
Source: C. Benton

NMS Science Program Update

1. Biogeochemical studies in Lower South Bay
2. HABs/toxins and Phytoplankton community
3. Water Quality Model development
4. NMS Work Products

D Senn, E Novick, P Bresnahan, R Holleman, and Zephyr Sylvester

San Francisco Estuary Institute

and MANY regional collaborators

sfbaynutrients.sfei.org

Key Science Collaborators

SFEI

E Novick

P Bresnahan

R Holleman

Z Sylvester

D Senn

USGS-Menlo Park

J Cloern

L Lucas

T Schraga

USGS-Sacramento

M Downing-Kunz

G Shellenbarger

D Schoellhamer

B Downing

B Bergamaschi

UC Santa Cruz

R Kudela

M Peacock

SCCWRP

M Sutula

UC Berkeley

M Stacey

4 basic components

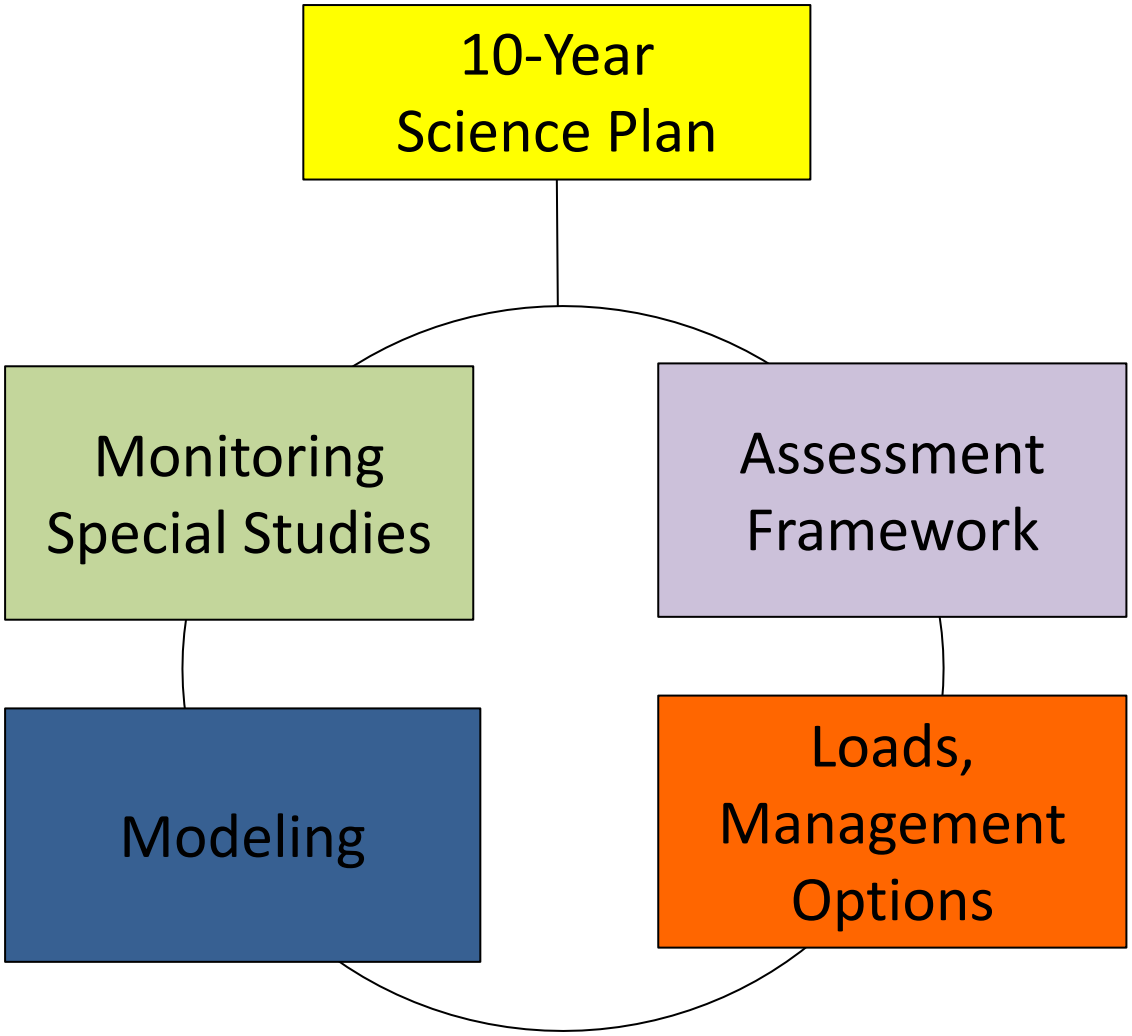
1. Nutrient sources, movement, transformations

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

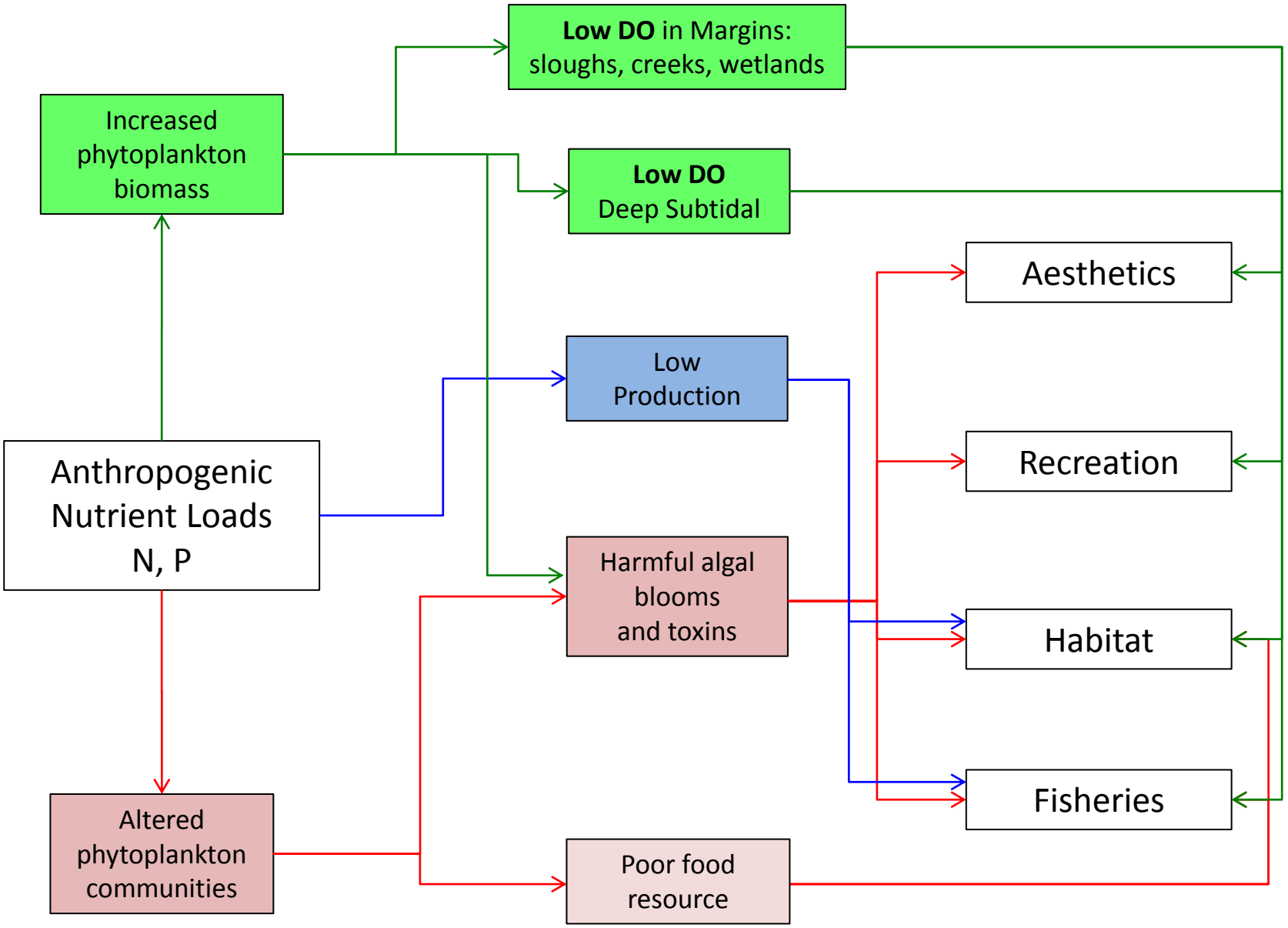
3. What management actions will maintain nutrients at protective levels?
   - Which would be most efficacious and cost-effective?

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

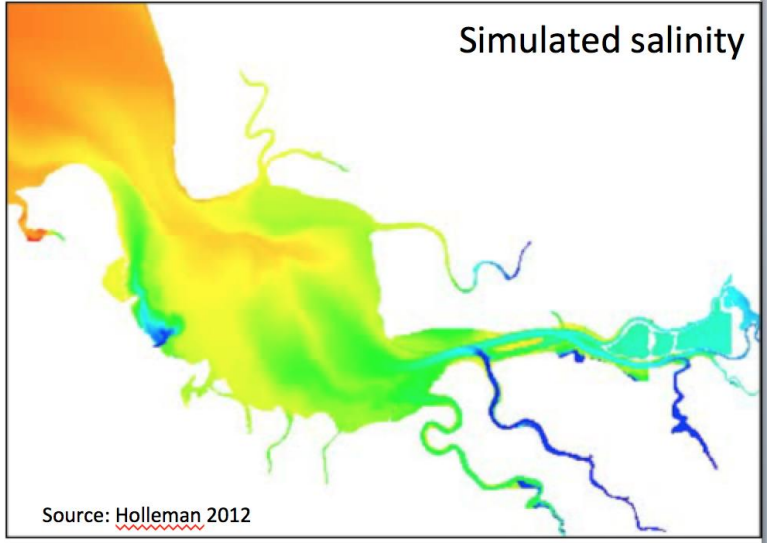
Nutrient Science Program



Potential Adverse Impacts of Nutrients in SFB



Lower South Bay

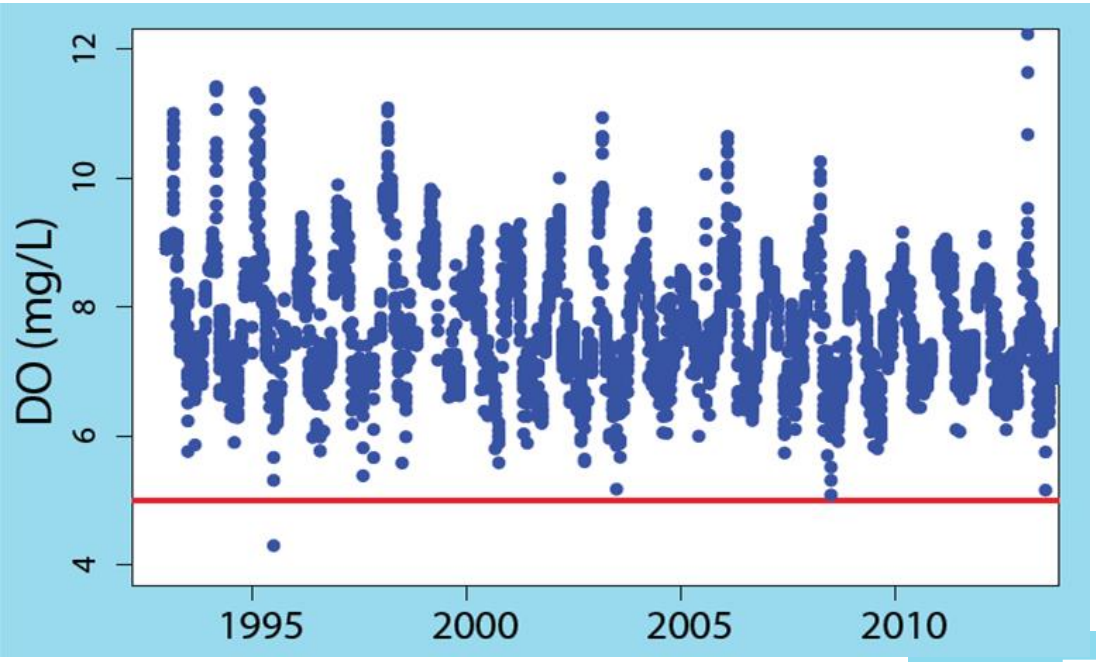


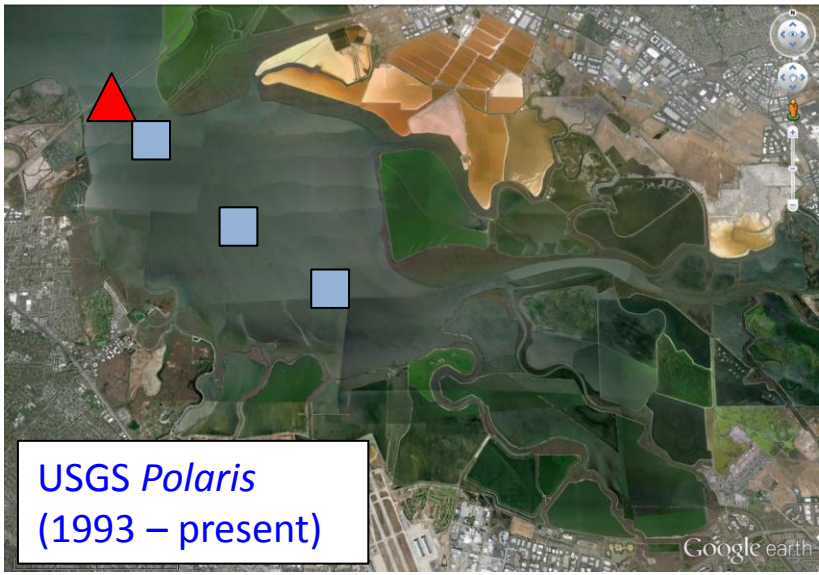
- Complex system, slow flushing
- Highest **N**itrogen and **P**hosphorous concentrations in the Bay
- 3 WWTPs
- Parameters of interest: algal biomass (chl-a), dissolved oxygen (DO) , algal community, toxins, **N** and **P**

Key Questions

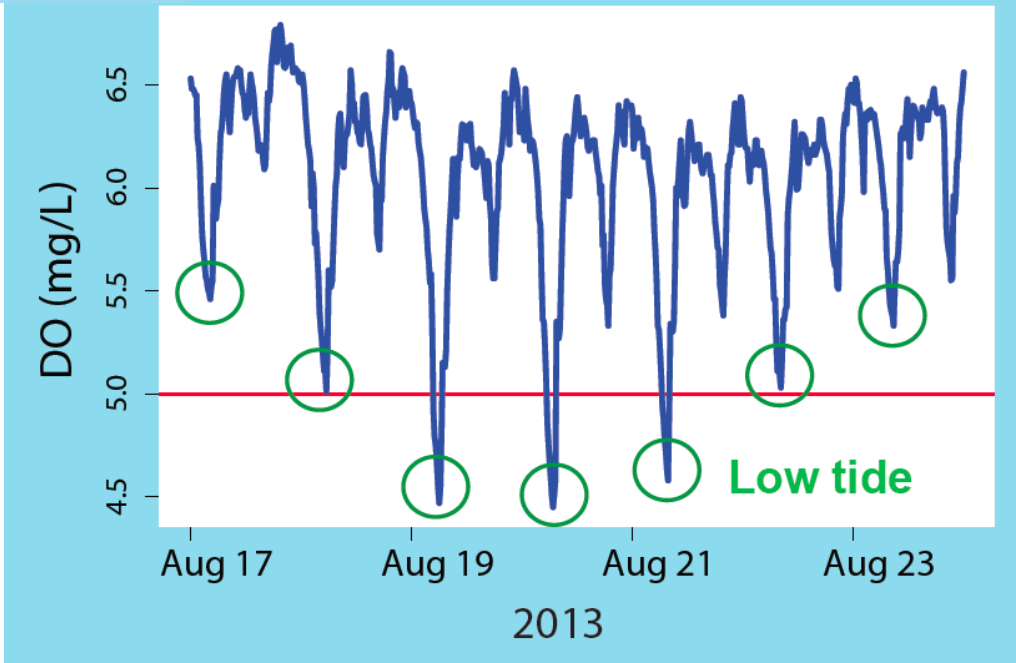
- Condition?: Open Bay and sloughs/creeks. Adverse impacts?
- Spatial variability: production, biomass, nutrient cycling?
- Restoration efforts effect on DO, algae?

Dissolved Oxygen – Deep subtidal





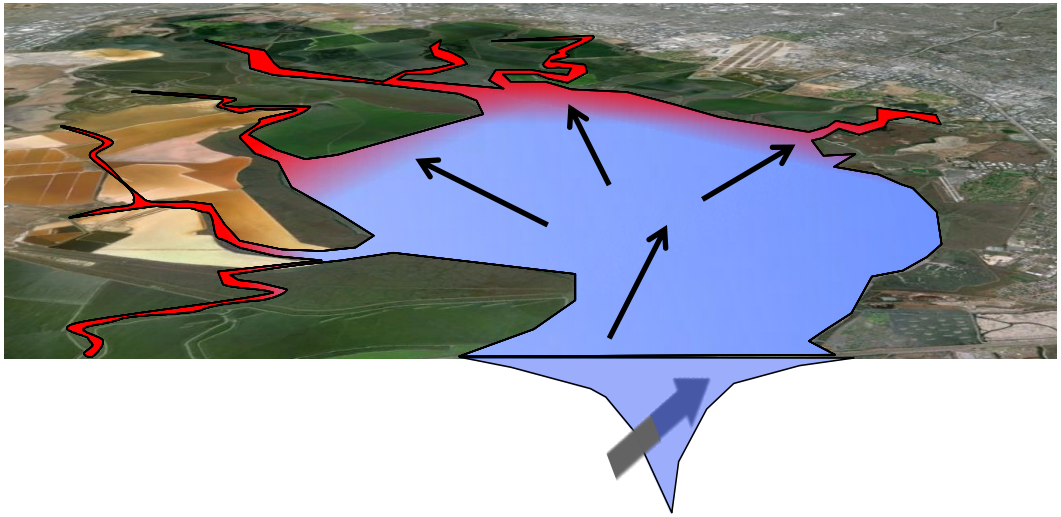
Dumbarton near-surface continuous sensor



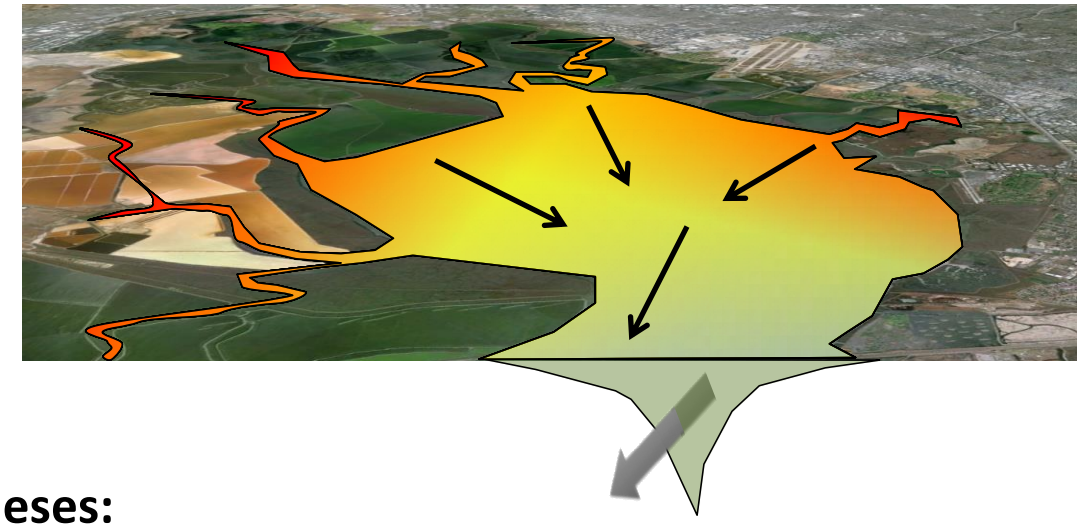
SFEI 2015

Conceptualization of water quality/source in LSB as a function of tide

Flood tide



Ebb tide



Margin Water:
Sloughs/Creeks/Marshes

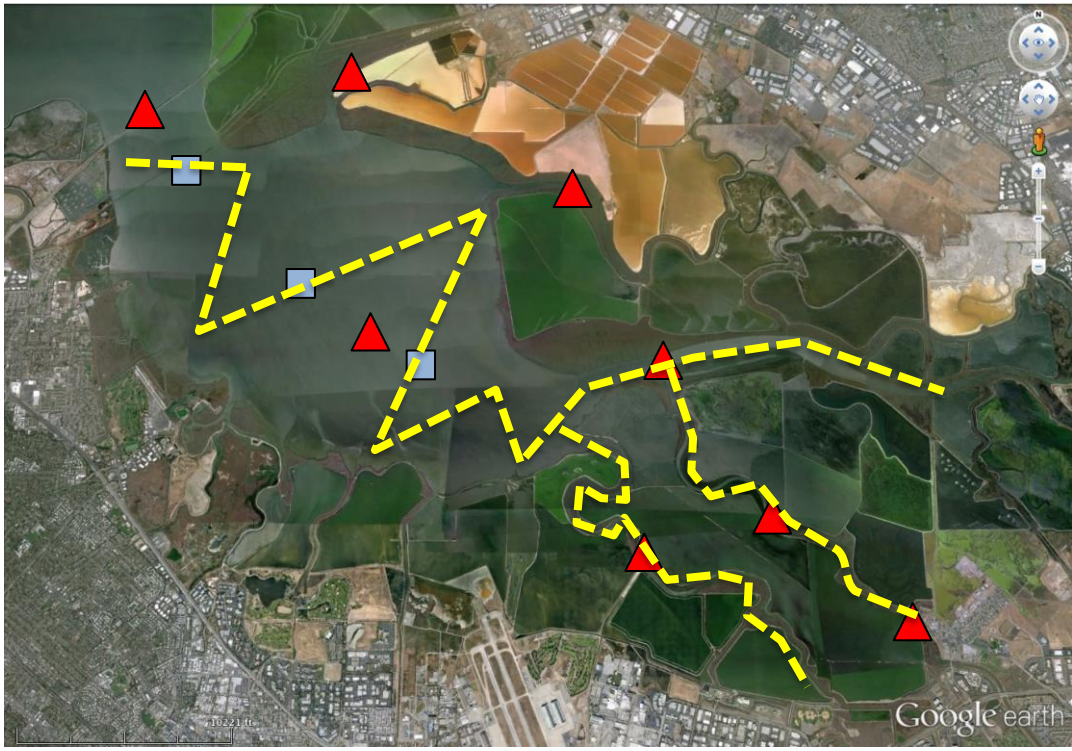
Open Bay Water:
Originating north
of Dumbarton

Hypotheses:

- Waters in sloughs/creeks have low(er) DO and higher algal biomass
- Exchange with restored salt ponds is one of several contributing factors

Need to measure…

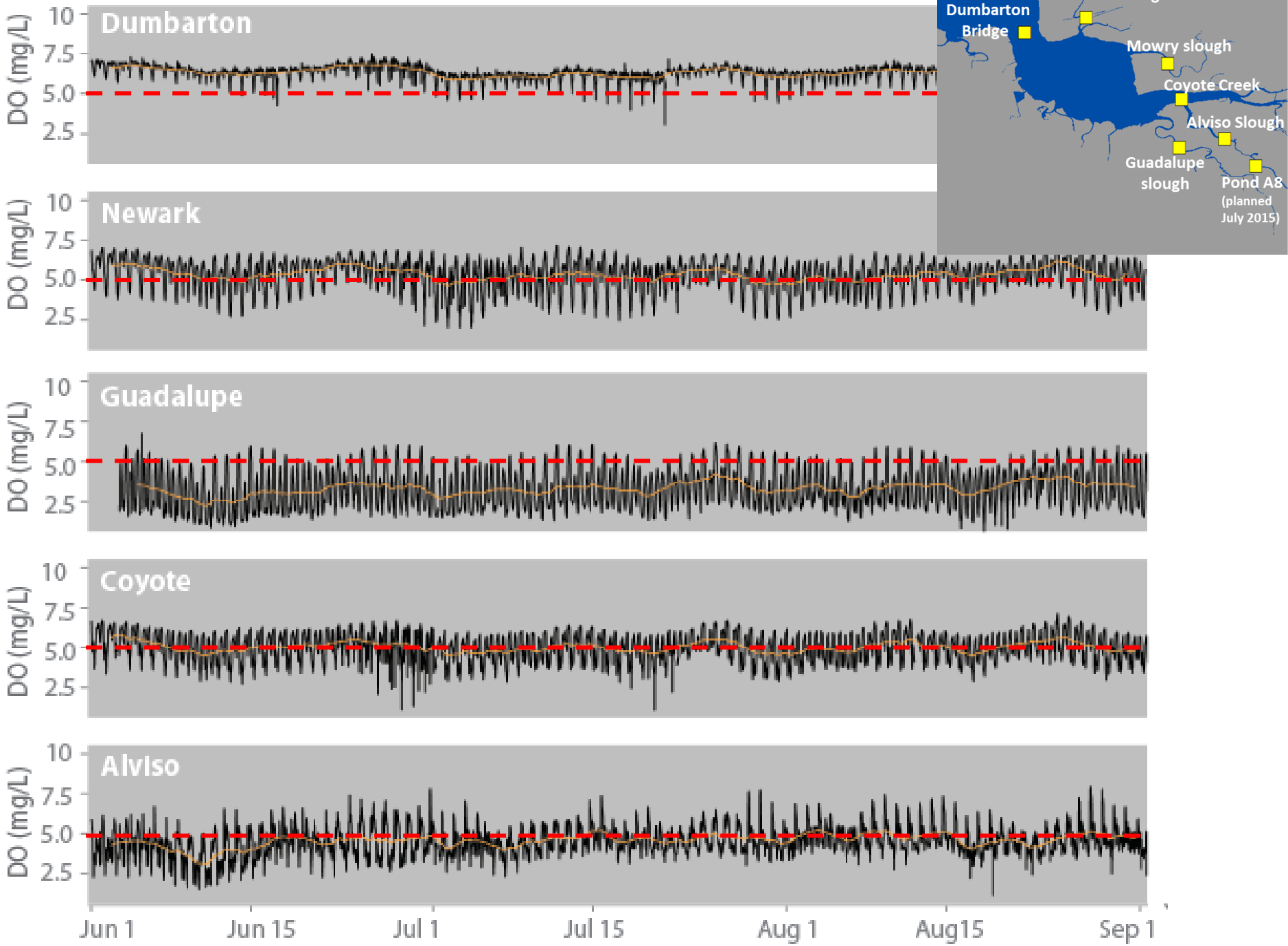
- The right things
- In the right places
- At the right times

