
Source: C. Benton

NMS Science Program Update

- Background
- Program Update
- Permit 2 directions

D Senn, Z Zhang, A Chelsky, T Winchell, E Nuss, A King, E King, I Wren[1]

and MANY regional collaborators

[1] Bay Keeper

sfbaynutrients.sfei.org

Collaborators

SFEI

Z Zhang, E Nuss, T Winchell, E King, A Chelsky, Ali King, D Senn

USGS-Menlo Park

J Cloern, L Lucas, C Martin, E Nejad, T Schraga

UC Santa Cruz

R Kudela, M Peacock

USGS-Sacramento

M Downing-Kunz, B Bergamaschi, B Downing, L Stumpner, T Kraus

SCCWRP

M Sutula; M Beck

UC Davis

R Holleman
E Gross

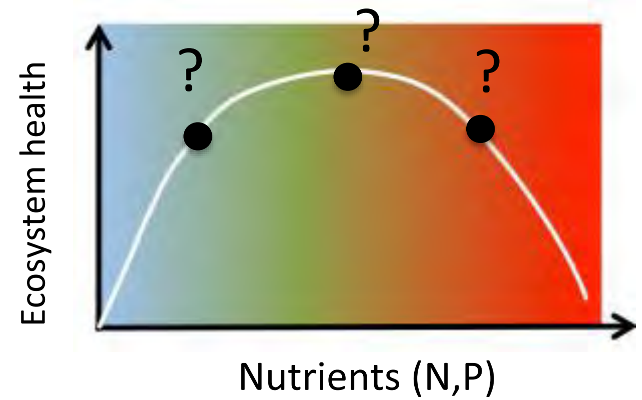
UC Berkeley

M Stacey

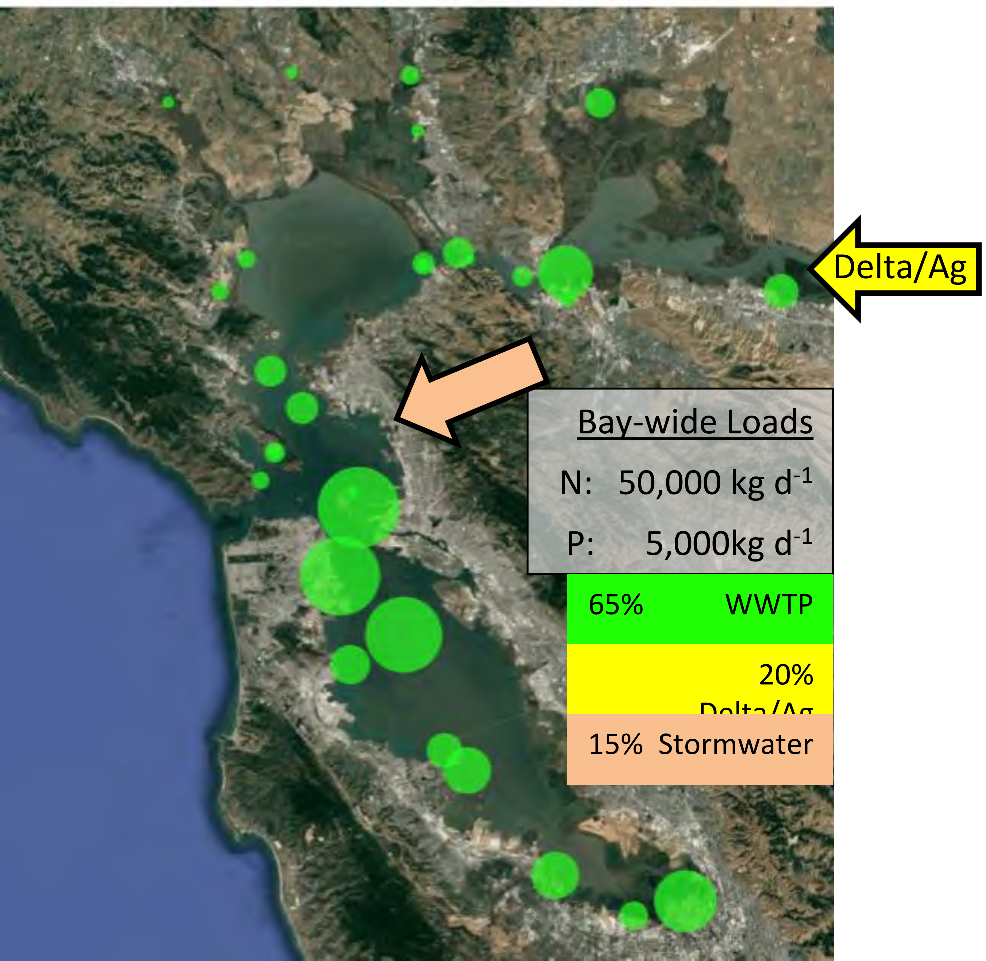
P de Valpine

Does SFB have nutrient problems?
- now?
- future?

How can impacts be mitigated or prevented?
- $5-10bill question



- Large algae blooms
- Low DO
- Harmful algae, toxins

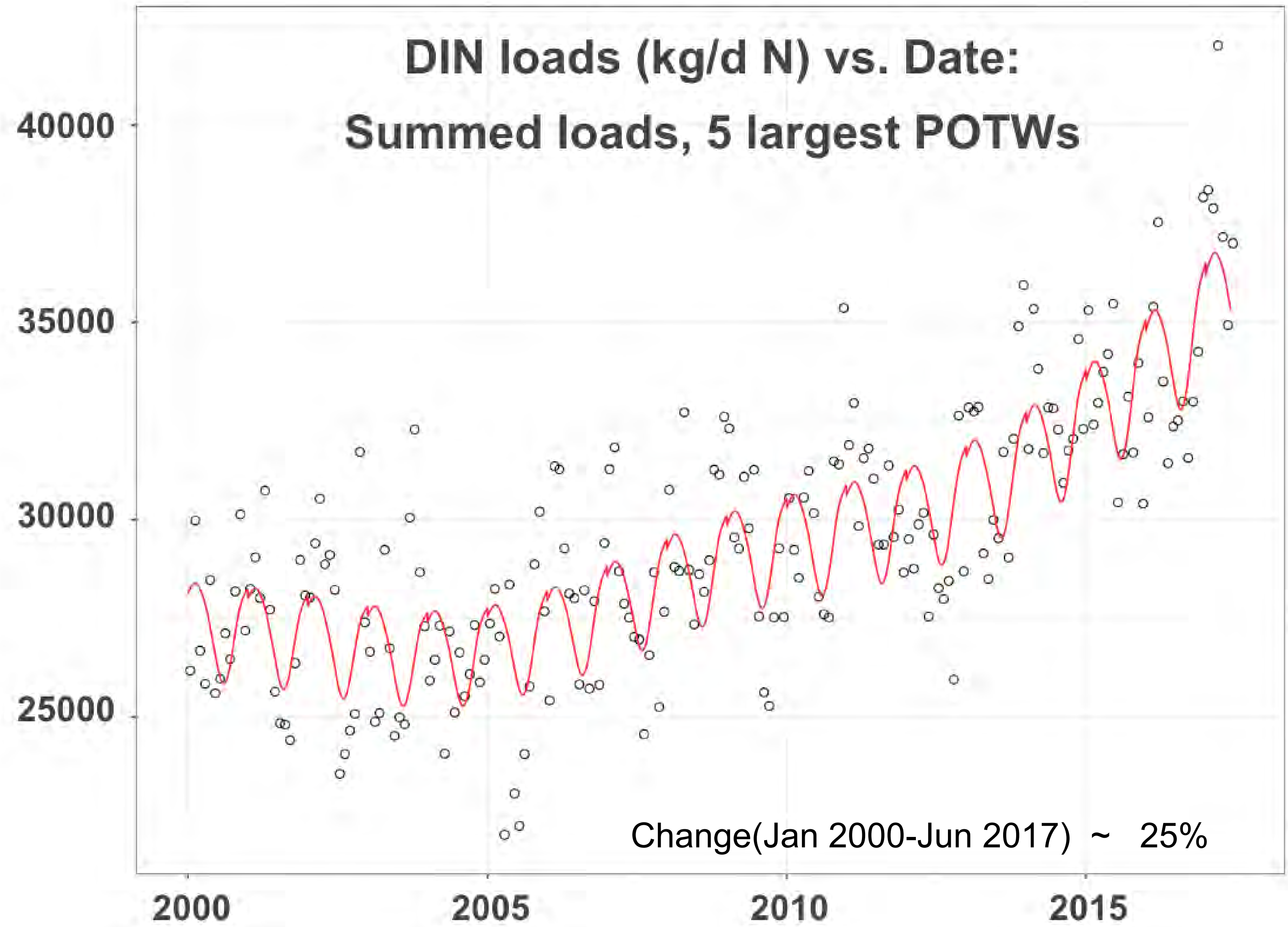


N and P loads place SFB in upper ~90%ile of estuaries worldwide (g m^{-2} d^{-1})

Cloern et al., in prep

And those loads are increasing…

Dissolved Inorganic Nitrogen (DIN) Loads ($NH_4^+ + NO_3^-$)



Does SFB have nutrient problems?

- now?
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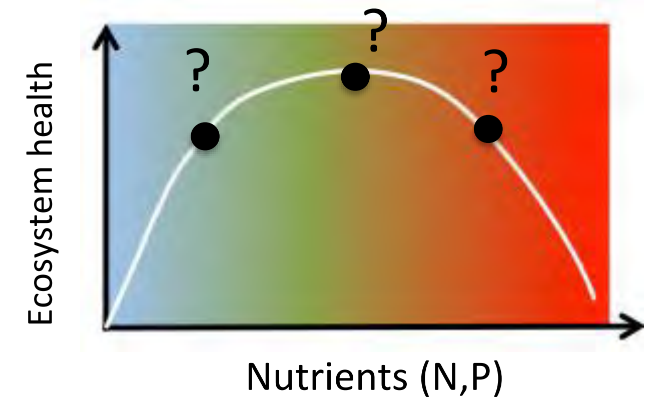
How can impacts be mitigated or prevented?

- $5-10bill question



- Large algae blooms
- Low DO
- Harmful algae, toxins

SFB doesn't use most of its nutrients

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

loads place SFB in upper ~90%ile
ies worldwide (g m^{-2} d^{-1})

Historically: Resistant to classic eutrophication symptoms

Cloern et al., in prep

Recently: Evidence of changing response to nutrients

ose loads are increasing…

e.g., Cloern et al., 2007, 2010

Nutrient Management Strategy

- What nutrient loads can SFB (subembayments) assimilate without adverse impacts?
- What management actions would be effective at achieving protective nutrient loads or concentrations?


November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

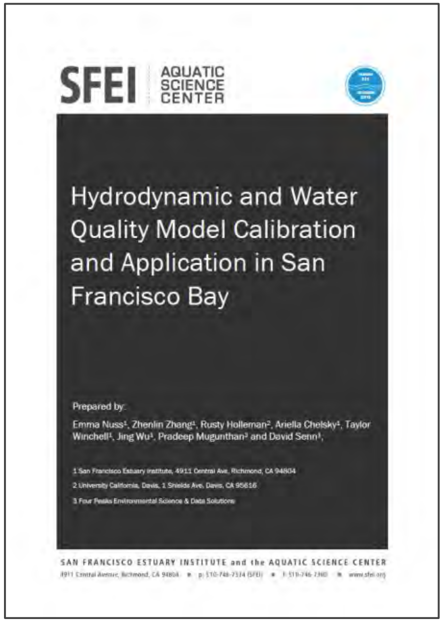
Tools/Approaches

- Monitoring
- Numerical Models
- Assessment Framework/Criteria
- Special Studies: Mechanistic/Quantitative Linkages to nutrients

Condition	**Link to Nutrients**	**Nutrient Dynamics**
• Monitoring • Assessment Framework	• Mechanisms • Dose : Response	• Inputs, transformations • Necessary Action

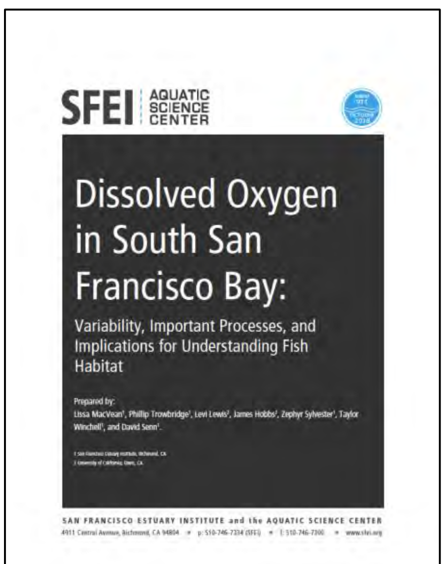
	Condition • Monitoring • Assessment Framework		**Link to Nutrients** • Mechanisms • Dose : Response		**Nutrient Dynamics** • Inputs, transformations • Necessary Action	
	Permit 1	Permit 2	Permit 1	Permit 2	Permit 1	Permit 2
Chl-a-DO Deep subtidal						
Chl-a-DO margins, sloughs						
HABs // Toxins						
Future Scenarios						
Coastal Effects						

Modeling (12/2018)

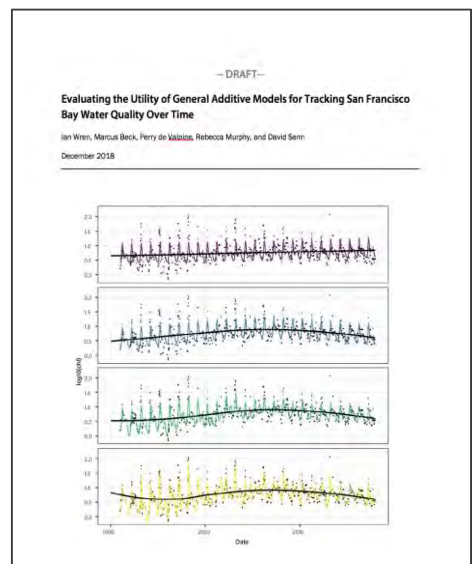


Monitoring // Moored Sensors (12/2018)

Oxygen & Habitat (10/2018)



Trends: chlorophyll (12/2018)

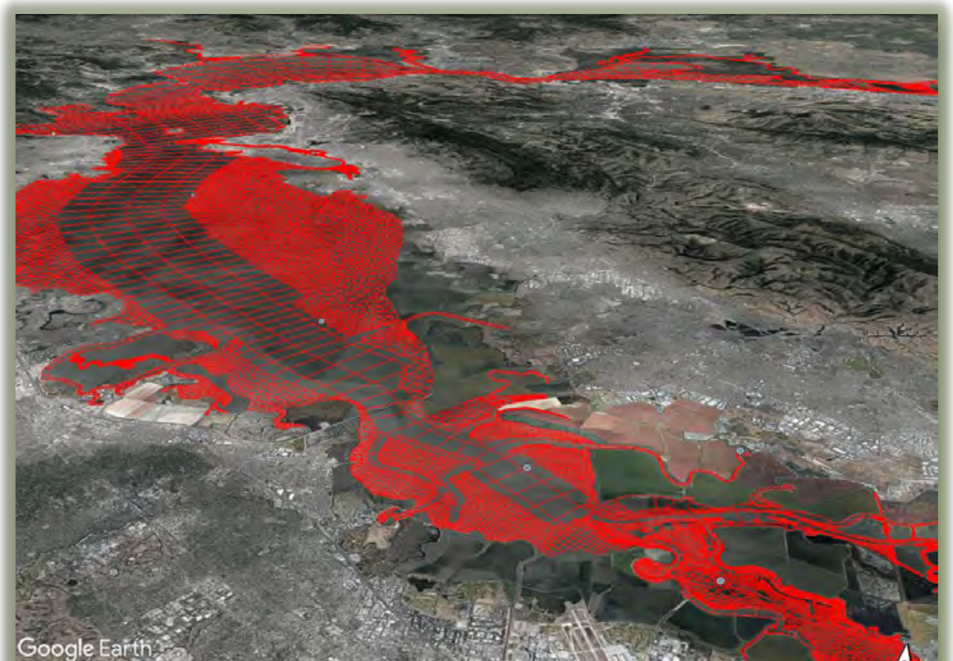


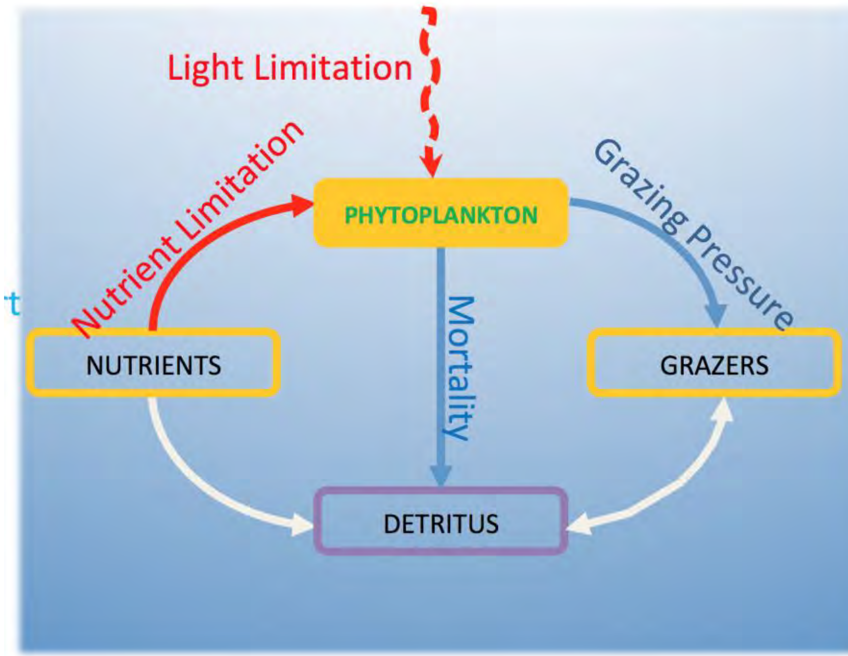
Numerical Models

Hydrodynamic model
(Transport)

+

Biogeochemical model
(In-situ)





Transport = advection + dispersion + mixing

In-situ = production + grazing + mortality

	Condition • Monitoring • Assessment Framework		**Link to Nutrients** • Mechanisms • Dose : Response		**Nutrient Dynamics** • Inputs, transformations • Necessary Action	
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Future Scenarios						
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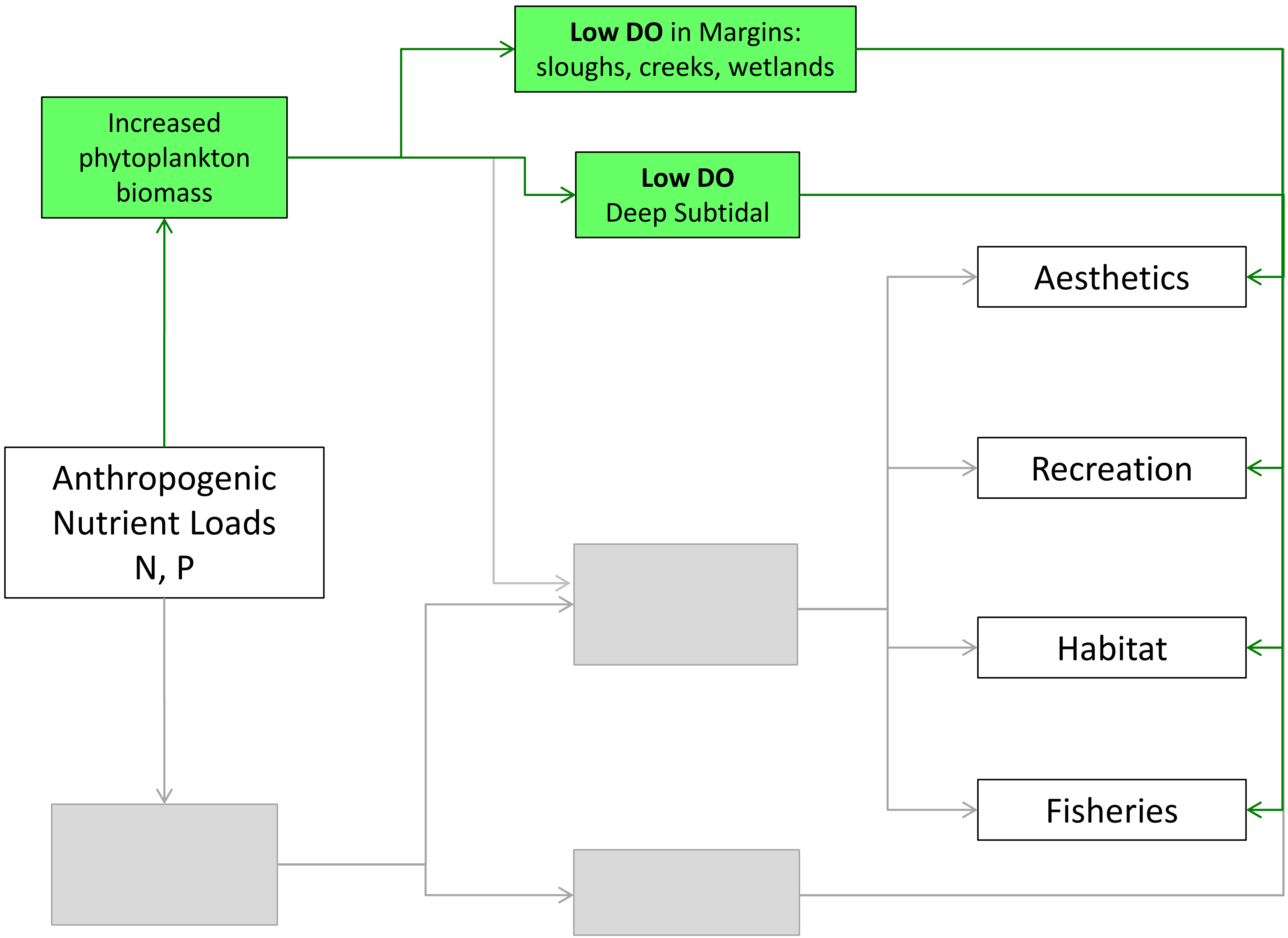
Potential Adverse Impacts of Nutrients in SFB



SFEI 2014, Sutula et al. 2017

Modeling related Management Questions

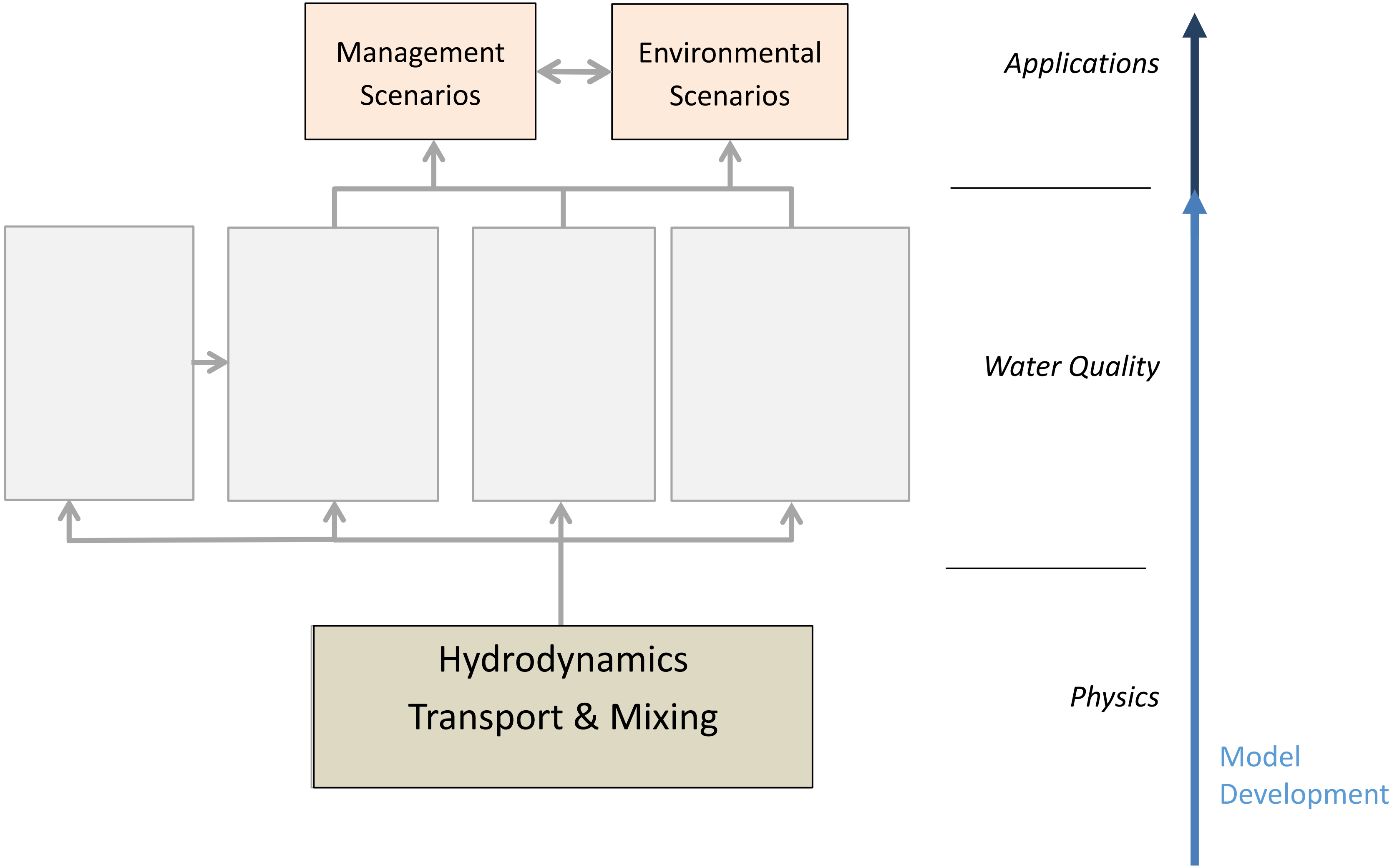
- Source apportionment: What are the nutrient sources to habitats ?

- Predict responses: numerous physical/biological forcings and their influence on nutrient-related responses?
  - Responses: chl, DO, HABs
  - Forcings: loads, tides, wind, suspended sediments, salinity/stratification (Q_{fresh}), upwelling, light, etc.

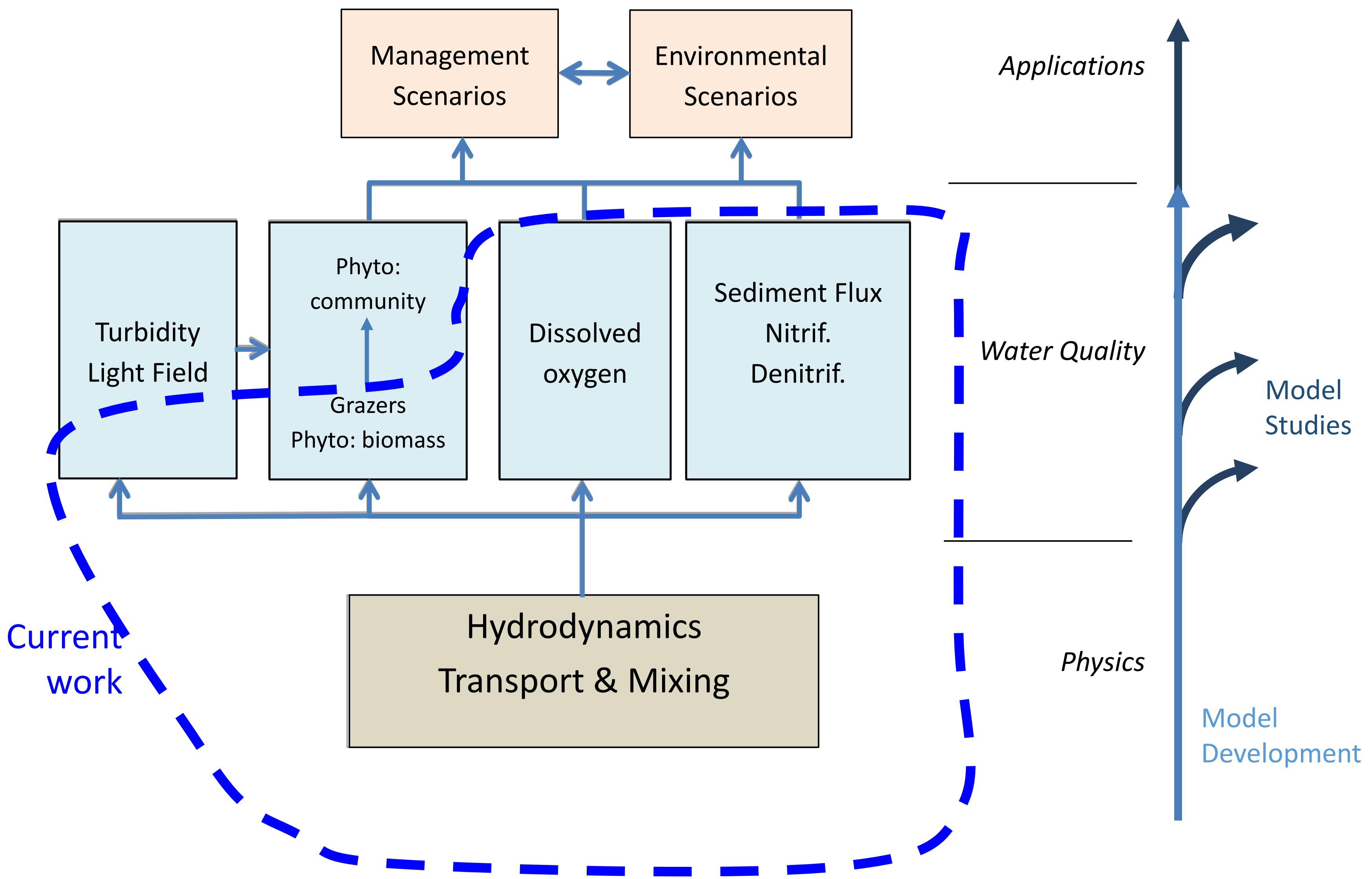
- Dose:Response -- How will the system respond to incremental increases/decreases in nutrient inputs?

- If nutrient reductions are needed, how with the system respond to various management alternatives?

Model Development and Application



Model Development and Application



How well does the model capture..

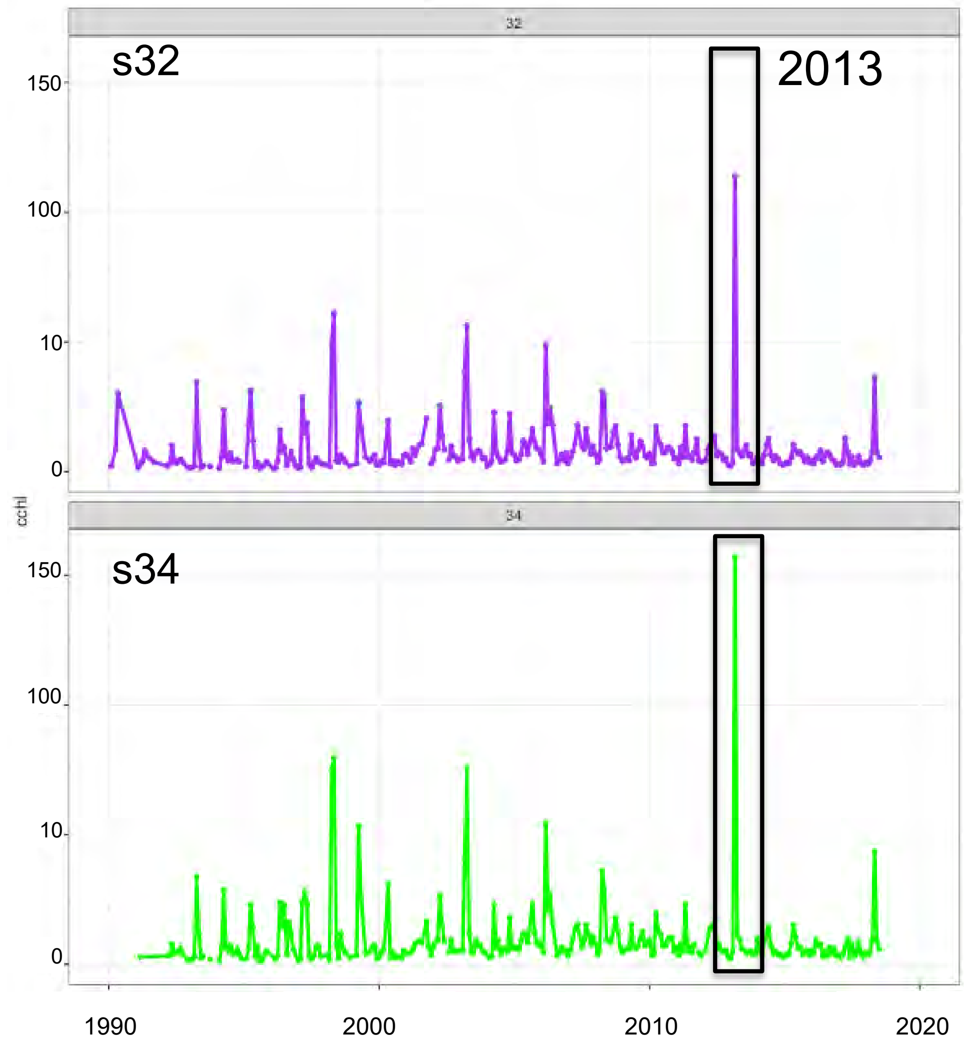
Phytoplankton biomass/blooms

- *Timing…Magnitude…Locations*
- *Factors controlling loss and gain*

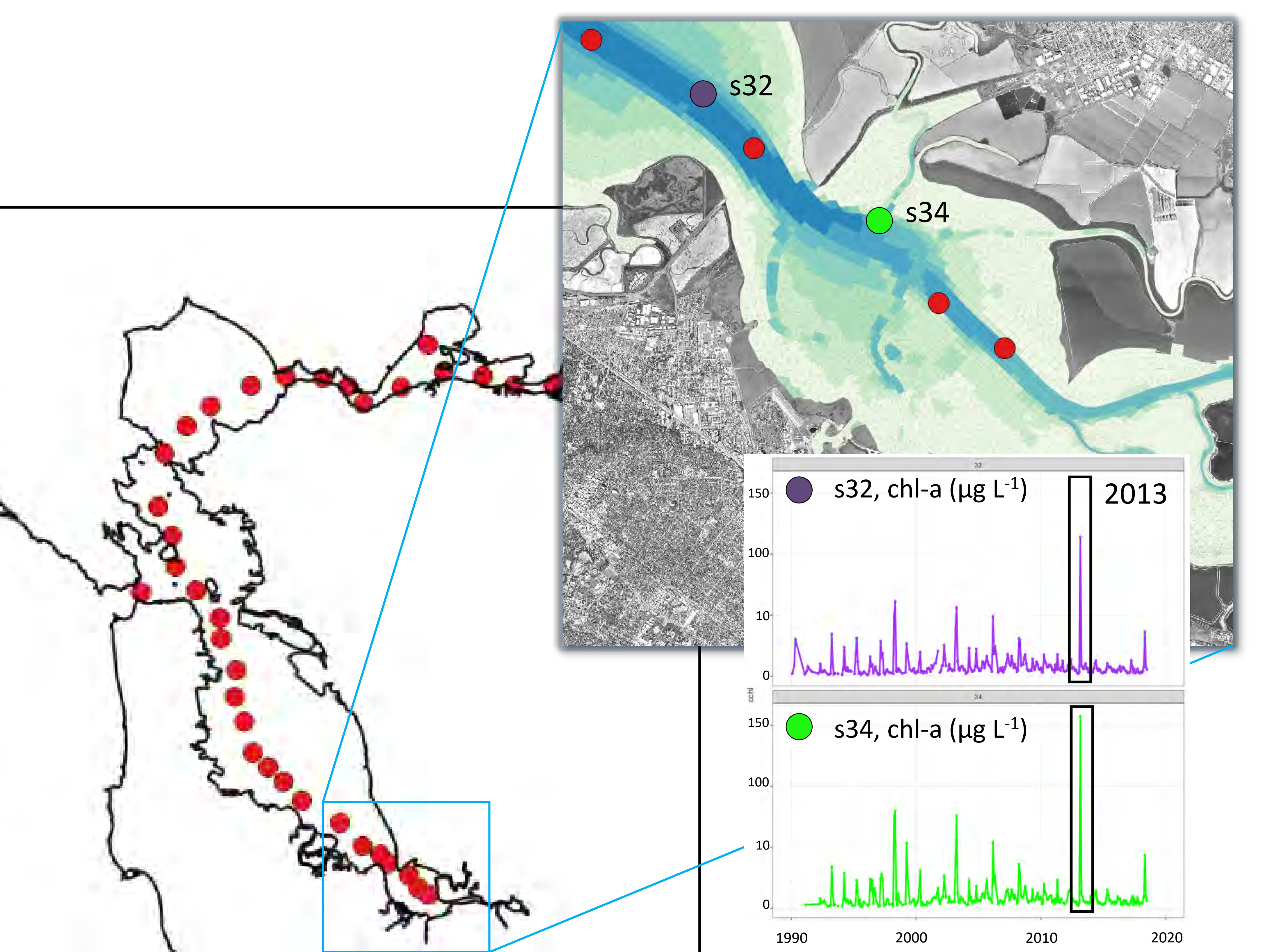
Nutrient levels and fate

Dissolved Oxygen

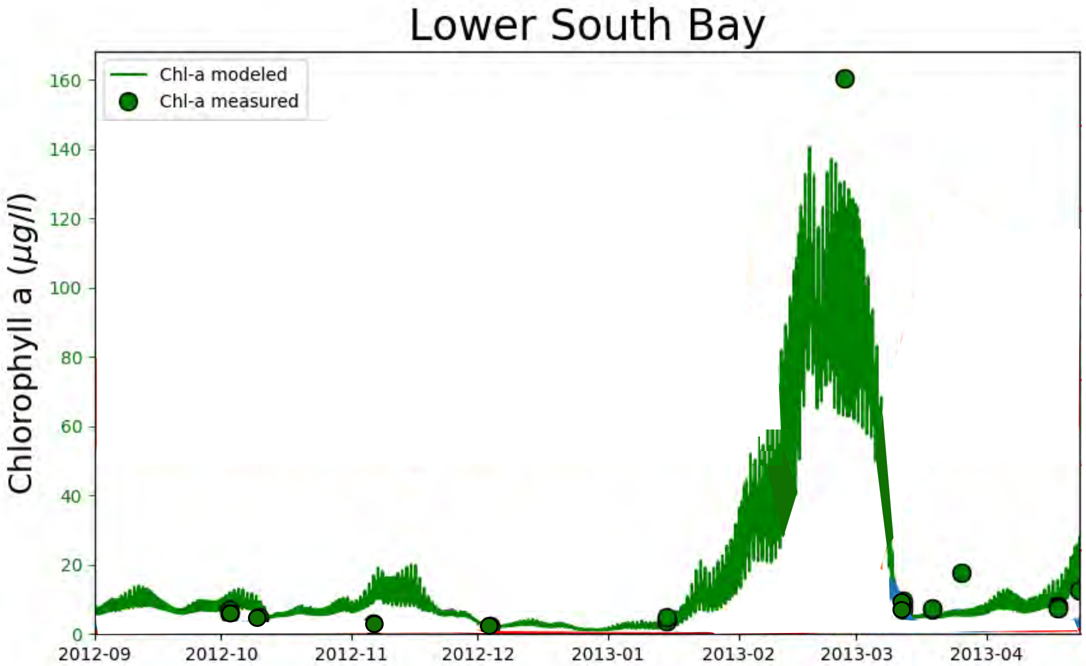
chl-a (µg L^{-1}) at two Lower South Bay Stations



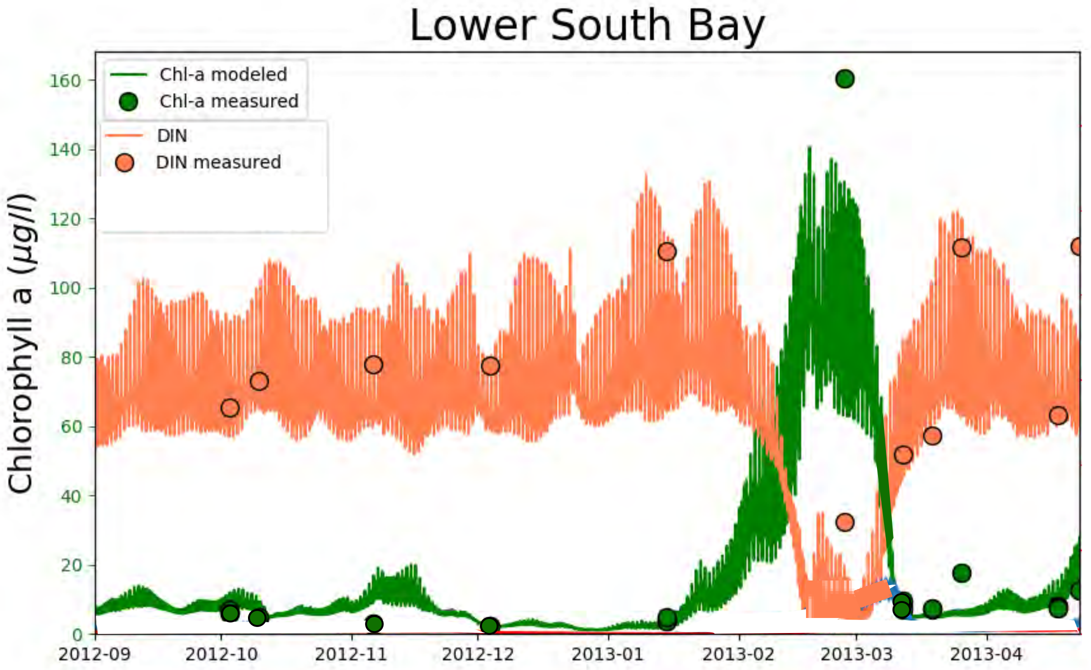
Across a range of conditions and responses



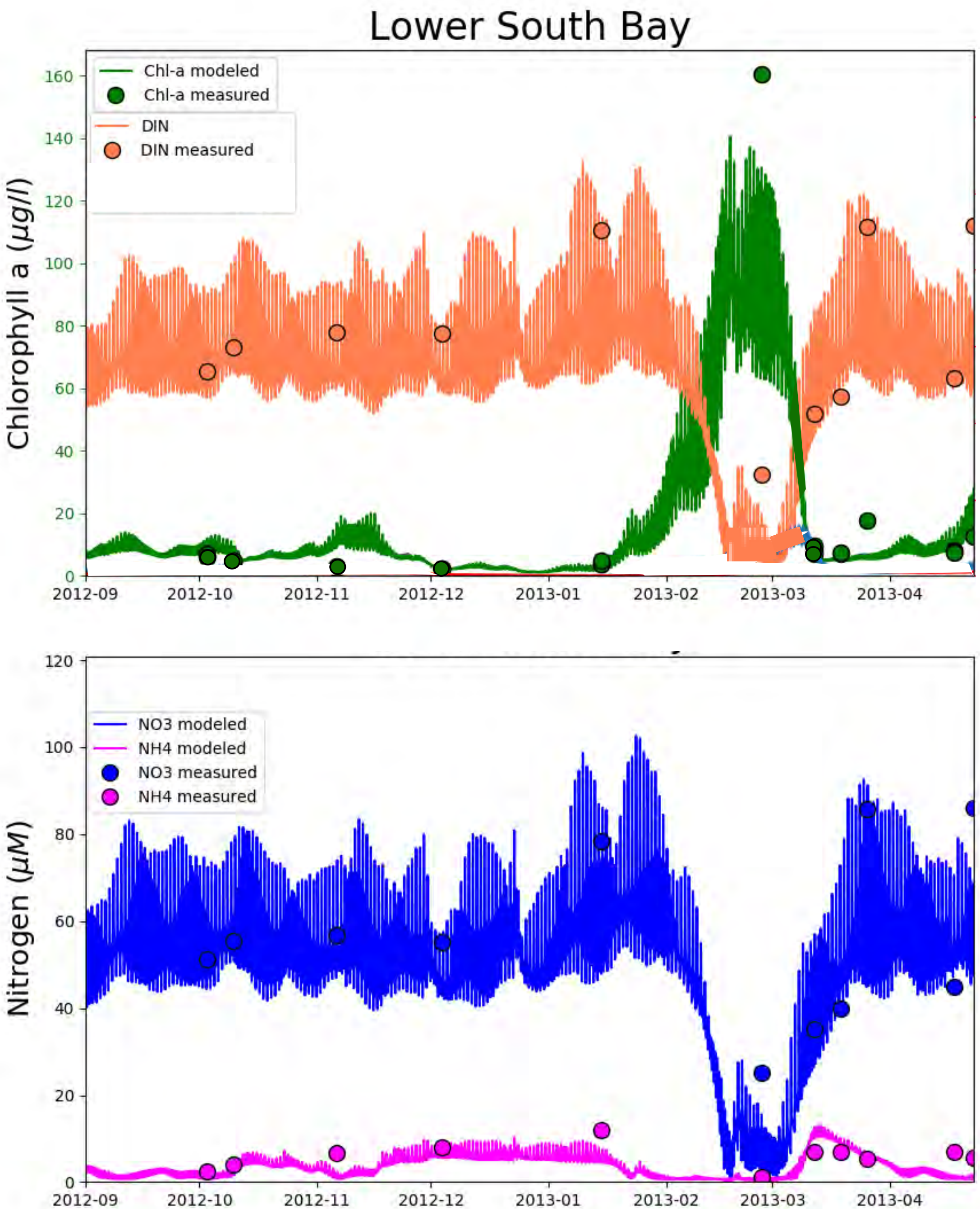
s32
s34
s32, chl-a (µg L-1)
2013
s34, chl-a (µg L-1)
150
100
10
0
1990
2000
2010
2020



Lower South Bay
Chl-a modeled
Chl-a measured
Chlorophyll a ($\mu g/l$)
0
20
40
60
80
100
120
140
160
2012-09
2012-10
2012-11
2012-12
2013-01
2013-02
2013-03
2013-04

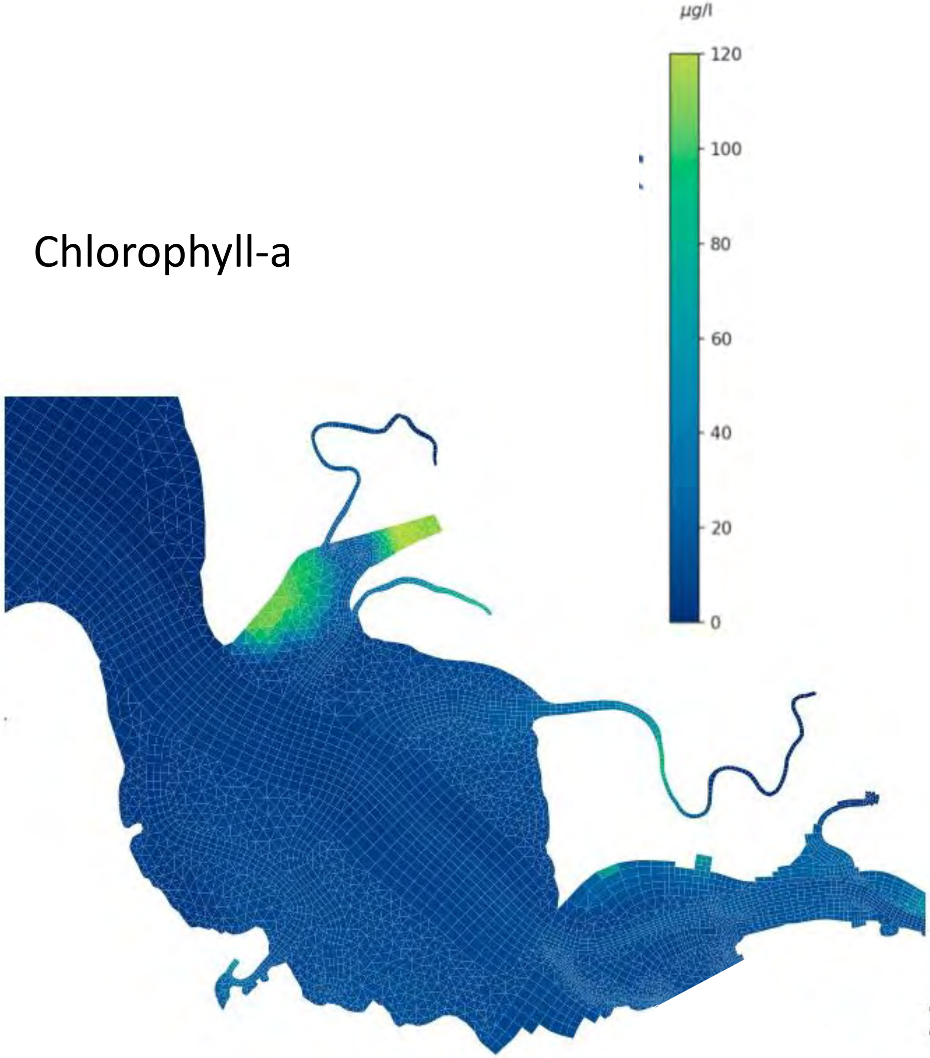


Lower South Bay
Chl-a modeled
Chl-a measured
DIN
DIN measured
Chlorophyll a ($\mu g/l$)
160
140
120
100
80
60
40
20
0
2012-09
2012-10
2012-11
2012-12
2013-01
2013-02
2013-03
2013-04

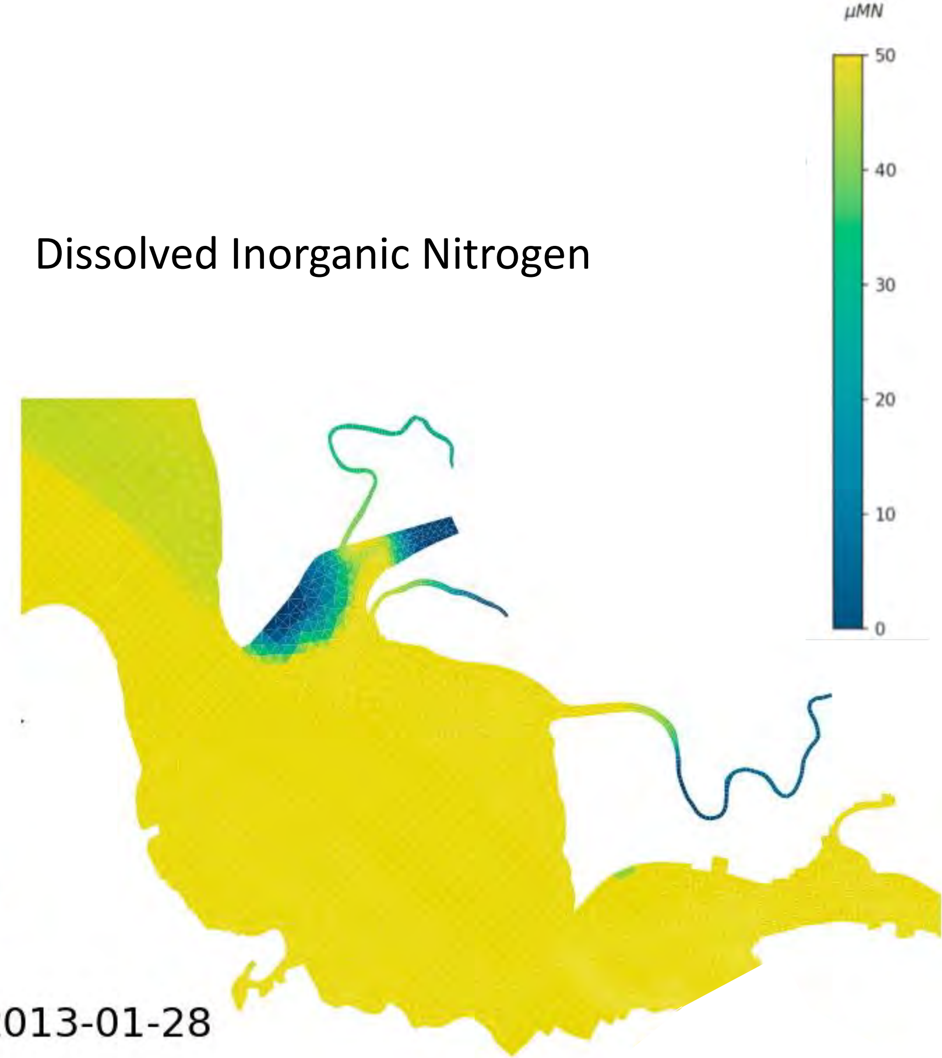


Lower South Bay
Chl-a modeled
Chl-a measured
DIN
DIN measured
Chlorophyll a (μg/l)
0
20
40
60
80
100
120
140
160
2012-09
2012-10
2012-11
2012-12
2013-01
2013-02
2013-03
2013-04
NO3 modeled
NH4 modeled
NO3 measured
NH4 measured
Nitrogen (μM)
0
20
40
60
80
100
120
2012-09
2012-10
2012-11
2012-12
2013-01
2013-02
2013-03
2013-04

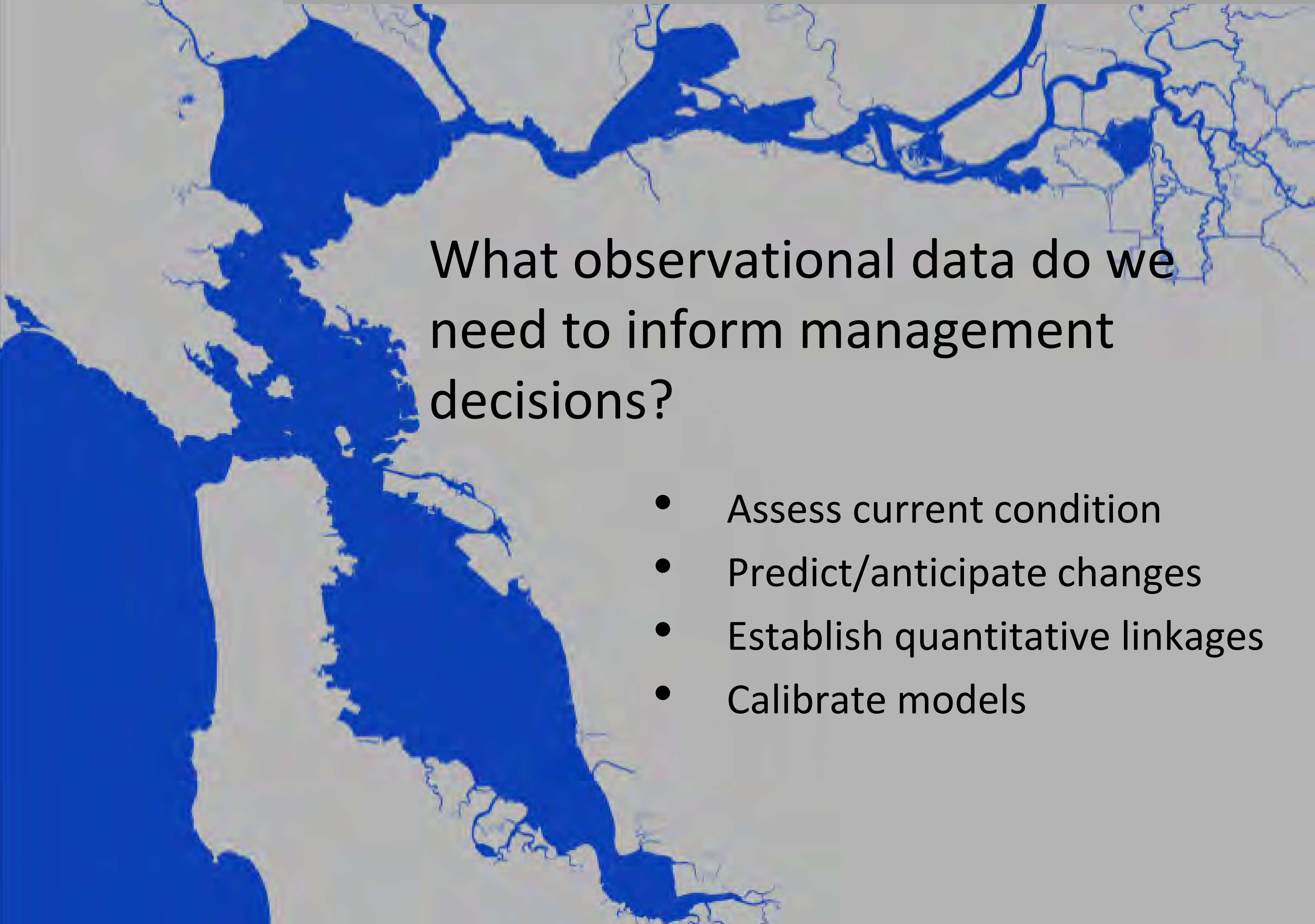
Chlorophyll-a



Dissolved Inorganic Nitrogen

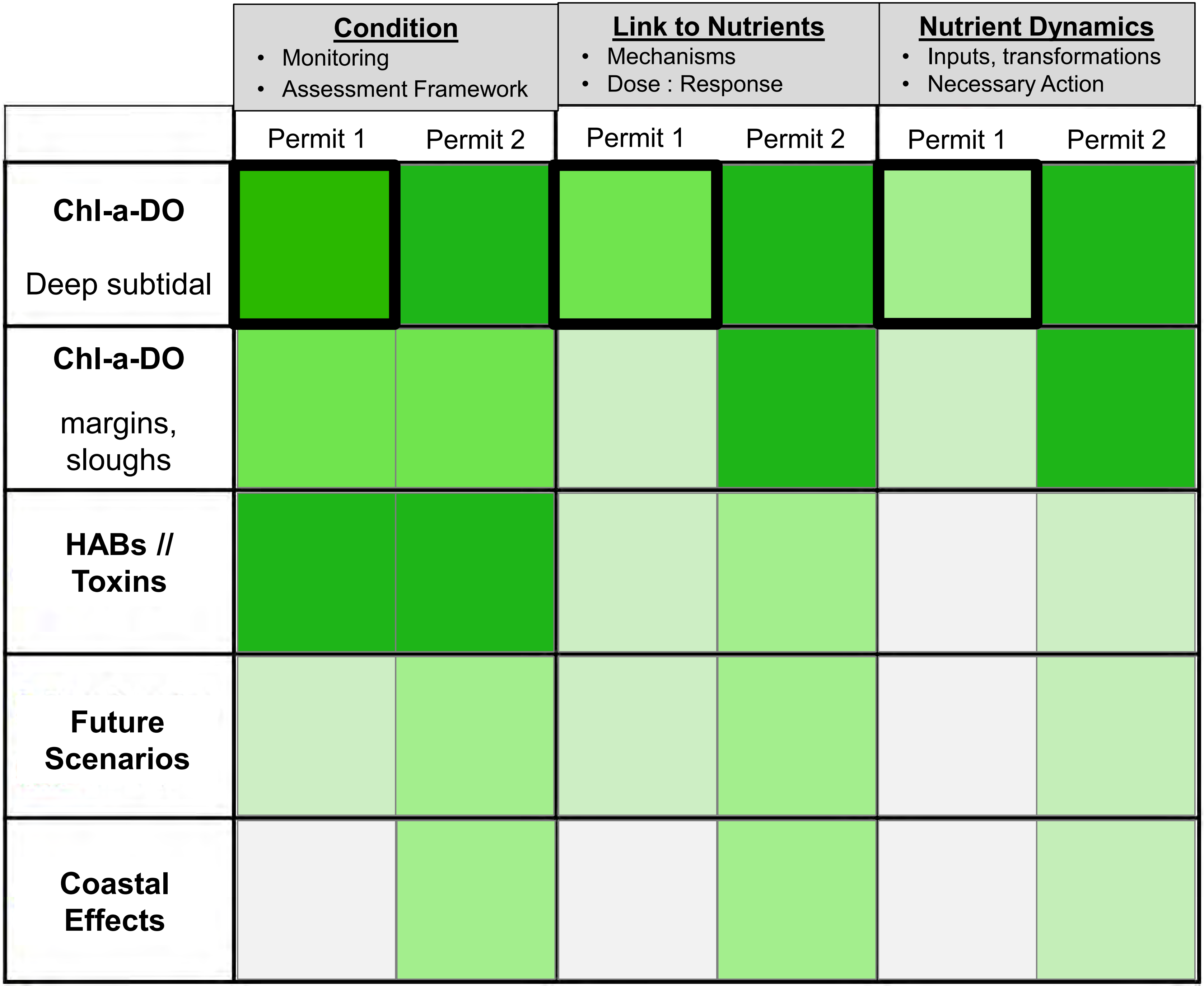


2013-01-28



What observational data do we need to inform management decisions?

- Assess current condition
- Predict/anticipate changes
- Establish quantitative linkages
- Calibrate models


Condition
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Chl-a-DO
Deep subtidal
Chl-a-DO
margins, sloughs
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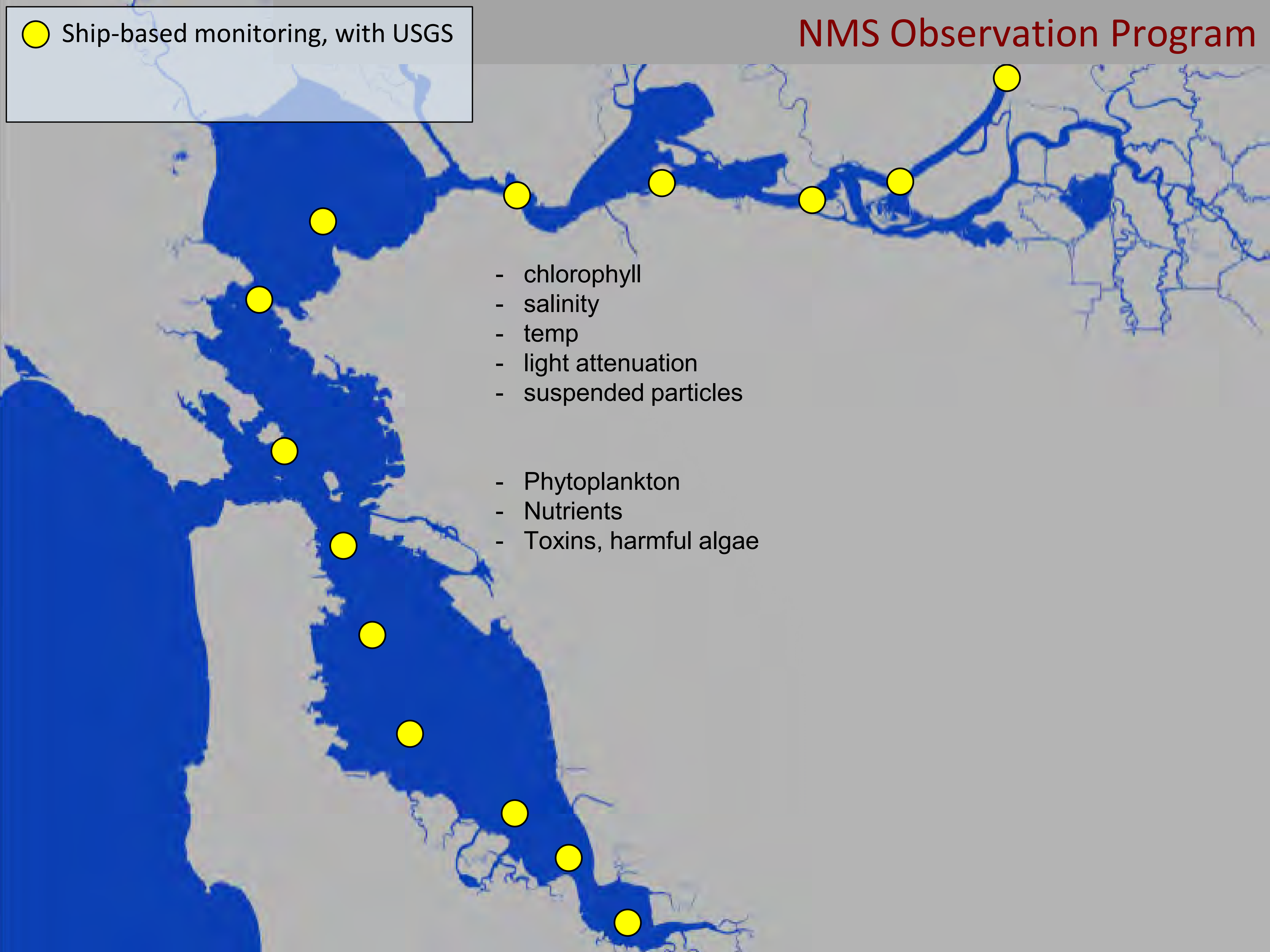
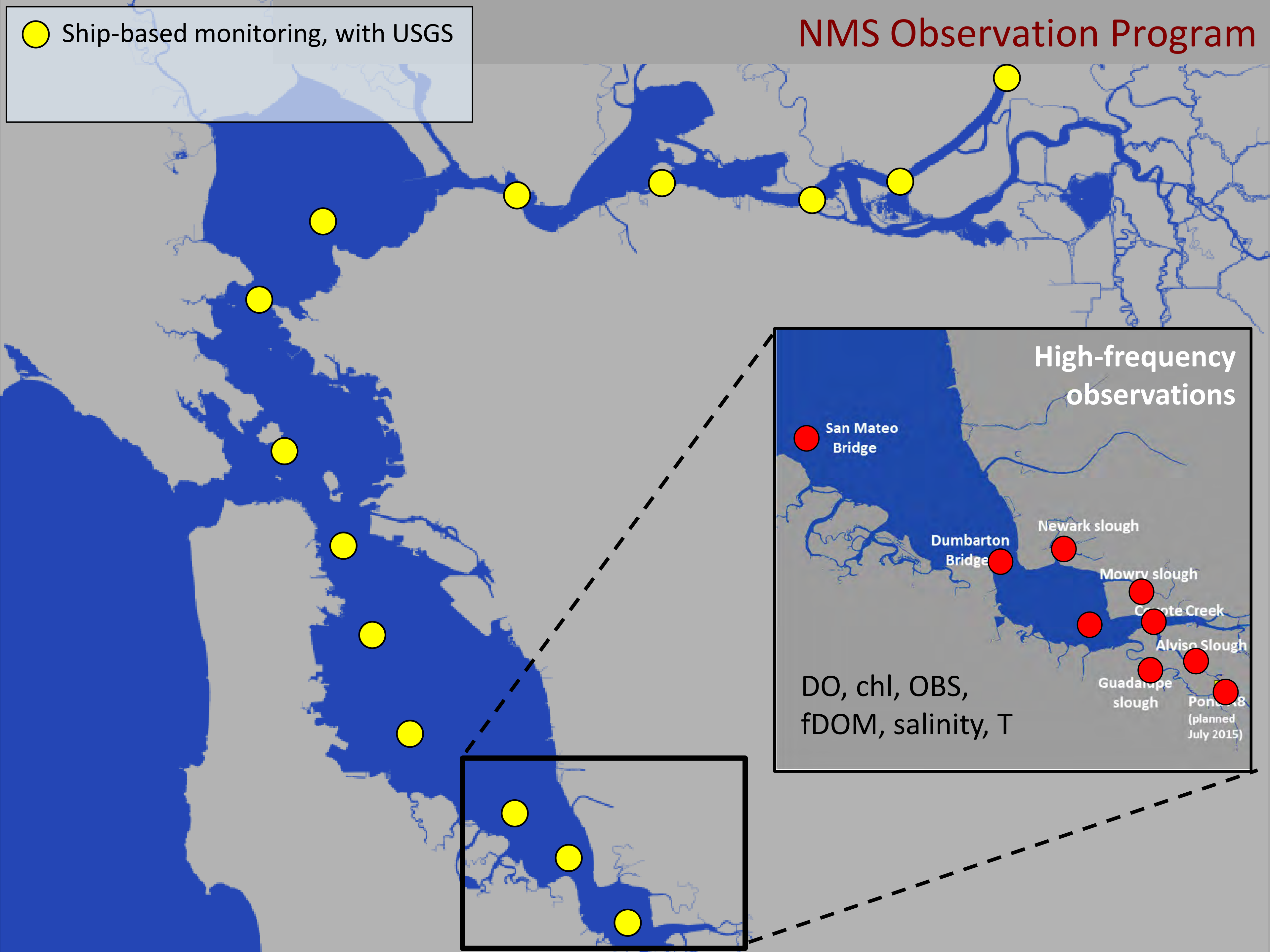
NMS Observation Program



- chlorophyll
- salinity
- temp
- light attenuation
- suspended particles

- Phytoplankton
- Nutrients
- Toxins, harmful algae

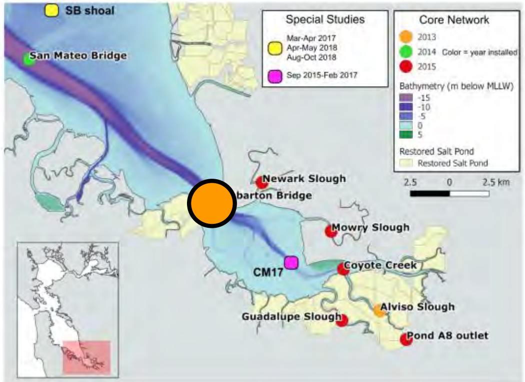
NMS Observation Program



High Frequency Mooring data:

- Dissolved Oxygen
- chl-a
- Other parameters

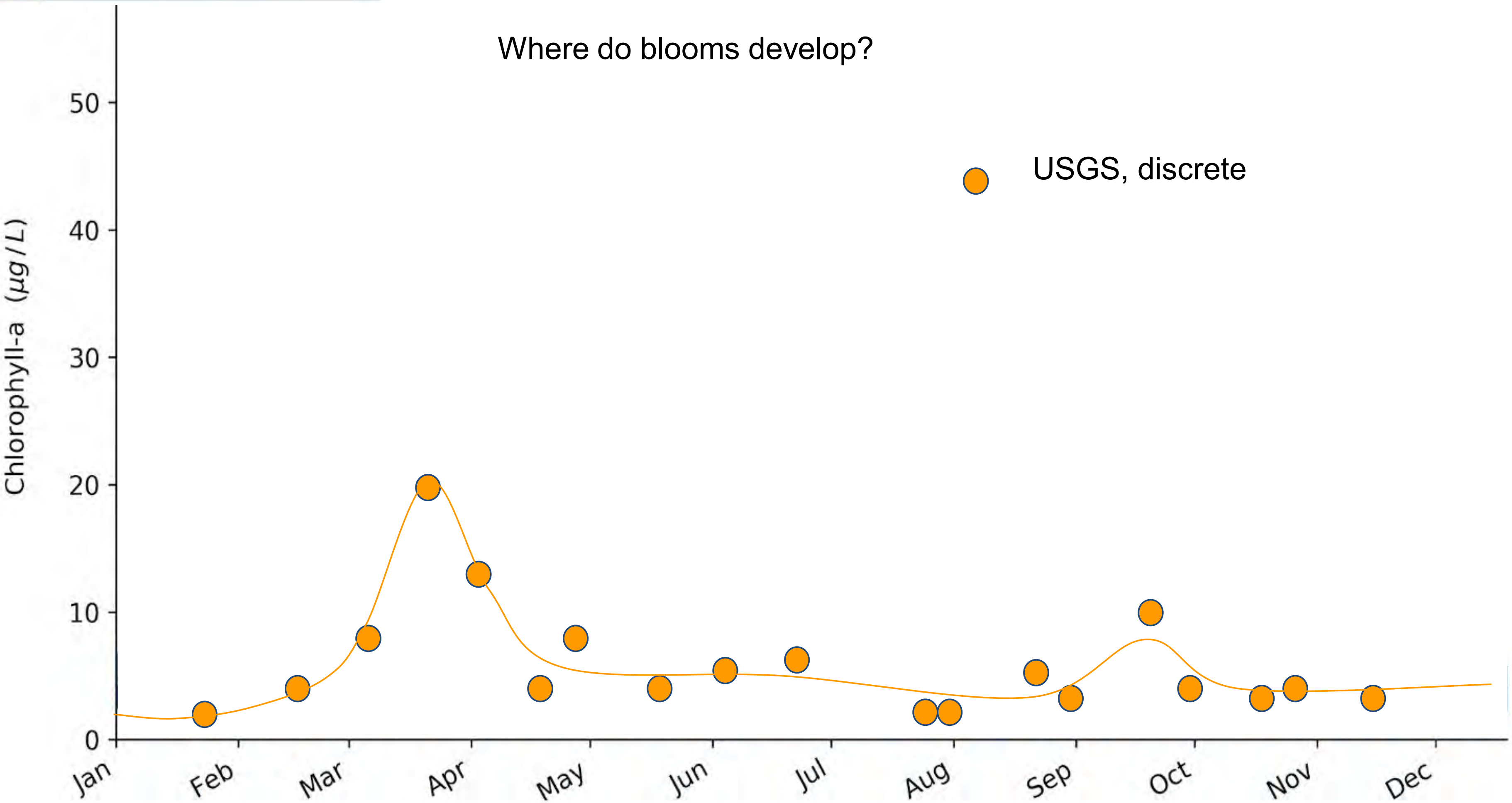
Photo: Shira Bezalel

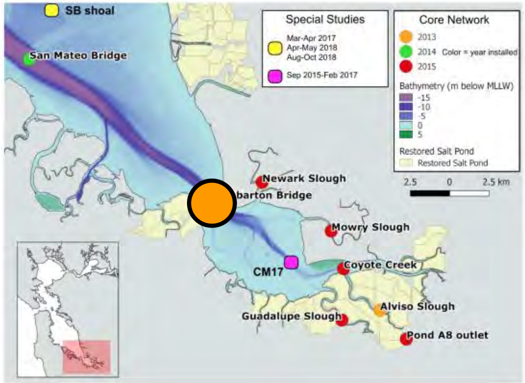


Jan-Dec 2017: Dumbarton Bridge

What factors regulate blooms magnitude, timine, duration?

Where do blooms develop?





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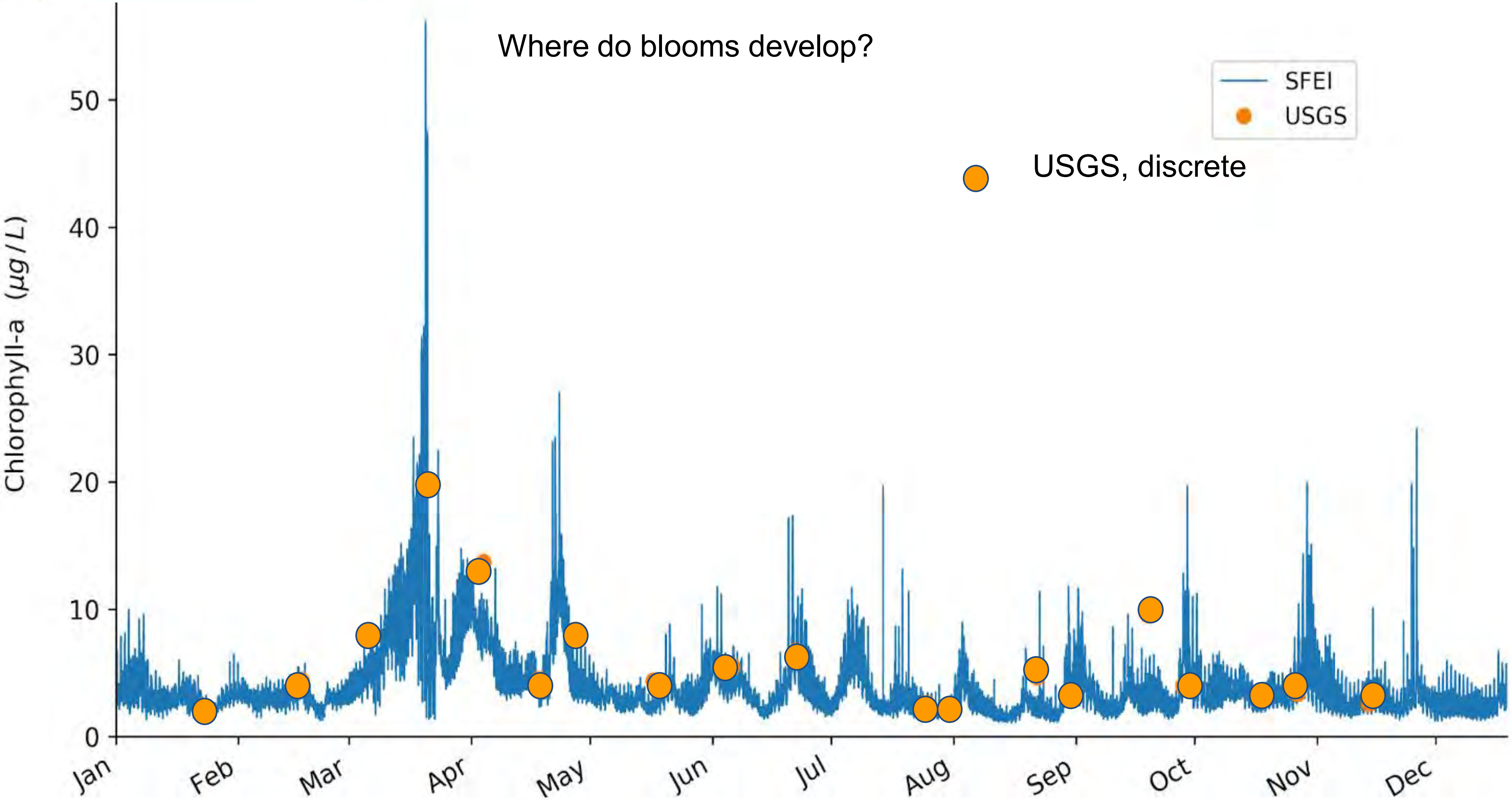
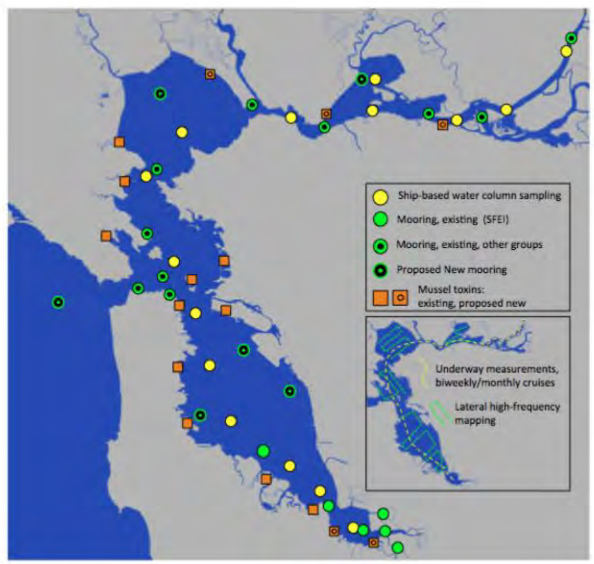
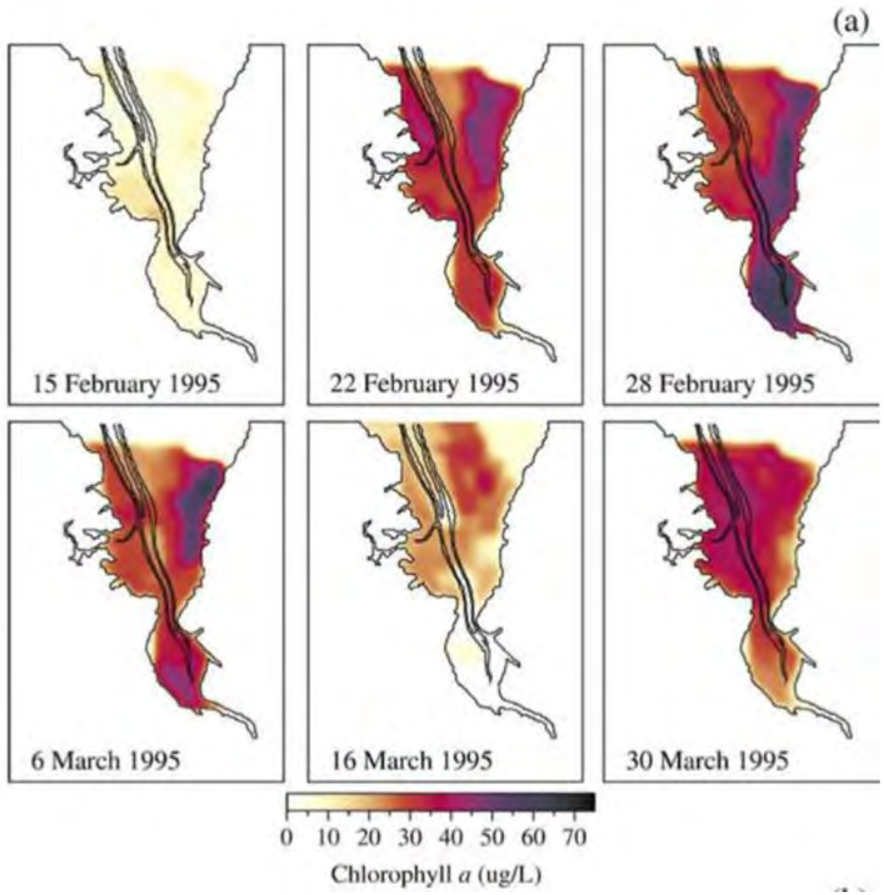


What monitoring network is needed to detect and describe ‘events’ with sufficient reliability/accuracy?

San Francisco Bay
Nutrient Management Strategy
Observation Program



December 2016

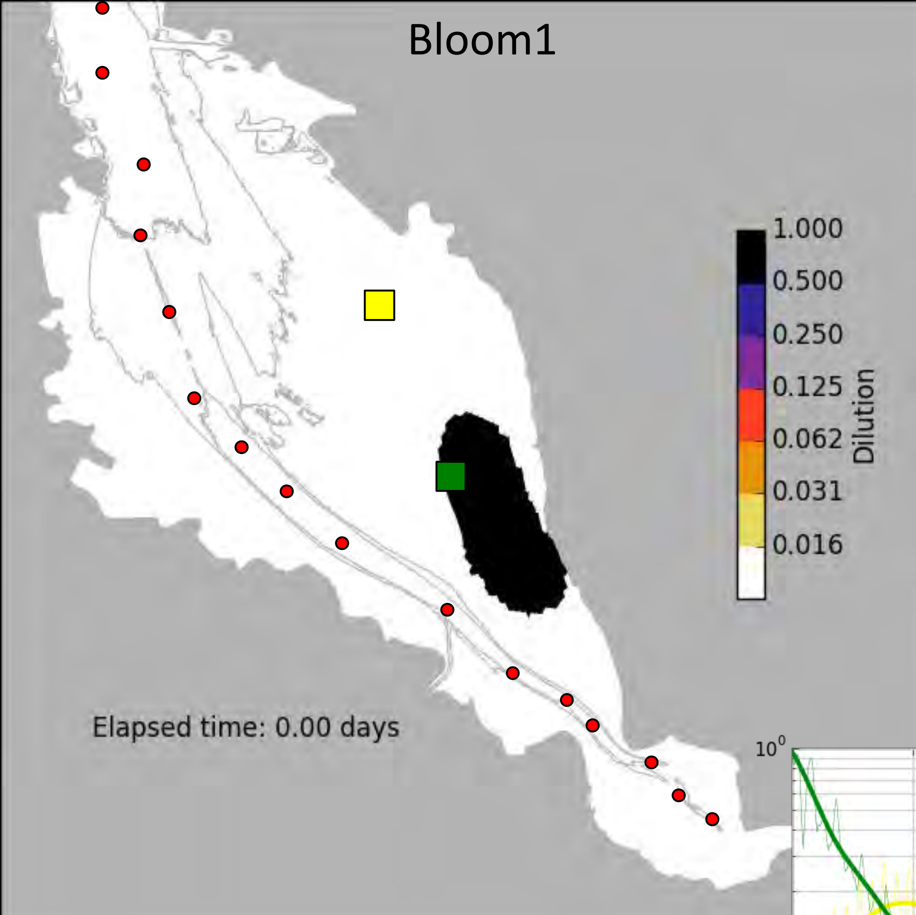


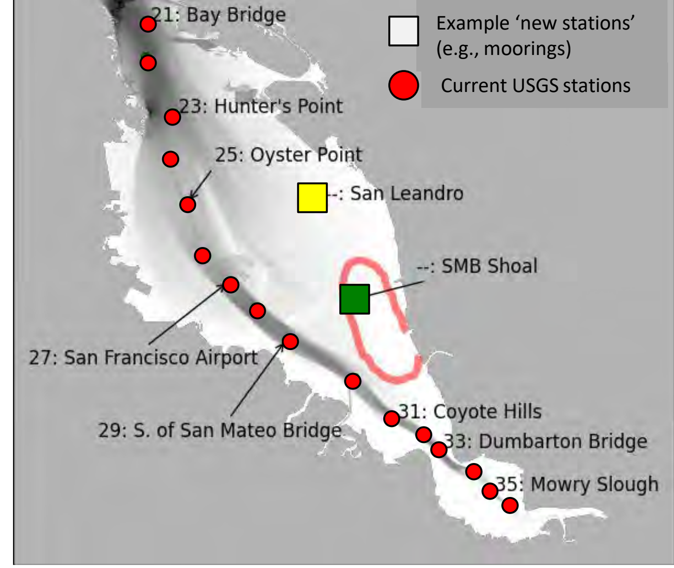
Thompson et al 2008

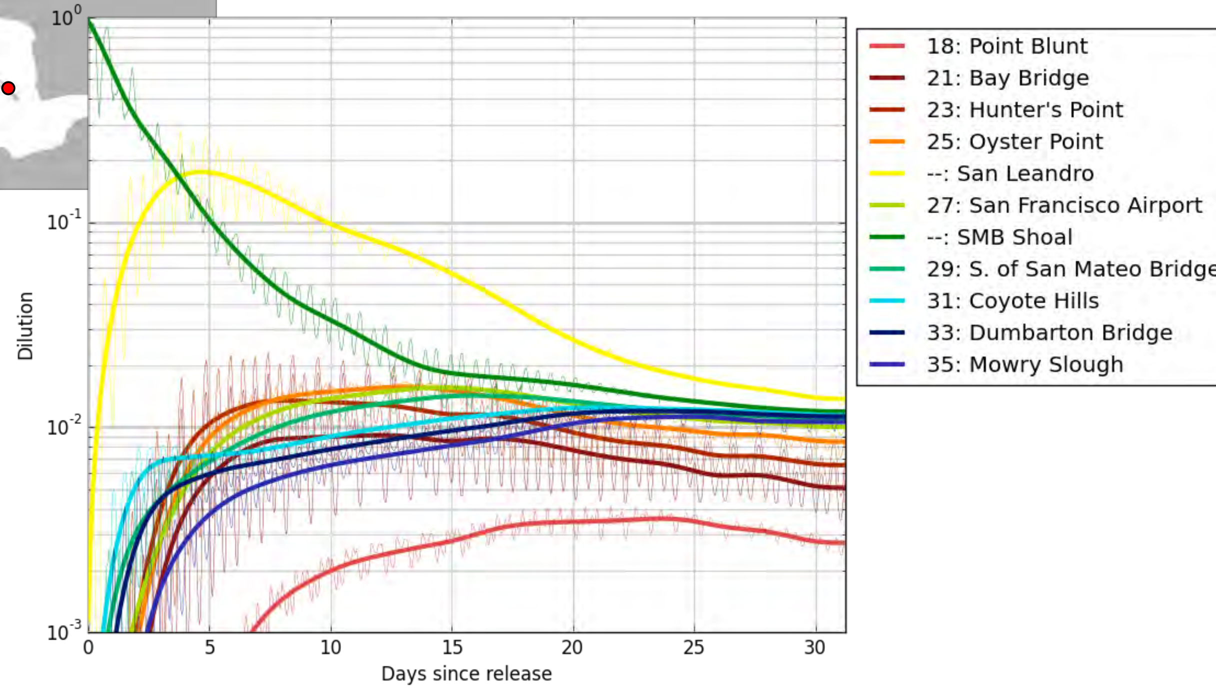
- Past studies have shown high phytoplankton biomass along shoals.

(Thompson et al., Cloern et al. 1985)

Is sampling in the channel sufficient to get things right?


Bloom1
1.000
0.500
0.250
0.125
0.062
0.031
0.016
Dilution
Elapsed time: 0.00 days


Example 'new stations' (e.g., moorings)
Current USGS stations
21: Bay Bridge
23: Hunter's Point
25: Oyster Point
--: San Leandro
--: SMB Shoal
27: San Francisco Airport
29: S. of San Mateo Bridge
31: Coyote Hills
33: Dumbarton Bridge
35: Mowry Slough


Dilution
Days since release
18: Point Blunt
21: Bay Bridge
23: Hunter's Point
25: Oyster Point
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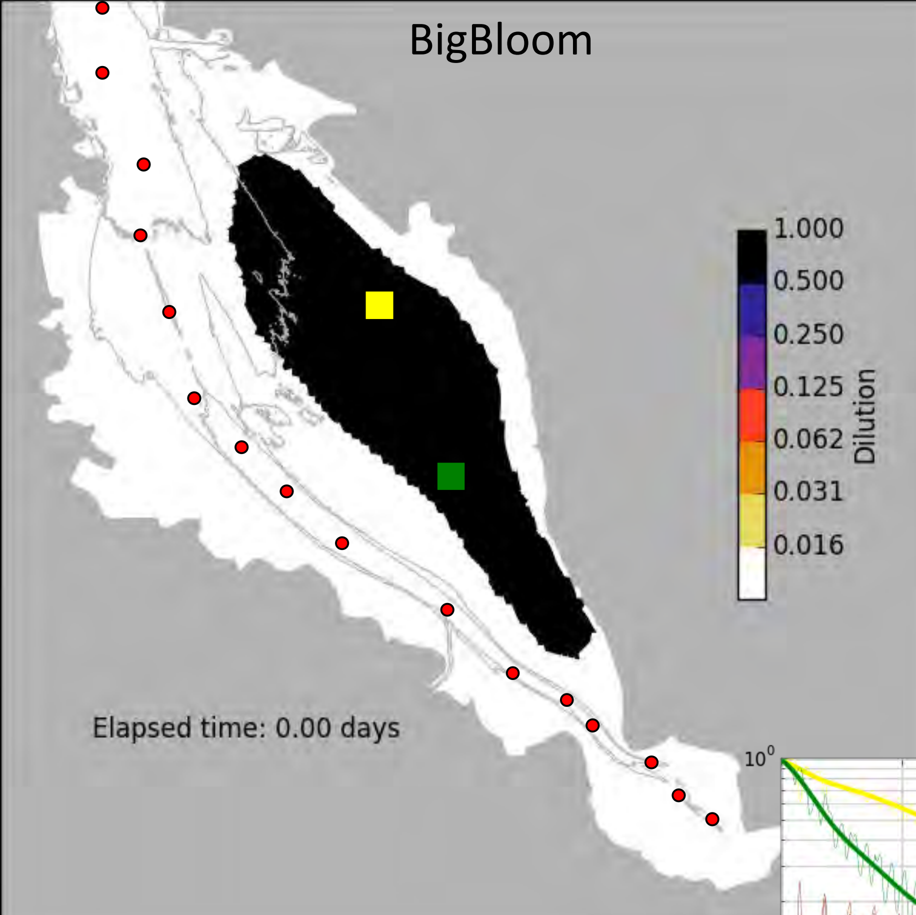
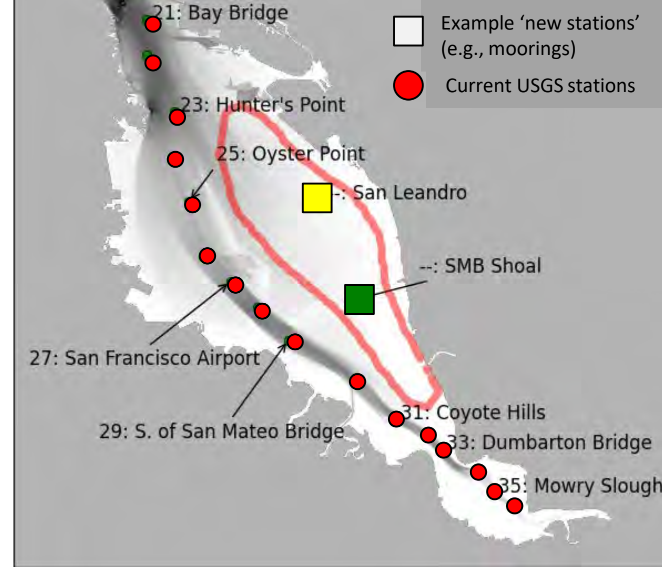

BigBloom
1.000
0.500
0.250
0.125
0.062
0.031
0.016
Dilution
Elapsed time: 0.00 days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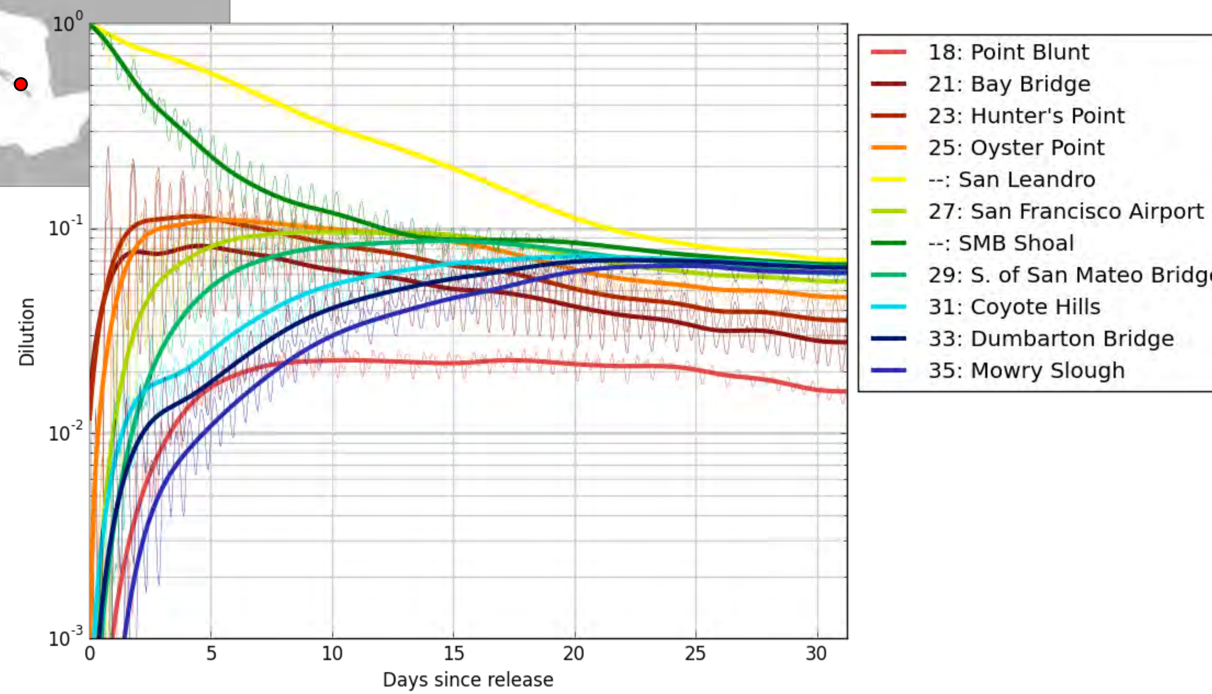
10^0
10^{-1}
10^{-2}
10^{-3}
Dilution
0
5
10
15
20
25
30
Days since release
18: Point Blunt
21: Bay Bridge
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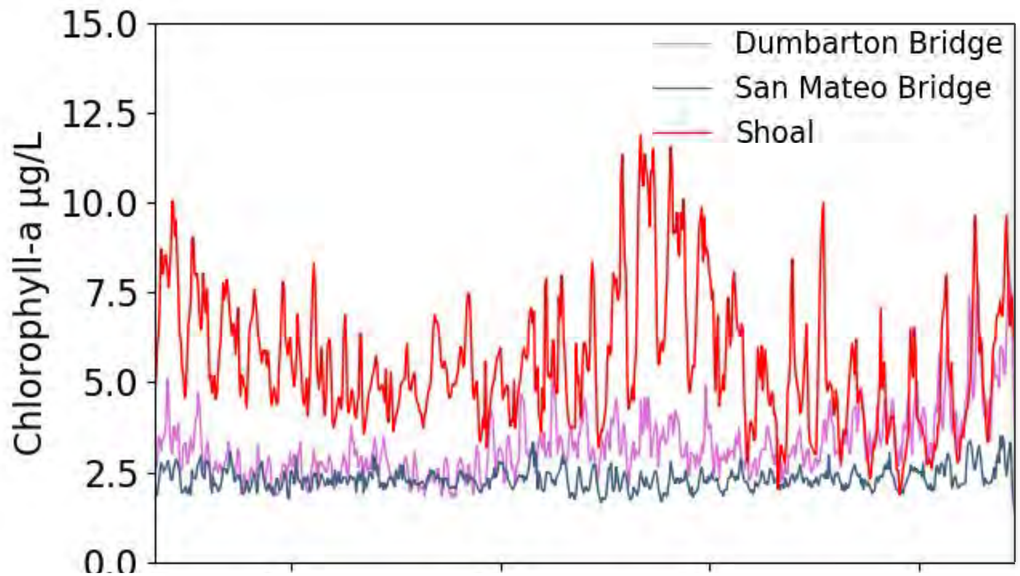
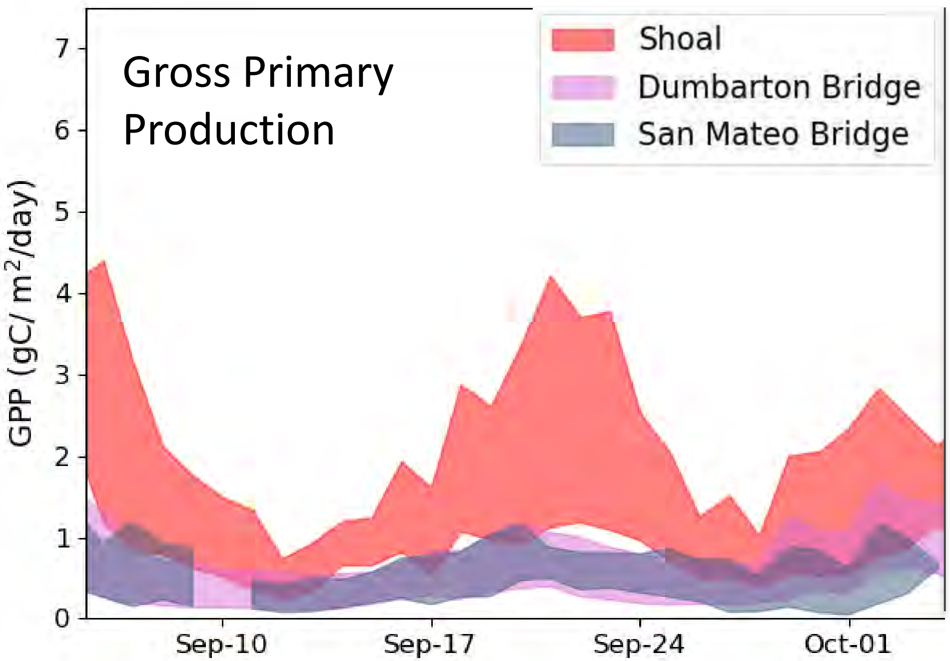
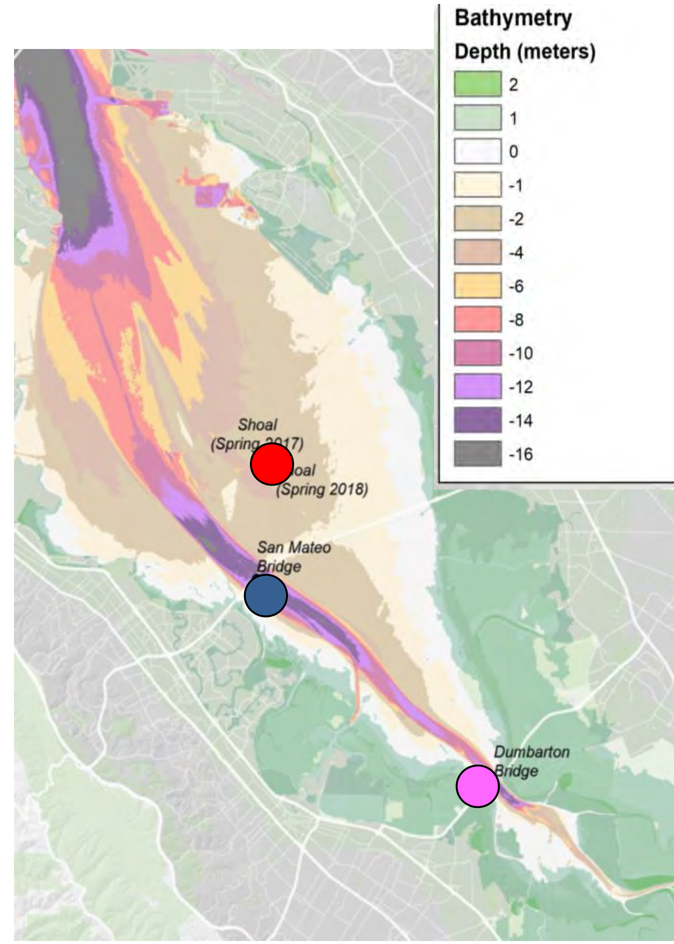
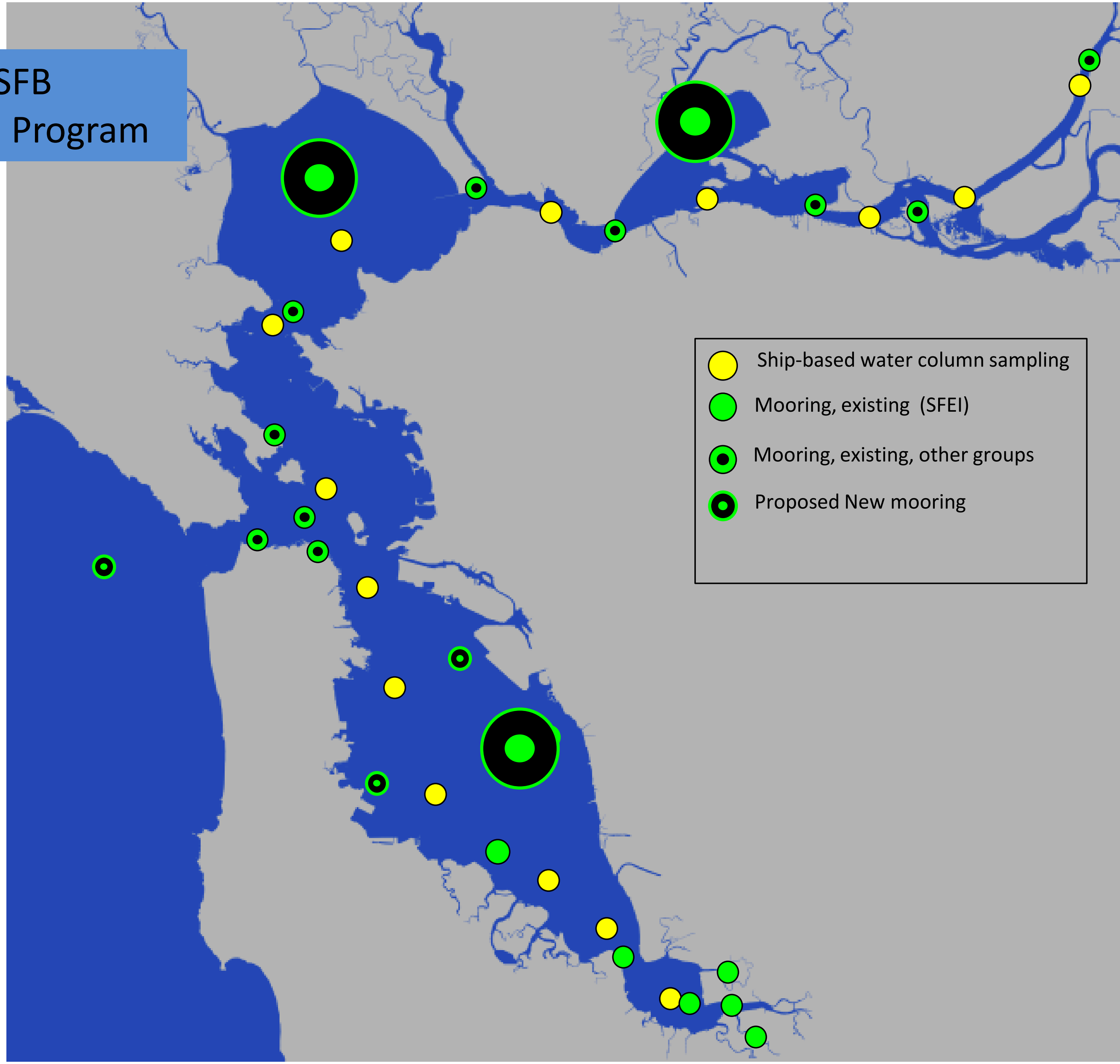

15.0
12.5
10.0
7.5
5.0
2.5
0.0
Chlorophyll-a µg/L
Dumbarton Bridge
San Mateo Bridge
Shoal


Gross Primary Production
Shoal
Dumbarton Bridge
San Mateo Bridge
GPP (gC/ m2/day)
7
6
5
4
3
2
1
0
Sep-10
Sep-17
Sep-24
Oct-01


Bathymetry
Depth (meters)
2
1
0
-1
-2
-4
-6
-8
-10
-12
-14
-16
Shoal
(Spring
oal
(Spring 2018)
San Mateo
Bridge
Dumbarton
Bridge

Next Generation SFB NMS Observation Program



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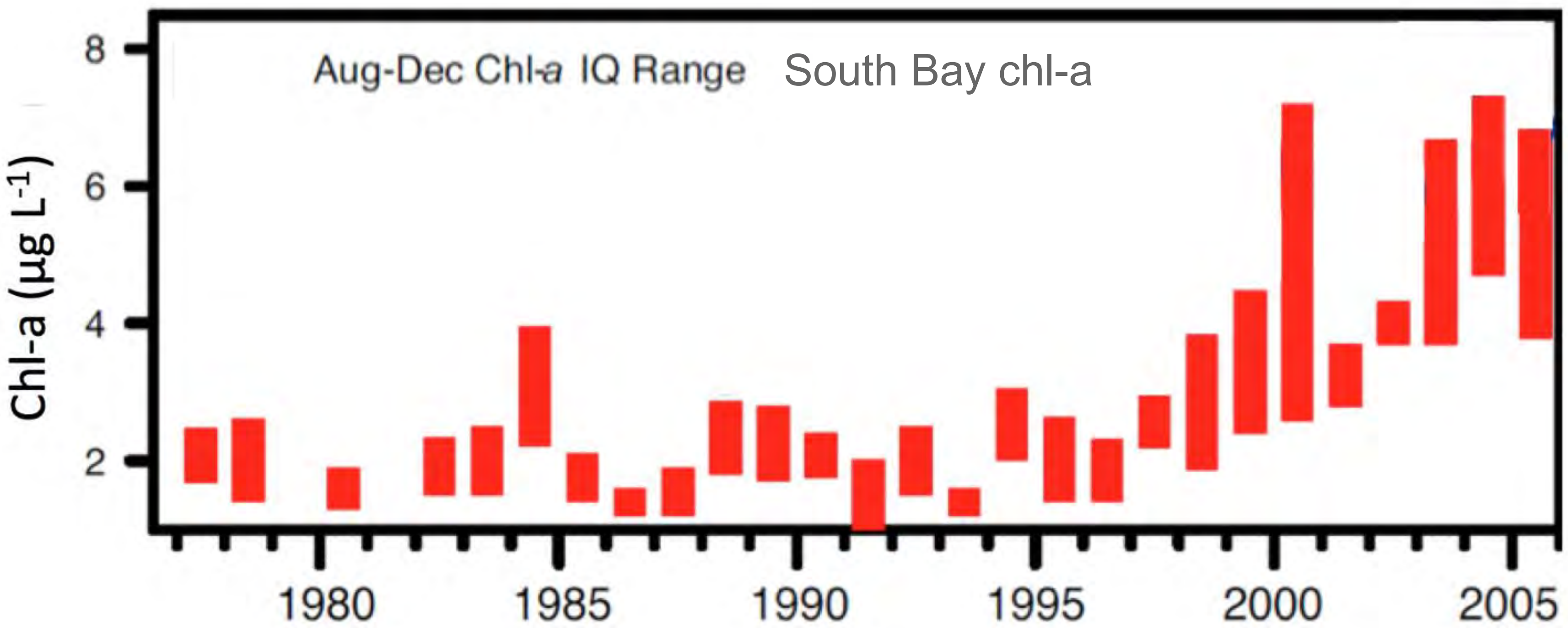
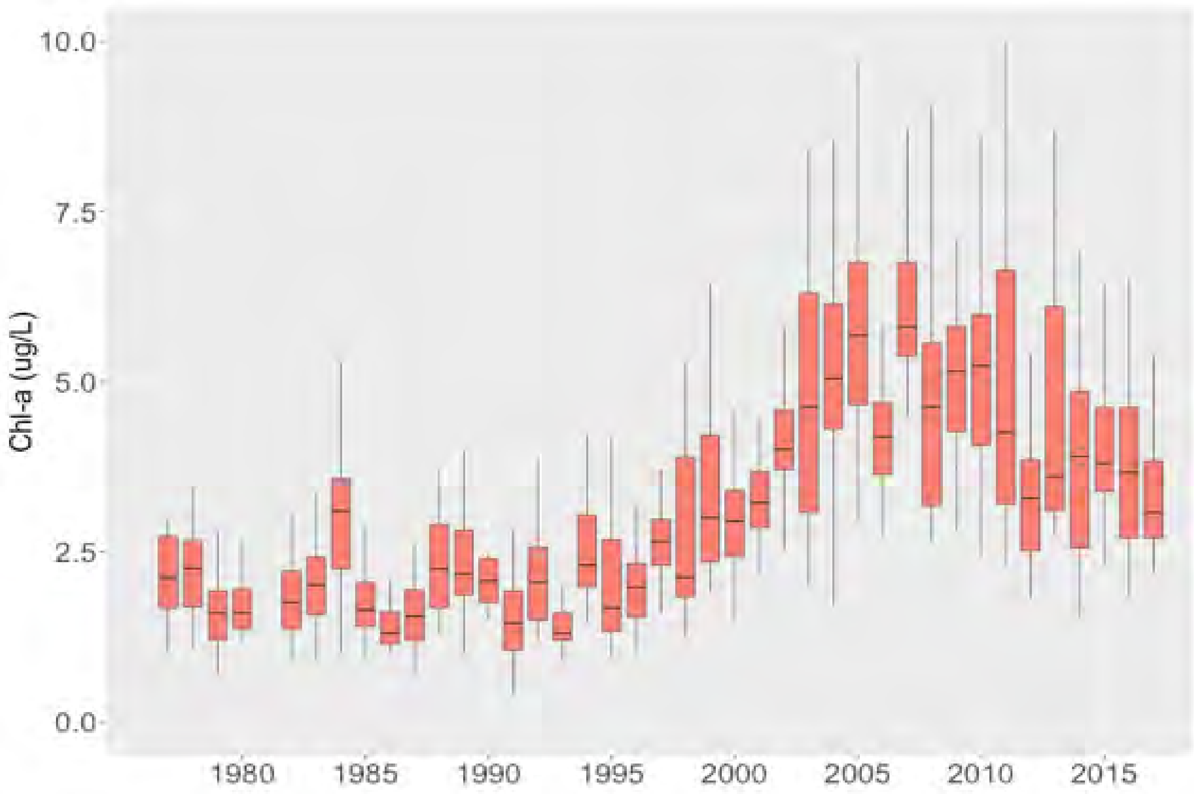
Chl-a-DO Deep subtidal						
Chl-a-DO margins, sloughs						
HABs // Toxins						
Future Scenarios						
Coastal Effects						

Potential biomass ~30-40 μg/L

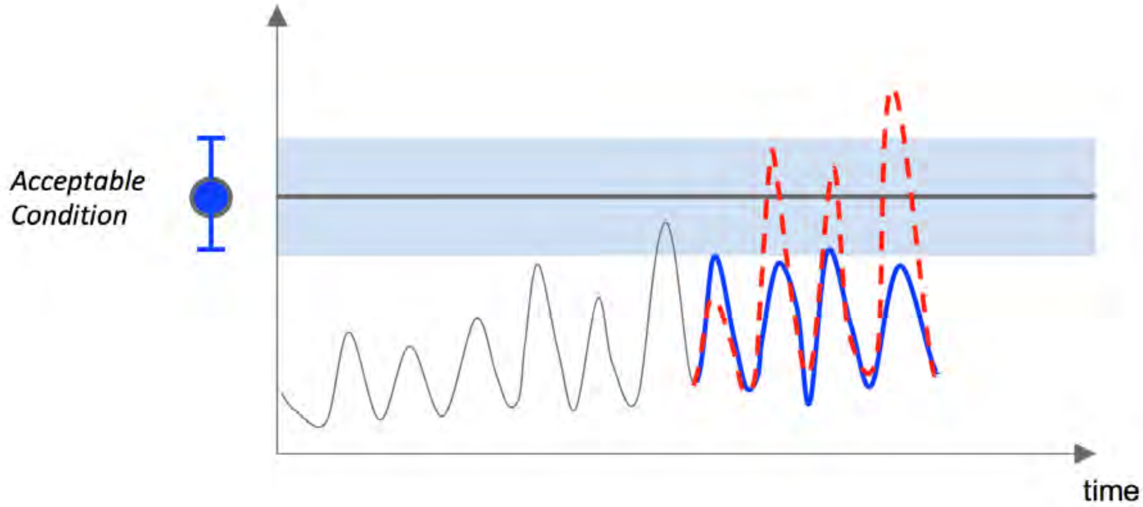


Cloern et al 2007

Potential biomass ~30-40 µg/L



SFEI 2017



1. When did changes cease to be statistically significant? Is the trend now negative (and significant)?

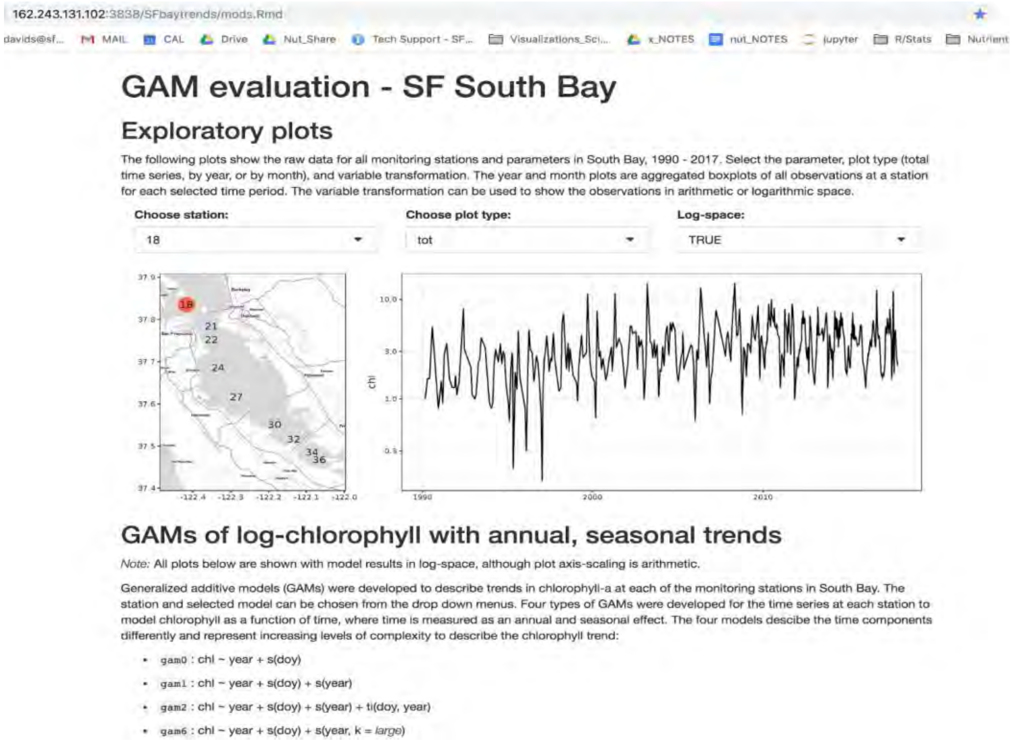
2. How does chl-a vary in other regions of SFB?

3. How do other relevant nutrient-related indicators changing over time? DO, gross primary productivity, nutrients, suspended sediments?

4. What trend magnitudes can realistically be detected? How long will it take to detect a sustained change?

5. What physical or biological factors could be causing or contributing to observed changes in water quality indicators?

https://sccwrp.shinyapps.io/sfbaytrends/



GAM evaluation - SF South Bay

Exploratory plots

The following plots show the raw data for all monitoring stations and parameters in South Bay, 1990 - 2017. Select the parameter, plot type (total time series, by year, or by month), and variable transformation. The year and month plots are aggregated boxplots of all observations at a station for each selected time period. The variable transformation can be used to show the observations in arithmetic or logarithmic space.

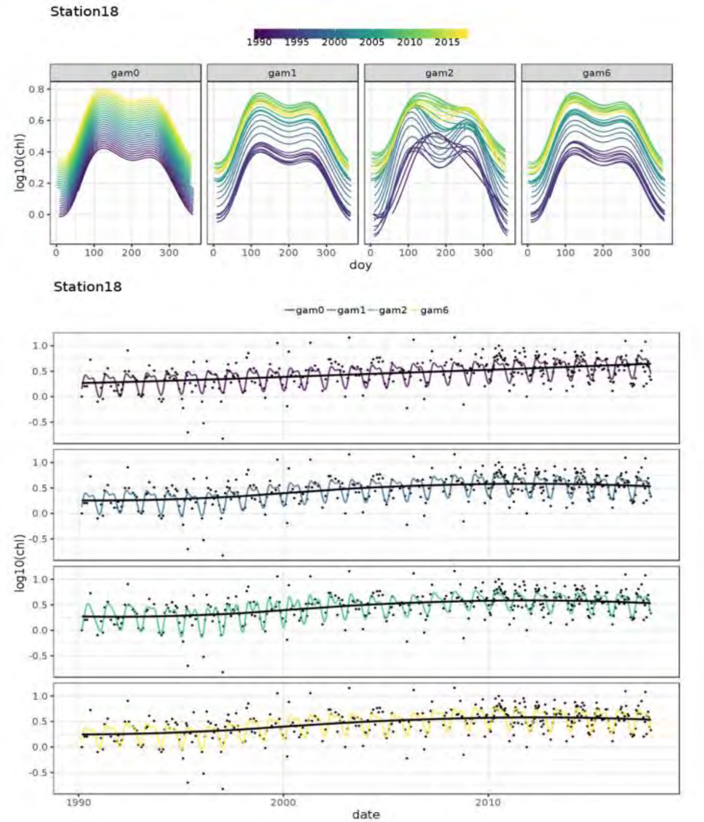
Choose station: 18
Choose plot type: tot
Log-space: TRUE

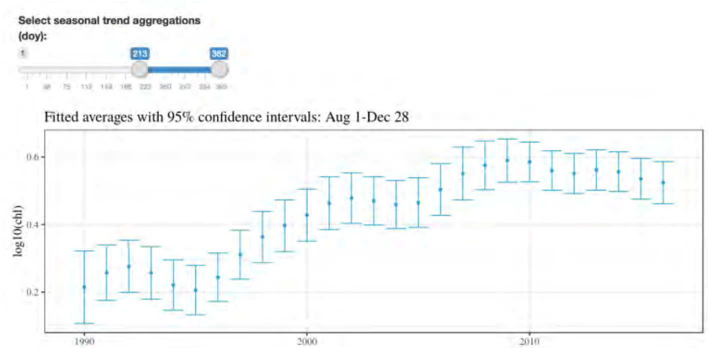
GAMs of log-chlorophyll with annual, seasonal trends

Note: All plots below are shown with model results in log-space, although plot axis-scaling is arithmetic.

Generalized additive models (GAMs) were developed to describe trends in chlorophyll-a at each of the monitoring stations in South Bay. The station and selected model can be chosen from the drop down menus. Four types of GAMs were developed for the time series at each station to model chlorophyll as a function of time, where time is measured as an annual and seasonal effect. The four models descibe the time components differently and represent increasing levels of complexity to describe the chlorophyll trend:

- `gam0` : chl ~ year + s(doy)
- `gam1` : chl ~ year + s(doy) + s(year)
- `gam2` : chl ~ year + s(doy) + s(year) + ti(doy, year)
- `gam6` : chl ~ year + s(doy) + s(year, k = *large*)

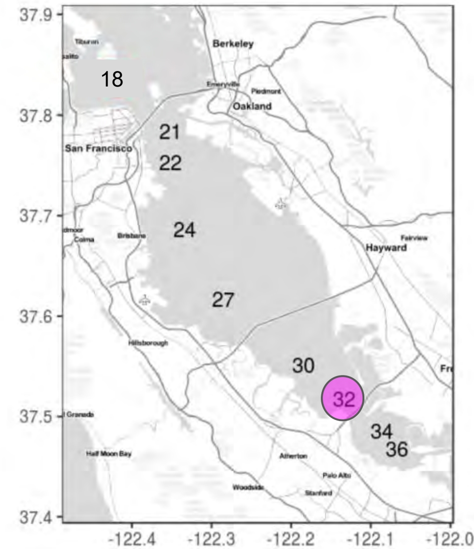




Evaluating the Utility of General Additive Models for Tracking San Francisco Bay Water Quality Over Time

Ian Wren, Marcus Beck, Perry de Valpine, Rebecca Murphy, and David Senn

December 2018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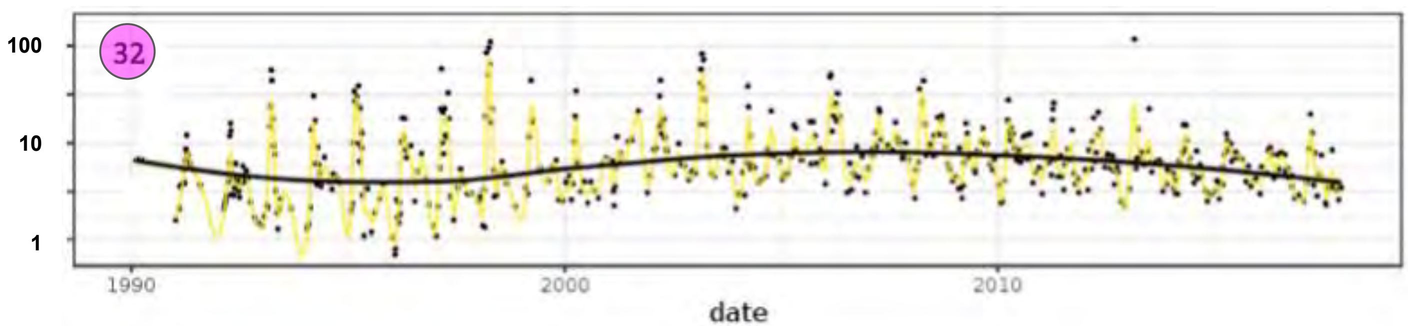
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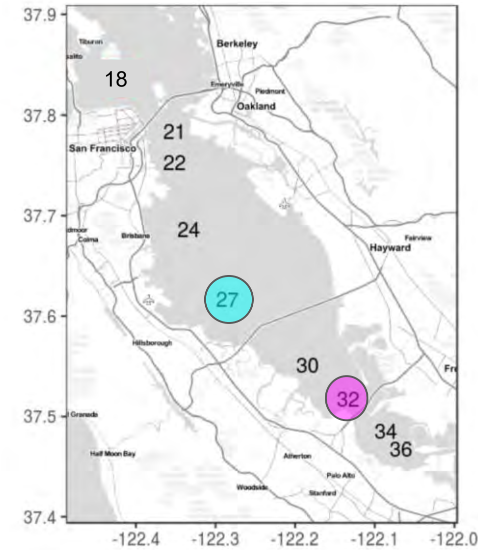

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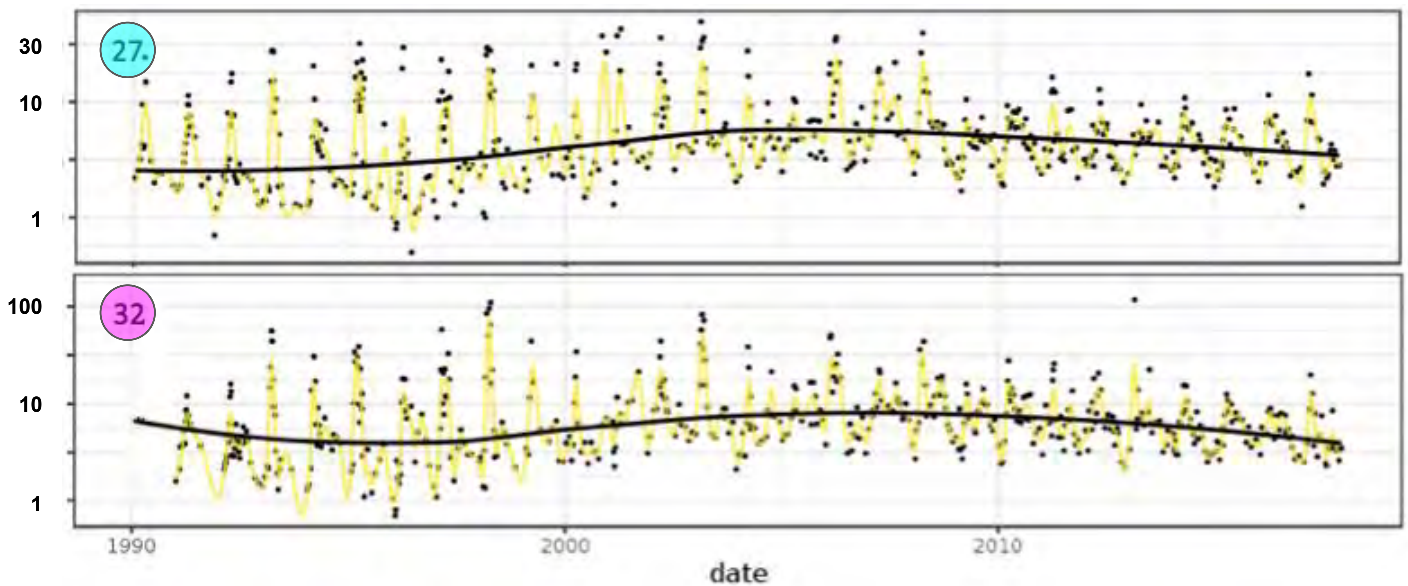

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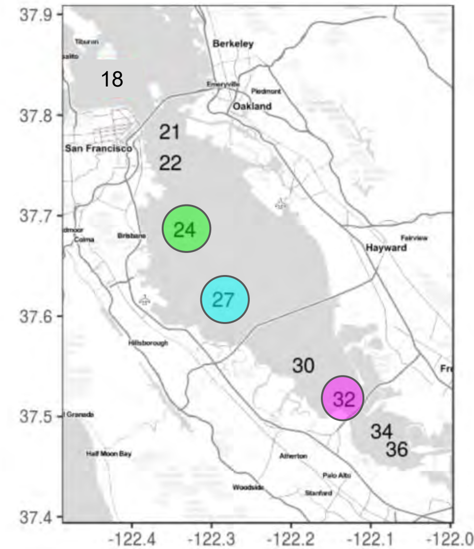
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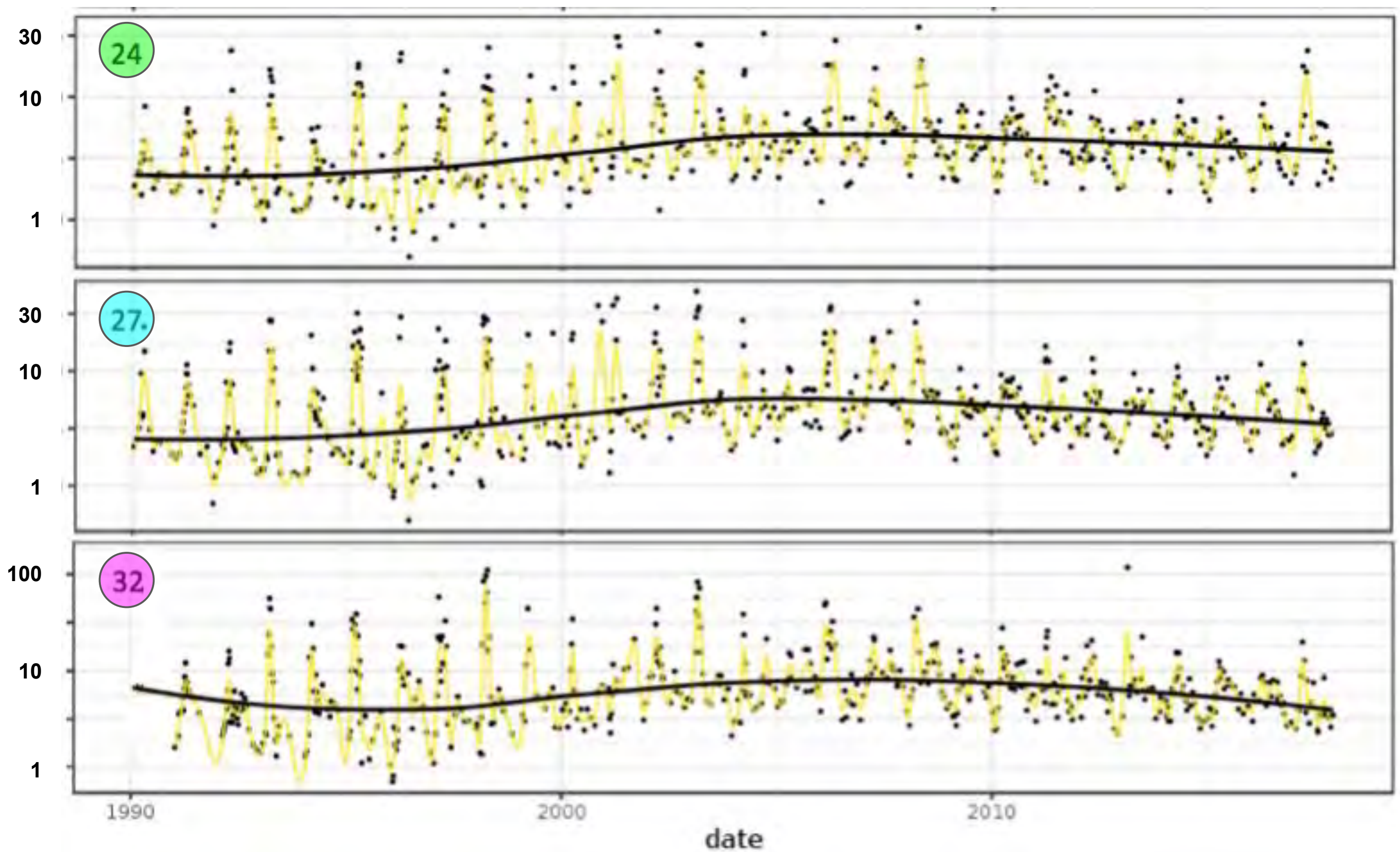
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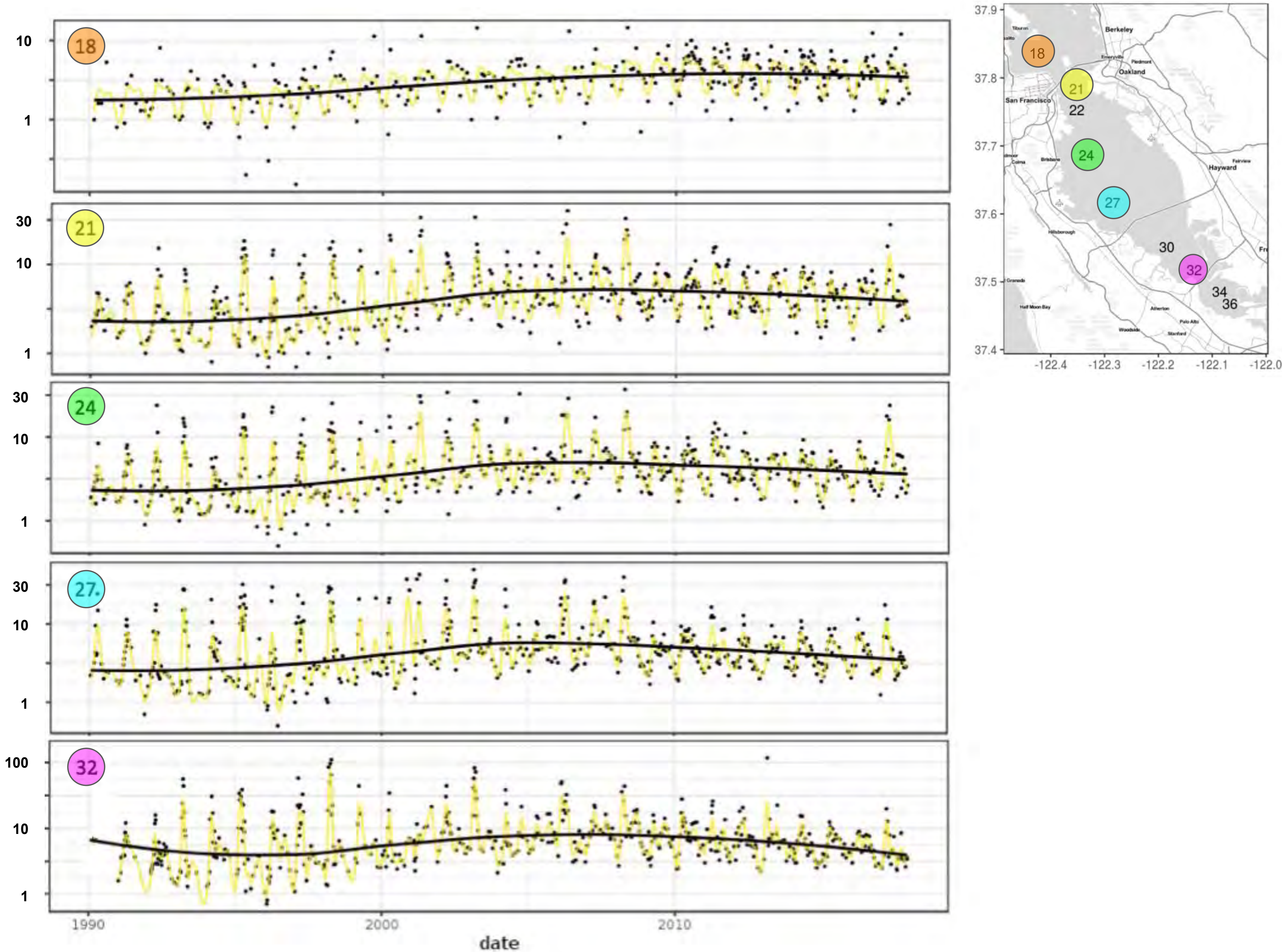

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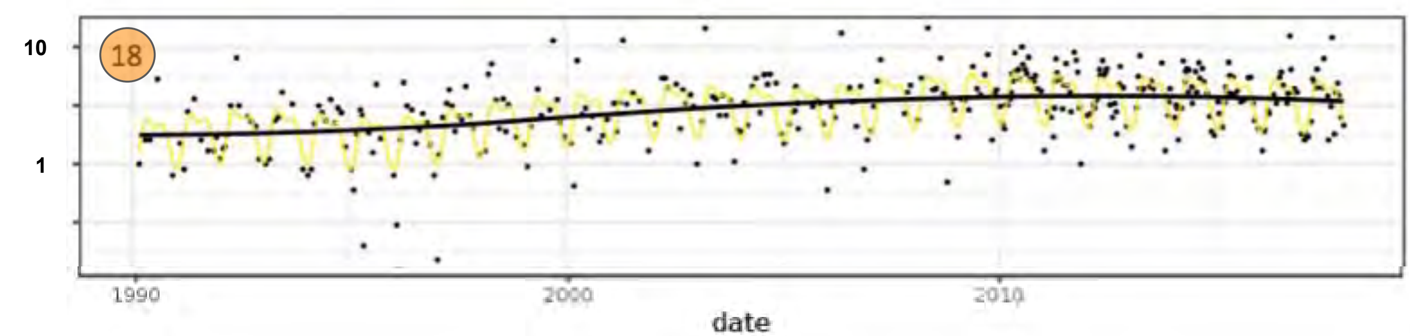
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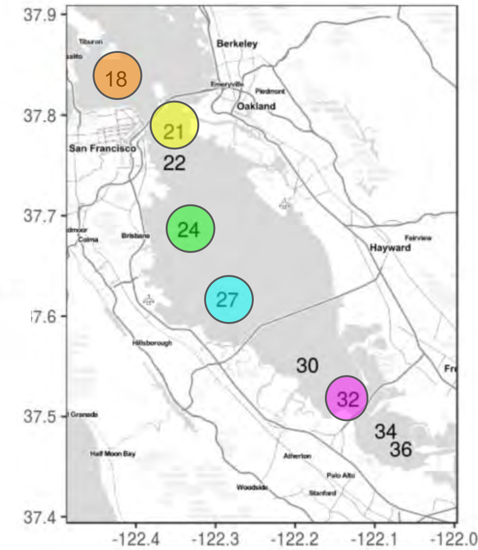
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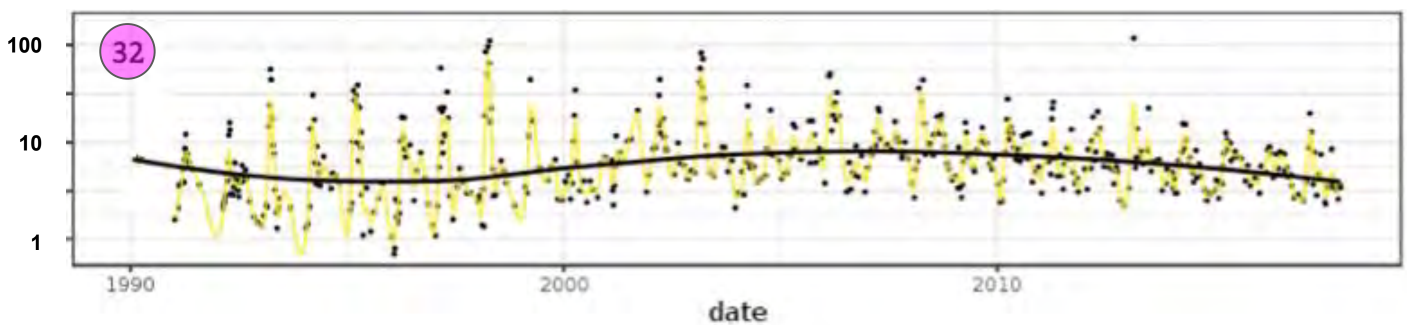
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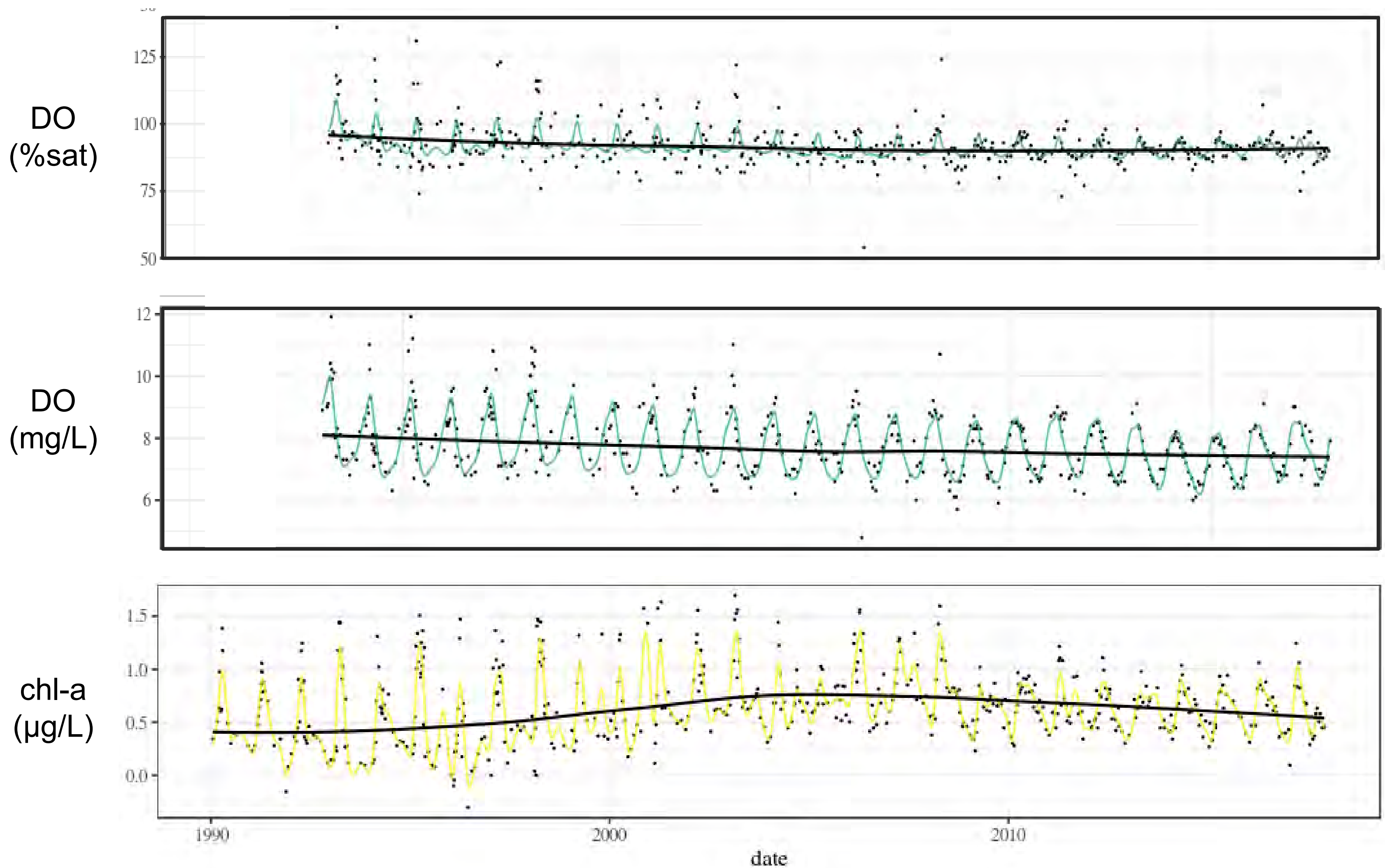
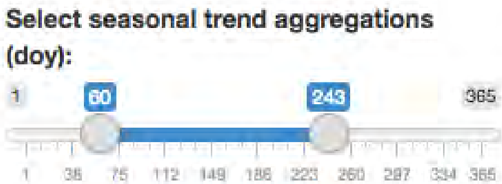
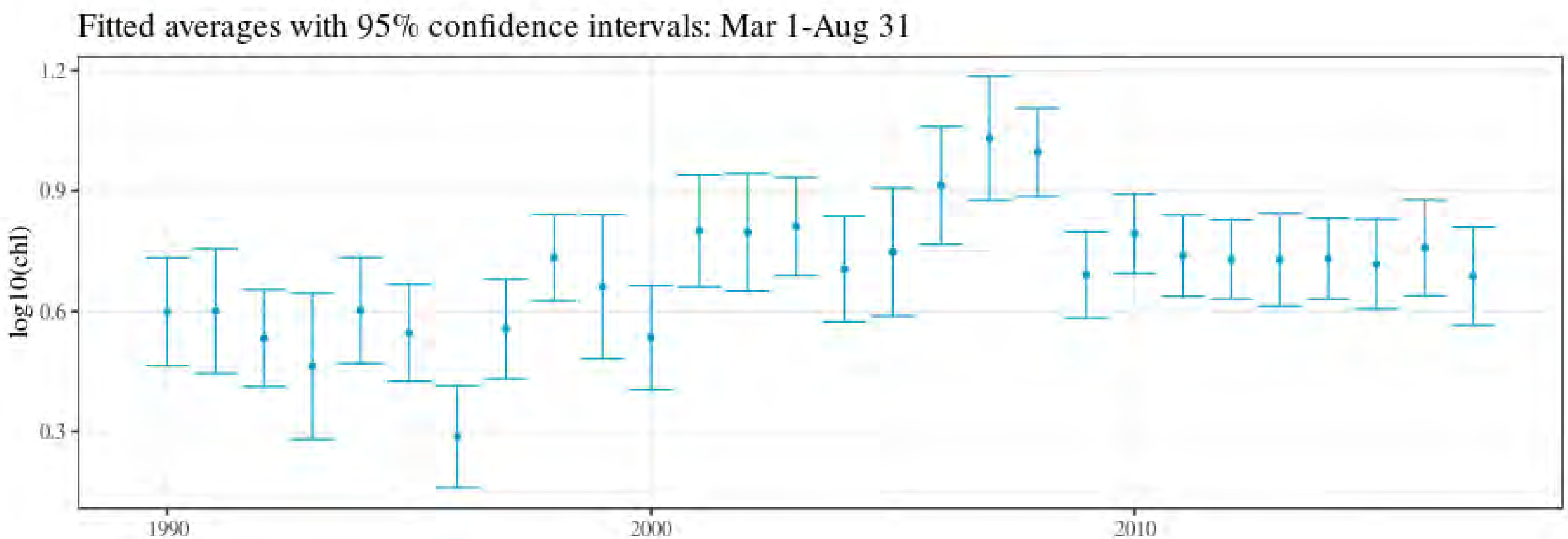
San Mateo Bridge (s27): Other parameters (GPP not shown)



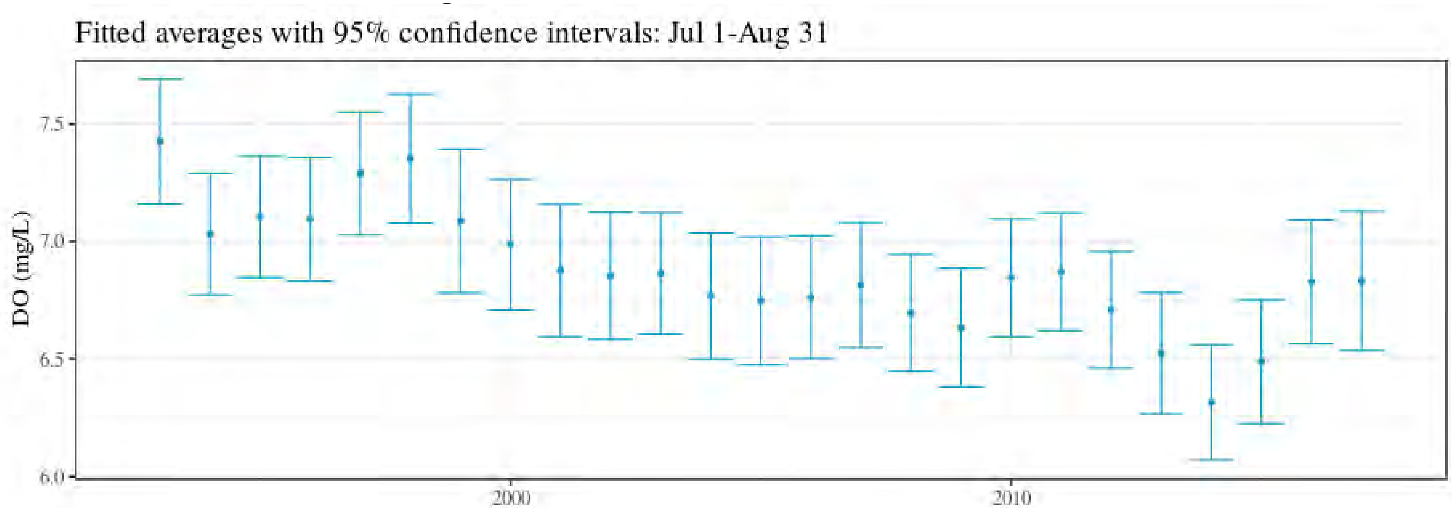
San Mateo Bridge (s27)



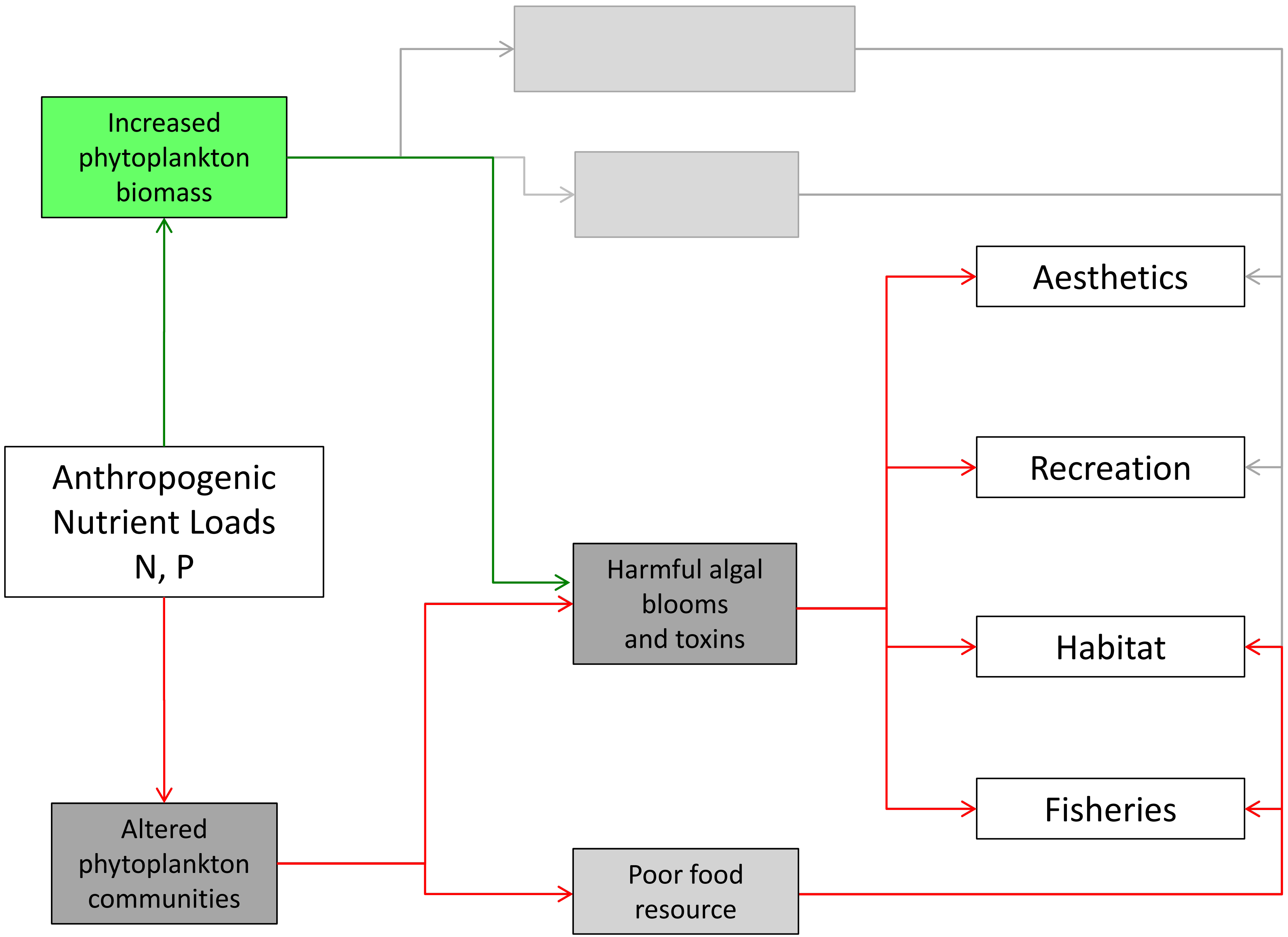
Spring/Summer chl-a



Summer bottom DO (mg/L)



Potential Adverse Impacts of Nutrients in SFB

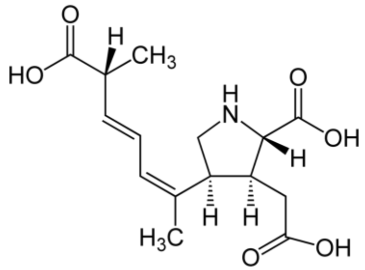


SFEI 2014, Sutula et al. 2017

	Condition • Monitoring • Assessment Framework		**Link to Nutrients** • Mechanisms • Dose : Response		**Nutrient Dynamics** • Inputs, transformations • Necessary Action	
	Permit 1	Permit 2	Permit 1	Permit 2	Permit 1	Permit 2
Chl-a-DO Deep subtidal						
Chl-a-DO margins, sloughs						
HABs // Toxins						
Future Scenarios						
Coastal Effects						

Domoic Acid

(Amnesic Shellfish Poisoning)

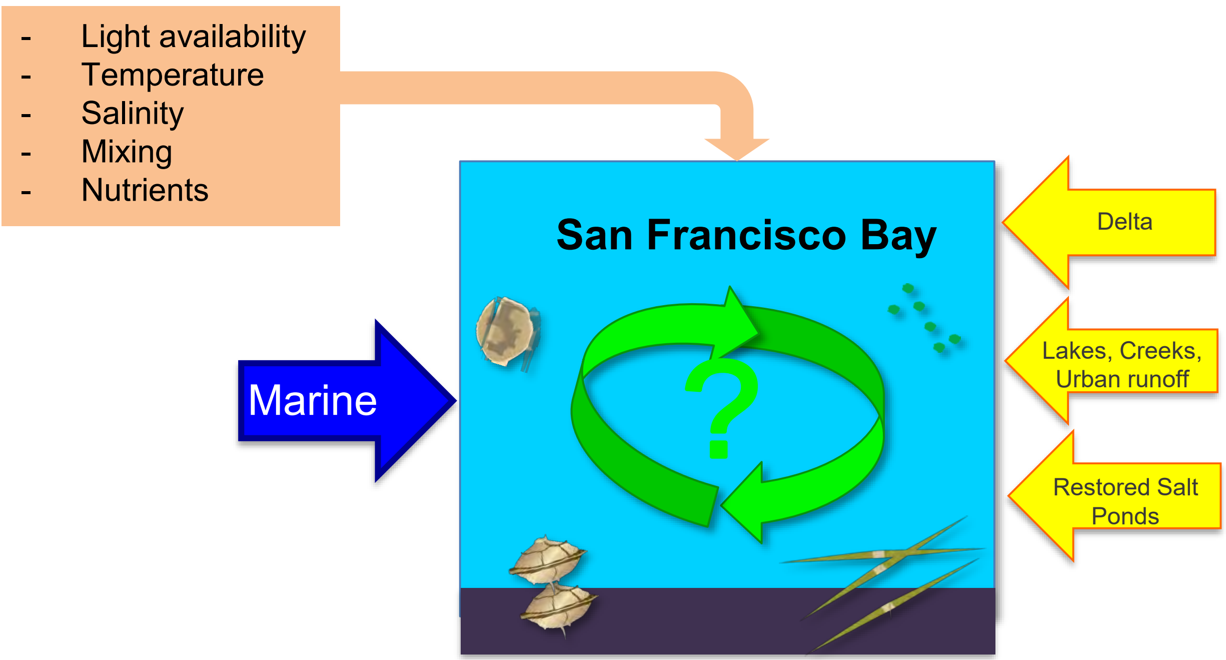


Pseudo-nitzchia

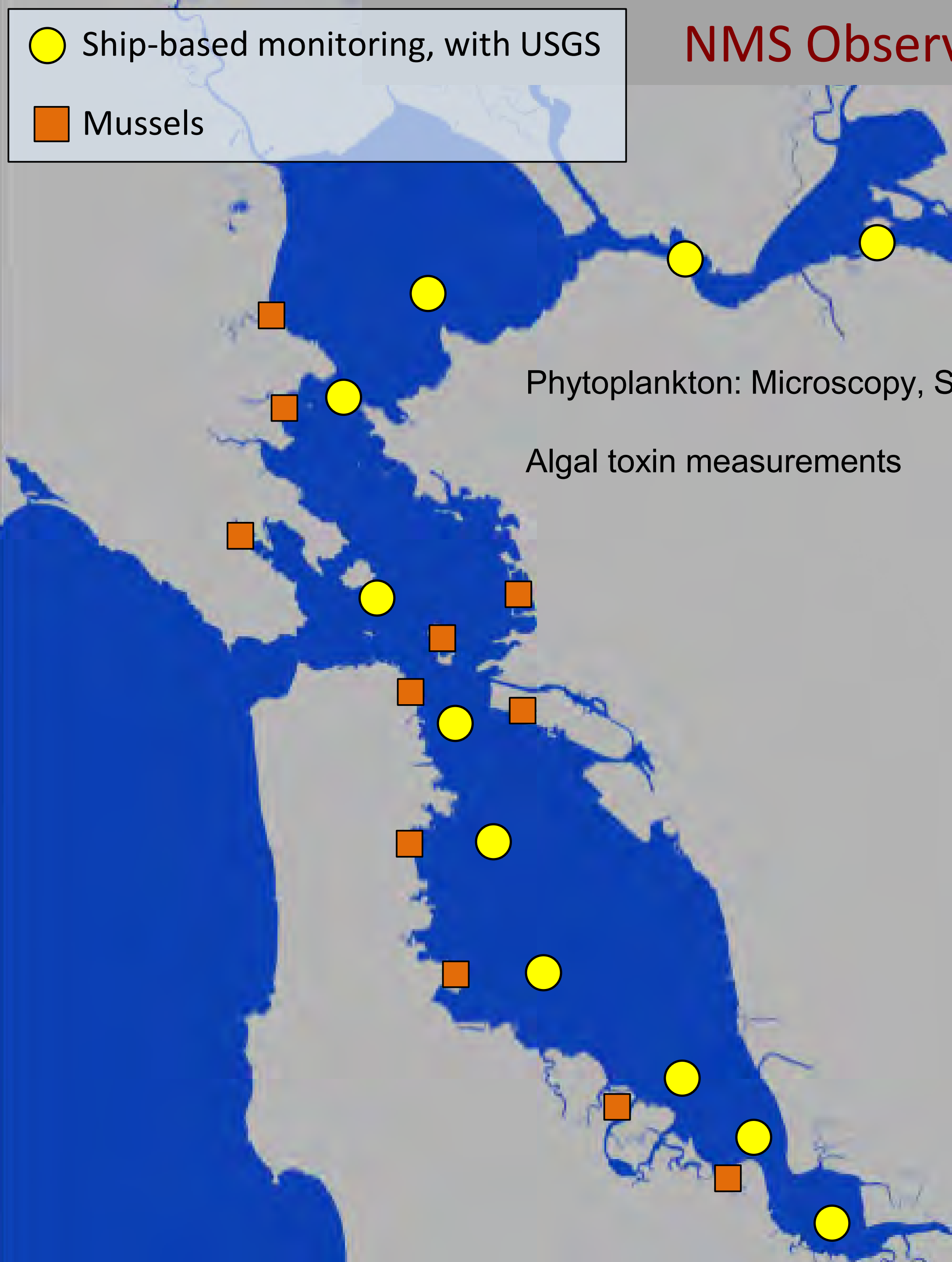
Photo: Eric Risberg, Associated Press

HABs and PhycoToxins in SFB: Science/Management Questions

1. Water Quality / Habitat Quality: Substantial HABs // phycotoxin threat ?
   a. Sensitive population(s)?   *Biota? Humans?*
   b. Current vs. *Future* Conditions? **Δ** Physical forcings → **Δ** HA+phycotoxin severity?
2. What factors regulate HA abundance and toxicity in SFB? transport, *in situ* production
3. Role of SFB nutrients: N,P → frequency or severity of HA events?
4. Protective nutrient loads, with respect to HAs and phycotoxins?



NMS Observation and Forecasting Program



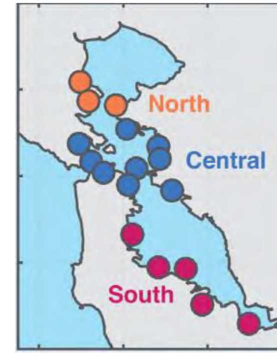
Phytoplankton: Microscopy, Sequencing (qPCR)

Algal toxin measurements

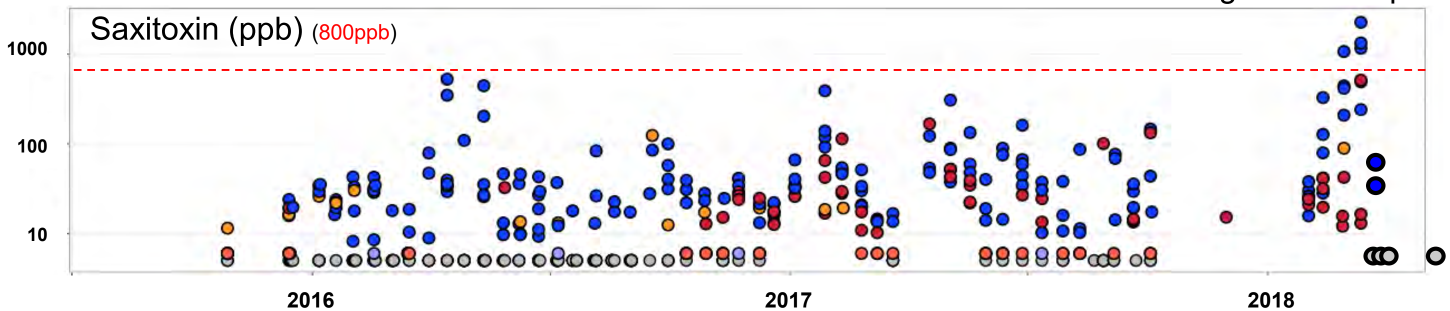
- Naturally occurring mussels
- Floating docks, readily-accessible
- Bi-weekly sampling (Sep 2015-present)
- Domoic Acid, Saxitoxin, Microcystin

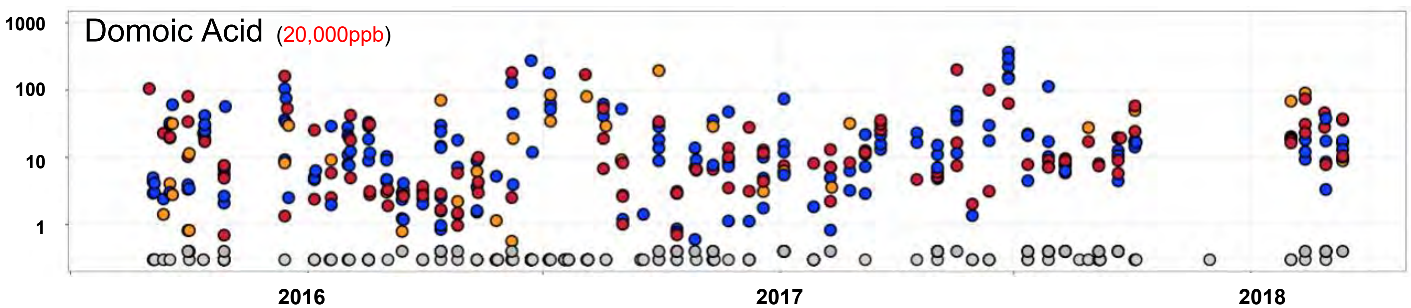
Mussel Toxin concentrations, 9/2015-3/2018

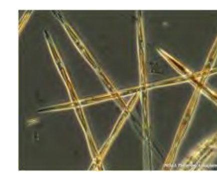
Lighter shade: [tox] < LOQ
Grey: [tox] < LOD

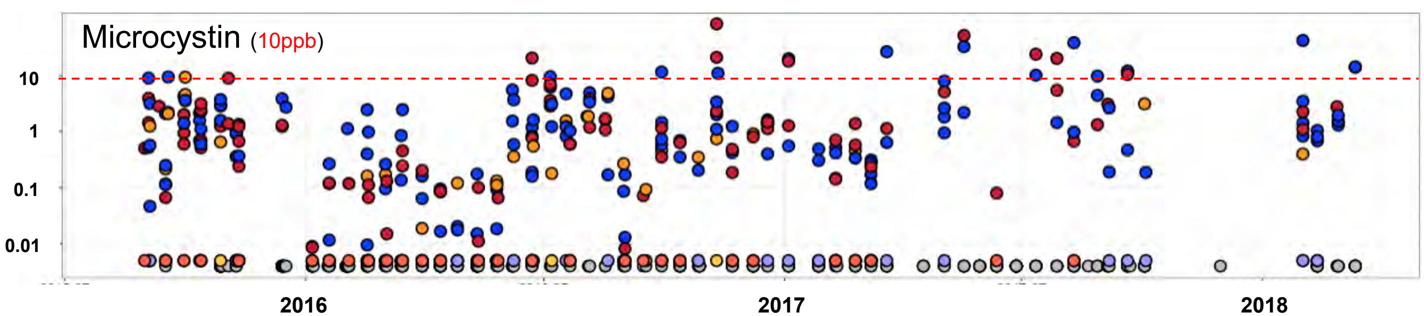


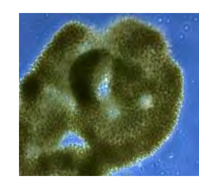
Symbol colors correspond
SFB region's in map





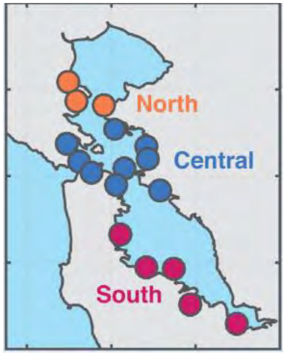






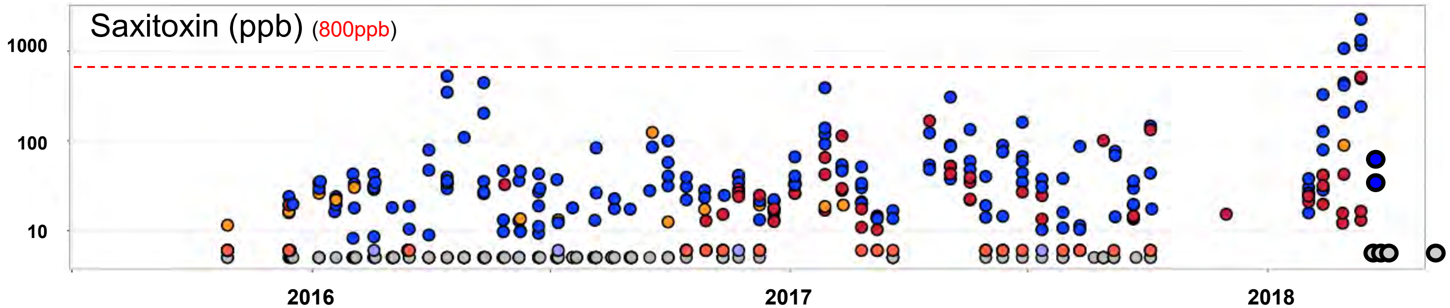
- Multiple phycotoxins regularly detected in biota
  - *Domoic Acid* — Low
  - *Microcystin* — Moderate/Elevated
  - *Saxitoxin* — Low/Moderate/Elevated
  - *Okadaic Acid* (Peacock et al 2018) — Moderate/Elevated

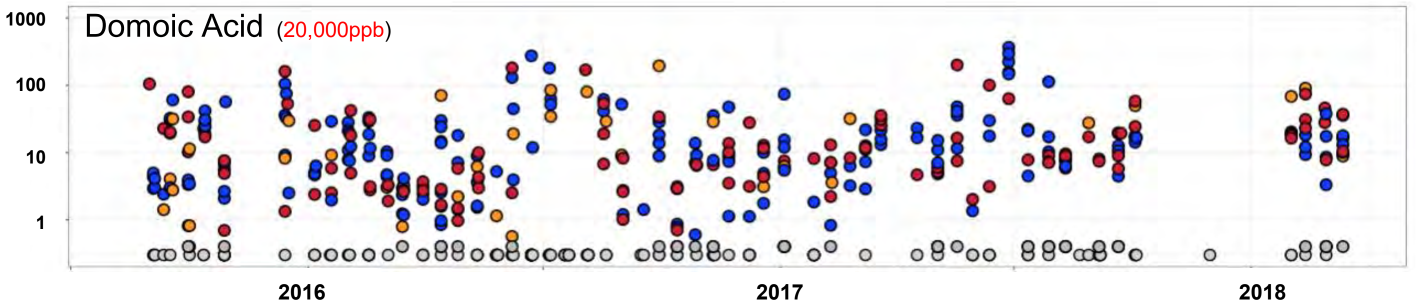
Lighter shade: [tox] < LOQ
Grey: [tox] < LOD

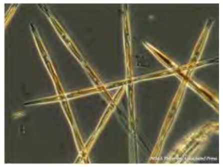


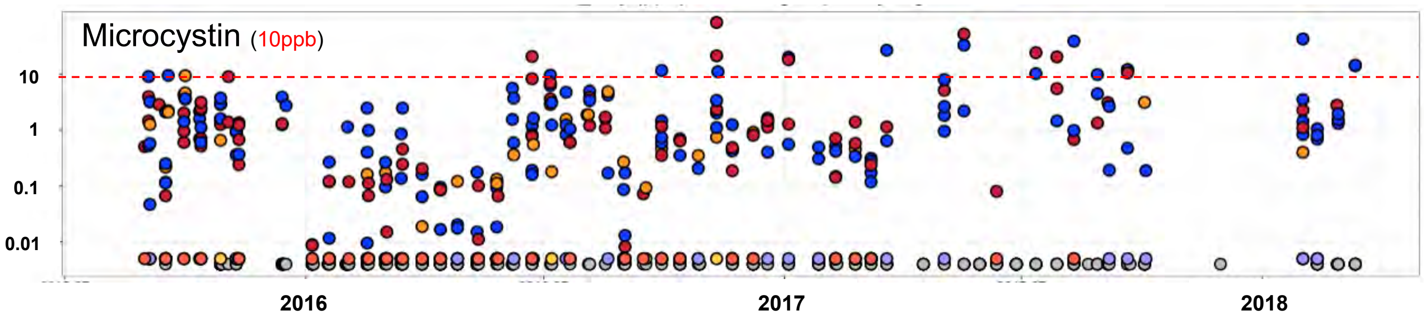
- Regularly detect phycotoxins in water (particulate, dissolved)

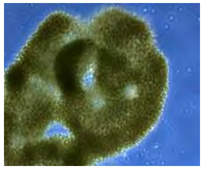
- Regularly detect multiple HA taxa



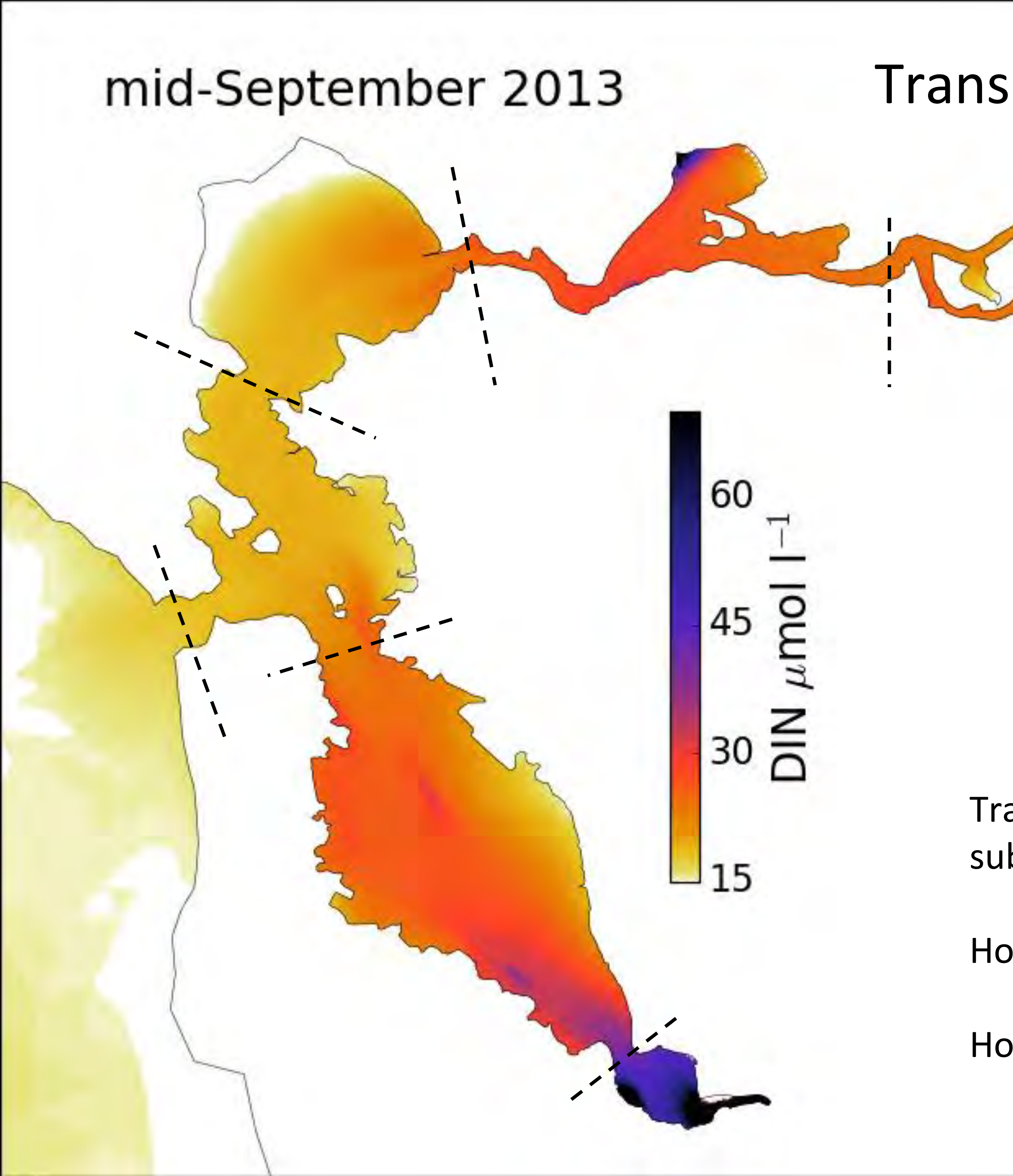








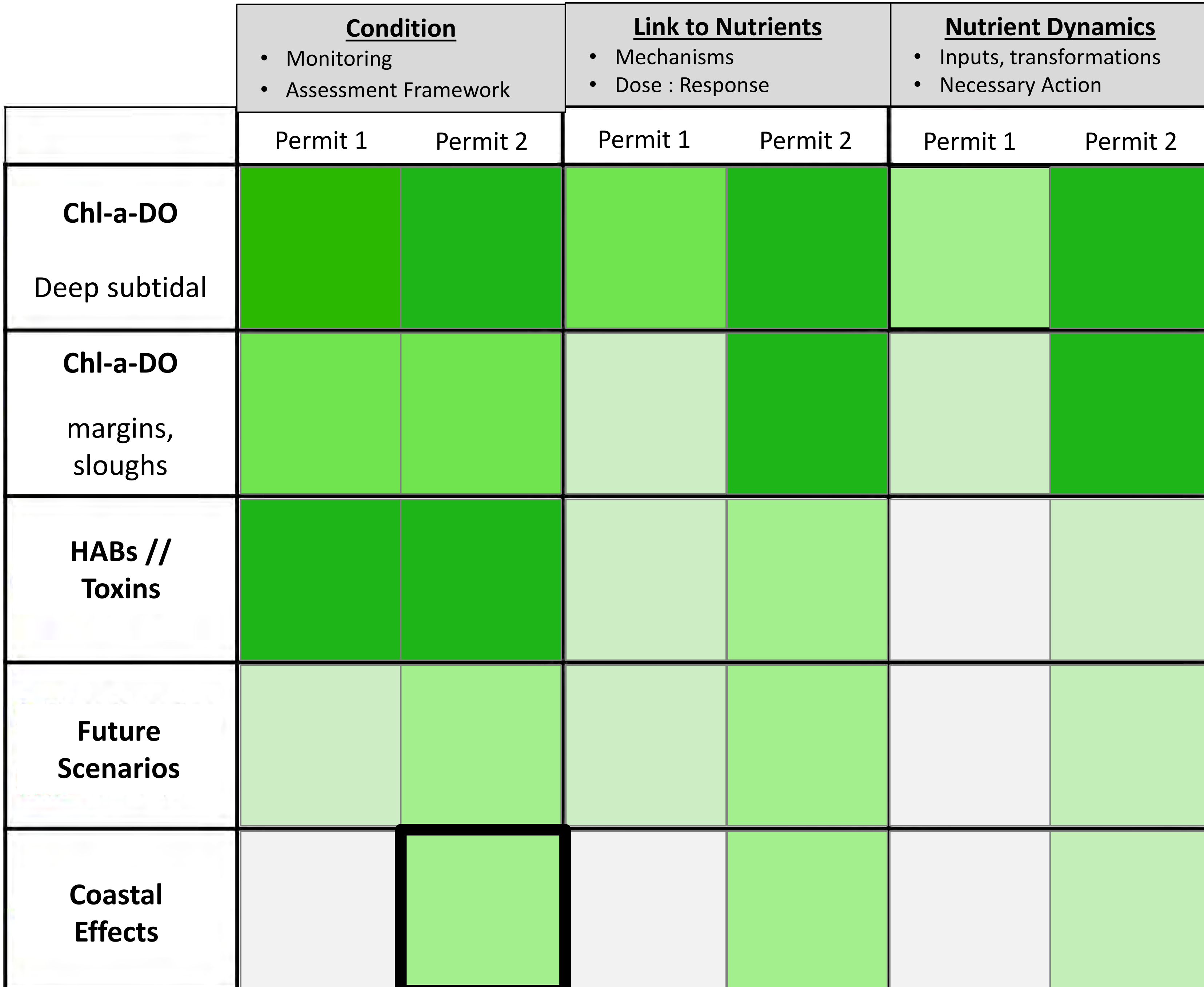
Transport and Fate of DIN



Transport and fate across subembayments

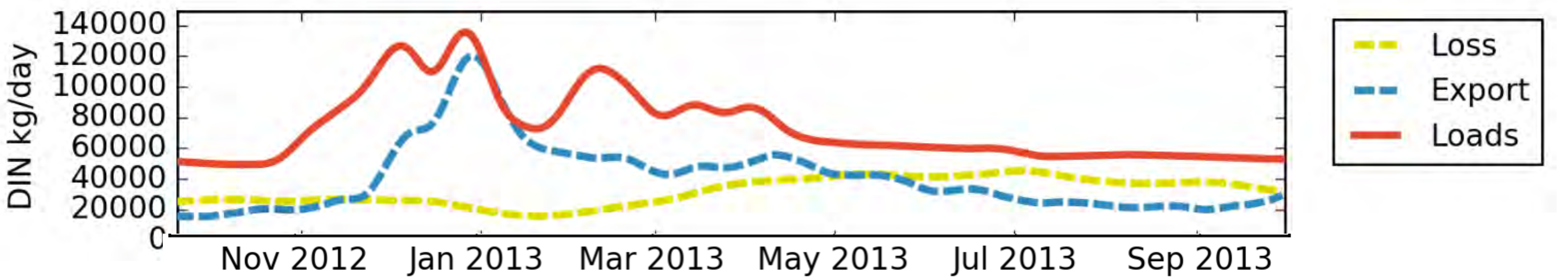
How local are nutrient pathways?

How much exported to coast?



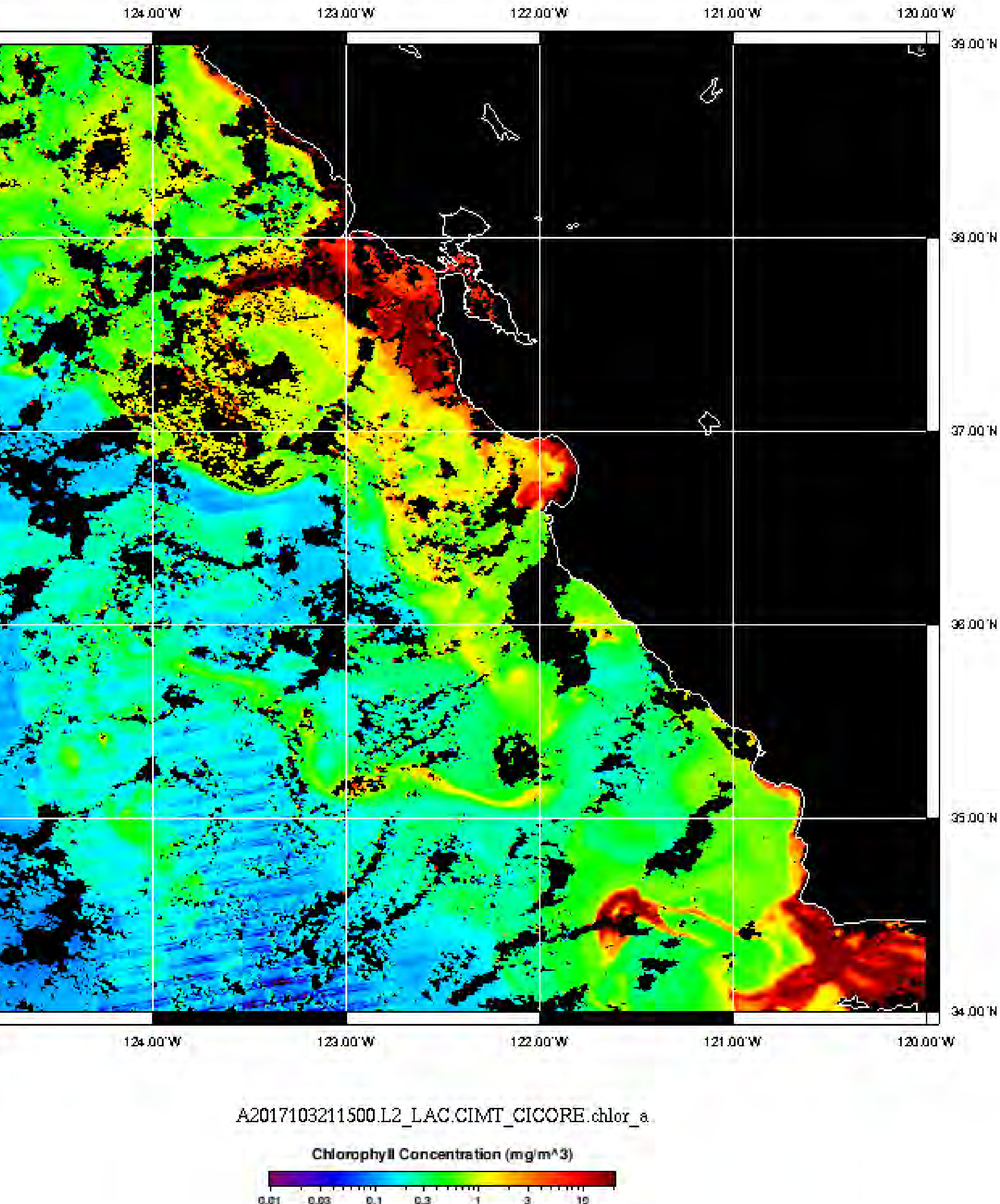
Condition
Monitoring
Assessment Framework
Link to Nutrients
Mechanisms
Dose : Response
Nutrient Dynamics
Inputs, transformations
Necessary Action
Permit 1
Permit 2
Permit 1
Permit 2
Permit 1
Permit 2
Chl-a-DO
Deep subtidal
Chl-a-DO
margins, sloughs
HABs // Toxins
Future Scenarios
Coastal Effects

Full Bay Budget



Export to the Coastal Ocean:

- 35 – 85% of loads, average 55%
- Significant nutrient source to coastal ocean


124.00°W
123.00°W
122.00°W
121.00°W
120.00°W
39.00°N
38.00°N
37.00°N
36.00°N
35.00°N
34.00°N
A2017103211500.L2_LAC.CIMT_CICORE.chlor_a
Chlorophyll Concentration (mg/m^3)
0.01
0.03
0.1
0.3
1
3
10

Overview…Major NMS progress over first 4 years of Permit #1

- Enhanced Monitoring//Observation network
  - New analytes (e.g., toxins)
  - New approaches: high-frequency data, moorings; mussels

- Major steps forward on Numerical Modeling
  - Physics/transport
  - Nutrient Loads and Transformations
  - Source tracking
  - Phytoplankton blooms

- Shift in perspective / understanding of condition
  - Everyday conditions for classic metrics or ‘responses’ parameters appear to be ok
  - Other (newer) issues require continued attention
    - Lower South Bay algal production and DO
    - Ambient conditions related to Harmful Algae and algal toxins
    - Exports to Coast
    - ‘Not Everyday conditions’...Future scenarios, Events

	Condition • Monitoring • Assessment Framework		**Link to Nutrients** • Mechanisms • Dose : Response		**Nutrient Dynamics** • Inputs, transformations • Necessary Action	
	Permit 1	Permit 2	Permit 1	Permit 2	Permit 1	Permit 2
Chl-a-DO Deep subtidal						
Chl-a-DO margins, sloughs						
HABs // Toxins						
Future Scenarios						
Coastal Effects						

Major Focus Areas or Challenges Ahead – Science Program 2019-2024

1. Building and Maintaining essential 'Tools'
   - Monitoring: What/Where/When → wise and timely decisions
   - Modeling: Predicting, Forecasting, Uncertainty

2. Identifying safe or protective loads and concentrations

3. Assessing risk of "events" – present, and future

4. Testing mechanistic linkages to nutrients:
   - HABs and toxins
   - Low DO in sloughs

5. Effects of Bay nutrients on coastal water quality ?

sfbaynutrients.sfei.org

Status/Progress Tracking: San Francisco Bay Nutrient Management Strategy

Background | Management Decisions & Questions | Goals & Work Elements | Work Progress | Project Tracking | NMS Meeting Materials | NMS Implementation | Bibliography

Reports and Work Products

Nutrient Strategy work products are available below, organized by Work Element. This list is regularly updated as new reports become available in draft and final versions.

Annual Reports

2015 NMS FY2015 Annual Report

2016 NMS FY2016 AnnualReport

2017_NMS_FY2017_AnnualReport

Work Element 1: Nutrient Program Administration

2012 Nutrient Strategy Nov 2012

2016 NMS Science Plan Report Sep2016

Work Element 2: Define the problem

2011 SFBay NutrientNumericEndpoint Development Lit Review

2014 Nutrient Conceptual Model Draft Final

2014 Suisun Synthesis I

2014 External Nutrient Loads to SF Bay

2015 Lower South Bay Synthesis Report June 2015

2016 Nutrient sources, sinks and transformations in the Delta (MainReport Jan 2016)

- Link to technical appendices (Nutrient sources, sinks and transformations in the Delta)

2016 Summary and Evaluation of Delta Subregions for Monitoring and Assessment

- Link to technical appendices (Summary and Evaluation of Delta Subregions for Monitoring and Assessment)

2016 Suisun Synthesis II: Influence of Nutrient Forms and Ratios on Phytoplankton Production

2017 Nutrient Forms Ratios Workshop Report

- Other workshop materials (panel charge, presentations, reading list, etc.)

Work Element 4: Establish Guidelines

2011 SF Bay NNE Development Lit Review

SF Bay AF Meeting Summary Feb 2014

Proposed Workplan for Assessment Framework Development

Assessment_Framework_January2016_report

2018 Lower South Bay Dissolved Oxygen and Fish Surveys

Work Element 5: Monitoring Program Development and Implementation

2014 Monitoring Program Development Plan Aug 2014

2014 Algal Pigment Final Report

2014 Moored Sensor Yr1 Progress Report

2015 SPATT (Algal Toxins) Final Report May 2015

2017 NMS Observation Program Design

Work Element 6: Modeling Strategy

2014_Model Development Plan to Support SFB Nutrient Management Decisions.pdf

2014_Detailed Modeling Workplan.pdf

FY2016 Modeling Plan

2017 Load Update and Load Reduction Scenario Runs (See Section 6)

2017_SFBay_Interim_Model_Validation_Report

2018_June_Delta_Suisun_Biogeochemical_Model_ProgressReport

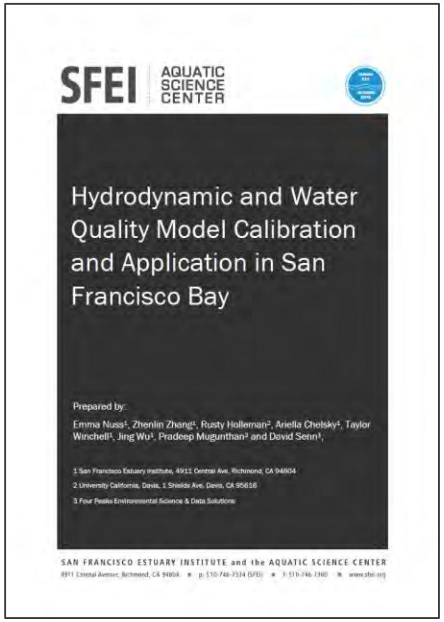
Work Element 7: Control Strategies

2017 Conceptual Nutrient Trading Program for San Francisco Bay (See Section 7, Freshwater Trust)

2017 Reducing Nutrients in San Francisco Bay through WWTP Sidestream Treatment (Y Shang [EBMUD]

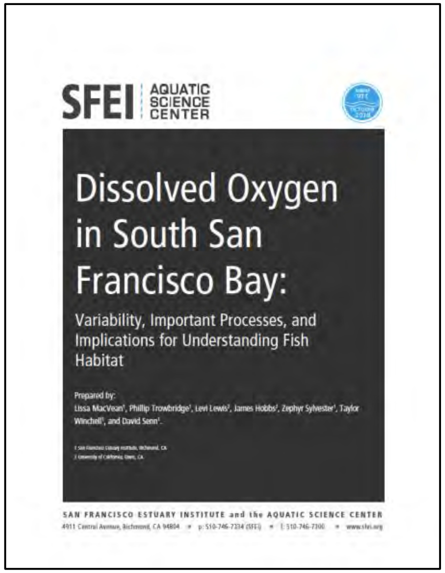
2017 Treatment Wetlands Opportunities Screening Report

Modeling

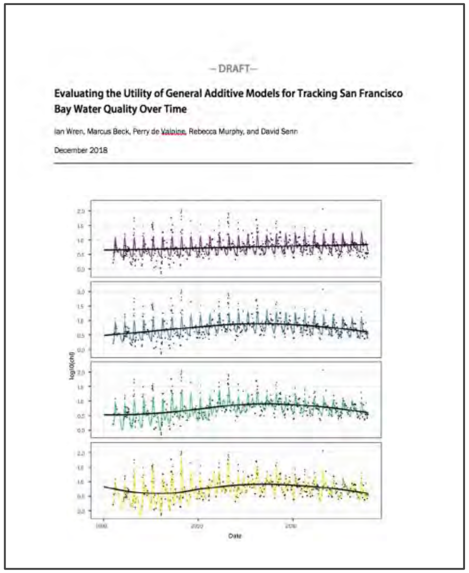


Monitoring // Moored Sensors

Oxygen & Habitat



Trends: chlorophyll



Collaborators

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P de Valpine

Acknowledgements:

Funding: Nutrient Watershed Permit (BACWA); Regional Monitoring Program; State Water Resources Control Board; In-kind funding from USGS (Cloern et al)

NMS Steering Committee, NMS Planning Subcommittee, and Stakeholders

SFEI staff, Collaborators, and Technical Advisors

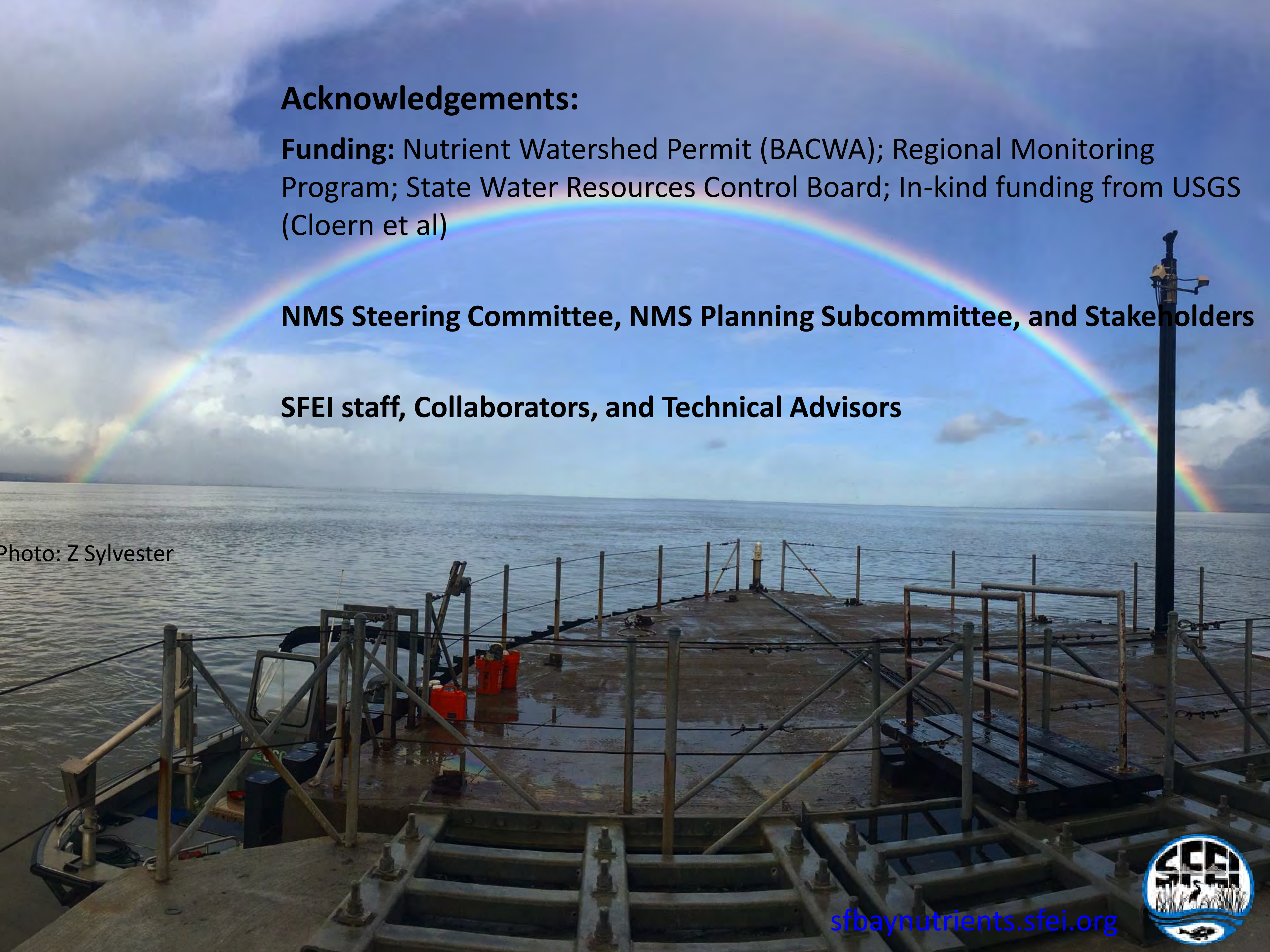

Photo: Z Sylvester

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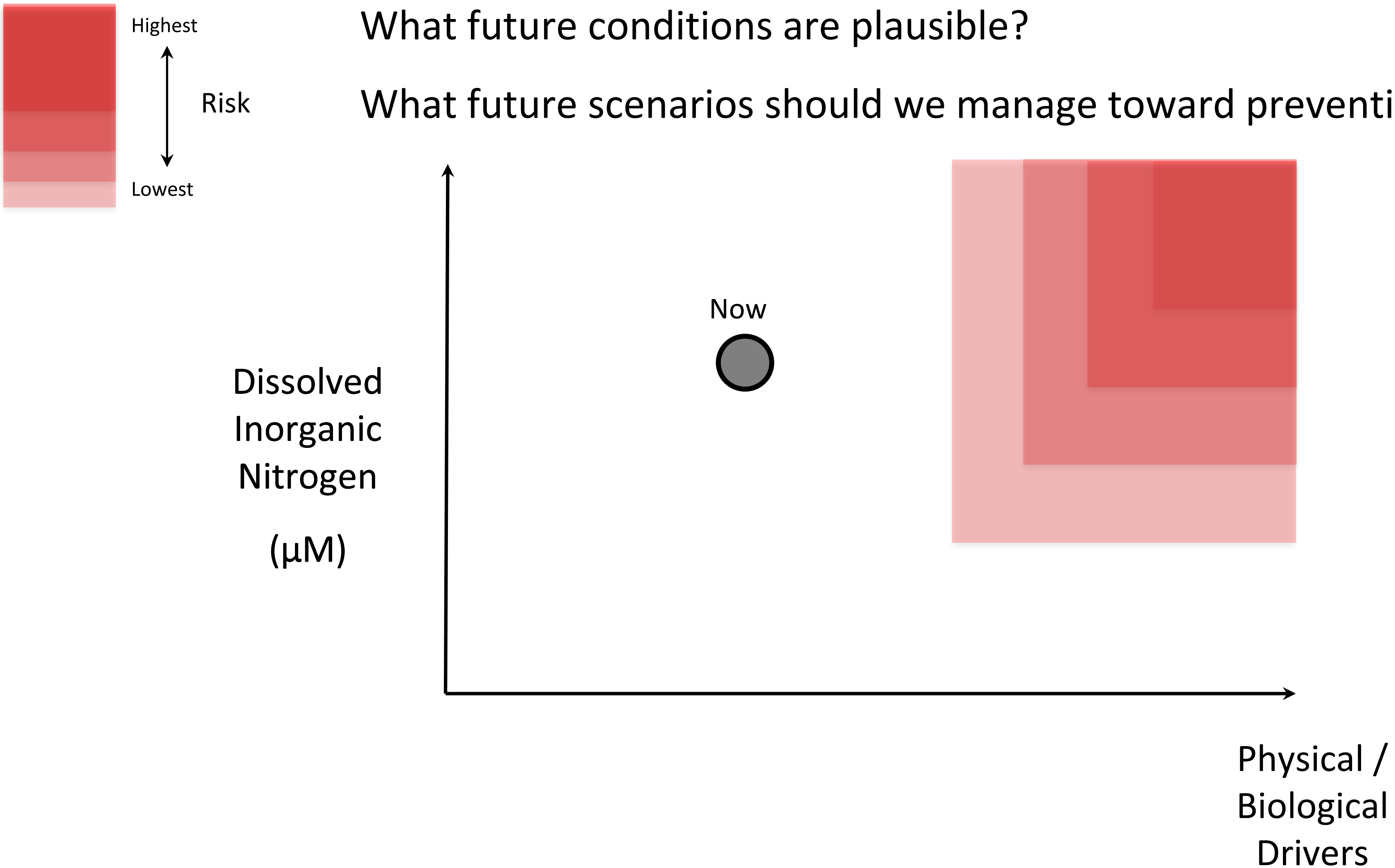
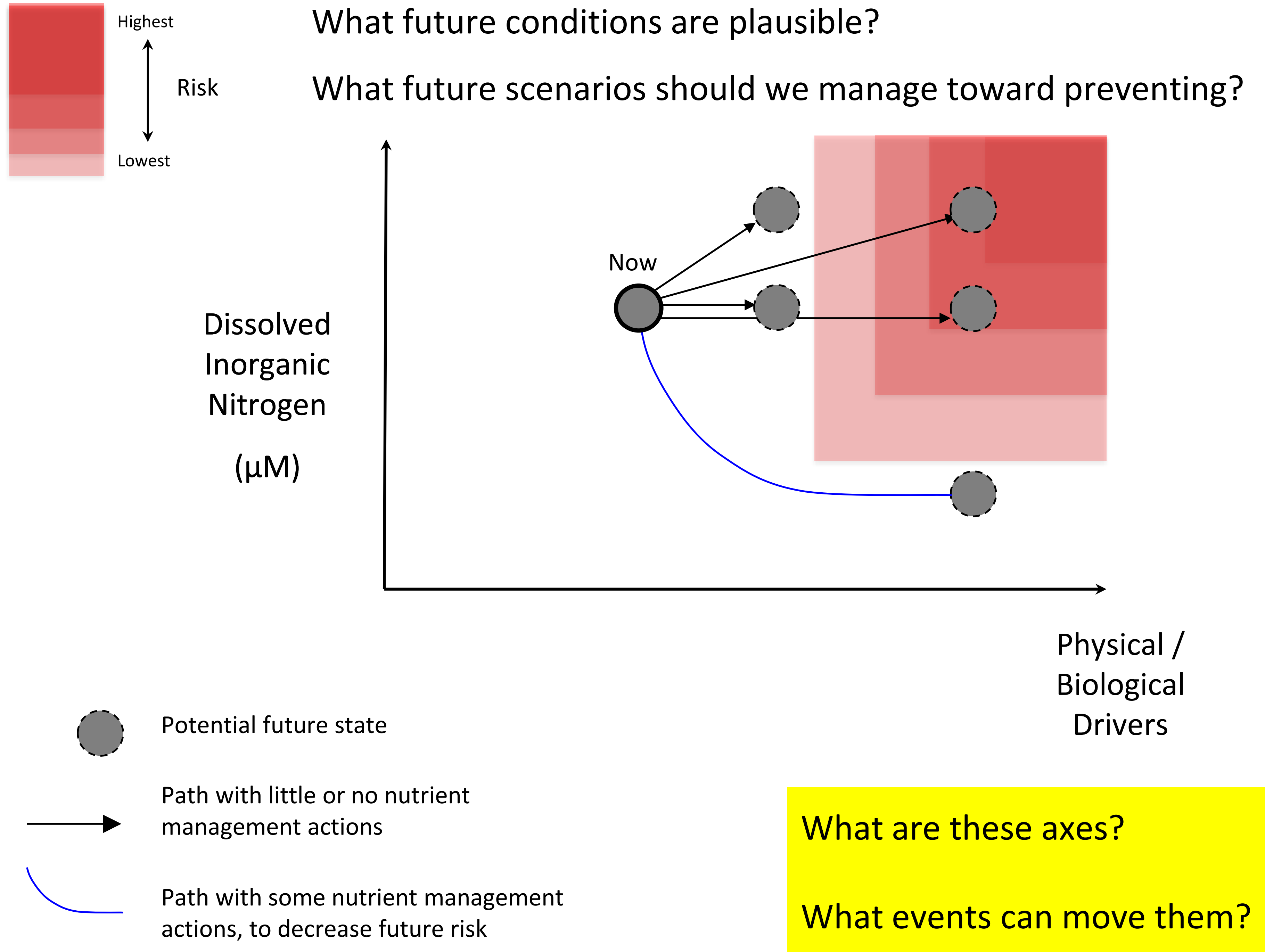
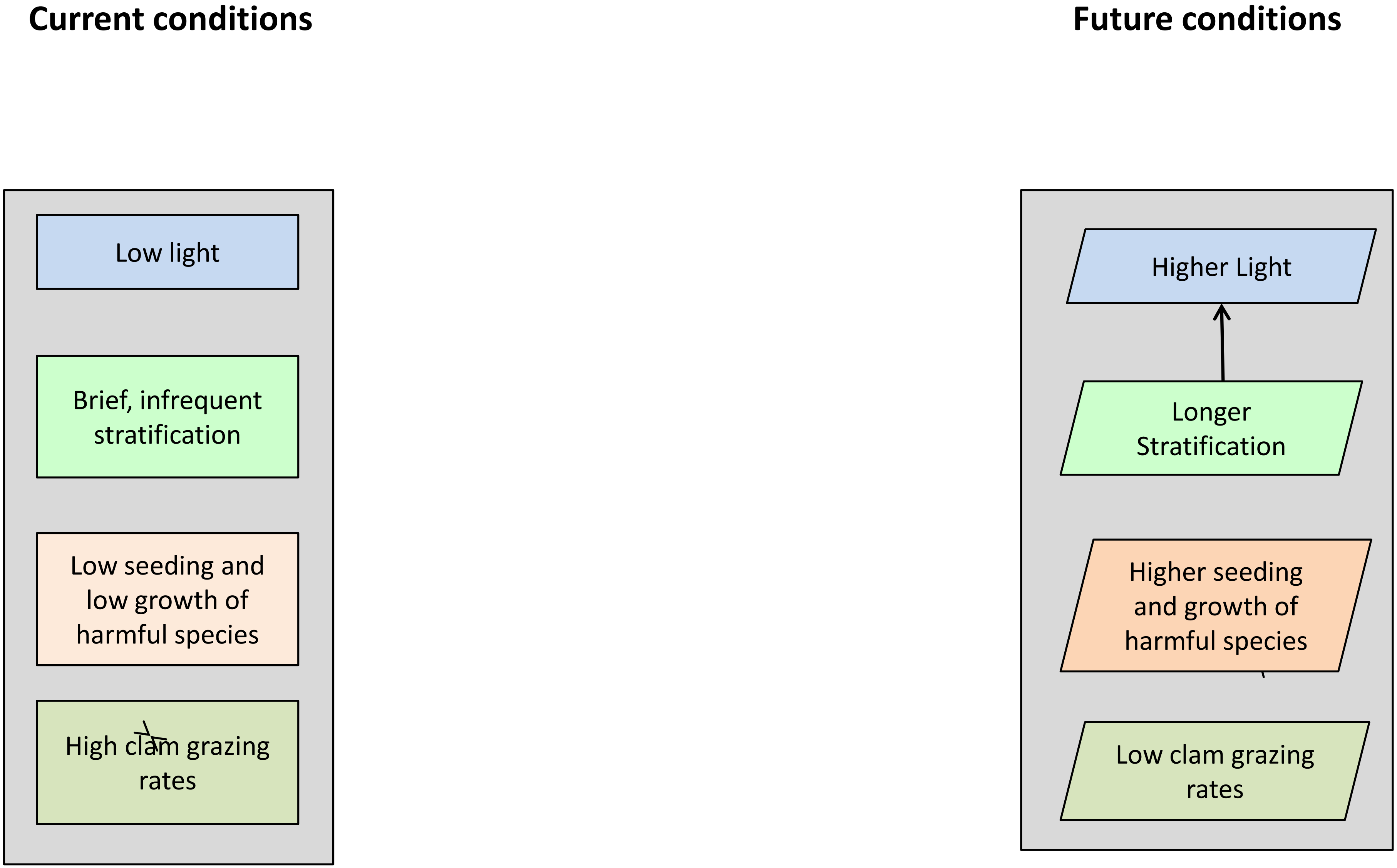
What future conditions are plausible?

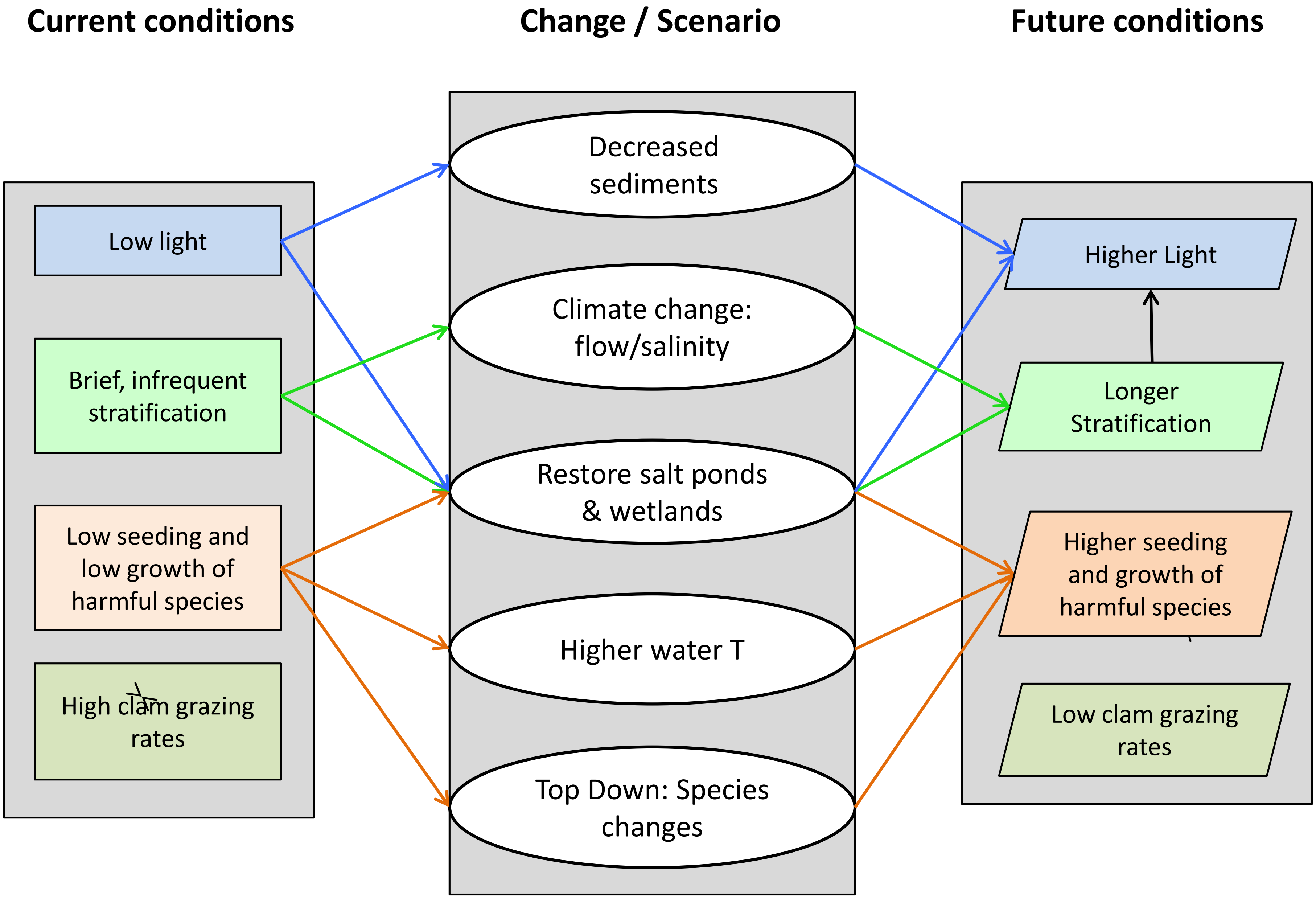
What future scenarios should we manage toward preventing?



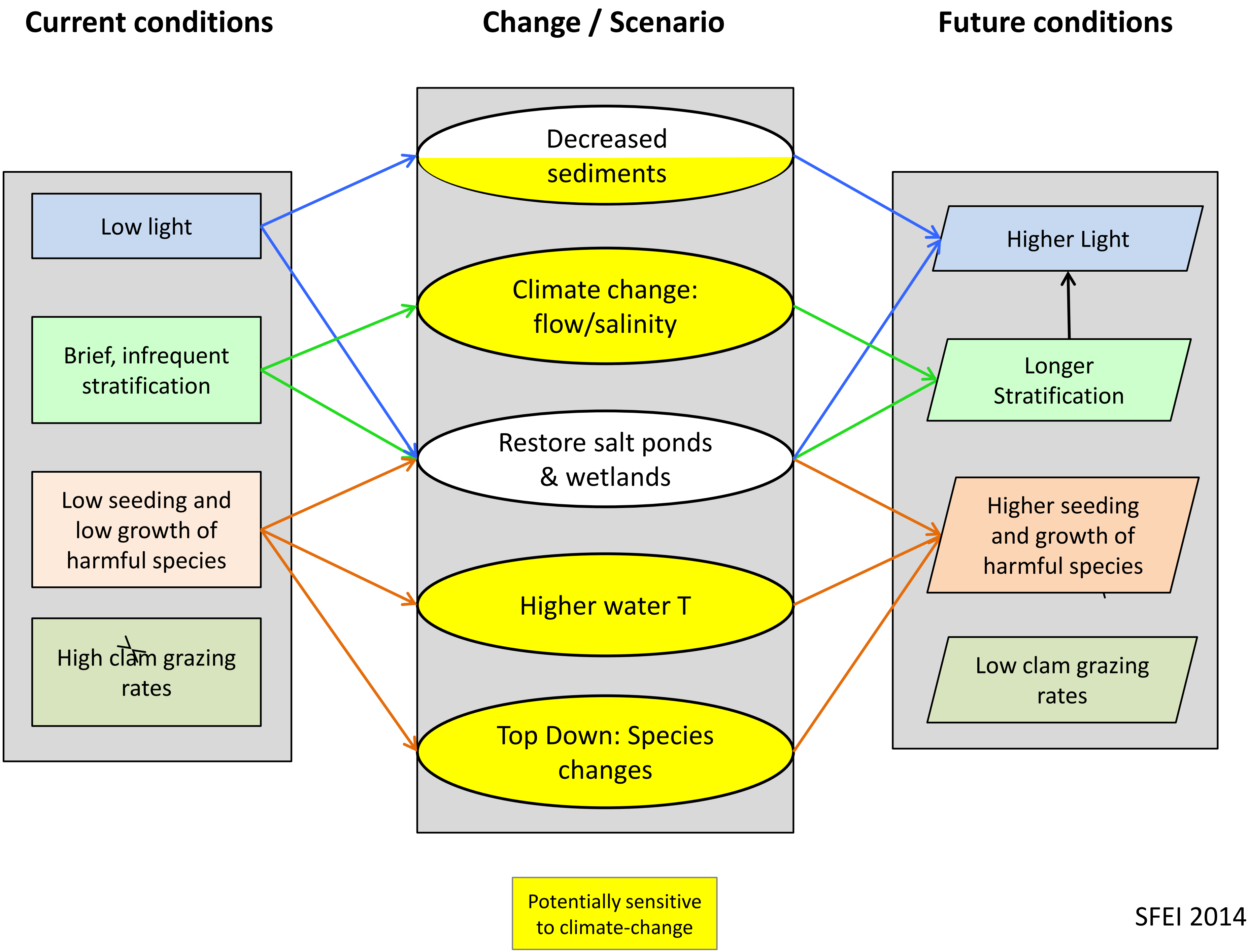

Highest
Risk
Lowest
What future conditions are plausible?
What future scenarios should we manage toward preventing?
Now
Dissolved
Inorganic
Nitrogen
(µM)
Physical /
Biological
Drivers
Potential future state
Path with little or no nutrient
management actions
Path with some nutrient management
actions, to decrease future risk
What are these axes?
What events can move them?


