
Source: C. Benton

# Nutrients Science Program Update

1. Background

2. Nutrient Science Program: updates and upcoming work

3. Summary

David Senn, Emily Novick, Anthony Malkassian, Jing Wu, and Collaborators

January 15 2014


Source: C. Benton

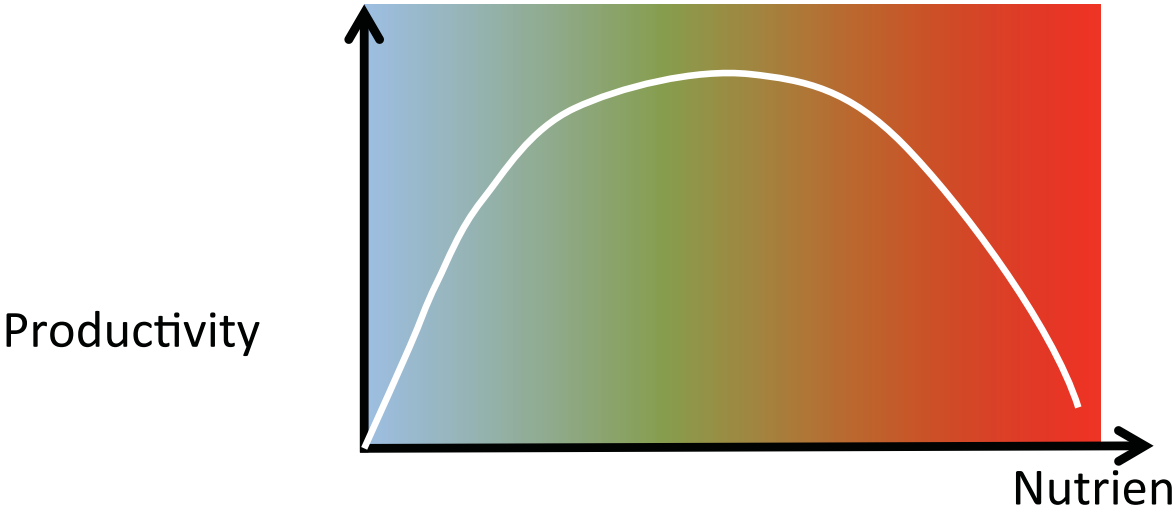
# Key Points

- Several priority issues identified and studies underway
  - Increasing phytoplankton abundance…Cause? Trajectory?
  - Dissolved oxygen in margin habitats (sloughs, creeks, wetlands)
  - Effects of nutrients on types of phytoplankton (HABs, food quality)
- For some issues, excellent data to begin cause/effect analysis
  - Phytoplankton abundance and composition
  - Nutrient loads, ambient concentrations
- More monitoring and process studies needed…
  - margin-habitat DO
  - phytoplankton composition and HABs/toxins
  - moored sensors and field investigations
- Modeling near-term next step to rigorously analyze/forecast

# How much is too much?

- N and P are essential nutrients…
  - *phytoplankton, benthic algae, aquatic plants*

- Excessive loads → ecosystem degradation
  - *'sensitivity' varies among estuaries*




Excessive algal blooms

Low DO

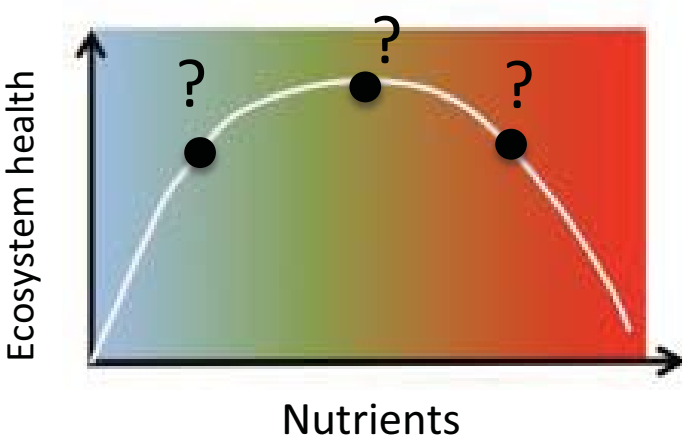
Harmful algal blooms (HABs) and toxins

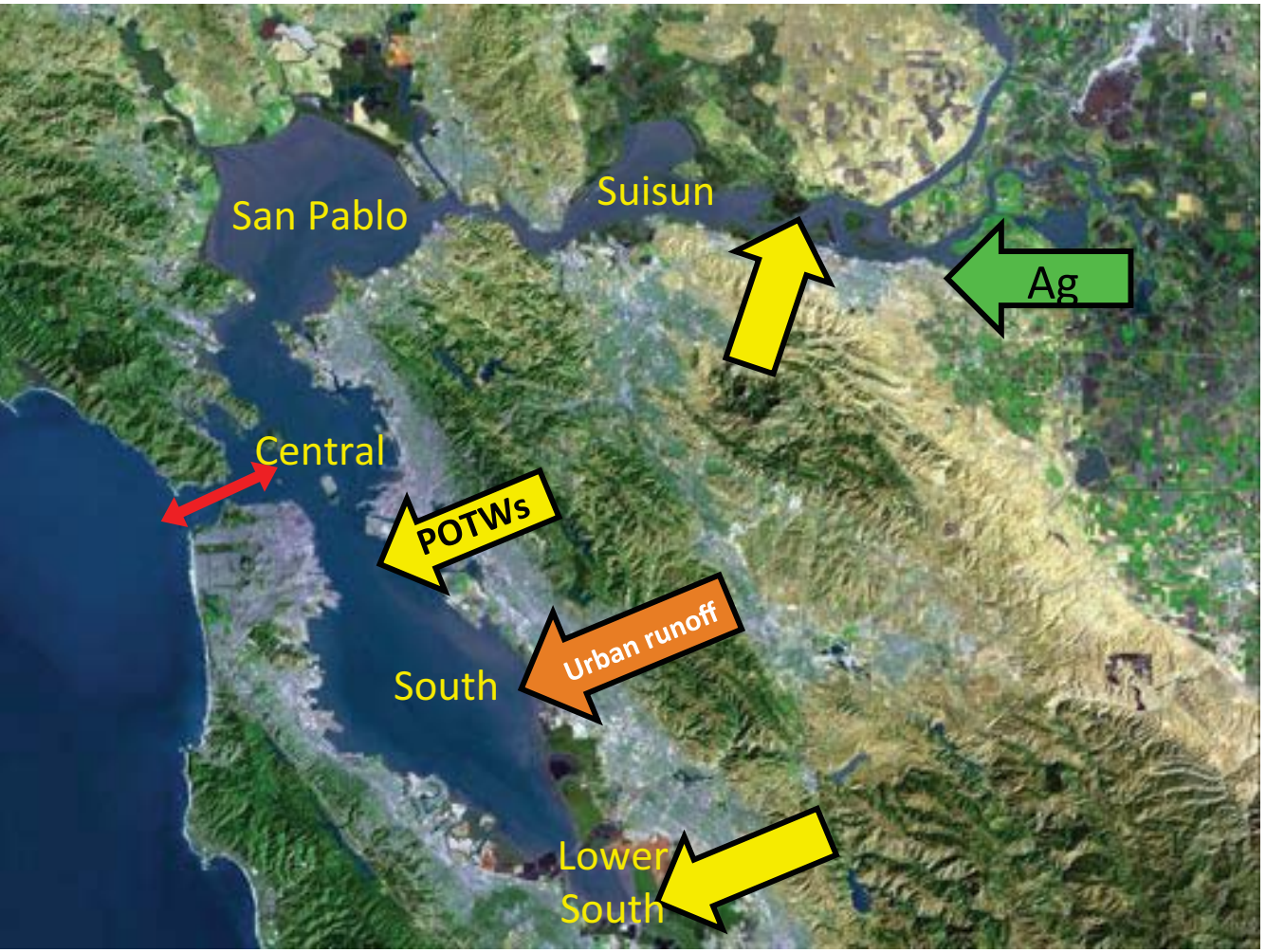
Altered species composition = bad food

# Does SFB have nutrient problems?

## How can impairment best be mitigated or prevented?

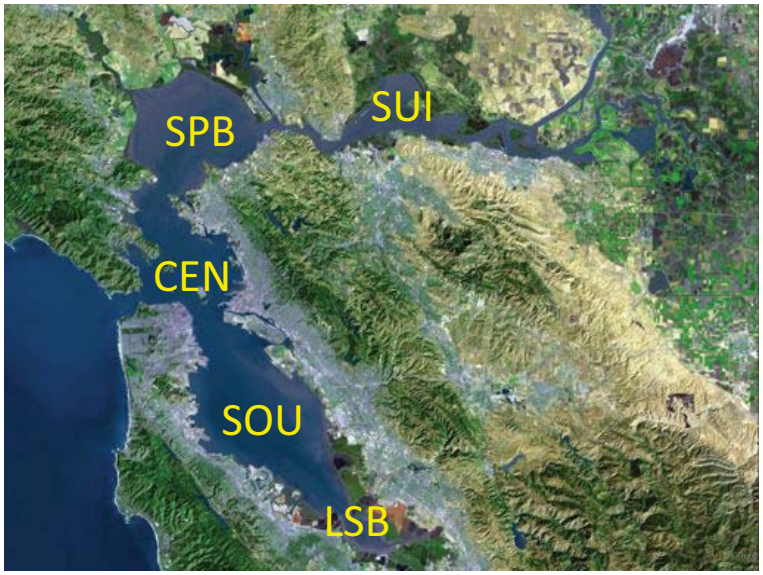
- Options differ by $billions

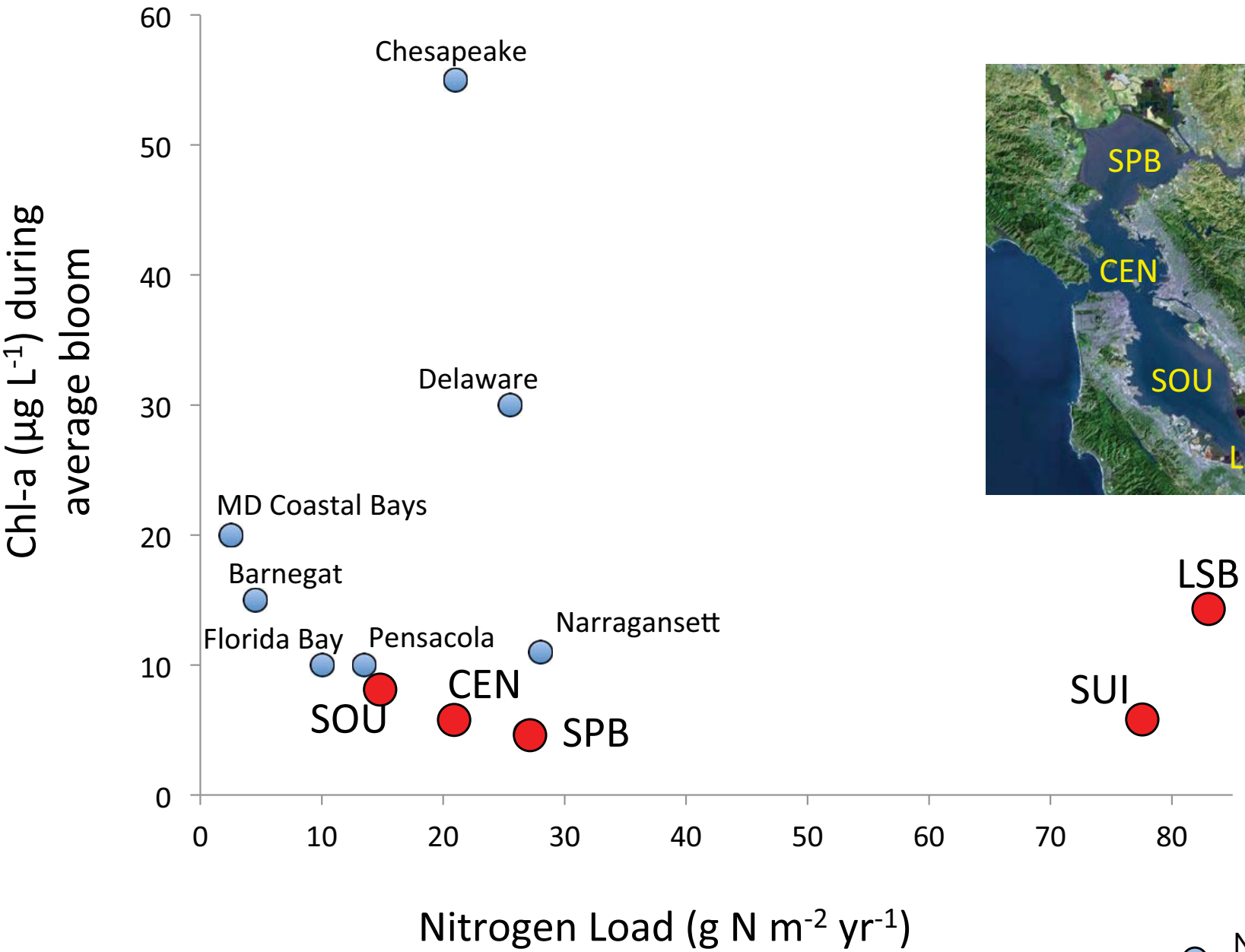


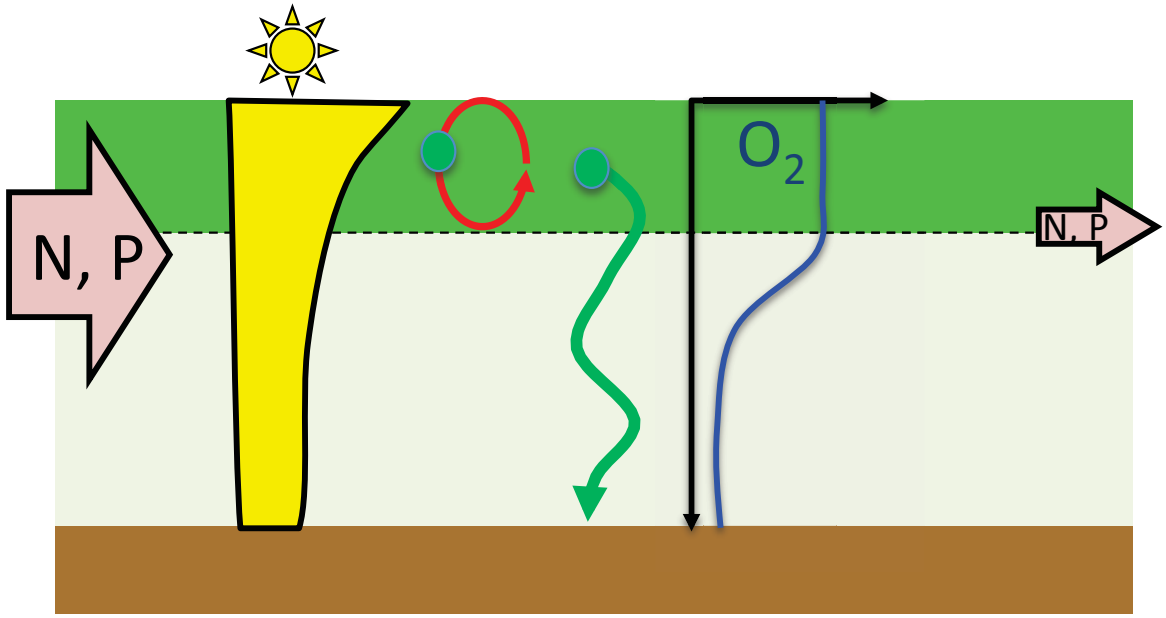

- Largest CA estuary
- Population = 7.6 mill
- 42 POTWs
- Drains 40% of CA

# High Direct N Loads to SFB Subembayments



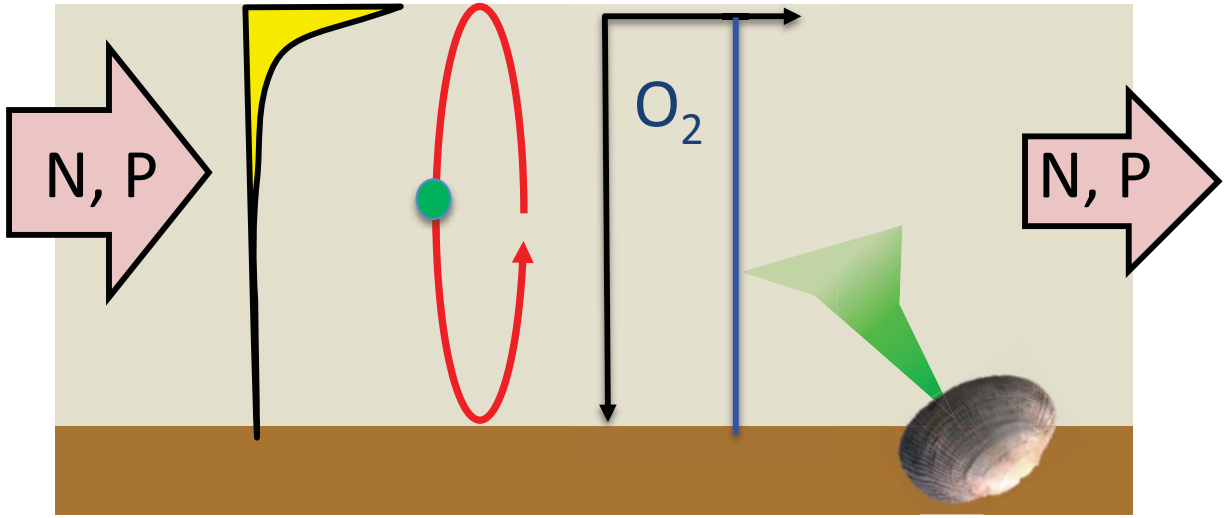



Chesapeake and many other estuaries

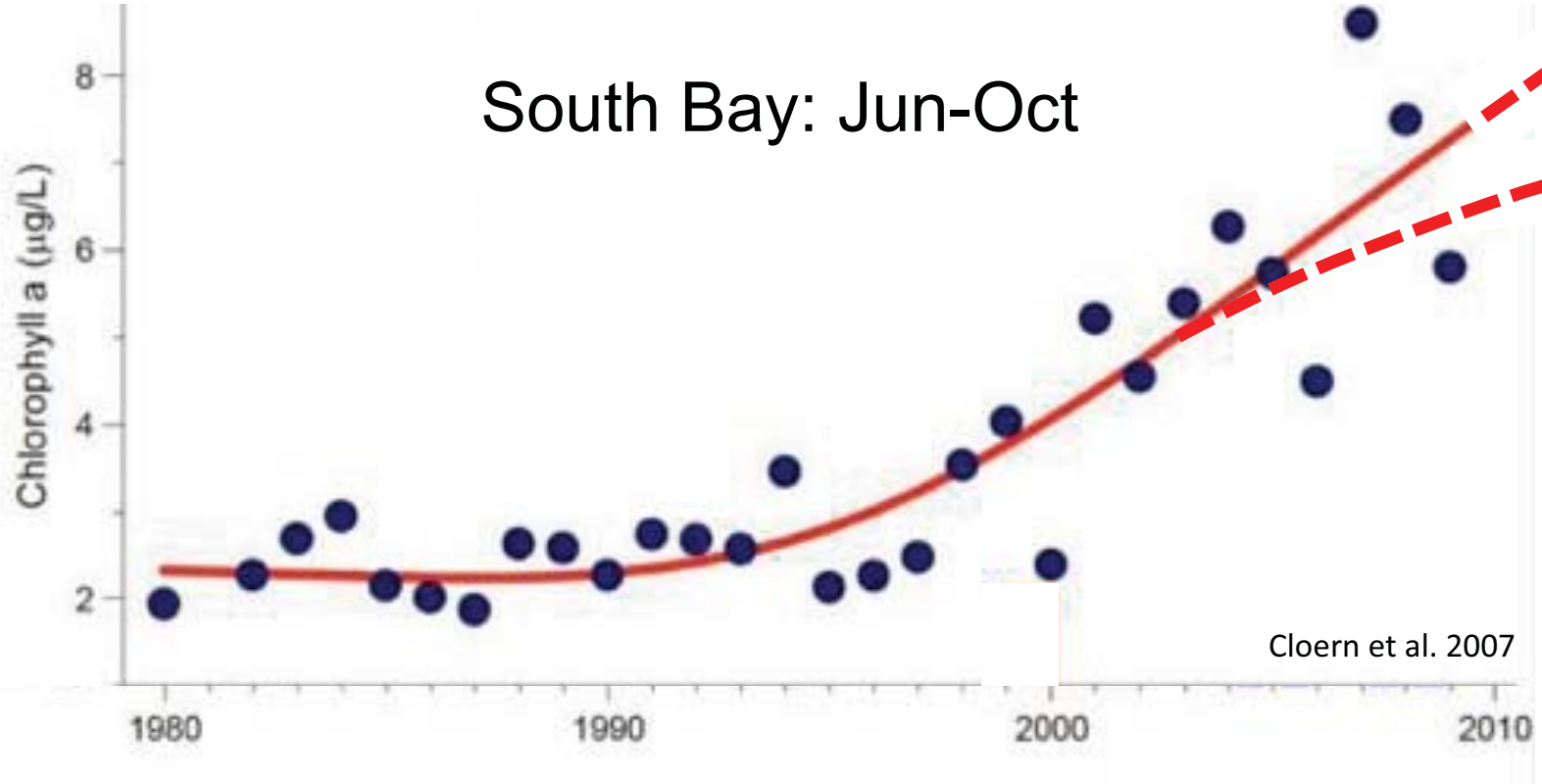



## San Francisco Bay

1. High turbidity
2. Strong tidal mixing
3. Filter-feeding clams



# Ecosystem response is changing in San Francisco Bay

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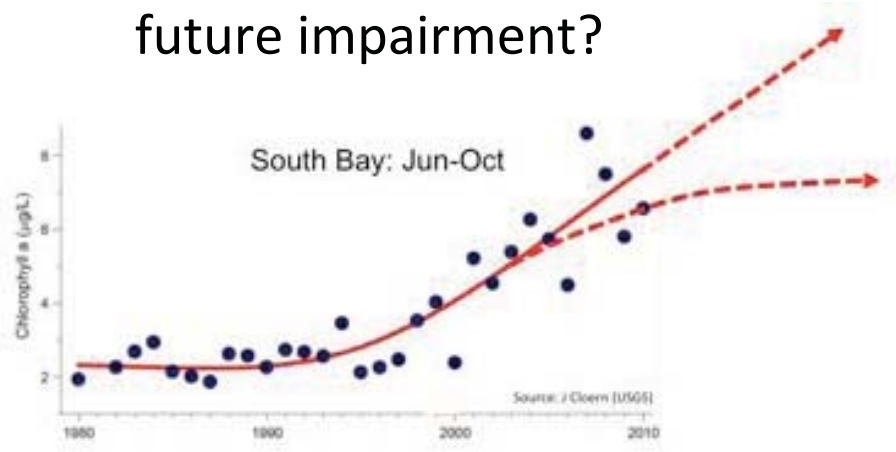
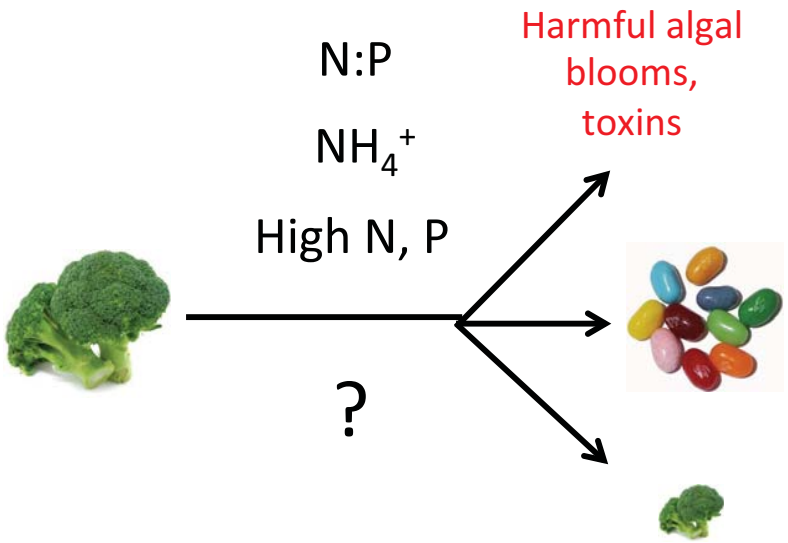
# High Priority Nutrient Issues

## Does increasing biomass signal future impairment?

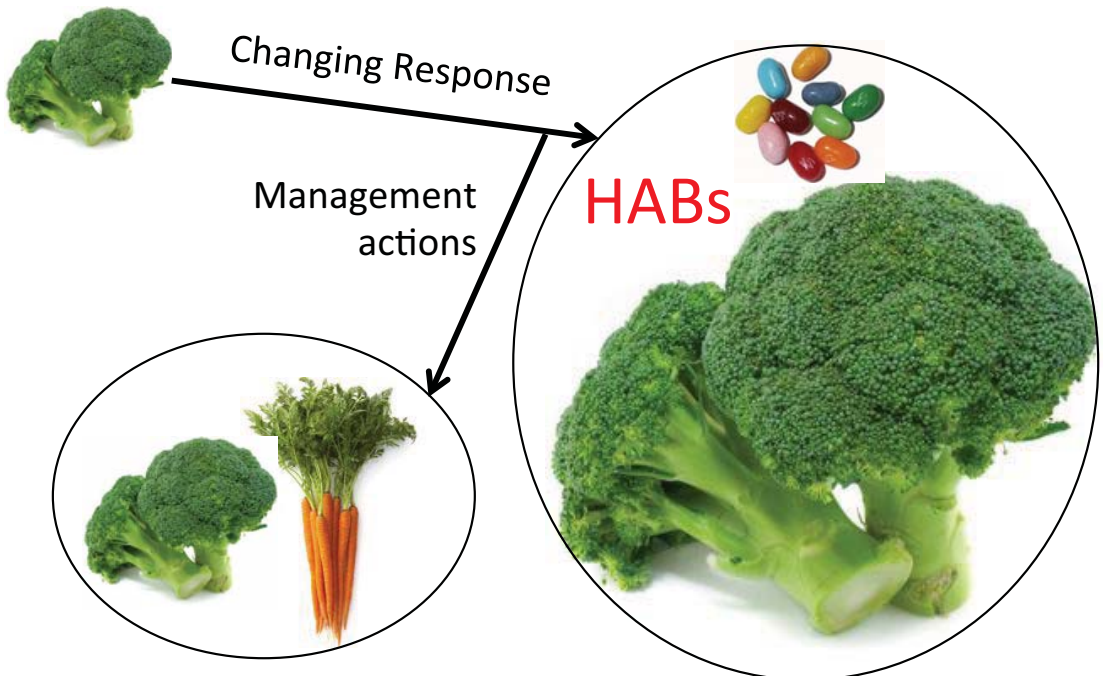



## Low DO in margin habitats?

## Food web impacts: phytoplankton composition and growth



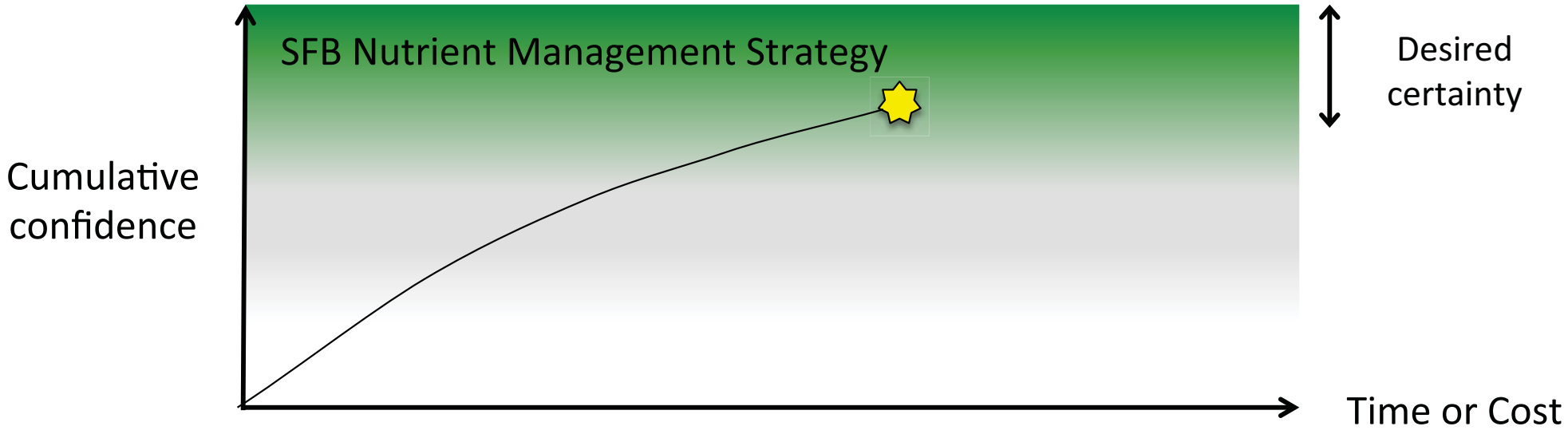

## Future scenarios: impairment and mitigation



# Major Decisions

*Large Uncertainties*

1. What constitutes impairment? Which areas are impaired?
2. Does SFB's trajectory signal future impairment?
3. What nutrient load reductions are needed? Where, how much?
4. How much time for science, planning, and implementation?