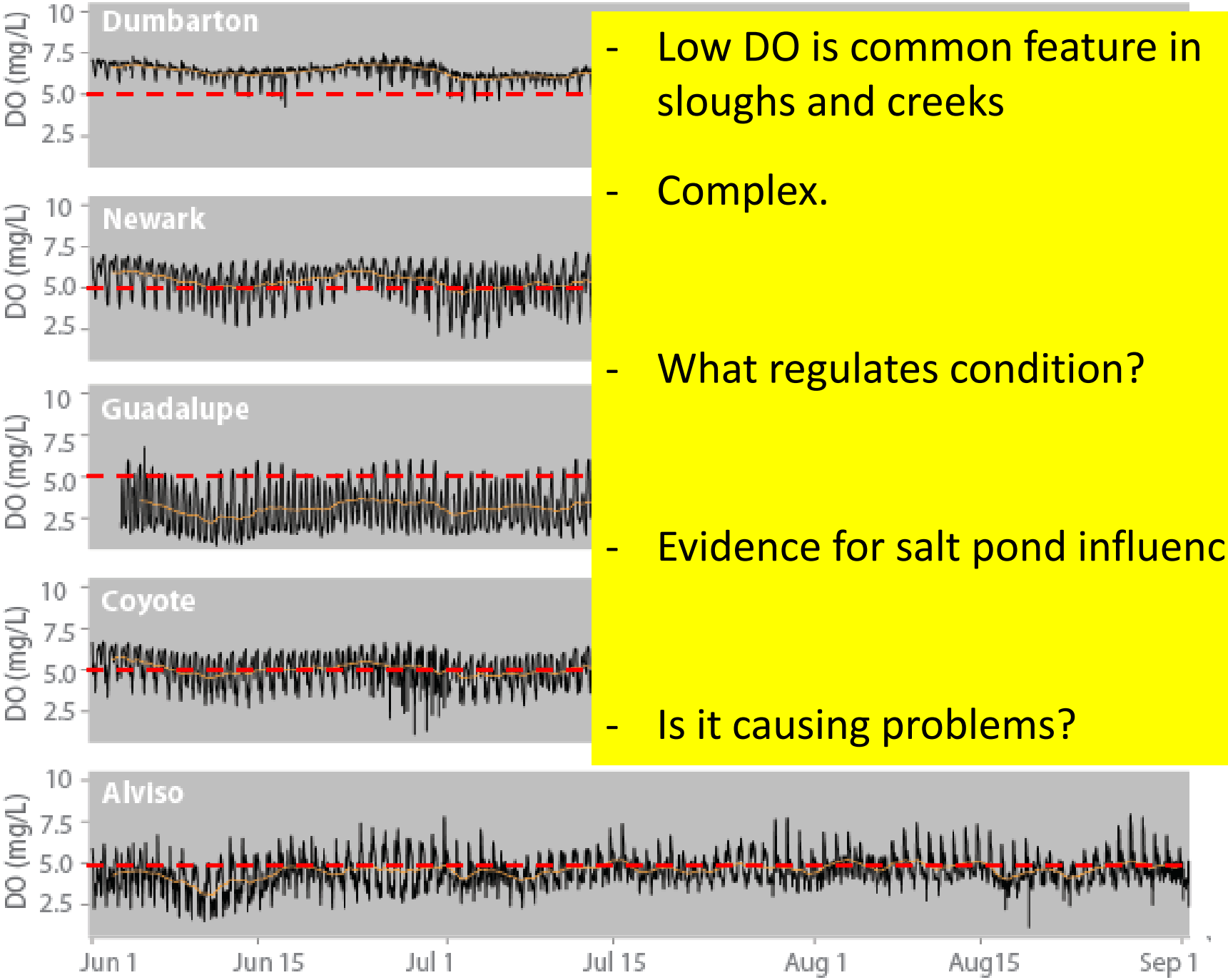


Long-term USGS *Polaris* (1970s – present)

Moored sensors: SFEI / USGS-Sac / UC Berkeley (2013 – present)

High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC (2015)


Dumbarton
Newark
Guadalupe
Coyote
Alviso
DO (mg/L)
10
7.5
5.0
2.5
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug15
Sep 1
Dumbarton Bridge
Newark slough
Mowry slough
Coyote Creek
Alviso Slough
Guadalupe slough
Pond A8 (planned July 2015)



- Low DO is common feature in sloughs and creeks
- Complex.
- What regulates condition?
- Evidence for salt pond influence?
- Is it causing problems?

Need to measure…

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

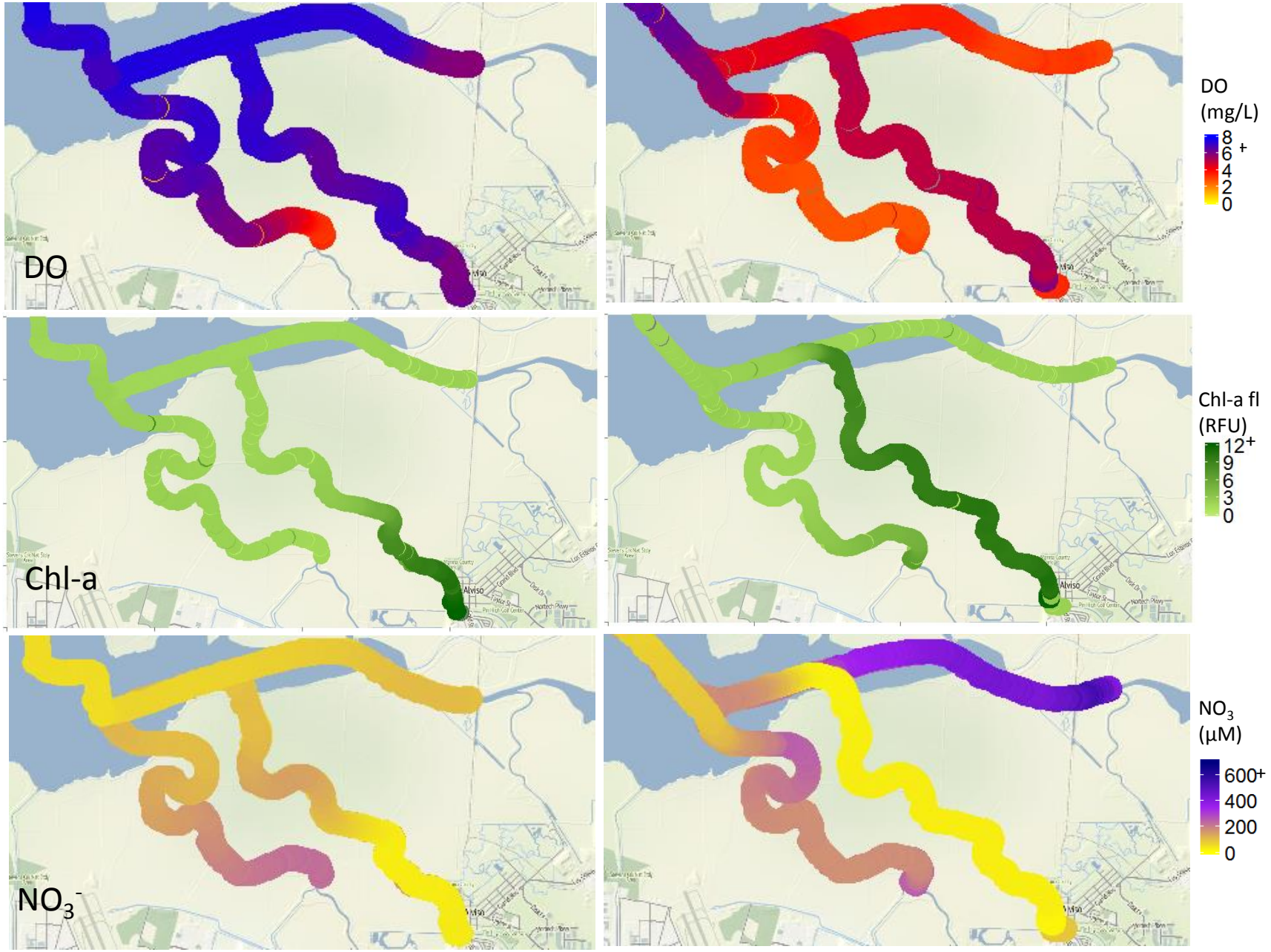
High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC

Bergamaschi, Downing et al.

Flood tide

July 15-16 2015

Ebb tide

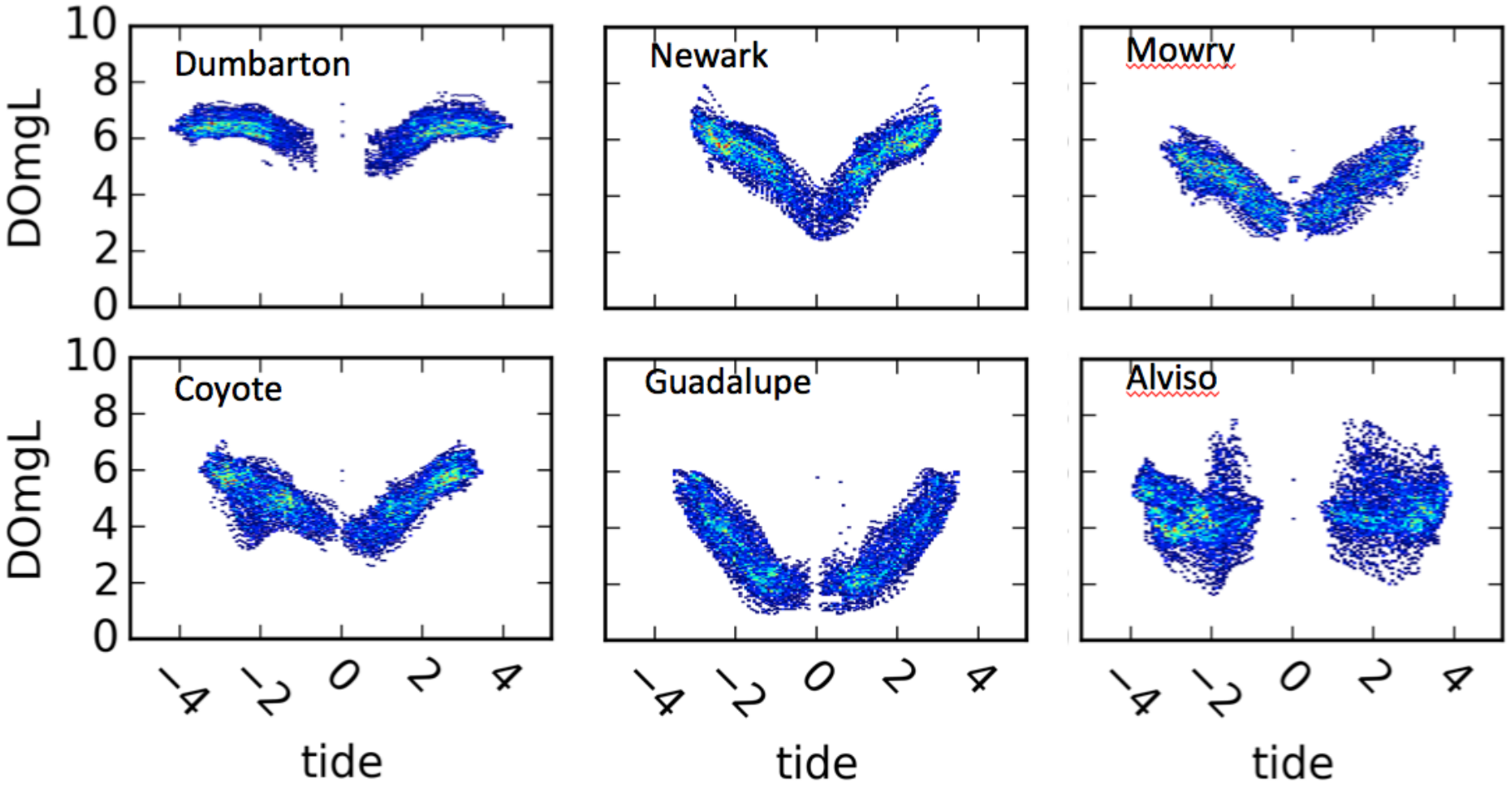


On-going work

- Data Analysis and interpretation

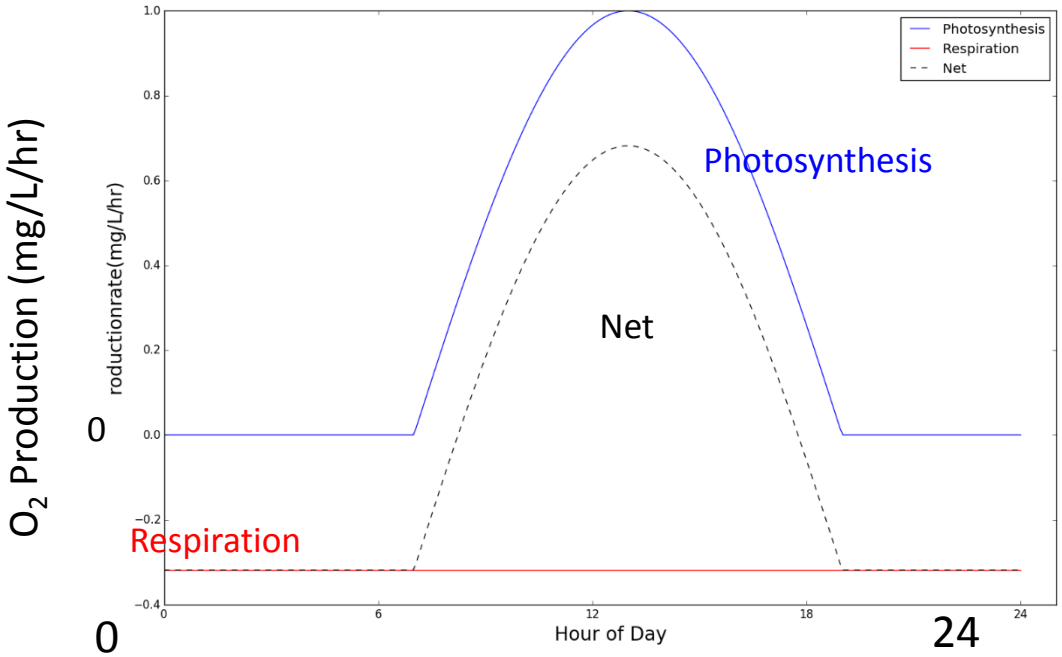
- Two major directions
  - Mechanistic interpretation….why?

  - What does it mean? Habitat quality


Dumbarton
Newark
Mowry
Coyote
Guadalupe
Alviso
DOmgL
DOmgL
10
8
6
4
2
0
-4
-2
0
2
4
tide
tide
tide

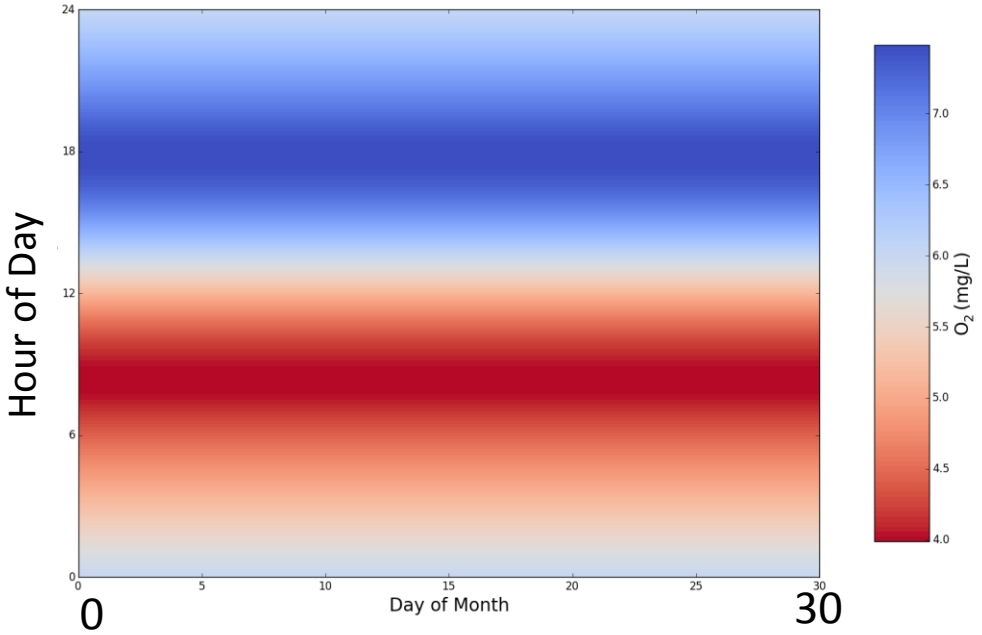
Diel Cycle…

Oxygen production and consumption.

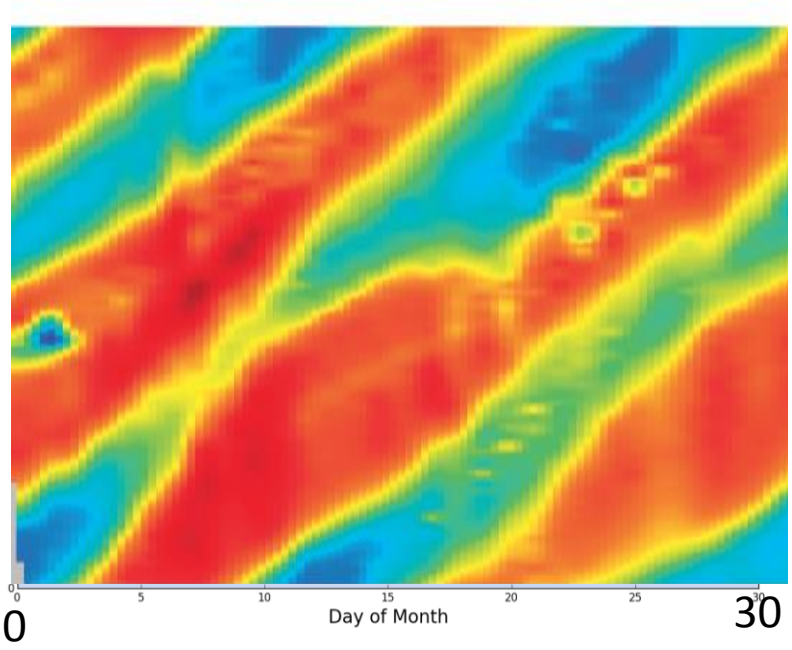


What we would expect to see if DO was primarily influenced by respiration and the diel production of DO

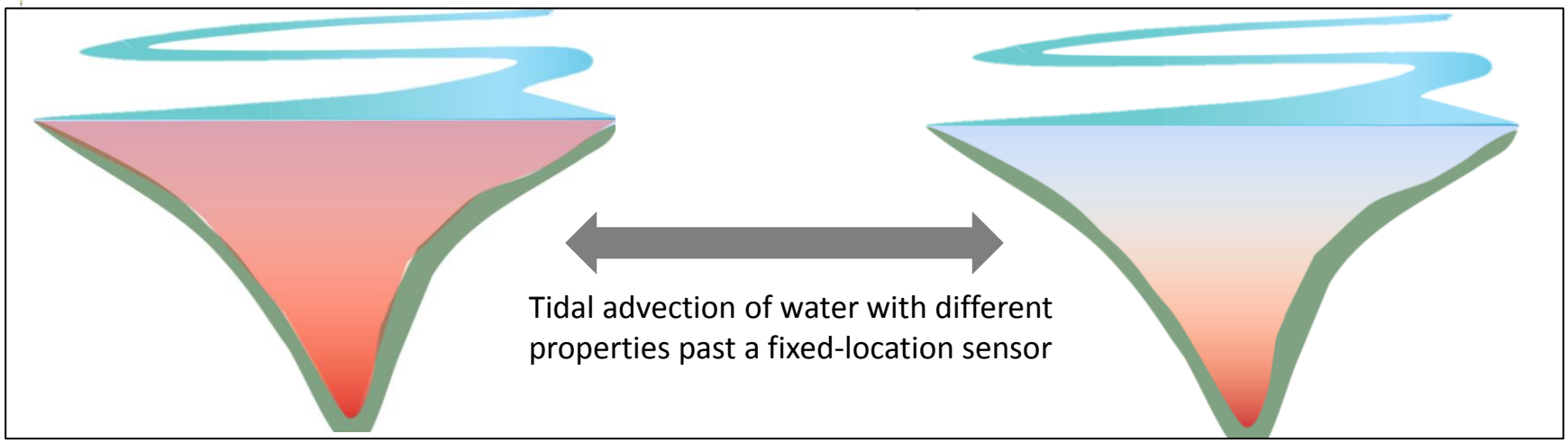
Photosynthesis/respiration only – 1 month



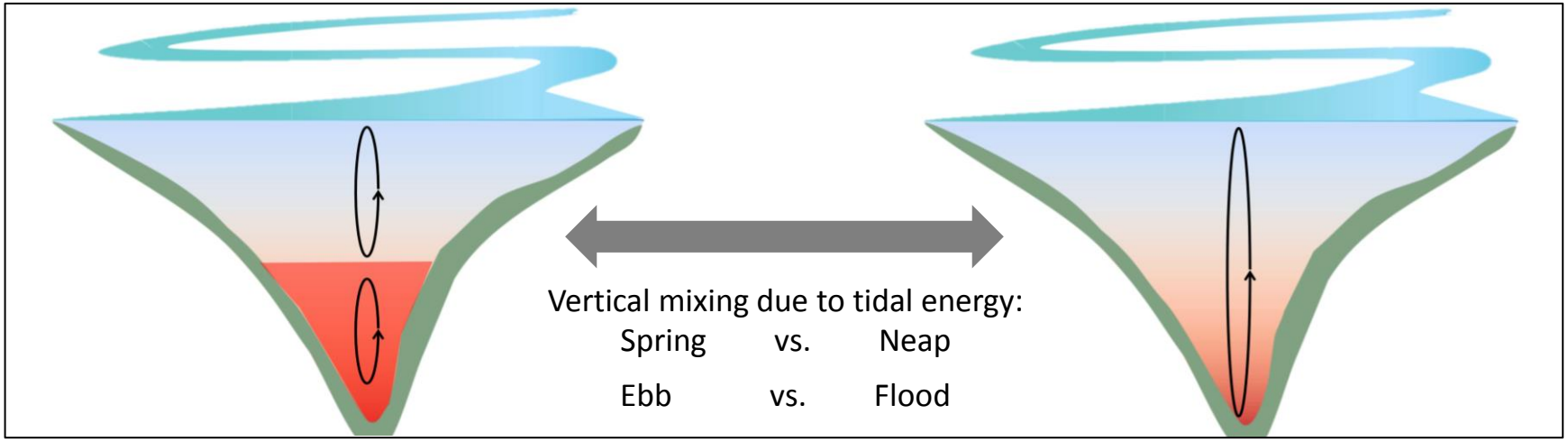
Guadalupe – Real data, 1 month, Jun-Jul



What causes observed tidal signal in dissolved oxygen in sloughs?



