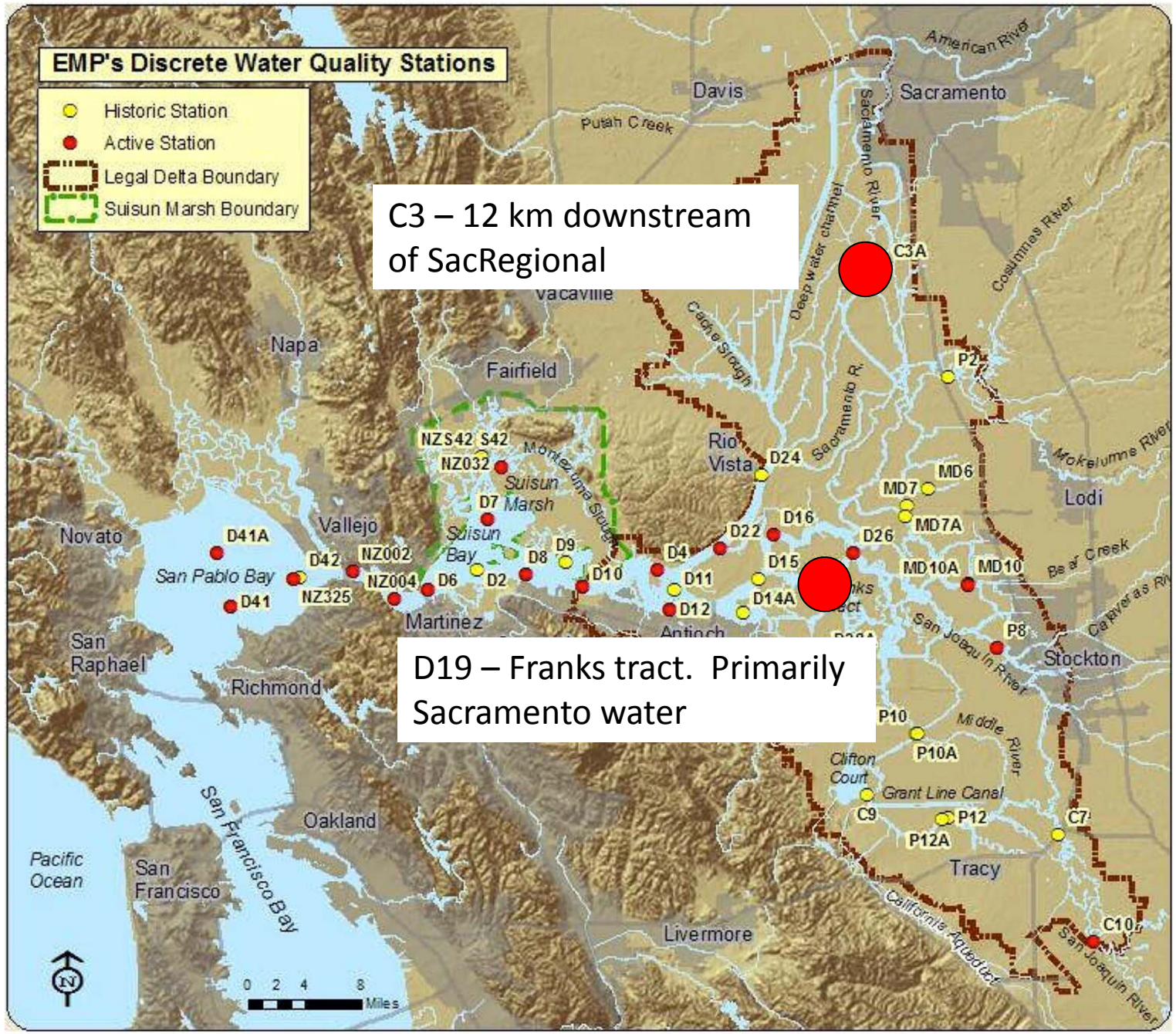
DIN (NO3+NH4) Budget: Delta

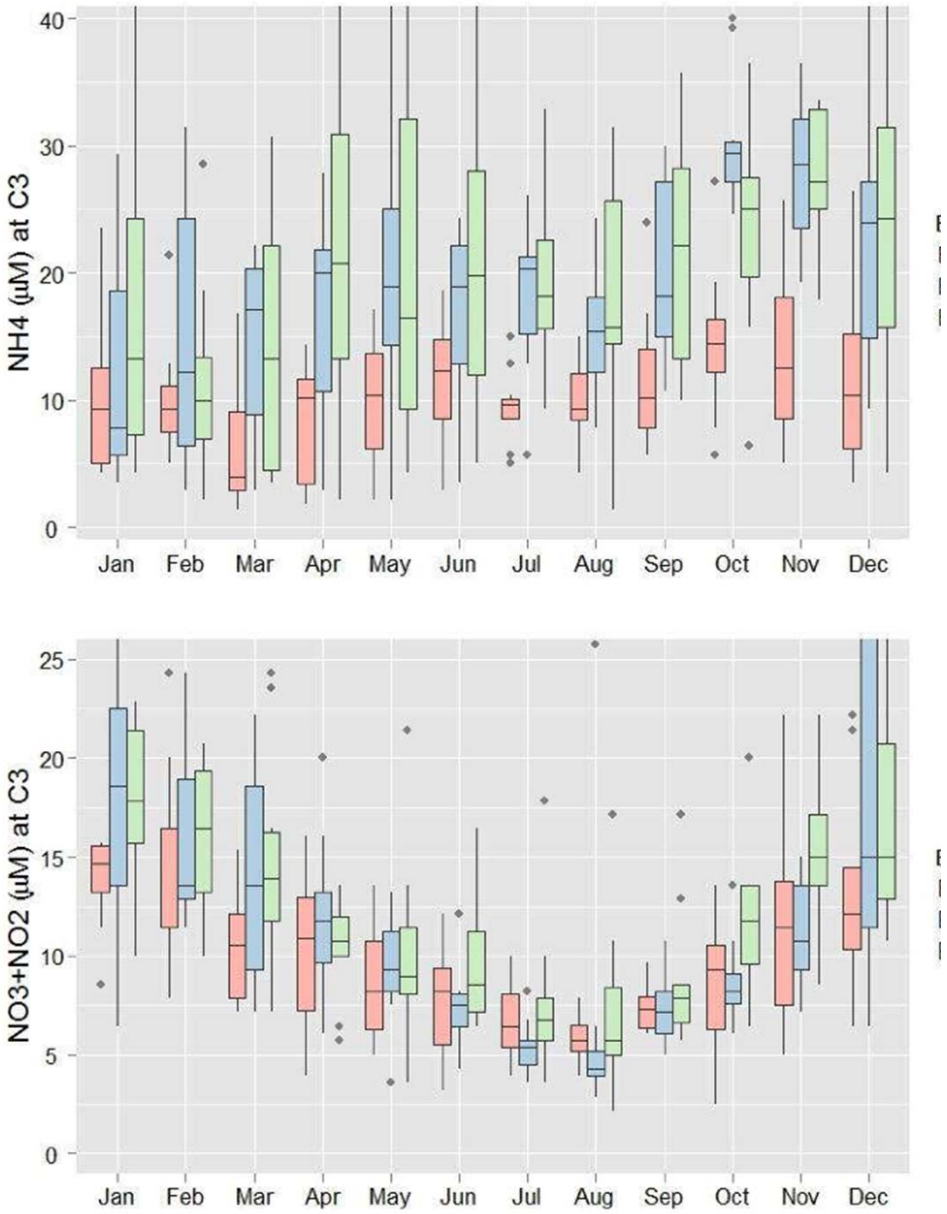


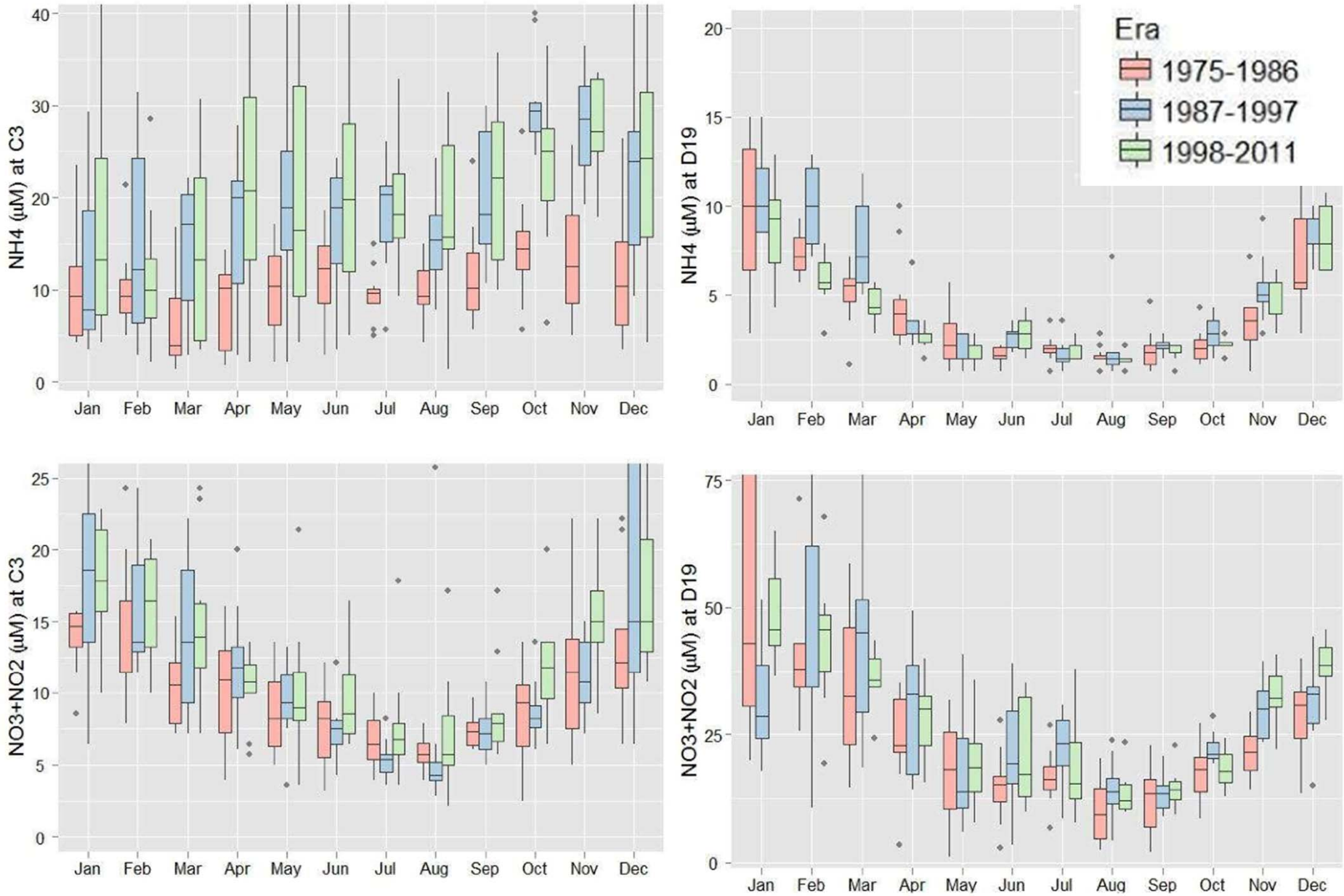
- Substantial net gains of dissolved inorganic N (NO3+NH4)
  - agricultural loads within the Delta?
  - how much denitrification occurs? Where, under what conditions?

PO4 Budget: Delta




EMP's Discrete Water Quality Stations
Historic Station
Active Station
Legal Delta Boundary
Suisun Marsh Boundary
C3 – 12 km downstream of SacRegional