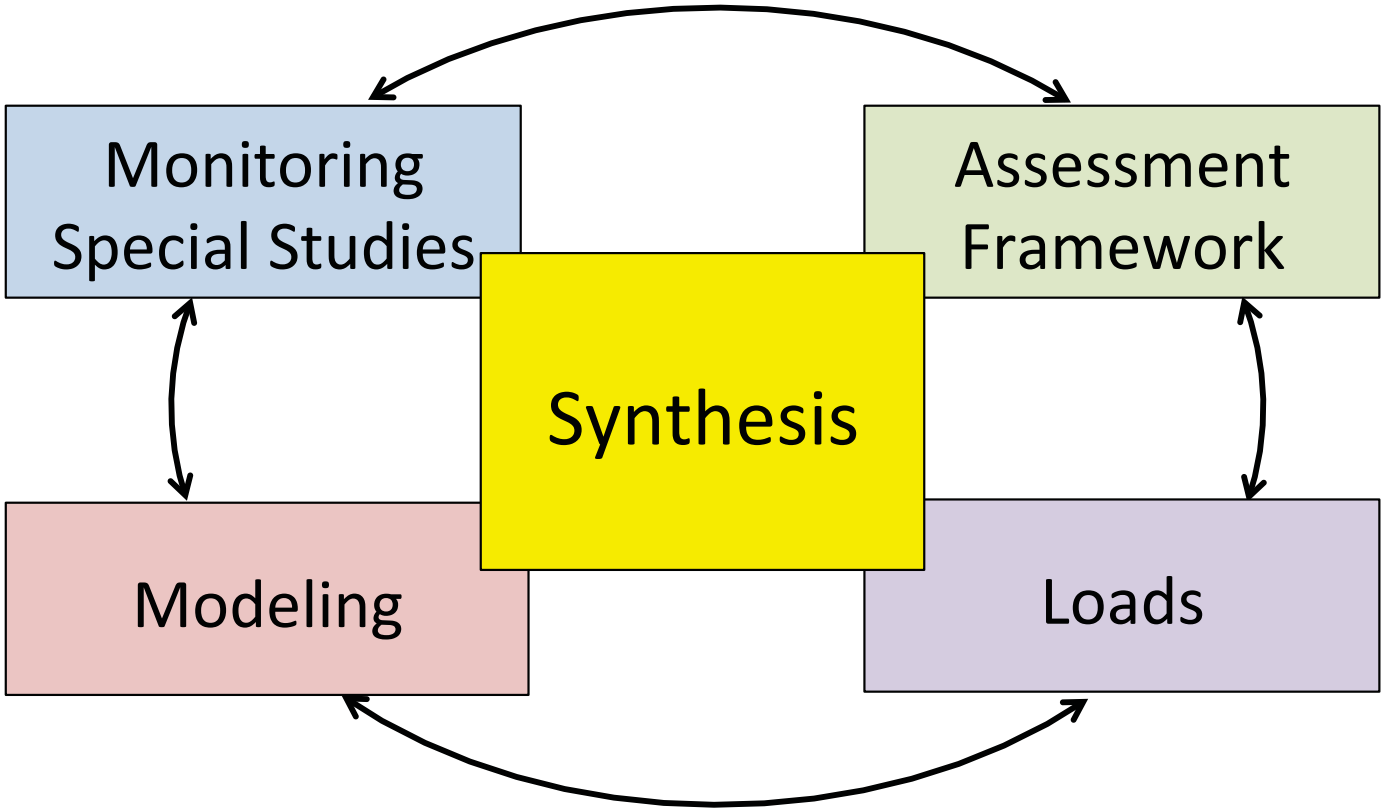


November 2012

San Francisco Bay Nutrient Management Strategy

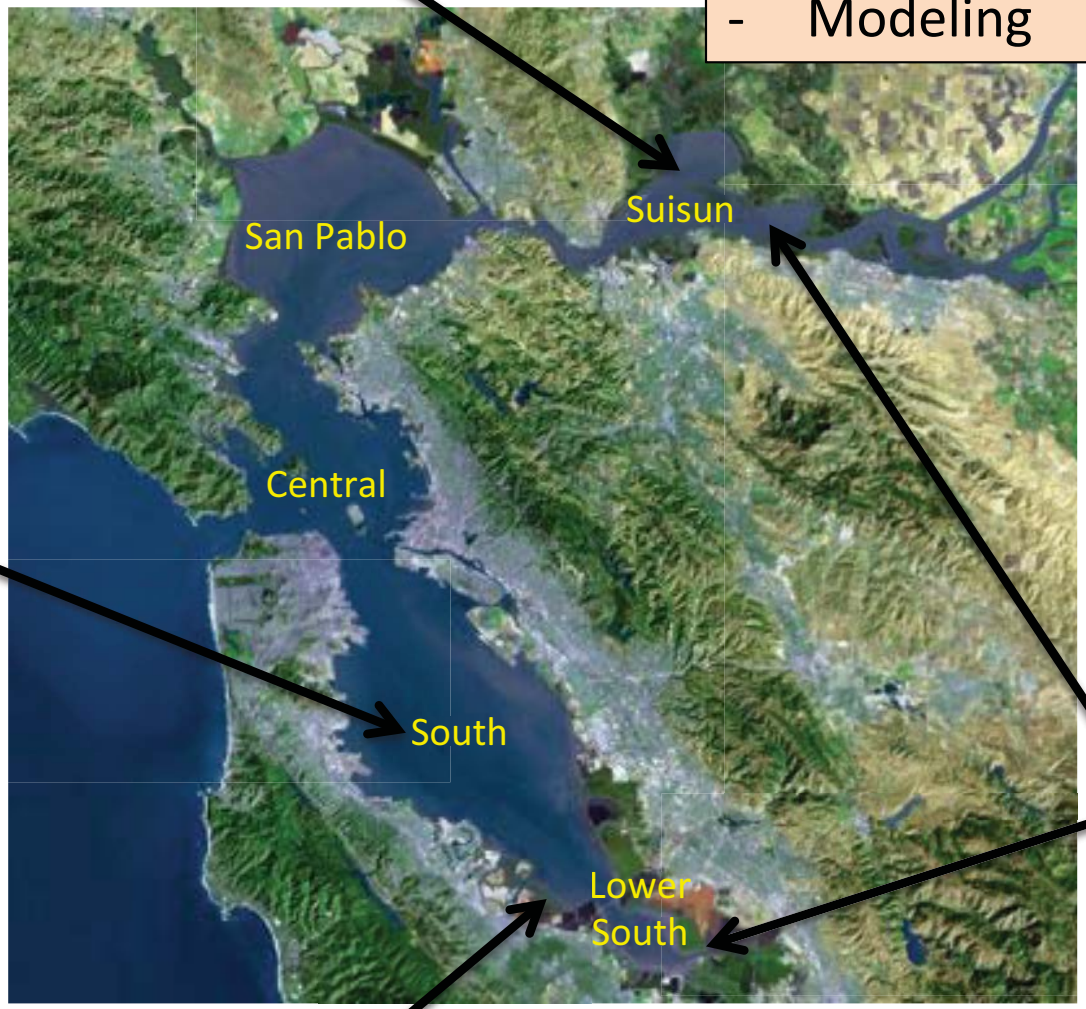
*San Francisco Bay Regional Water Quality Control Board*

# Nutrient Science Program



5. On-going work
- Monitoring program development
  - Phyto composition, HABS, Moored sensors
- Modeling

4. Causes of changing phytoplankton species




2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in SB and LSB

5. On-going work
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  - Phyto composition, HABS, Moored sensors
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4. Changing phytoplankton species


2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in LSB

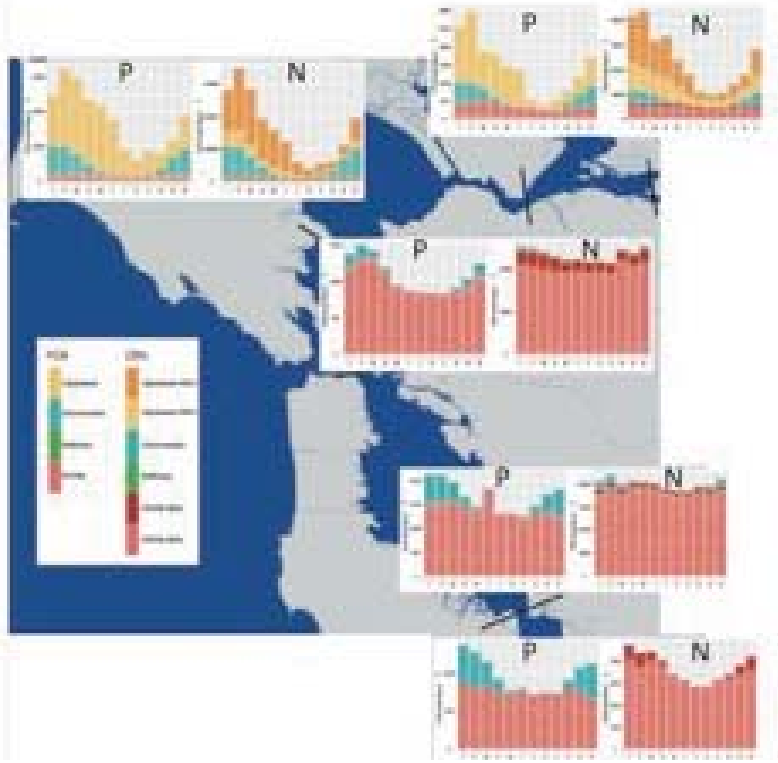
# Quantify N and P Loads

Bay-wide:

- 65% POTWs
- 20% Delta
- 15% stormwater

Spatial variability in dominant sources

- Southern: POTWs
- Northern: Delta + POTWs

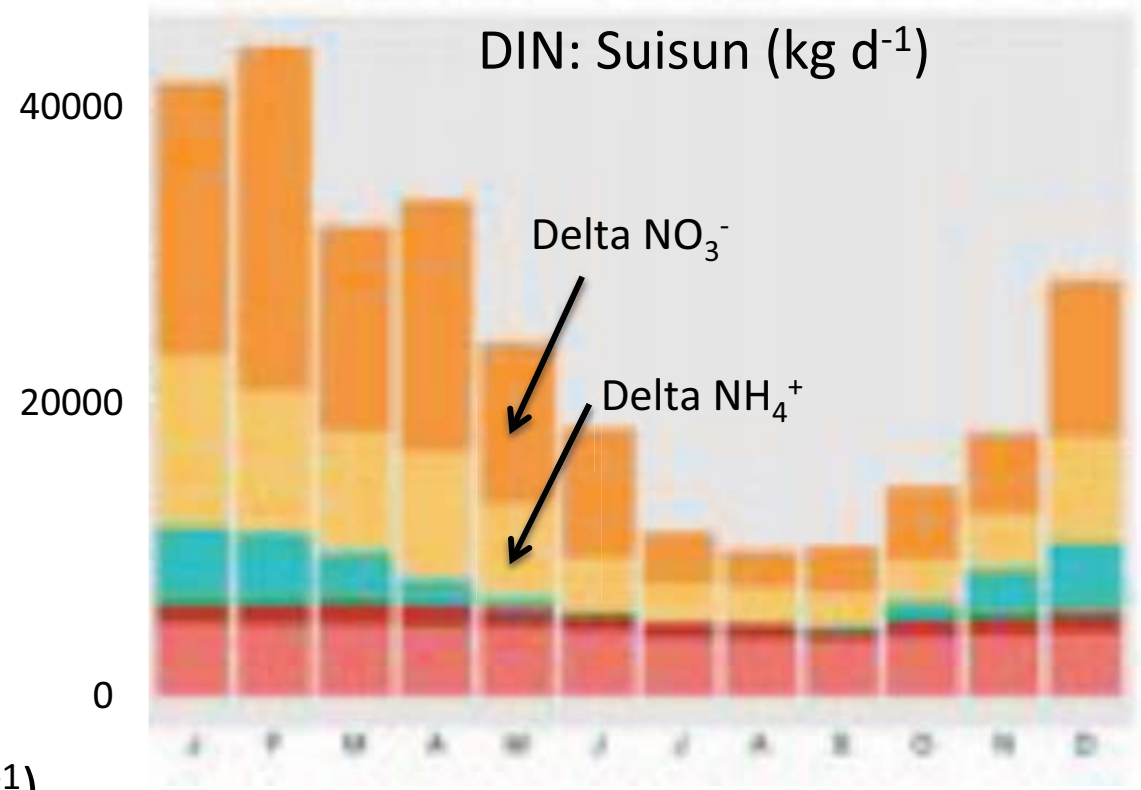


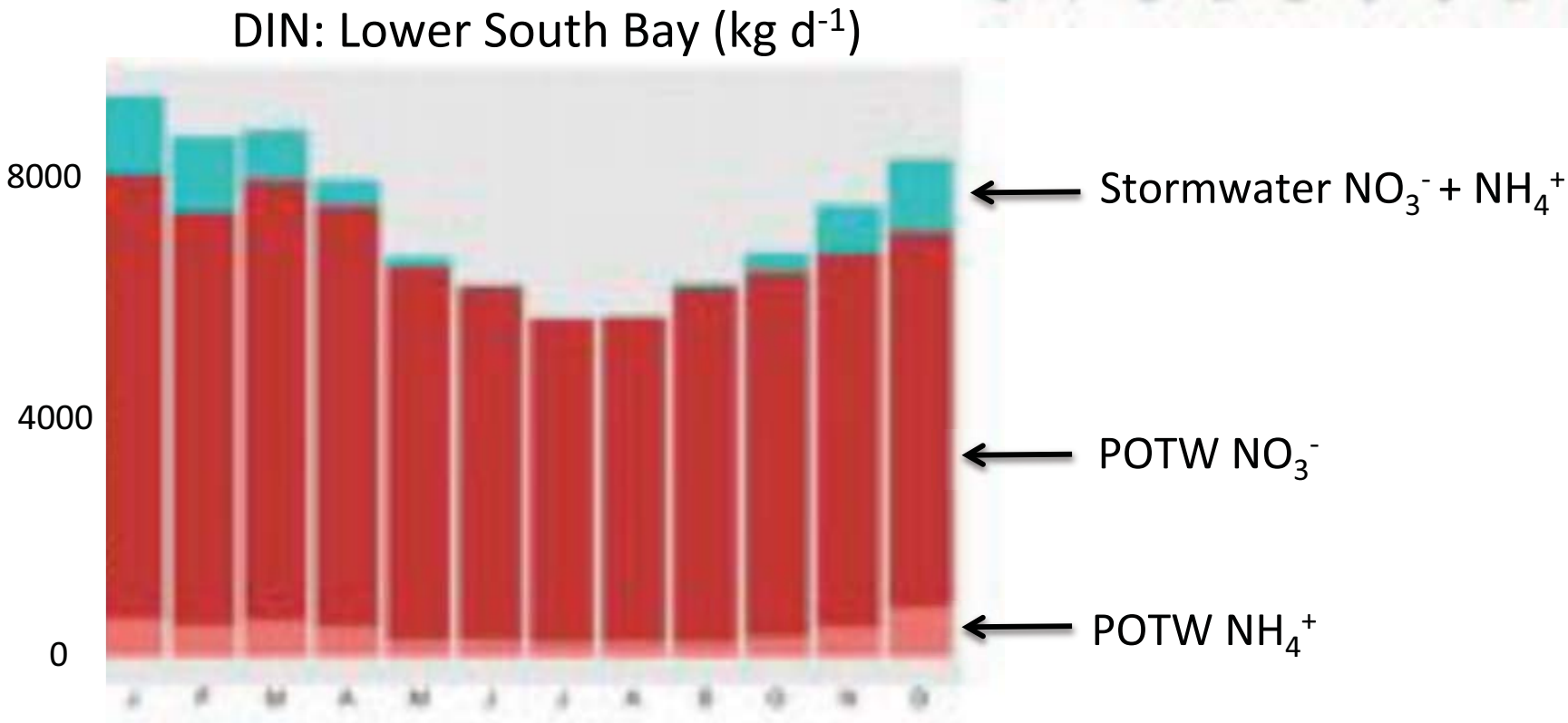

Novick and Senn (2013)

# Sources of Nitrogen

DIN = nitrate + ammonium

Source and seasonality vary by subembayment



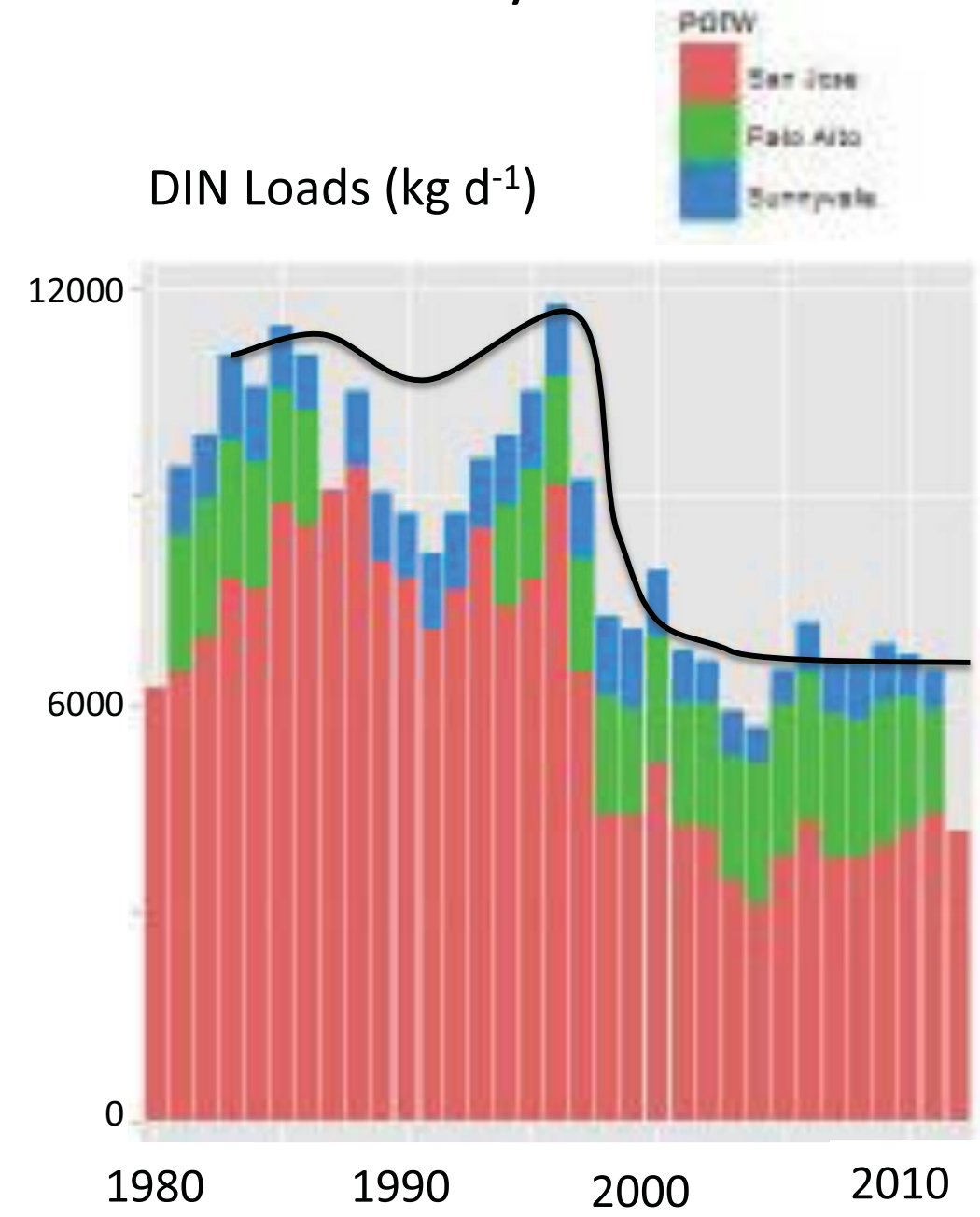

Novick and Senn 2013

# Changes in Loads and Ambient Concentrations over time

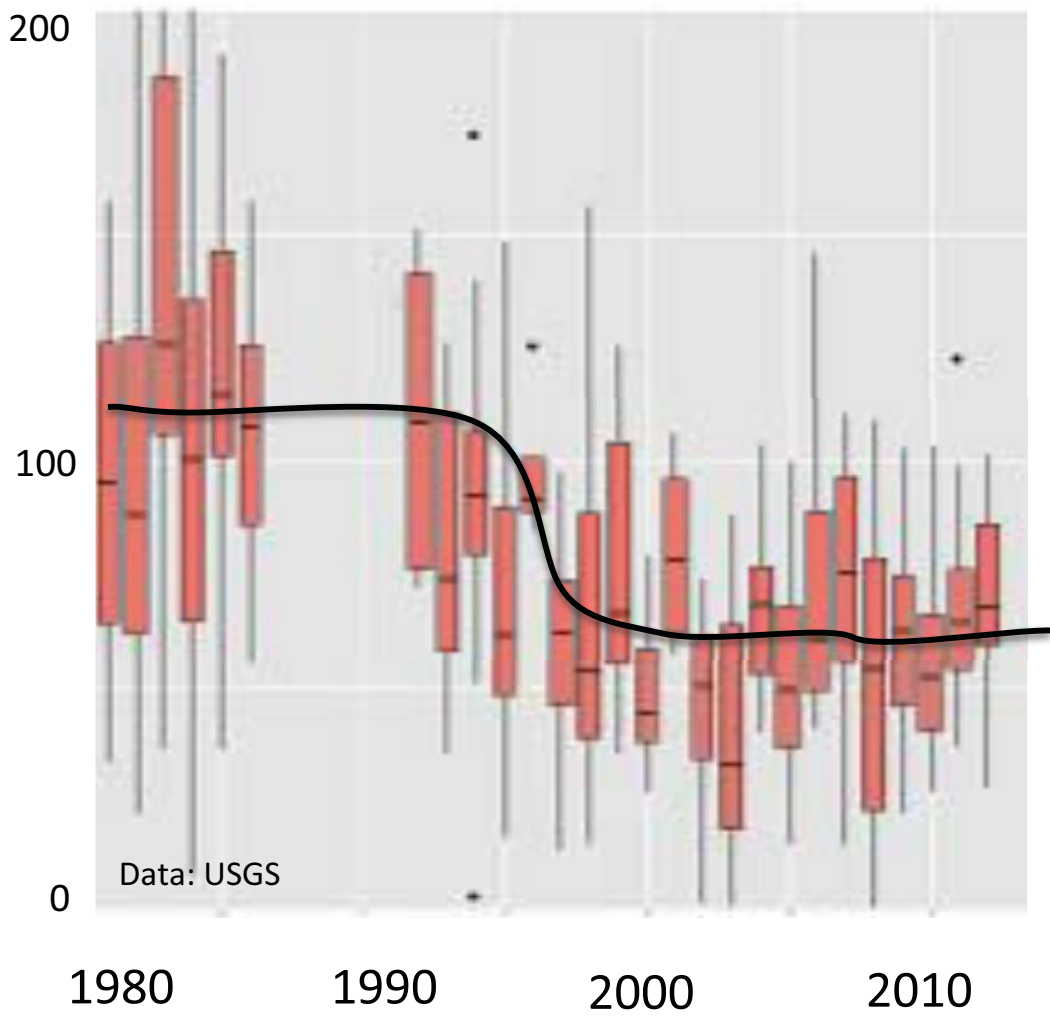
## Lower South Bay

SFEI (2014)

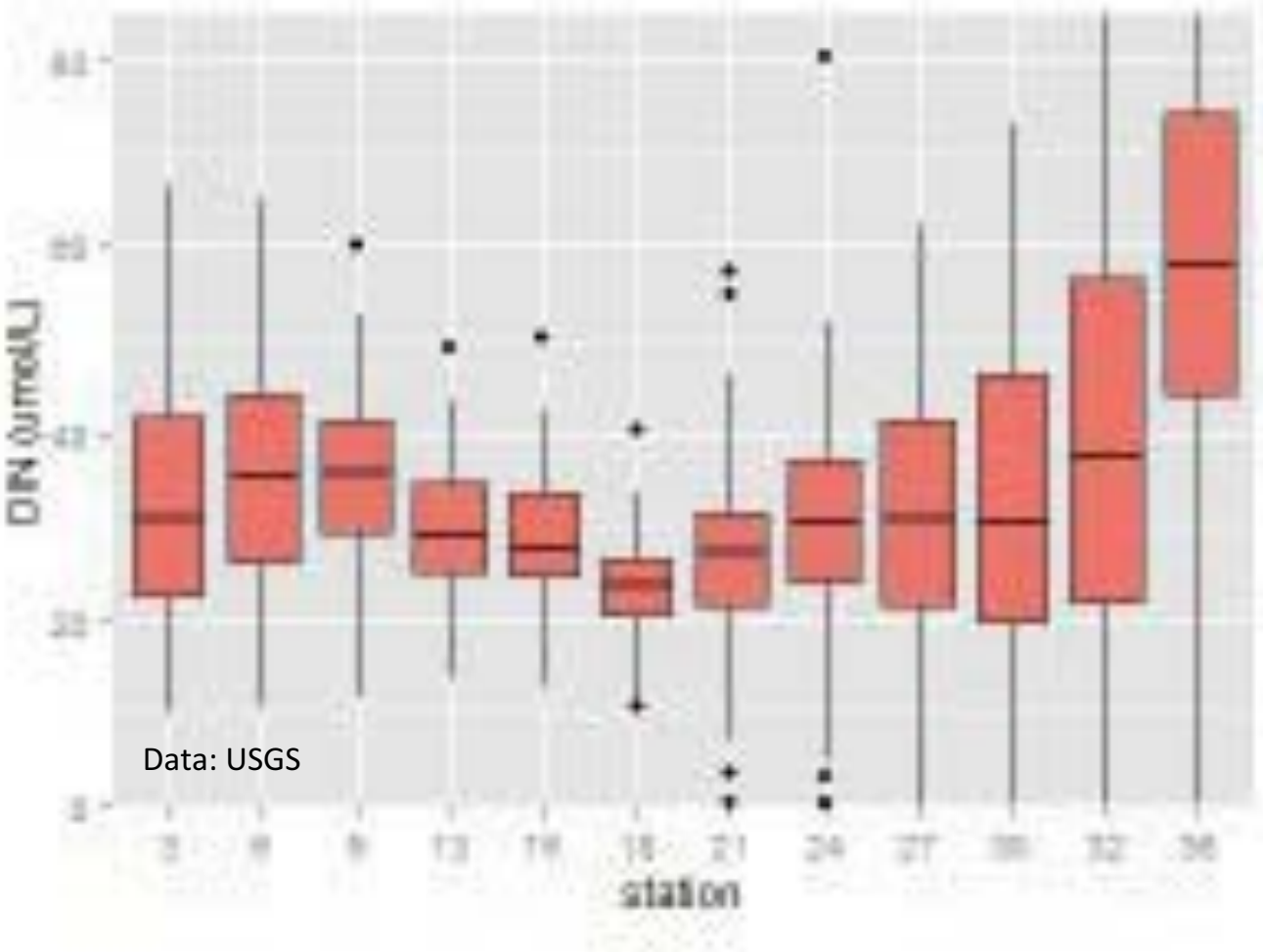
DIN Loads (kg $d^{-1}$)




DIN ambient concentration (µmol $L^{-1}$)



# Bay-wide DIN (µmol $L^{-1}$): 2005-2012

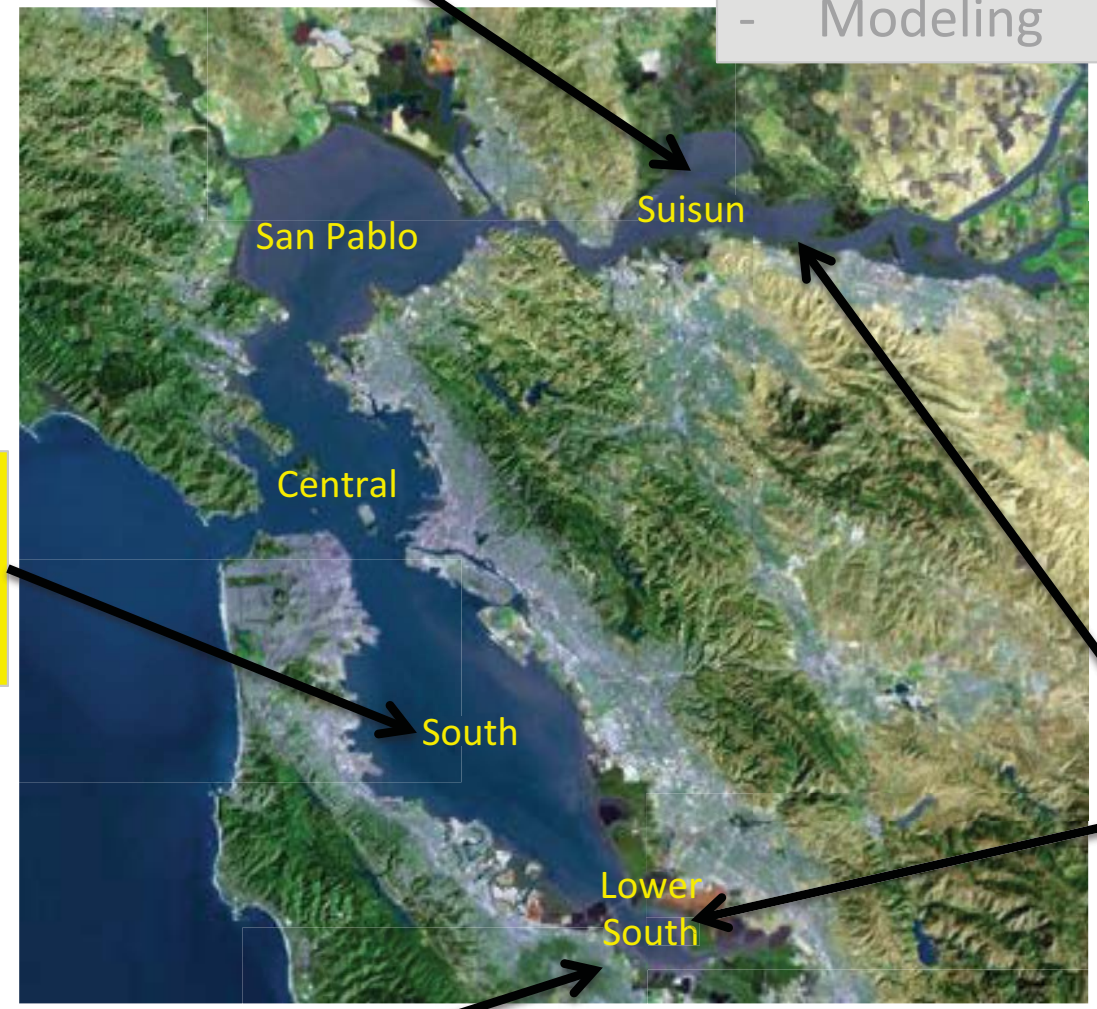




Suisun Bay | San Pablo Bay | Central Bay | South Bay | Lower South Bay

SFEI (2014)

5. On-going work
- Moored sensors
- Monitoring program development
- Phytoplankton detection
- Modeling

4. Changing phytoplankton species



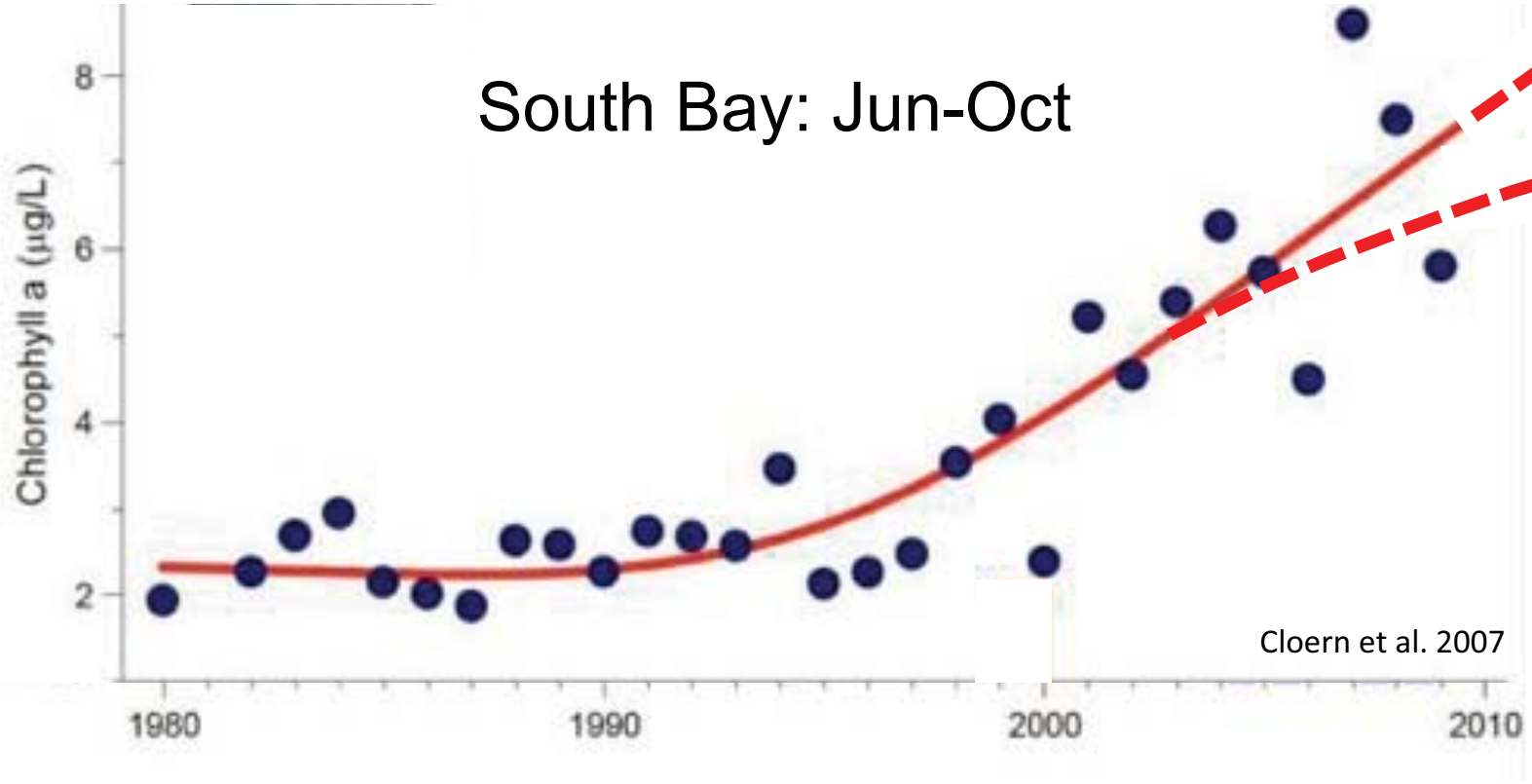

2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in LSB

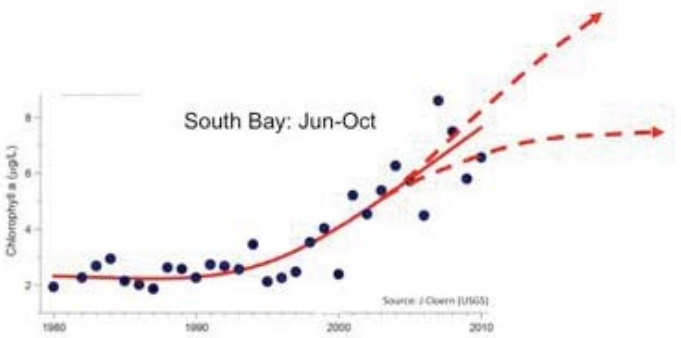
# What is the trajectory?

# What's causing the change?



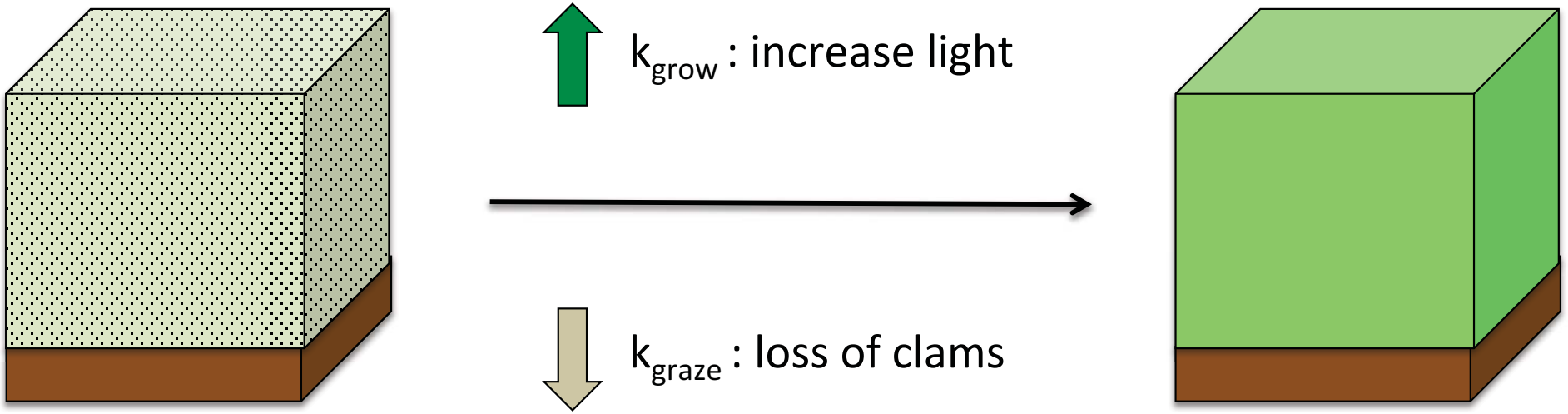

What factors contribute to
increasing phytoplankton biomass in South Bay?

What data collection and modeling are needed
to predict future conditions?



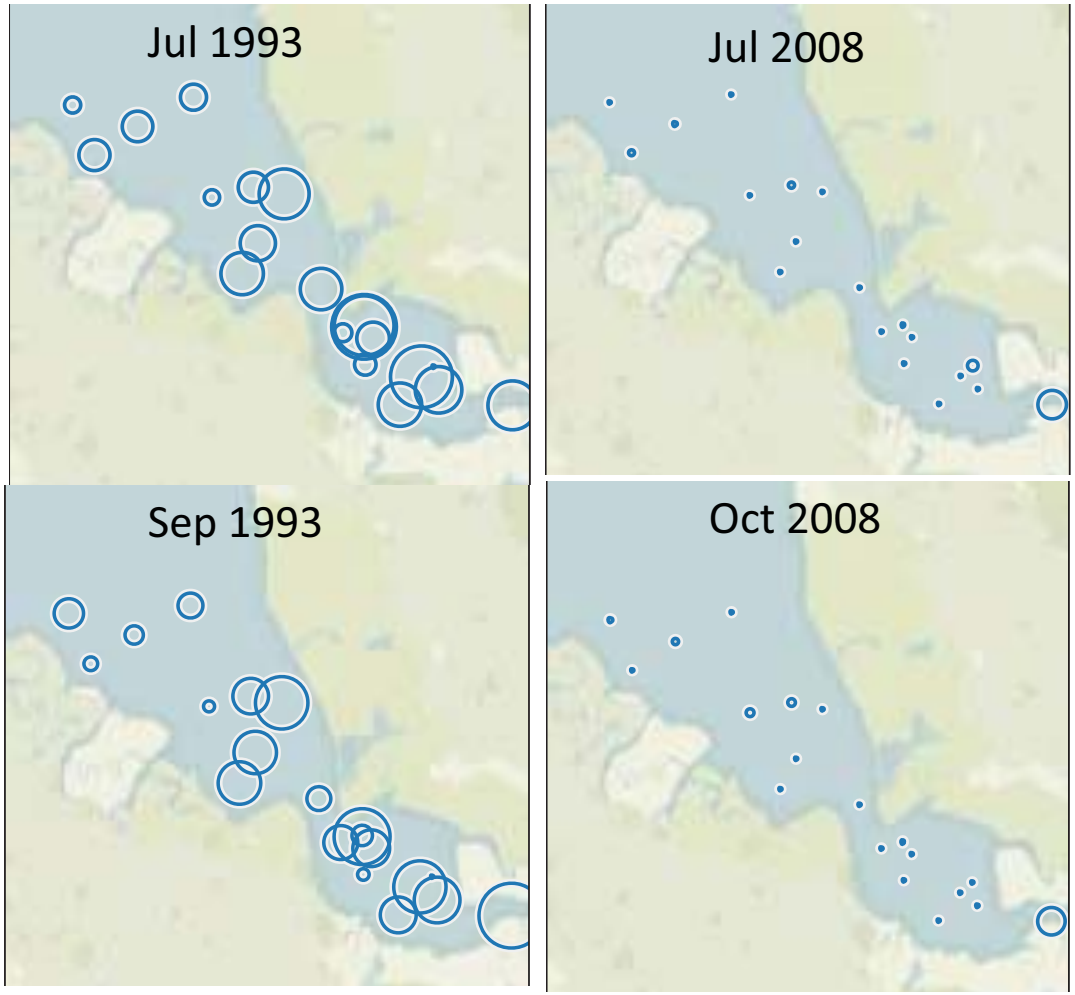

*net growth*

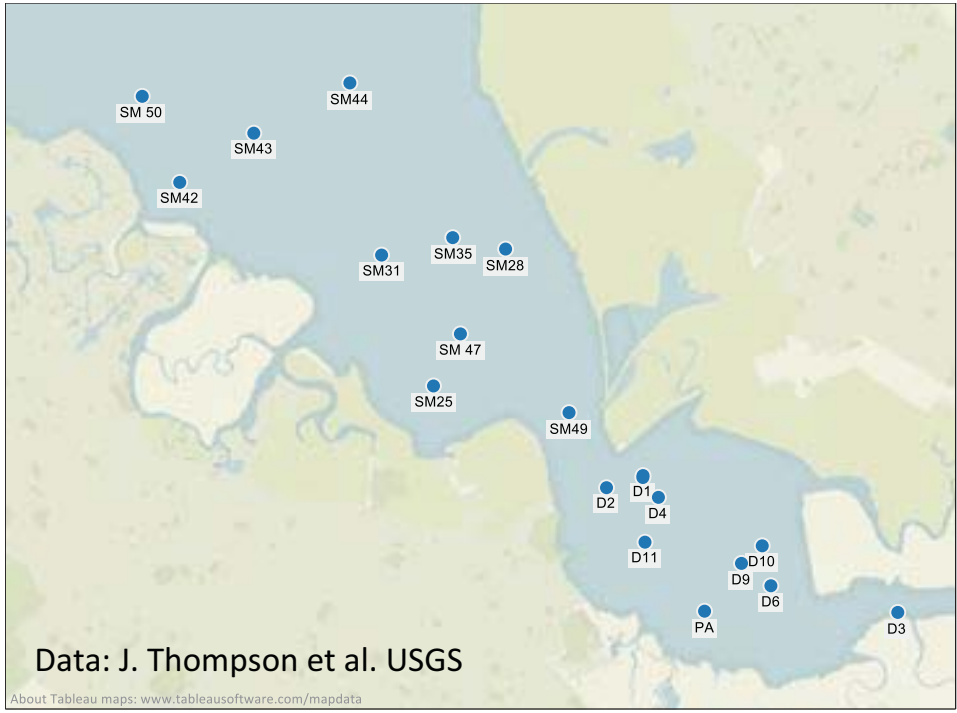
Rate of biomass accumulation = $( k_{grow} + k_{graze} ) \bullet B \pm$ *transport*



# Hypothesis: Loss of clams causes increased phytoplankton biomass

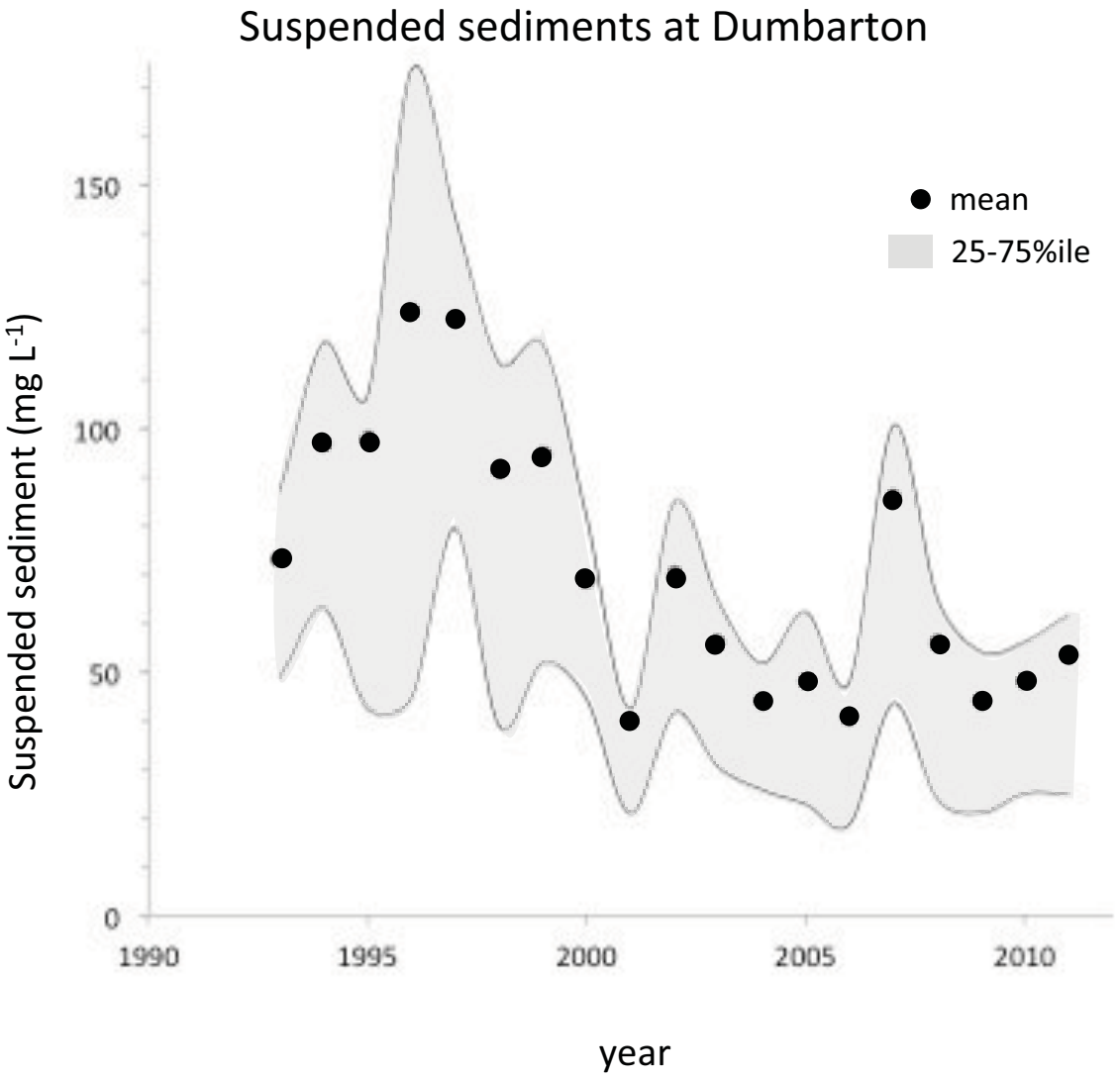
Cloern et al. 2007, 2010




Thompson et al., 2014; SFEI (2014)

# Hypothesis: More light available for phytoplankton growth



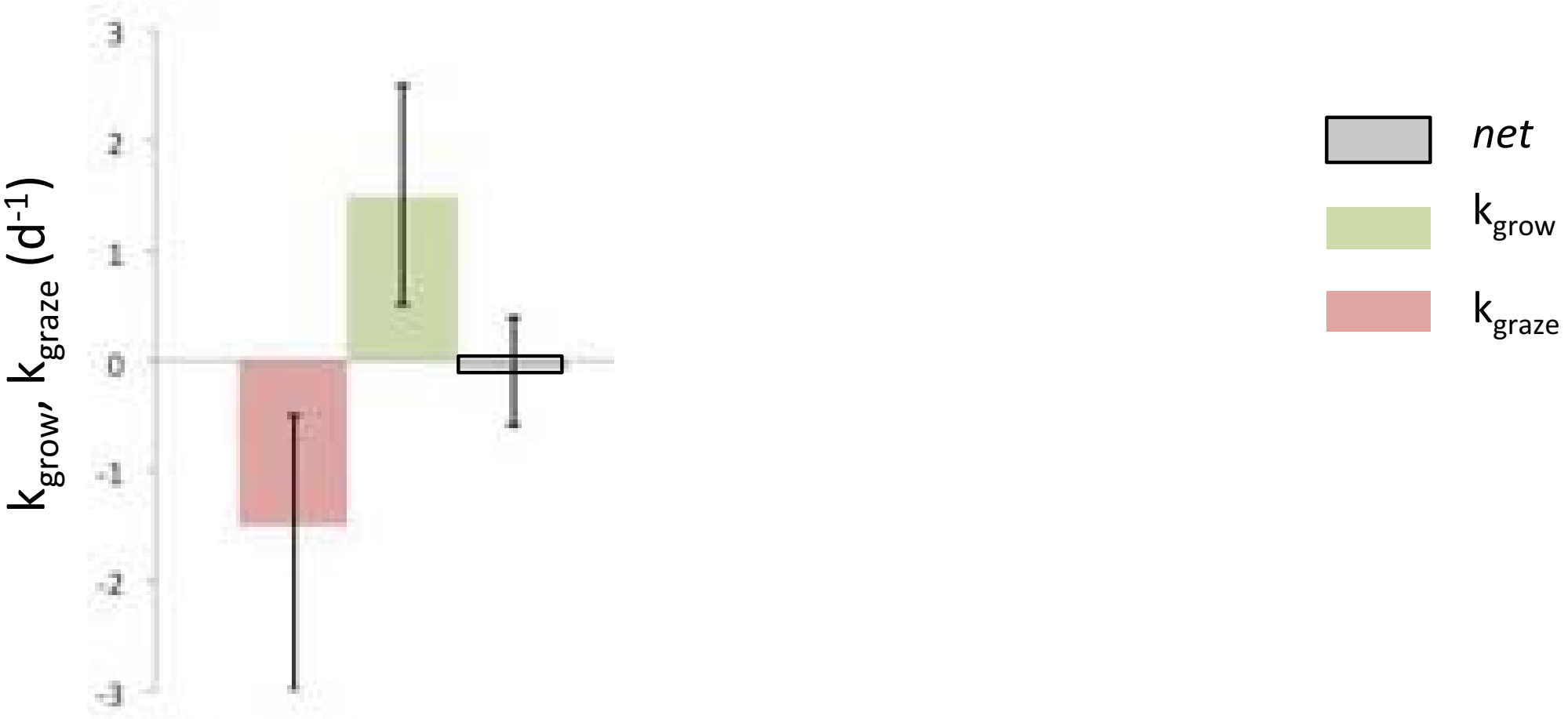

- 2x increase in light
- 2x increase in growth rate

Data: D Schoellhamer et al. (USGS)

SFEI (2014)

$$\text{Rate of biomass accumulation} = \overbrace{(k_{grow} + k_{graze})}^{\textit{net growth}} \cdot B \pm \textit{transport}$$

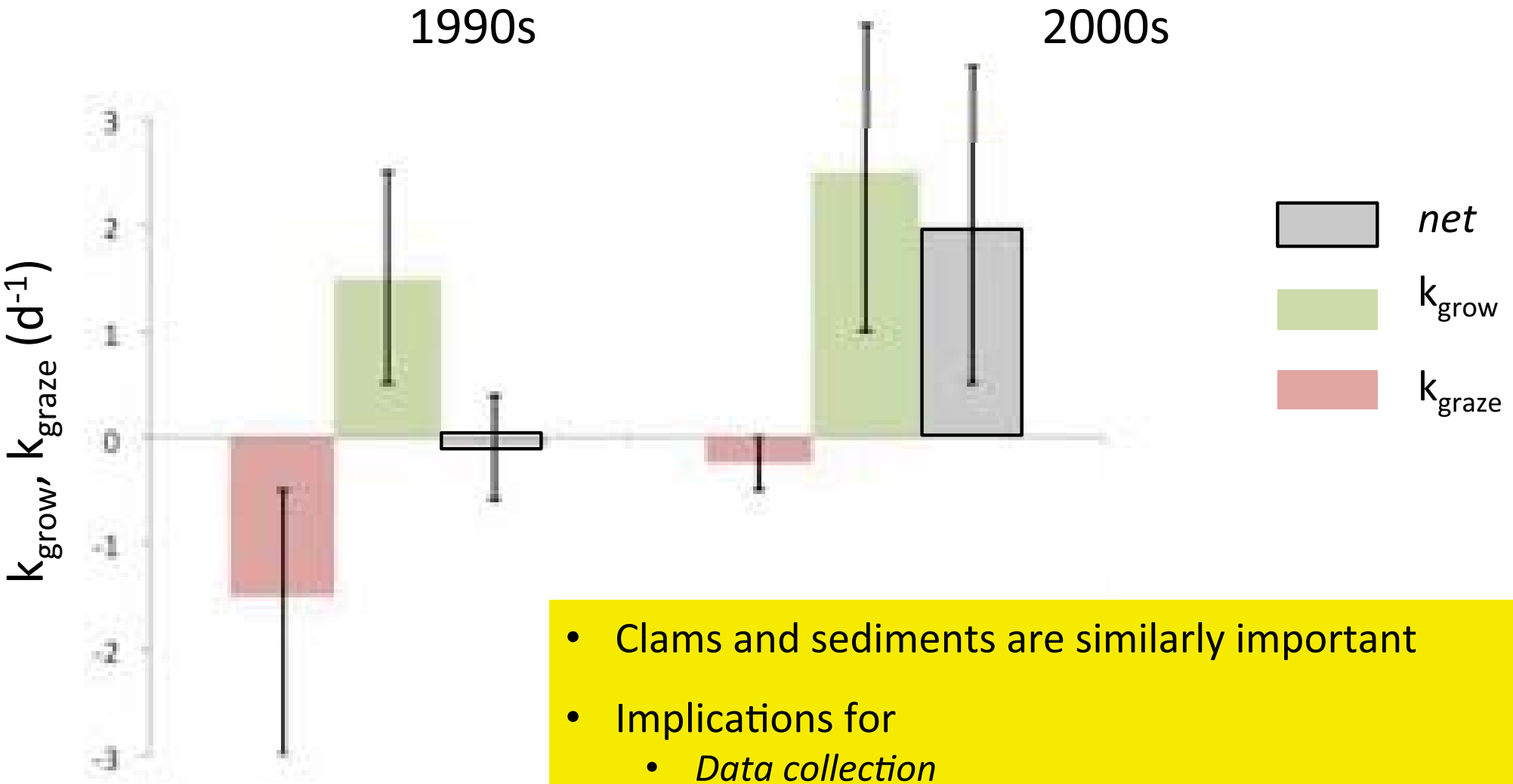
1990s




SFEI (2014)

Rate of biomass accumulation = ( $k_{grow}$ + $k_{graze}$ ) • B ± *transport*

*net growth*

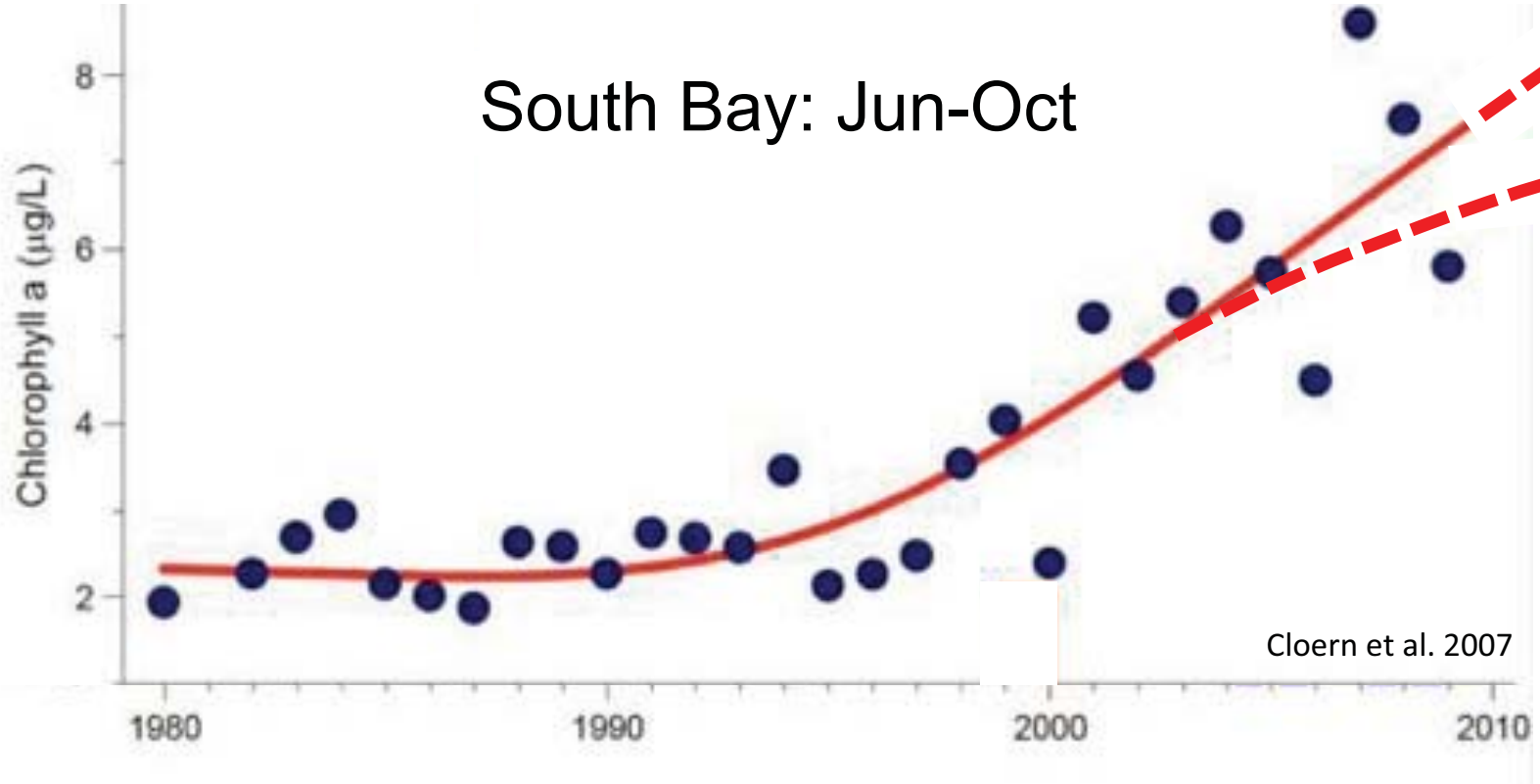



- Clams and sediments are similarly important
- Implications for
  - *Data collection*
  - *modeling*

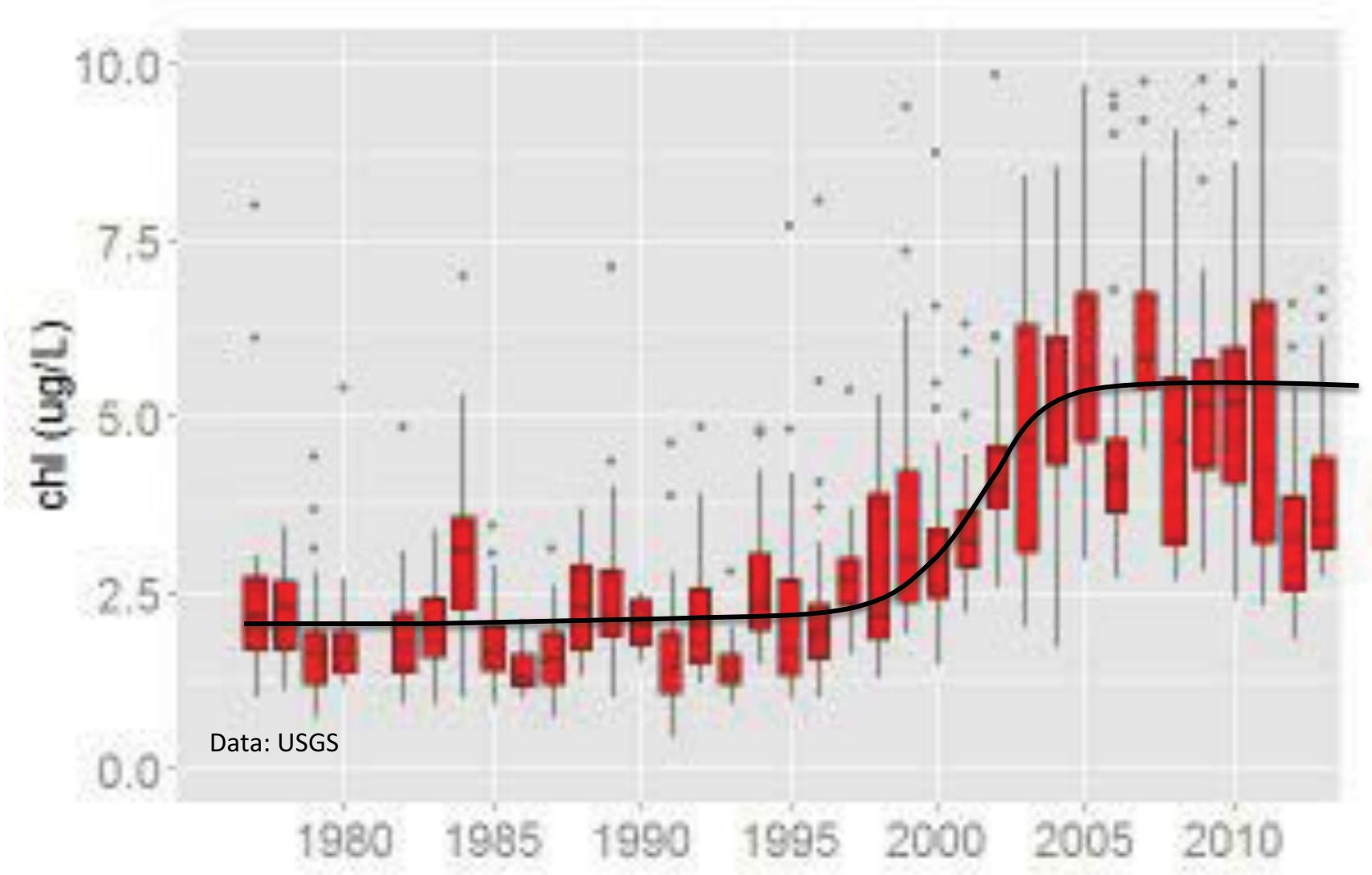
SFEI (2014)

# What is the trajectory?

# What's causing the change?




# South Bay – summer/fall chl-a




- Has South Bay reached a new steady-state/sensitivity?
  - *Monitoring, modeling*

SFEI (2014)

5. On-going work
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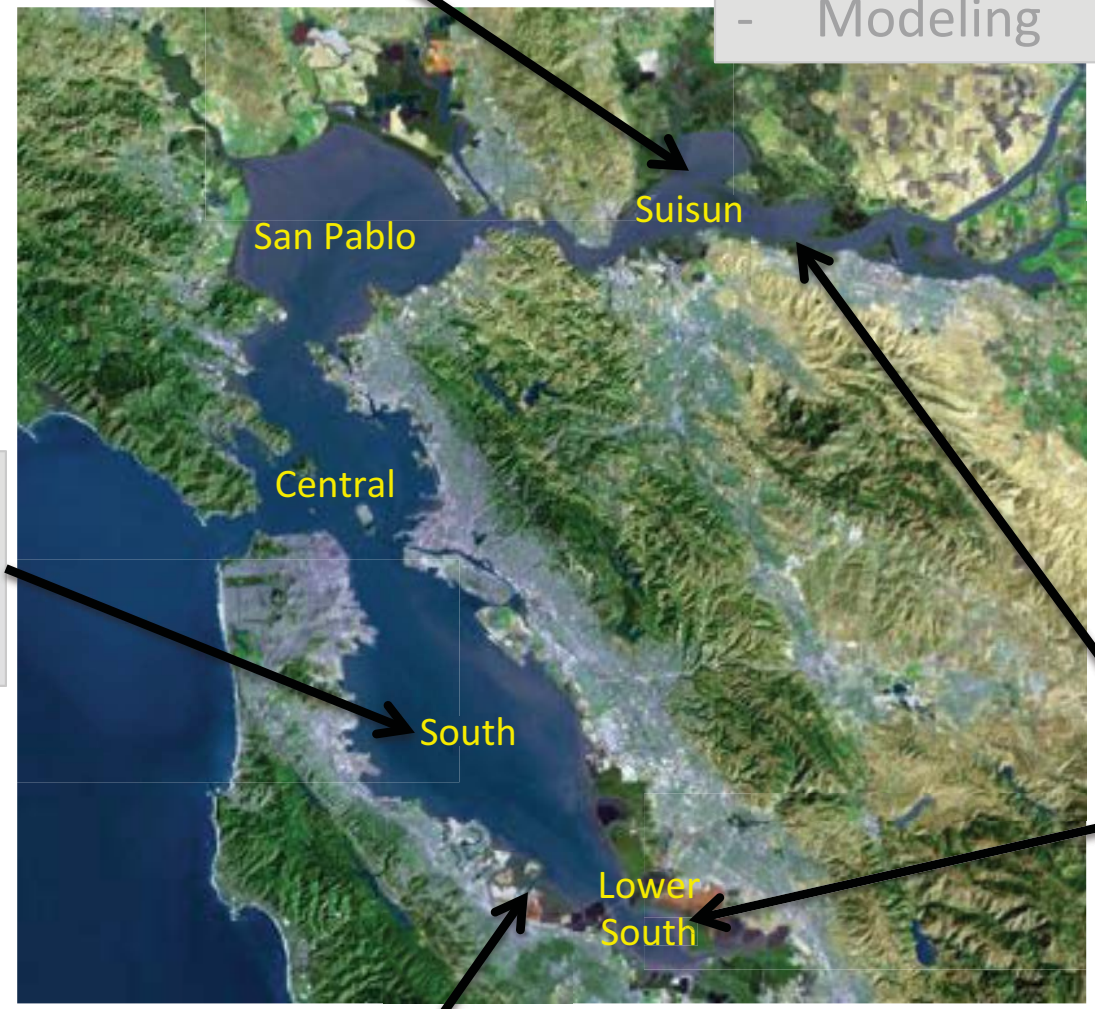
4. Changing phytoplankton species

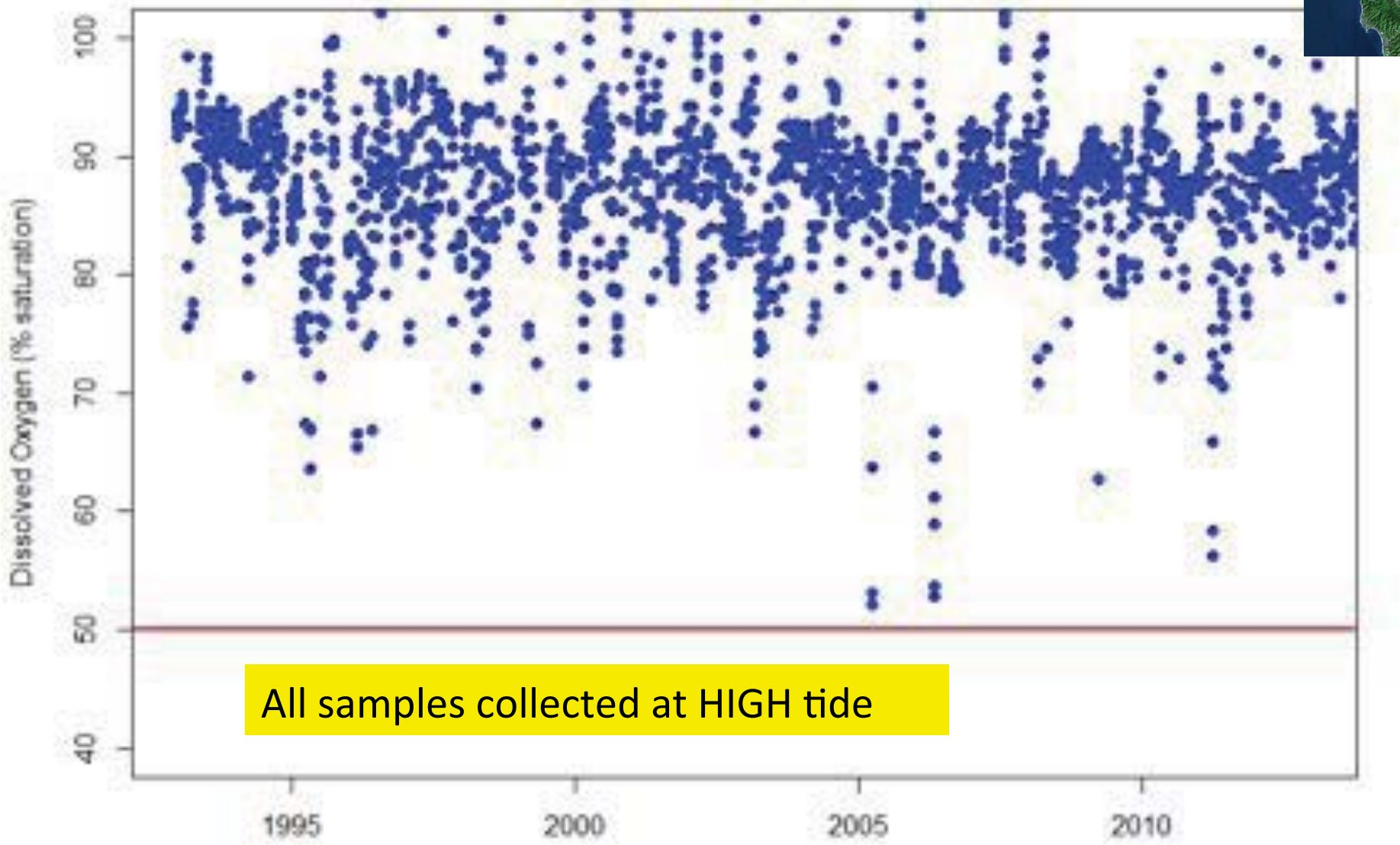



2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in SB and LSB

# Dissolved Oxygen (%sat) in South Bay
# **Deep subtidal**

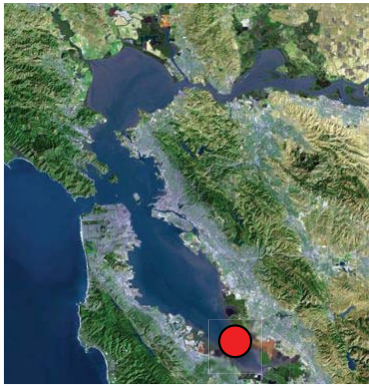


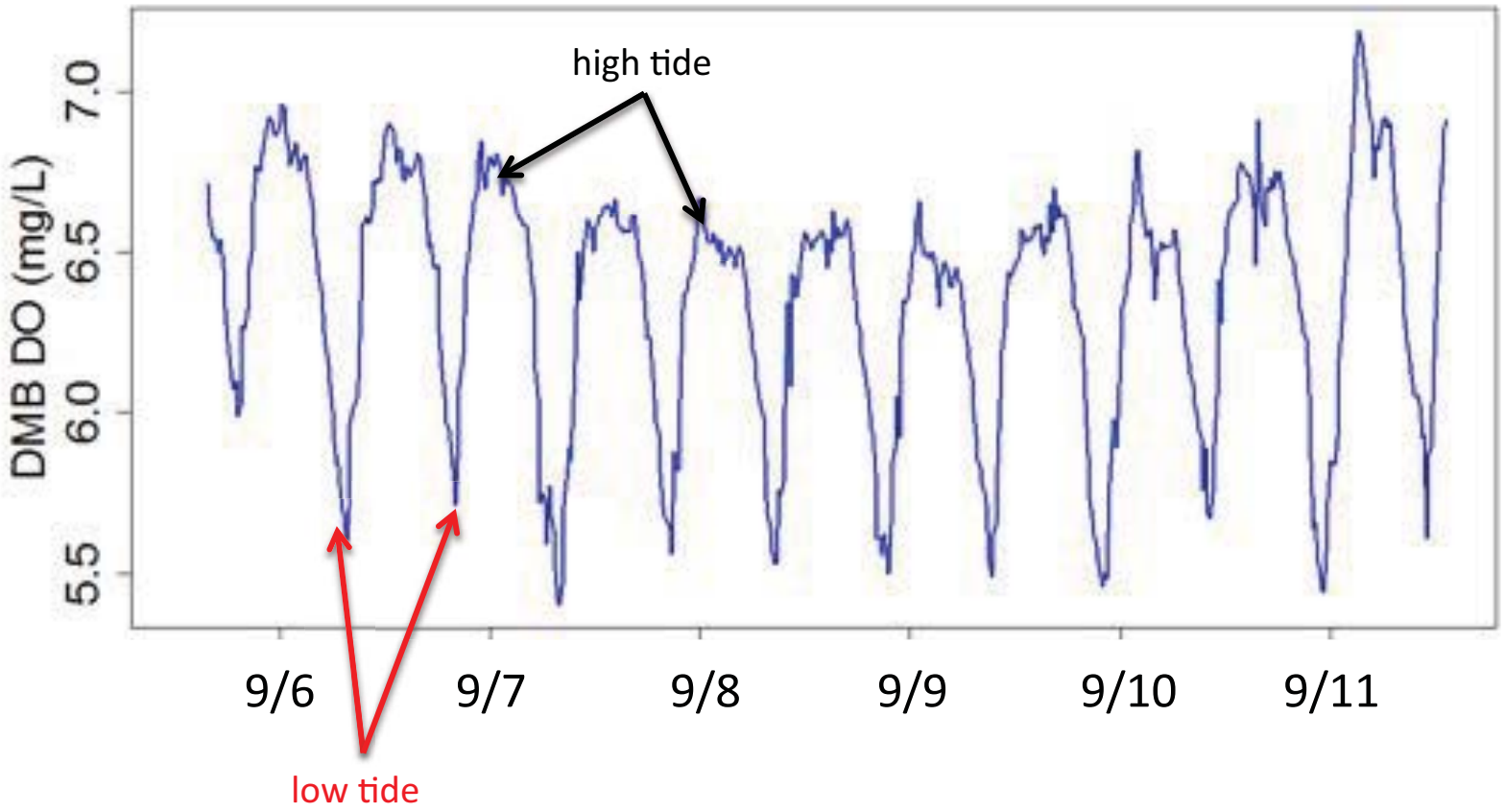

All samples collected at HIGH tide

SFEI (2014)

Data: USGS

# Continuous Dissolved Oxygen – Dumbarton Bridge (surface) September 2013

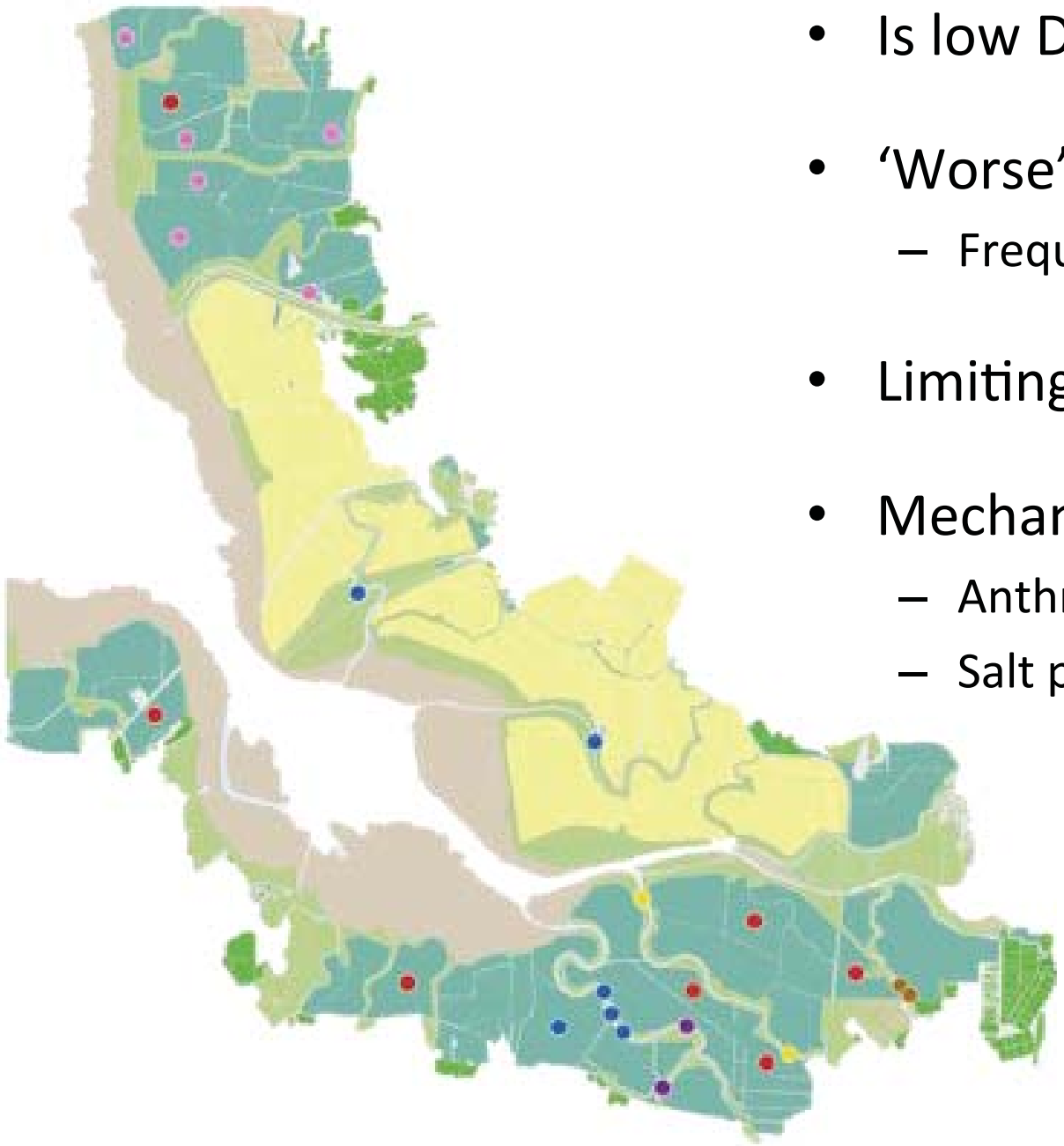





*Hypothesis*: Low DO in shallow habitats contributes to this effect at low tide

SFEI (2014)

# DO in Sloughs and Former Salt Ponds (data = 2004-2012)



## Key Questions

- Is low DO occurring?
- 'Worse' than natural conditions?
  - Frequency, duration, severity
- Limiting habitat for fish and benthos?
- Mechanisms…?
  - Anthropogenic nutrients?
  - Salt ponds?

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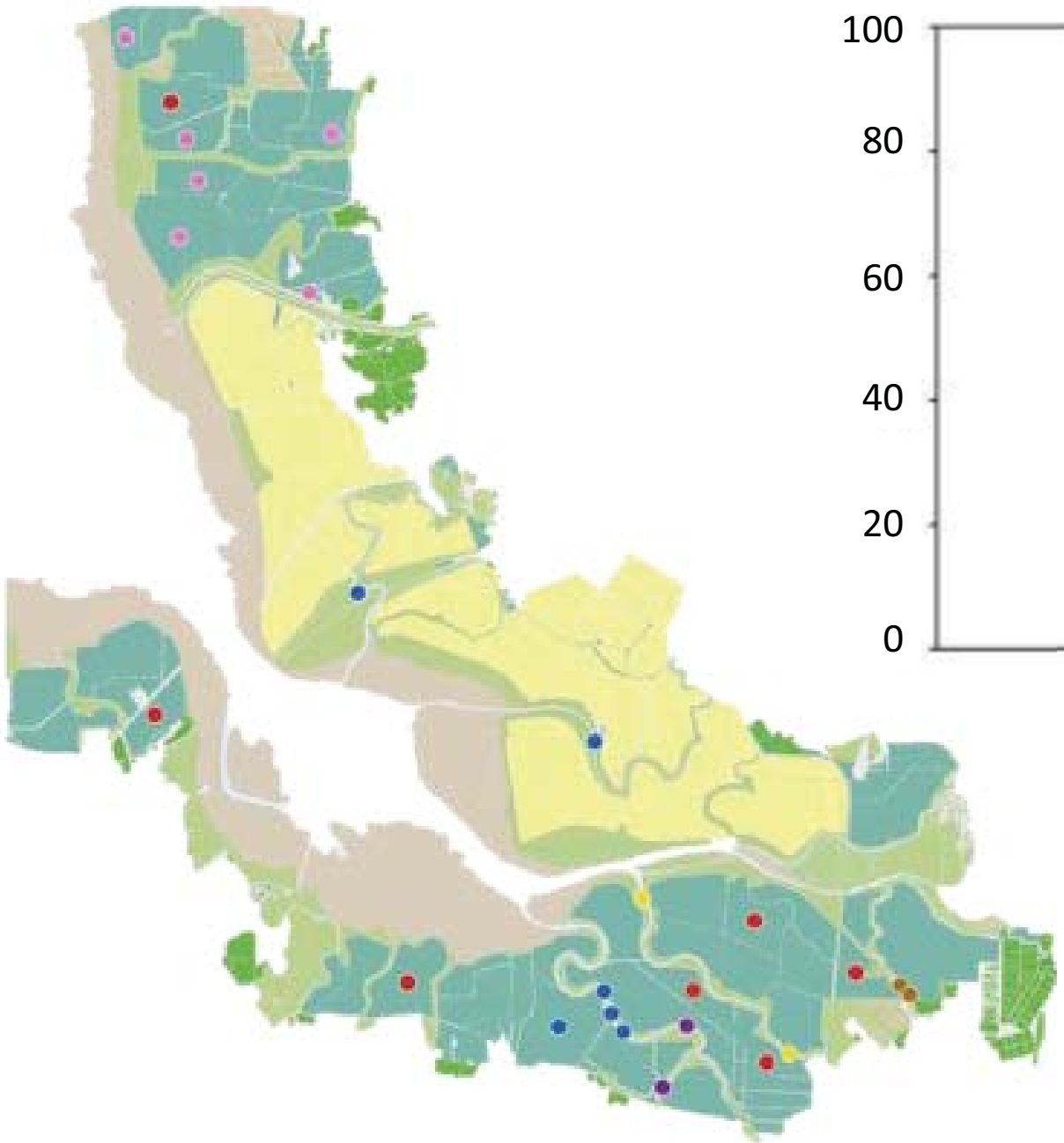
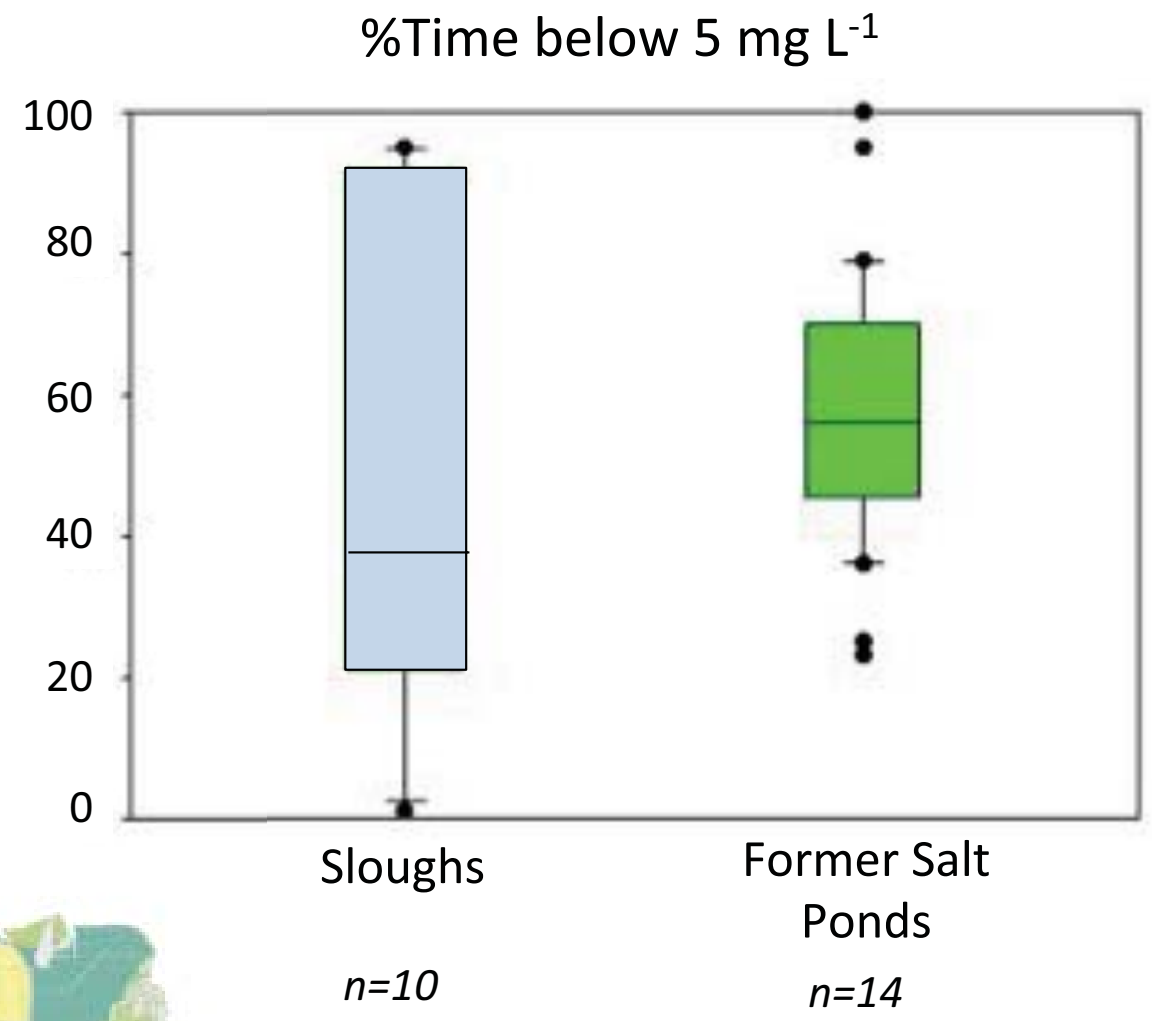
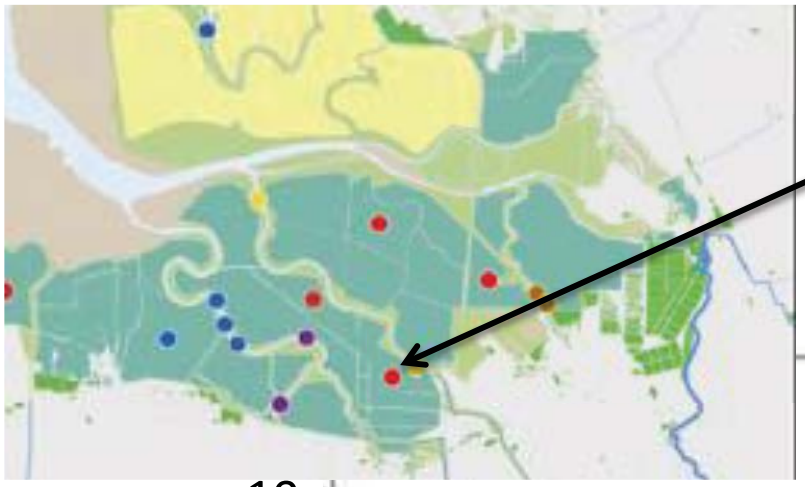
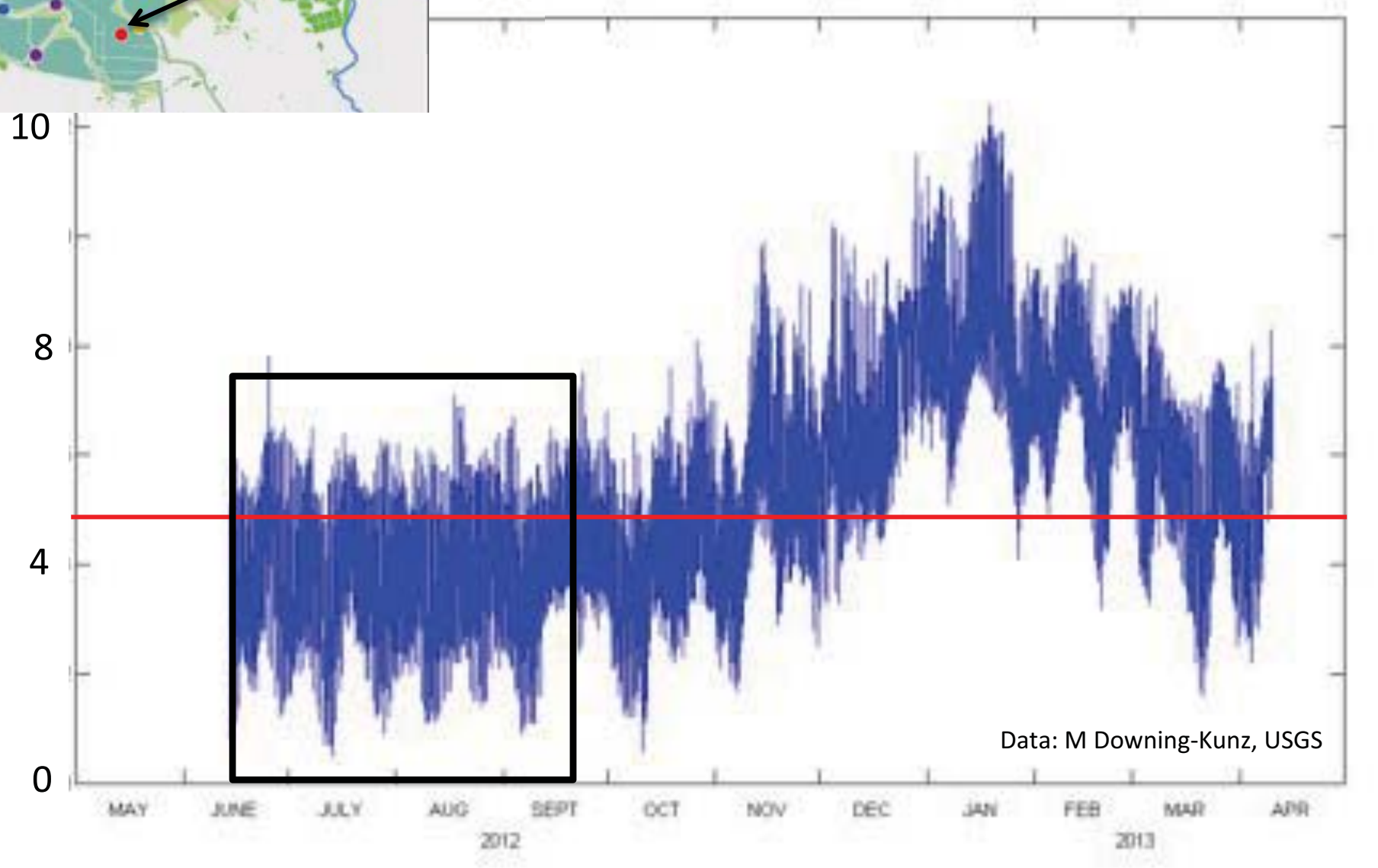





SFEI (2013)



Alviso Slough: June 2012 – April 2013



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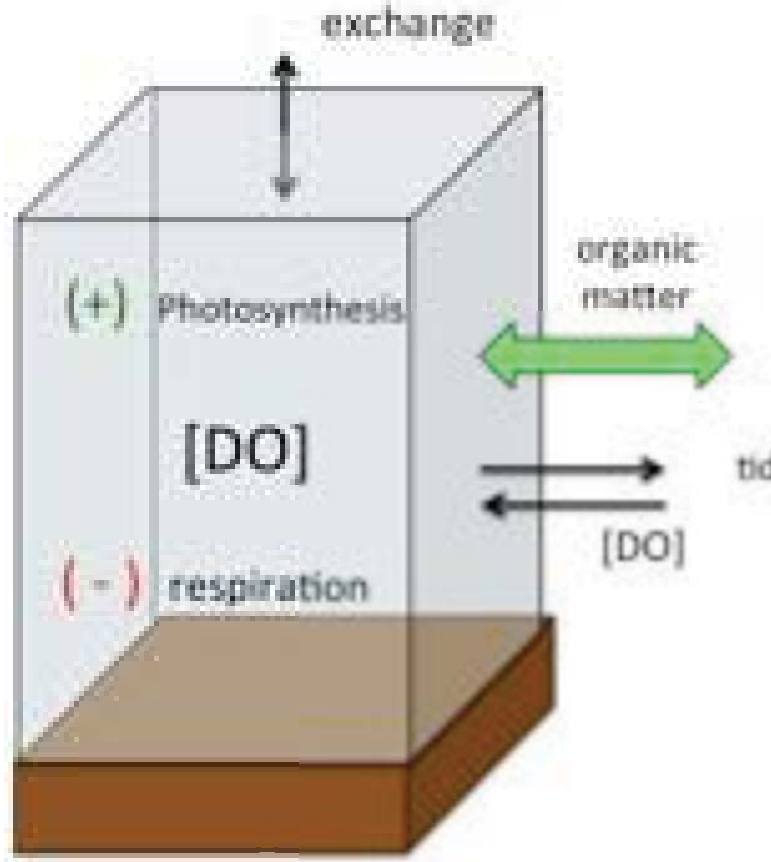
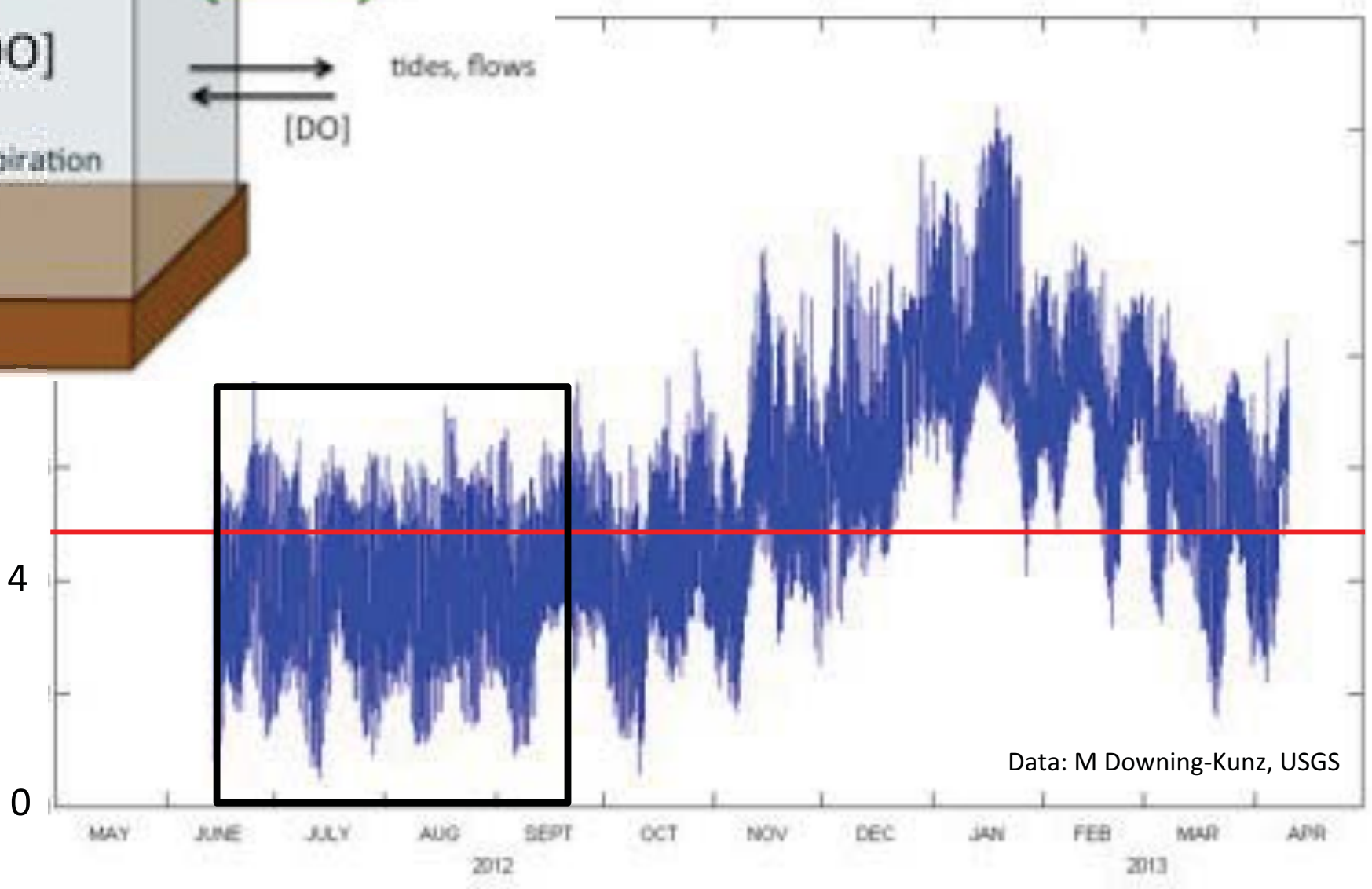
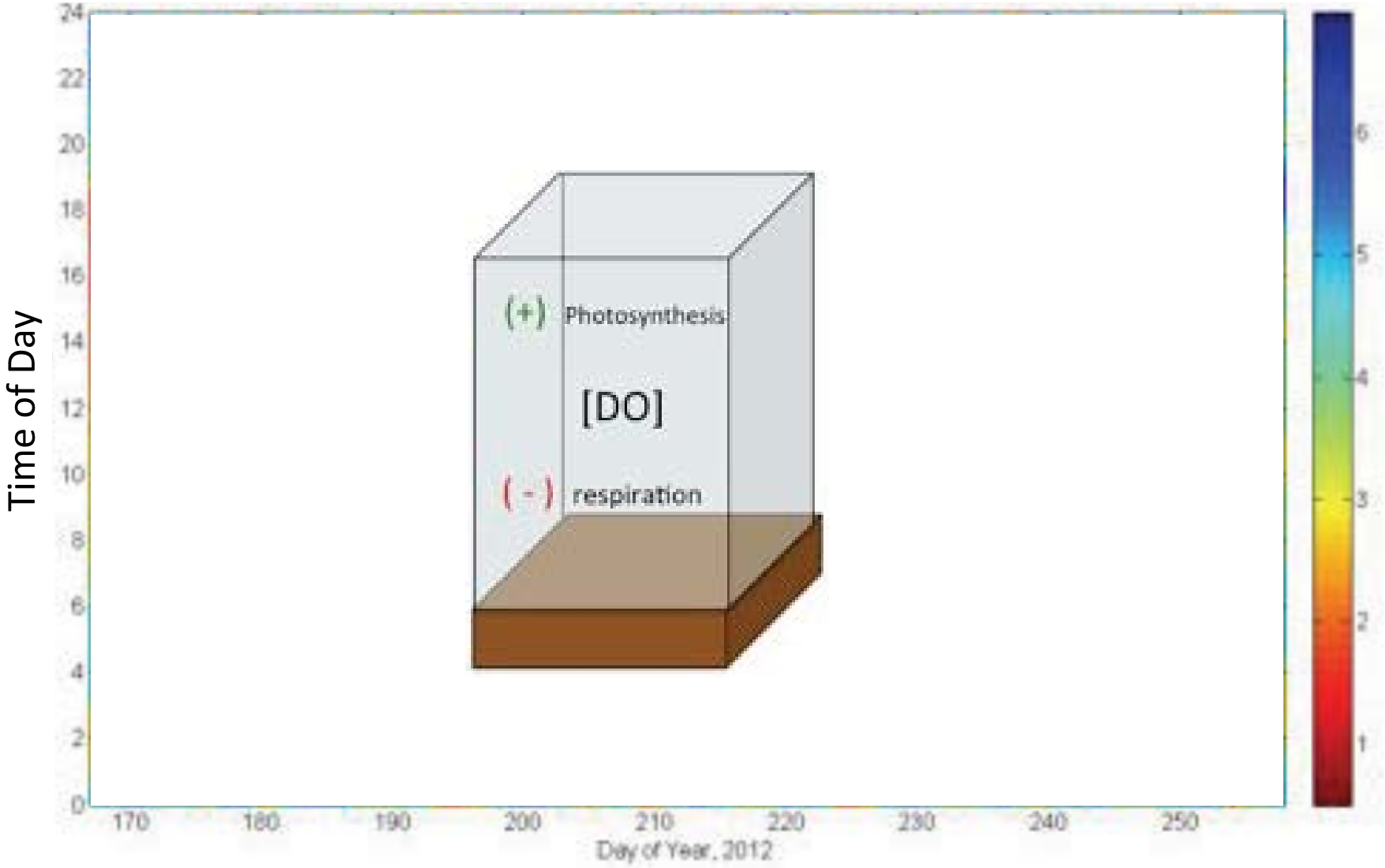


# DO production vs. DO consumption vs. tides……Who wins?




Jun 15 2012

Sep 14 2012

Date

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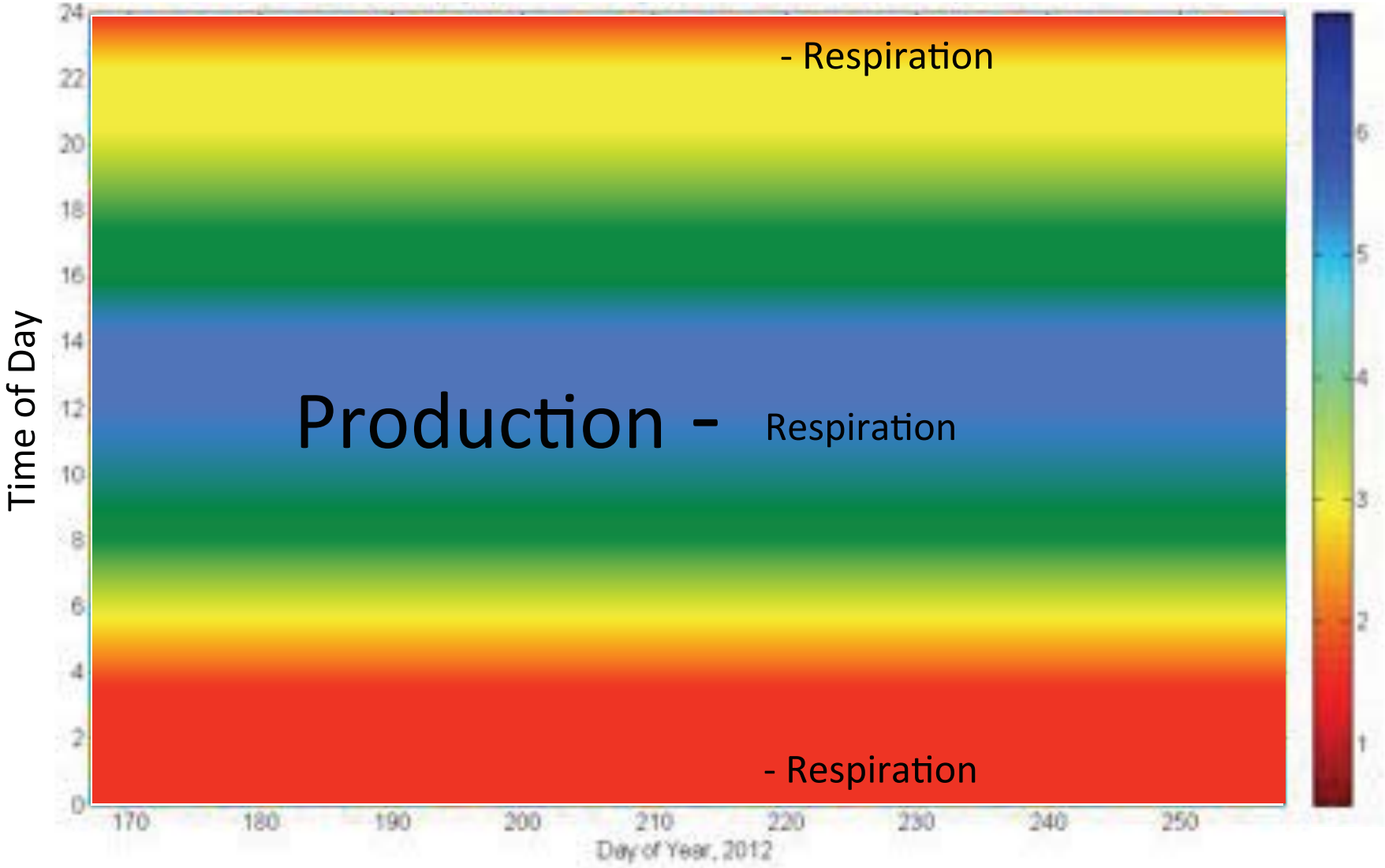

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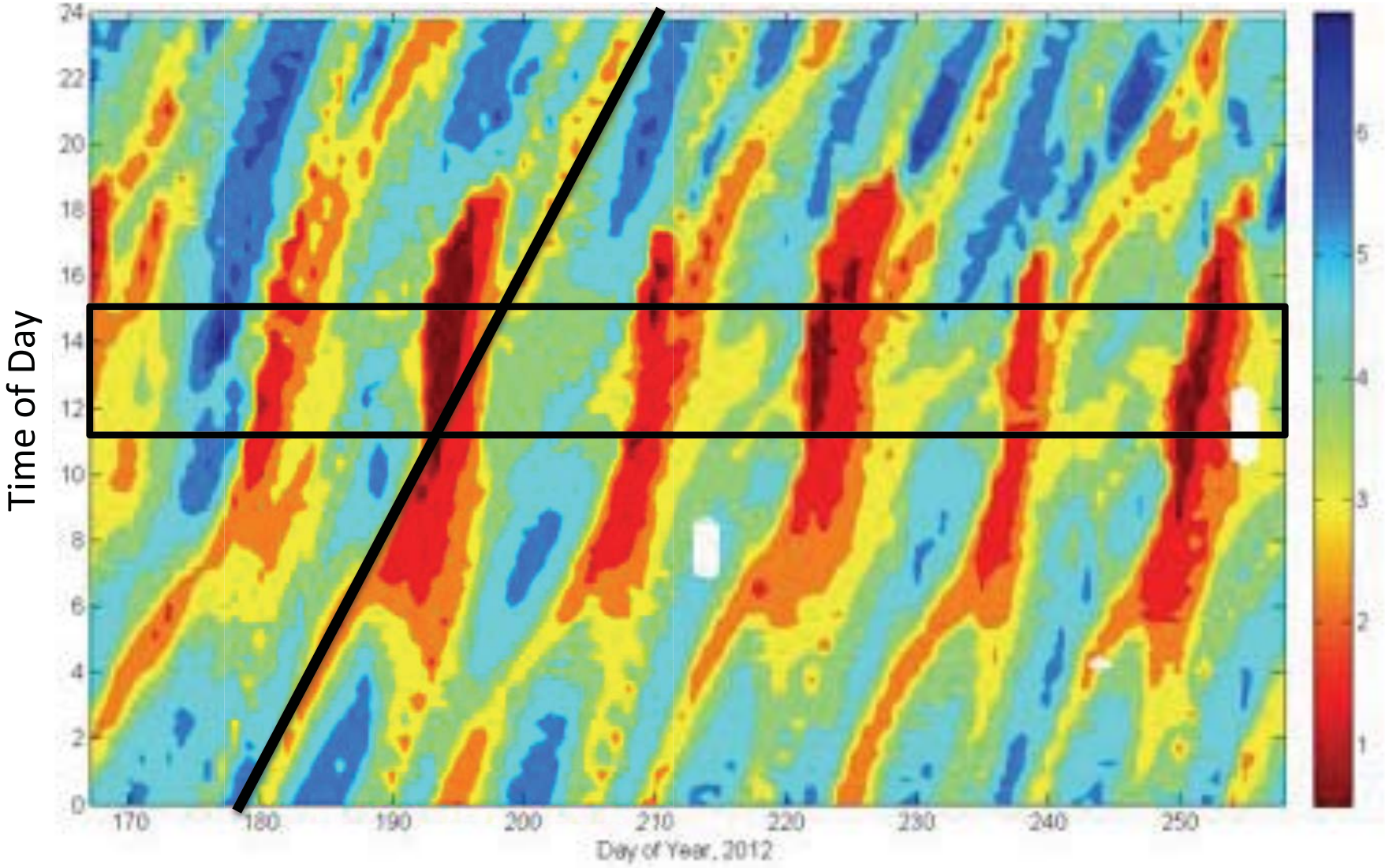


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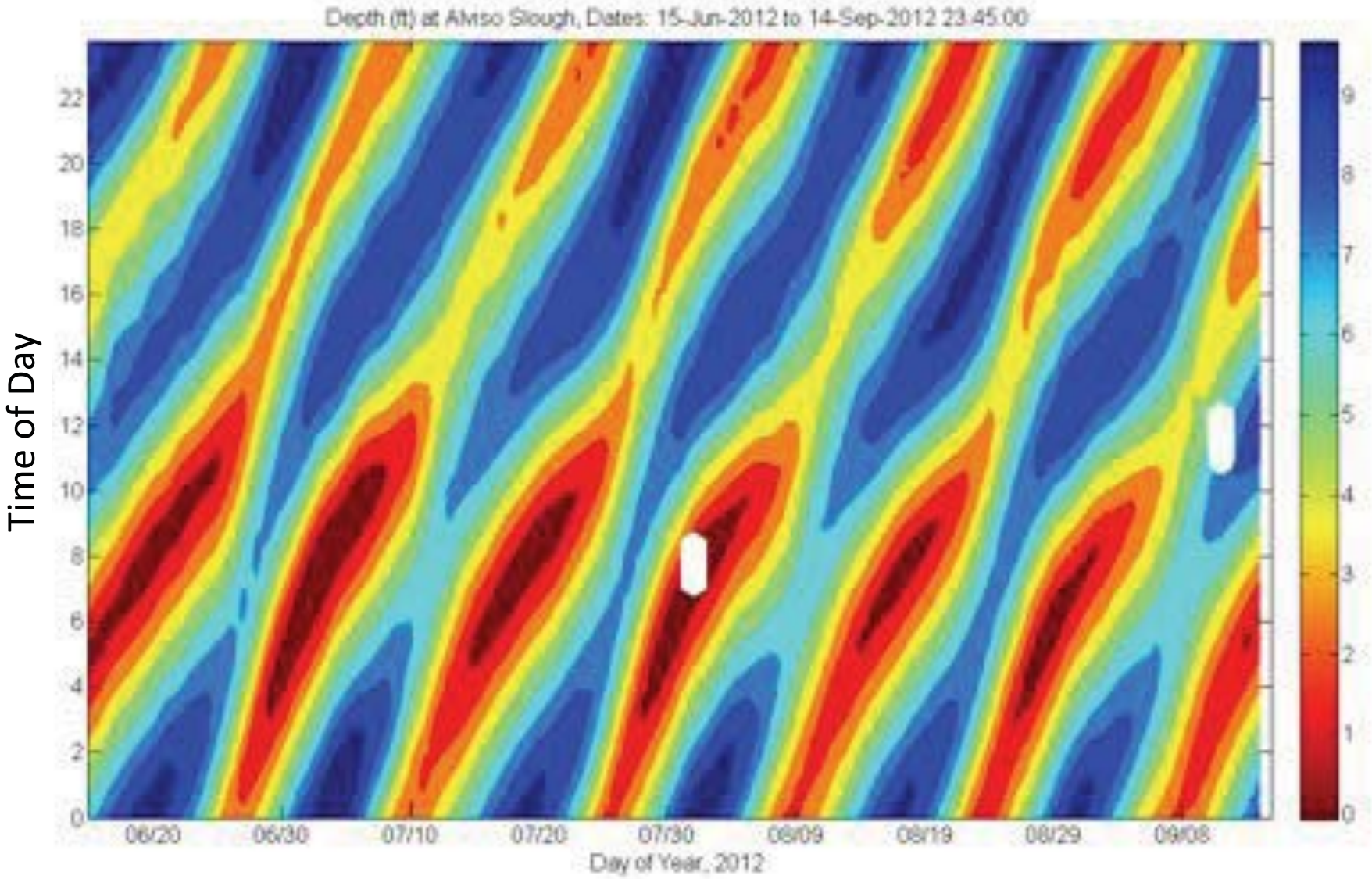
SFEI (2014)

Data: M Downing-Kunz, USGS

Mean = 3.9 mg $L^{-1}$

# Depth

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SFEI (2014)

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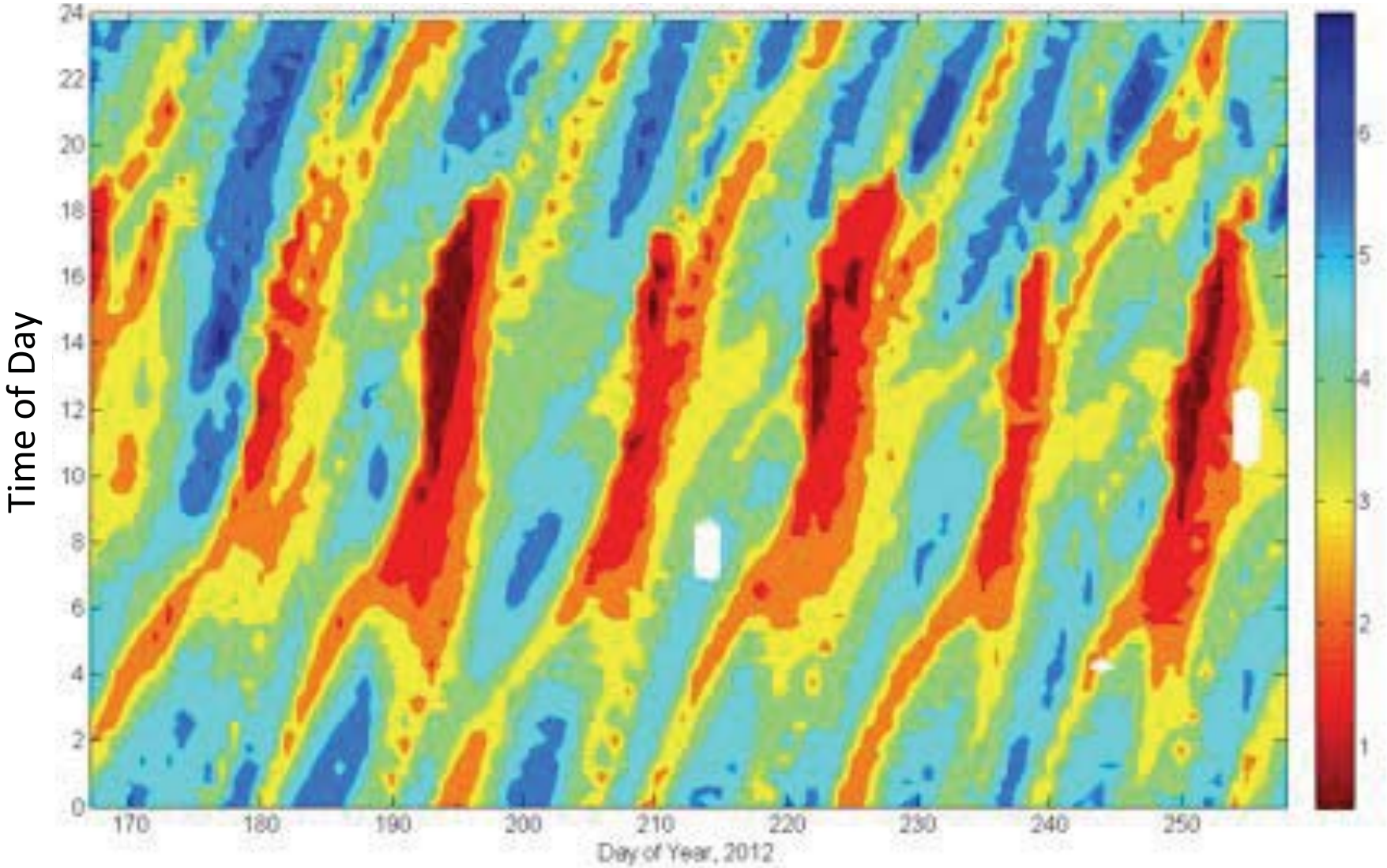
# DO with Depth Overlay

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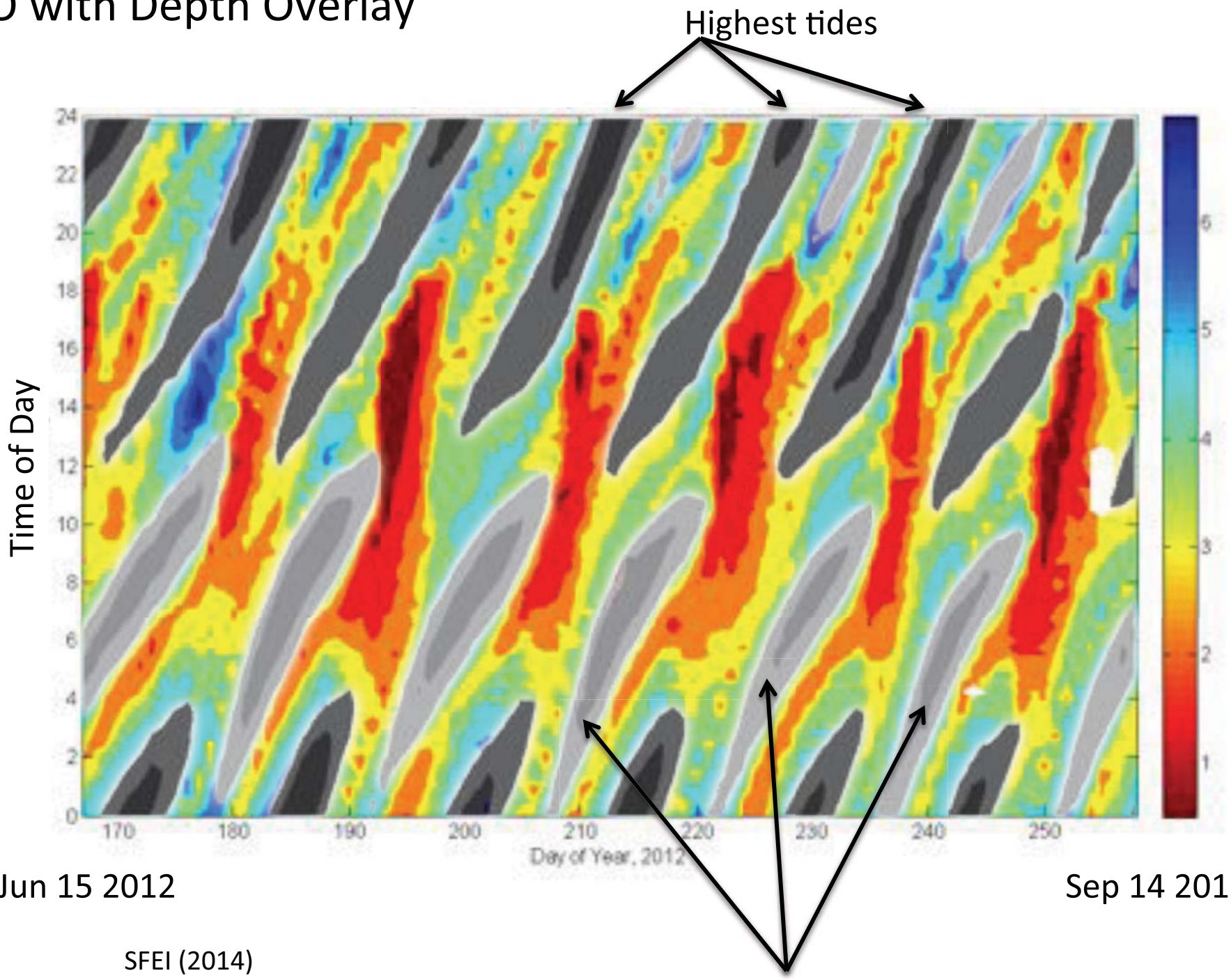
Mean = 3.9 mg $L^{-1}$

# DO with Depth Overlay




Jun 15 2012

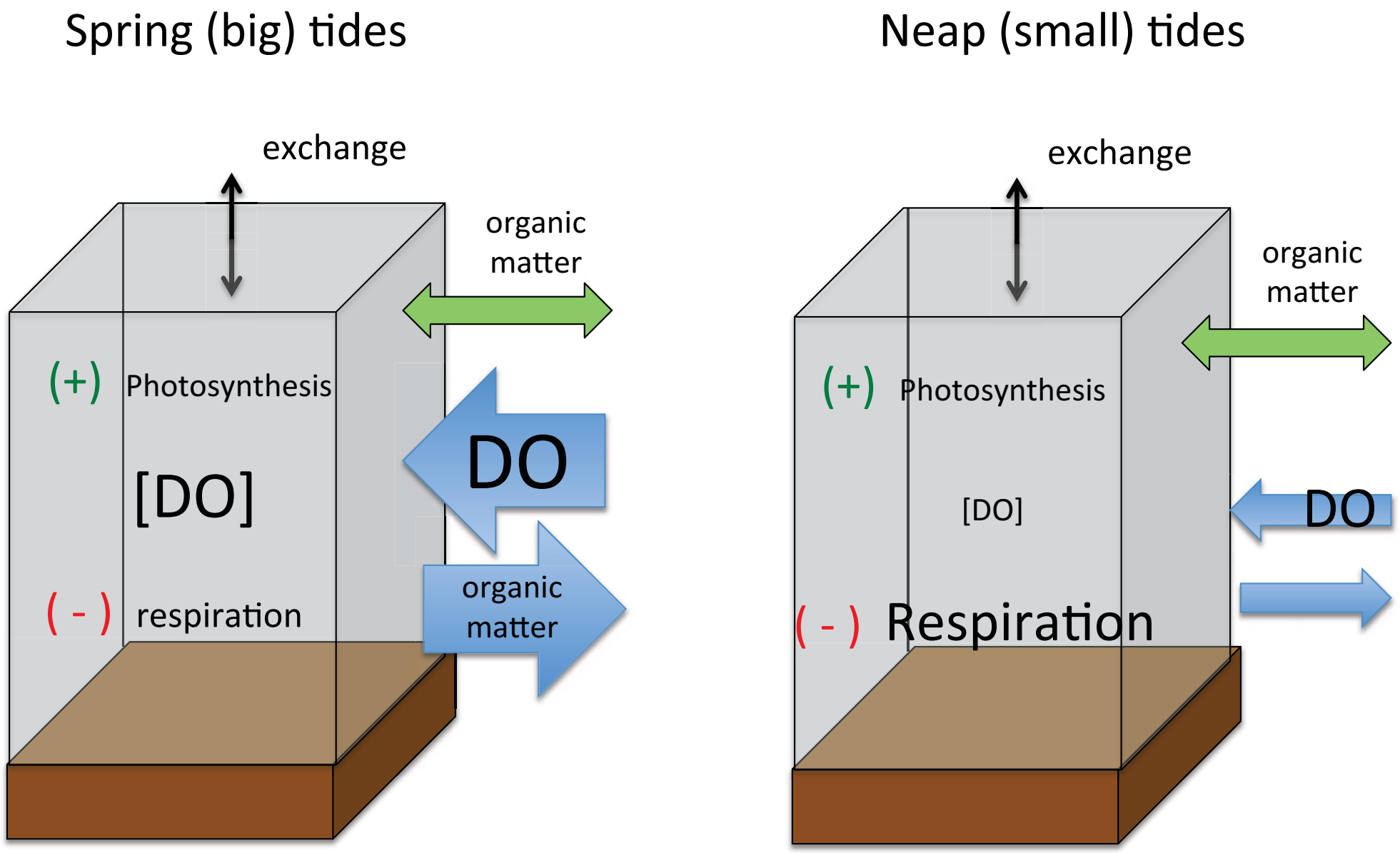
Sep 14 2012

SFEI (2014)

Data: M Downing-Kunz, USGS

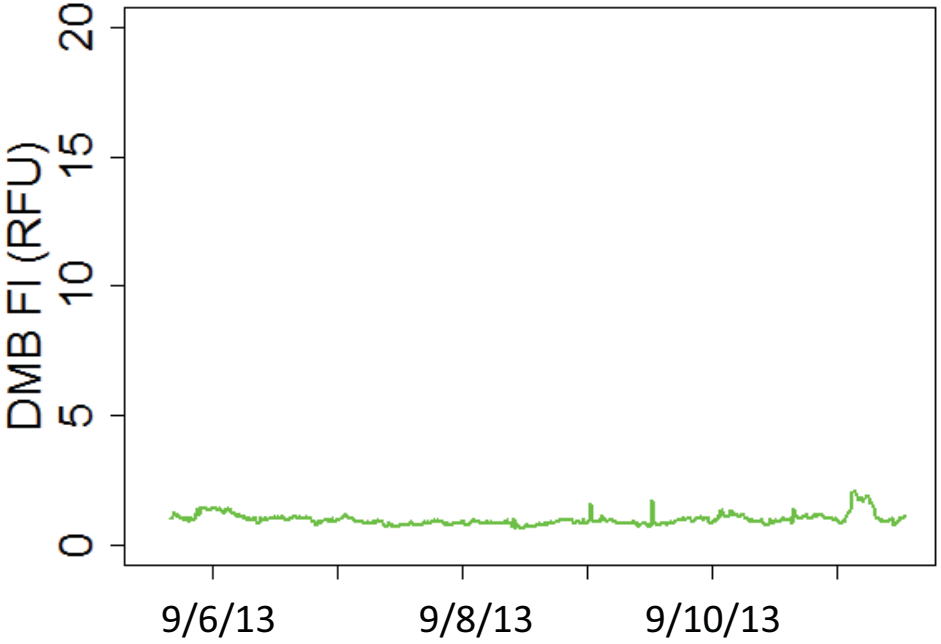
Mean = 3.9 mg $L^{-1}$

# Working hypothesis #1

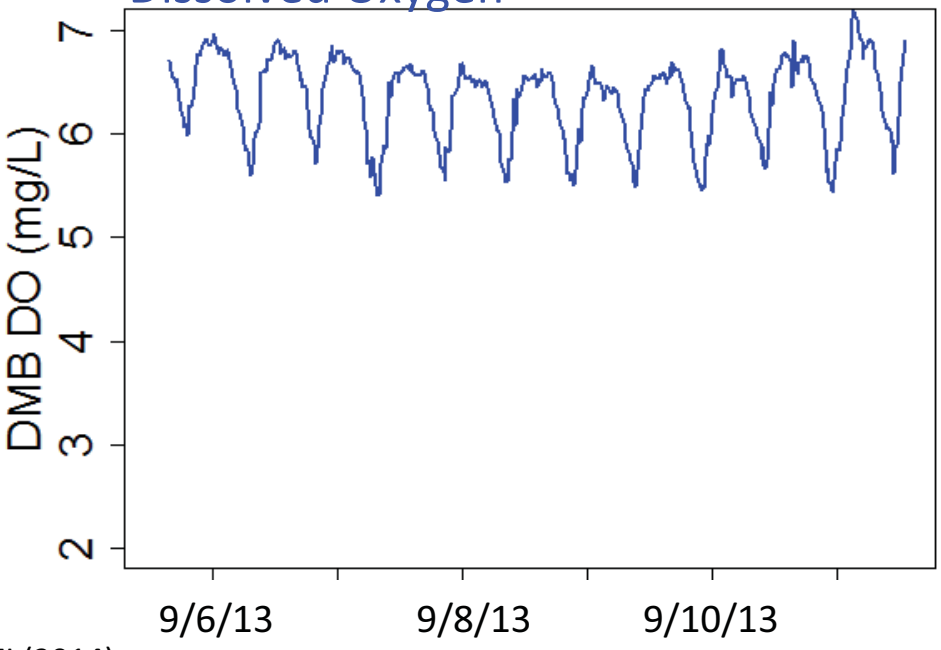


## Dumbarton

Chl-a

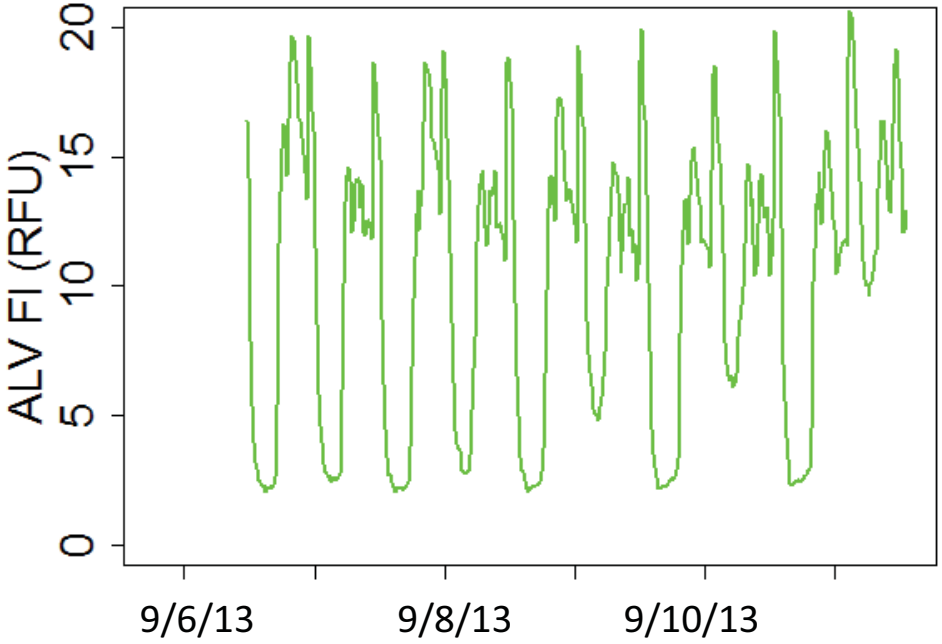



Dissolved Oxygen

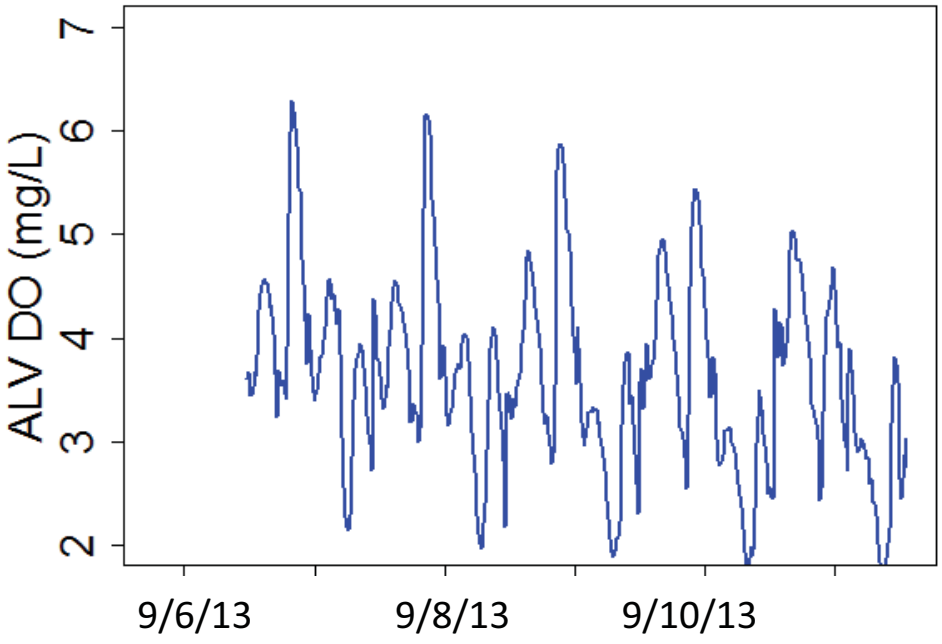



## Alviso Slough

Chl-a



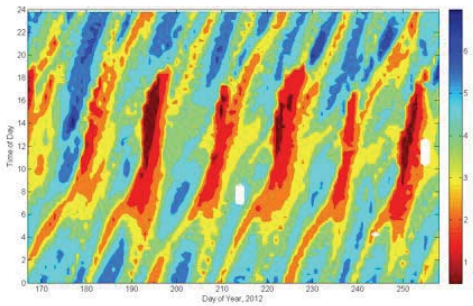

Dissolved Oxygen

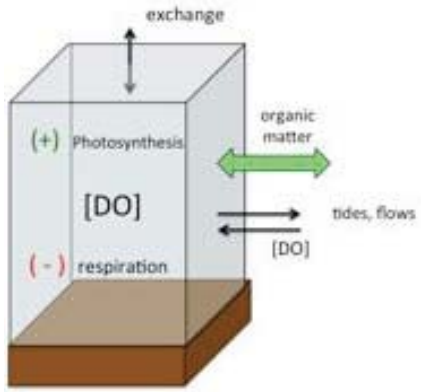


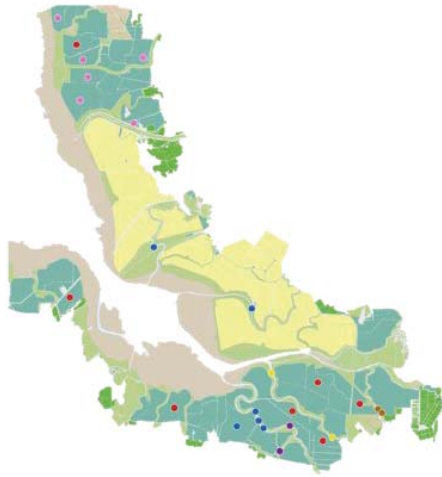

SFEI (2014)

# Questions/Implications

- Is important habitat being lost?
  - *5 mg $L^{-1}$ appropriate threshold?*
  - *Habitat/fish studies ?*
- How common is low DO in margin habitats?
  - *Coordinated/systematic monitoring*
- What factors contribute to low DO, and would nutrient load reductions improve condition?
  - *Monitoring, special studies*
  - *Modeling*

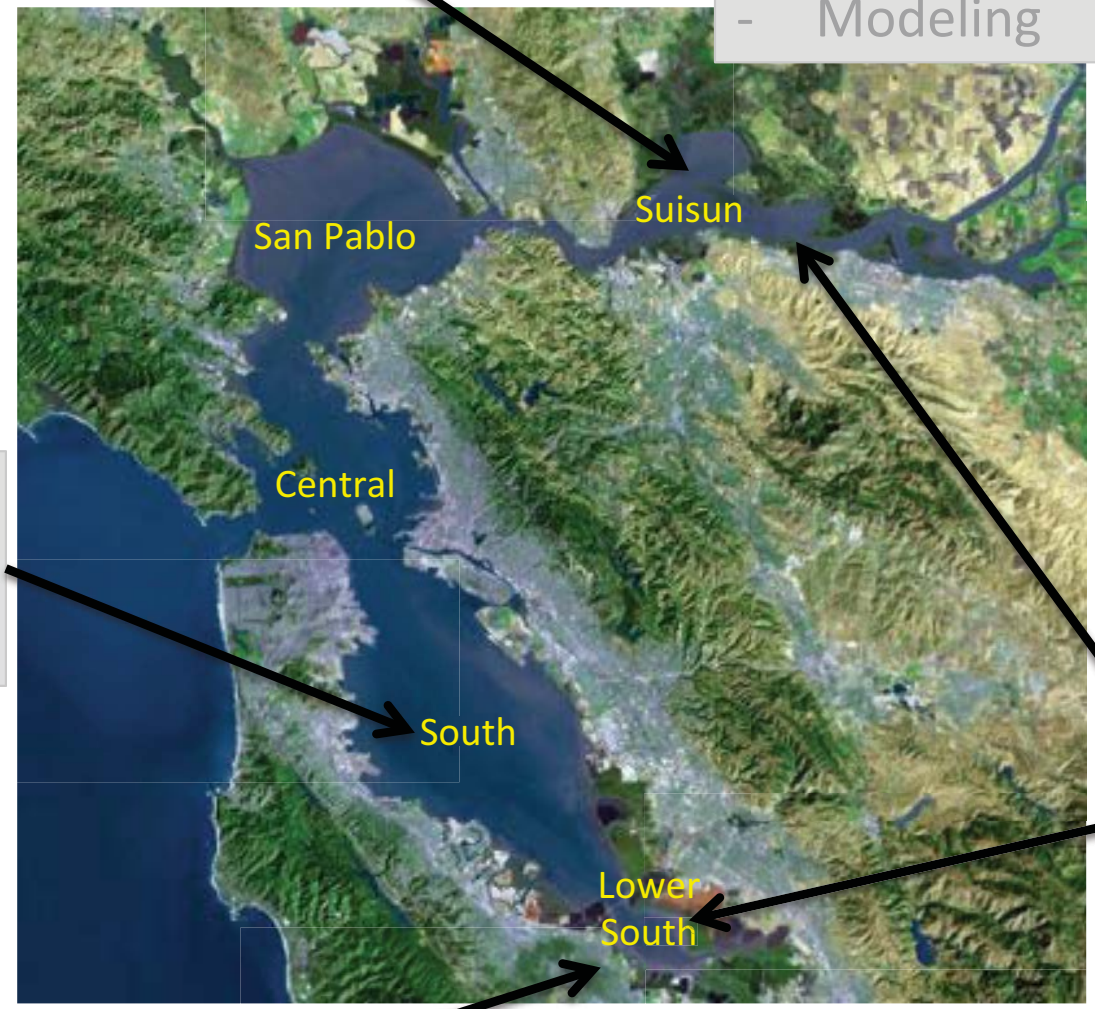


4. Changing phytoplankton species

5. On-going work
- Moored sensors
- Monitoring program development
- Phytoplankton & HAB detection
- Modeling



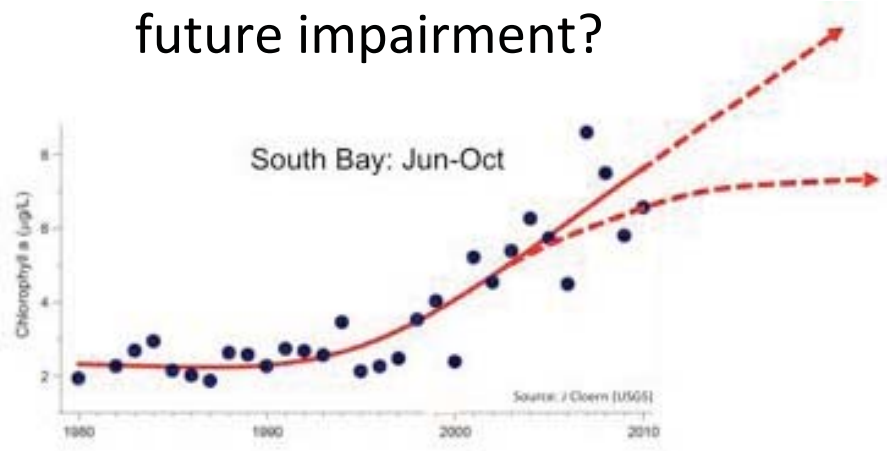

2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in LSB

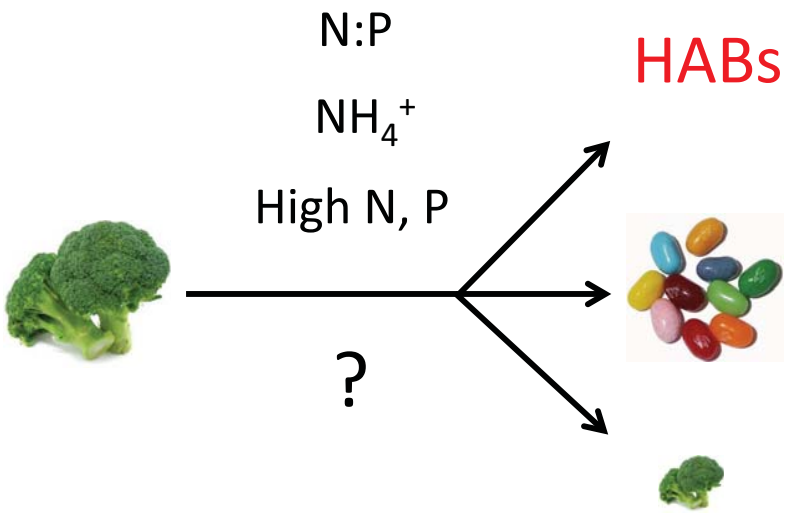
# High Priority Nutrient Issues

Does increasing biomass signal future impairment?

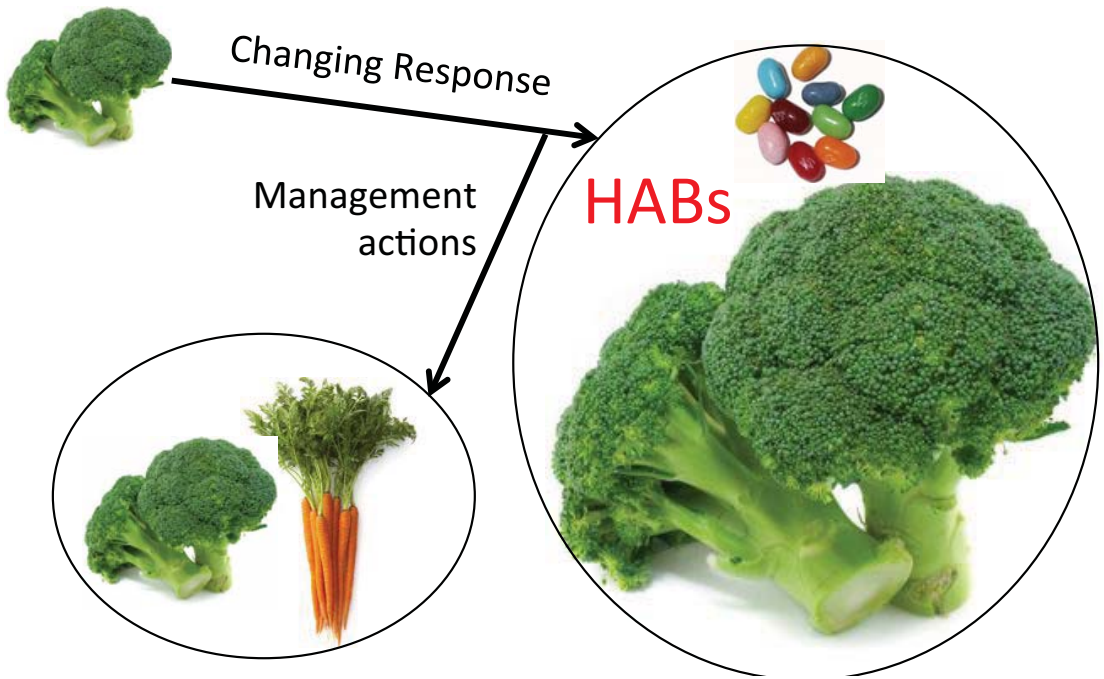



Low DO in margin habitats?

Impacts on phytoplankton composition and growth

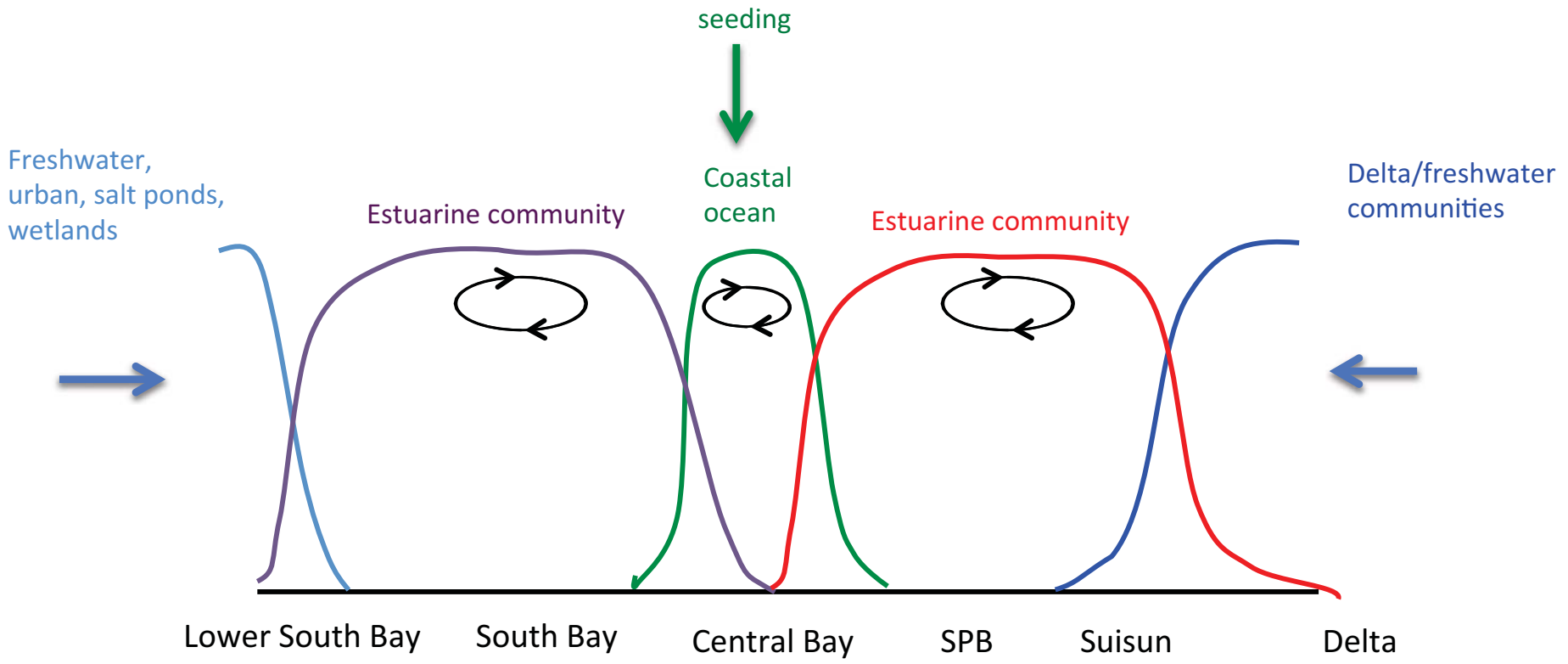



Test future scenarios: impairment and mitigation

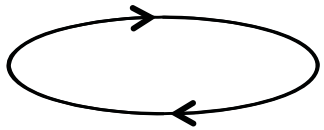


# What shapes community phytoplankton community composition?

# Are conditions in SFB adversely impacting phytoplankton composition?




Internal processes



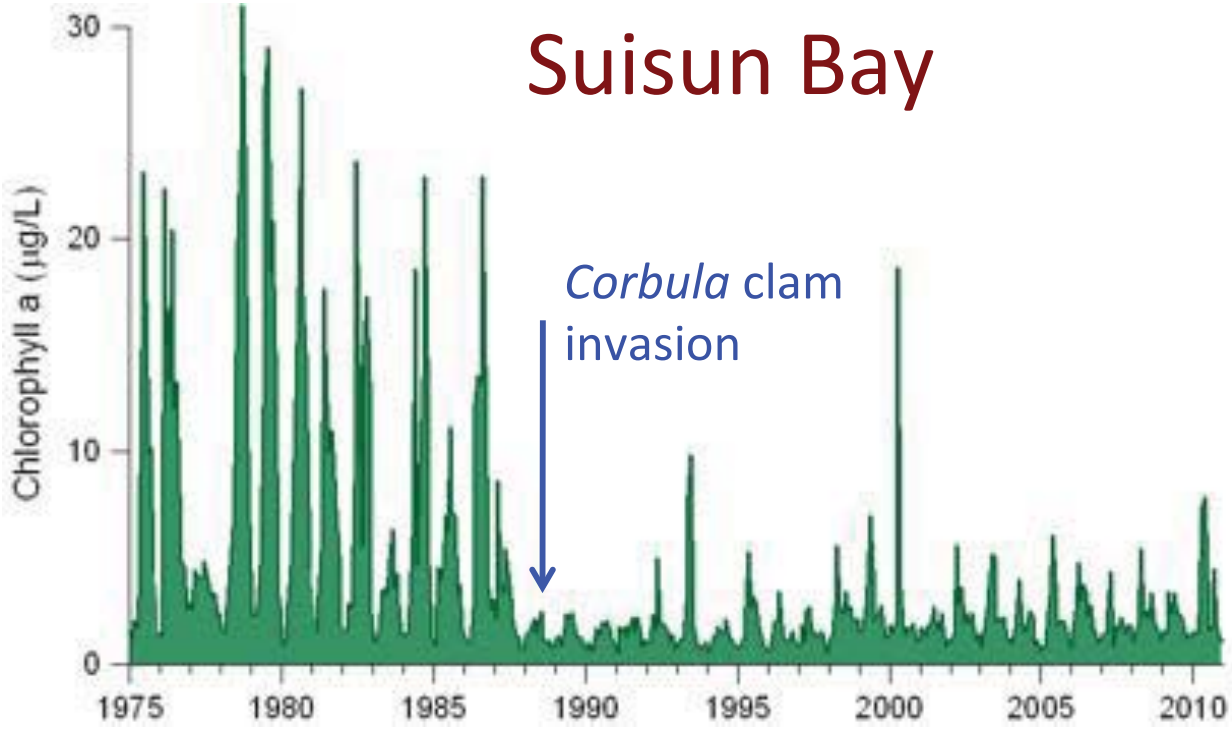
- Light
- T
- Residence time
- Size-selective grazing by clams
- Nutrients

# Phytoplankton

## Suisun Bay

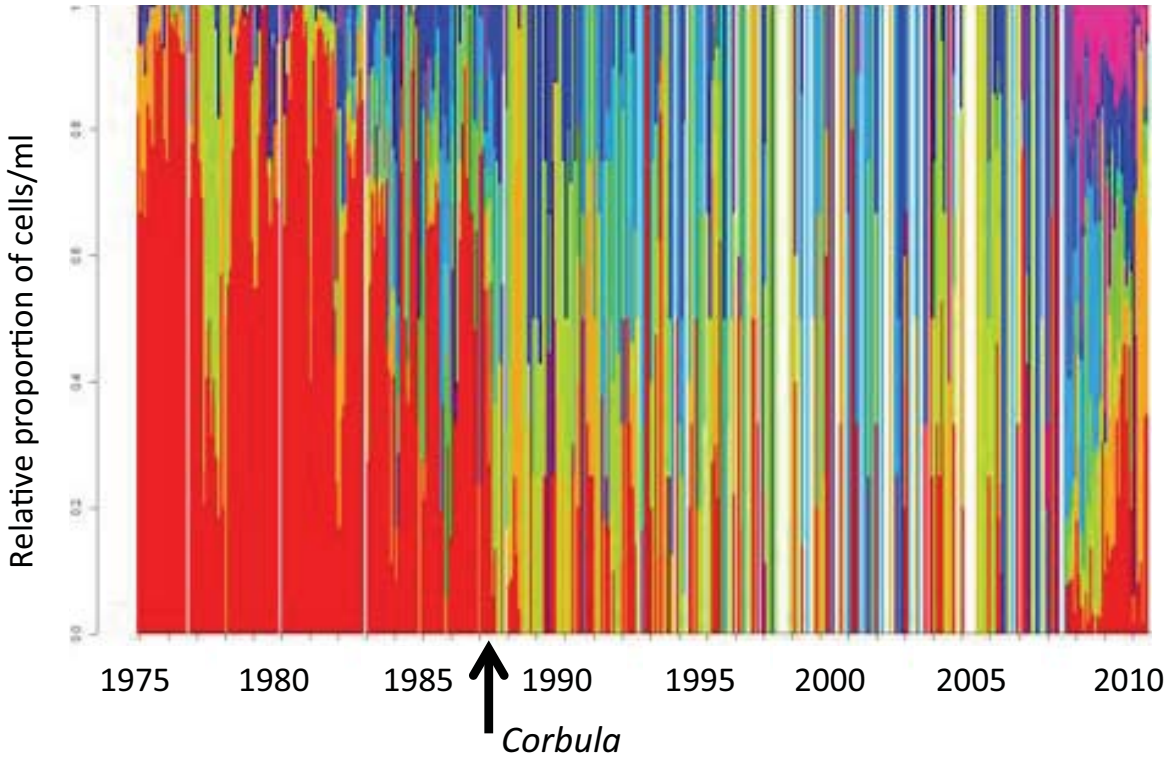
**Drivers/stressors: Biomass**

- Clams
- Light limitation
- Nutrients ($NH_4^+$)
- Residence time




**Drivers/stressors: Composition**

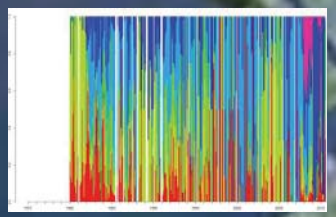
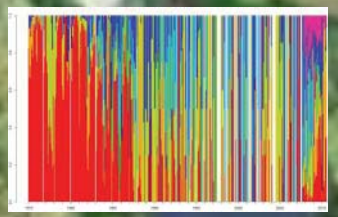
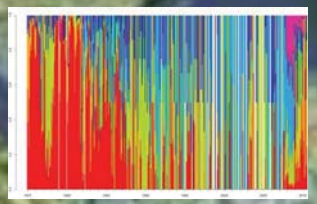
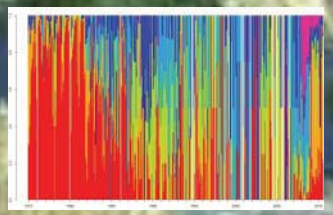
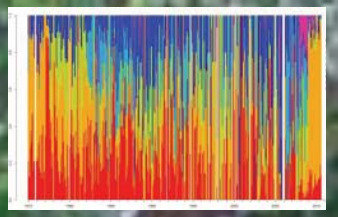
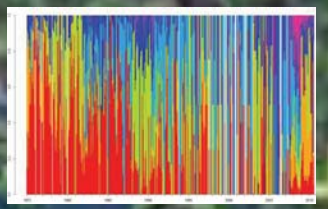
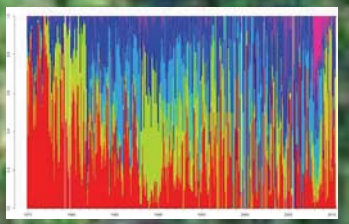
- Clams (size-selection)
- Nutrients
- other


J. Cloern, USGS; IEP/DWR; Senn et al. 2013

# Phytoplankton composition 1975-present

Data: IEP/DWR

- Characterize how phytoplankton composition varies seasonally/spatially, and has changed temporally

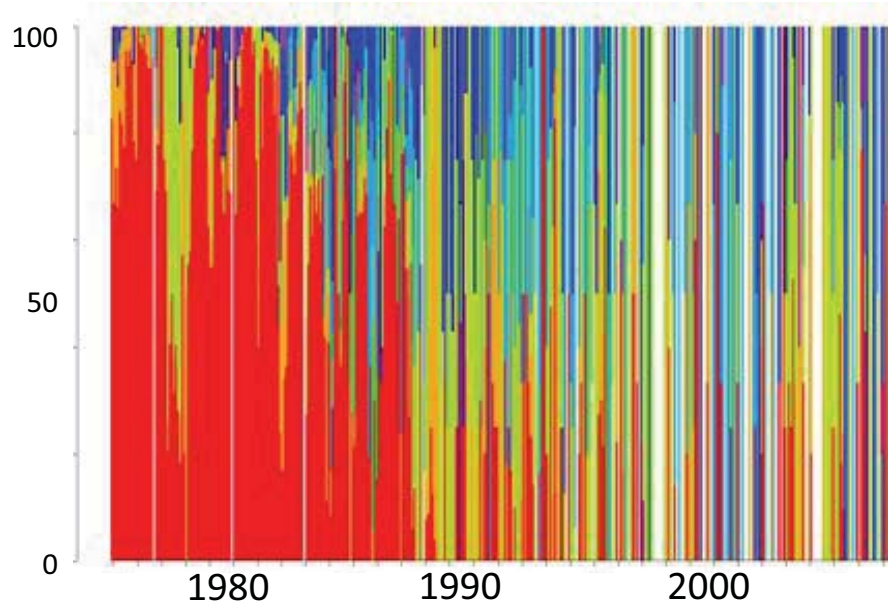
- Quantify role of regulating factors, including nutrients

- Determine 'protective' nutrient levels (?)

Cyanobacteria
Green Algae
Other Flagellates
Euglenoids
Dinoflagellates
Cryptomonads
Pennate Diatoms
Centric Diatoms

# Monthly phytoplankton composition
(%total of cells/mL)

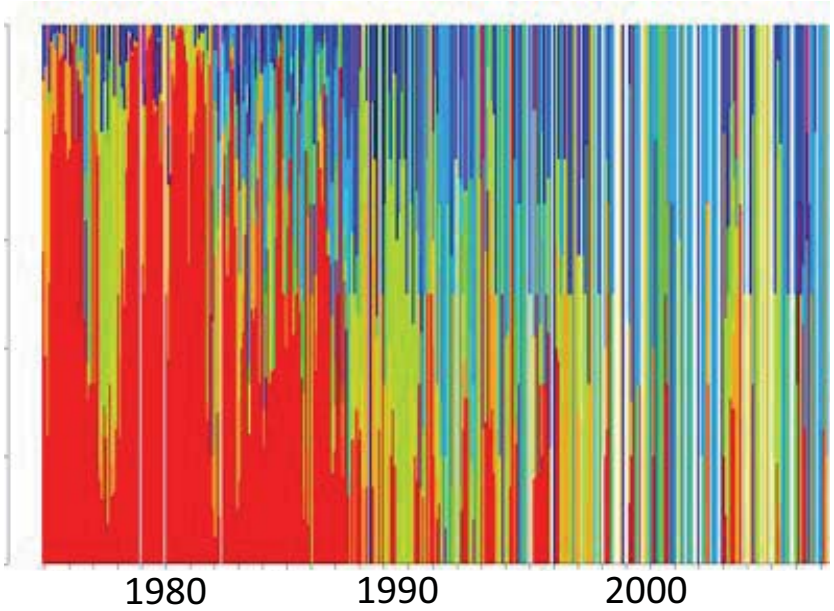
D7



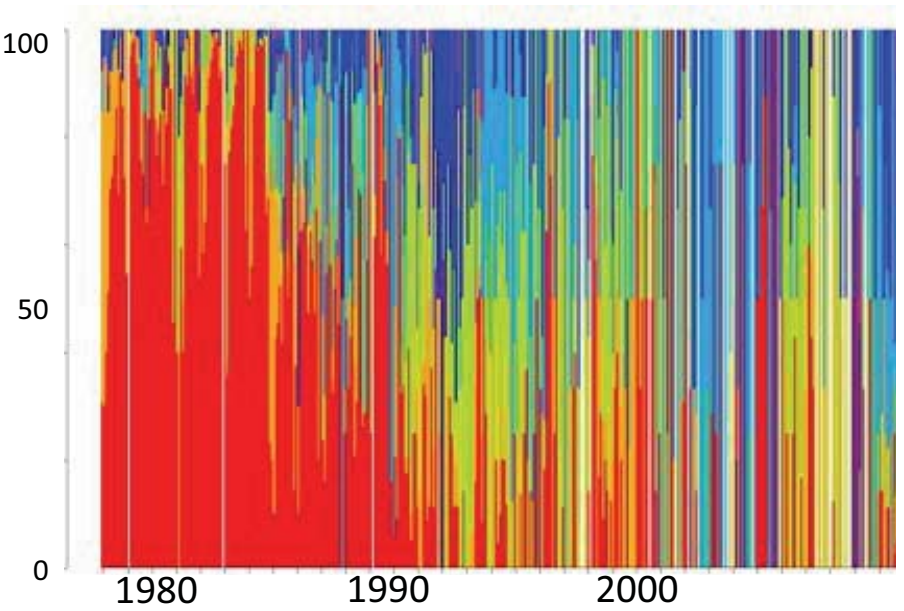



Data: IEP/DWR

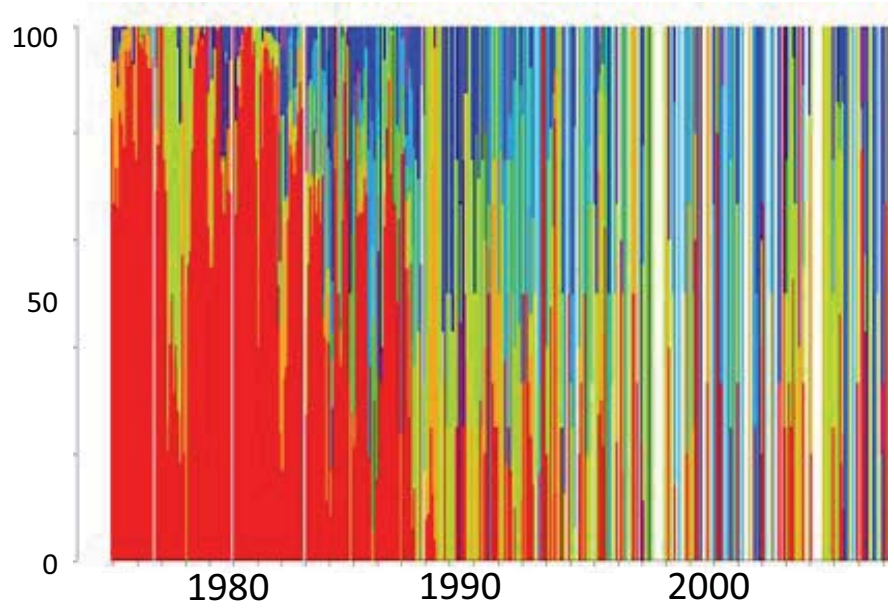
D8




D4



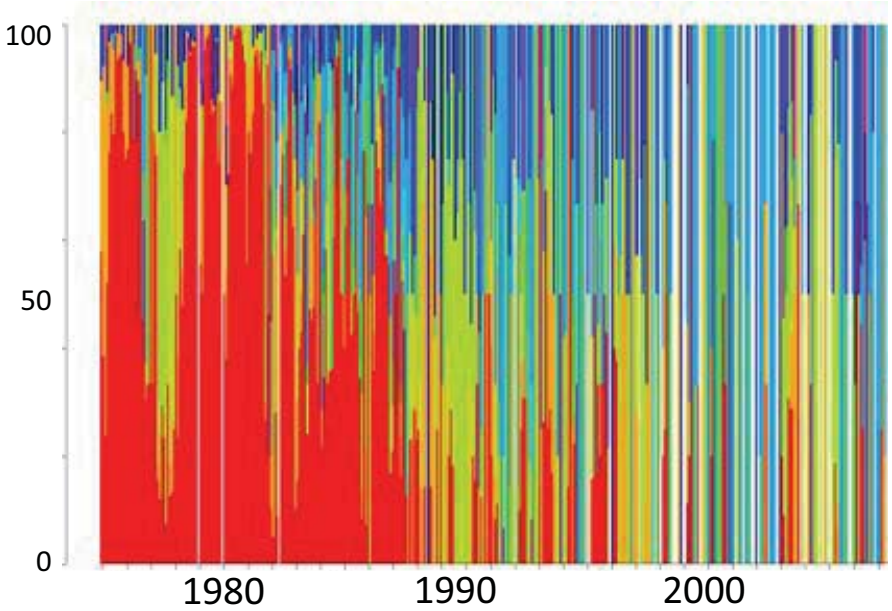
D7



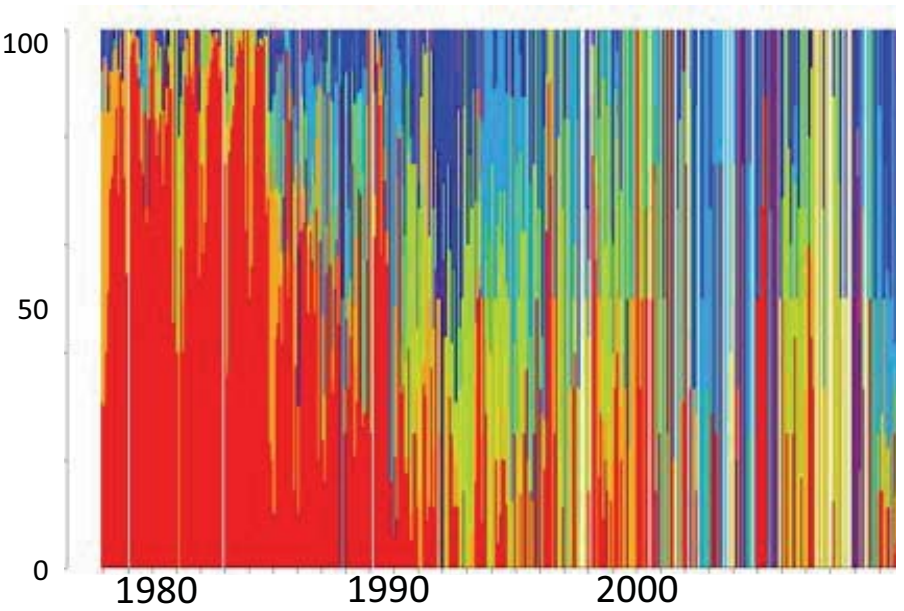

- 8 classes of organisms
- ~1500 individual compositions
- Reduce to fewer variables
  - 8 → 2
  - 1500 → 10

Data: IEP/DWR


D8

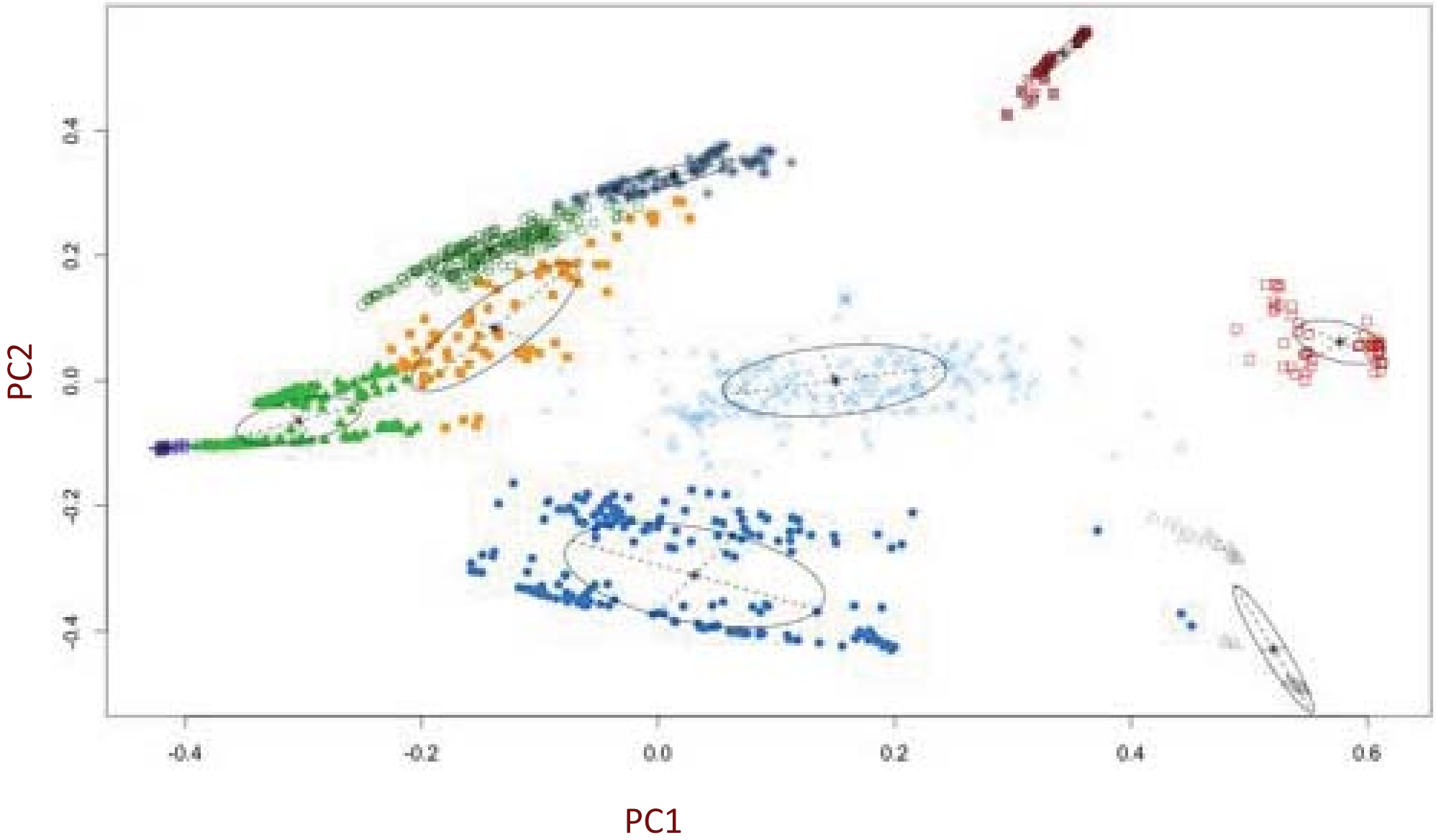



D4



# Principal Components Analysis

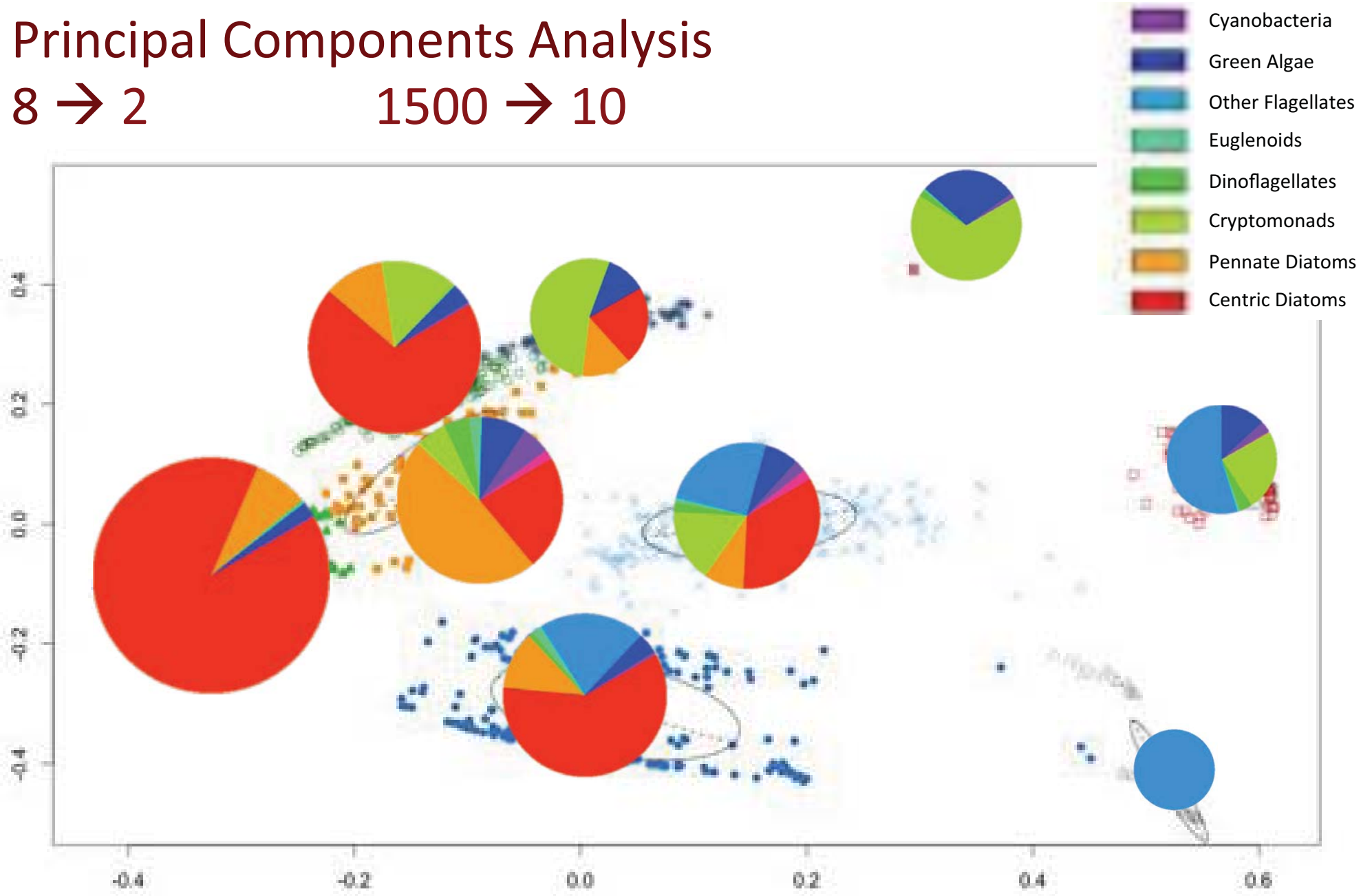
8 → 2 1500 → 10




SFEI (2014)

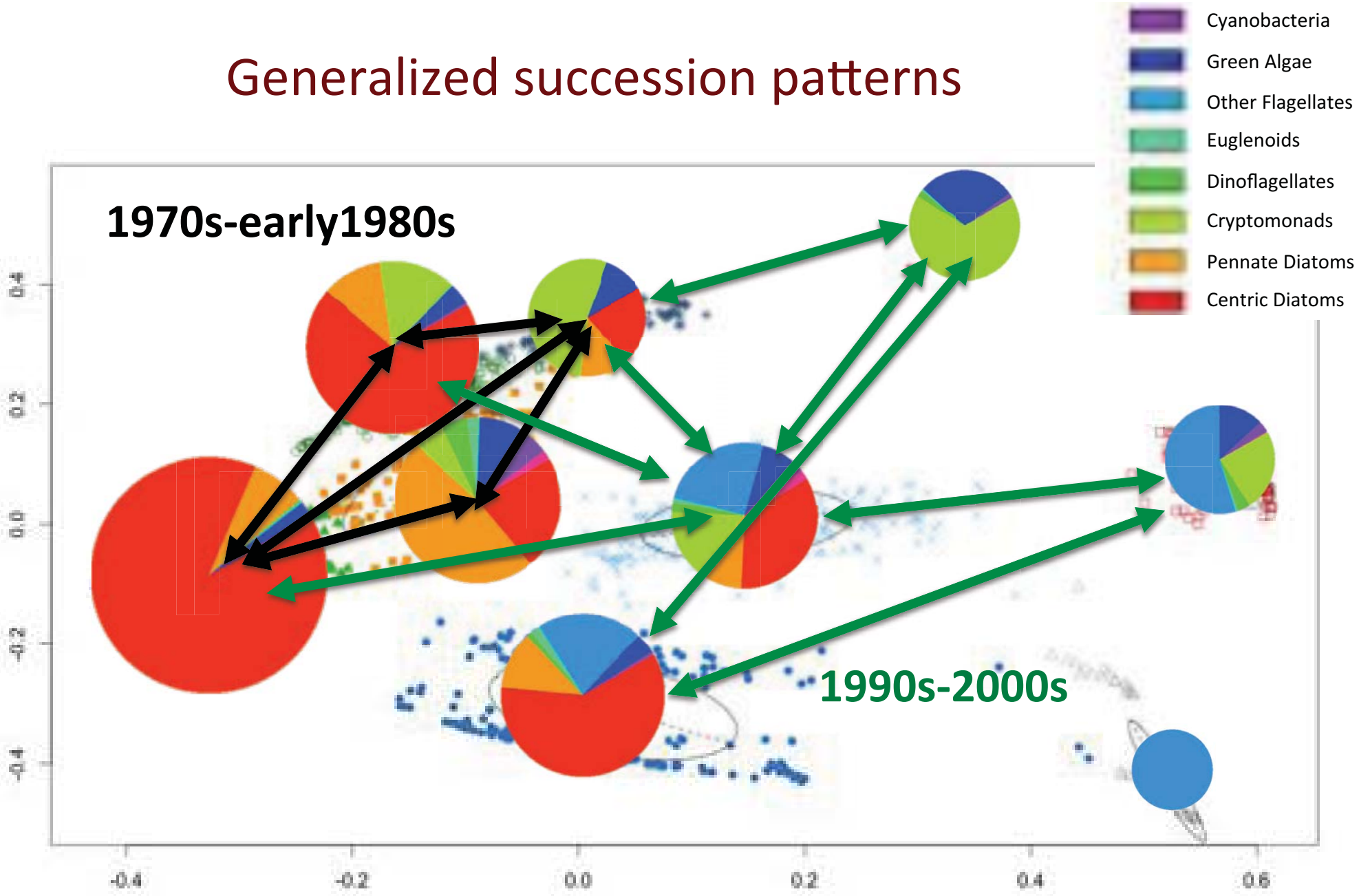
# Principal Components Analysis

8 → 2 1500 → 10




SFEI (2014)

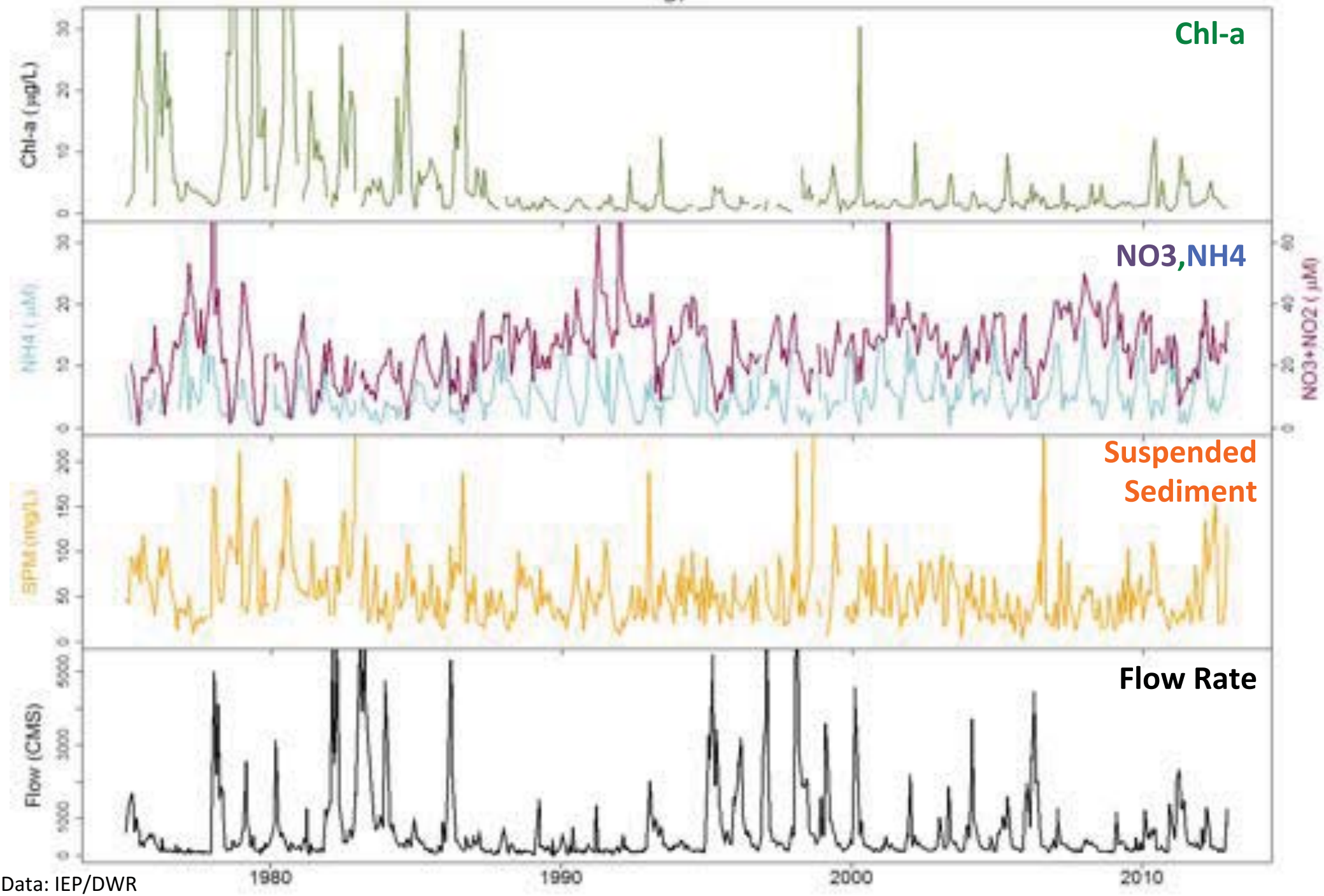
# Generalized succession patterns




Seasonal succession

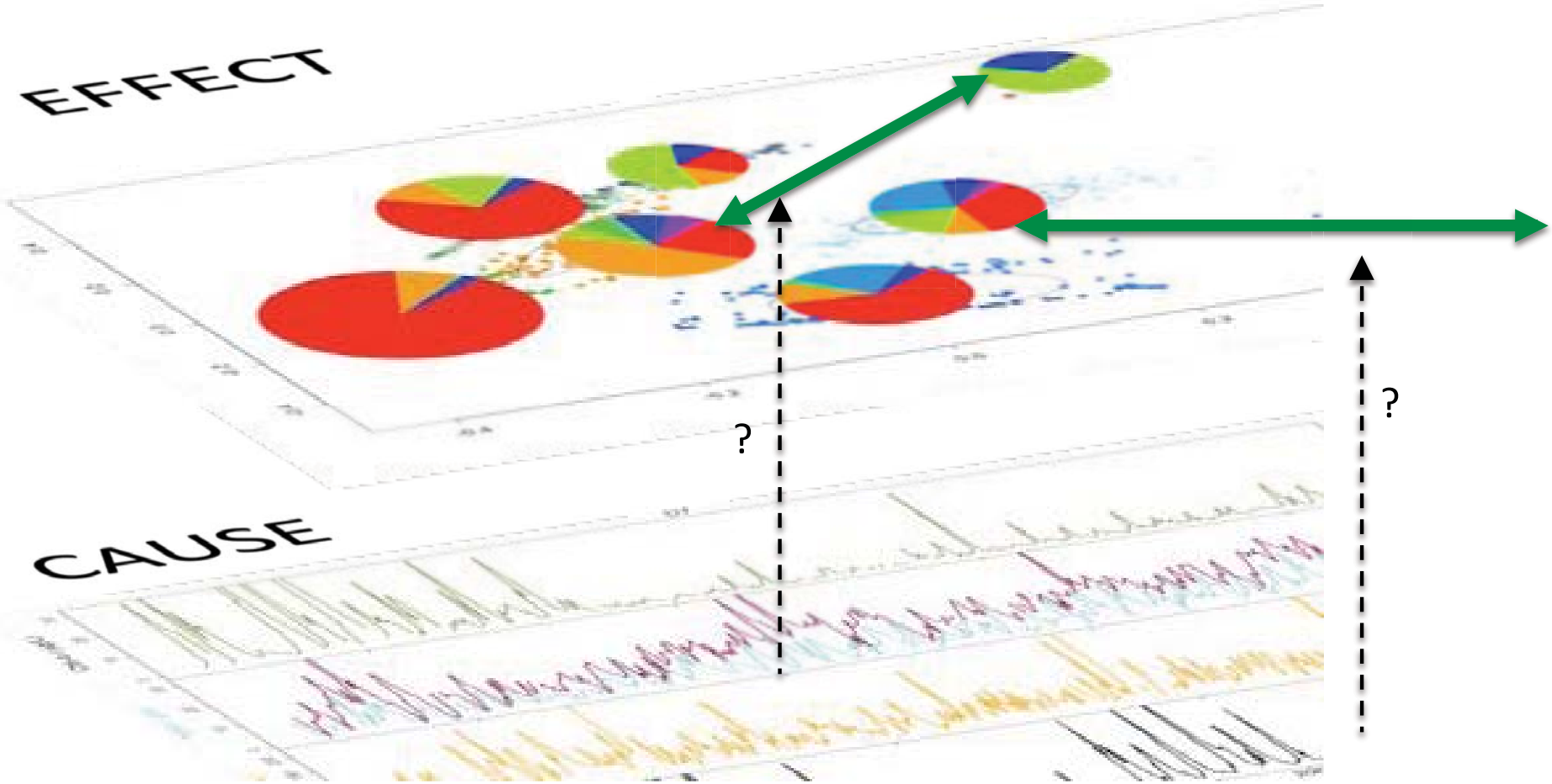
SFEI (2014)

# Physical and Chemical Environment – Suisun Bay 1975-2013




Data: IEP/DWR
SFEI (2014)

# Next Steps



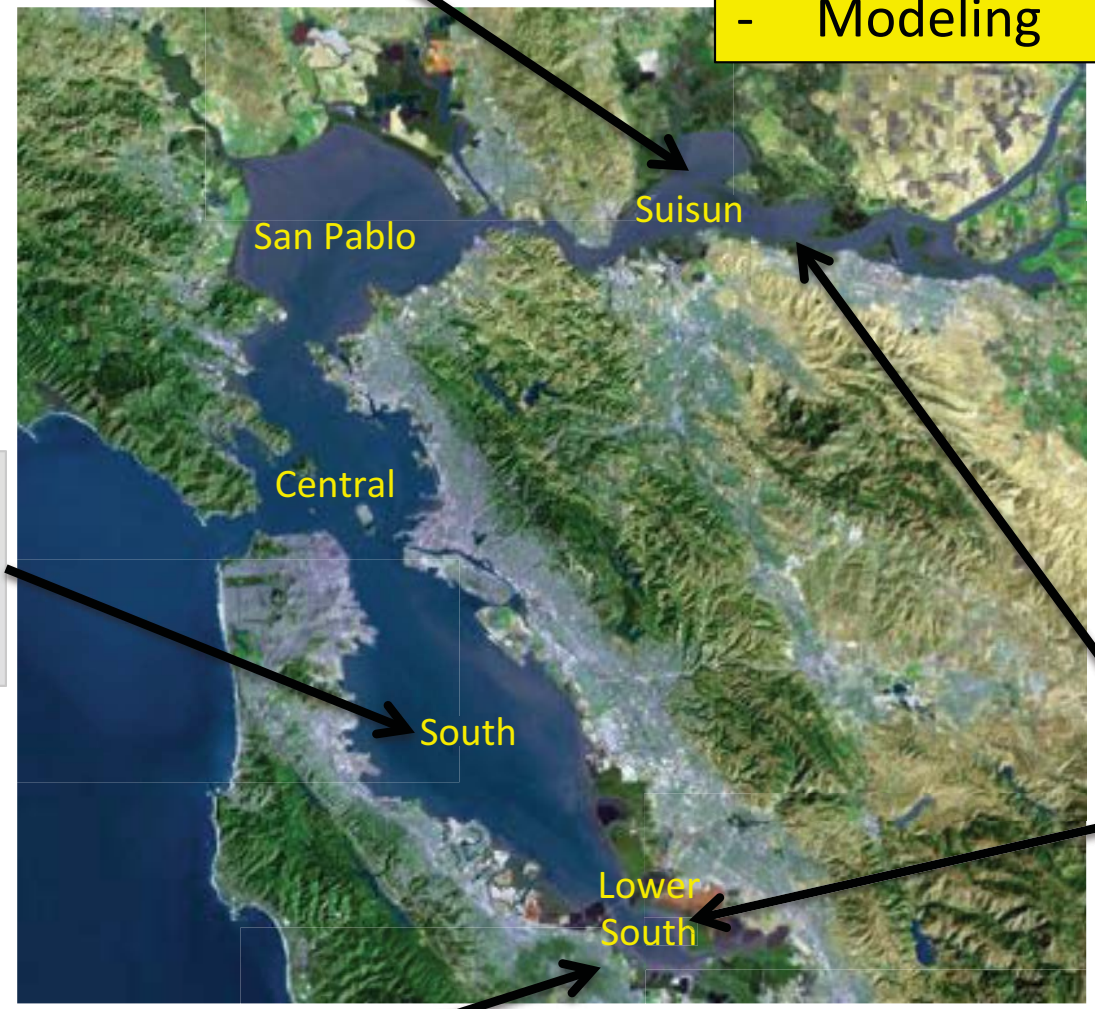

Can we identify causal mechanisms for phytoplankton shifts?

# Key Points

- Several priority issues identified and studies underway
  - Increasing phytoplankton abundance…Cause? Trajectory?
  - Dissolved oxygen in margin habitats (sloughs, creeks, wetlands)
  - Effects of nutrients on types of phytoplankton (HABs, food quality)
- For some issues, excellent data to begin cause/effect analysis
  - Phytoplankton abundance and composition
  - Nutrient loads, ambient concentrations
- More monitoring and process studies needed…
  - margin-habitat DO
  - phytoplankton composition and HABs/toxins
  - moored sensors and field investigations
- Modeling a near-term next step to rigorously analyze data and forecast

5. On-going work
- Monitoring program development
  - Phyto composition, HABS, Moored sensors
- Modeling

4. Changing phytoplankton species




2. Changes in phytoplankton biomass

1. Nutrient Loads Spatial/seasonal variability

3. Dissolved Oxygen in LSB

# Monitoring Program Development

- Special studies
  - Cost-effective phytoplankton monitoring
  - Algal toxins
- Moored sensors
- Data analysis to inform program development
  - Where/when/what to measure
  - Institutional support/collaboration

# Phytoplankton pigments to quantify species composition and abundance

*Collaborators:*

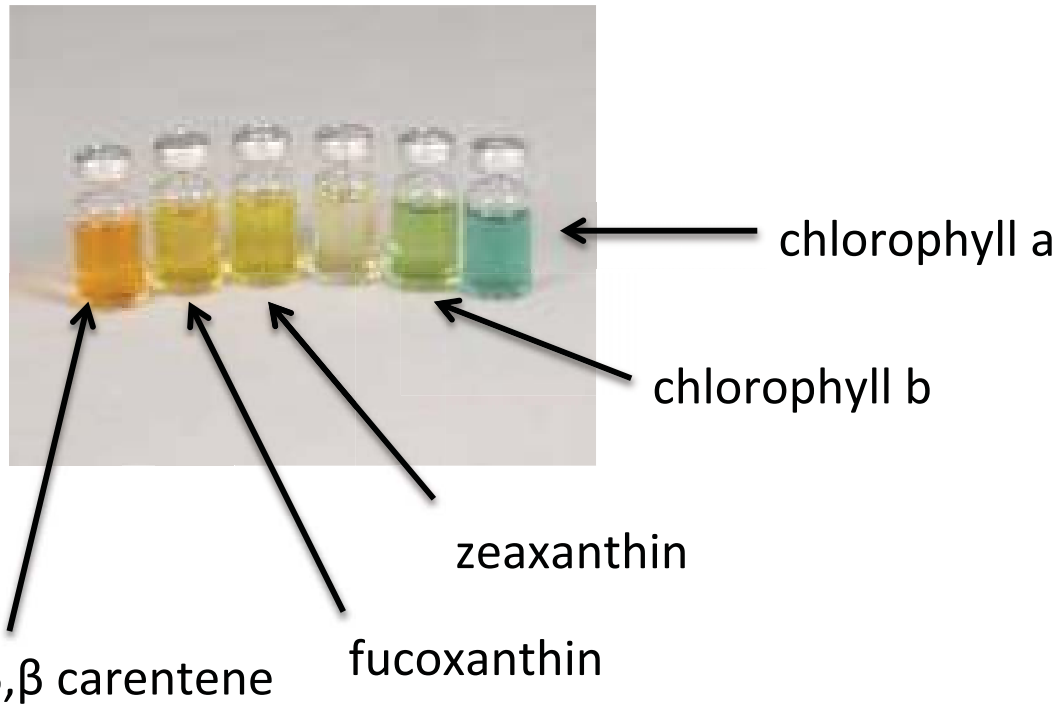
UC Santa Cruz: M Peacock, R Kudela

USGS: J Cloern, T Schraga

Pigments

$40-60$/sample

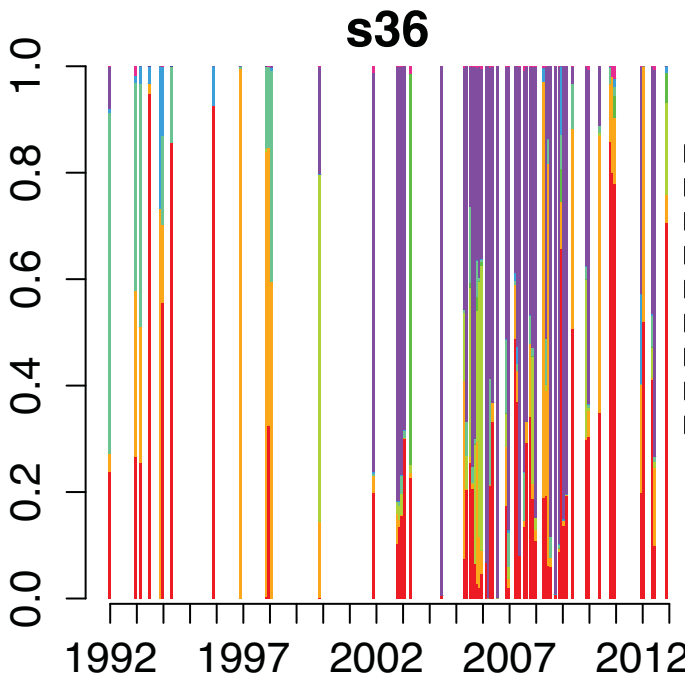
faster




Microscopy

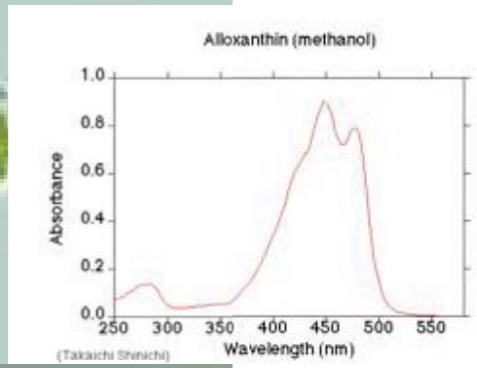
$300-400/sample

Time-consuming

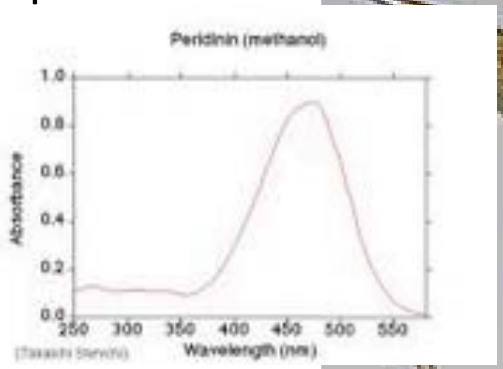


Chrysophyceae

alloxanthin



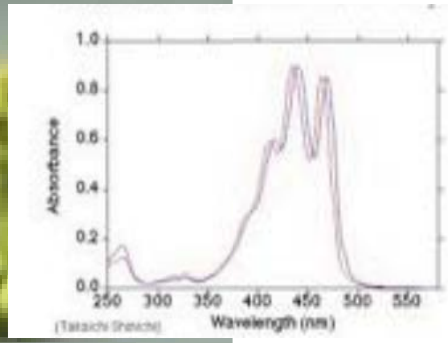

peridinin



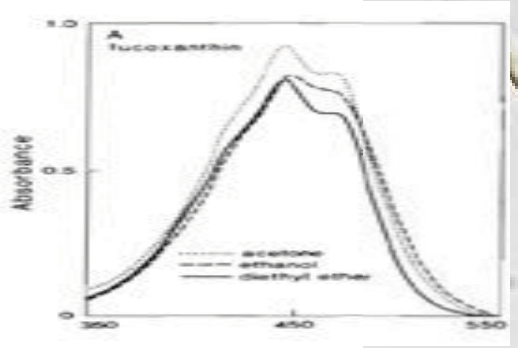

Dinoflagellates

Green Algae

prasinoxanthin



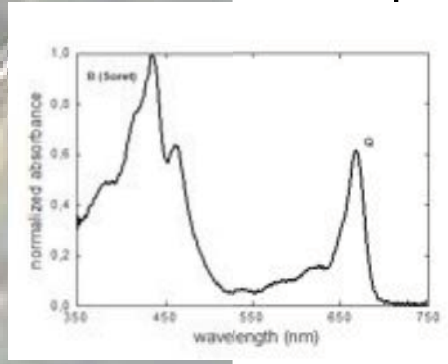

fucoxanthin



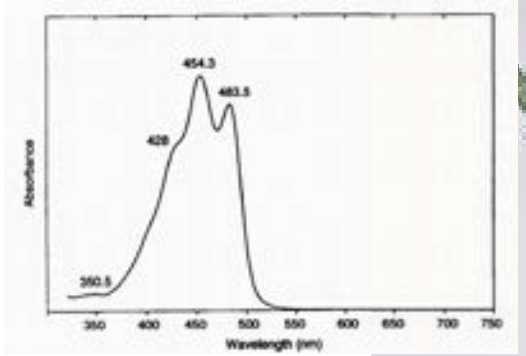

Diatoms

Chlorophyceae

chlorophyll b



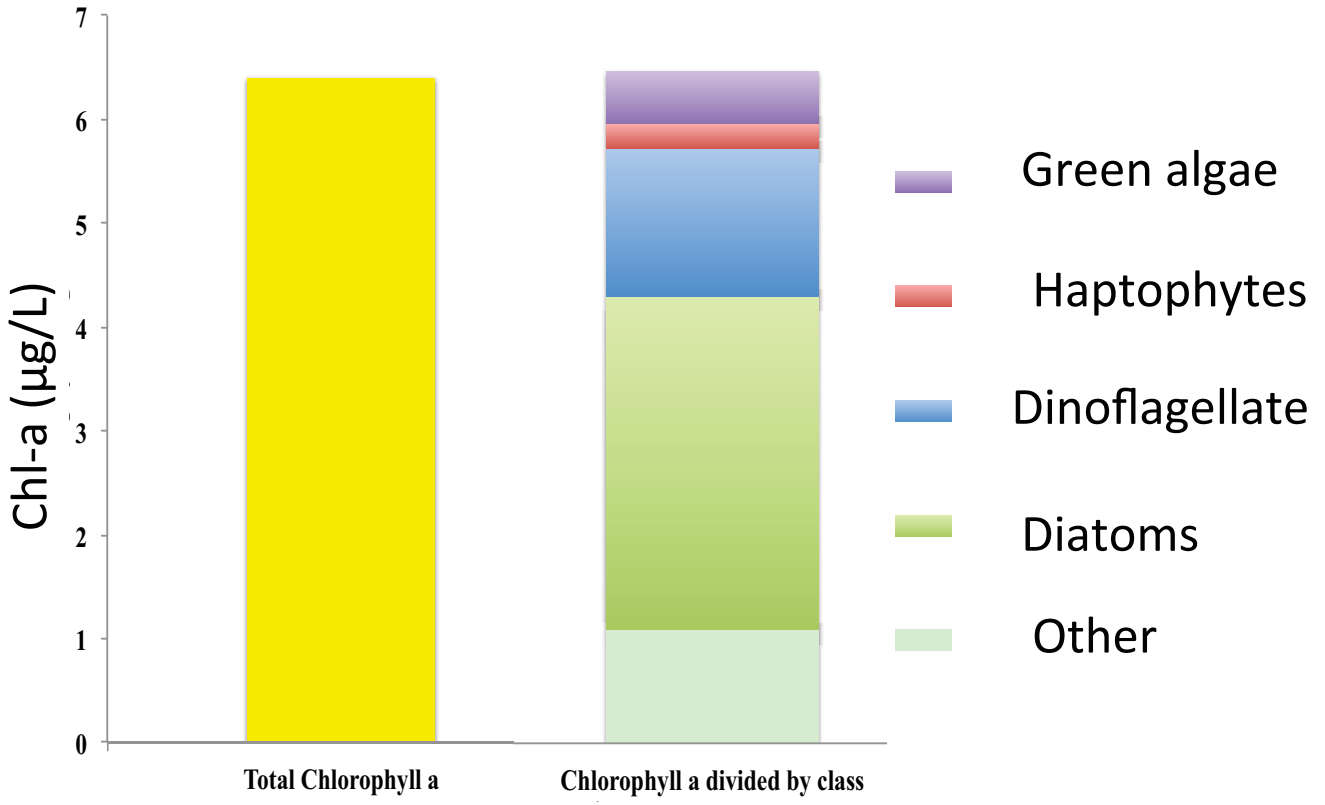

zeaxanthin



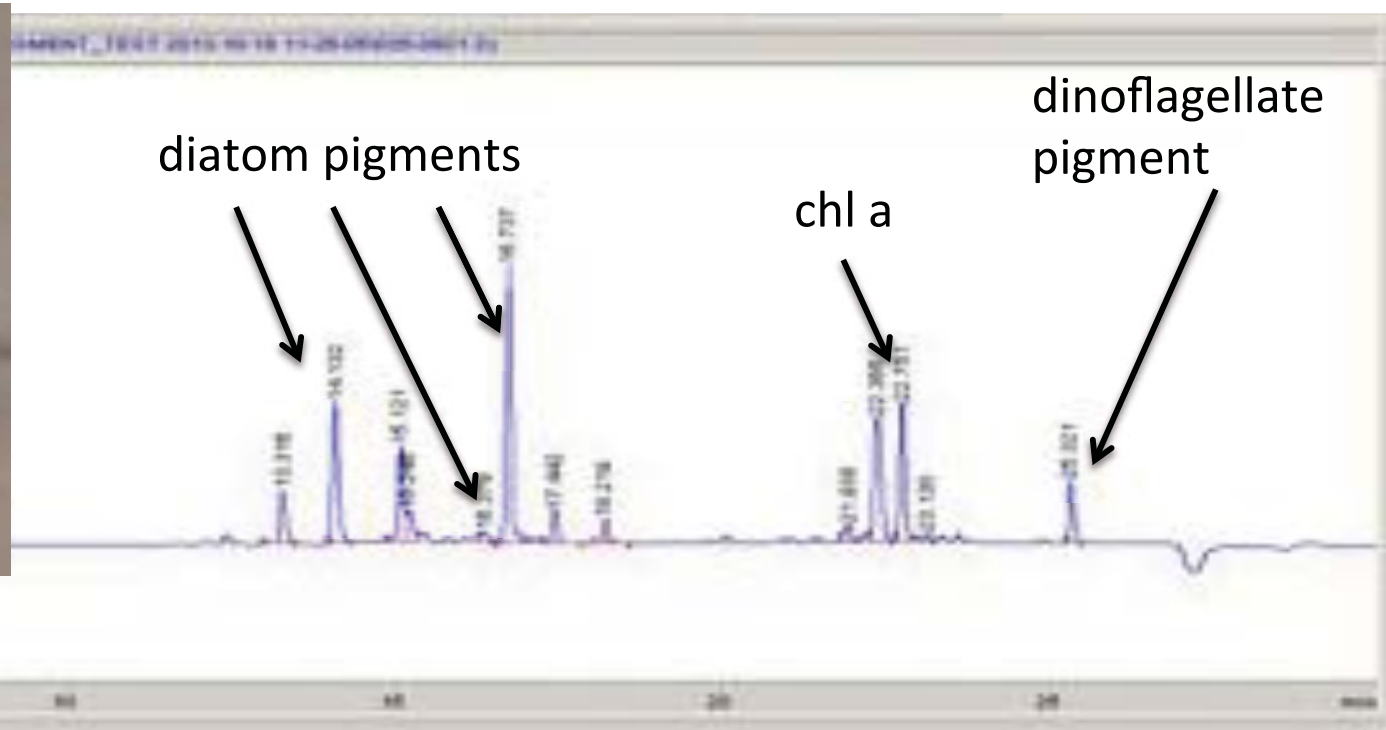

Cyanobacteria


Water Quality
Sampling
Stations

June 2013


Chl-a (µg/L)
0
1
2
3
4
5
6
7
Total Chlorophyll a
Chlorophyll a divided by class
Green algae
Haptophytes
Dinoflagellate
Diatoms
Other


Akashiwo sanguinea


diatom pigments
chl a
dinoflagellate
pigment

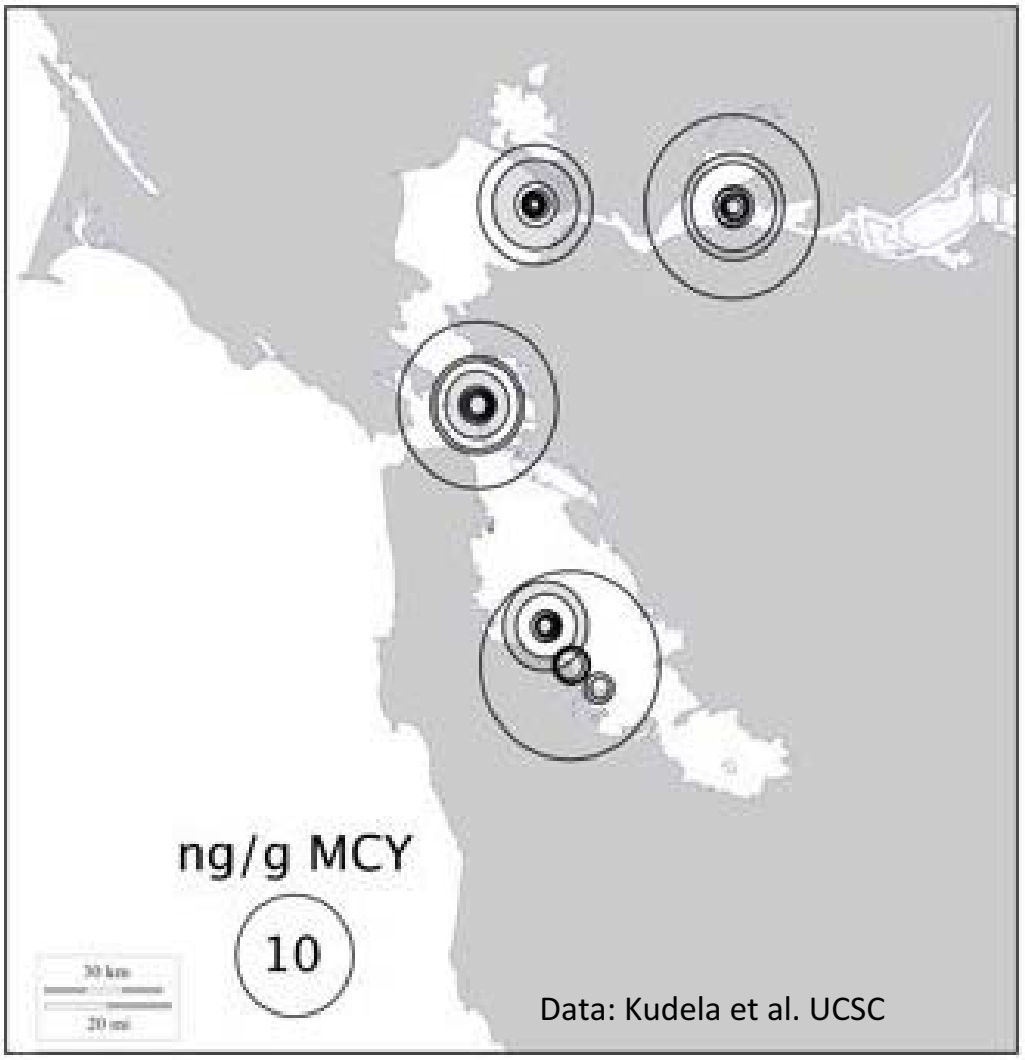
# Monitoring for algal toxins (2011-2013)

*Collaborators: UCSC, USGS*

Funding: USGS, RMP

Solid Phase Adsorption Toxin Tracking

## SPATT Microcystins





Circles are centered on the midpoint of each USGS *Polaris* transect with underway SPATT

# Monitoring for algal toxins (2011-2013)

*Collaborators: UCSC, USGS*

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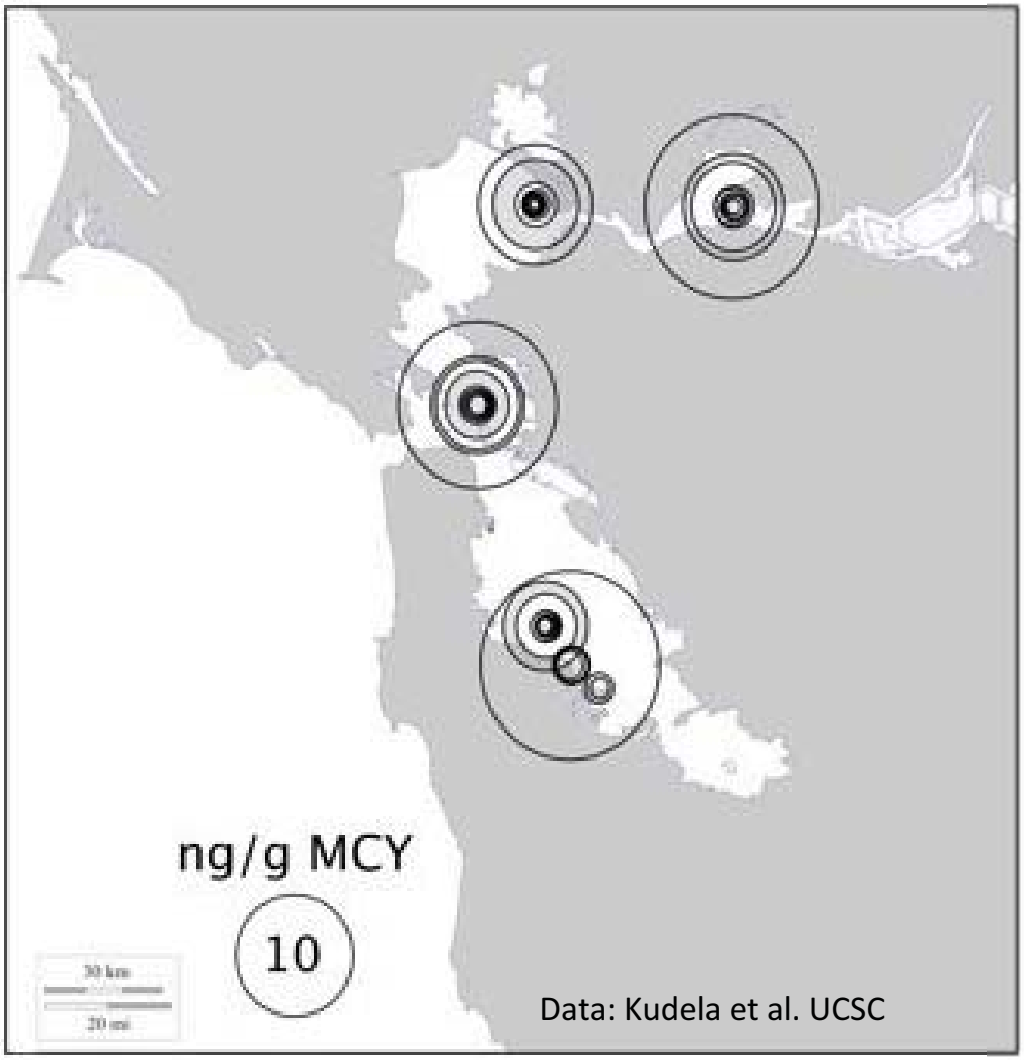
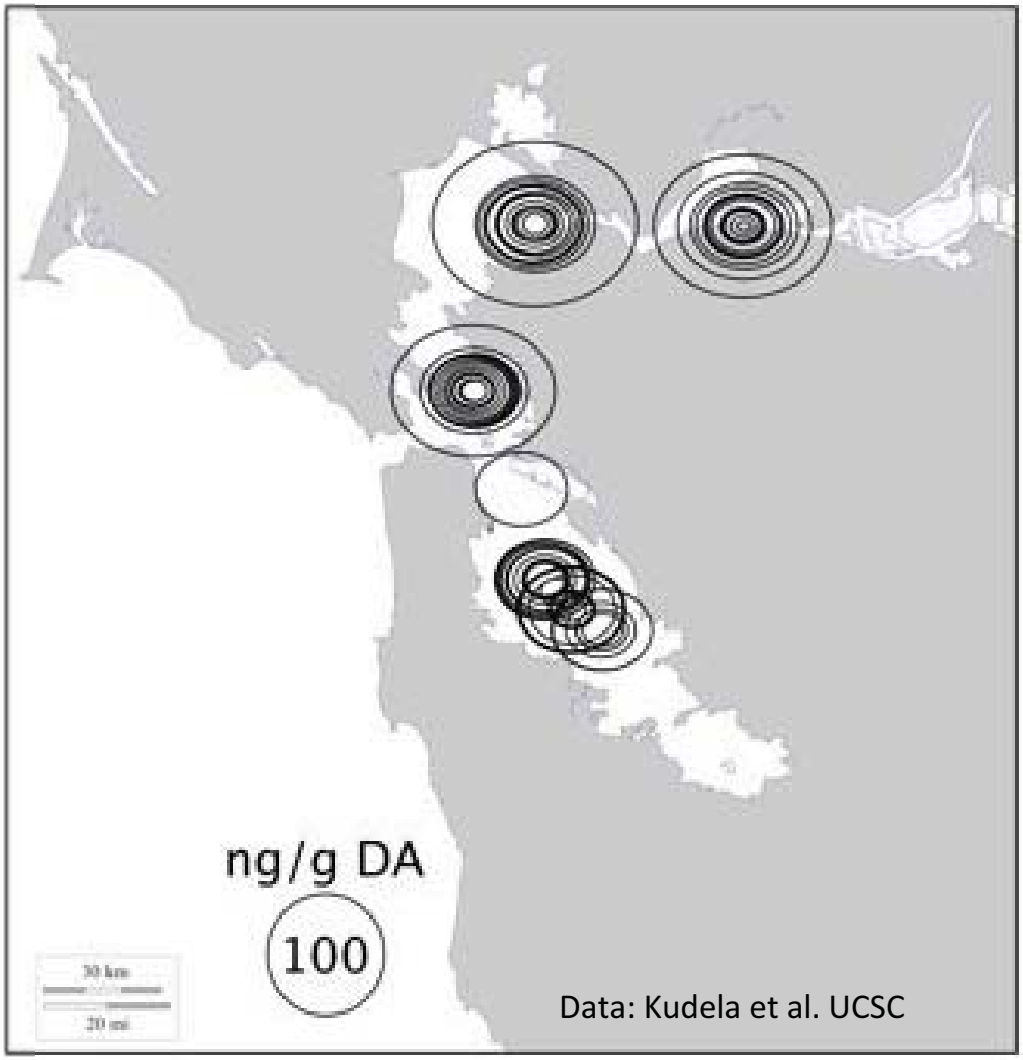
## SPATT Microcystins




## SPATT Domoic Acid




Circles are centered on the midpoint of each USGS *Polaris* transect with underway SPATT

# Moored sensors

- DO
- T, salinity
- Chl
- Turbidity
- pH
- …


Three Pilot Stations:

- July-present

# Moored sensors

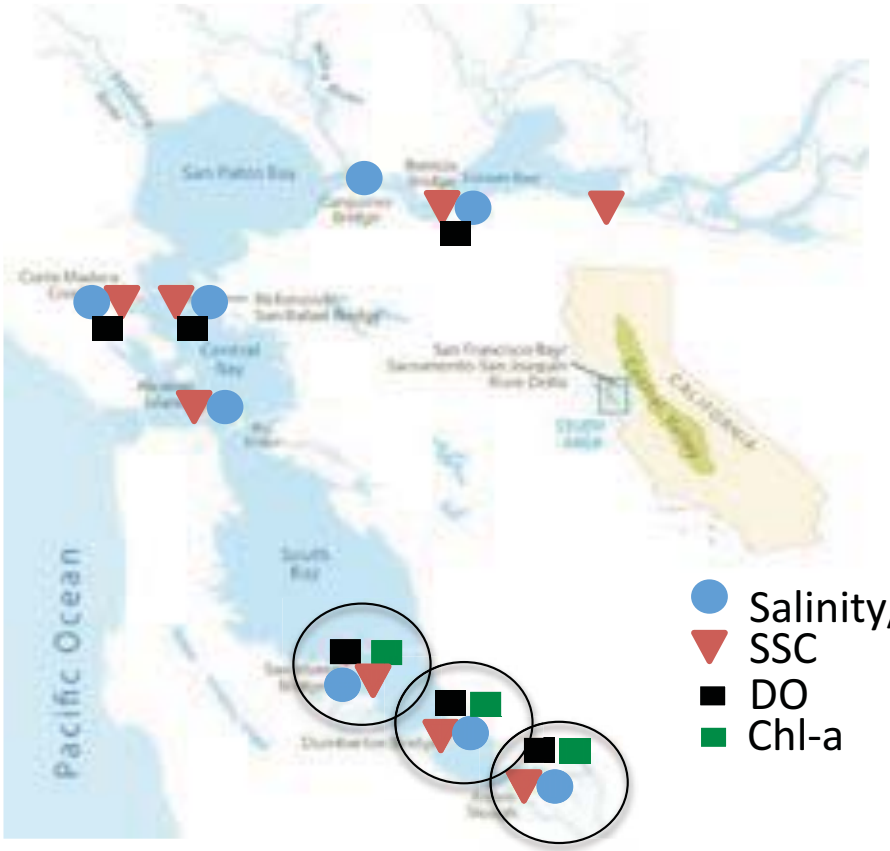
- DO
- T, salinity
- Chl
- Turbidity
- pH
- …


*On-going work…*

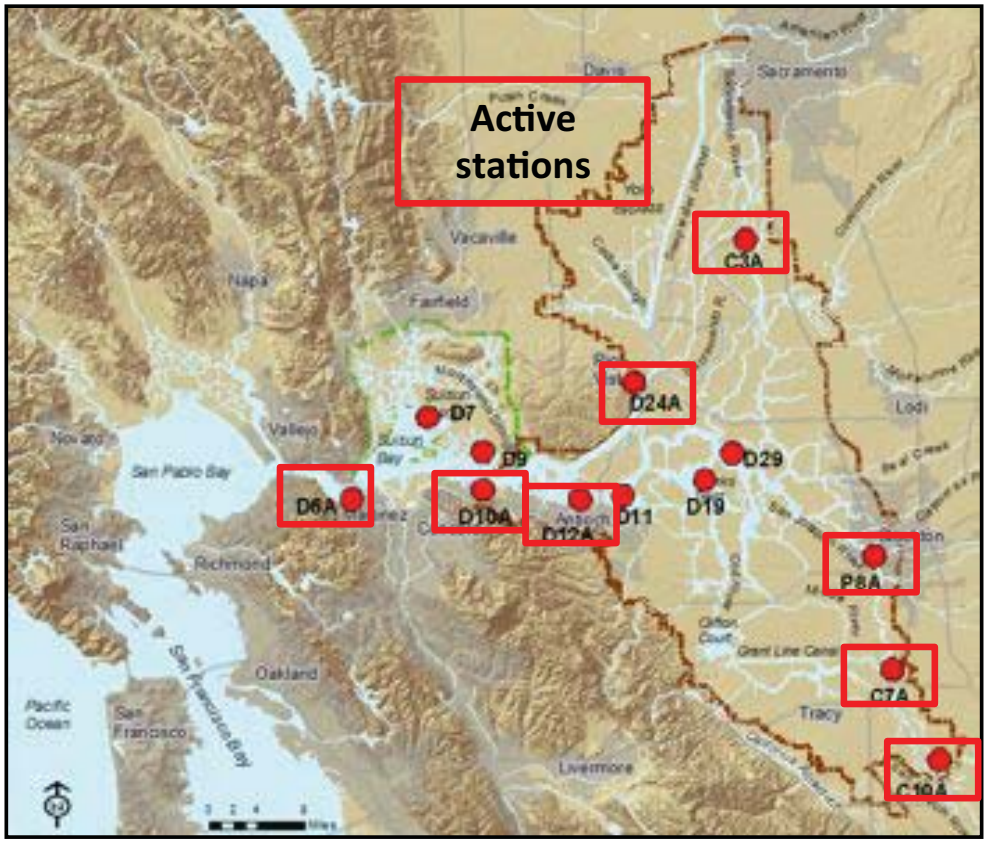
- Optimum locations
- Balance between ship-based and moored sensors
- Real-time data and expandable platforms
- Collaboration

# Moored sensor stations

USGS-Sacramento + SFEI/RMP

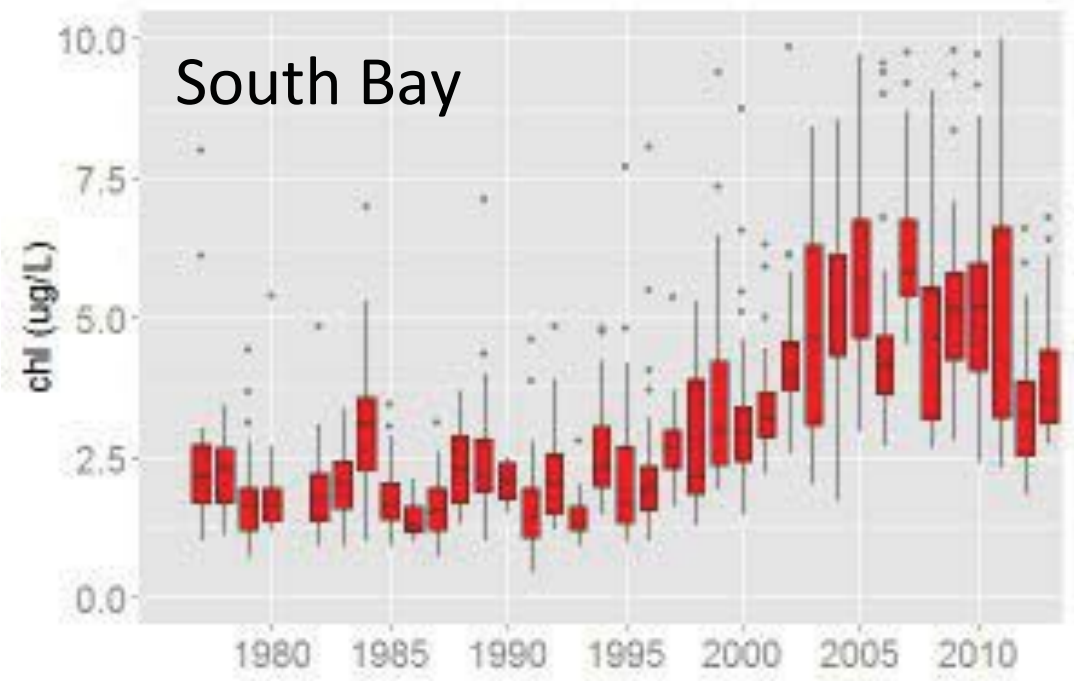



DWR




USGS/SFEI collaborative stations

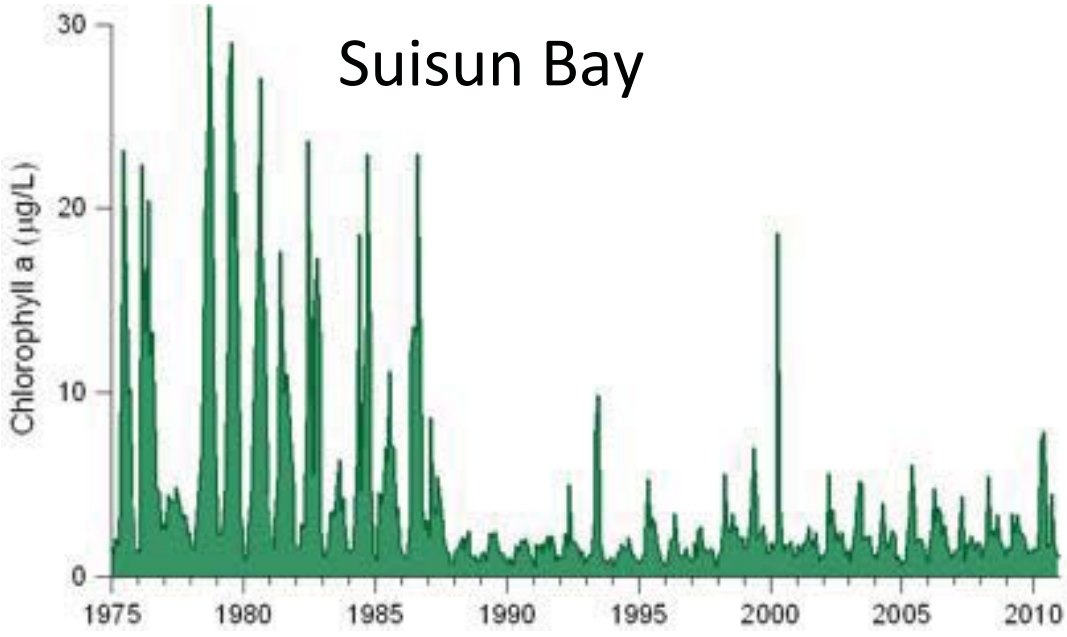
# Water Quality and Hydrodynamic Modeling



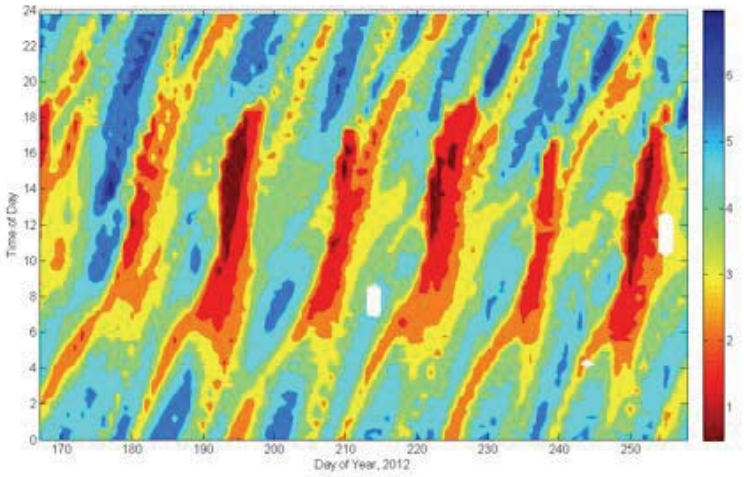

What can explain these changes or conditions?

What will conditions be under future scenarios?

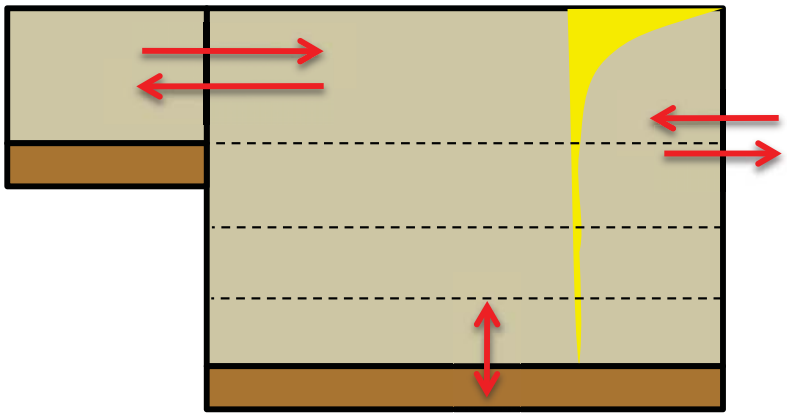
What management actions would prevent/mitigate impairment?

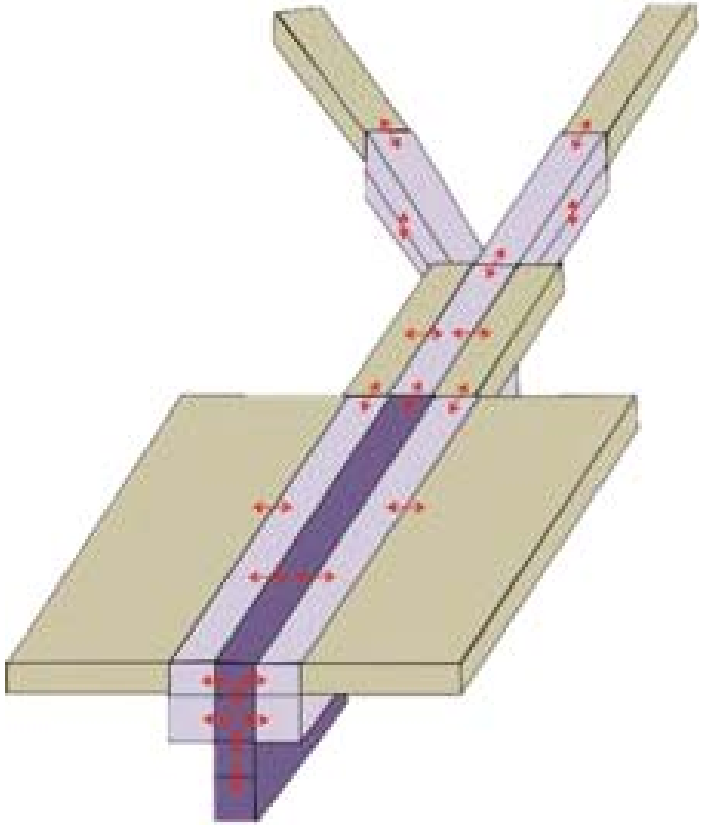



DO: Alviso Slough

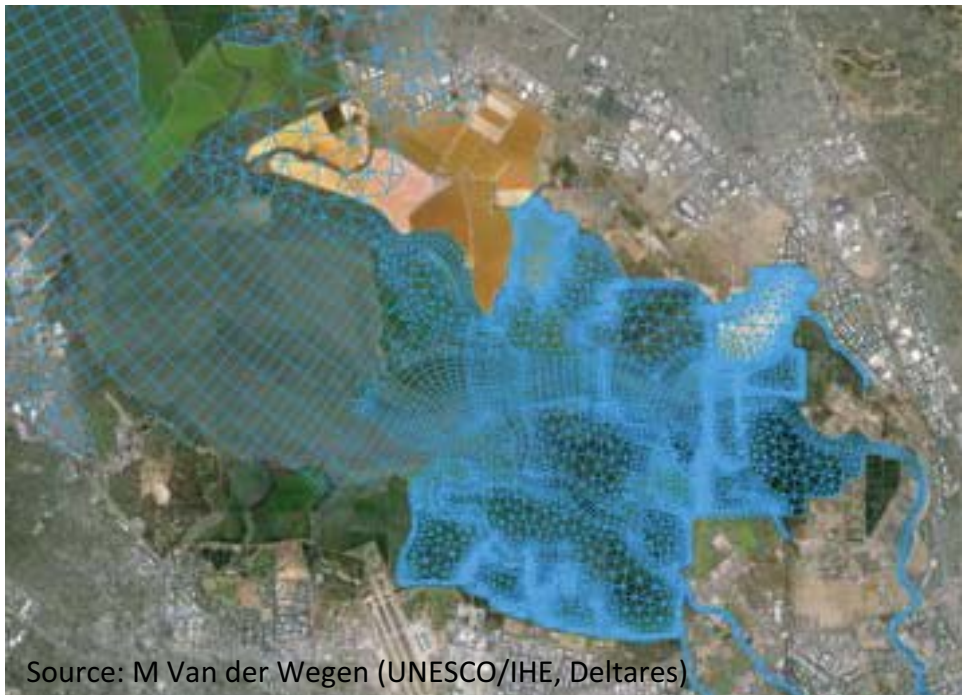


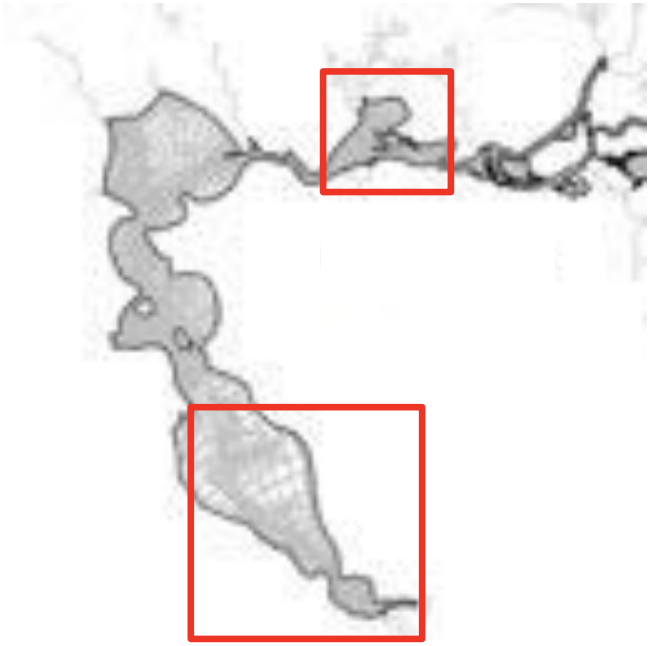
# Water Quality Modeling





- residence time
- light
- clams
- $NH_4^+$ impacts on production
- budgets: transformations, sources, and sinks






If a portion of the Bay is impaired, how to best mitigate?

One date: Oct 20 2002

ALL

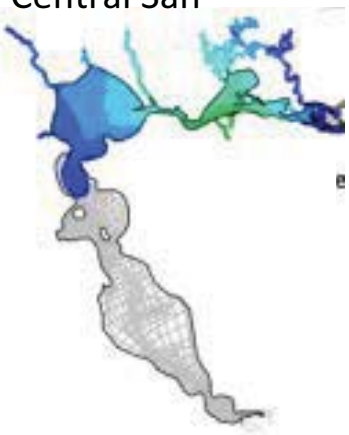
Central San

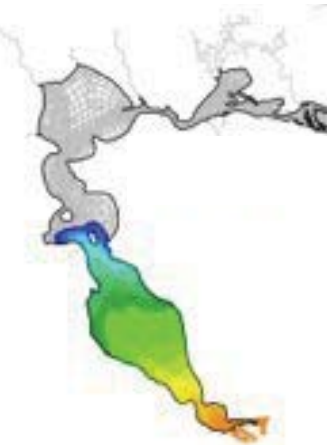
Sac Regional

EBDA

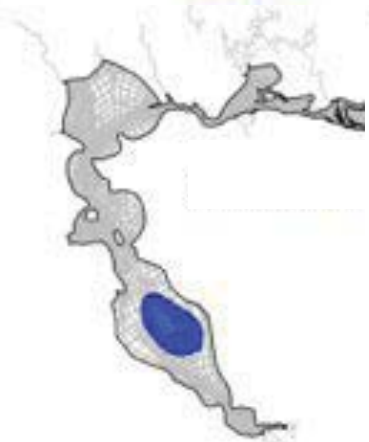
SJSC, Palo Alto, Sunnyvale

Conservative





Decaying ($0.05\ d^{-1}$)



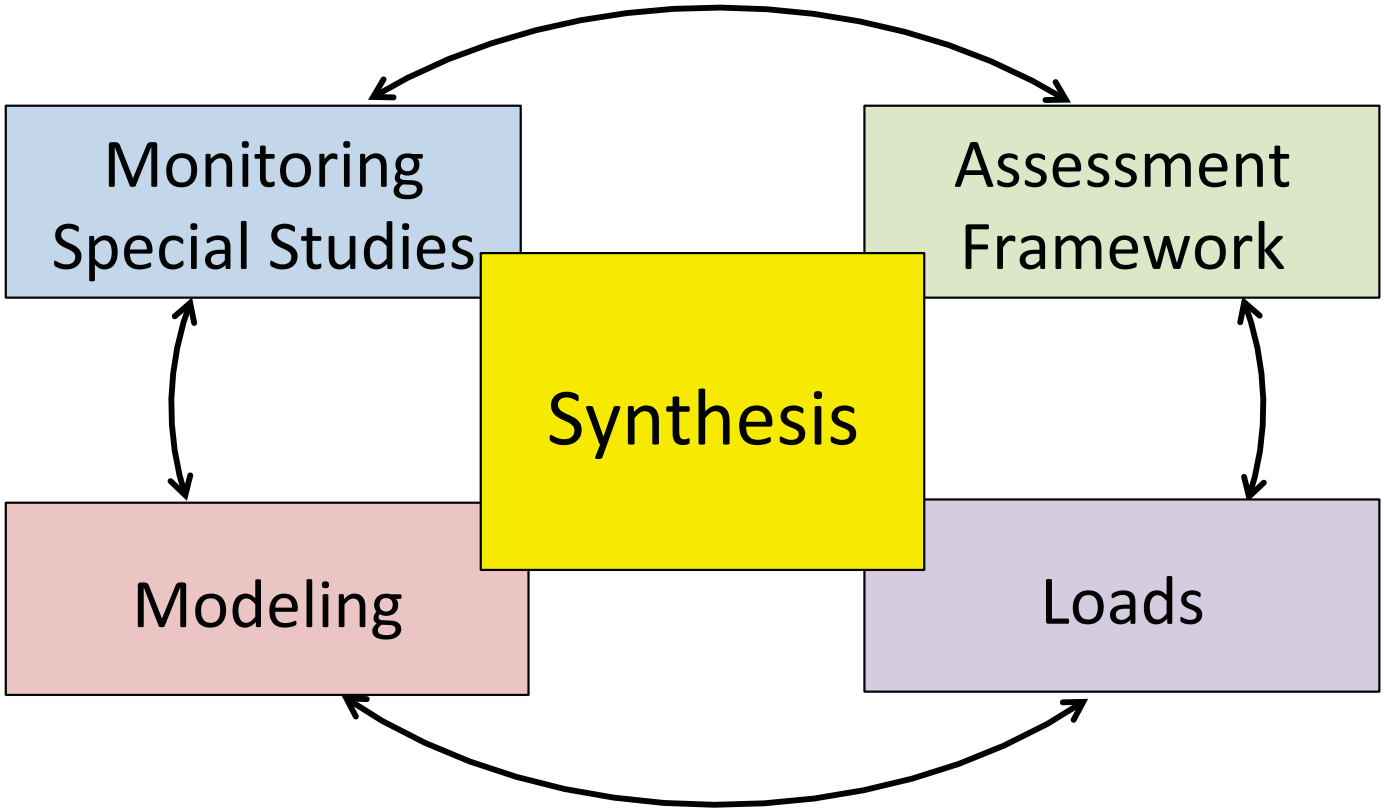
Source: E Gross, S Grinsberg RMA

November 2012

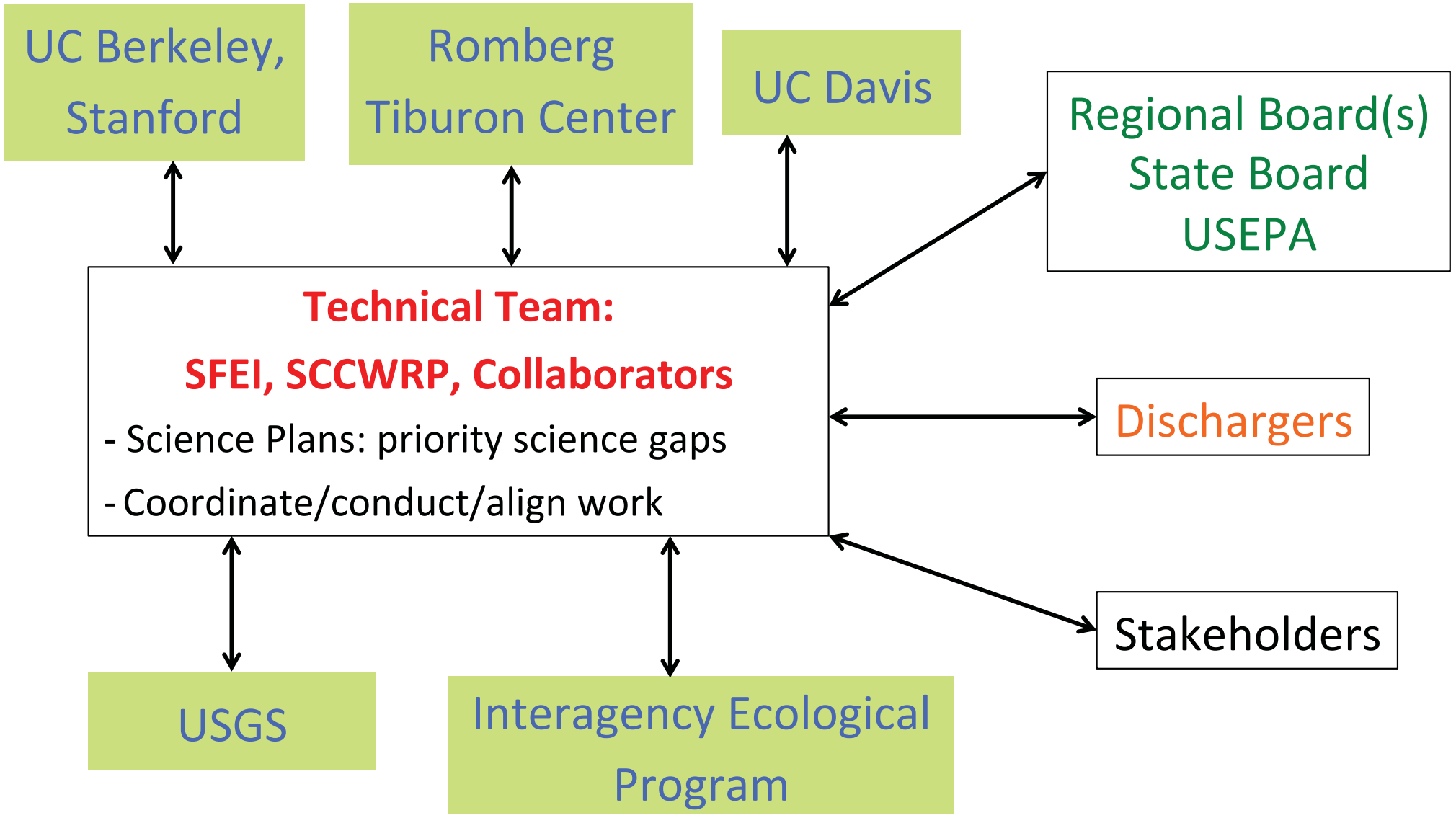
San Francisco Bay Nutrient Management Strategy

*San Francisco Bay Regional Water Quality Control Board*

# Nutrient Science Program



# Nutrient Science Program




Source: C. Benton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