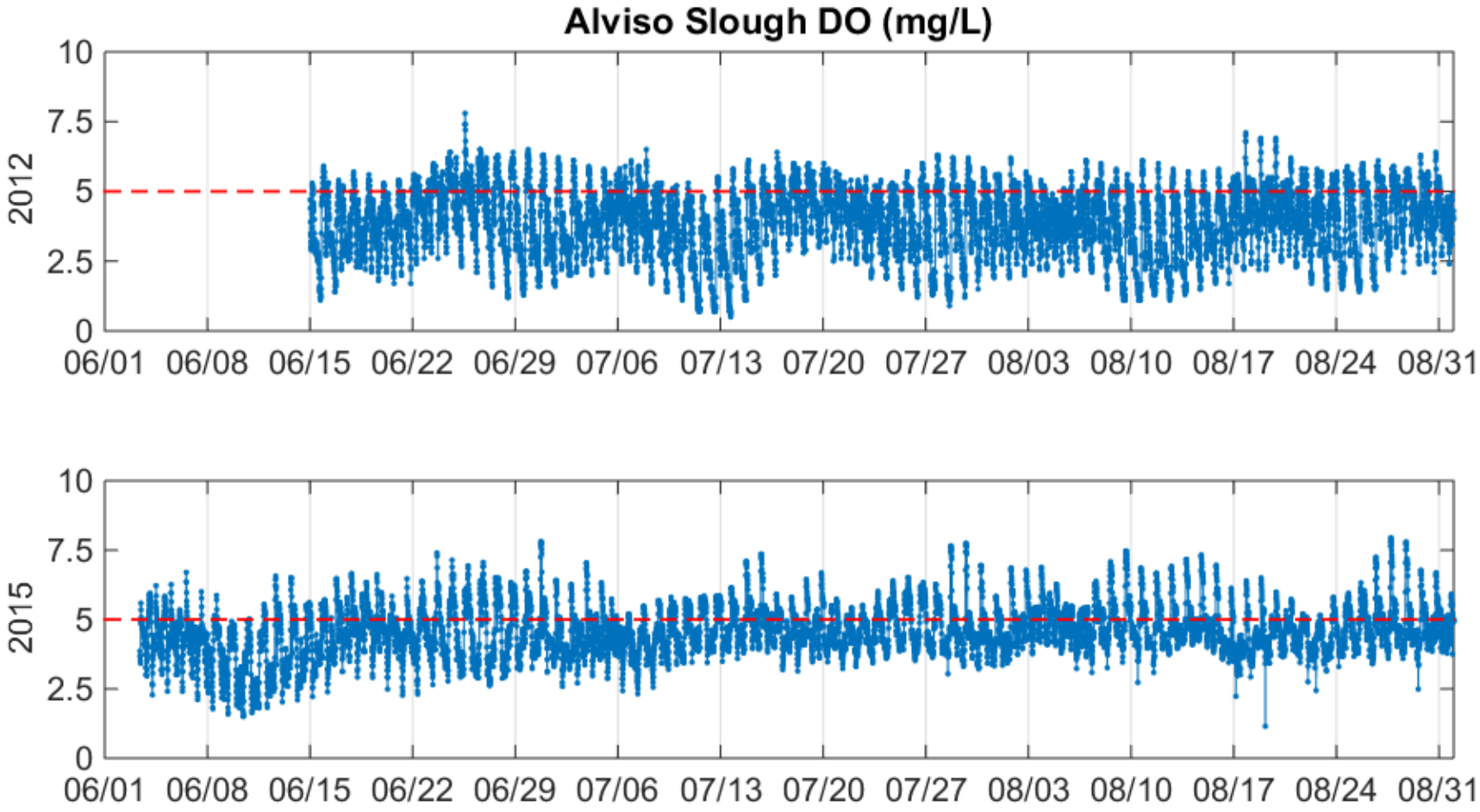
---- OR ----



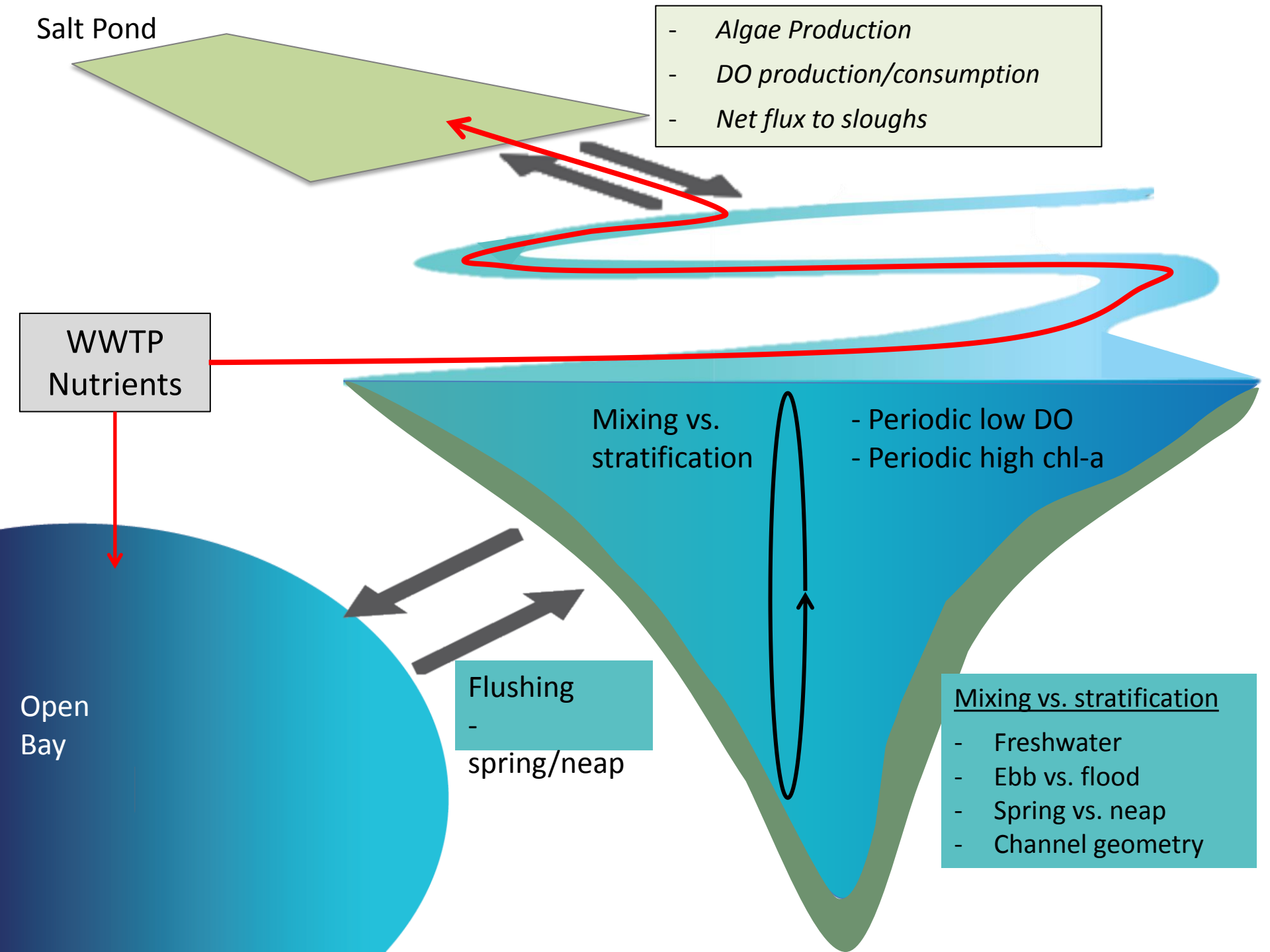
---- OR ----

BOTH or OTHER

Interannual variability



Data: M Downing-Kunz (USGS)


Salt Pond
- Algae Production
- DO production/consumption
- Net flux to sloughs
WWTP Nutrients
Mixing vs. stratification
- Periodic low DO
- Periodic high chl-a
Open Bay
Flushing - spring/neap
Mixing vs. stratification
- Freshwater
- Ebb vs. flood
- Spring vs. neap
- Channel geometry

Habitat-driven data analysis ←→ Protective DO

1. Sensitivity to low DO differs by
   - Species
   - Life stage
   - Motility
   - Habitat utilization

2. Both intensity (deficit) and duration may be important

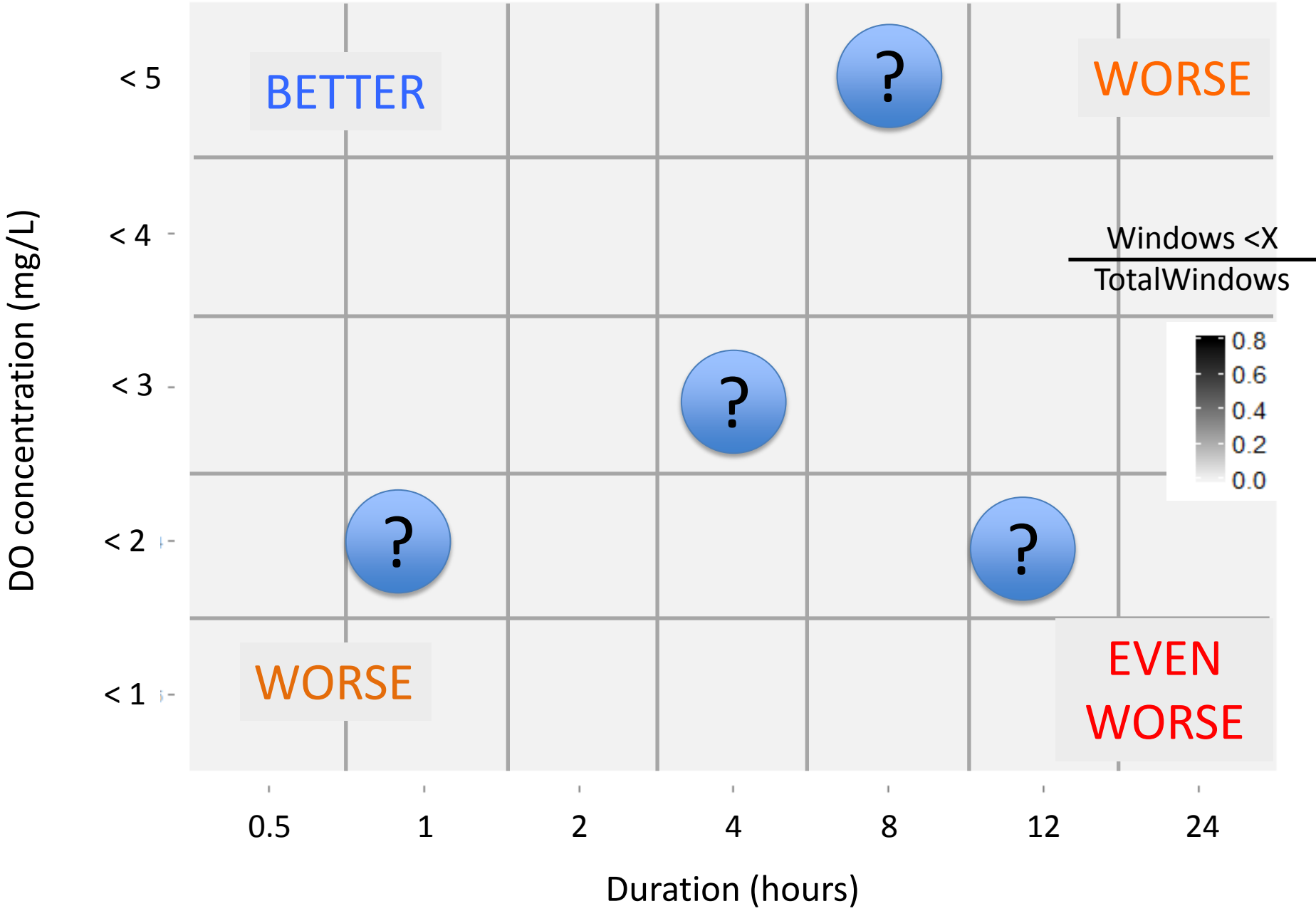
3. Effects related to 1 - 2 will also differ depending on organisms
   1. Acute
   2. Chronic effects / Stress
   3. Avoidance
   4. Individual vs. population effects…e.g. decreased reproductive success

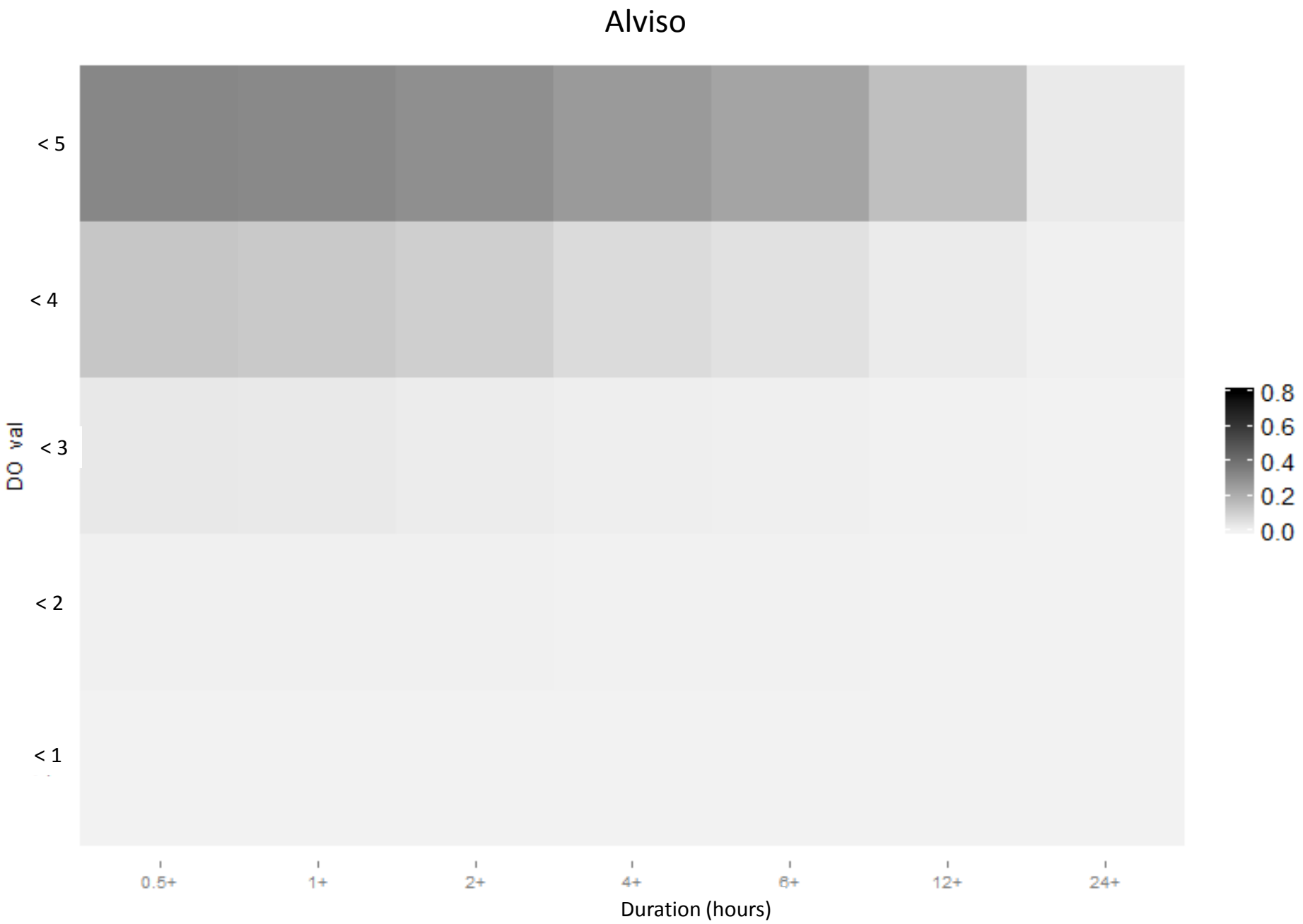
Habitat-driven data analysis ←→ Protective DO

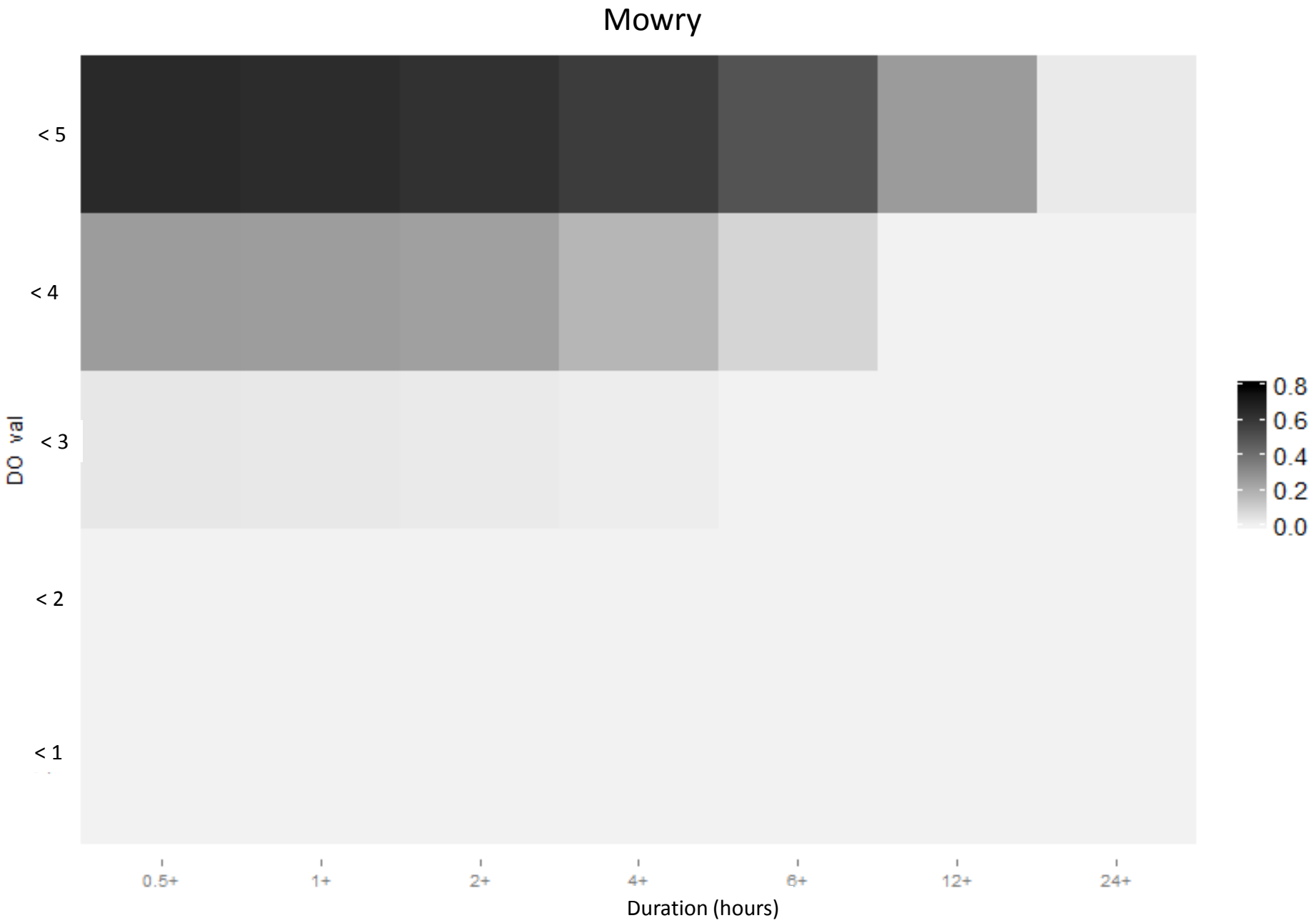
1. Start by analyzing data quantitatively but flexibly, without fixed values of what is “good” vs. “ok” vs. “bad”

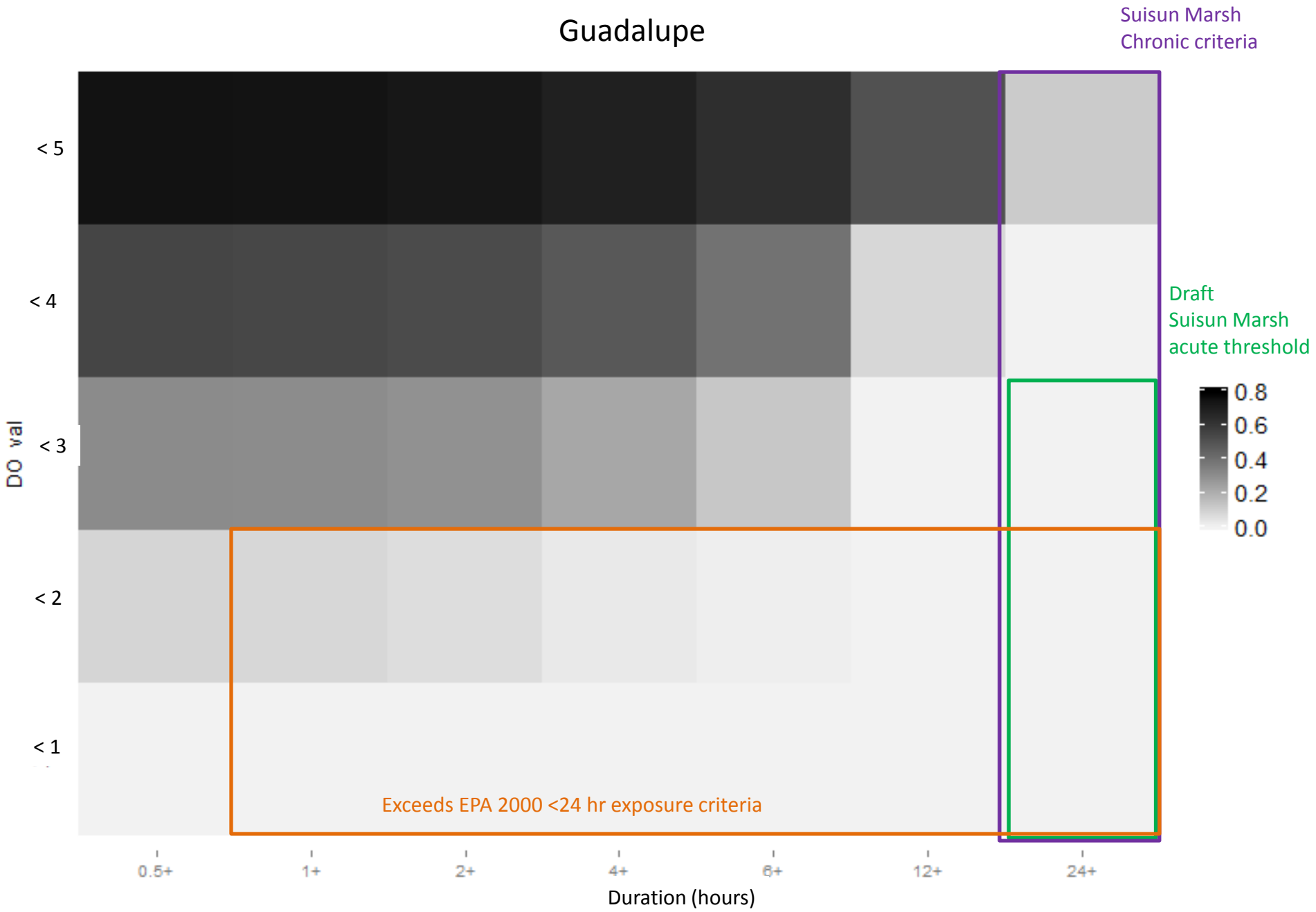
2. Sensitivity-analysis-type approach…
   - Work backward to identify data gaps
     - We frequently see condition A, B, and C but seldom see conditions X, Y, Z
     - What types of effects could occur
   - What has been shown to be important in other systems?

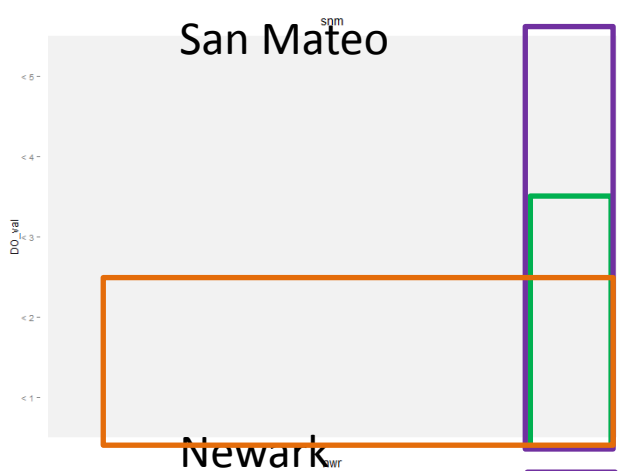
What do aquatic organisms experience in LSB habitats? Exposure and Duration

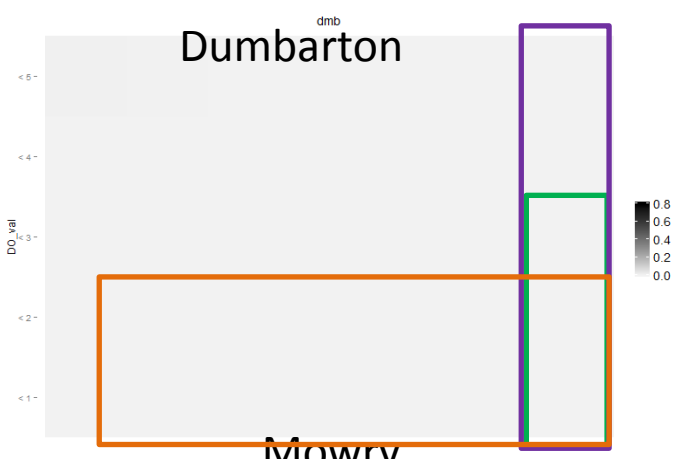


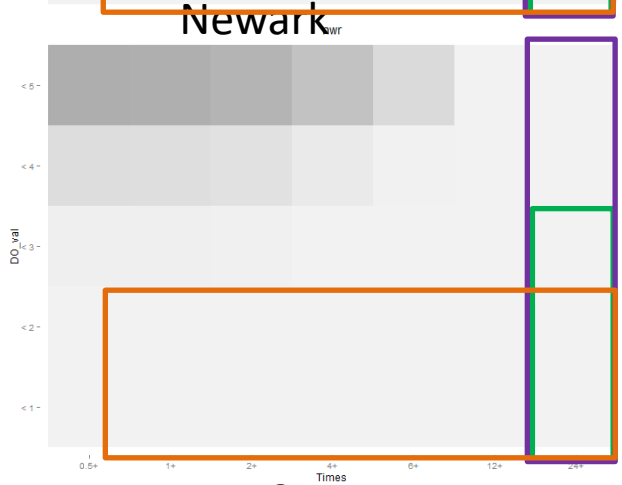

Alviso
DO val
< 5
< 4
< 3
< 2
< 1
0.5+
1+
2+
4+
6+
12+
24+
Duration (hours)
0.8
0.6
0.4
0.2
0.0

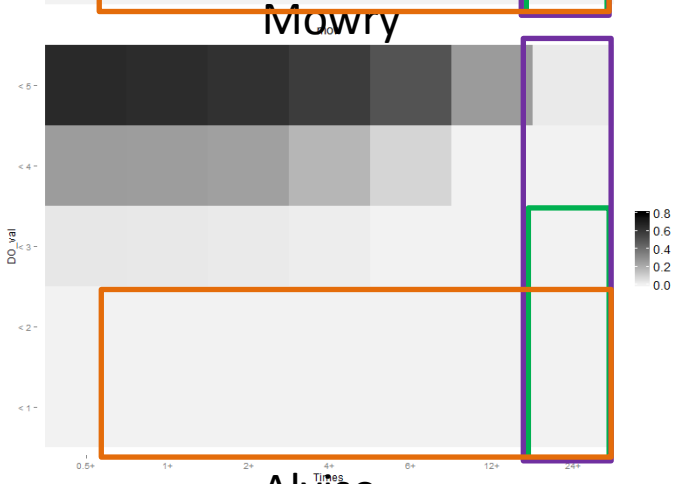

Mowry
DO val
< 5
< 4
< 3
< 2
< 1
0.8
0.6
0.4
0.2
0.0
0.5+
1+
2+
4+
6+
12+
24+
Duration (hours)

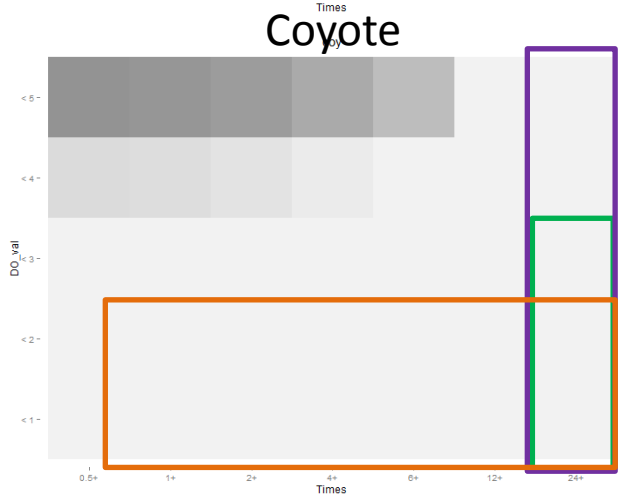

Guadalupe
Suisun Marsh
Chronic criteria
Draft
Suisun Marsh
acute threshold
0.8
0.6
0.4
0.2
0.0
DO val
< 5
< 4
< 3
< 2
< 1
Exceeds EPA 2000 <24 hr exposure criteria
0.5+
1+
2+
4+
6+
12+
24+
Duration (hours)

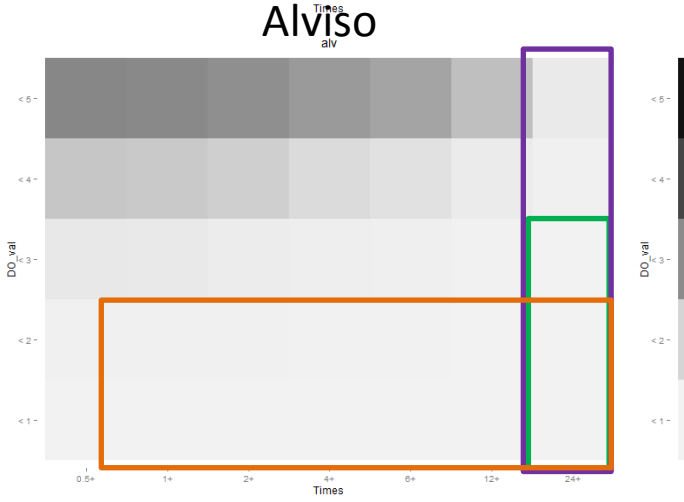


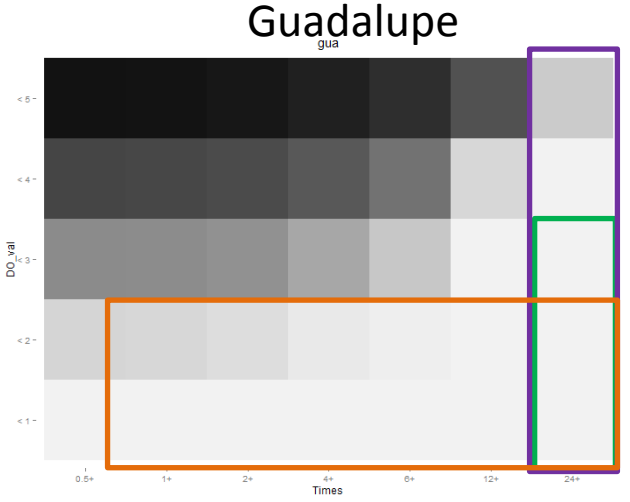










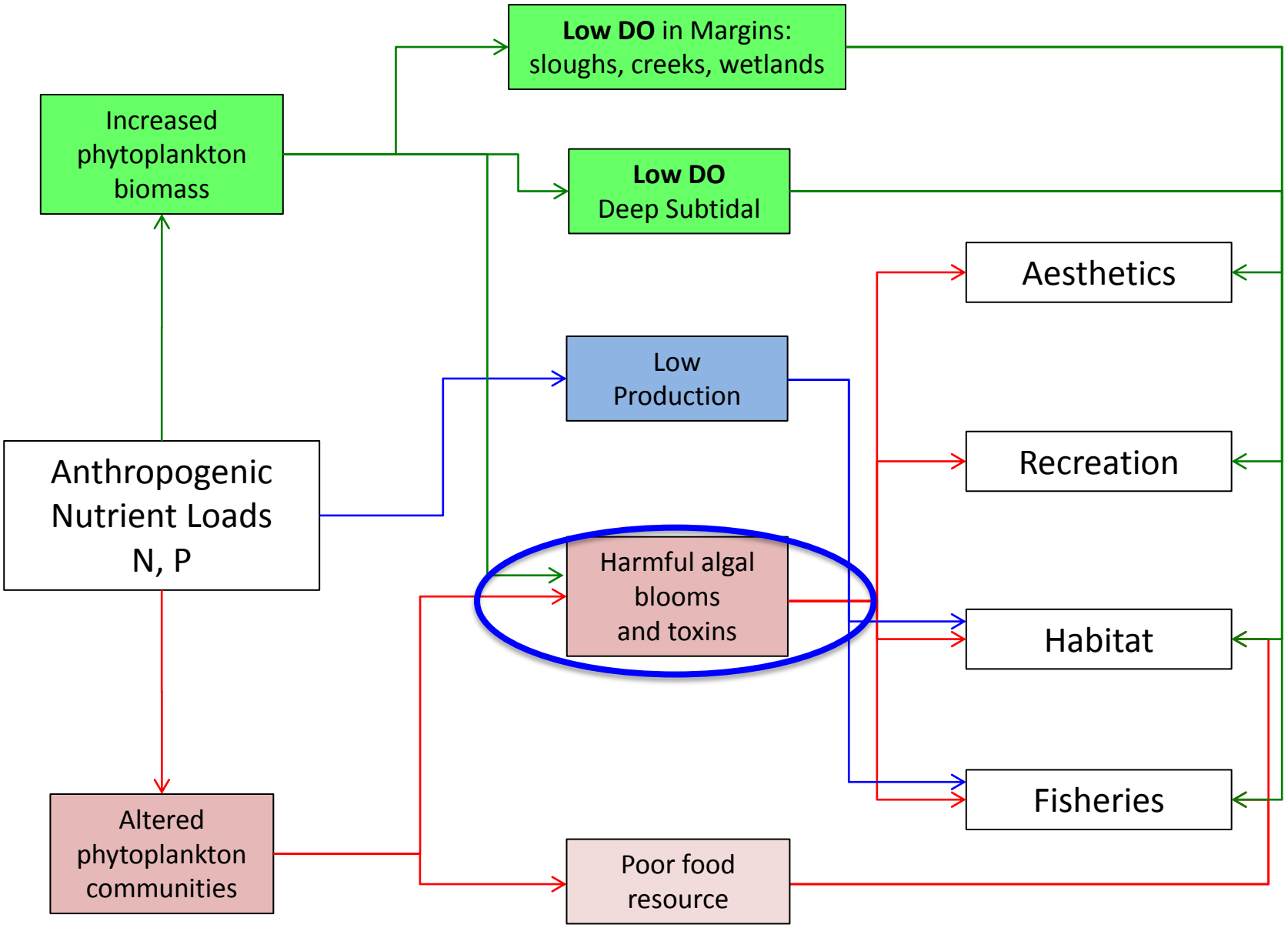


- Relevant species for Lower South Bay?
- DO chronic data for those species?

Key Messages

- Lower South Bay is a complex and heterogeneous biogeochemical reactor: N transformations / Dissolved Oxygen / Blooms
- Low(er) DO in sloughs
  - Strong tidal variability
  - Variability: within sloughs, among sloughs, multiple time scales (tidal, seasonal, event
  - Influenced by multiple factors
- Continuing work…
  - Field investigations …physical/biogeochemical processes in sloughs, ponds
  - Modeling
  - Is the low DO adversely impacting biota?
  - Importance of Nutrient ←→ Salt Pond restoration
  - Algal toxins and HAB-forming organisms??
- Opportunities for co-management of Nutrients and Salt Ponds ?

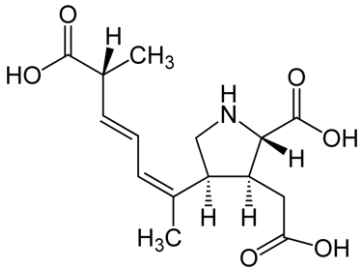
Potential Adverse Impacts of Nutrients in SFB

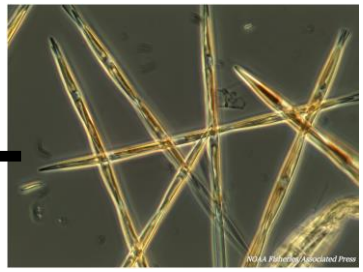


West Coast Summer 2015 *Pseudo-nitzchia* bloom

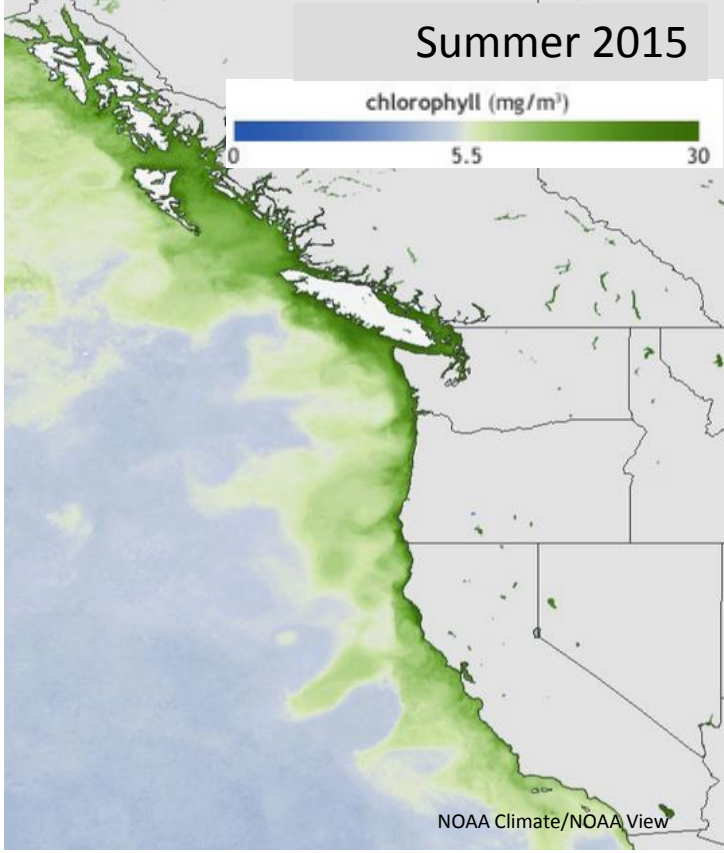
Domoic Acid

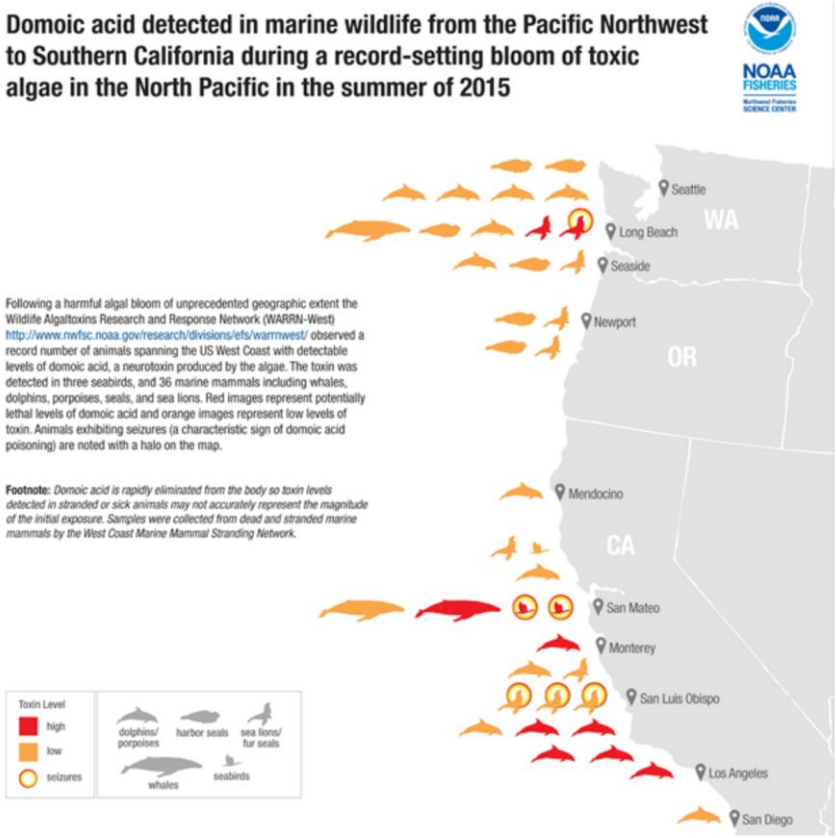
(Amnesic Shellfish Poisoning)





Pseudo-nitzchia spp





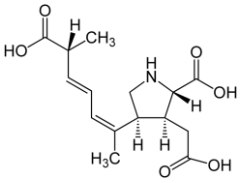
National Oceanic and Atmospheric Administration

Photo: Eric Risberg, Associated Press

Harmful Algal Blooms (HABs)

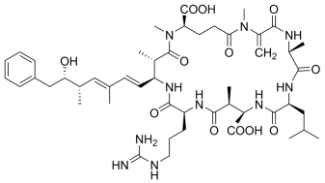
Example Toxin Producing Organisms

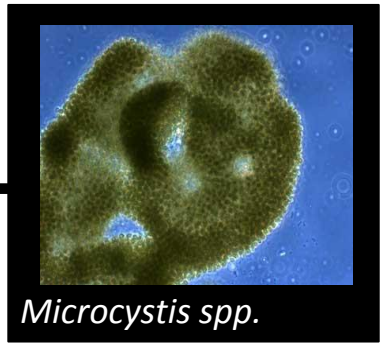
Domoic Acid
(Amnesic Shellfish Poisoning)



Pseudo-nitzschia spp.

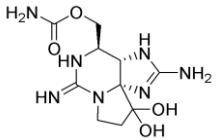
Microcystin toxins
(hepatotoxin)





Microcystis spp.

Saxitoxin
(Paralytic Shellfish Poisoning)



Alexandrium spp.

When are toxins produced?

When they are stressed…e.g.,

- Salinity, Temperature
- Nutrients (- P, - Si; + N, +metals)
- Light conditions

Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?

Complex issue, multiple components

HAB-forming species?

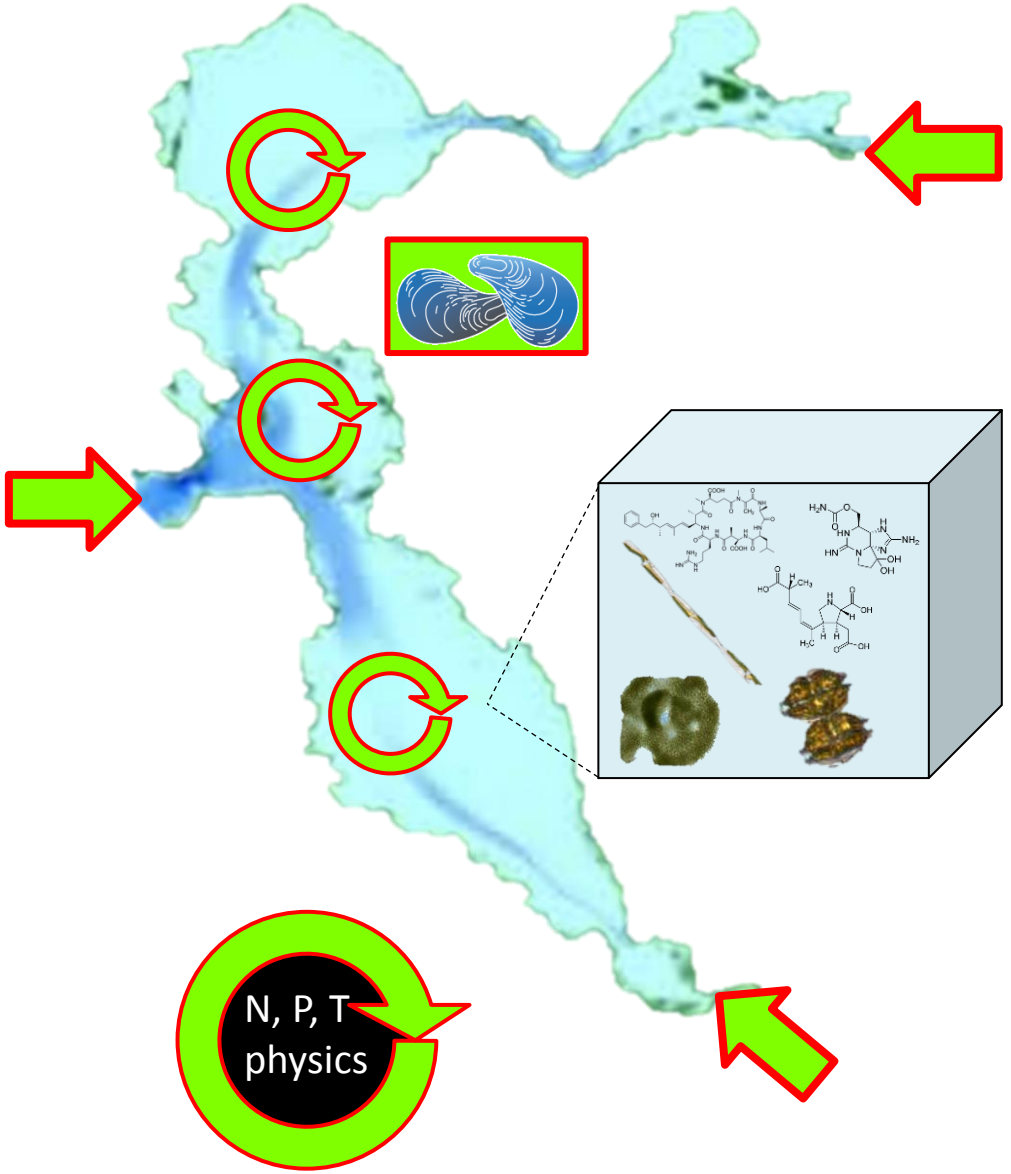
Toxins in water?

Toxins in biota?

External Sources?

Internal production, role of nutrients?

Acceptable risk, protective nutrient inputs?



Collaborators: UCSC: Peacock, Kudela; USGS: Cloern, Schraga

Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?

?

?

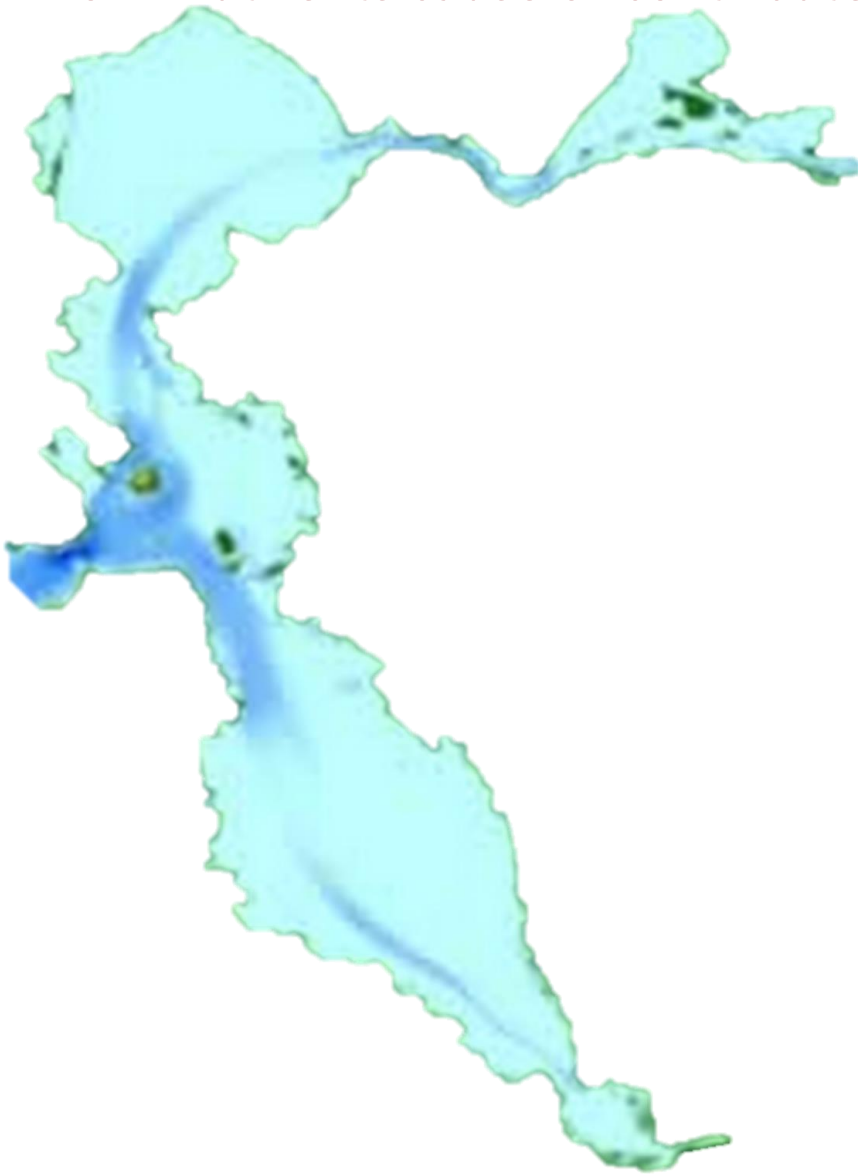
?

?

?

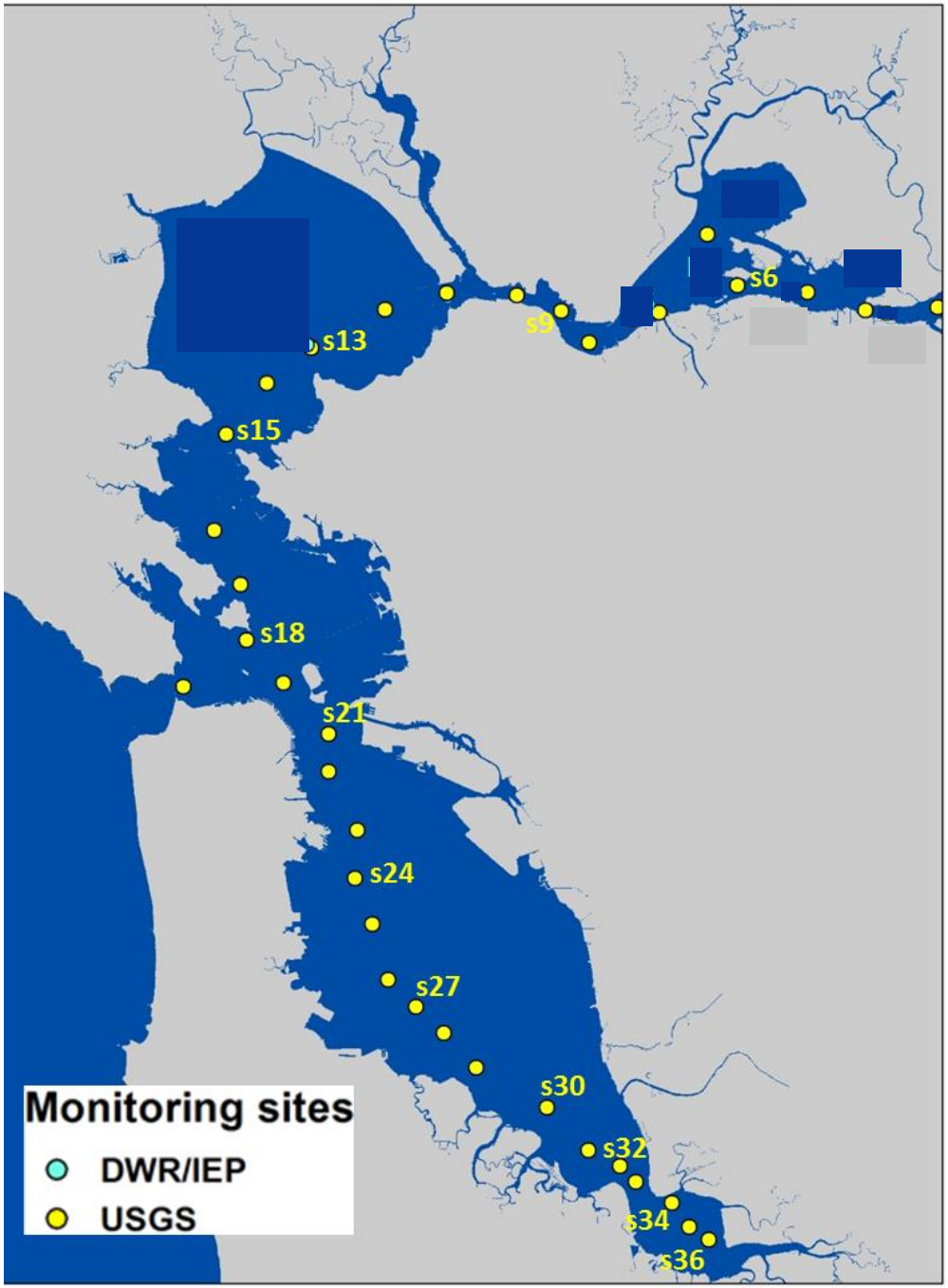
?

HAB-forming species?



For example…

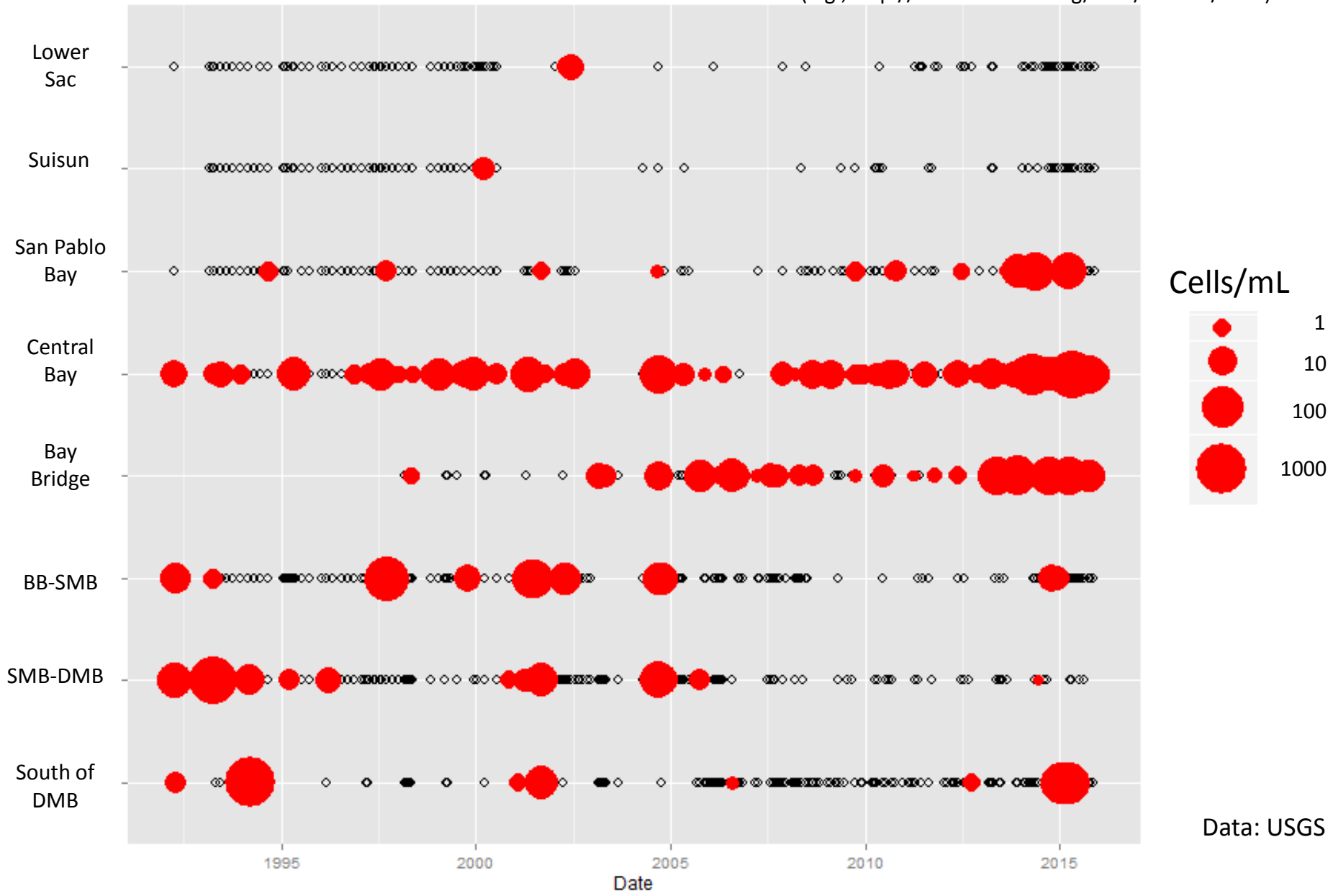
Do we see *Pseudo-nitzchia*?



Data: USGS

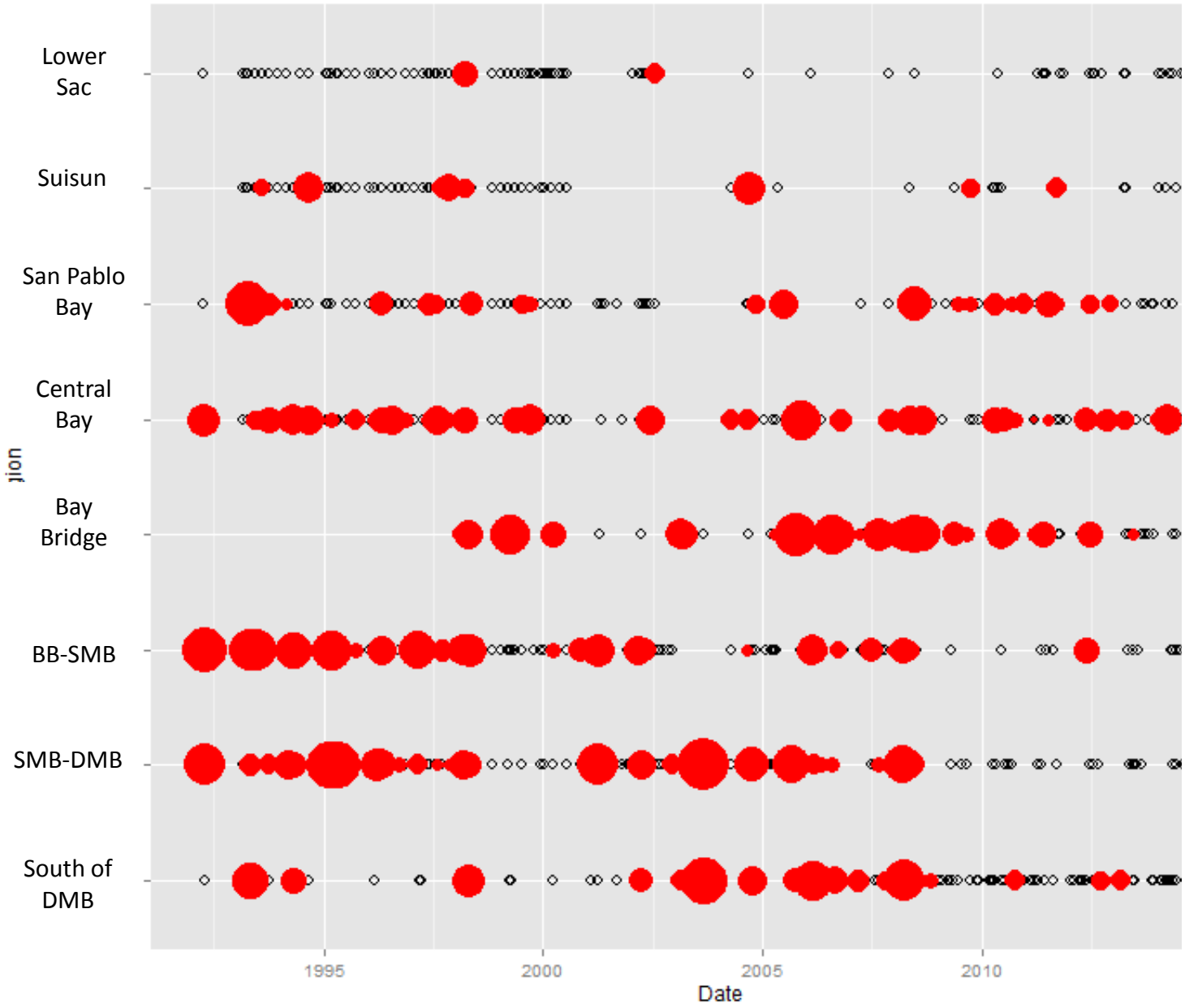
Pseudo-nitzchia spp.

- Detected in Central / South / Lower South Bay with non-trivial frequency and non-trivial abundance
- Scientific community considers 10 cells/mL (10,000 cells/L) threshold for a 'bloom' (e.g., http://www.cencoos.org/data/models/habs)



Data: USGS

Alexandrium spp. (saxitoxin, Paralytic Shellfish Poisoning)

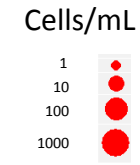


Cells/mL

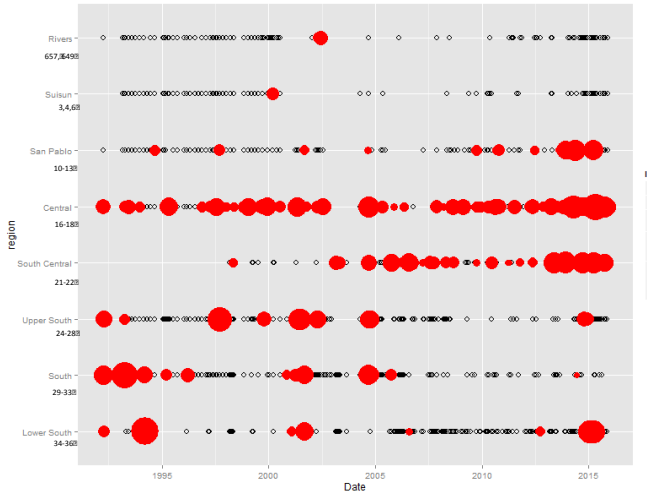
1
10
100
1000

Data: USGS

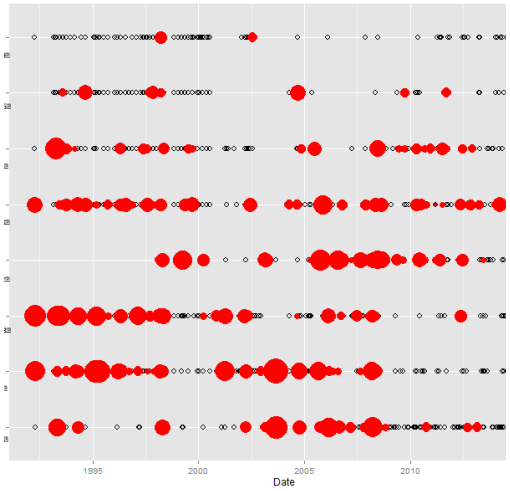
Multiple HAB-forming species are commonly detected in SFB



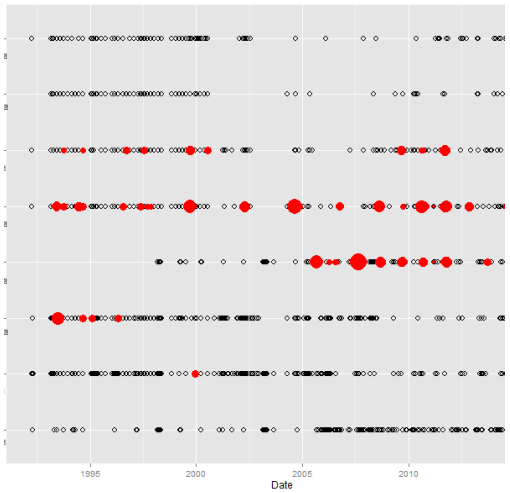
Pseudo-nitzchia spp.



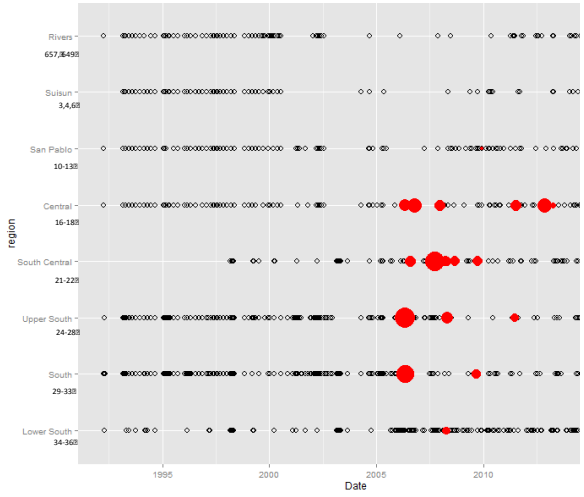
Alexandrium spp



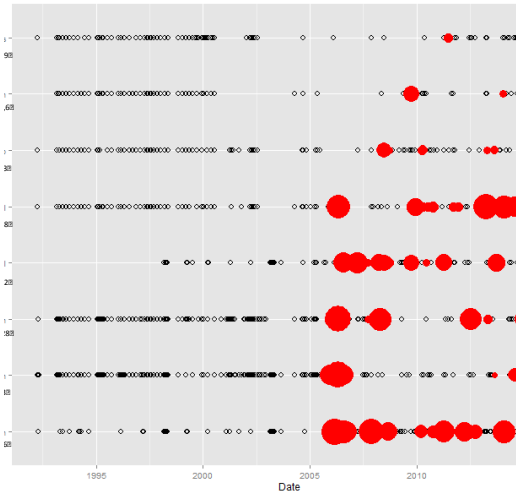
Dinophysis spp.



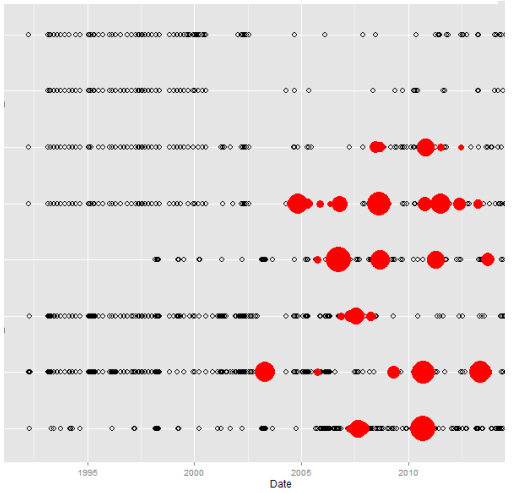
Karenia spp



Karlodinium spp.

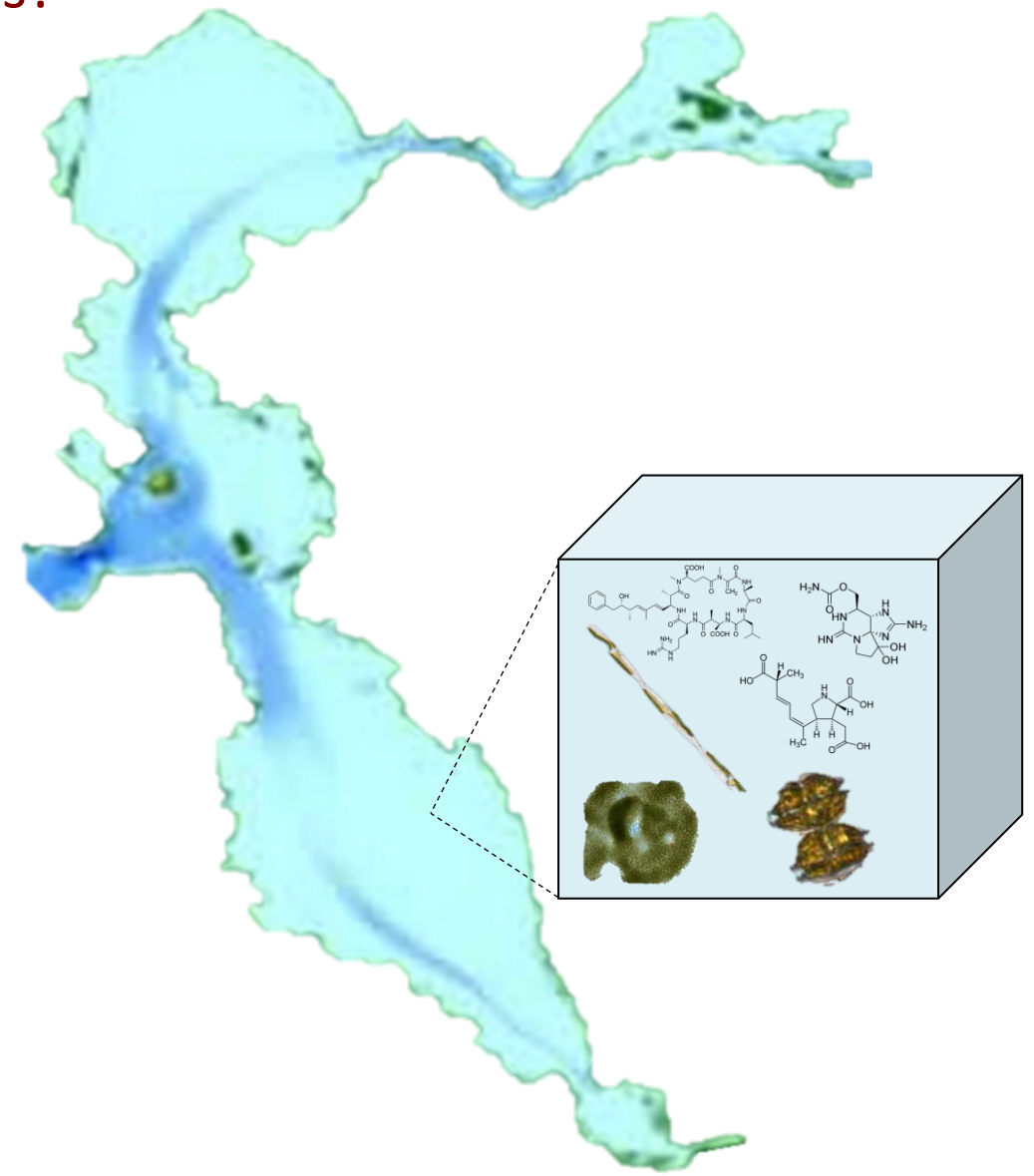


Heterosigma spp.

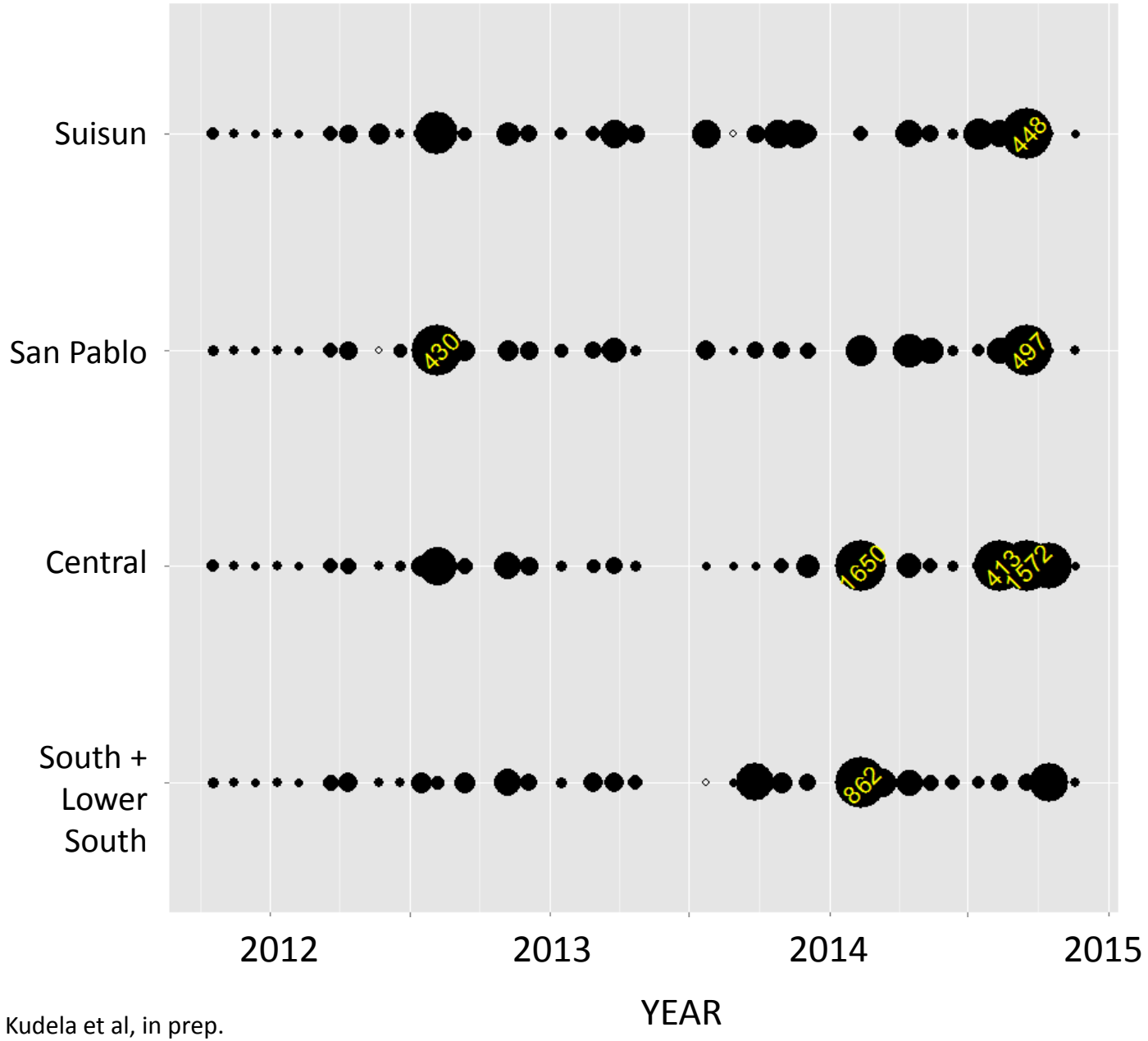


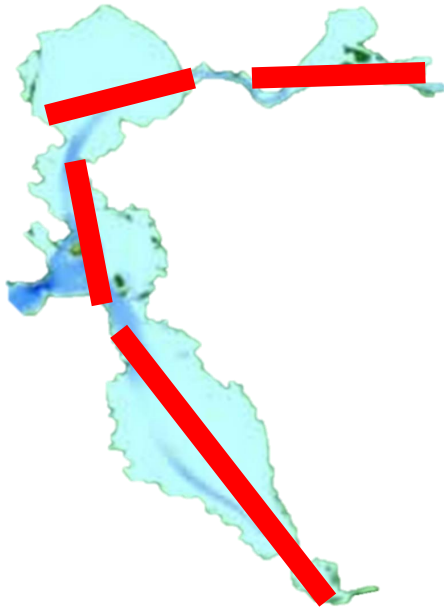
Harmful algal blooms and toxins?

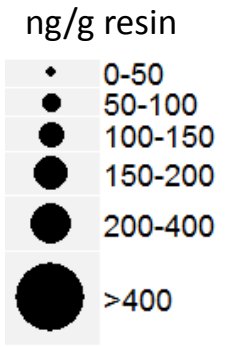
YES	HAB-forming species?
	Toxins in water?
	Toxins in biota?
	External Sources?
	Internal production, role of nutrients?
	Acceptable risk, protective nutrient inputs?



Are toxins present? **Domoic Acid…**spatial average







Kudela et al, in prep.

Harmful algal blooms and toxins?

YES HAB-forming species?

YES Toxins in water?

Toxins in biota?

Sources?

Internal production,
role of nutrients?

Acceptable risk,
protective nutrient inputs?

Are toxins entering the food web?

Mussel Watch (RMP)

- Deployed mussels Bay-wide
- Time-integrated “sampler”

Mytilus californianus

Peacock et al. *in prep*

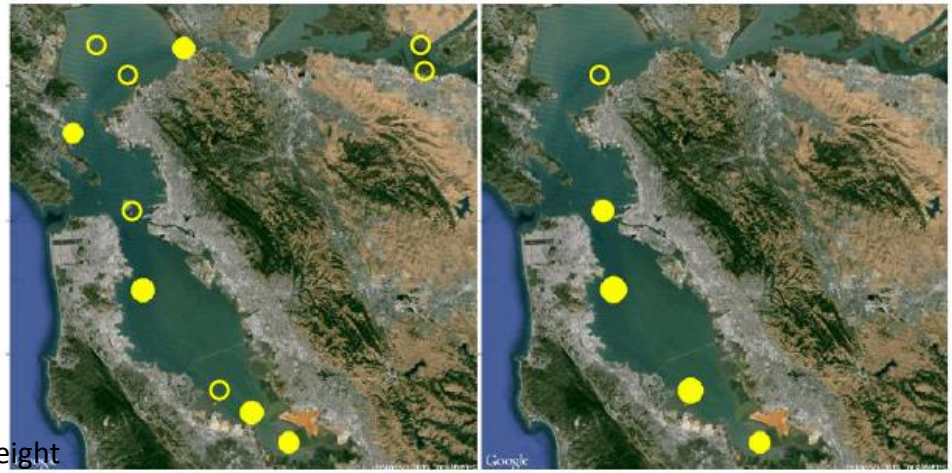
Mussel Watch Samples

Domoic Acid
(*Pseudo-nitzchia*)

DA detected in all samples

- DA << 20 ppm regulatory limit for shellfish

Saxitoxin
(*Alexandrium*)



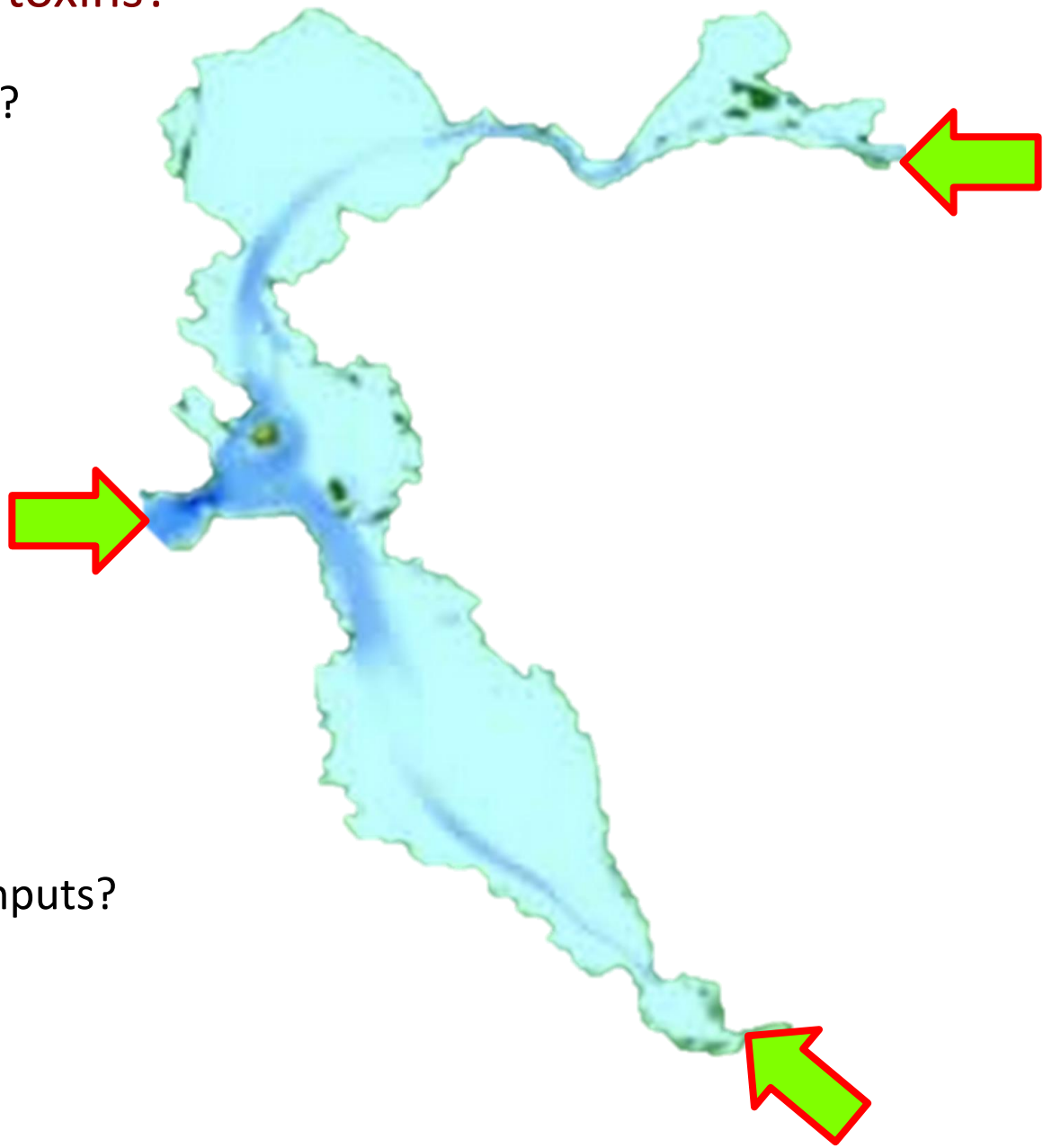
Deployment period: 90 days.

Peacock et al. *in prep*

All units wet weight

Harmful algal blooms and toxins?

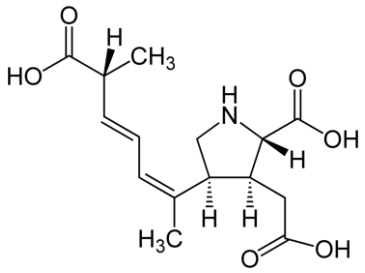
YES	HAB-forming species?
YES	Toxins in water?
YES	Toxins in biota?
GG Delta LSB	Sources?
	Internal production, role of nutrients?
	Acceptable risk, protective nutrient inputs?



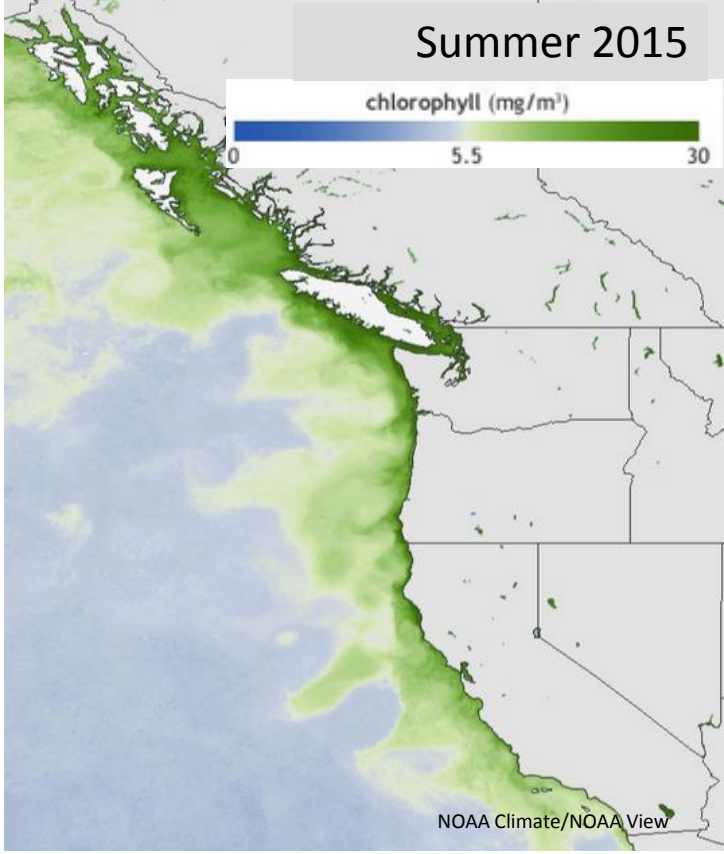
Sources from the coastal ocean?

Domoic Acid

(Amnesic Shellfish Poisoning)



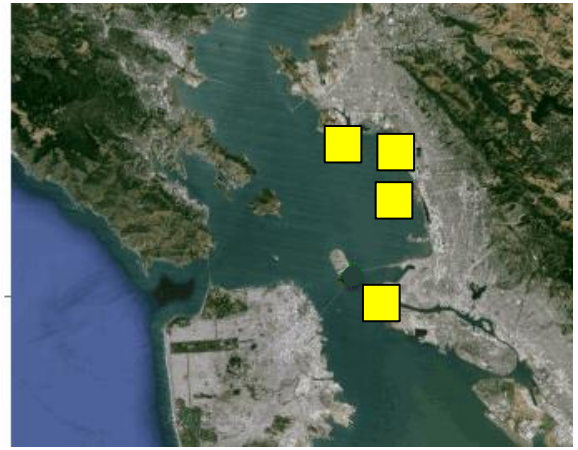
Pseudo-nitzchia spp

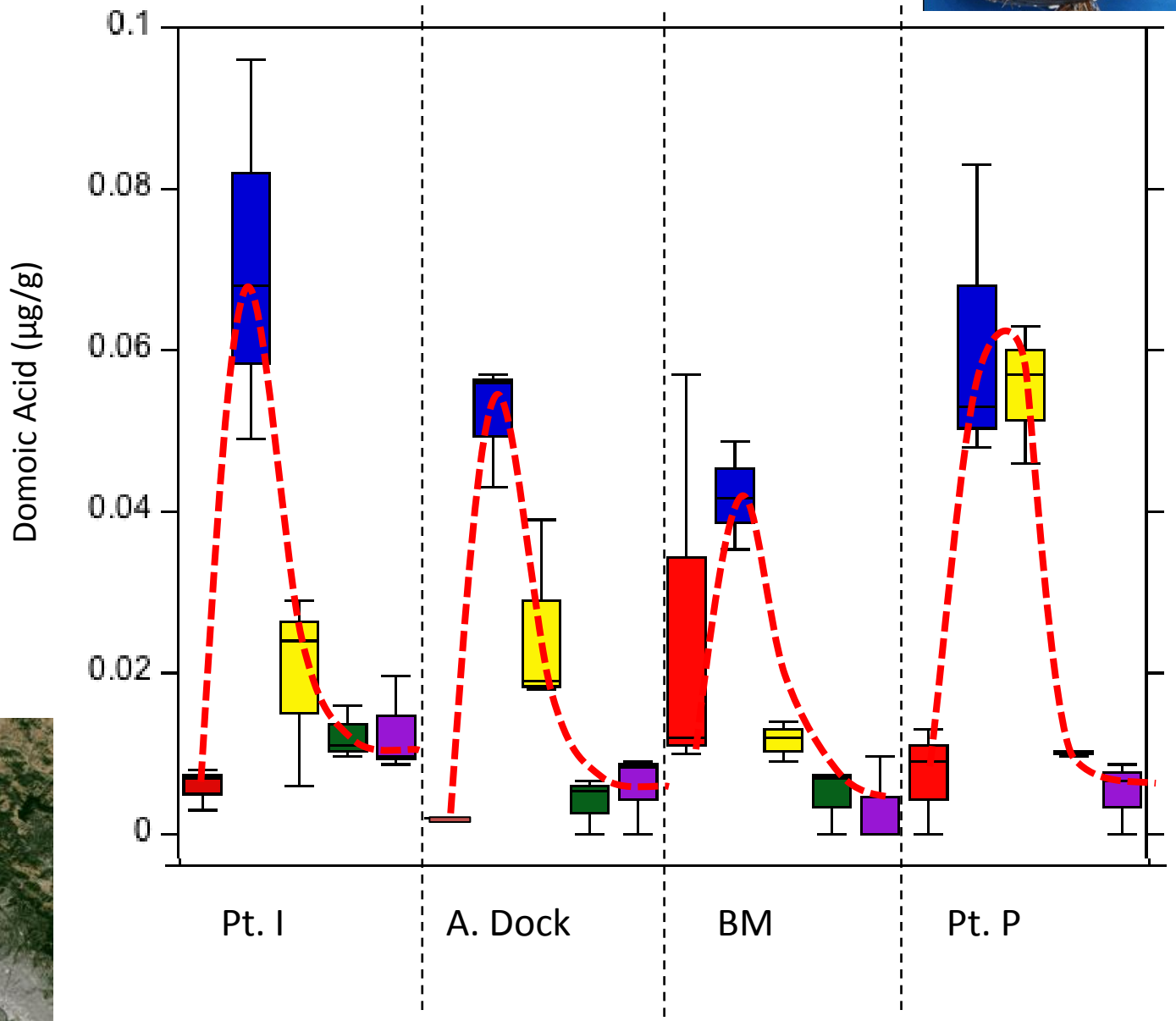


Test with naturally-occurring mussels

Peacock et al. *in prep*

Domoic Acid in Central Bay mussels – Apr-Aug 2015





Peacock et al. *in prep*

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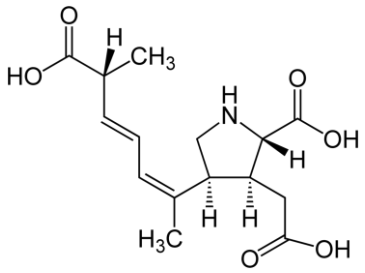
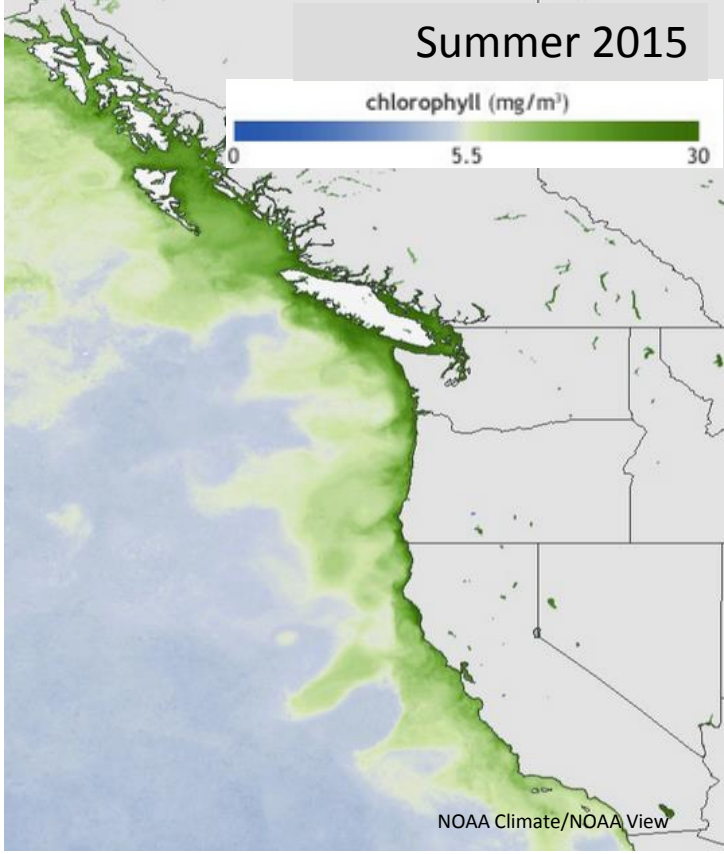


Pseudo-nitzchia spp



- Apparently no “big” internal event in Central Bay in Summer/early-Fall 2015
- What about rest of Fall?
- What about elsewhere inside the Bay?

Best approach for toxin monitoring?

- Spatially-integrated water (SPATT)
- Discrete water samples…. “grab samples”
- Biota

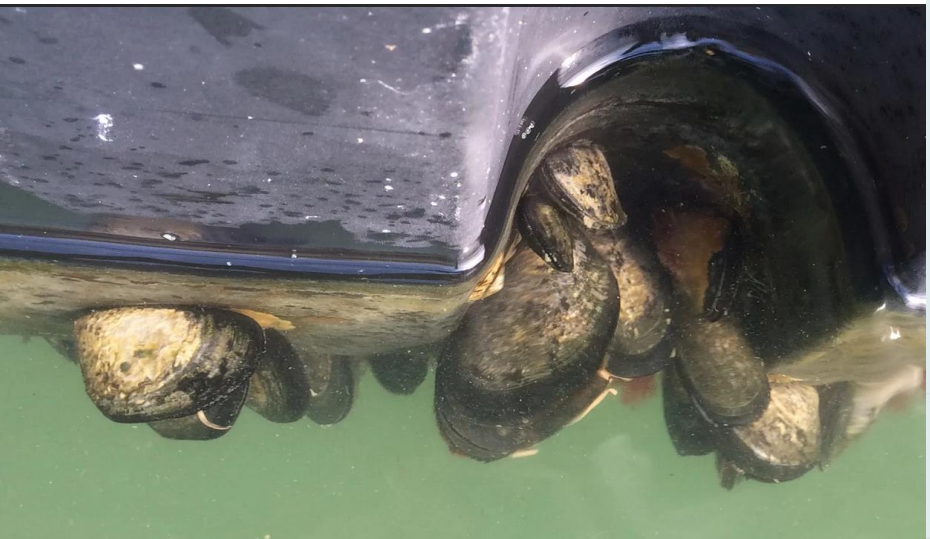
- All approaches have pros and cons…
  - Spatial averaging
  - Time-averaging
  - Translate to actual concentrations
  - Effort/cost

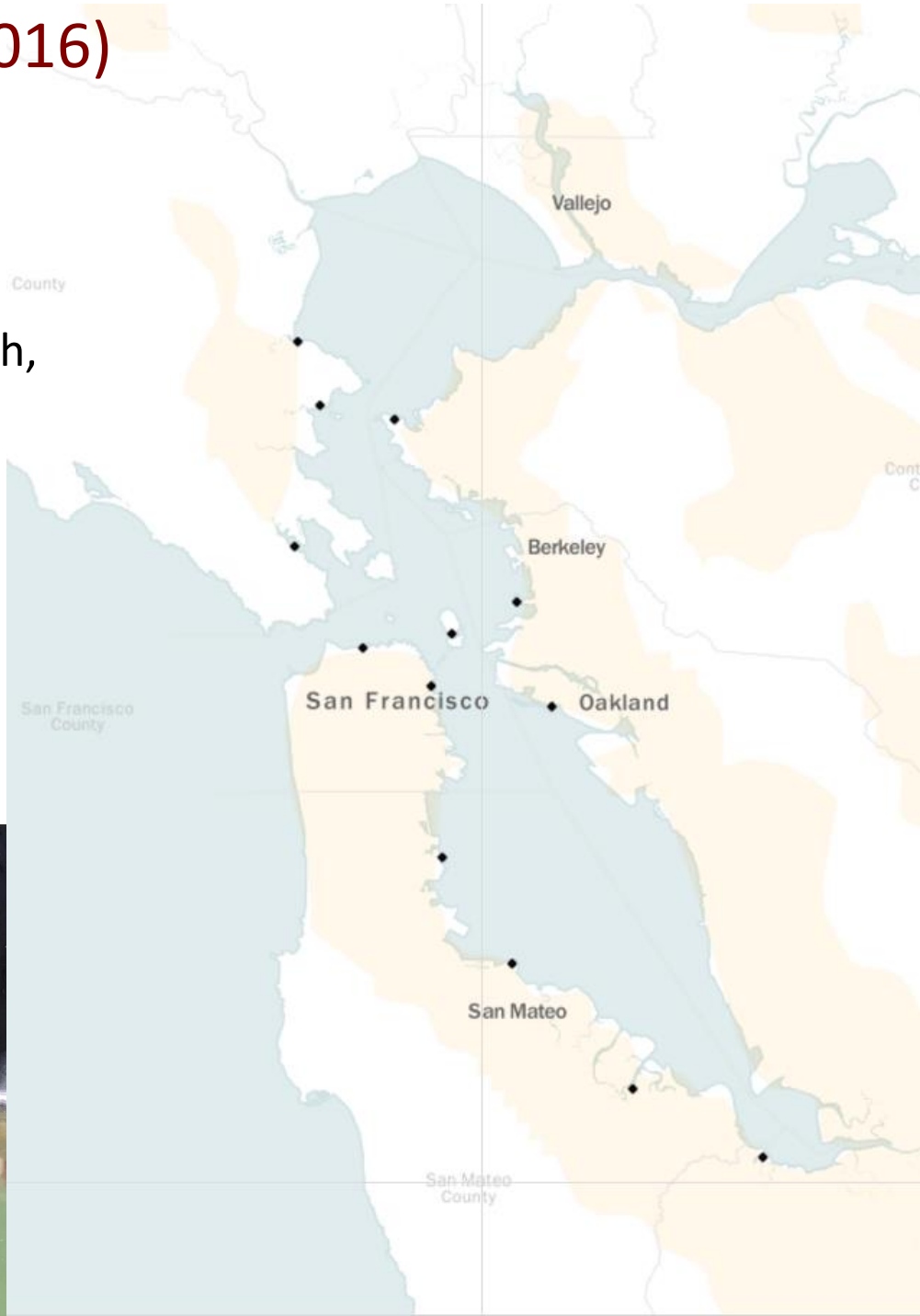
Bay-wide mussel survey (FY2016)

- Naturally occurring mussels
- Accessible from land, floating docks.
- Found throughout South, Lower South, Central, and western San Pablo

Approach:

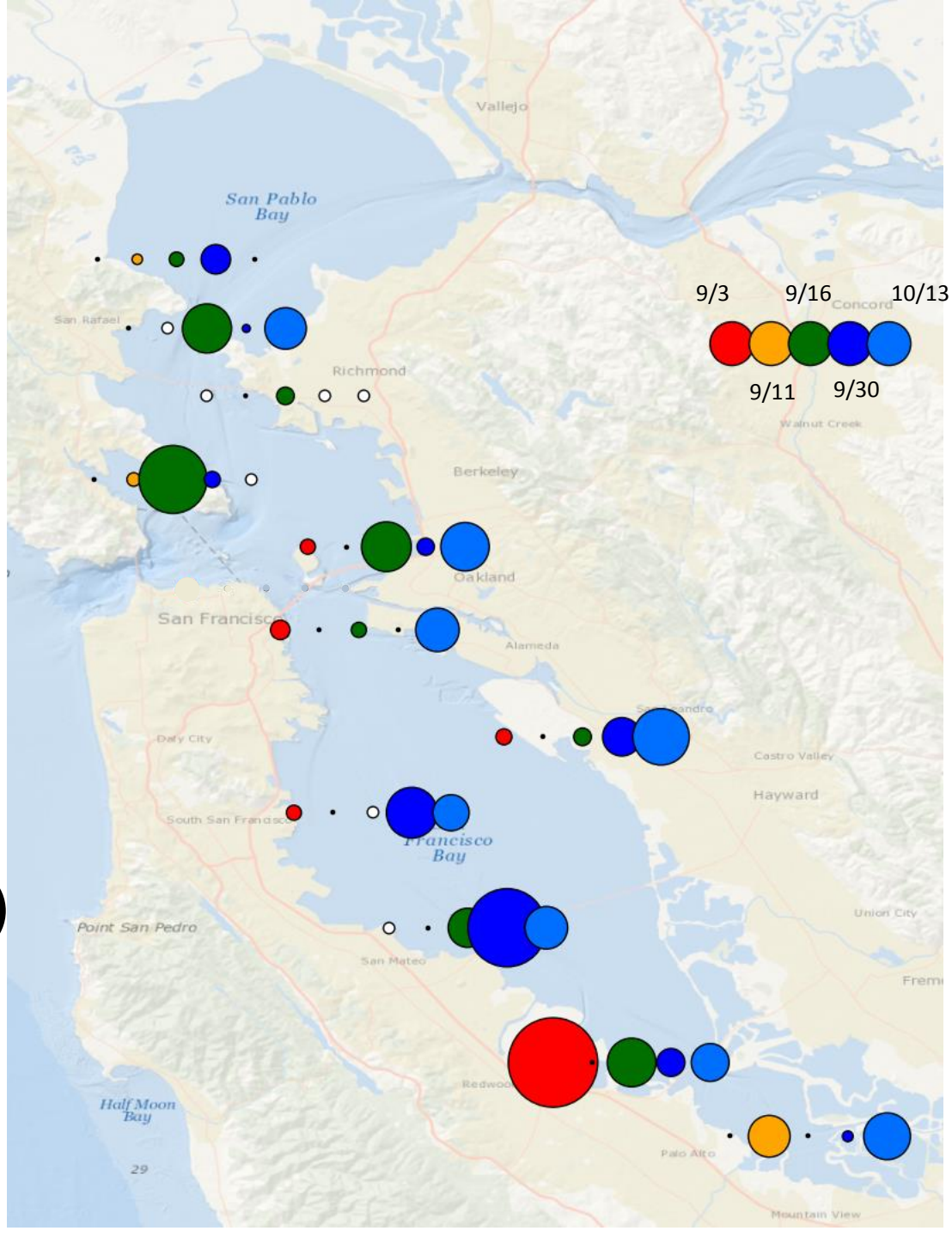
- Bi-weekly sampling
- ~10 sites Bay-wide, in 2-3 days.
- Oversample, analyze subset.





Domoic Acid concentration in mussels

Sep-Oct 2015



100 ppb

1 ppb

Nondetect

No Sample

Harmful algal blooms and toxins?

YES — HAB-forming species?

YES — Toxins in water?

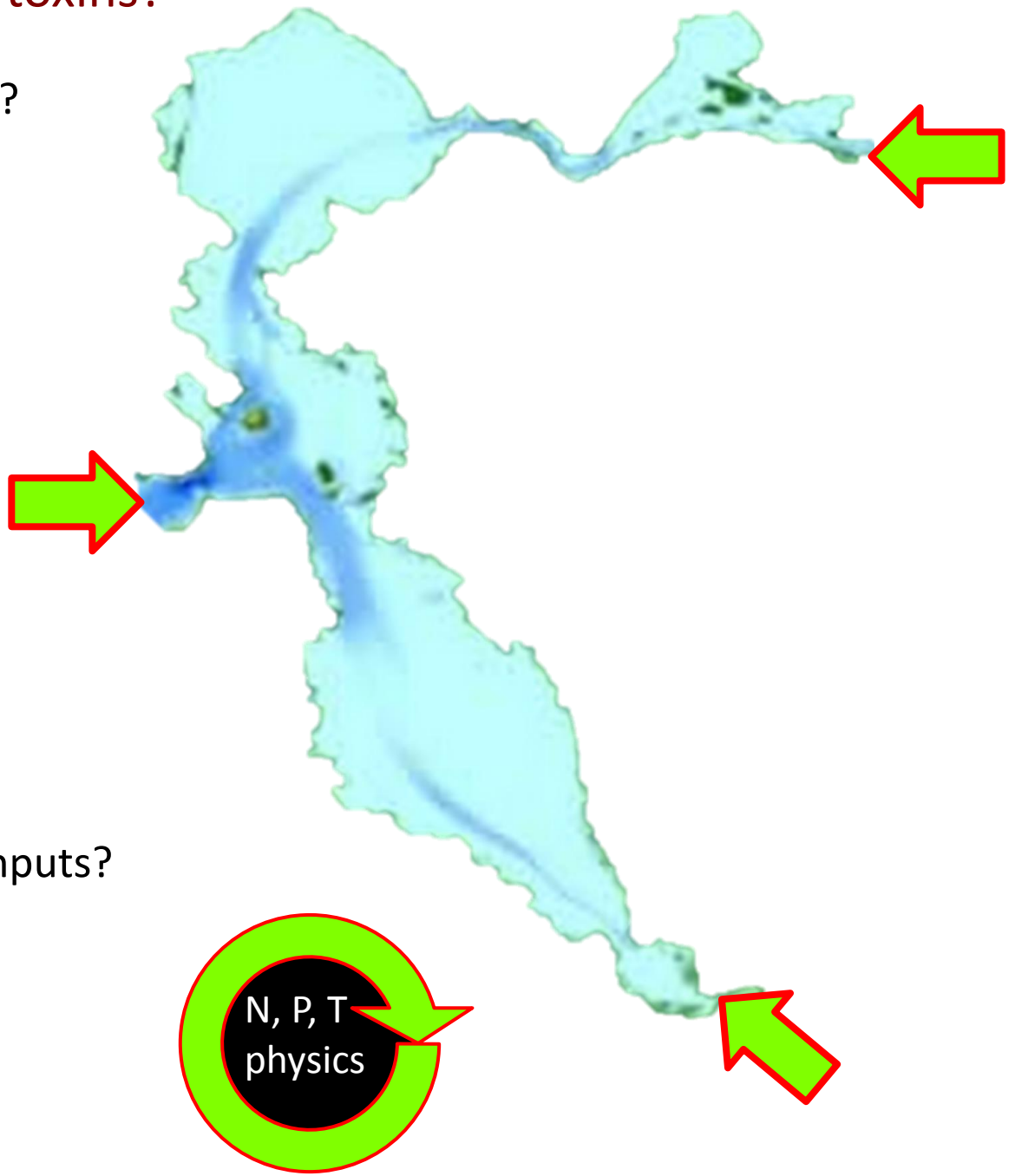
YES — Toxins in biota?

GG YES
Delta ??
LSB …

Sources?

Internal production, role of nutrients?

Acceptable risk, protective nutrient inputs?



Mussel Watch Samples

Domoic Acid
(*Pseudo-nitzchia*)

DA detected in all samples

- DA << 20 ppm regulatory limit for shellfish

Microcystin
(*Microcystis)*

Microcystin detected in most mussel samples

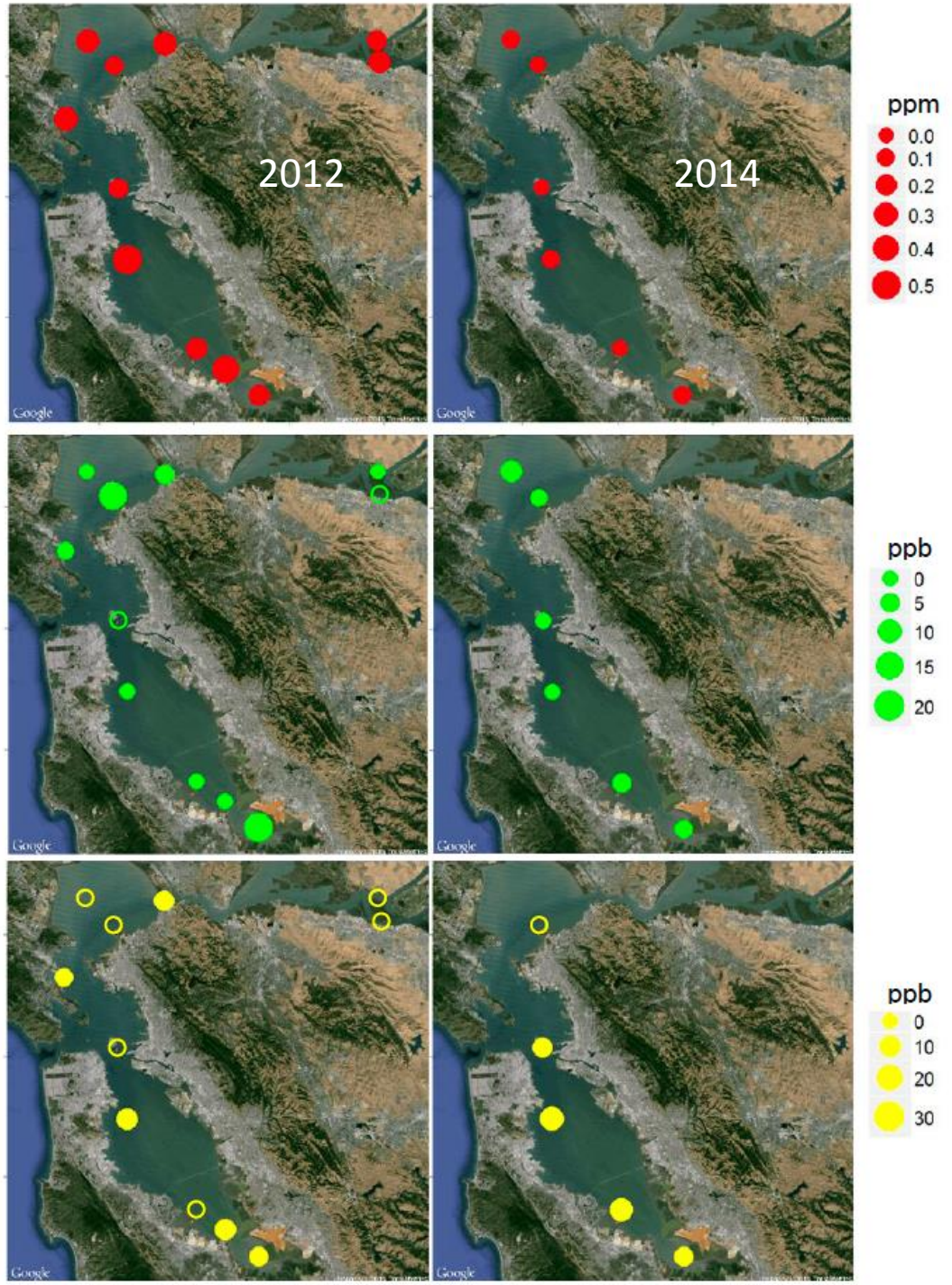
- Some samples with MC > 10 ppb OEHHA limit
- Commonly considered a freshwater toxin
- Source?

Saxitoxin
(*Alexandrium*)

Deployment period: 90 days.

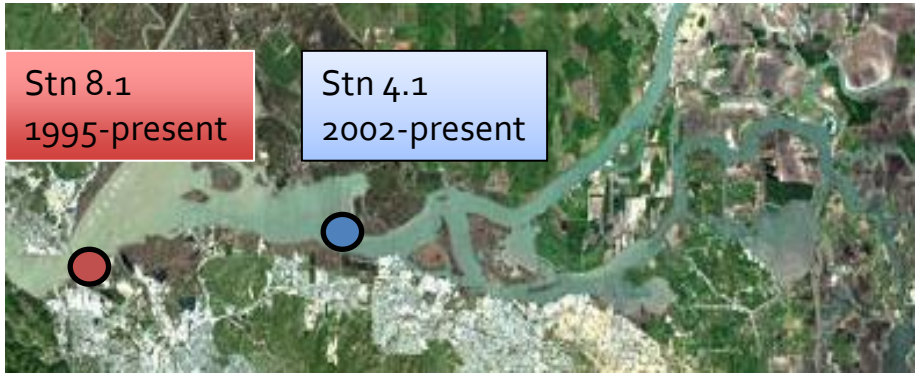
Peacock et al. *in prep*

All units wet w



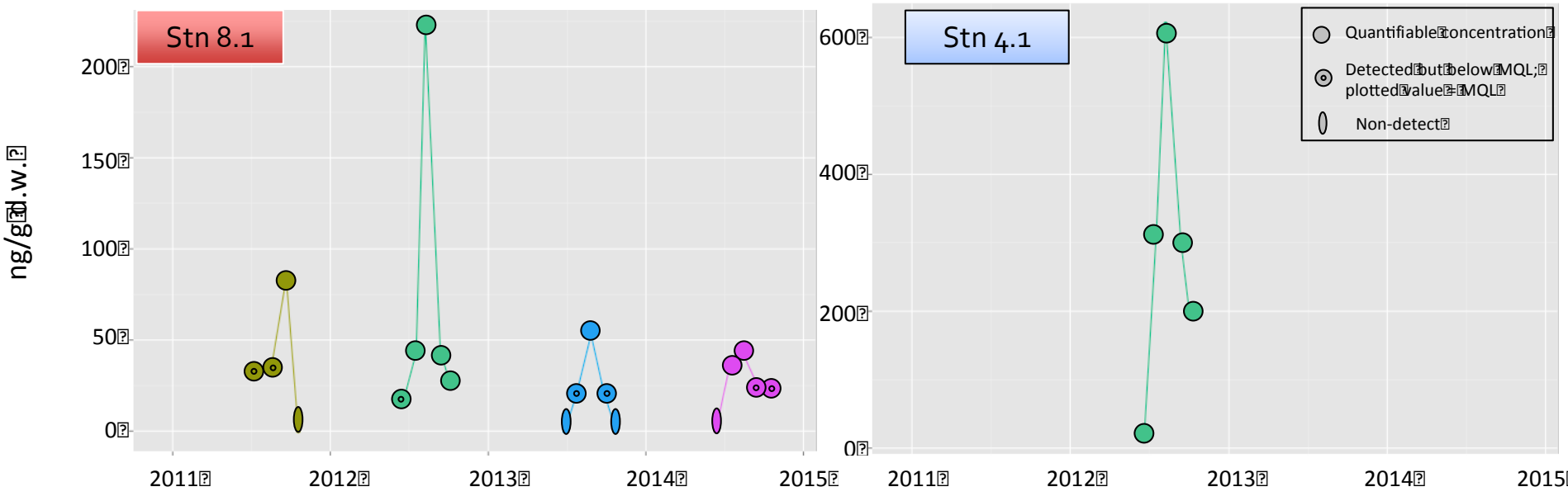
Archived *Potamocorbula* to explore Microcystin inputs from the Delta?

with R Stewart (USGS) and T Otten (OSU)



- Substantial *Microcystis* blooms in the Delta have been reported in the past several years
- To date, no systematic monitoring of toxin levels.
- Limited information about *Microcystis* or microcystin in Delta prior to ~2005
- Can we use a multi-year archive of monthly *Potamocorbula* samples to assess past toxin levels?

Proof of concept, initial data…additional sample analysis underway

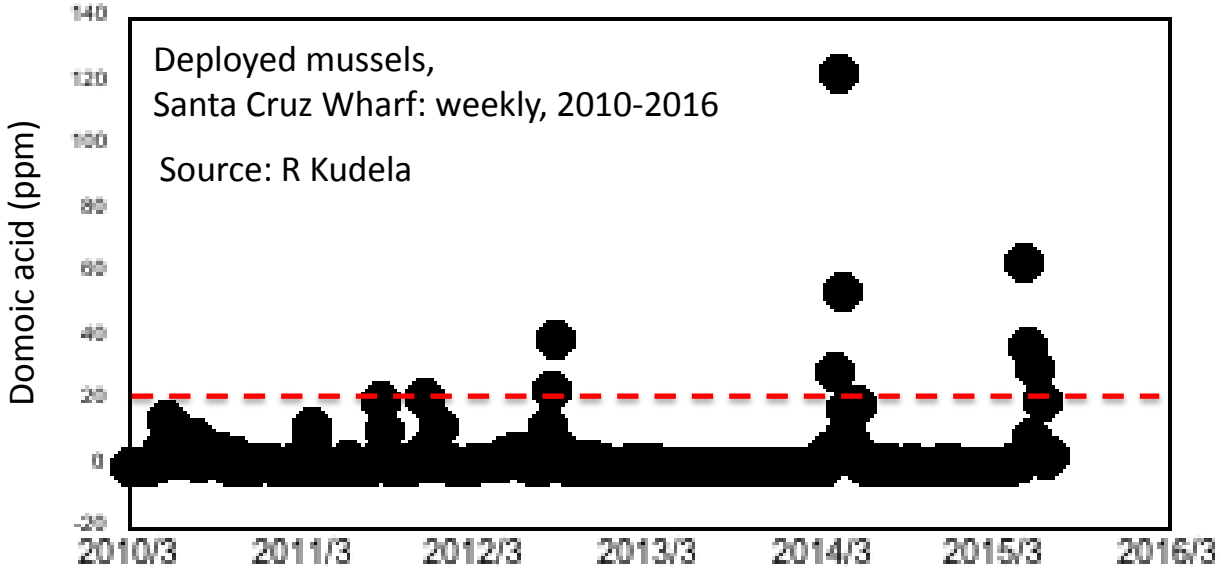


Key Messages

- Algal toxins and HAB-forming organisms commonly detected Bay-wide
  - ✔ Water ✔ Biota …at low/moderate levels, nonetheless concerning
  - Multiple species, multiple toxins
  - Exploring: Sources, Mechanisms, Monitoring
  - Linkage to Nutrients? Adverse Impacts?
- Observations to date appear to reflect 'typical conditions' in SFB. Nutrient concentrations are sufficient in SFB to support HAB 'events'
- Should SFB nutrient management considerations focus on 'typical conditions', or on 'events'?

Example: Santa Cruz Wharf, weekly mussel sampling.

- Vast majority of samples had low Domoic Acid (<<20ppm)
- During short-lived 'events', DA was orders of magnitude higher than 'typical conditions'
- Observing and distinguishing between 'typical' and 'event' required frequent monitoring



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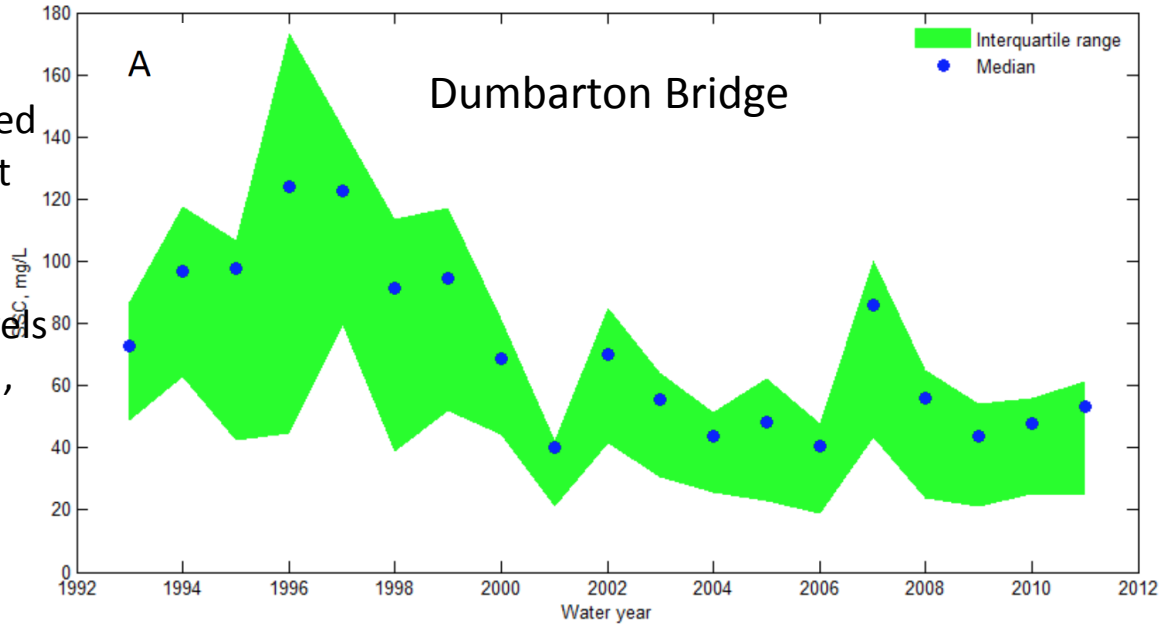
  - Linkage to Nutrients? Adverse Impacts?
- Observations to date appear to reflect 'typical conditions' in SFB. Nutrient concentrations are sufficient in SFB to support HAB 'events'
- How should future scenarios inform management considerations?

e.g.,

Substantial decreases in suspended sediments Bay-wide over the past 10-20 years.

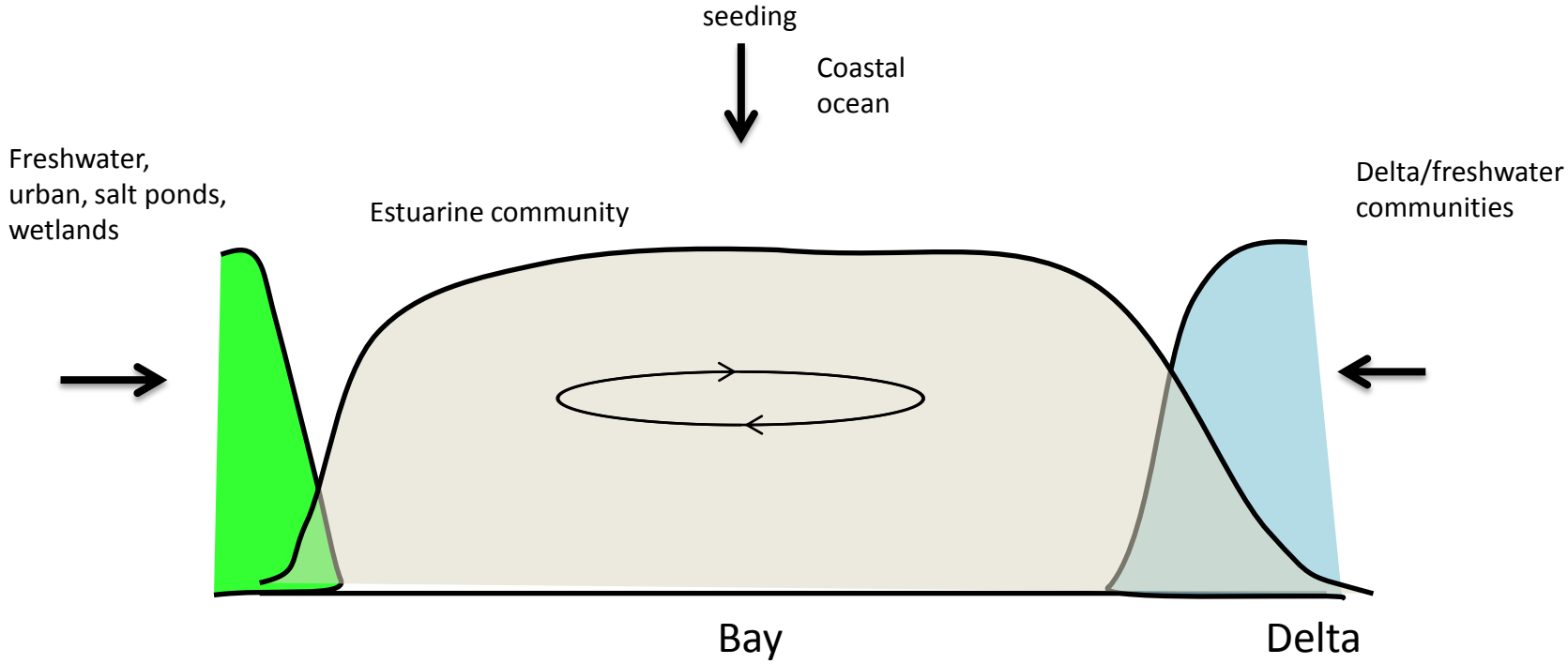
Proportional increases in light levels to support phytoplankton growth, including HAB-forming species



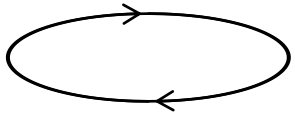
Schoellhamer et al (2015)
SFEI (2015)

What shapes community phytoplankton community composition?

Are conditions in SFB adversely impacting phytoplankton composition?



Internal processes



- Light
- T
- Residence time
- Selective grazing
- Nutrients

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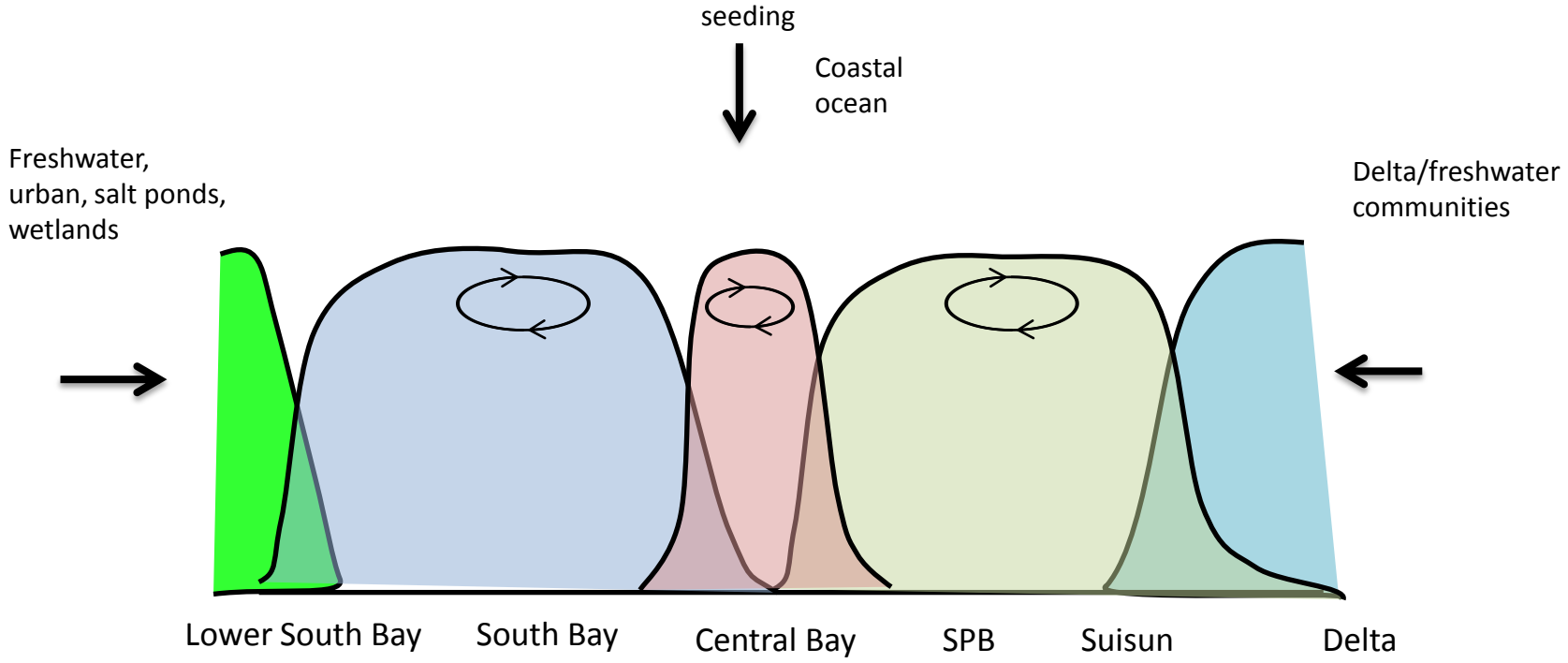
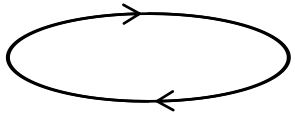
Are conditions in SFB adversely impacting phytoplankton composition?

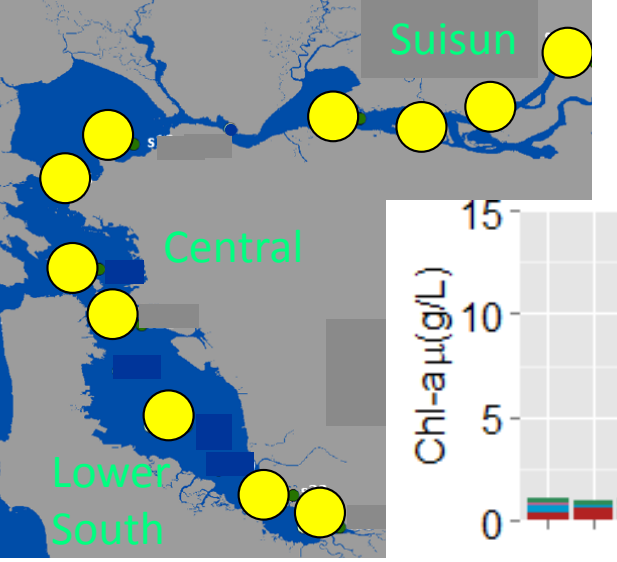


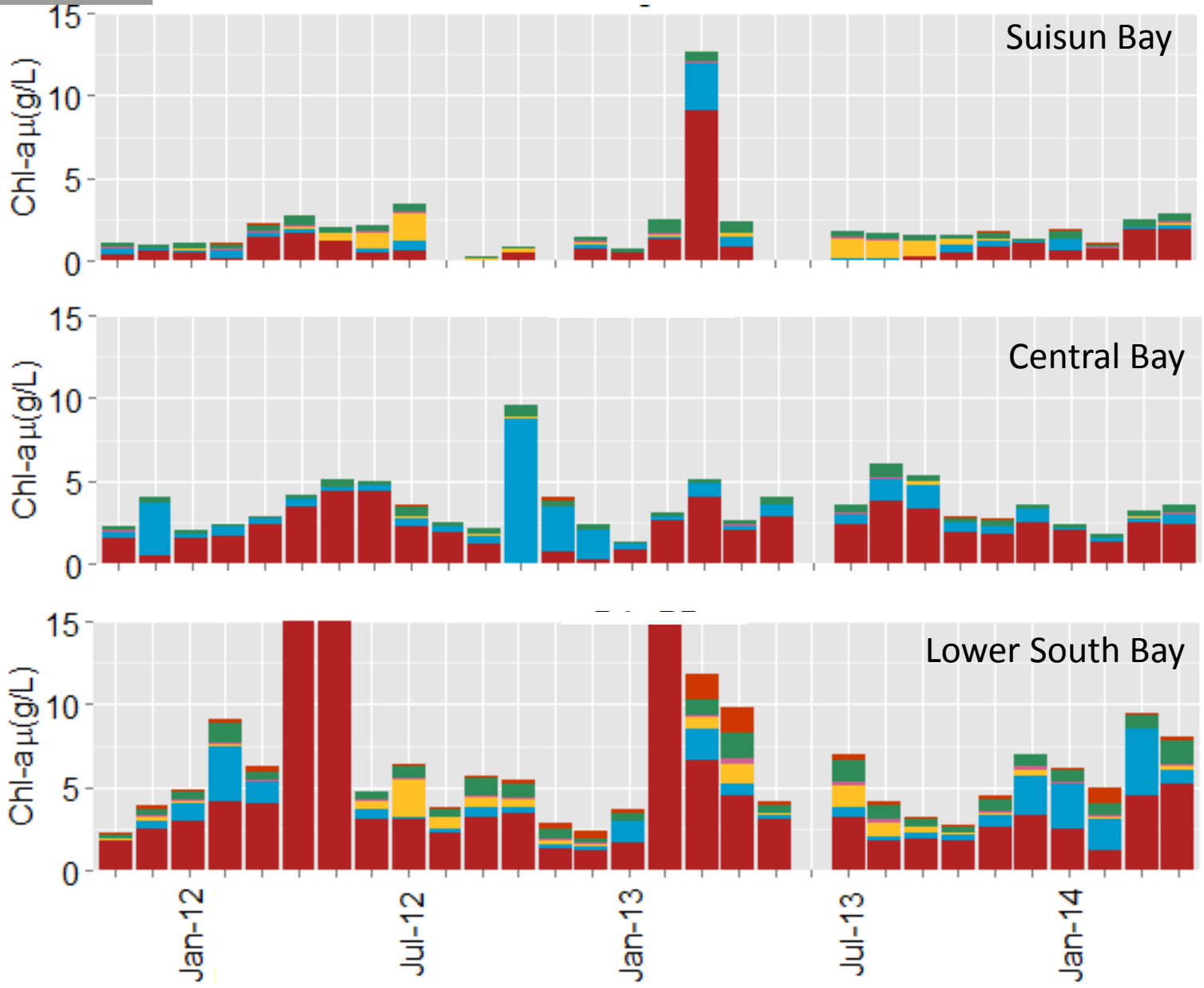
Internal processes



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

SFEI 2014





Class

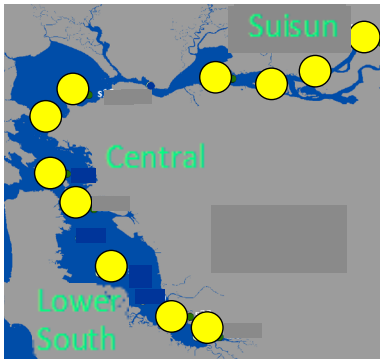
- Other
- Eustigmatophyte
- Cryptophyte
- Chlorophyte
- Cyanobacteria
- Dinoflagellate
- Diatom

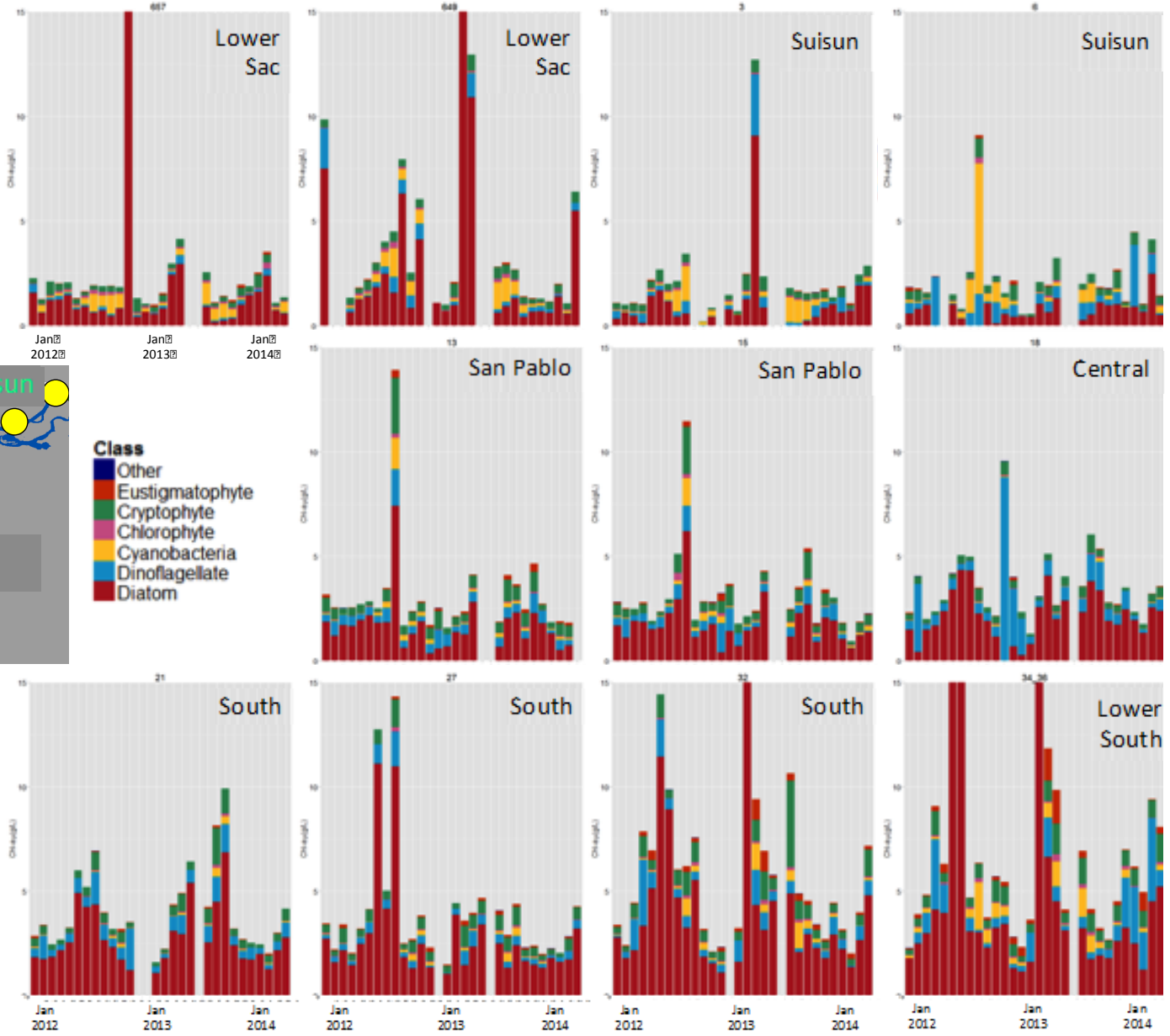
Peacock et al in prep.

Seasonal and spatial variability in class-level phytoplankton community: Insights for…

- Internal processes/forcings
- HABs
- Food Quality

All Data

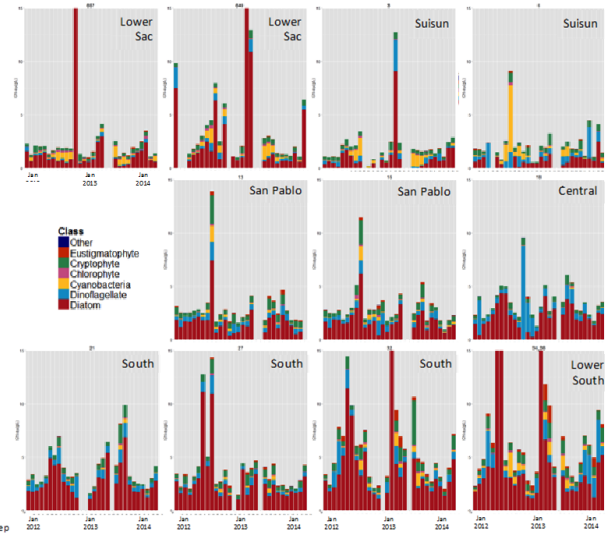




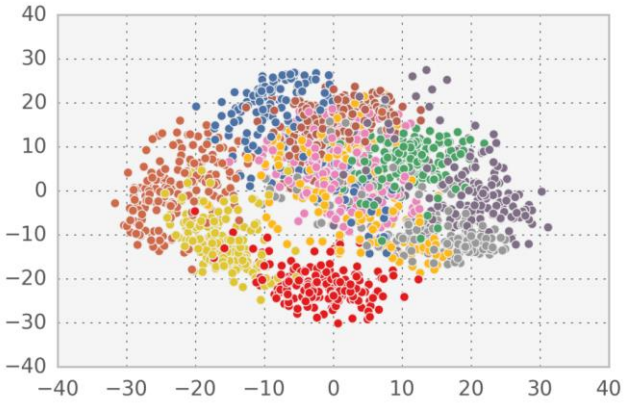
Peacock et al., in prep

How to identify patterns/cycles? One approach

- nMDS: nonmetric MultiDimensional Scaling
- Finding patterns in phyto. composition data
- Computes “distance” between samples, places optimally in 2D based on similarity of composition
- Similar samples clustered, disparate samples dispersed

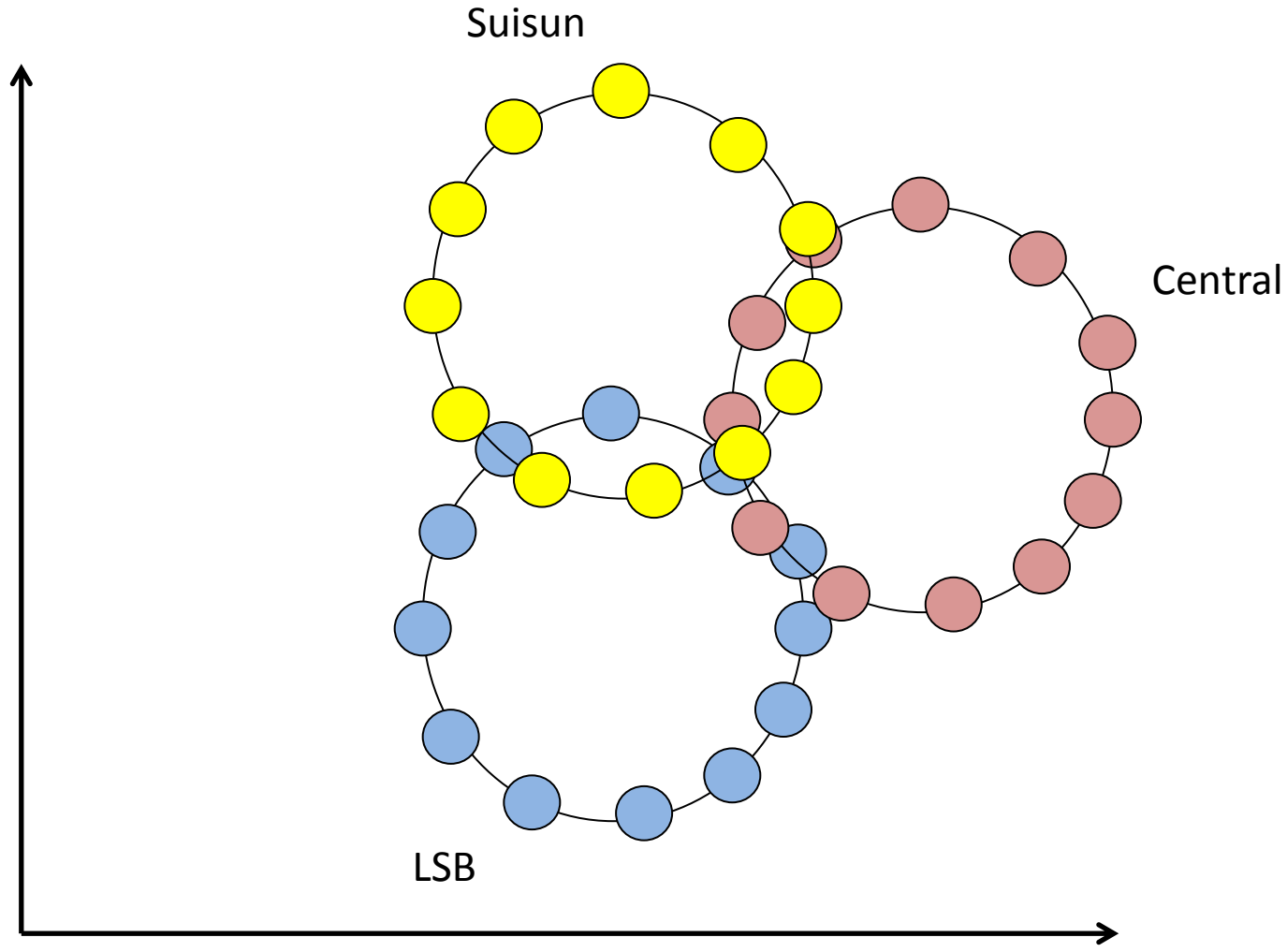


Peacock et al., in prep



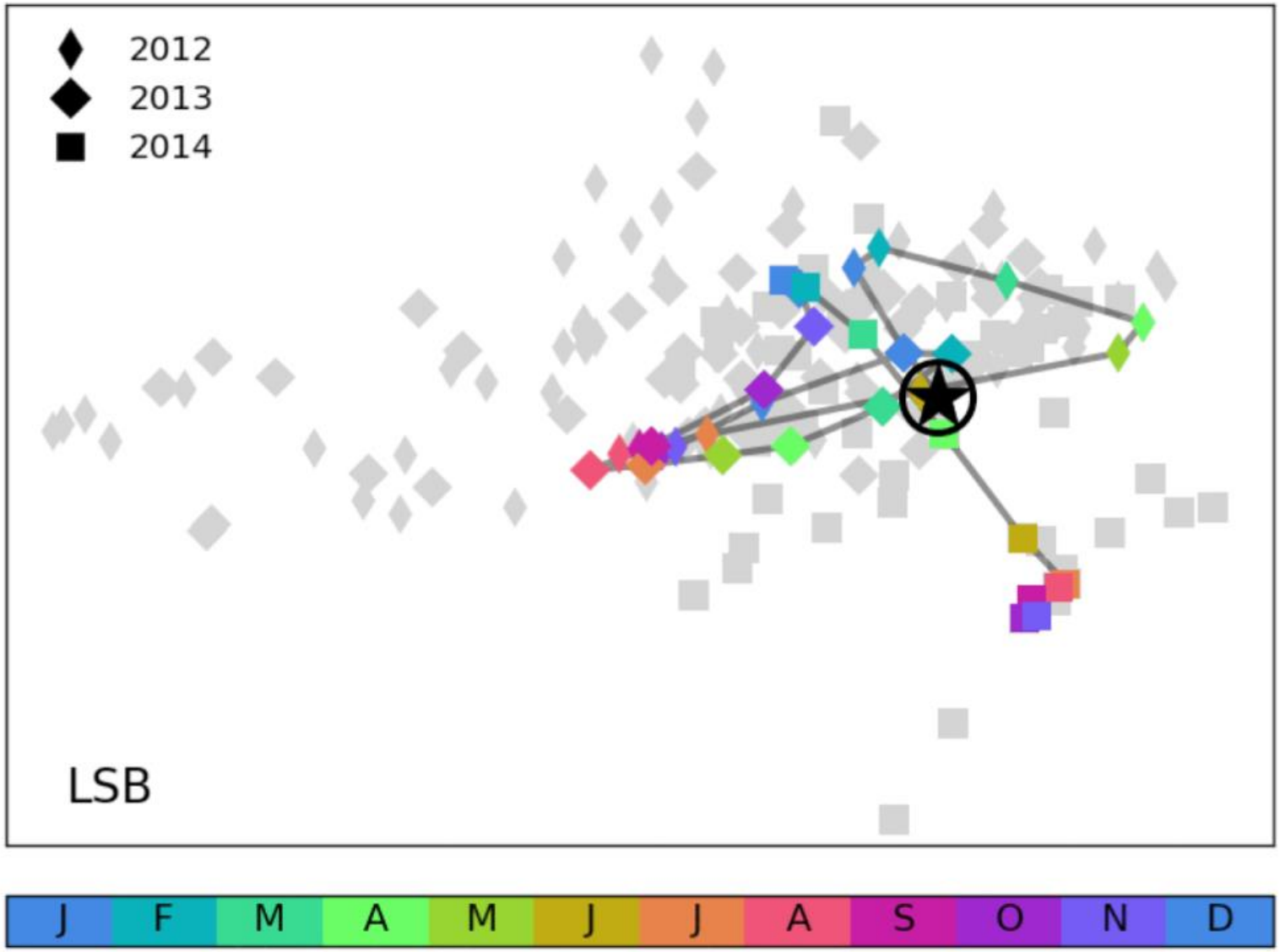
Hypotheses:

- Coherent seasonal community shifts
- Subembayments exhibit distinct seasonal cycles, some overlap



Lower South Bay

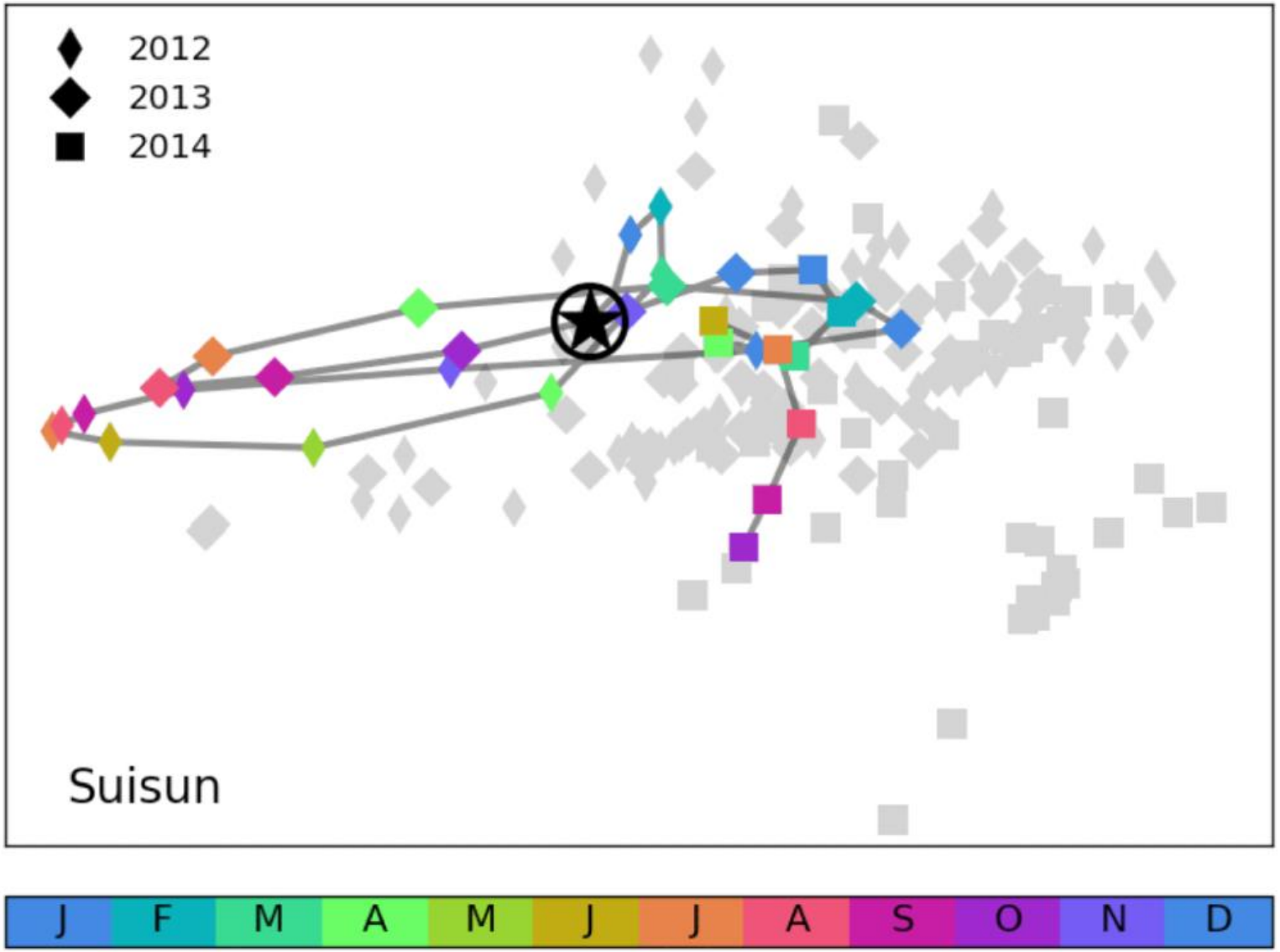
Note: Colors indicate month/season, shape indicates year



Averaged by month, highlighting Lower South Bay stations

Suisun Bay

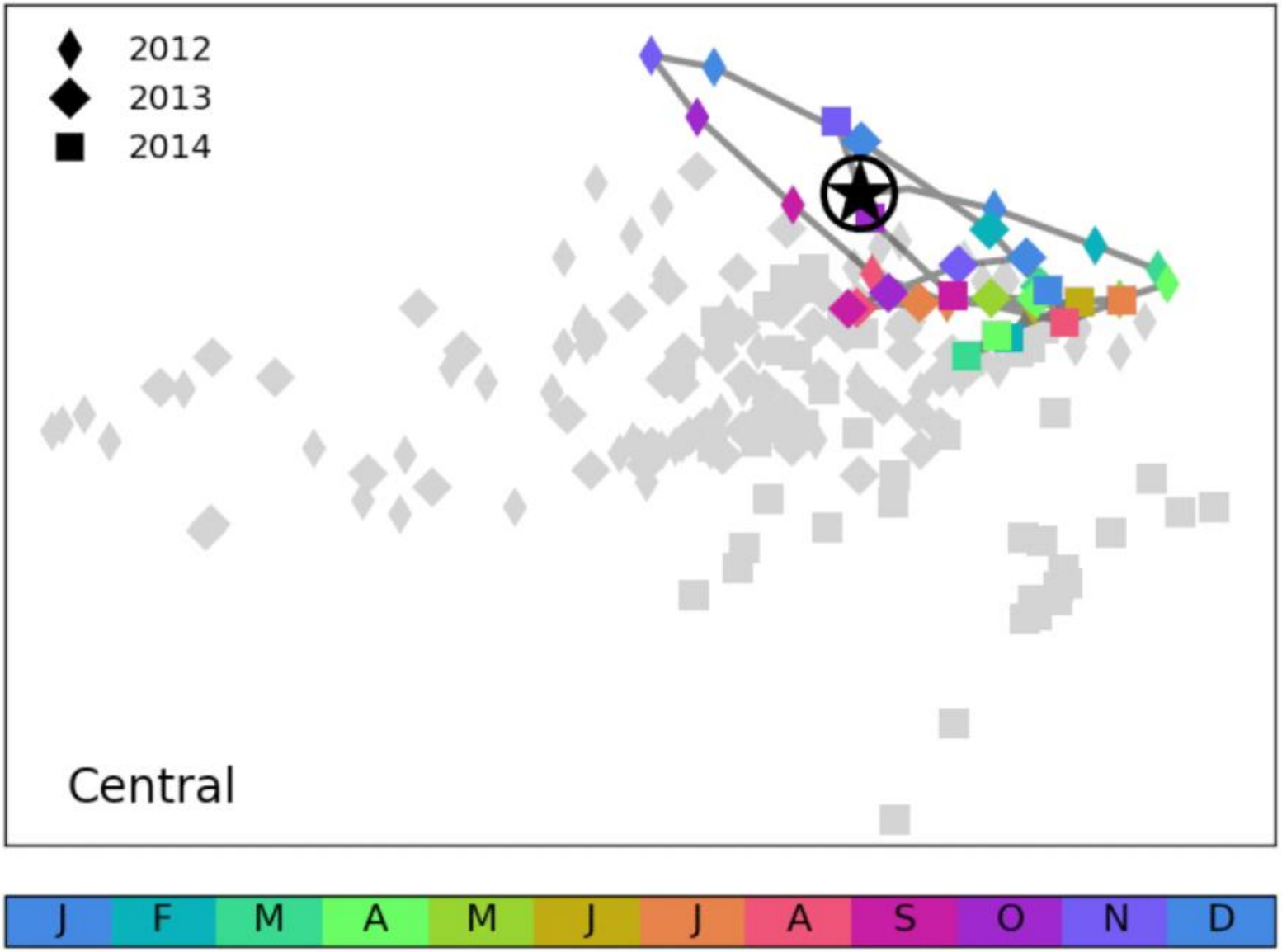
Note: Colors indicate month/season, shape indicates year



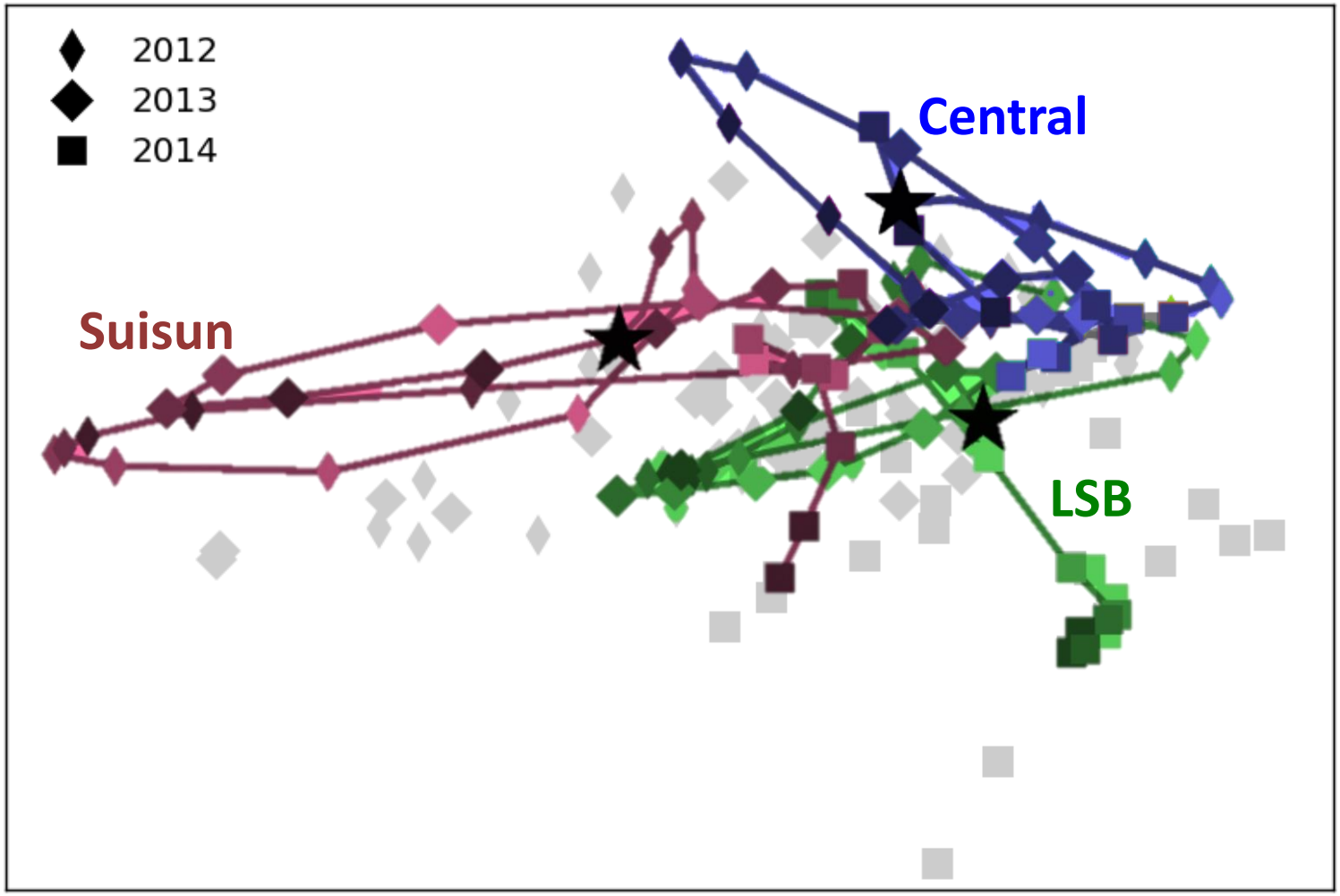
Averaged by month, highlighting Suisun Bay stations

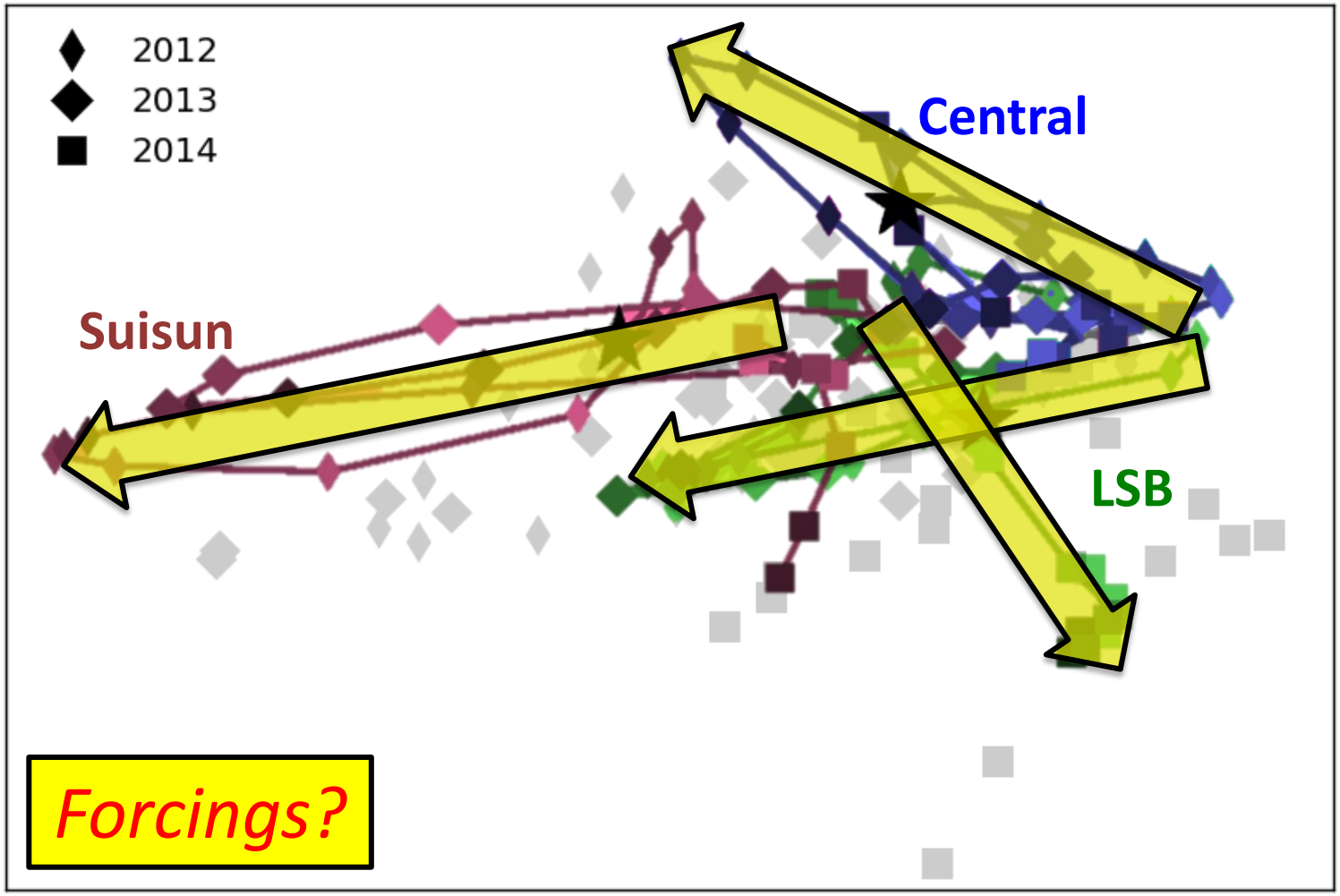
Central Bay

Note: Colors indicate month/season, shape indicates year



Averaged by month, highlighting Central Bay stations


2012
2013
2014
Central
Suisun
LSB


2012
2013
2014
Central
Suisun
LSB
Forcings?

Key Messages

- Lower South Bay is a complex and heterogeneous biogeochemical reactor: N transformations / Dissolved Oxygen / Blooms
  - Frequent Low DO in sloughs
  - Large and complex biogeochemical gradients
  - Role of nutrients? Field investigations and modeling underway
  - Adverse effects? Condition assessment
- Algal toxins and HAB-forming organisms commonly detected Bay-wide
  - ✔ Water ✔ Biota …at low/moderate levels, nonetheless concerning
  - Multiple species, multiple toxins
  - Exploring: Sources, Mechanisms, Monitoring
  - Linkage to Nutrients? Adverse Impacts?
- Overall Science Plan and Science Program
  - Major progress on priority fronts, guided by Science Plan
  - Optimized team: internal/external…deep expertise + utility players
  - Effort is under-funded if timeline goals are to be met

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