D19 – Franks tract. Primarily Sacramento water
American River
Davis
Sacramento
Putah Creek
Sacramento River
Deep water channel
Cosumnes River
C3A
Vacaville
Napa
Fairfield
Cache Slough
Sacramento R.
P2
NZS42
S42
NZ032
Suisun Marsh
Montezuma Slough
Rio Vista
D24
Mokelumne River
MD6
MD7
Lodi
D7
D16
MD7A
Vallejo
Suisun Bay
D22
D26
Novato
D41A
D42
NZ002
D9
D4
D15
MD10A
MD10
Bear Creek
San Pablo Bay
NZ004
D6
D8
D2
D10
D11
D14A
D41
NZ325
D12
Martinez
Antioch
San Joaquin River
P8
Stockton
San Raphael
Richmond
P10
Middle River
P10A
Clifton Court
Grant Line Canal
C9
P12
P12A
C7
Tracy
Oakland
San Francisco Bay
Pacific Ocean
San Francisco
California Aqueduct
Livermore
C10
0 2 4 8
Miles
N


NH4 (µM) at C3
0
10
20
30
40
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
NO3+NO2 (µM) at C3
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Era
1975-1986
1987-1997
1998-2011


NH4 (µM) at C3
NH4 (µM) at D19
NO3+NO2 (µM) at C3
NO3+NO2 (µM) at D19
Era
1975-1986
1987-1997
1998-2011
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec