Source: C. Benton

Nutrients Science Program Update

1 Background

2 Science Activities: recent/current work

3 What's next? …*Science Plan*

David Senn, Emily Novick, and ….

January 30 2015

The Team: Key Science Collaborators

SFEI

Emily Novick

Anthony Malkassian
(joint postdoc, UCSC)

Phil Trowbridge

Don Yee

Dave Senn

SCCWRP

Martha Sutula

USGS-Menlo Park

Jim Cloern

Lisa Lucas

Tara Schraga

Melanie Raimonet
(joint postdoc, SFEI)

UC Berkeley

Mark Stacey

UCSC

Raphe Kudela

Misty Peacock
(joint postdoc, SFEI)

USGS-Sacramento

Maureen Downing-Kunz

Greg Shellenbarger

Dave Schoellhamer

Program Update

- Web resource for tracking NMS progress
  - sfbaynutrients.sfei.org

- Major Work Products completed in 2014

1. Loading study
2. Conceptual Model: *Scientific Foundation for a San Francisco Bay Nutrient Strategy*
3. Suisun Synthesis I
4. Moored Sensor Year 1 report
5. Monitoring Program Development Plan
6. Detailed Modeling Plan

- Major Work Products anticipated in Q1/Q2 2015

1. Lower South Bay Synthesis
2. Suisun Synthesis II
3. Assessment Framework v1.0
4. Science Plan

- Building strong team of science collaborators

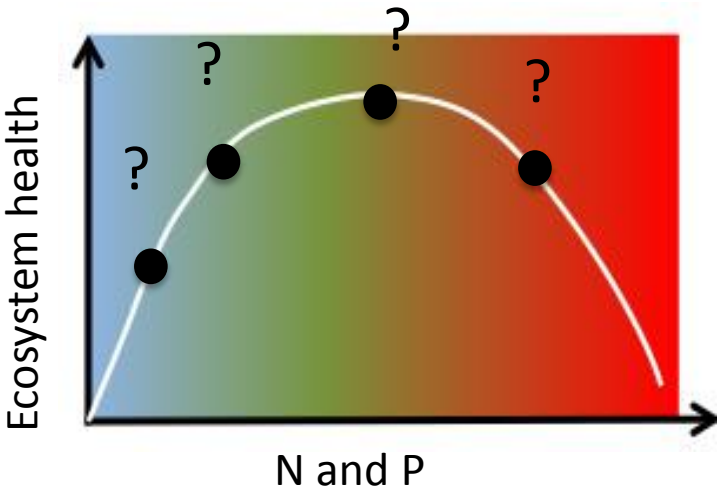
- Work moving forward on several fronts

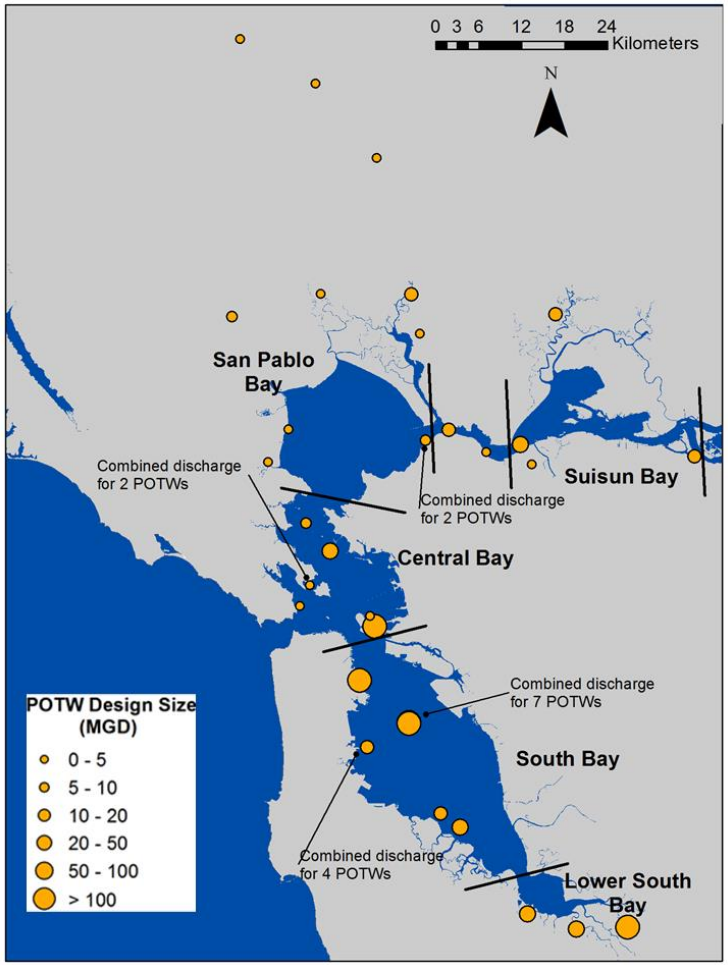
Focus Areas:

1. Monitoring program development
2. Modeling
3. Assessment framework
4. Special Studies: HABs, DO in margin habitats

Does SFB have nutrient problems?

How can adverse impacts best be mitigated or prevented?





N and P in SFB

- Large loads
- High concentrations
- 'Muted' response

Cloern and Jassy 2012
SFEI 2014a

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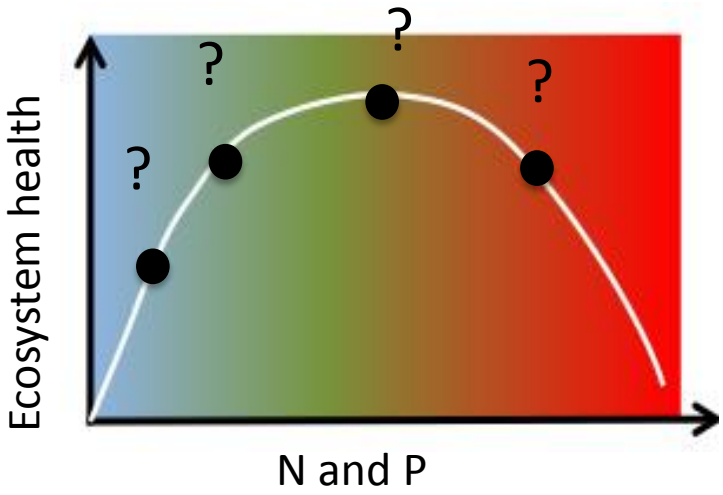
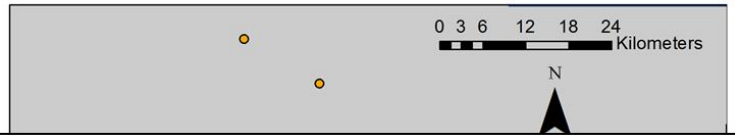
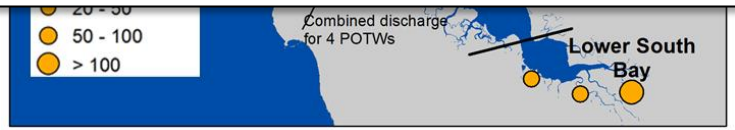




SFB doesn't use most of its nutrients

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



N and P in SFB

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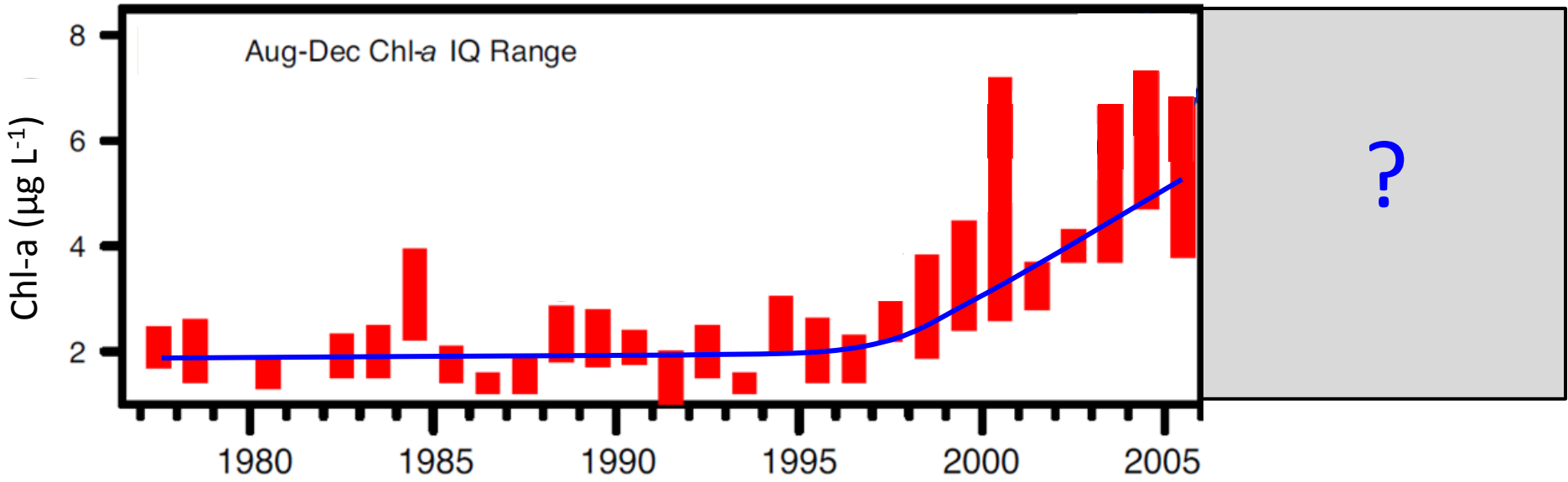
Cloern and Jassy 2012
SFEI 2014a

Evidence of changing ecosystem response

South Bay phytoplankton biomass



Cloern et al. 2007

Other indications of adverse impacts:

- Algal toxins detected Bay-wide and in the Delta

Kudela et al. in prep

- Ecosystem decline in Suisun Bay and Delta (multiple stressors)
  - Important Nutrient Link?

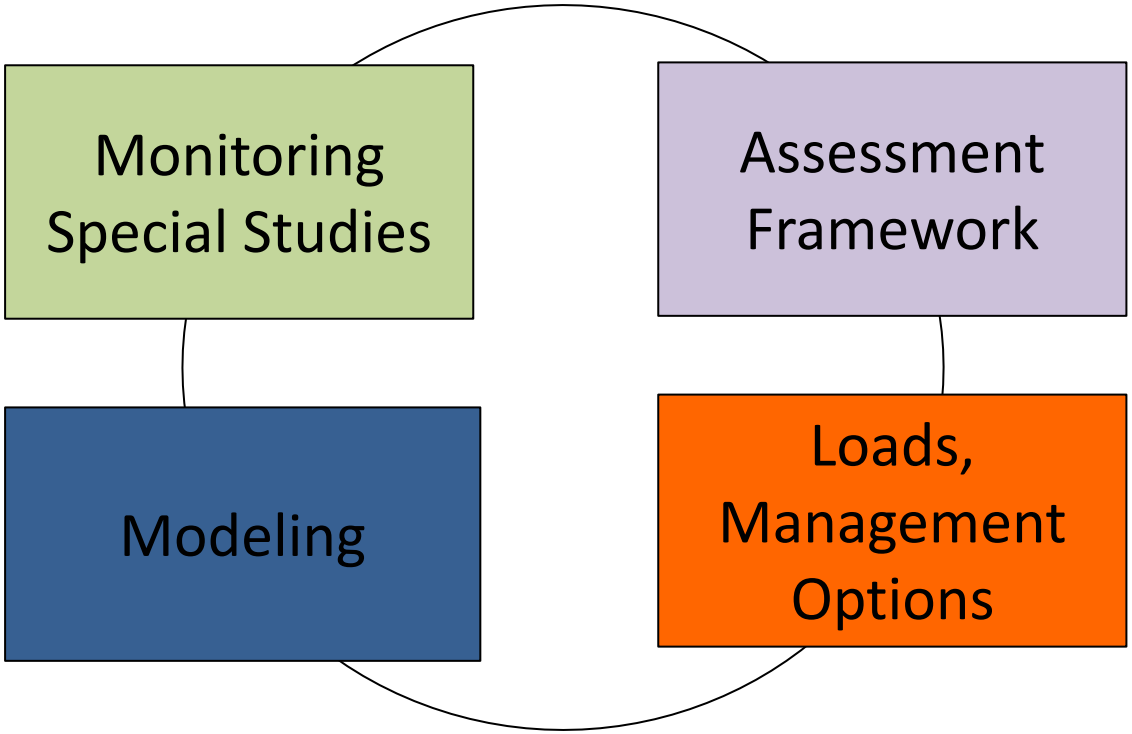
Dugdale et al., 2007; Parker et al, 2012a,b
Glibert et al., 2011; Glibert et al., 2012

November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

Nutrient Science Program



4 basic components

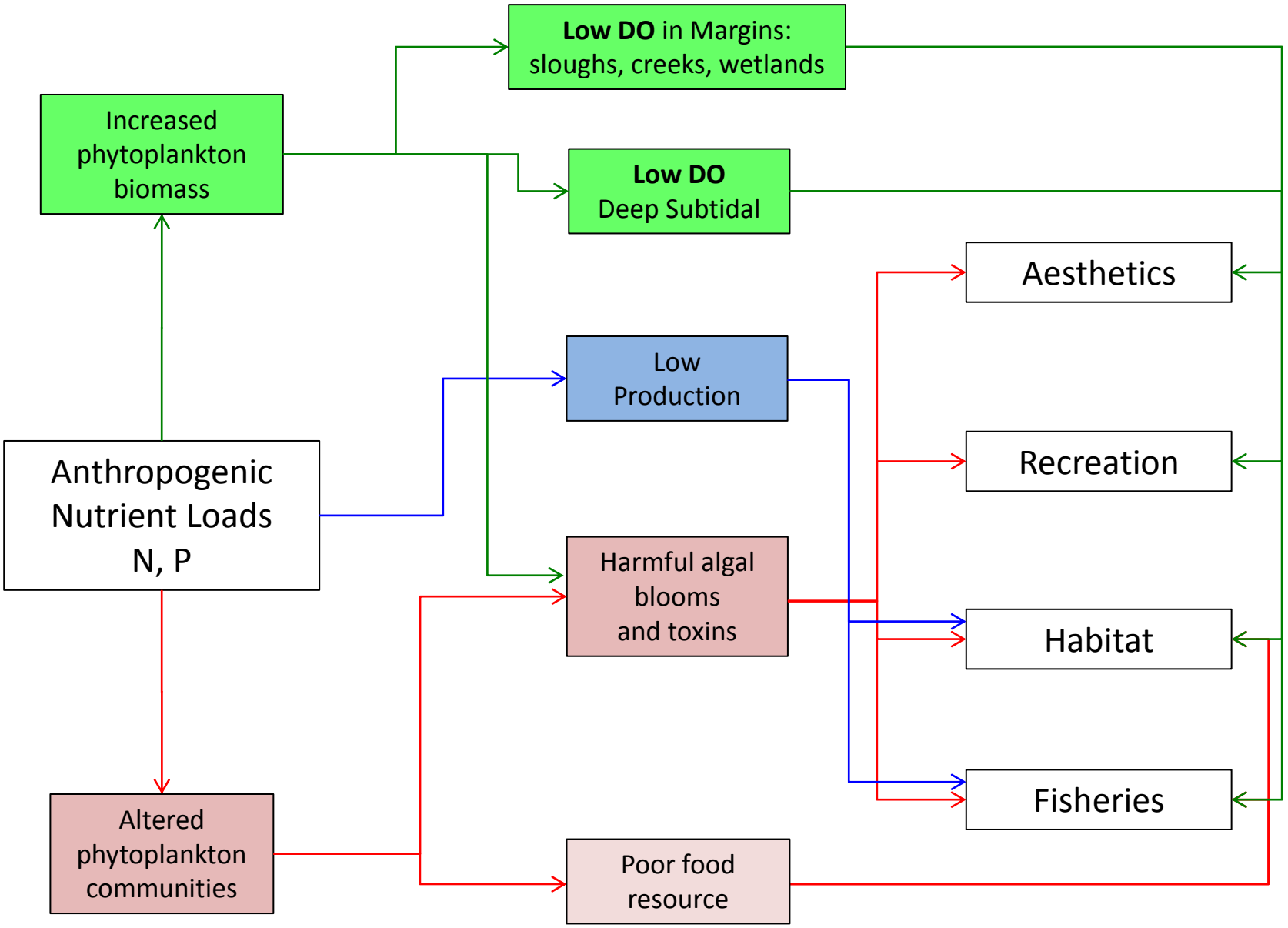
1. Nutrient sources, movement, transformations?

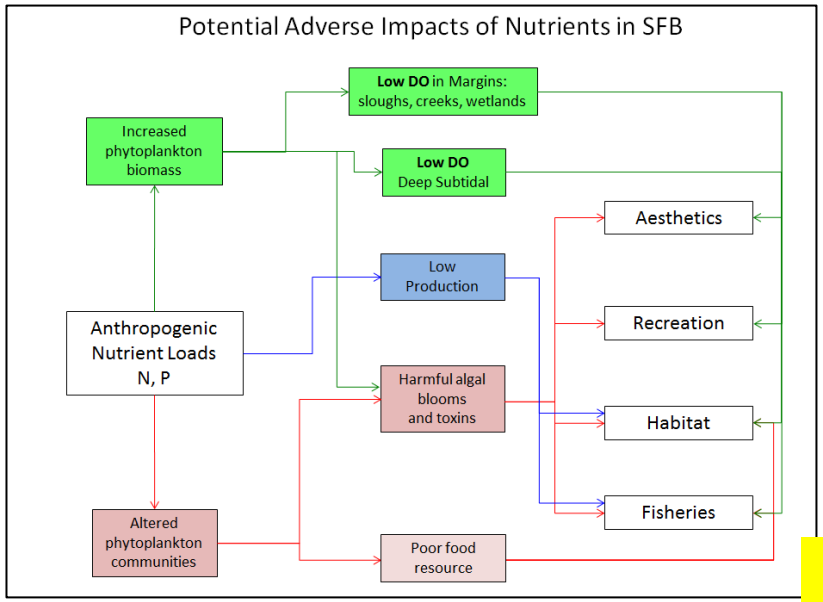
2. Ecosystem response to nutrients
   - Causing problems?
   - Develop best-possible understanding of dose:response
   - What are protective nutrient levels? (now, future)

3. What management actions will maintain nutrients at protective levels?
   - Which would be most efficacious and cost-effective?

4. With limited resources, and limited time, what is the best approach for 1, 2, and 3?

Potential Adverse Impacts of Nutrients in SFB





4 basic components

November 2012

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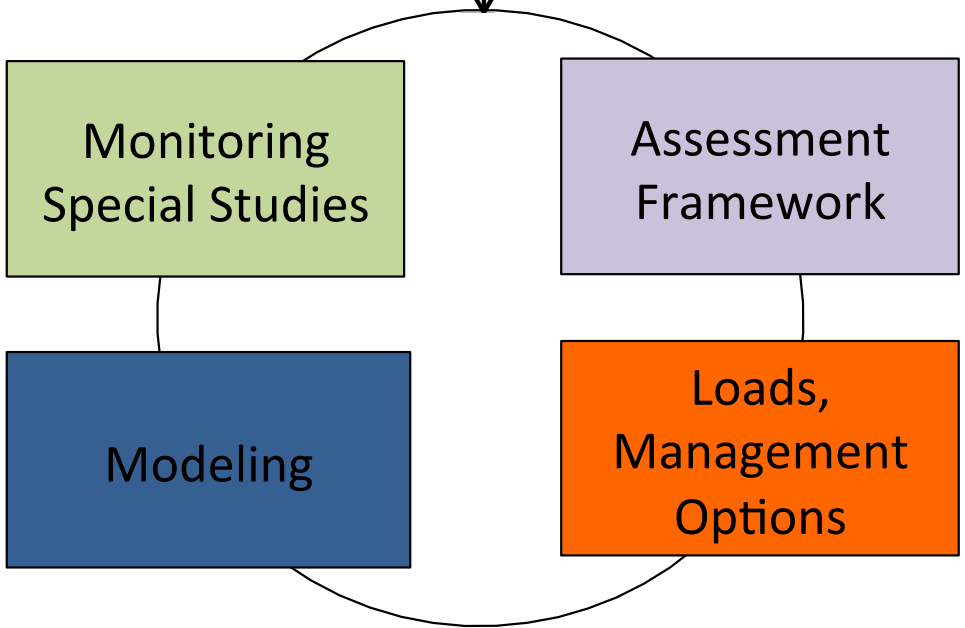
Science Plan



Update Topics – CY2014

1. Lower South Bay:
   - Nutrient cycling/transformations
   - Dissolved oxygen: observations and on-going work

2. Bay-wide work on phytoplankton assemblages, HABs, toxins

3. Changing ecosystem response: exploring underlying causes

4. Science Plan development

Understanding nutrient loads, transport, and cycling

Important for …

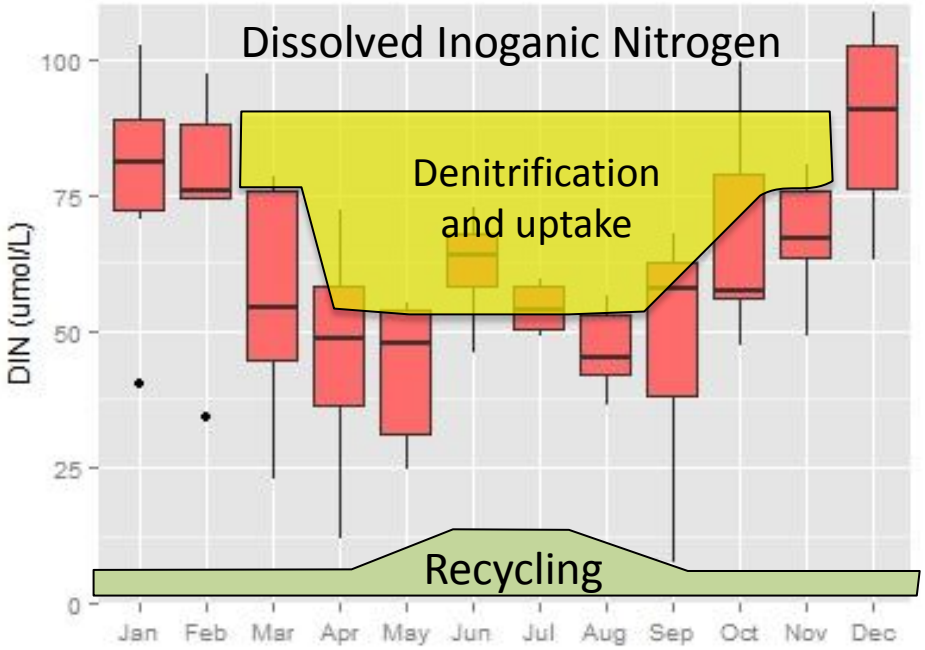
- determining acceptable loads
- source attribution
- evaluating effectiveness of load reduction scenarios

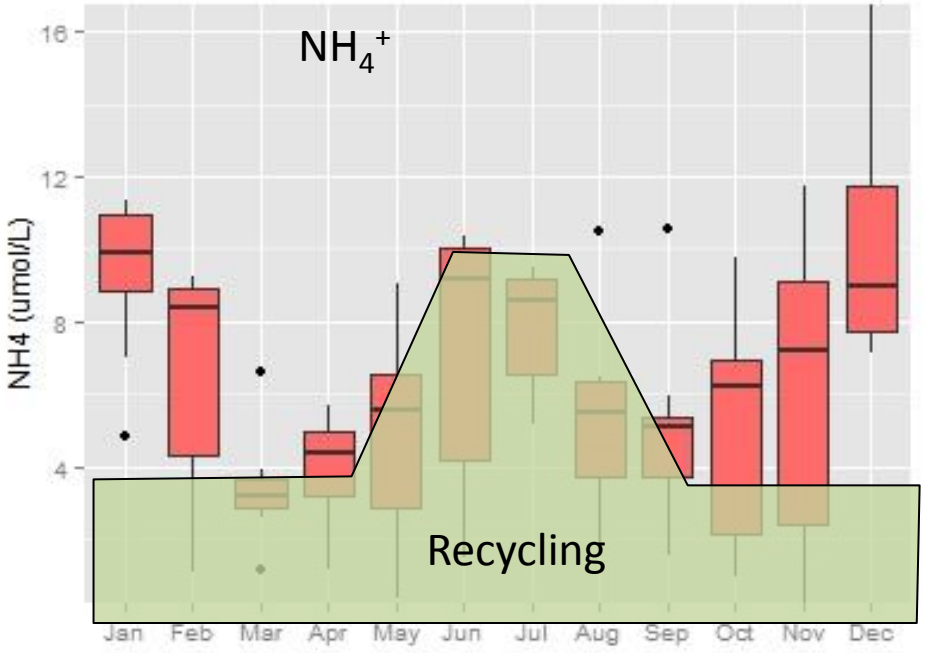
But complex

- Strong influence of physics/hydrodynamics
- Spatially and temporally variable
- Numerous parameters and processes

Seasonal Patterns: Lower South Bay

- Ambient water quality suggests substantial *in situ* transformations
- How much?





Estimating Dissolved Inorganic Nitrogen loss and uptake: Summer Mass Balance

Estimating Dissolved Inorganic Nitrogen loss and uptake: Summer Mass Balance

$$\frac{dM}{dt} = \dot{M}_{POTW} - \dot{M}_{loss/trans} + \dot{M}_{tide,in} - \dot{M}_{tide,out}$$

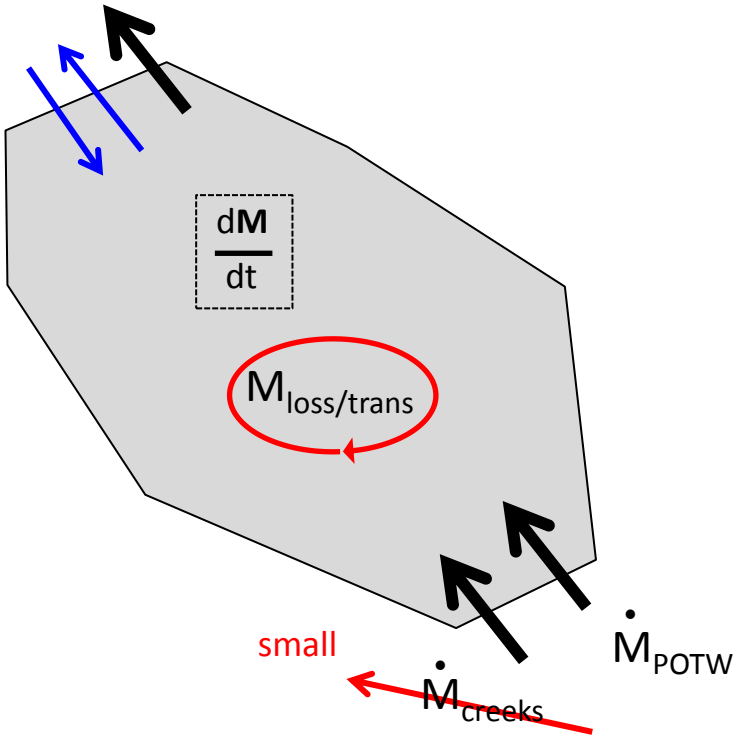
$\frac{dM}{dt} = 0$

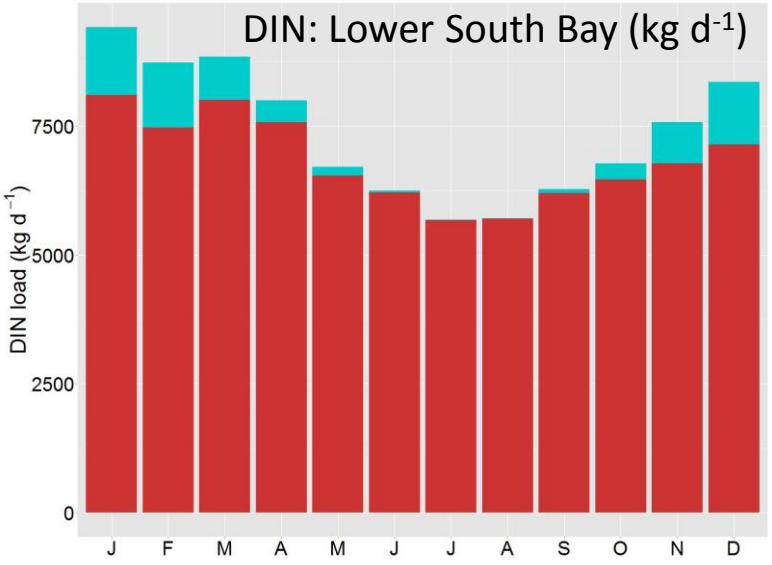
$$\dot{M}_{loss/trans} = \dot{M}_{POTW} + \dot{M}_{tide,in} - \dot{M}_{tide,out}$$

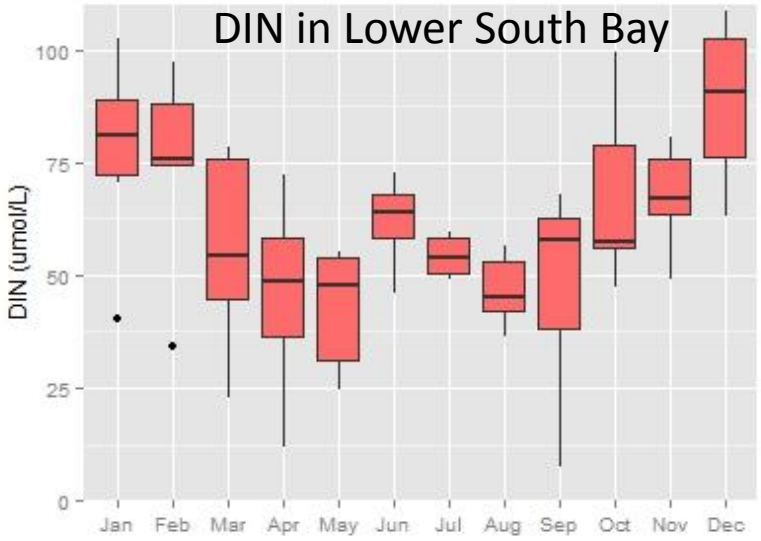
$$\dot{M}_{efflux,net} = \dot{M}_{tide,out} - \dot{M}_{tide,in}$$

$Q_{tide.eff,\ in}$

$Q_{tide.eff,\ out}$



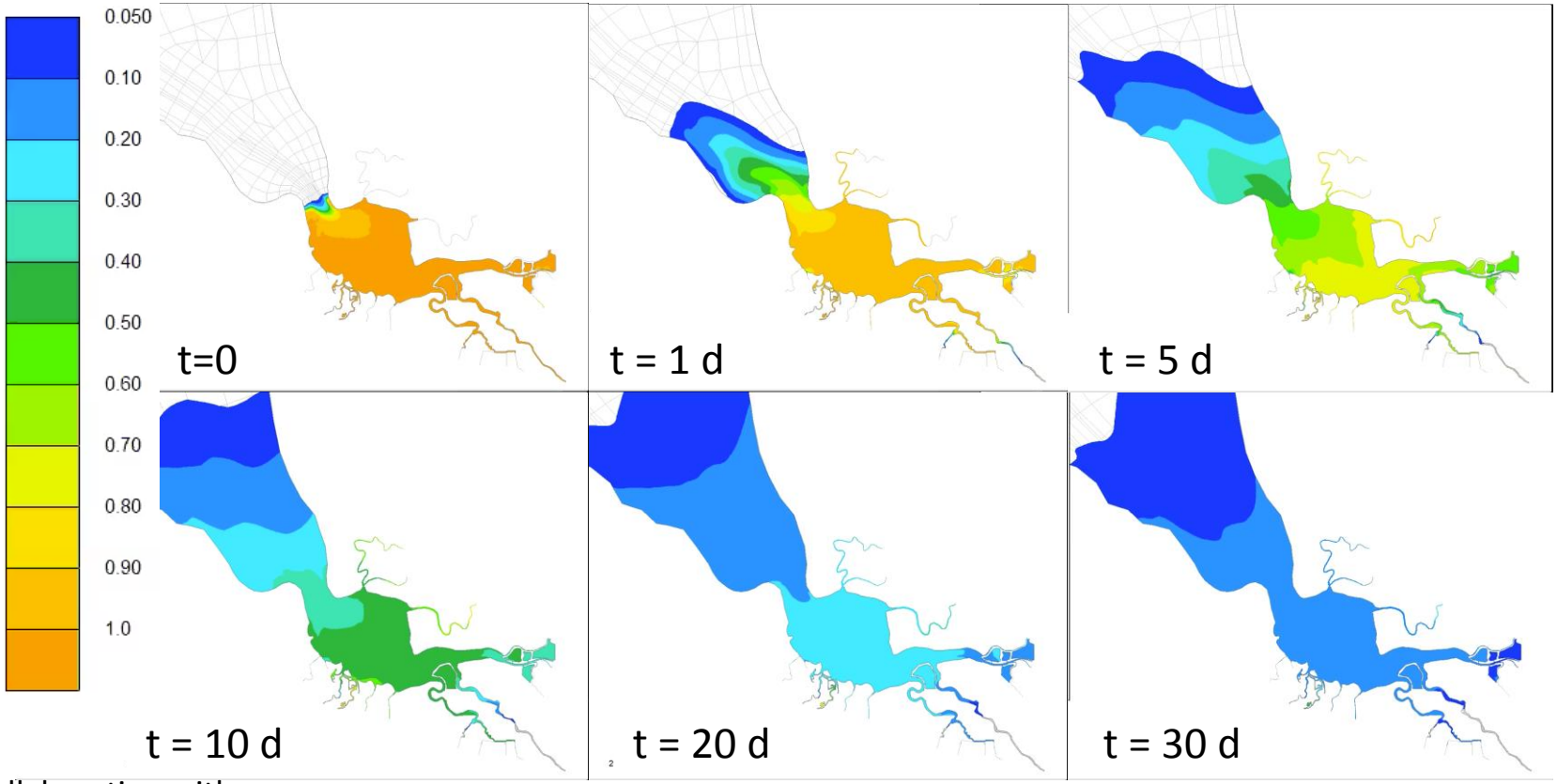




SFEI 2015

Estimating $Q_{tide.eff}$

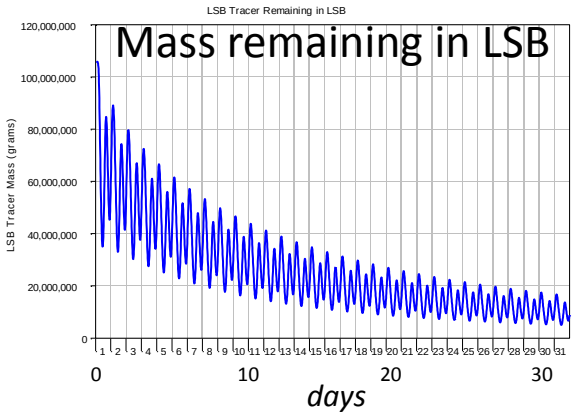
- Seed with conservative tracer at t=0
- Idealized tidal cycle
- Track loss of tracer over time to estimate $Q_{tide,eff}$



In collaboration with
RMA: S Grinbergs, E Gross

$k_{tide,eff} = 0.06\ d^{-1}$

$Q_{tide.eff,net} = 5.4 \times 10^6 \quad m^3\ d^{-1}$



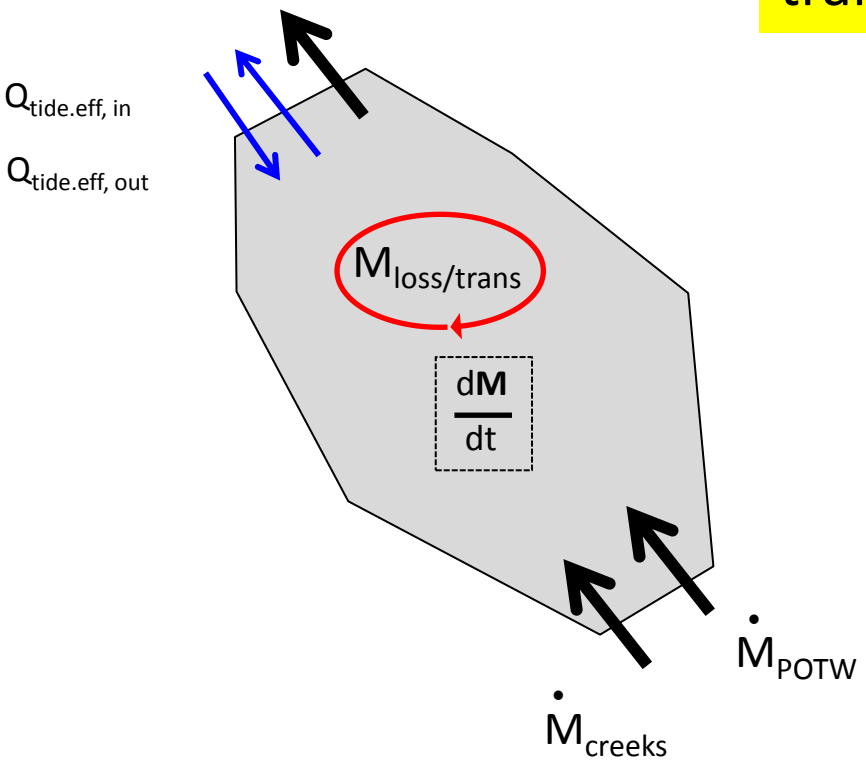
Estimating Dissolved Inorganic Nitrogen loss and uptake: Mass Balance

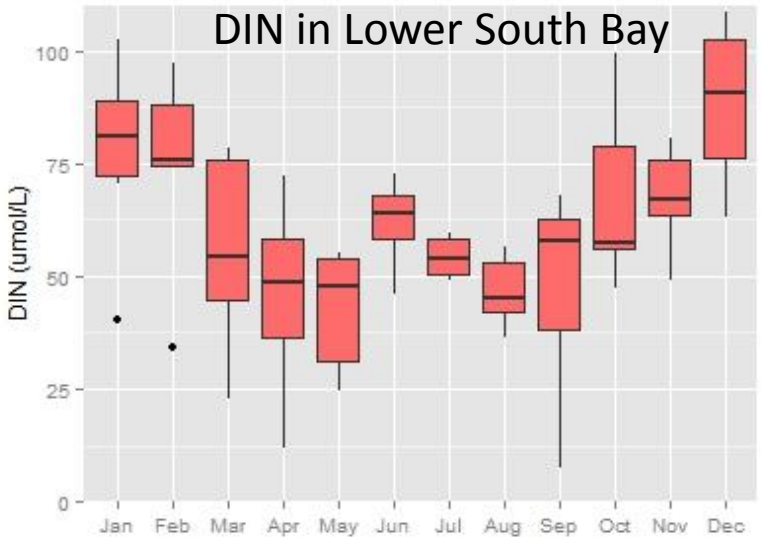
$$\dot{M}_{loss/trans} = \dot{M}_{POTW} + \dot{M}_{tide,in} - \dot{M}_{tide,out}$$

$$\dot{M}_{loss/trans} = 5400\ kg/d + 2000\ kg/d - 3000\ kg/d$$

$$M_{loss/trans} = 4400\ kg/d$$

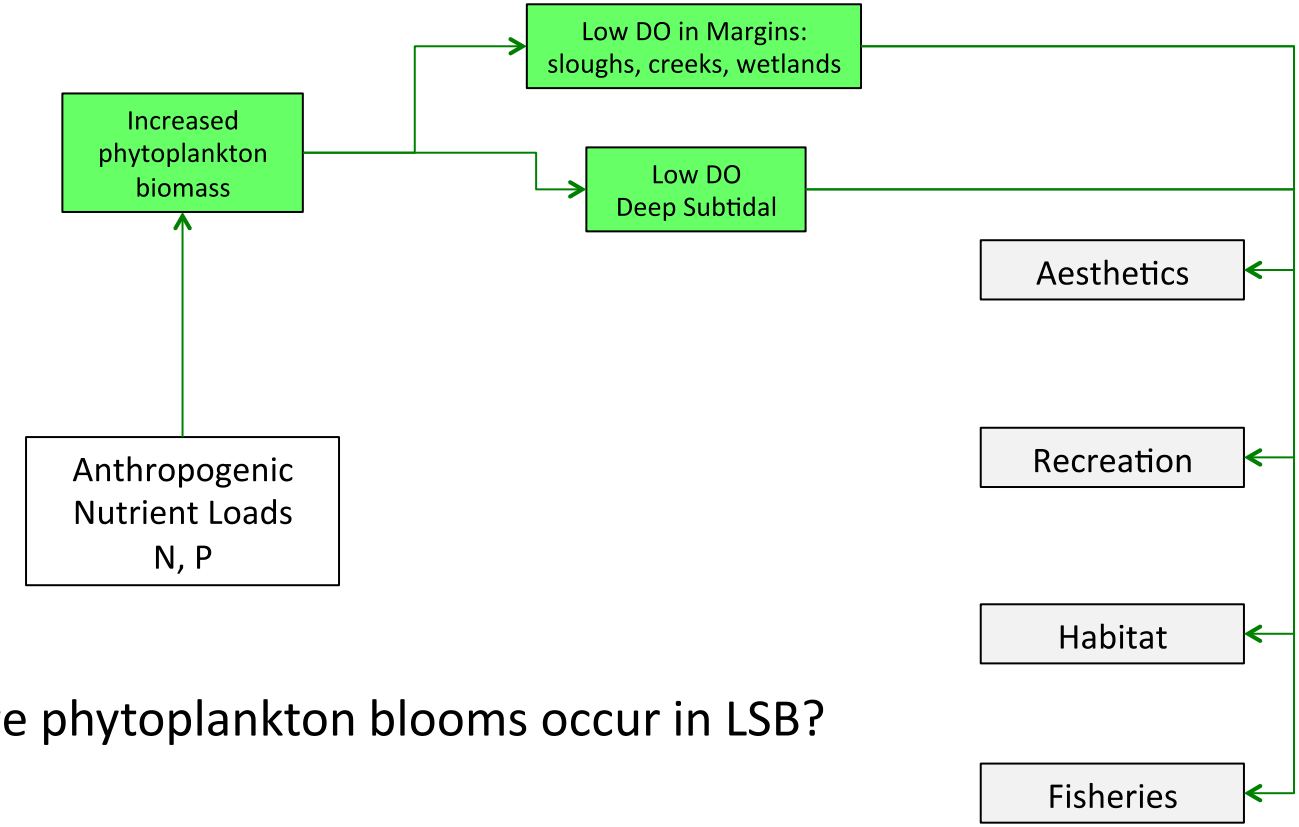
60% of total DIN load is lost or transformed during summer months





Summary

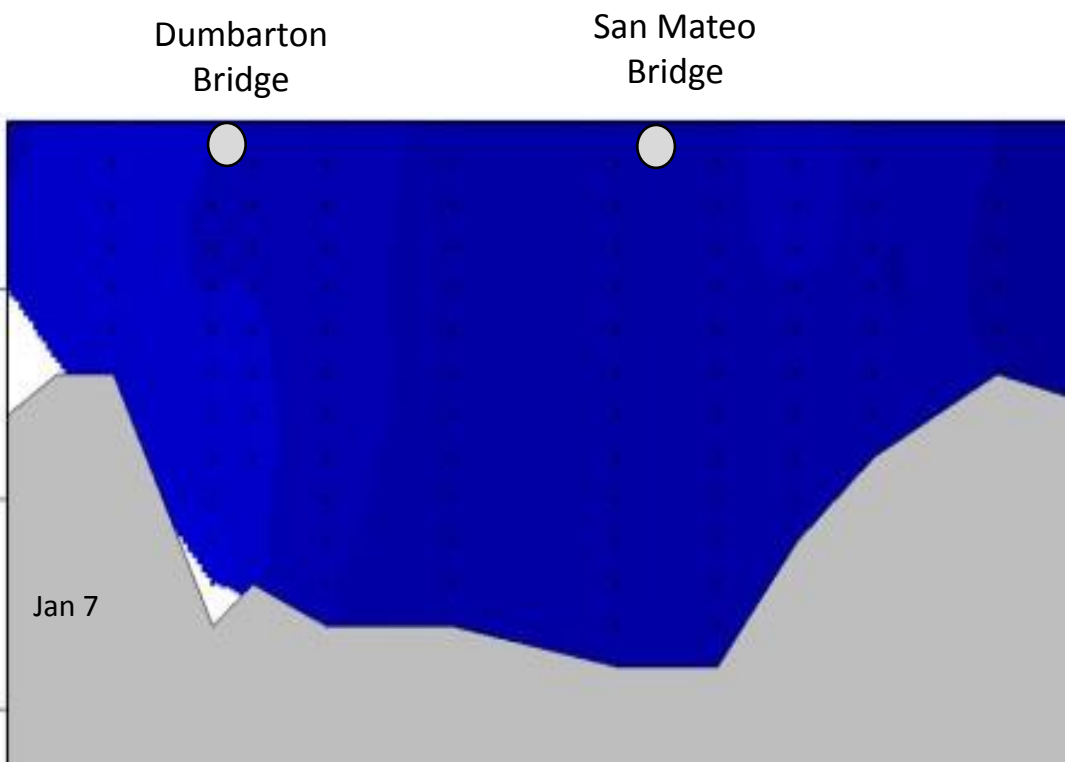
- LSB appears to be a vigorous biogeochemical reactor
  - Good news: it has substantial assimilative capacity
  - But that capacity is already being tapped
- Uptake requires biomass growth (phytplankton, benthic algae)
- Denitrification requires organic C, anaerobic conditions
- Is there evidence for these?

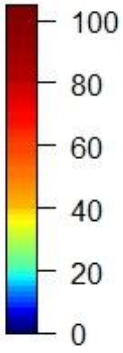


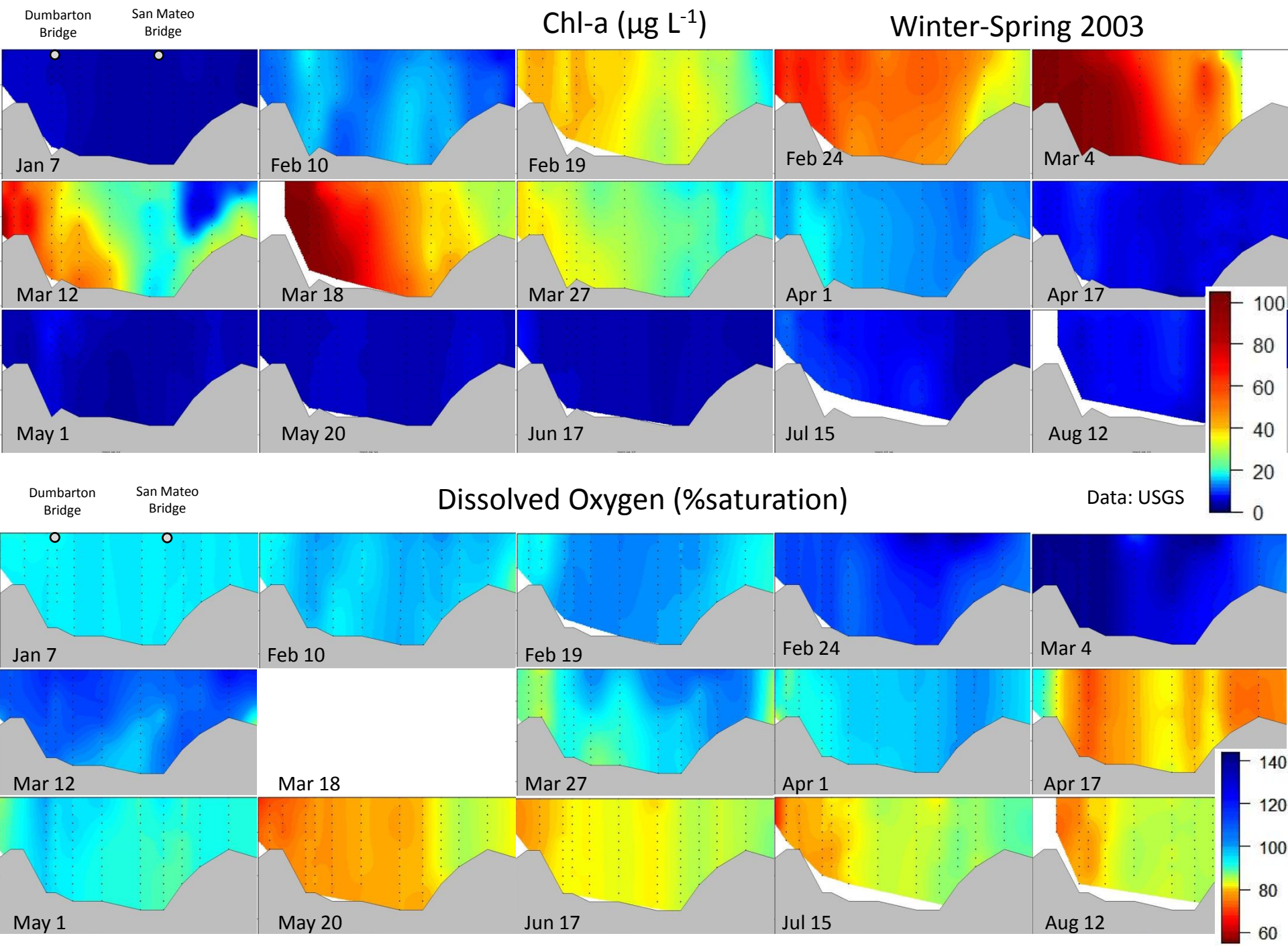
- Do large phytoplankton blooms occur in LSB?
- Does LSB experience low DO?
  - open-Bay areas
  - sloughs/creeks/marshes
- How do we best assess this?

Chl-a (µg L^{-1})

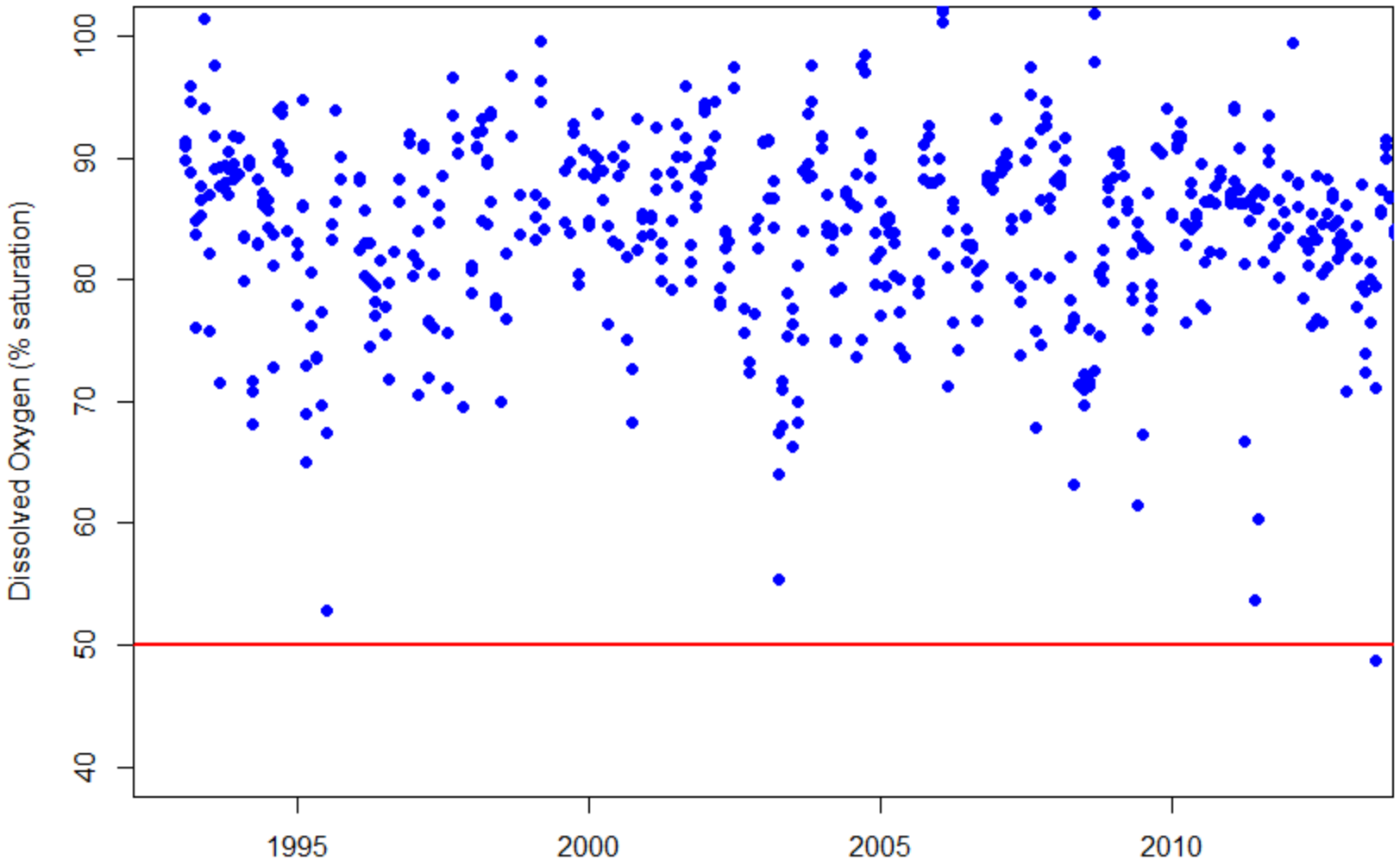
Winter-Spring 2003






Dumbarton Bridge
San Mateo Bridge
Chl-a (µg L-1)
Winter-Spring 2003
Jan 7
Feb 10
Feb 19
Feb 24
Mar 4
Mar 12
Mar 18
Mar 27
Apr 1
Apr 17
May 1
May 20
Jun 17
Jul 15
Aug 12
100
80
60
40
20
0
Dumbarton Bridge
San Mateo Bridge
Dissolved Oxygen (%saturation)
Data: USGS
Jan 7
Feb 10
Feb 19
Feb 24
Mar 4
Mar 12
Mar 18
Mar 27
Apr 1
Apr 17
May 1
May 20
Jun 17
Jul 15
Aug 12
140
120
100
80
60

DO %saturation: Discrete samples in LSB deep channel



Minimum DO, **LSB stations**, all months

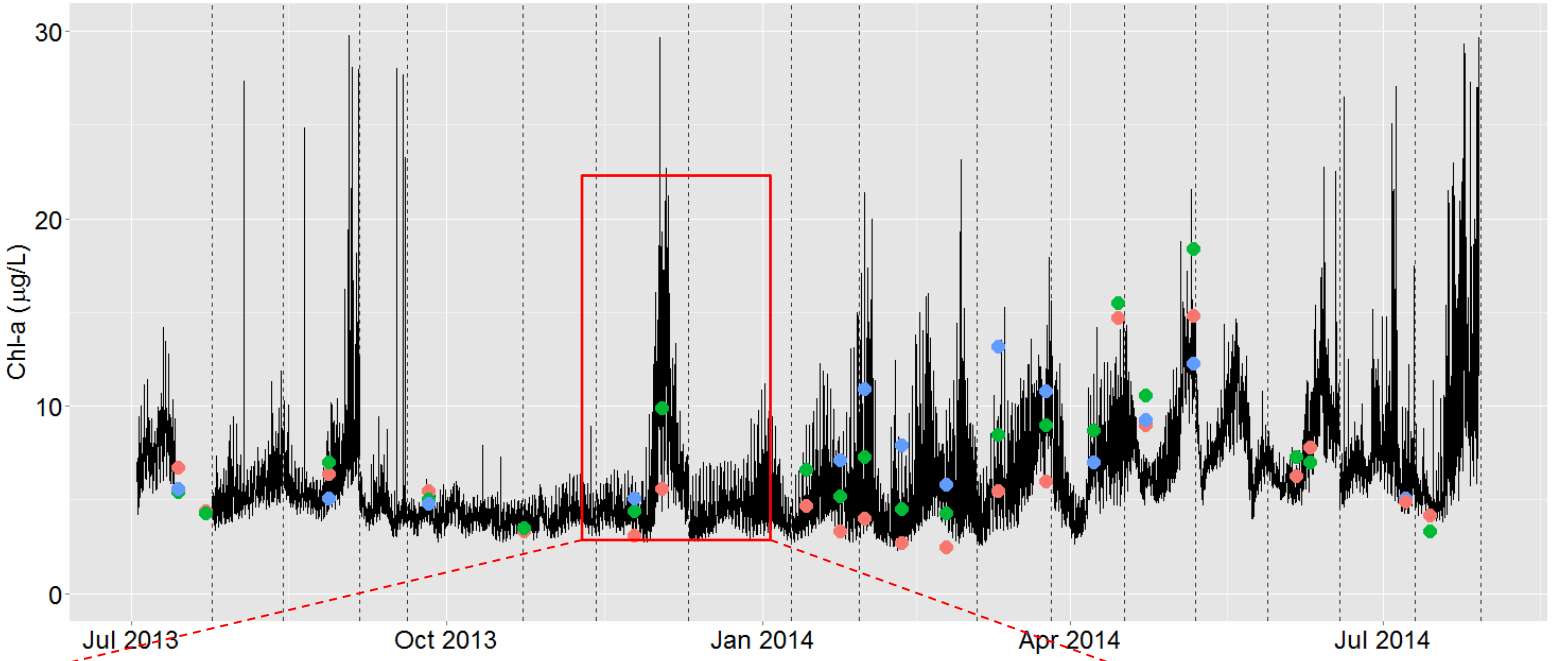
NOTE: Most samples collected at high tide

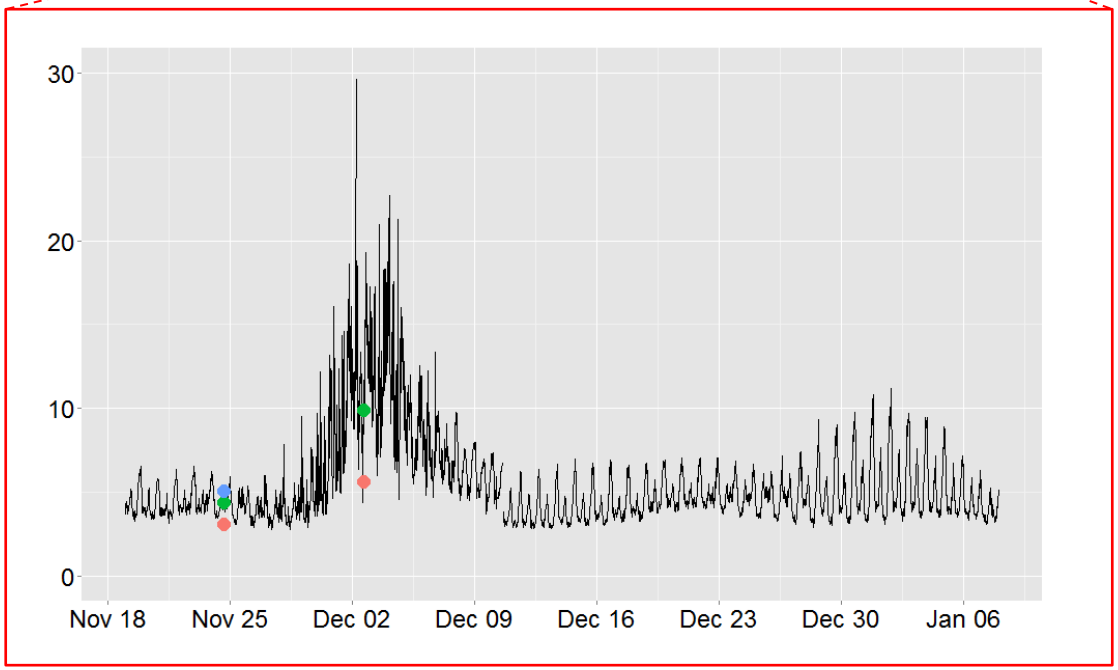
Data: USGS
SFEI 2015

Moored Sensor Monitoring in Lower South Bay

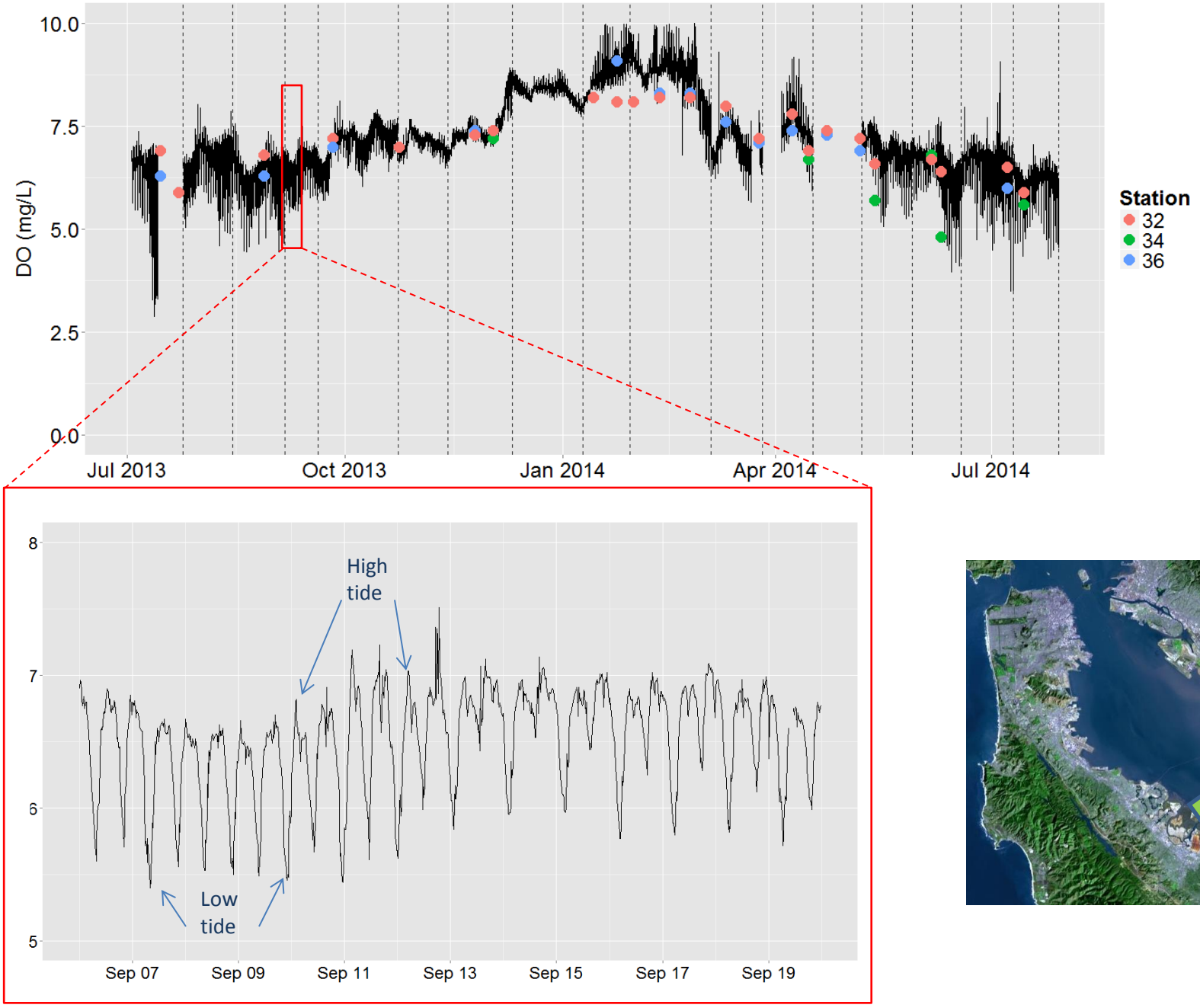
July 2013-present

- Assess condition
- Improve understanding of processes
- Model calibration


Chl-a (µg/L)
30
20
10
0
Jul 2013
Oct 2013
Jan 2014
Apr 2014
Jul 2014
StationNumber
32
34
36


30
20
10
0
Nov 18
Nov 25
Dec 02
Dec 09
Dec 16
Dec 23
Dec 30
Jan 06

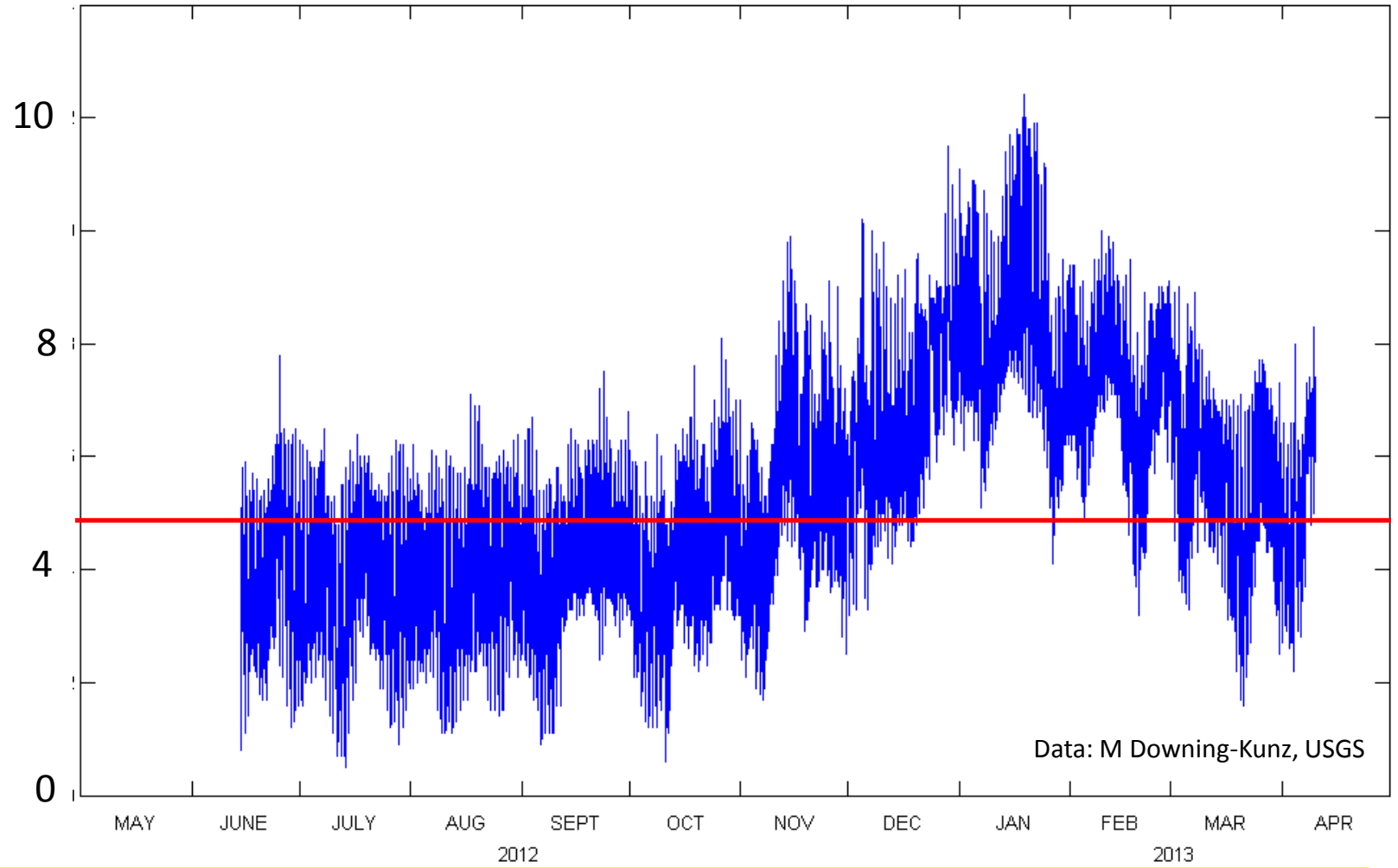
SFEI 2014b


10.0
7.5
5.0
2.5
0.0
DO (mg/L)
Jul 2013
Oct 2013
Jan 2014
Apr 2014
Jul 2014
Station
32
34
36
8
7
6
5
High tide
Low tide
Sep 07
Sep 09
Sep 11
Sep 13
Sep 15
Sep 17
Sep 19

SFEI 2014b

What about DO in shallow margin habitats?

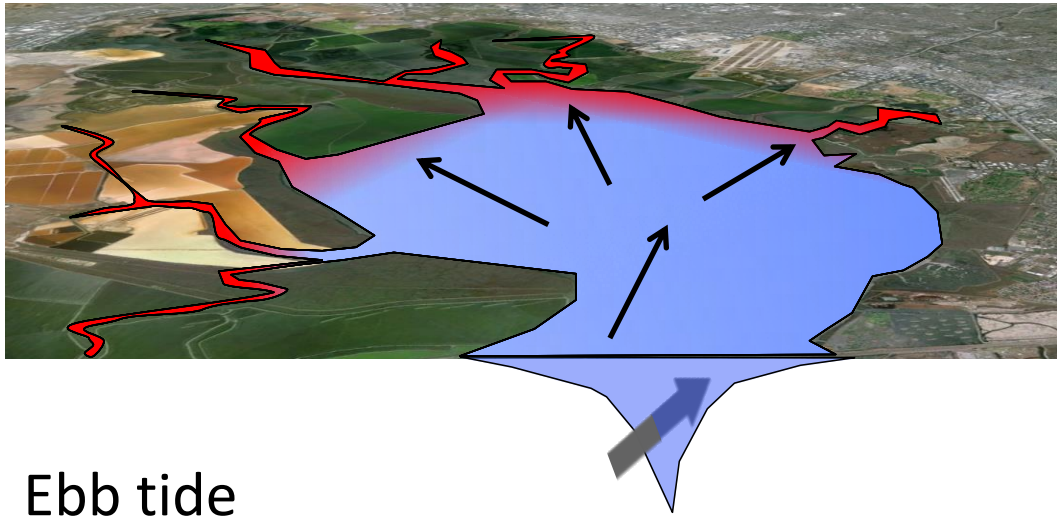
e.g., Alviso Slough: June 2012 – April 2013



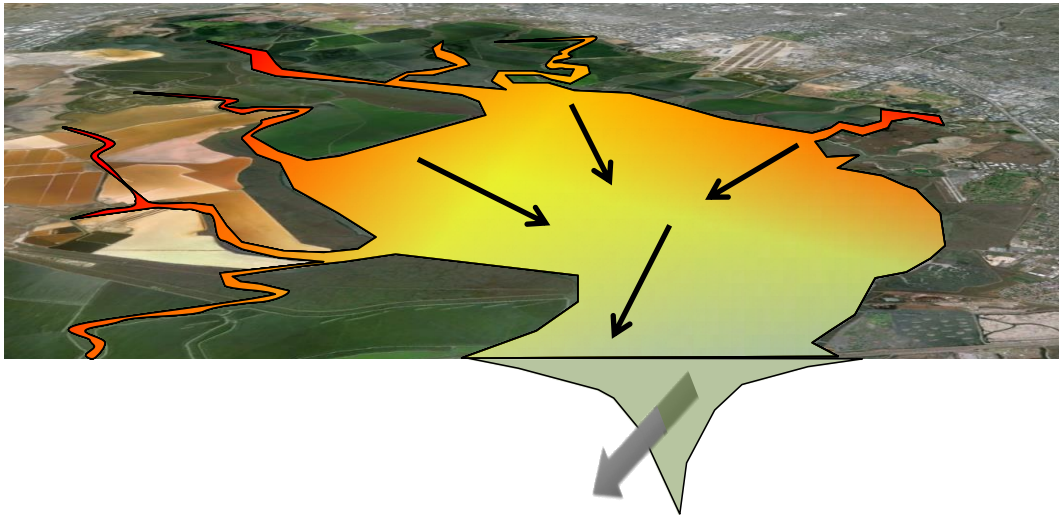
High Chlorophyll also observed (5-10x open Bay concentrations)

Conceptualization of Water Quality (and source) in LSB as a function of tide

Flood tide

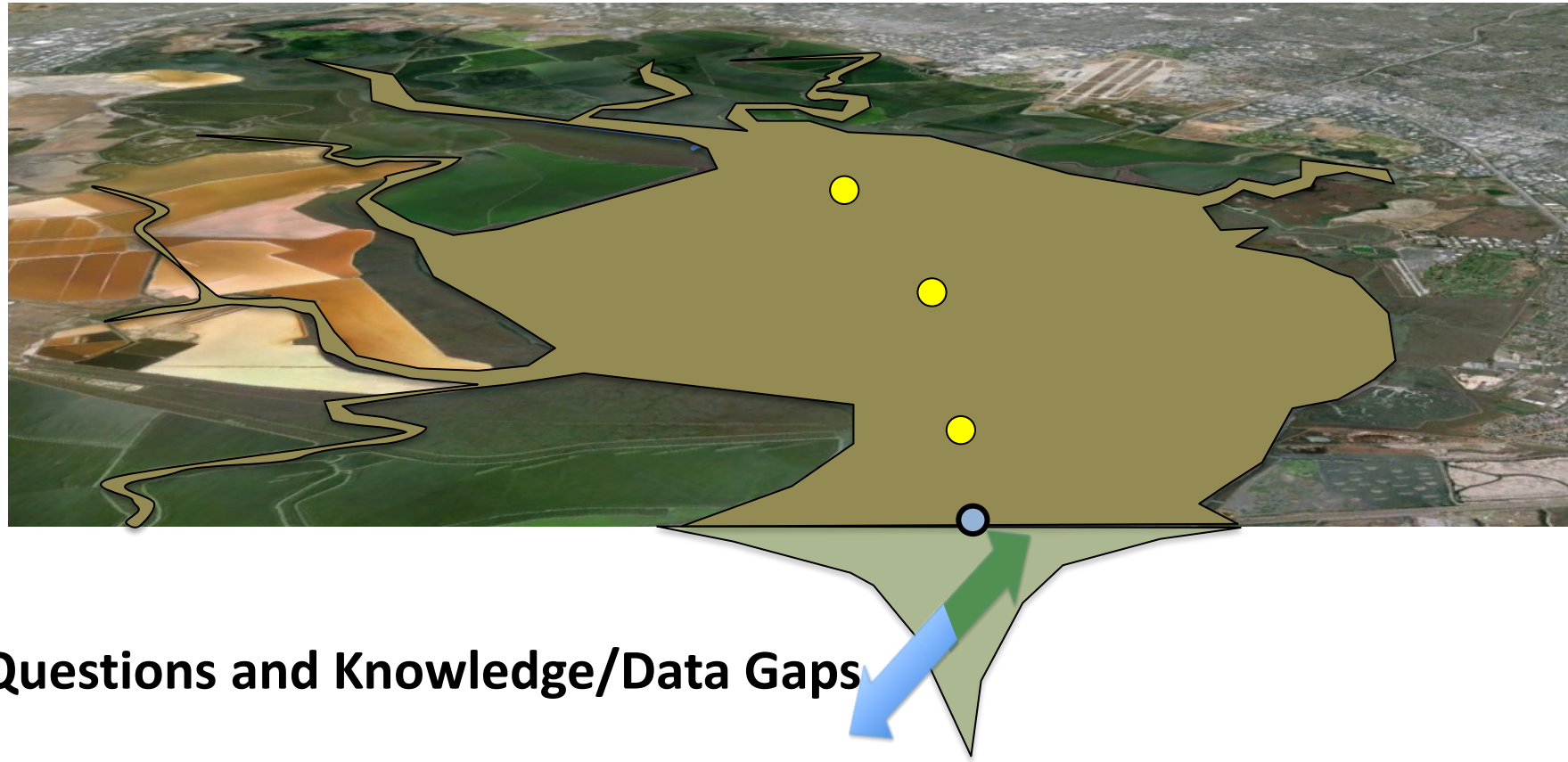


Ebb tide



Margin Water:
Sloughs/Creeks/Marshes

Open Bay Water:
Originating north
of Dumbarton

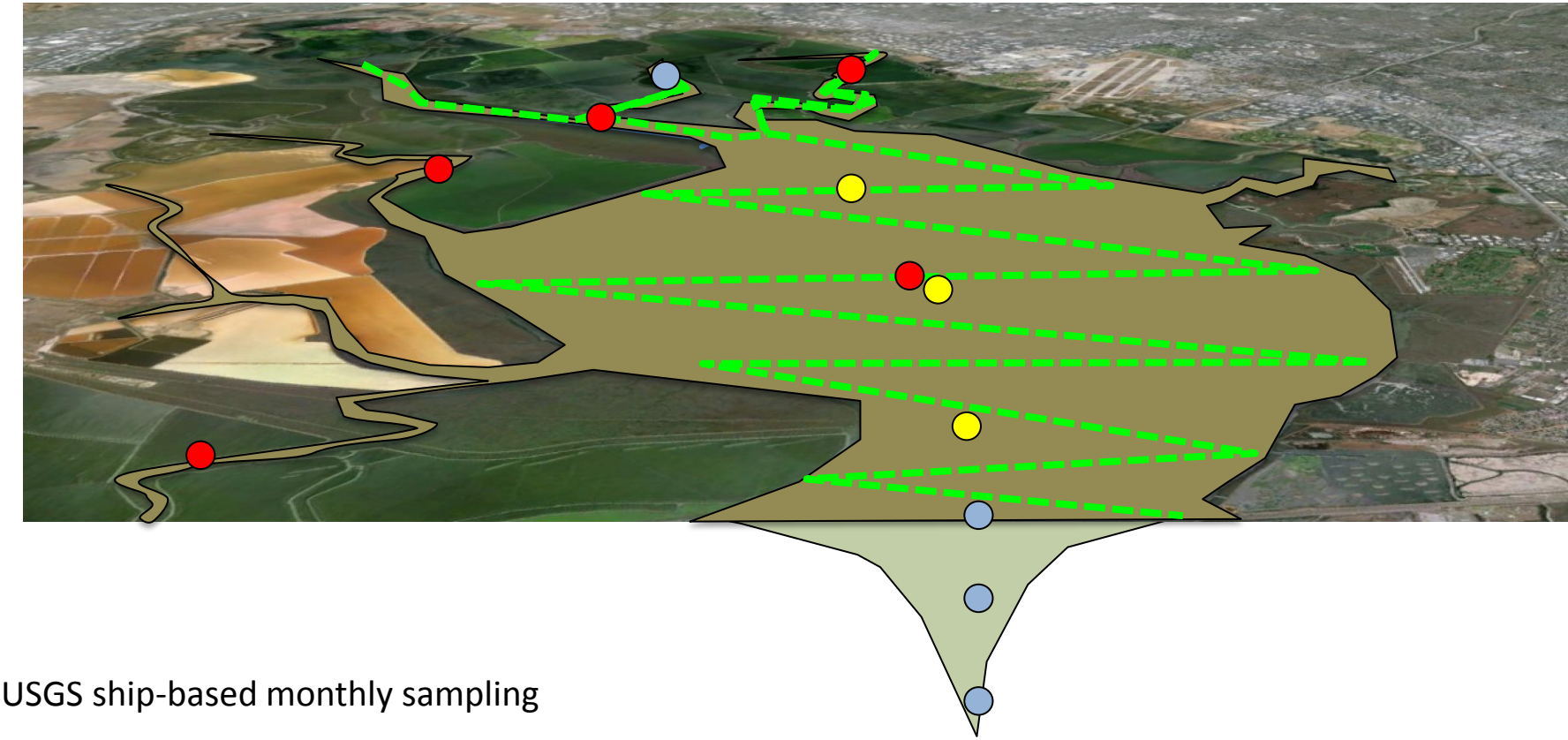


Key Questions and Knowledge/Data Gaps

- How widespread and severe is low DO in shallow margin habitats?
  - What is causing it? What is role of anthropogenic nutrients?
  - Is it adversely impacting biota?

- Does DO in open-Bay/deep-subtidal habitats reach levels that adversely impact habitat quality?

- What is the source of the biomass leading to low DO?



USGS ship-based monthly sampling

Moored stations (SFEI/USGS)

Anticipated moored stations in 2015

Proposed biogeochemical mapping

Need to measure…

- The right things
- In the right places
- At the right times

Summary and Next steps: Part 1

LSB vigorous biogeochemical reactor

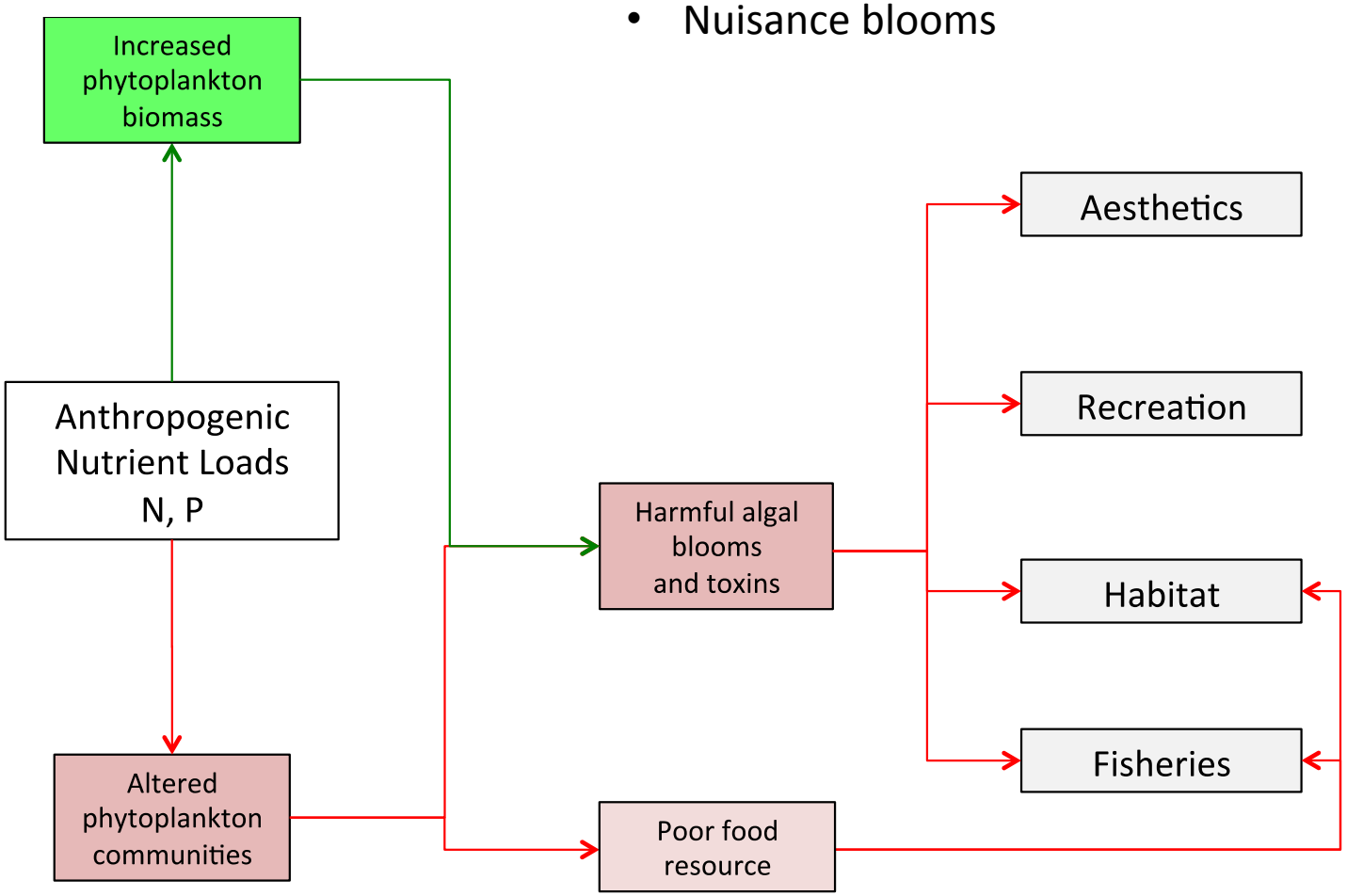
- Simple 'model' suggests substantial N removal occurs
- Potential for large blooms
- Potential for low DO in margins and substantial fluctuations in open Bay

Next Steps

- Field investigations
  - Continue moored sensors, and expand into margins
  - Nitrate sensors at key locations
  - Biogeochemical mapping (proposed)
  - Process (rate) measurements
- Modeling

Part 2: Phytoplankton community, HABs, toxins

- Food quality (phytoplankton) for supporting food web
- Toxins → impacts on aquatic biota, humans
- Nuisance blooms



Part 2: Phytoplankton community, HABs, toxins

- Are HAB species and toxins present in the Bay?

- What factors regulate HAB and toxin abundance?
  - Role of nutrients?

- What represents an adverse impact from HABS/ toxins?
  - target organism/pathway being protected?
  - unacceptable risk?

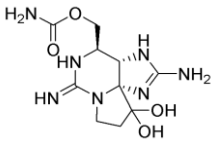
- What nutrient concentrations would be protective?

Example Toxin Producing Organisms

When are toxins produced?

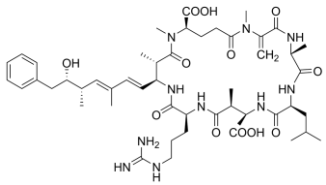
- When the phytoplankton are stressed
  - Salinity, Temperature
  - Nutrients (- P, - Si; + N, +metals)
  - Light conditions
  - Re-suspension of resting cells
- Other theories:
  - Defense against grazers
  - Binding of metals (iron)
  - Competitive interactions with other species

Saxitoxin
(Paralytic Shellfish Poisoning)



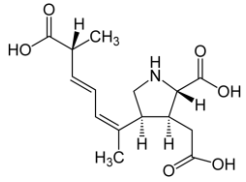
Alexandrium spp.

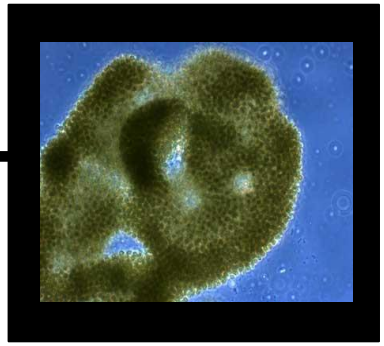
Domoic Acid
(Amnesic Shellfish Poisoning)



Pseudo-nitzschia spp.

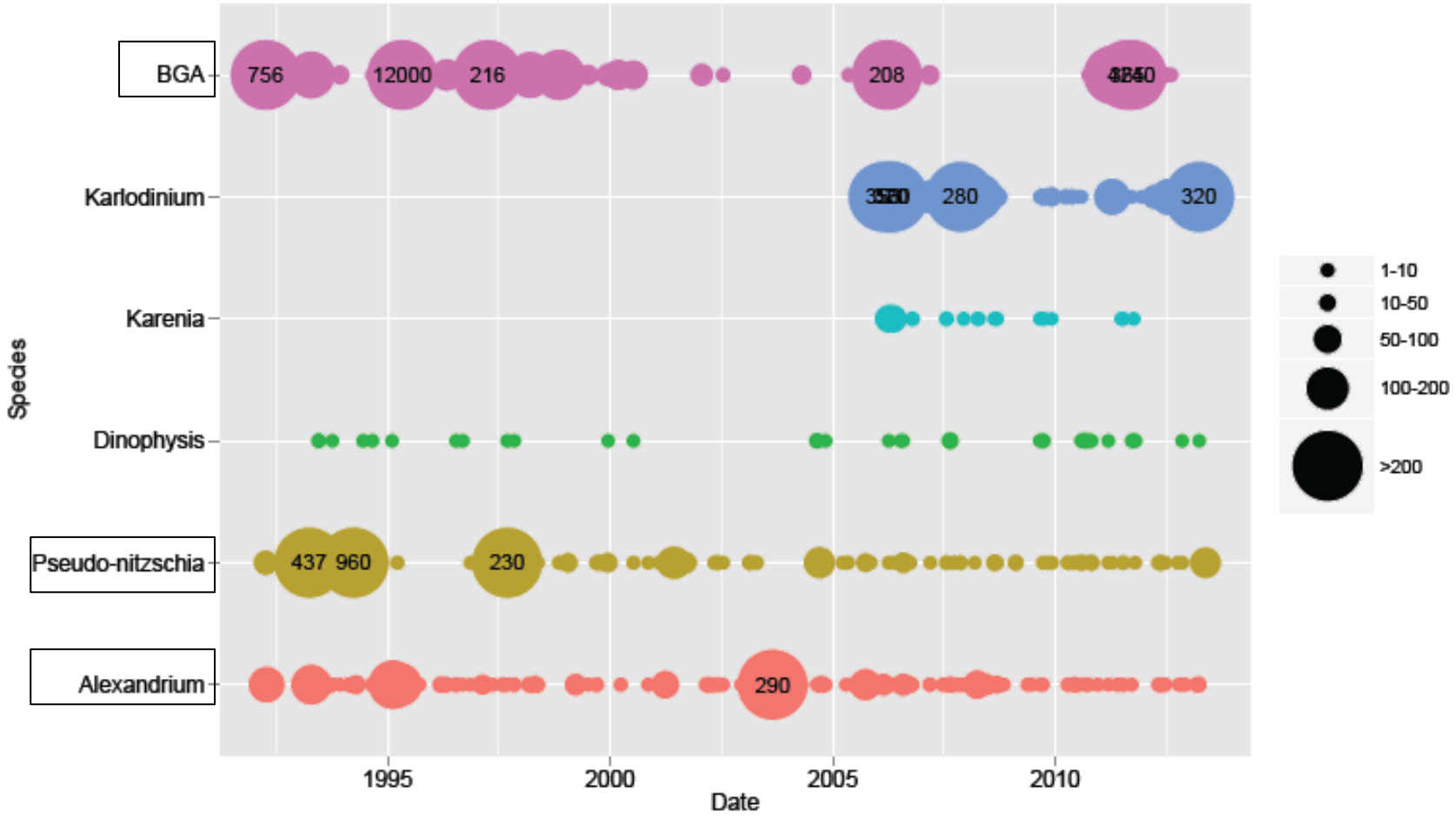
Microcystin toxins





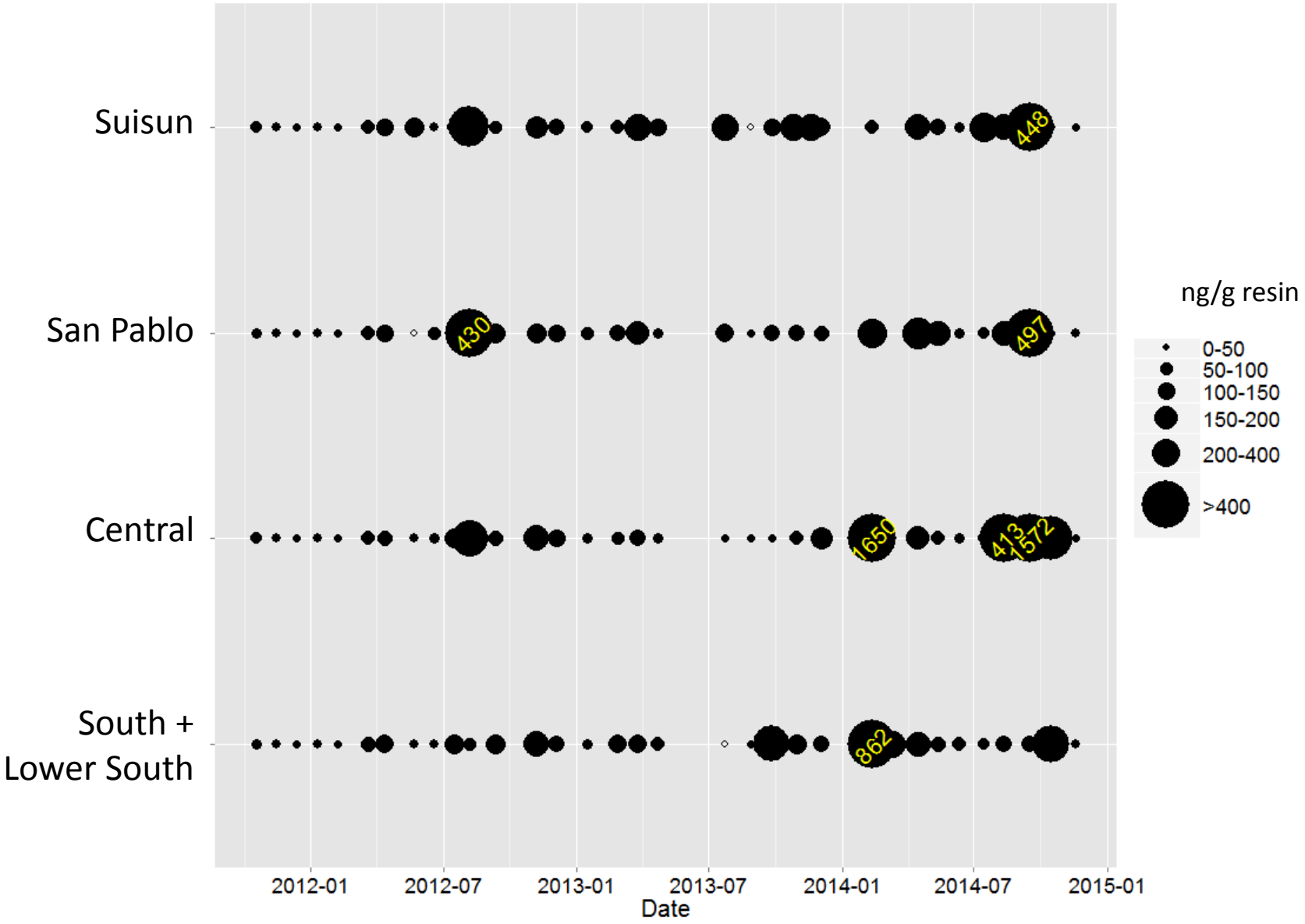
Microcystis spp.

Are HAB-forming species present in the Bay?



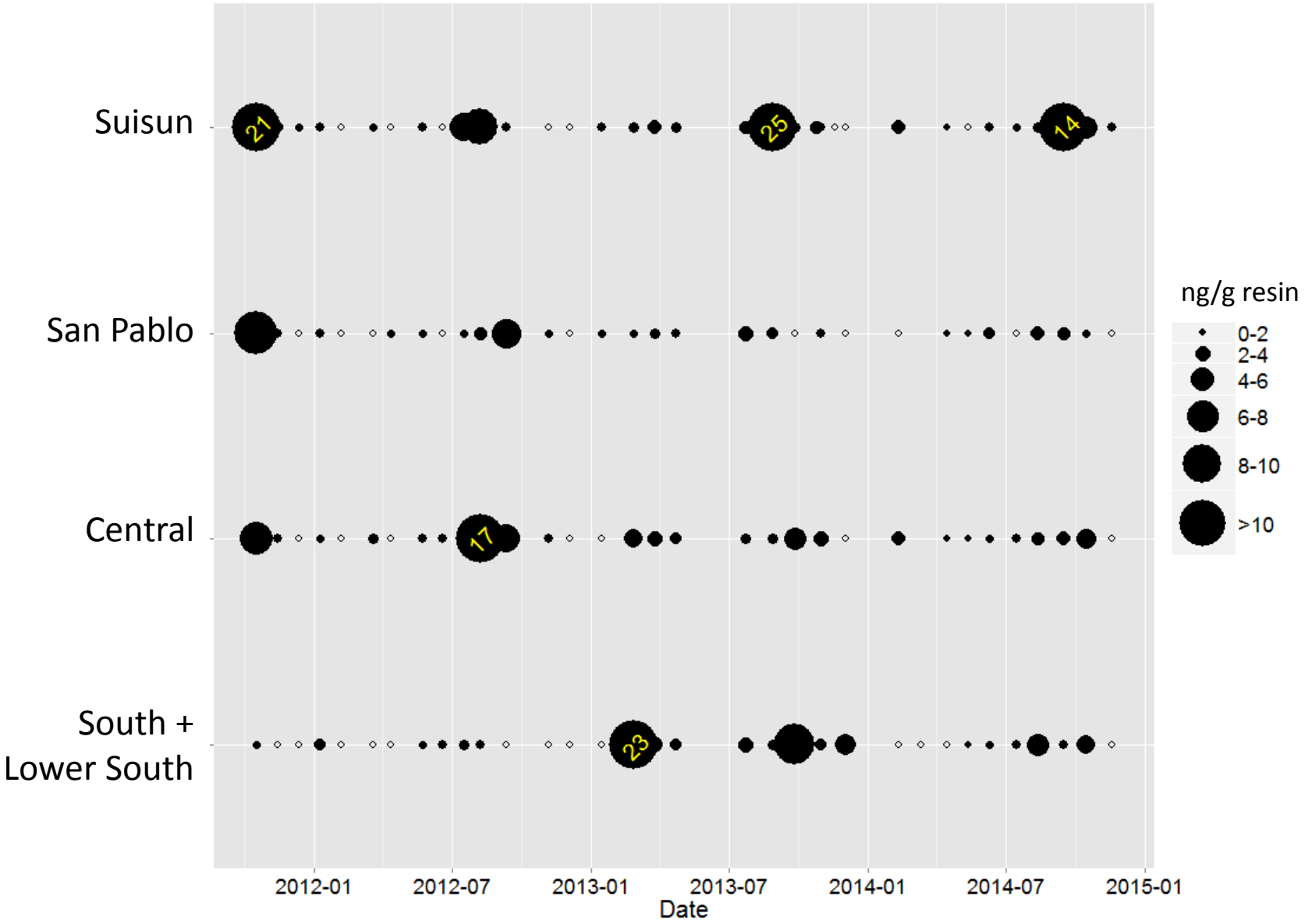
Data: USGS
Sutula et al., in prep

Are toxins present? Spatially-Integrated Domoic Acid



Kudela et al, in prep.

Are toxins present? Spatially-Integrated Microcystin



Kudela et al, in prep.

Are toxins entering the food web (i.e., primary consumers)?

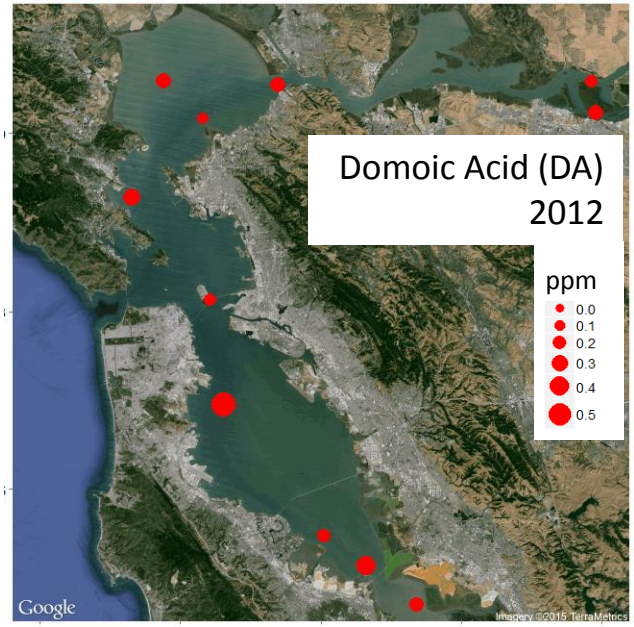
Mussel Watch (RMP)

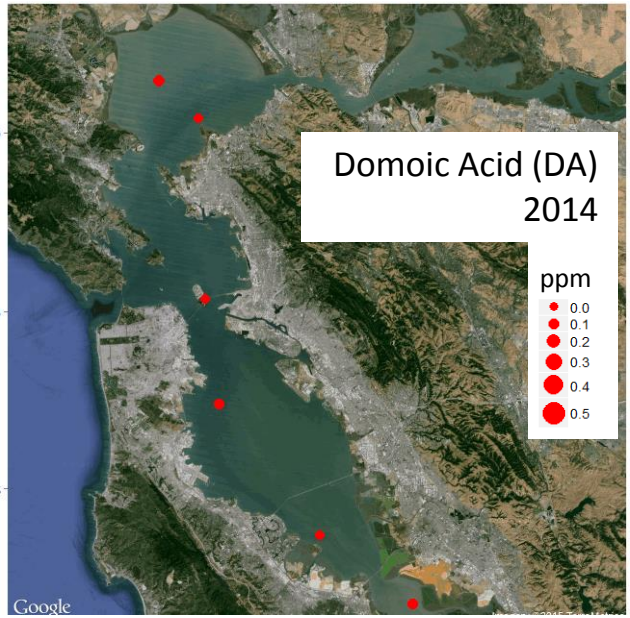
Evidence that toxins are entering the food web

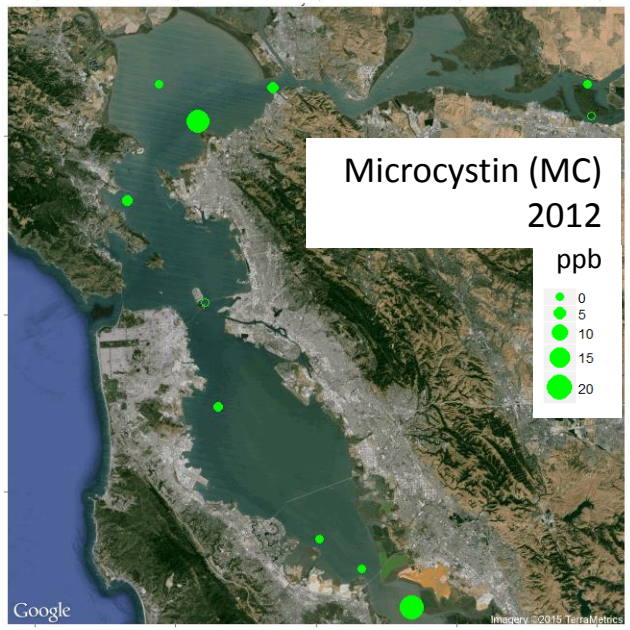
- DA detected in all samples
- MC detected in most samples
- DA << 20 ppm regulatory limit for shellfish

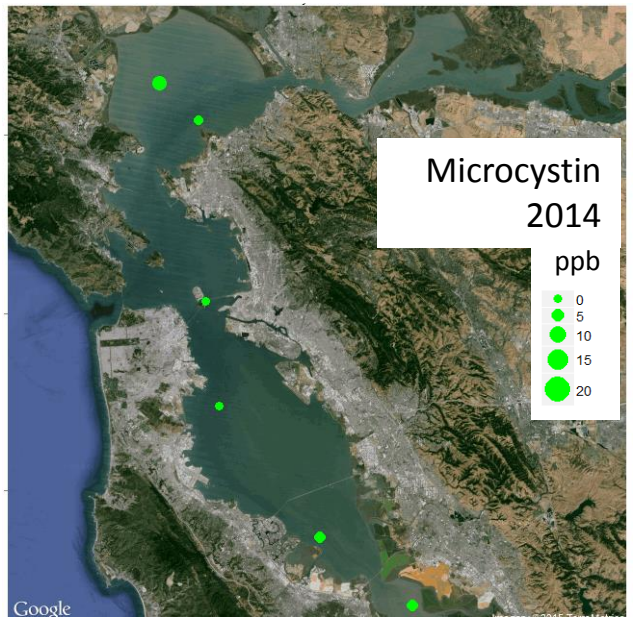
Valuable Monitoring Approach?

- Pro: Direct measure of accumulation in biota
- Con: Rapid depuration of DA, logistics/cost









All units wet weight

On-going Work (FY2014-2015)
: Intensive Bay-wide study of phytoplankton community and toxins

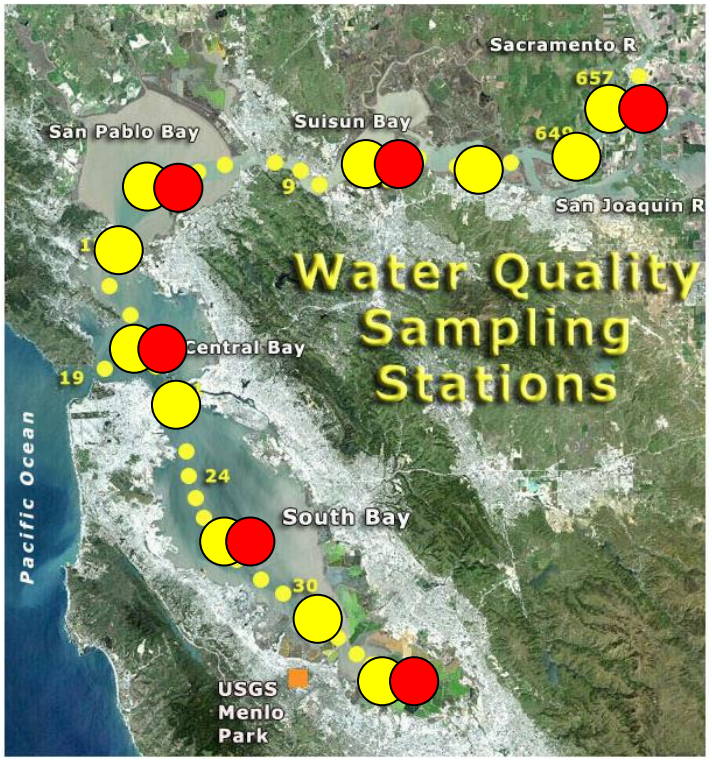
- Sample archive for phytoplankton pigments and toxins
- November 2011 - April 2014 (1-2 times per month)

Pigment >400 samples

Toxins ~200 samples

75 matched with microscopy

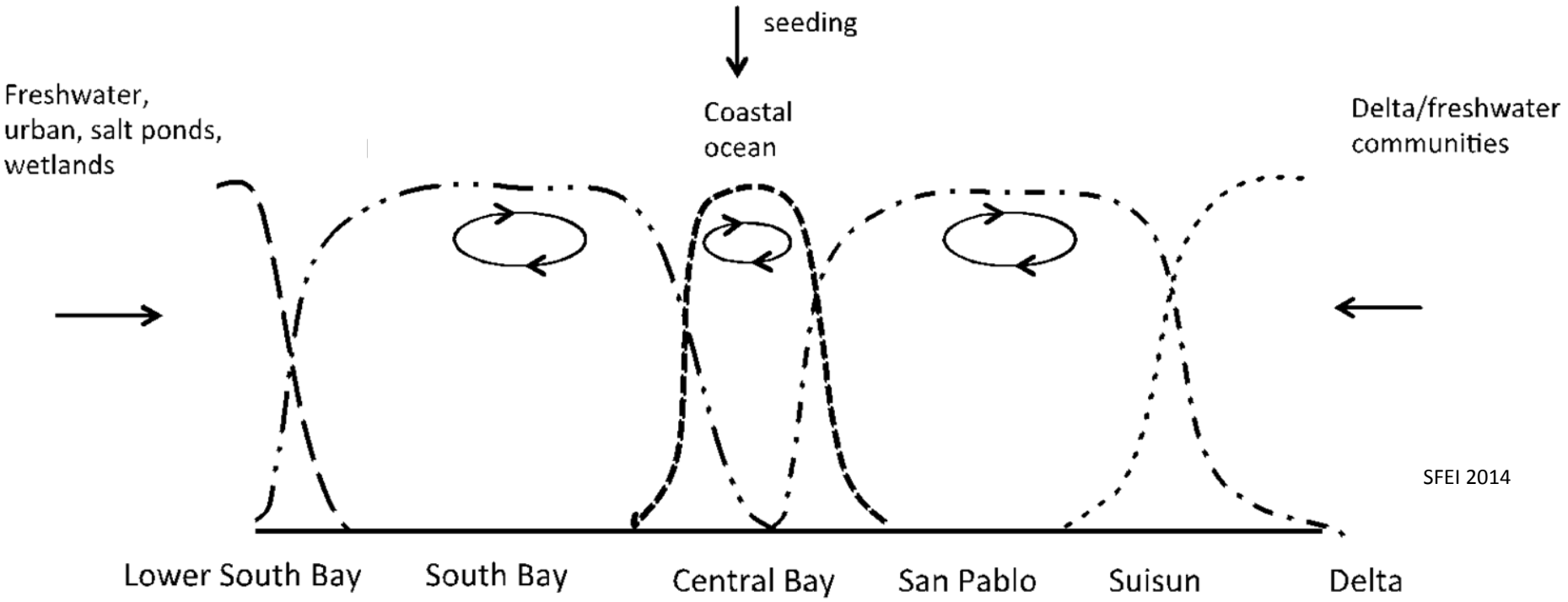
- Measure pigments to quantify ~biomass of different classes of organisms
- Measure array of toxins on co-collected samples
- Statistical analysis (physical, chemical conditions), and support modeling



Peacock et al., in prep

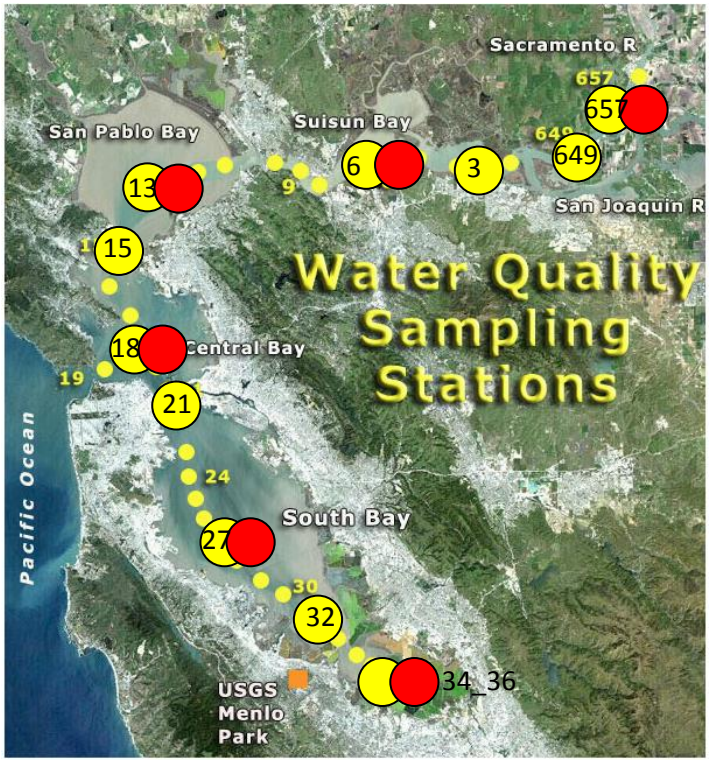
What shapes phytoplankton community composition and occurrence of HABs/toxins?

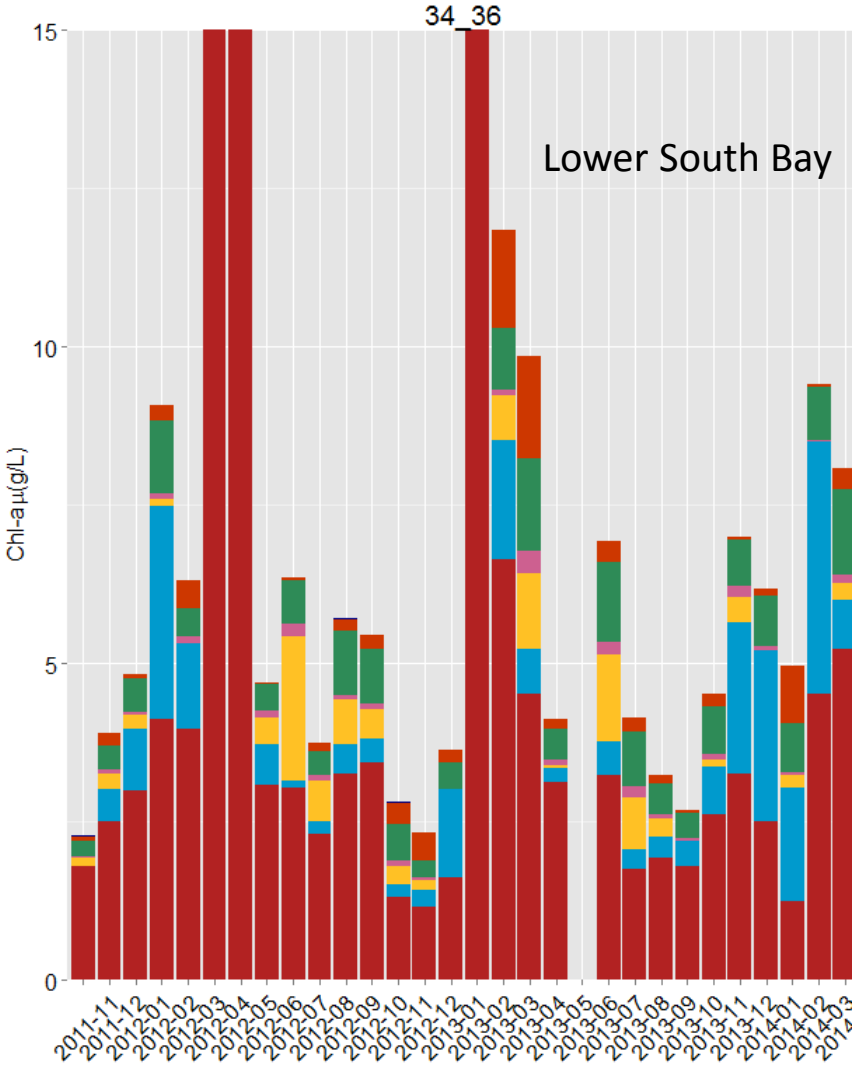
Are nutrients adversely impacting phytoplankton composition in SFB?



Internal processes

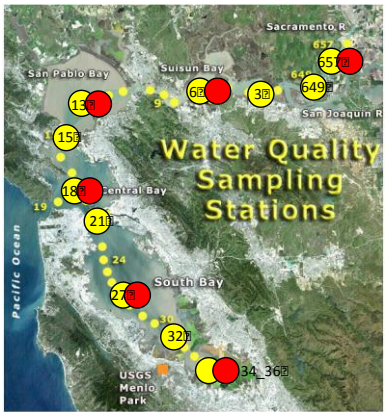
- Light
- Temperature
- Mixing
- Residence time
- Grazing
- Nutrients





Class

- Other
- Eustigmatophyte
- Cryptophyte
- Chlorophyte
- Cyanobacteria
- Dinoflagellate
- Diatom



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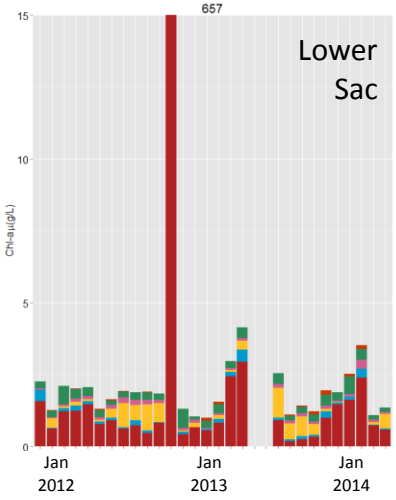
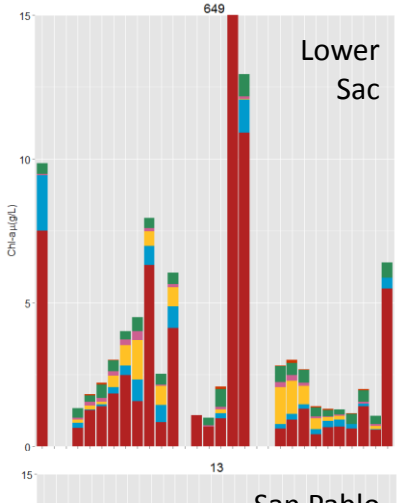
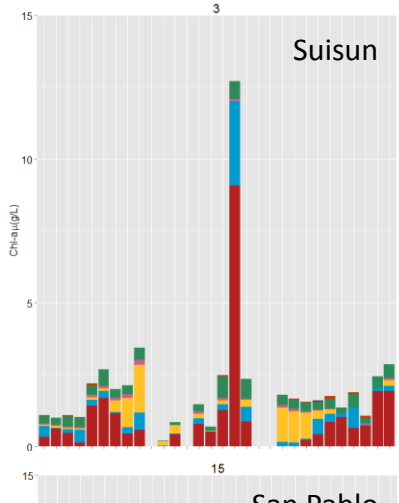
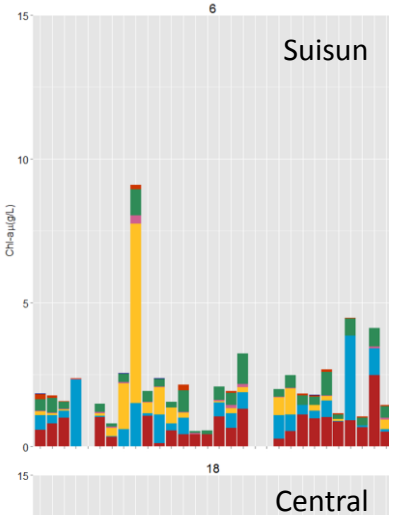
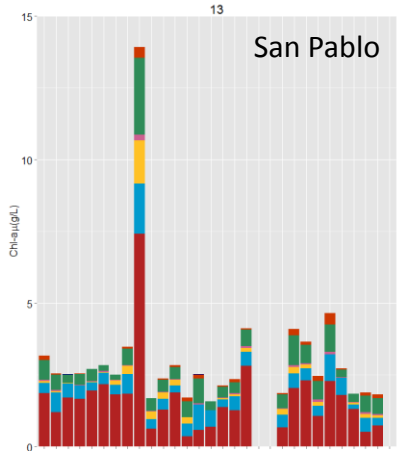
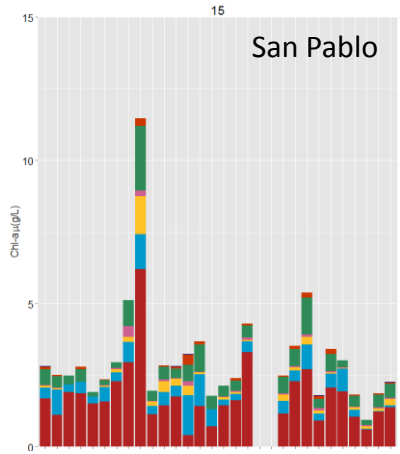


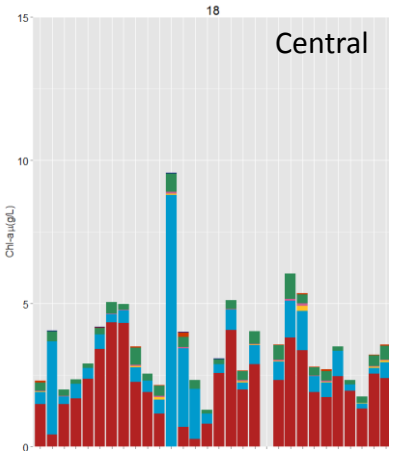


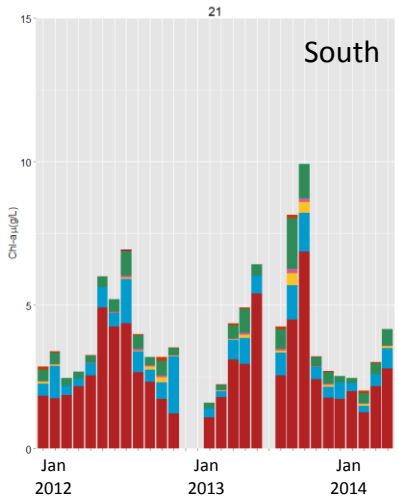


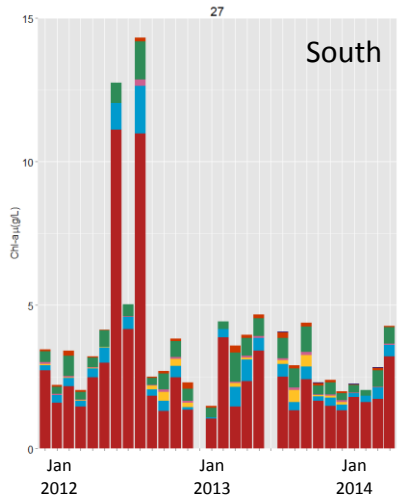


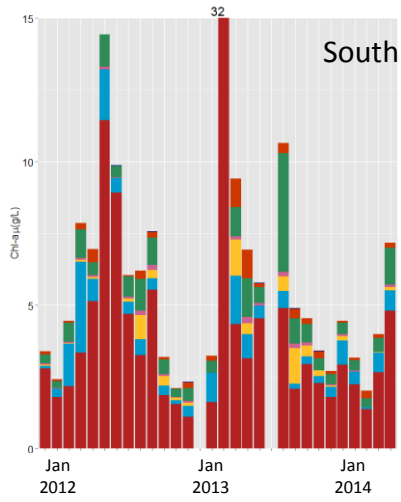


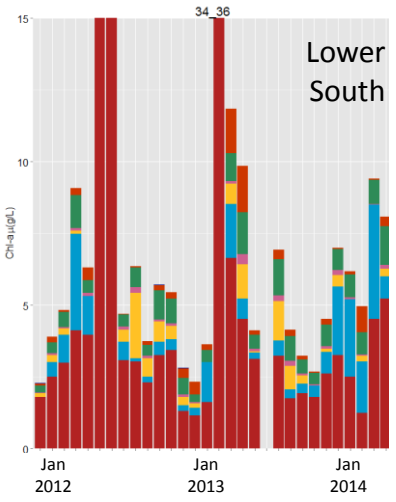












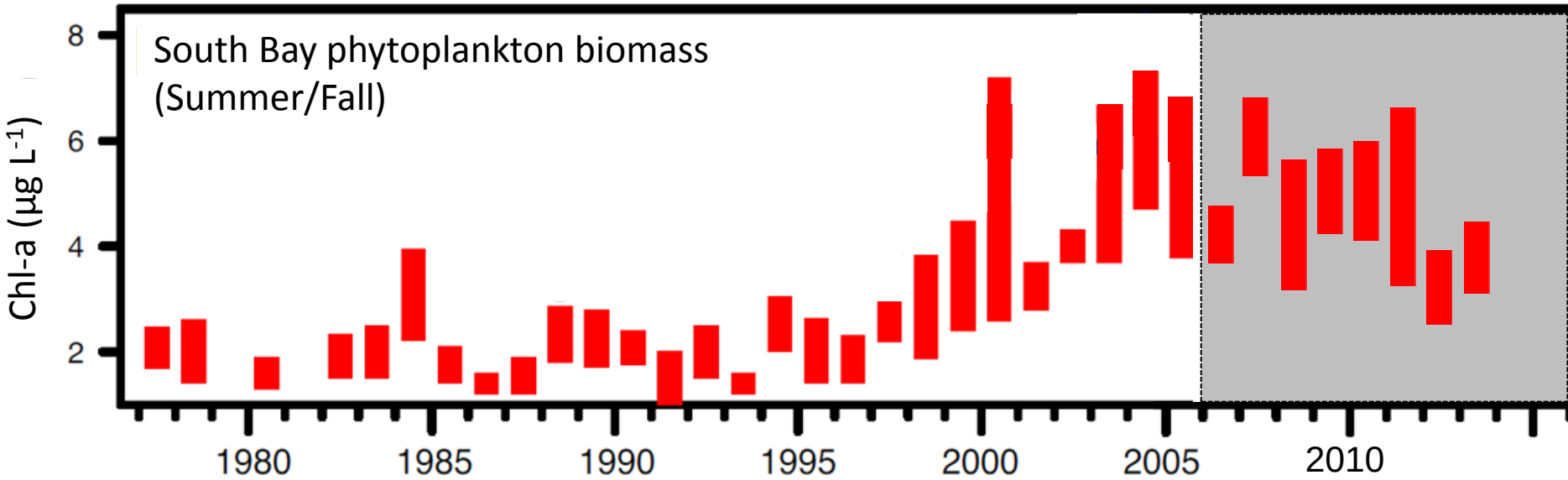
Peacock et al., in prep

Phytoplankton/HABs and Toxins: What's next?

Water column samples: Toxin measurements

Statistical analysis: associations with physical/chemical data, and mechanistic interpretations

Changing ecosystem response in San Francisco Bay: Underlying causes, future scenarios



Cloern et al. 2007

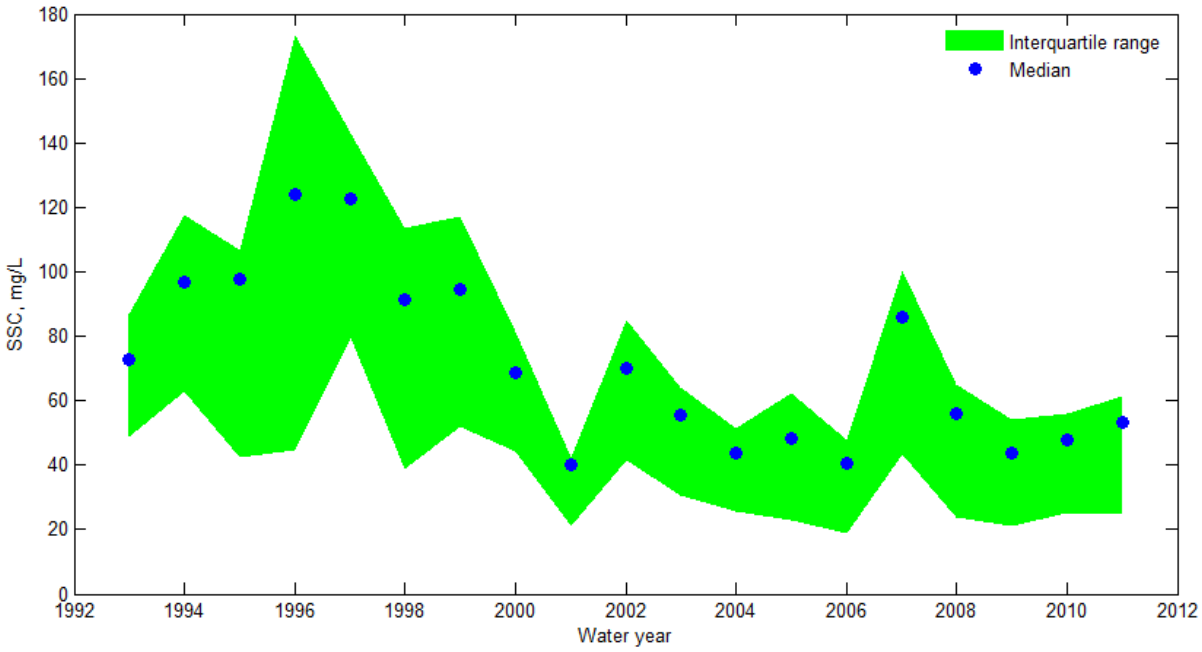
Data: USGS
SFEI 2015

- South Bay and Lower South Bay appear to have reached a new 'state'
  - 3x-higher biomass, with unknown cause

- Possible causes…
  - Decreased suspended sediments
  - Decreased grazing by benthos
  - Changes in wind speed/direction?
  - Climate Oscillations (changes in upwelling, coastal currents)

Raimonet et al., in prep

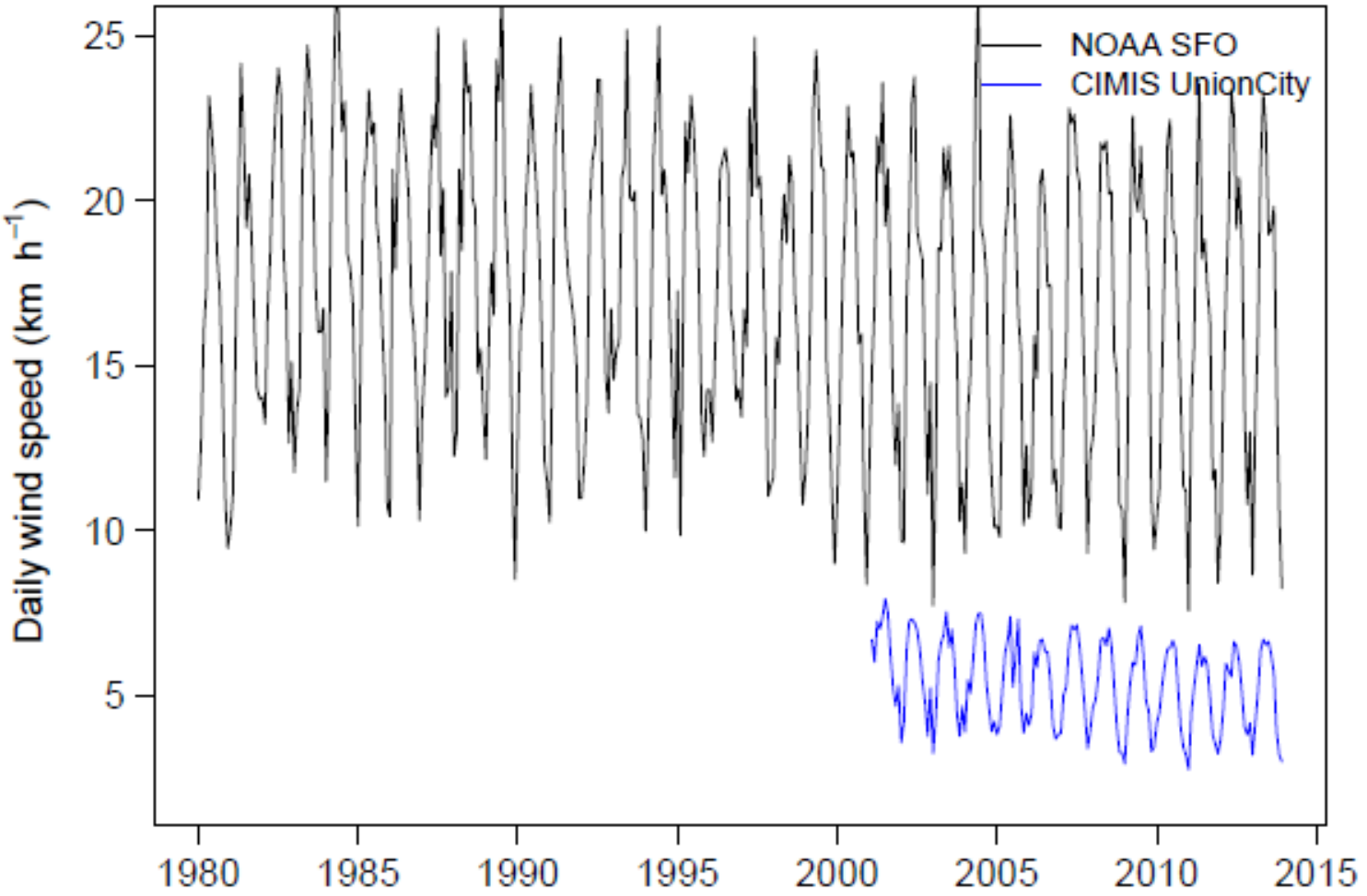
Suspended Sediment Concentration – Dumbarton Bridge



- 40-50% decrease in suspended sediments
- 40-50% higher light levels and potential growth rate

Schoellhamer et al. 2015; SFEI 2015

Raimonet et al., in prep



Nb: alongshore winds increase outside of the Bay, favoring upwelling. However wind speed decreases at 3/4 stations inside the bay.

Raimonet et al., in prep

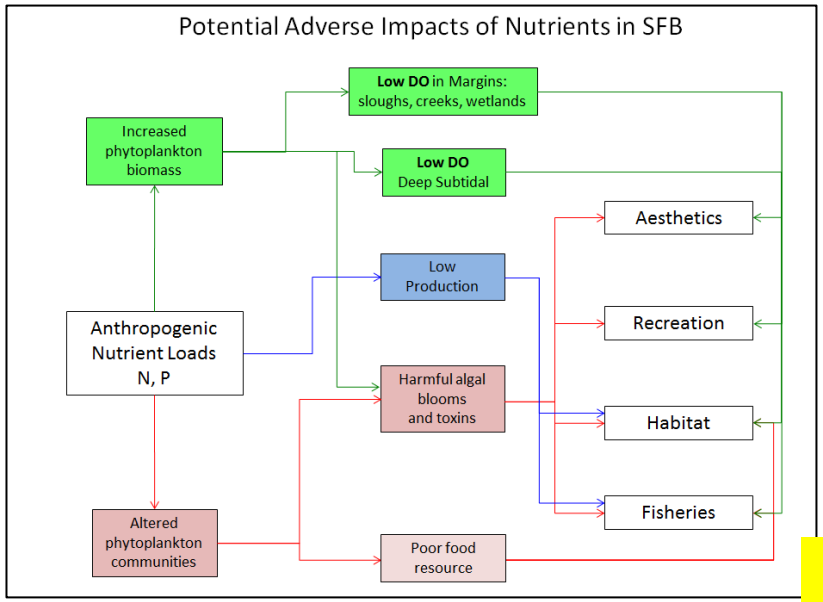
4 basic components

1. Nutrient sources, movement, transformations?

2. Ecosystem response to nutrients
   - Causing problems?
   - Develop best-possible understanding of dose:response
   - What are protective nutrient levels? (now, future)

3. What management actions will maintain nutrients at protective levels?
   - Which would be most efficacious and cost-effective?

4. With limited resources, and limited time, what is the best approach for 1, 2, and 3?



4 basic components

November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

1. Nutrient sources, movement, transformations?

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   - Develop best-possible understanding of dose:response
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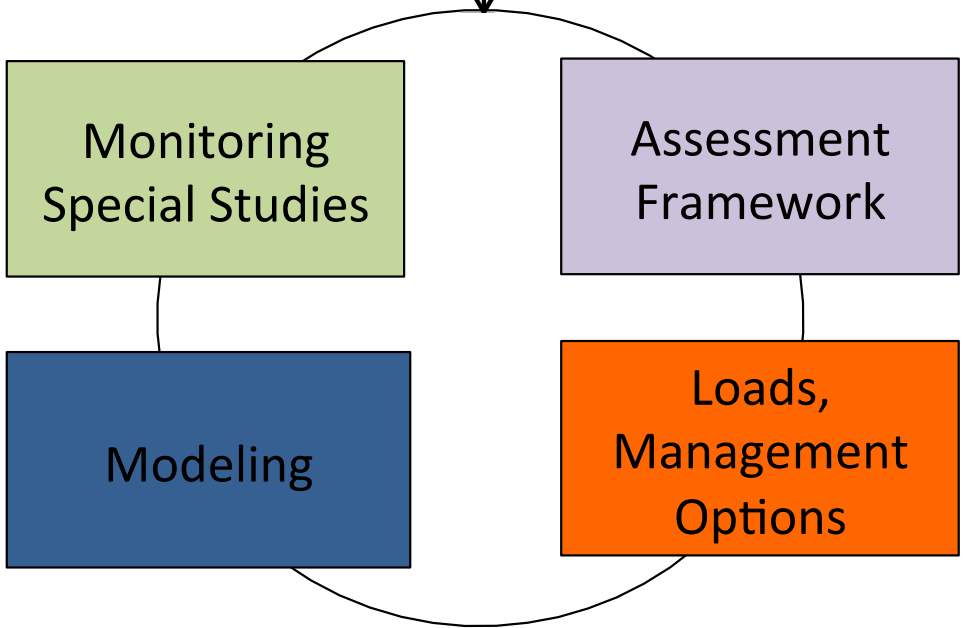
With limited resources, and limited time, what is the best approach for 1, 2, and 3?

Science Plan



Key Messages

- Algal toxins and HAB-forming organisms commonly detected Bay-wide
  - Adverse Impacts? Causes? Linkage to Nutrients?
  - HABs and toxins major focus of current and future work

- New method used to build multi-year Bay-wide record of phytoplankton community composition (weekly-monthly)
  - Explore spatial and seasonal variability and factors regulating composition

- Lower South Bay appears to be a vigorous biogeochemical reactor: N transformations/Dissolved Oxygen
  - Field investigations and modeling will lead to improved understanding

- Low dissolved oxygen observed in sloughs/creeks, and large variability in open waters of Lower South Bay
  - Adverse impacts? Causes? Linkages to Nutrients?

Key Messages

- Underlying causes of changing ecosystem response remain a mystery, yet could have major implications for management implications
  - Examine historical record, model future scenarios

- Developing multi-year Science Plan to prioritize…Major current focus…
  - HABs, toxins, nutrient transformations
  - Dissolved oxygen, in particular in sloughs and creeks

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Source: C. Benton

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