Current conditions
Future conditions
Low light
Brief, infrequent stratification
Low seeding and low growth of harmful species
High clam grazing rates
Higher Light
Longer Stratification
Higher seeding and growth of harmful species
Low clam grazing rates

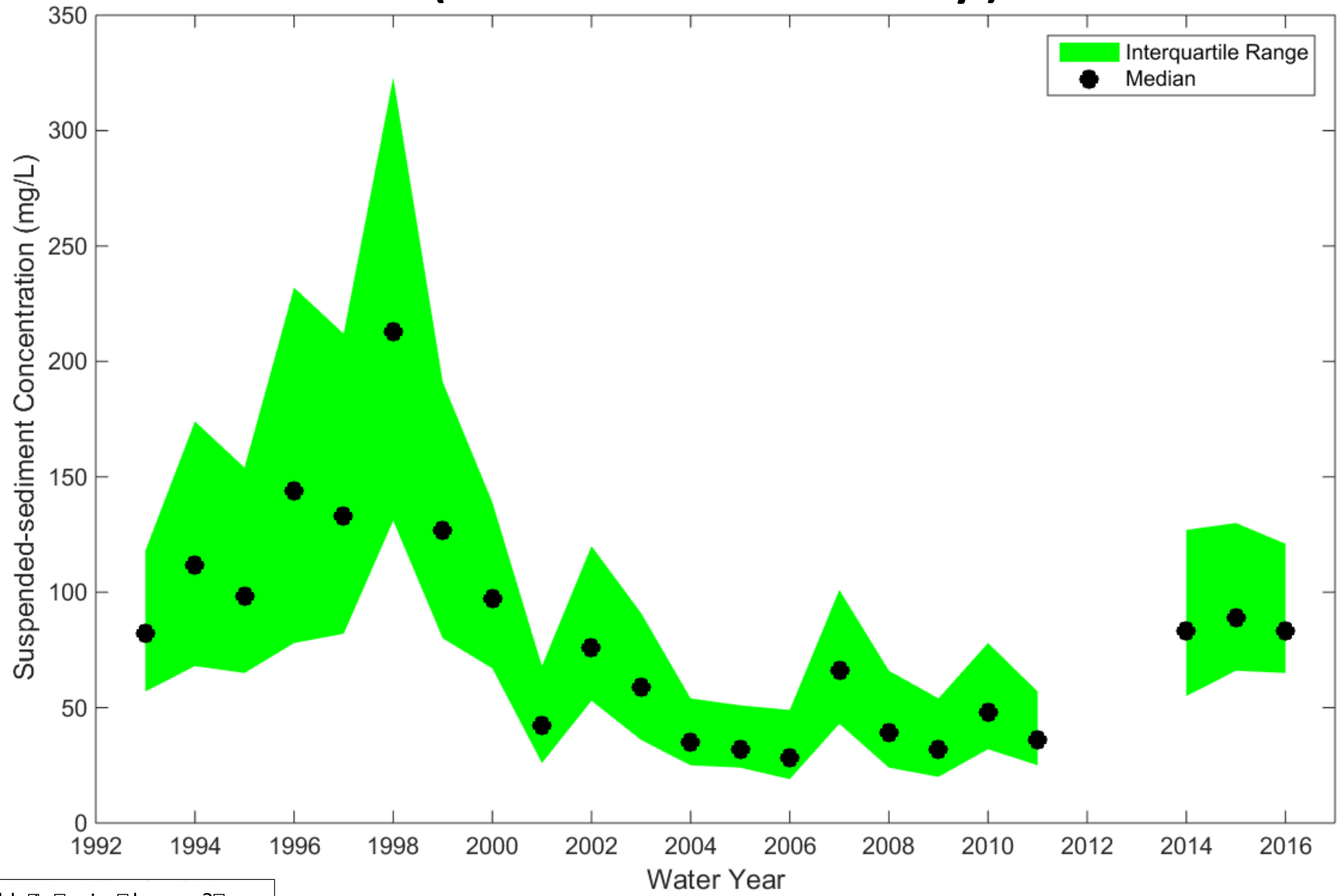
SFEI 2014

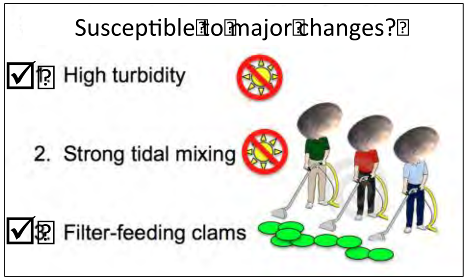

Current conditions
Change / Scenario
Future conditions
Low light
Brief, infrequent stratification
Low seeding and low growth of harmful species
High clam grazing rates
Decreased sediments
Climate change: flow/salinity
Restore salt ponds & wetlands
Higher water T
Top Down: Species changes
Higher Light
Longer Stratification
Higher seeding and growth of harmful species
Low clam grazing rates

SFEI 2014


Current conditions
Change / Scenario
Future conditions
Low light
Brief, infrequent stratification
Low seeding and low growth of harmful species
High clam grazing rates
Decreased sediments
Climate change: flow/salinity
Restore salt ponds & wetlands
Higher water T
Top Down: Species changes
Higher Light
Longer Stratification
Higher seeding and growth of harmful species
Low clam grazing rates
Potentially sensitive to climate-change
SFEI 2014

Suspended sediments…Dumbarton Bridge (Lower South Bay)





Schoellhamer et al. 2015
SFEI 2015

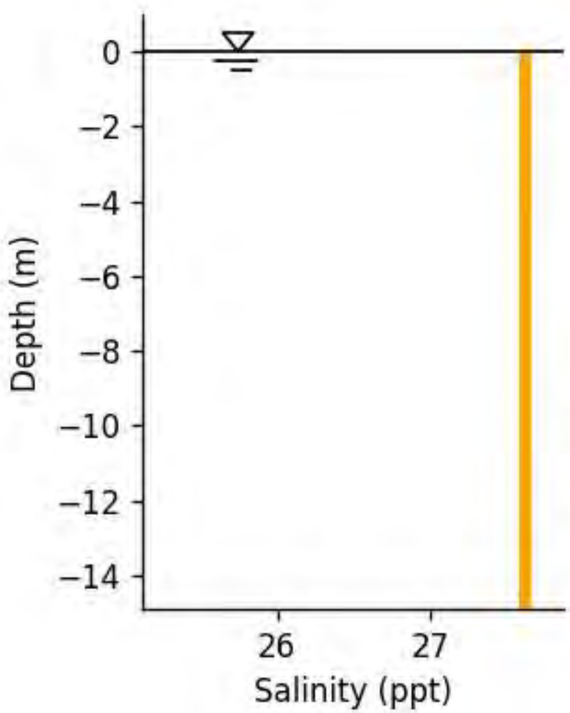
Stratification Modeling

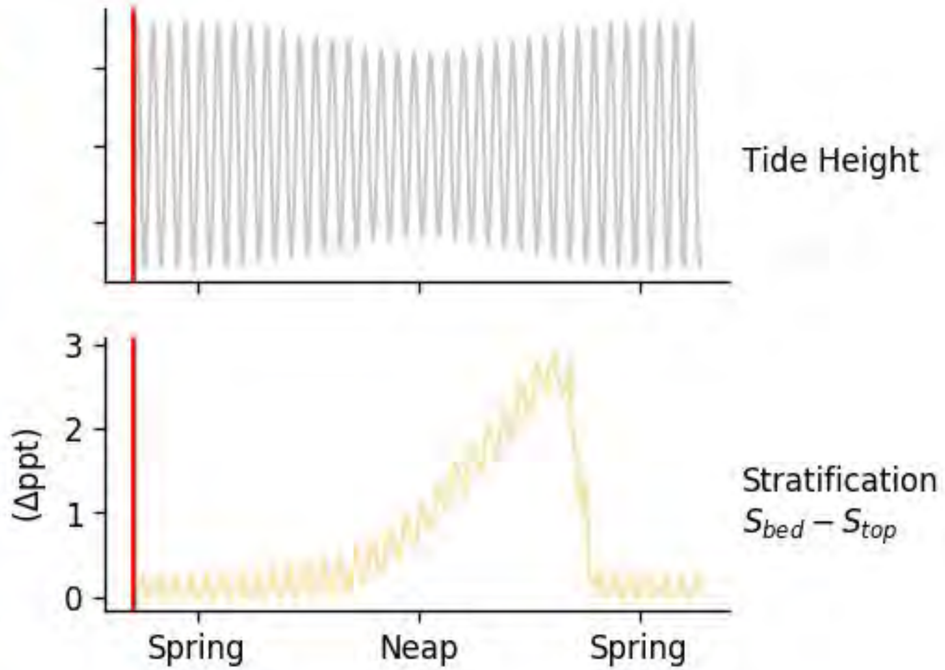
Stratification: when surface waters are distinct and isolated from water lower down.

Hypothesis: persistent stratification enables phytoplankton blooms

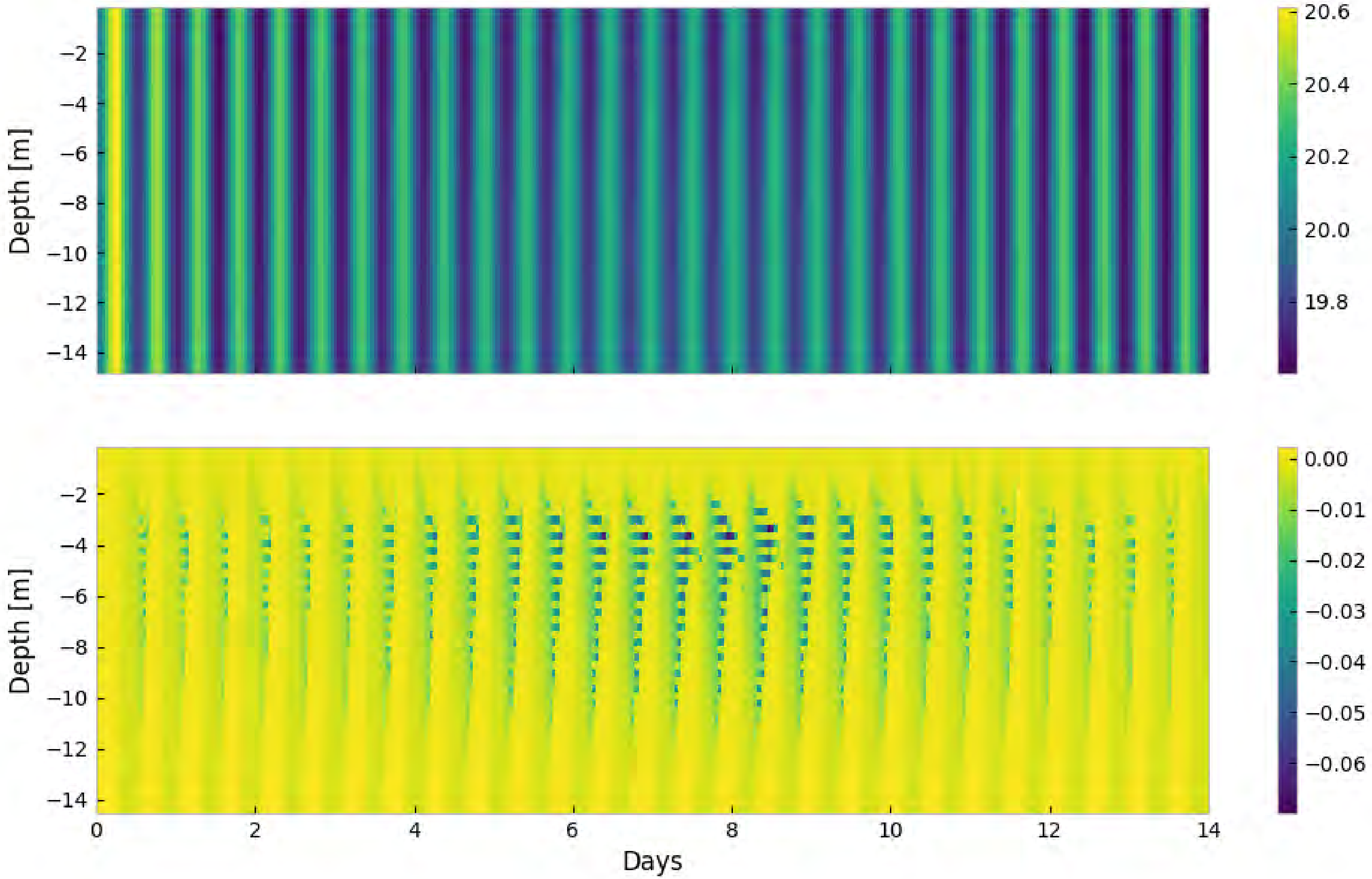
Typical in SF Bay:

Flood tide mixes / Ebb tide stratifies

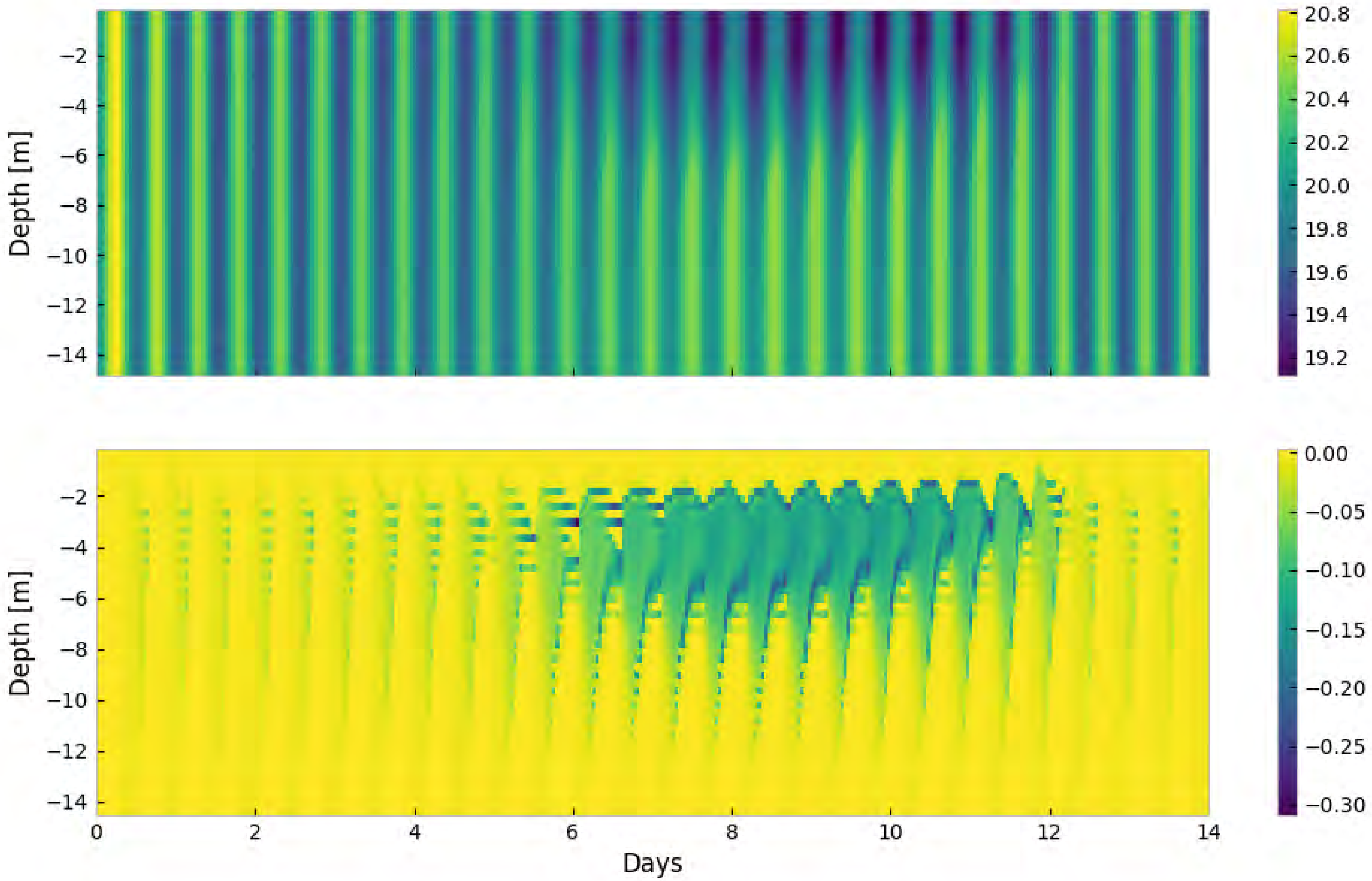




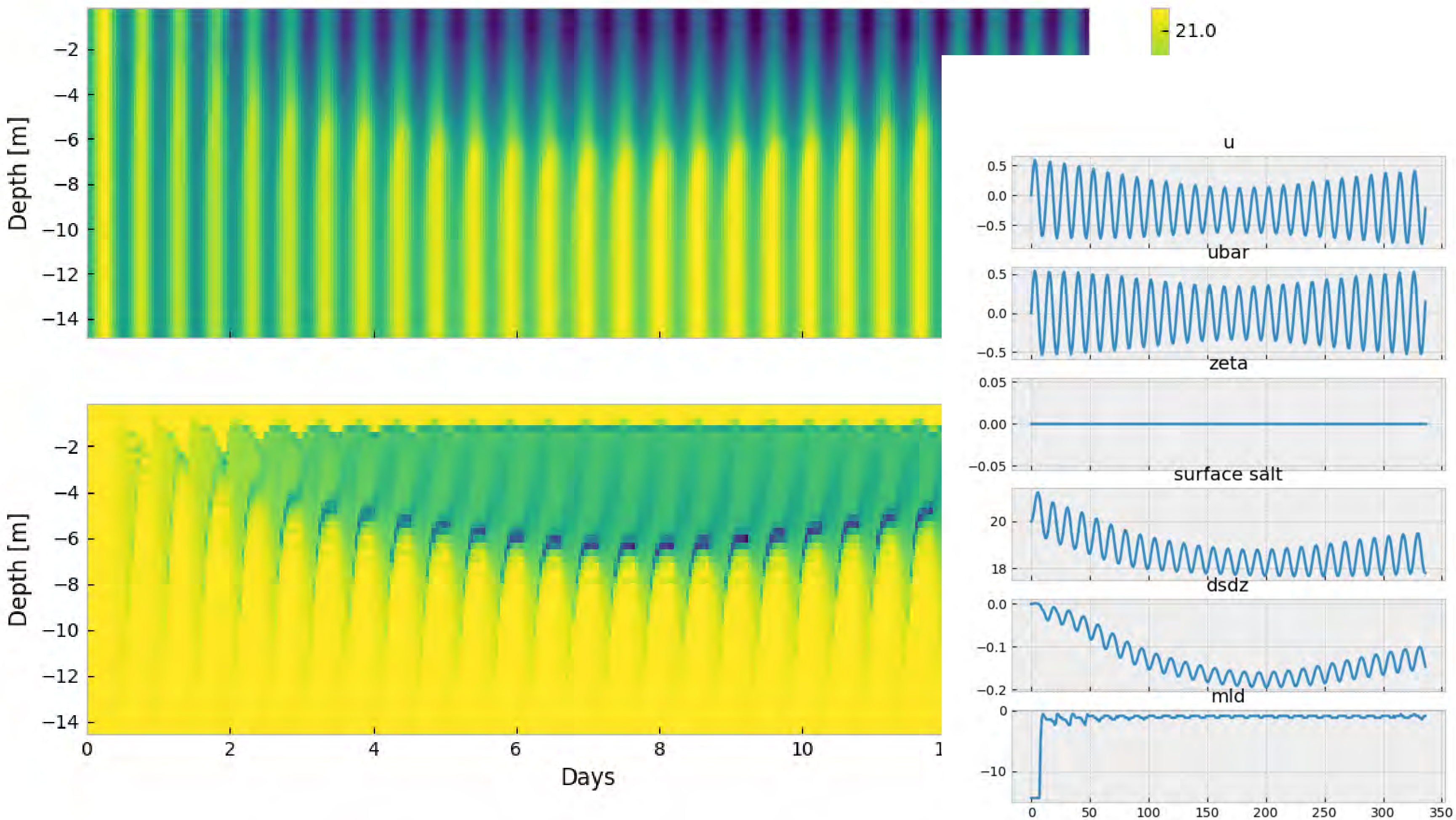
0.444 and ds/dx = 0.1 psu/km



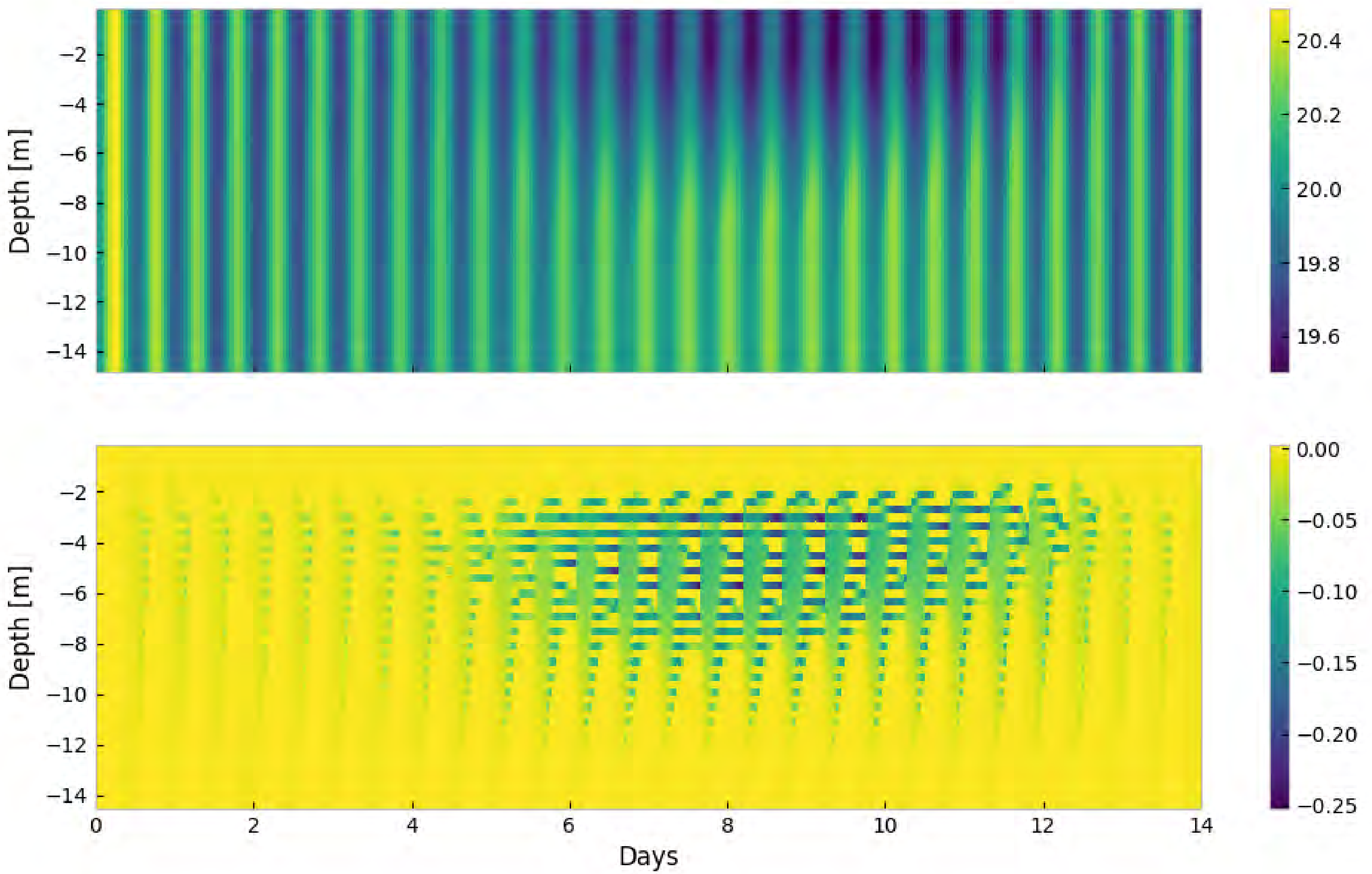
0.444 and ds/dx = 0.133 psu/km



0.444 and ds/dx = 0.200 psu/km



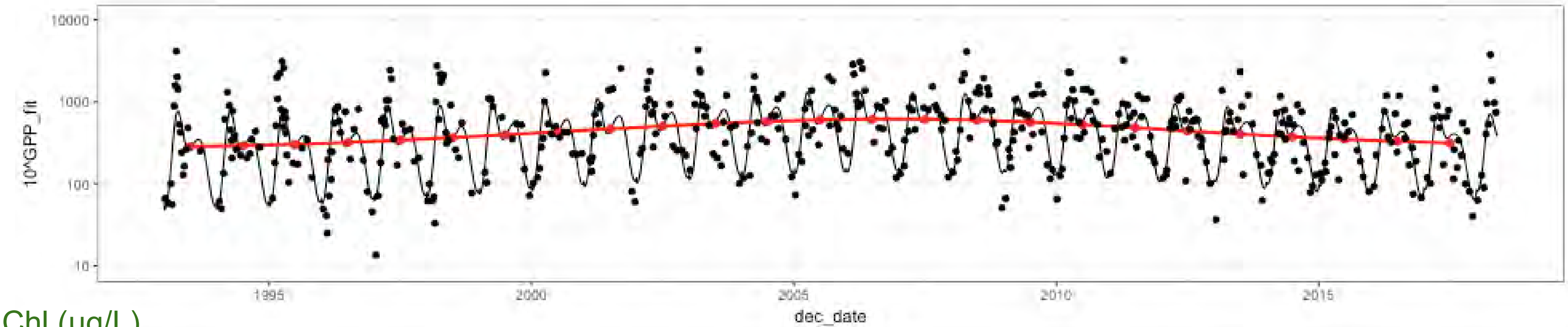
0.333 and ds/dx = 0.100 psu/km



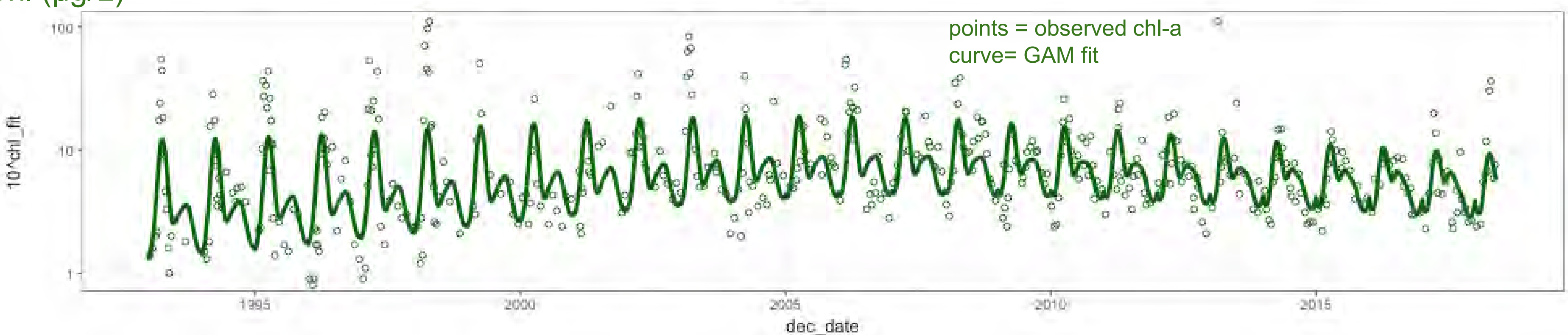
Now let's look at GPP...Station 32, 1992-early2018

points = calculated GPP based on observed chl-a, k_{ext}, and I_o
Black curve = GAM fit to daily GPP
Red curve = annual cumulative GPP/365 (units of mgC/m2/d)

GPP (mg C m^{-2} d^{-1})



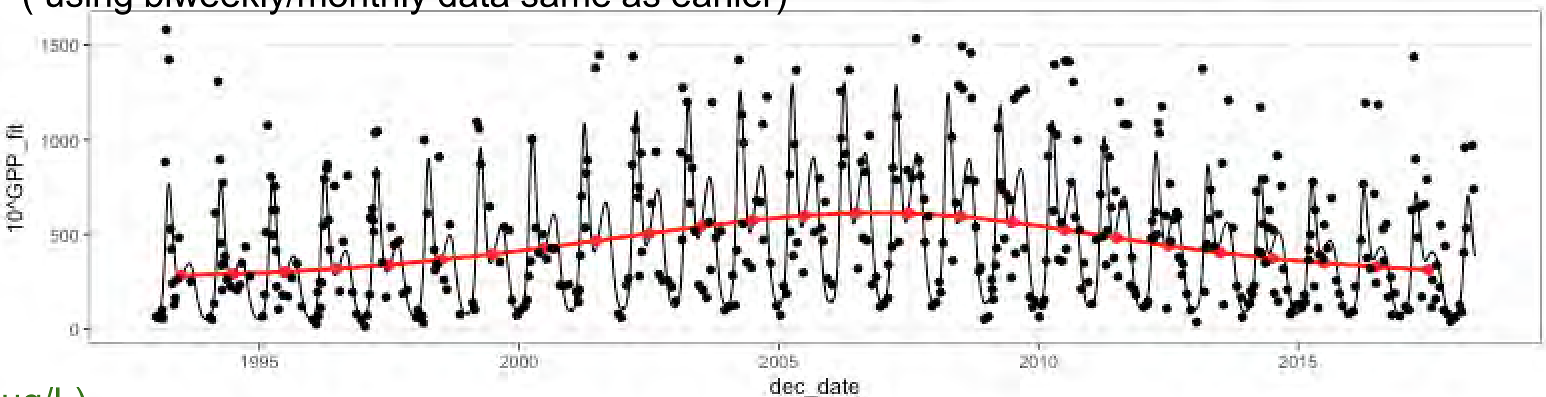
Chl (µg/L)



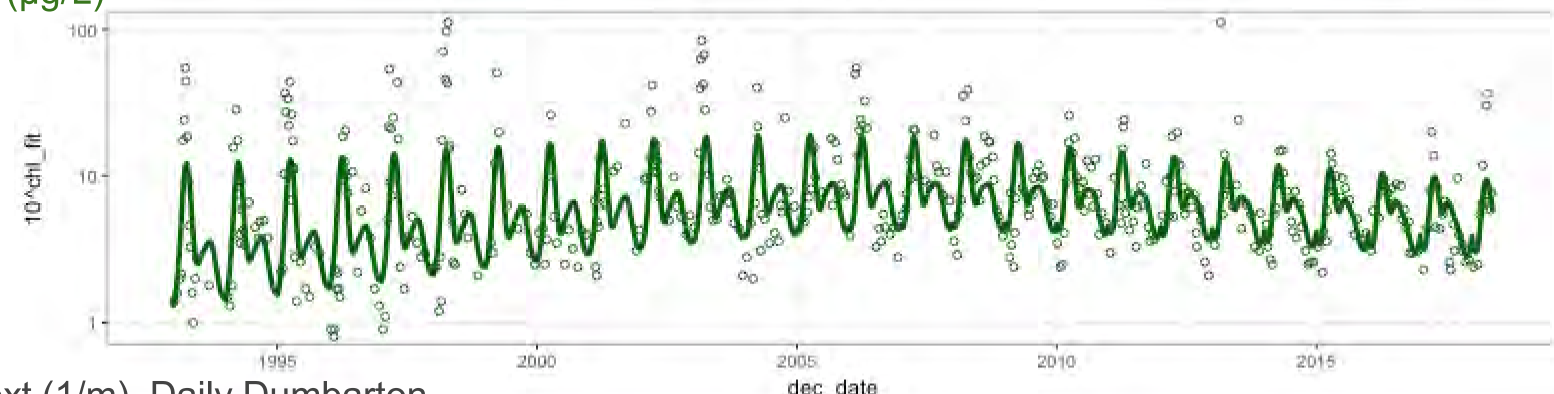
NOTE: To address diffferences in data density across years (and stations, later), annual cumulative GPP was calculated based on the GAM fit values.. See subsequent slides

Same as slide 13 and 15, but linear y-axis for GPP (some data outside axis limits)

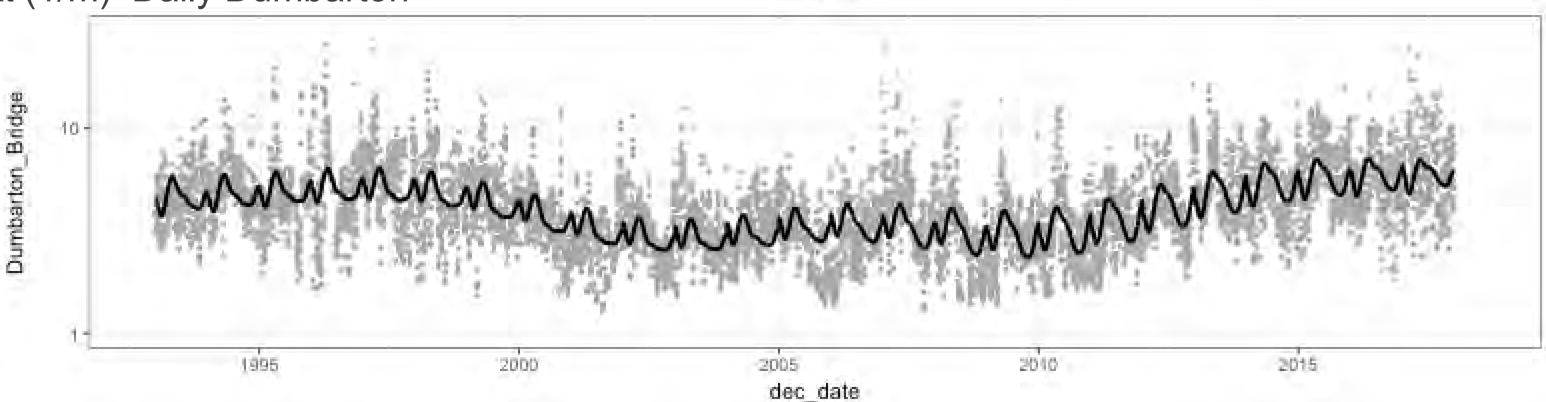
GPP (using biweekly/monthly data same as earlier)



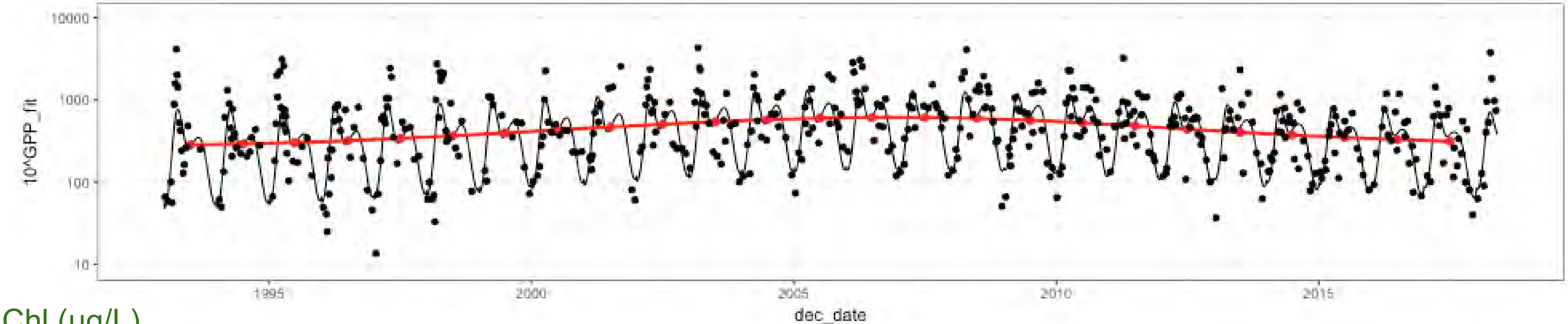
Chl (µg/L)



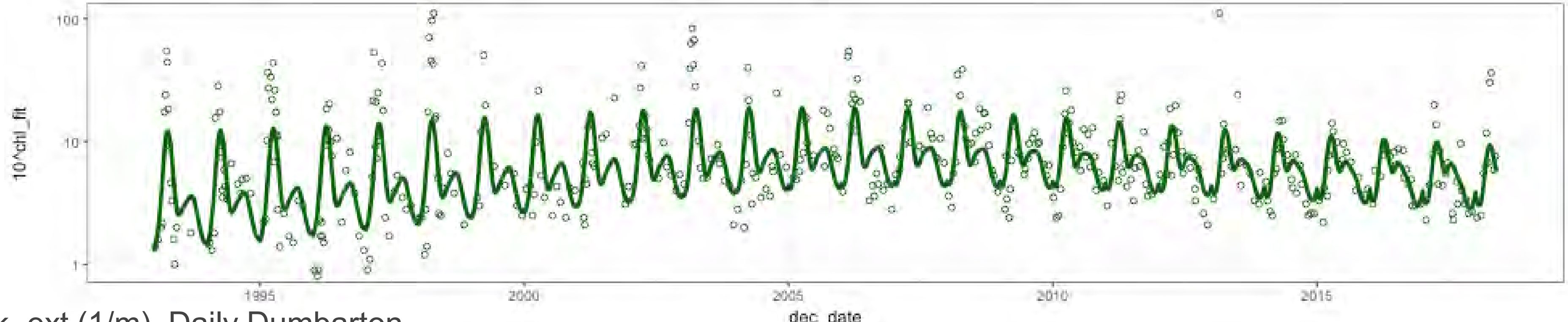
k_ext (1/m) Daily Dumbarton



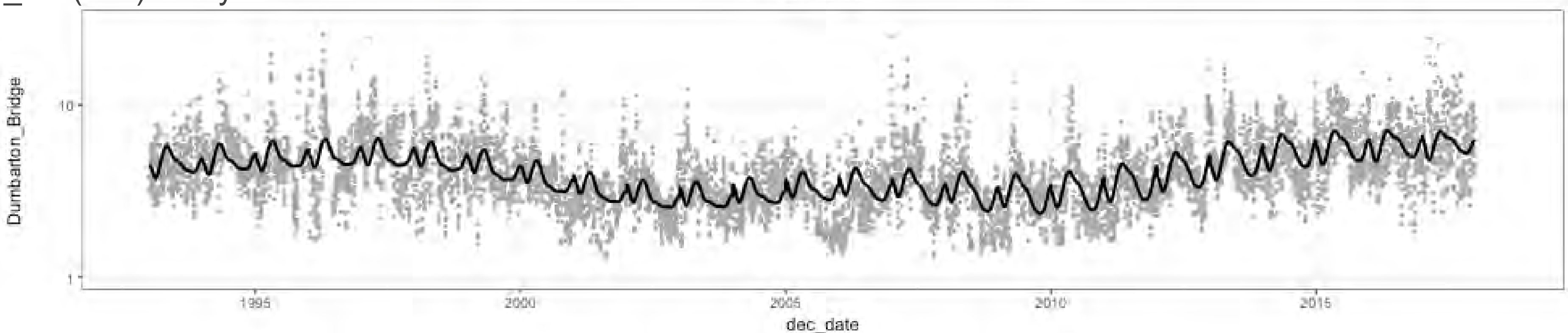
GPP (using biweekly/monthly data same as earlier)



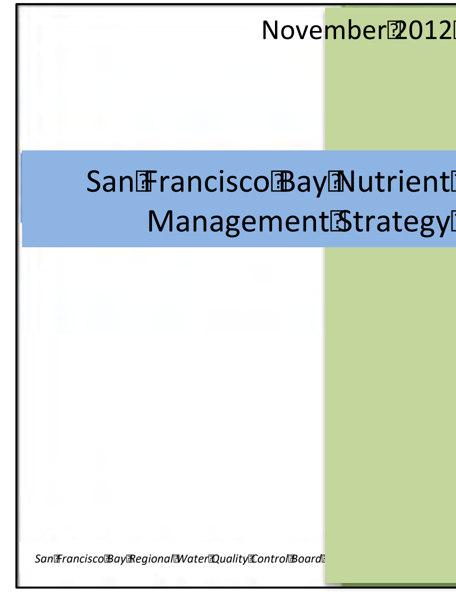
Chl (μg/L)



k_ext (1/m) Daily Dumbarton



Nutrient Management Strategy


November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

- What nutrient loads can SFB (subembayments) assimilate without adverse impacts?
  - Nutrient Loads, Cycling/Losses/Transformations
  - Biological Responses
  - Dose : Response
  - Condition Assessment: Criteria, Observations

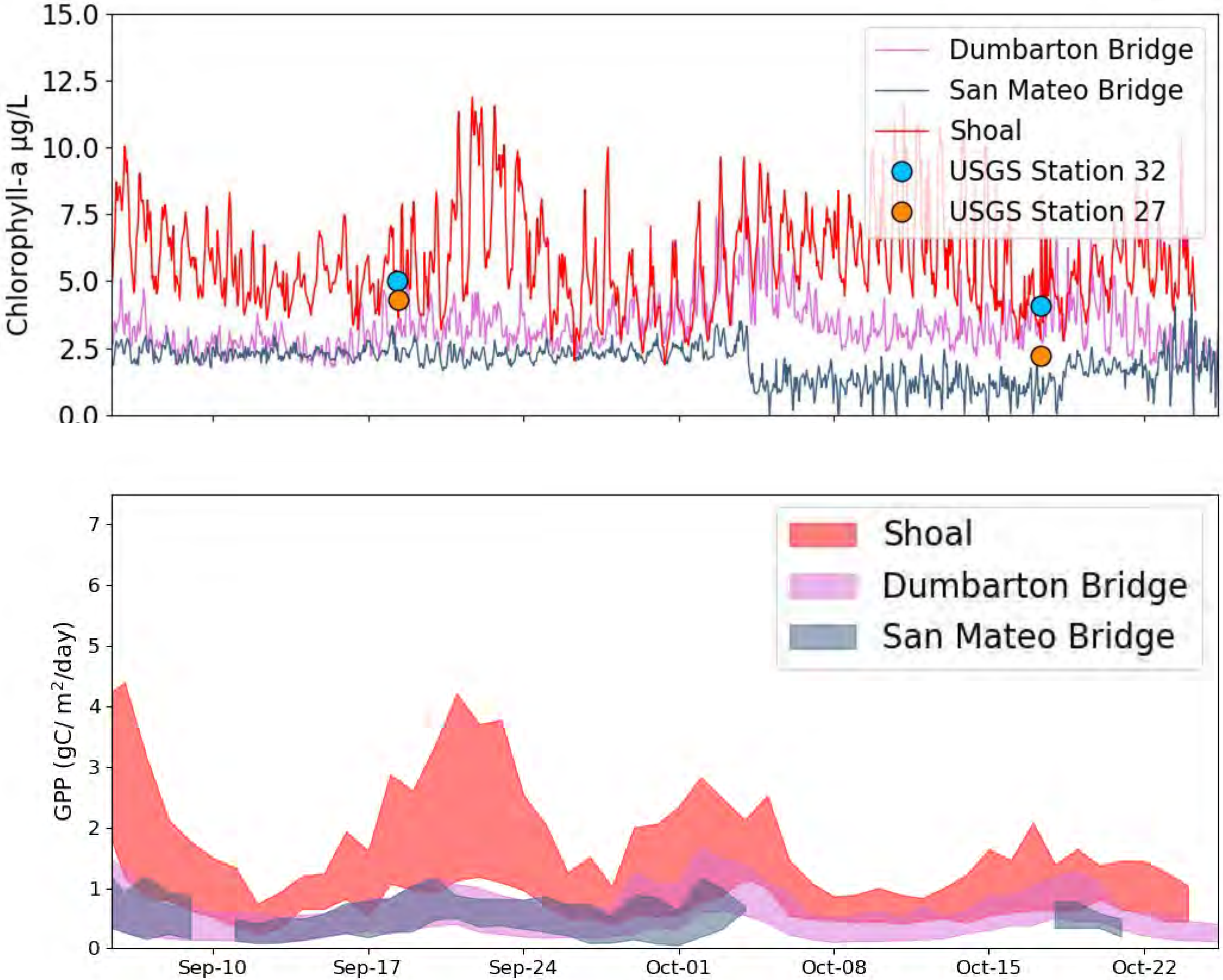
- What management actions would be effective at achieving protective nutrient loads or concentrations?

Focus Areas

- Phytoplankton Blooms & DO
- Harmful Algae & Toxins
- Coastal Exports

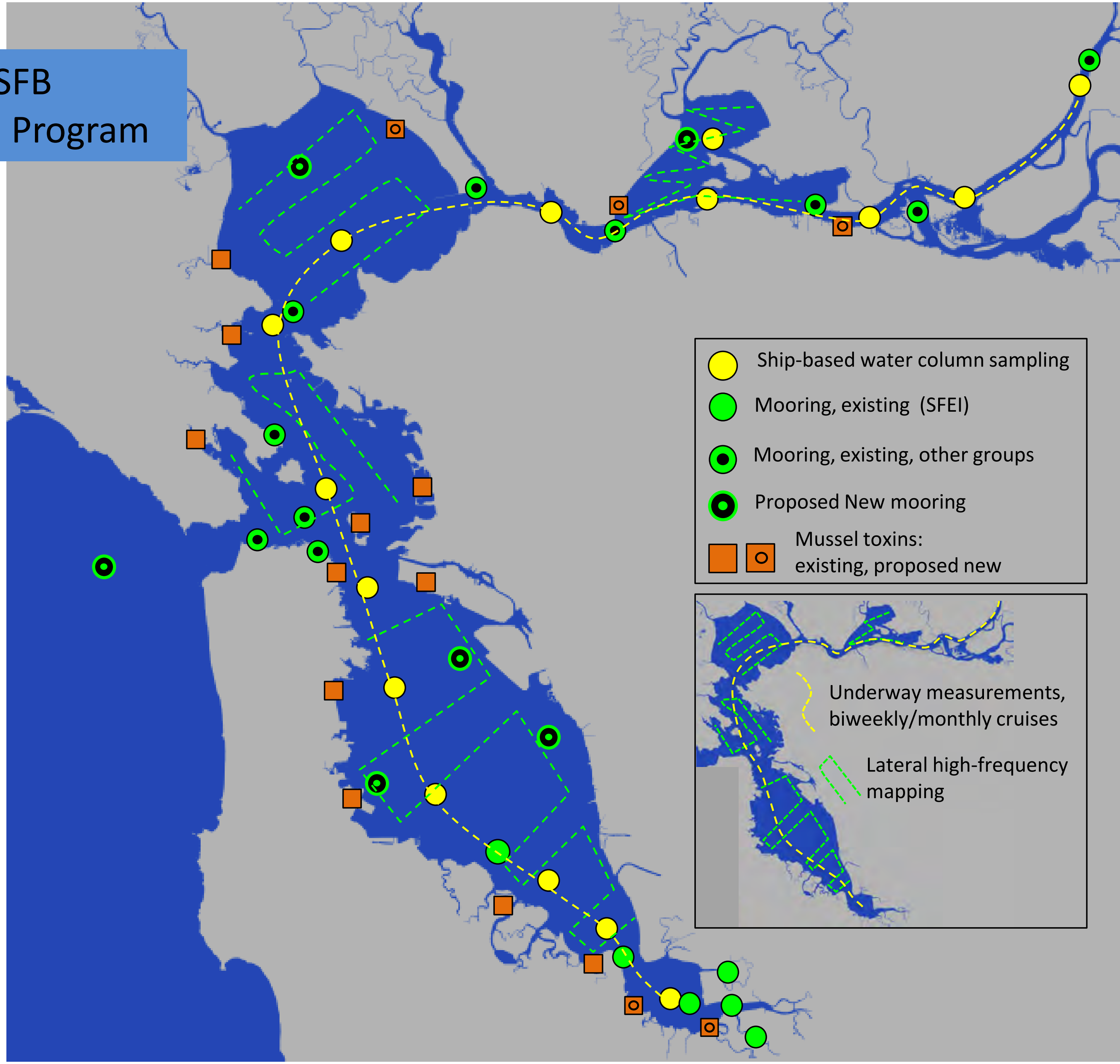
Tools/Approaches

- Monitoring
- Numerical models
- Assessment Framework/Criteria
- Special Studies: Mechanistic/Quantitative Linkages to nutrients



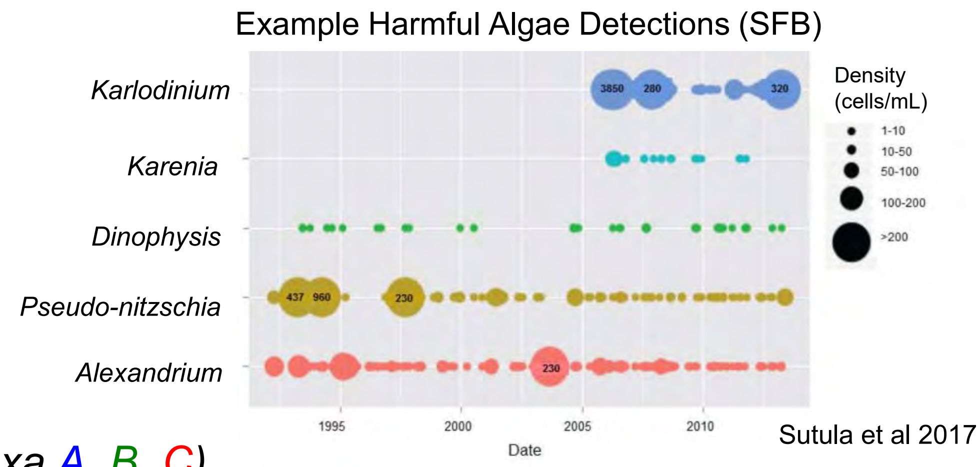
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Chlorophyll-a µg/L
Dumbarton Bridge
San Mateo Bridge
Shoal
USGS Station 32
USGS Station 27
7
6
5
4
3
2
1
0
GPP (gC/ m^2/day)
Shoal
Dumbarton Bridge
San Mateo Bridge
Sep-10
Sep-17
Sep-24
Oct-01
Oct-08
Oct-15
Oct-22

Next Generation SFB NMS Observation Program



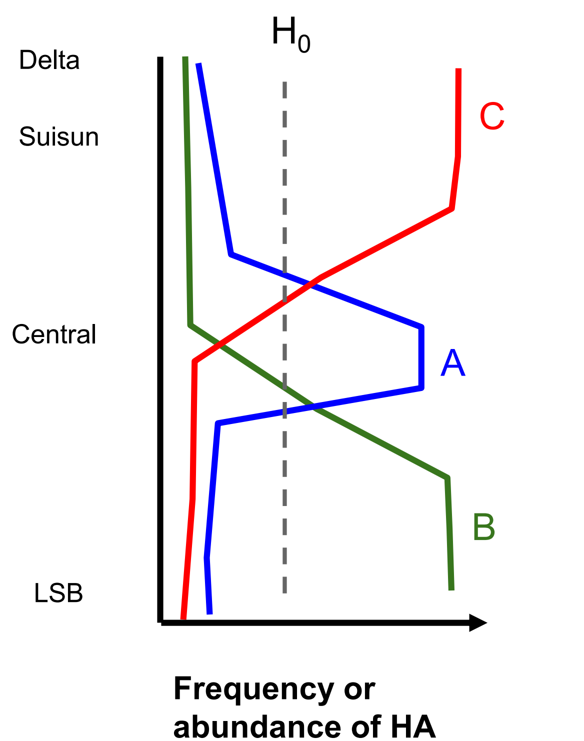
What can we learn, mechanistically, about HAs in SFB using long-term data?

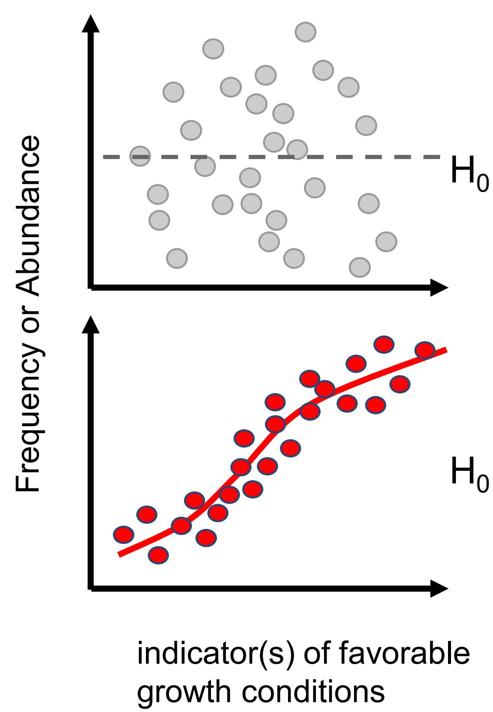
- source?
- internal growth?
- resident population(s)?
- Predictors?

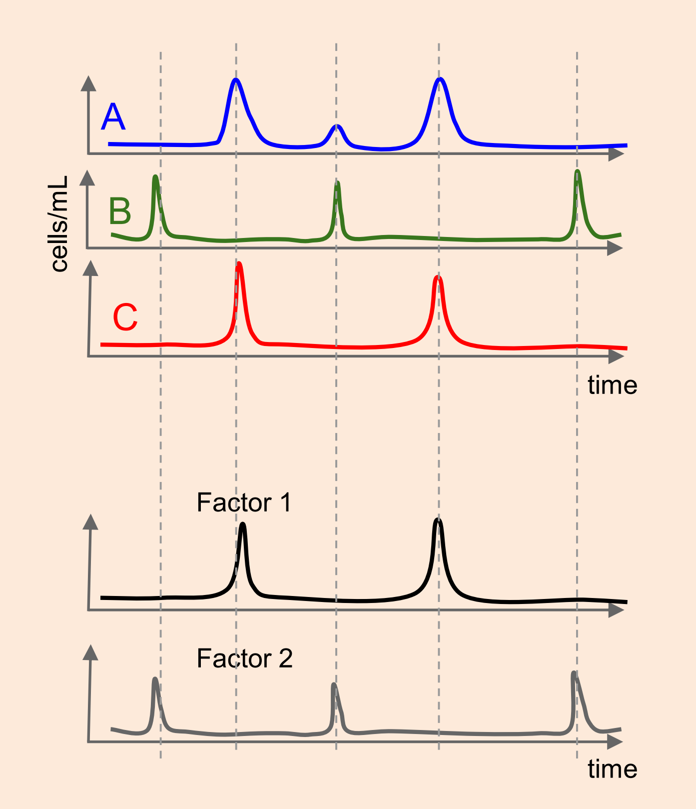


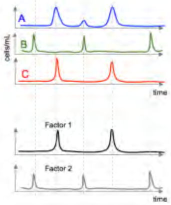
Sutula et al 2017

Develop and 'Test' conceptual models (HA taxa A, B, C)

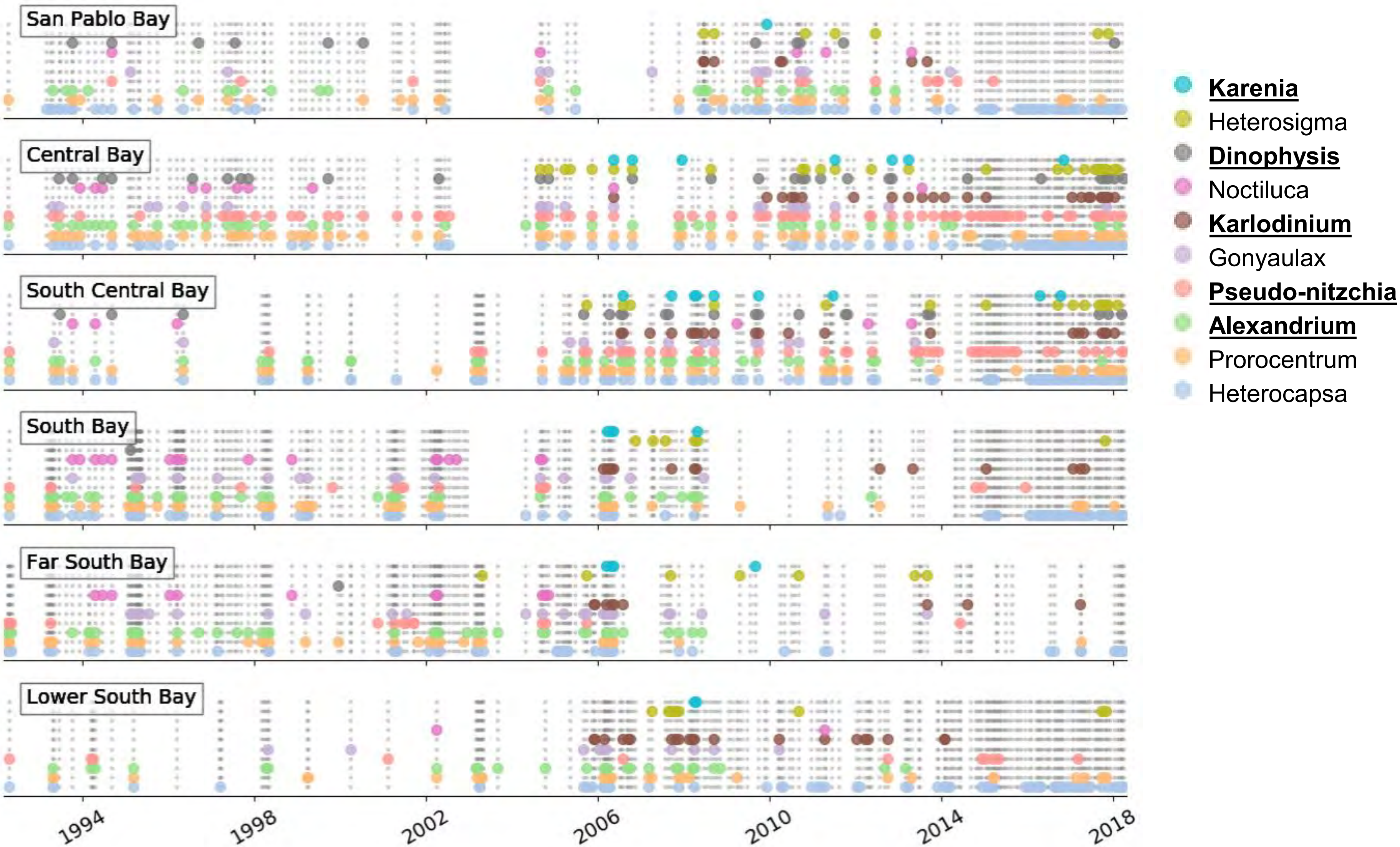




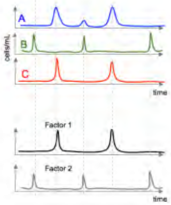




Microscopy: Dates/Locations of Presence/Absence

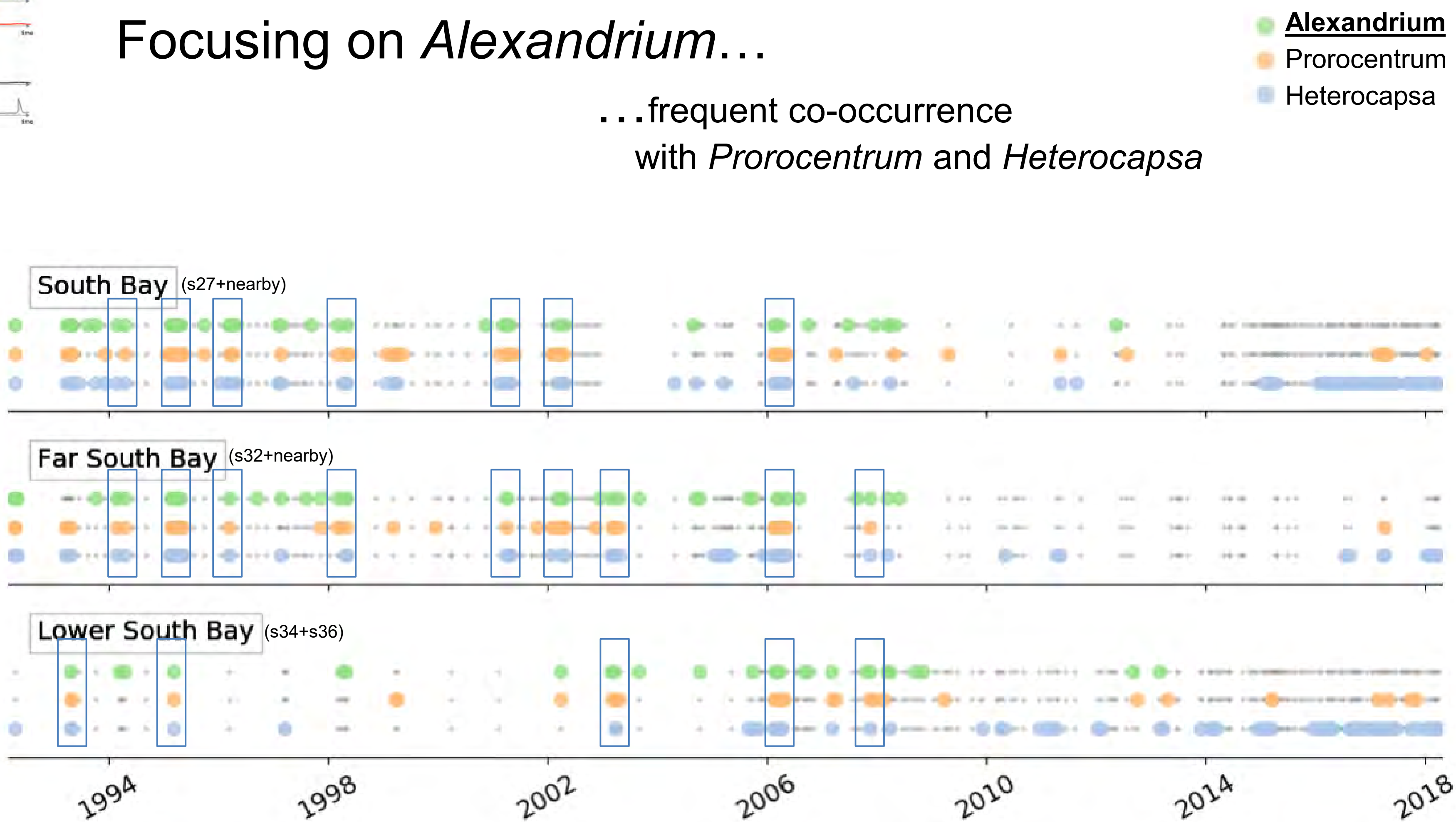


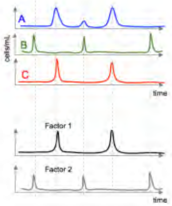
Underlined: HA of concern
Others: Potential HA (?)



Focusing on *Alexandrium*…

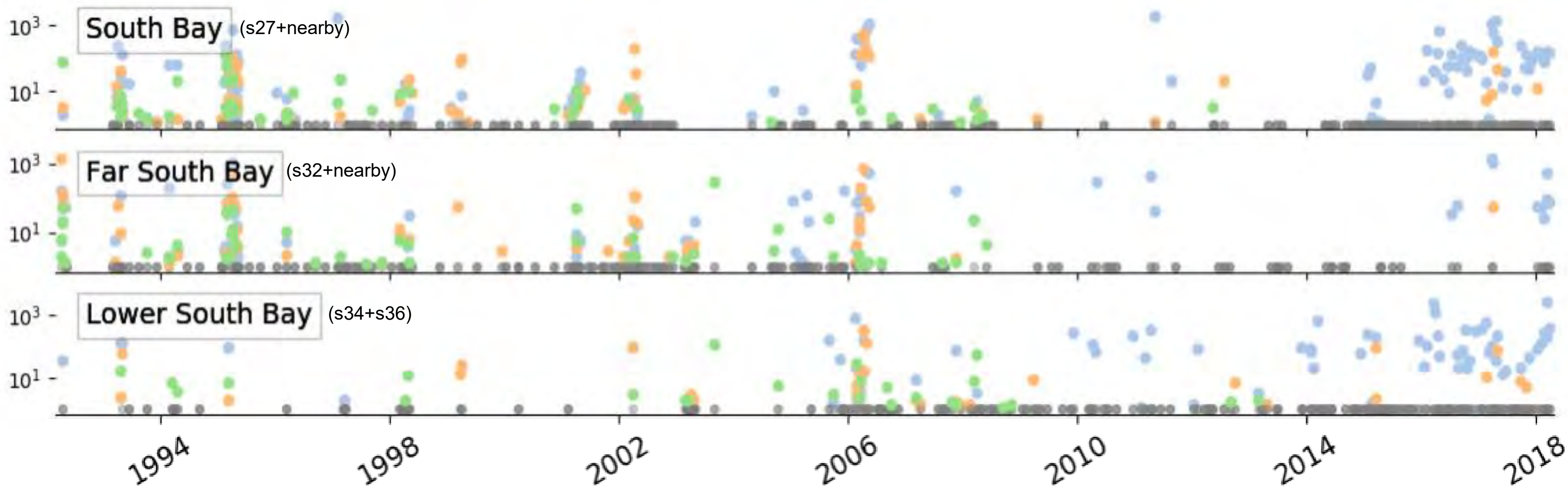
…frequent co-occurrence
with *Prorocentrum* and *Heterocapsa*

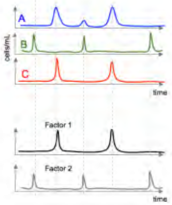




Densities (cells/mL)

Alexandrium
Prorocentrum
Heterocapsa



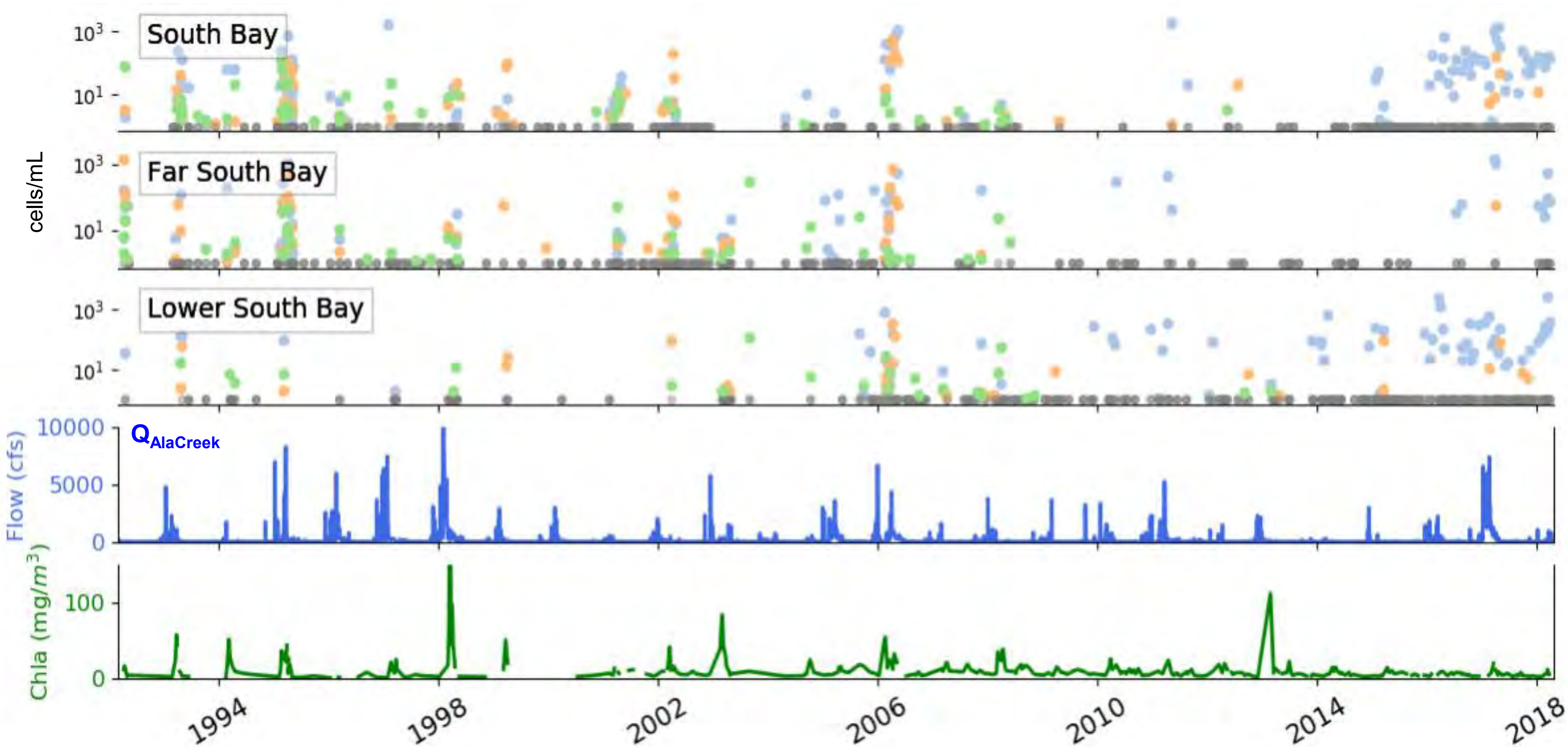


Densities (cells/mL)

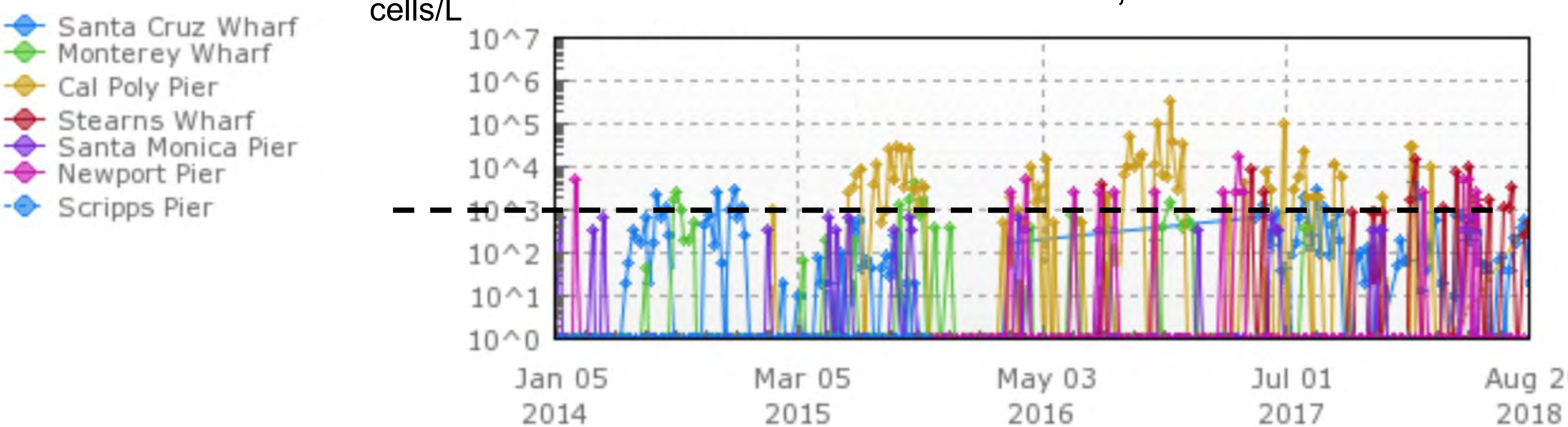
- *Alexandrium, Prorocentrum, Heterocapsa:*

…Commonly appear together
- during/after major freshwater flow events
- during elevated chl-a (blooms)

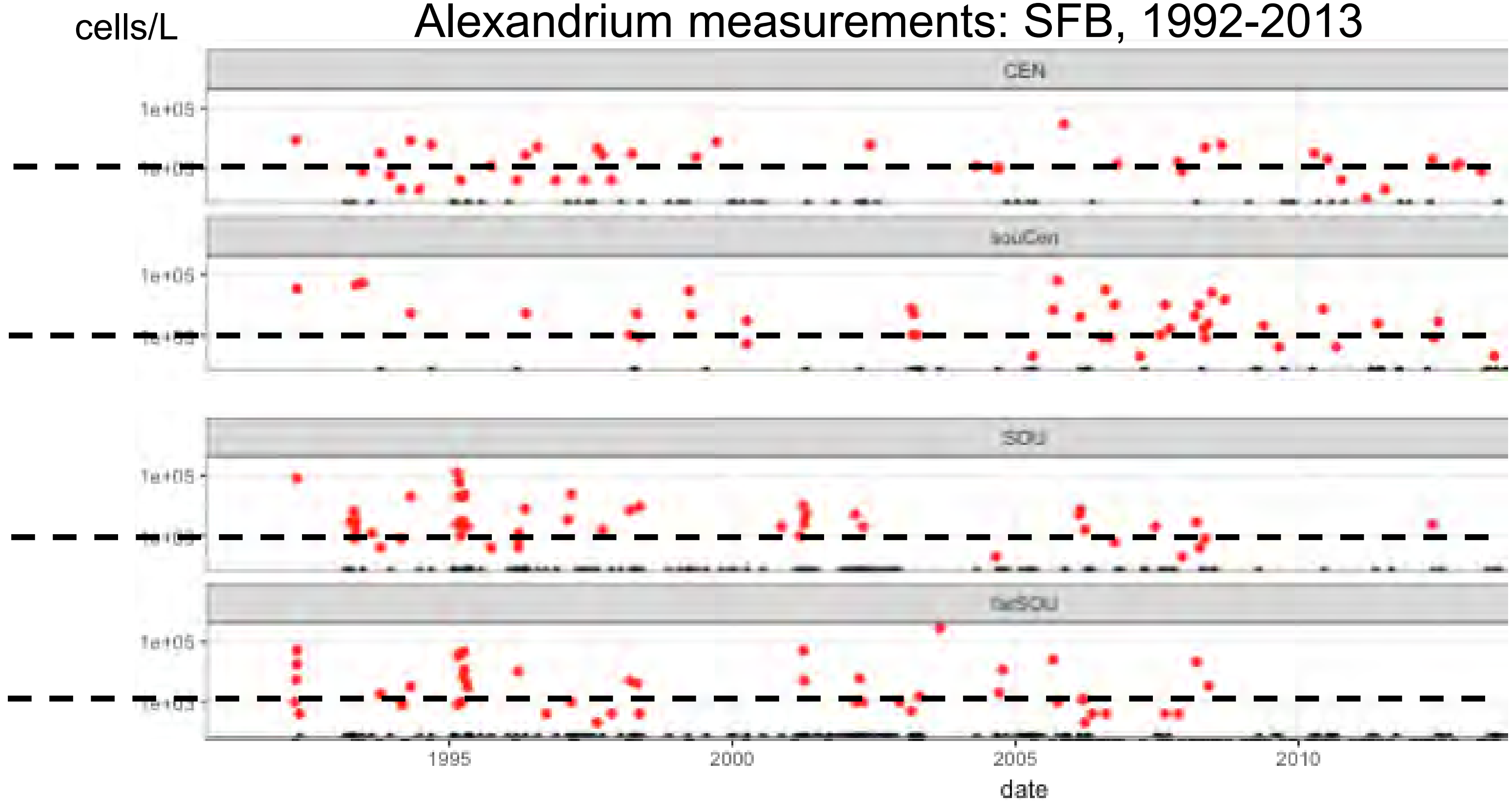
…*Alexandrium* reach non-trivial densities
- comparable to coastal CA events (~10^4-10^5 cells / **Liter**)
- but comprise small proportion of overall biovolume



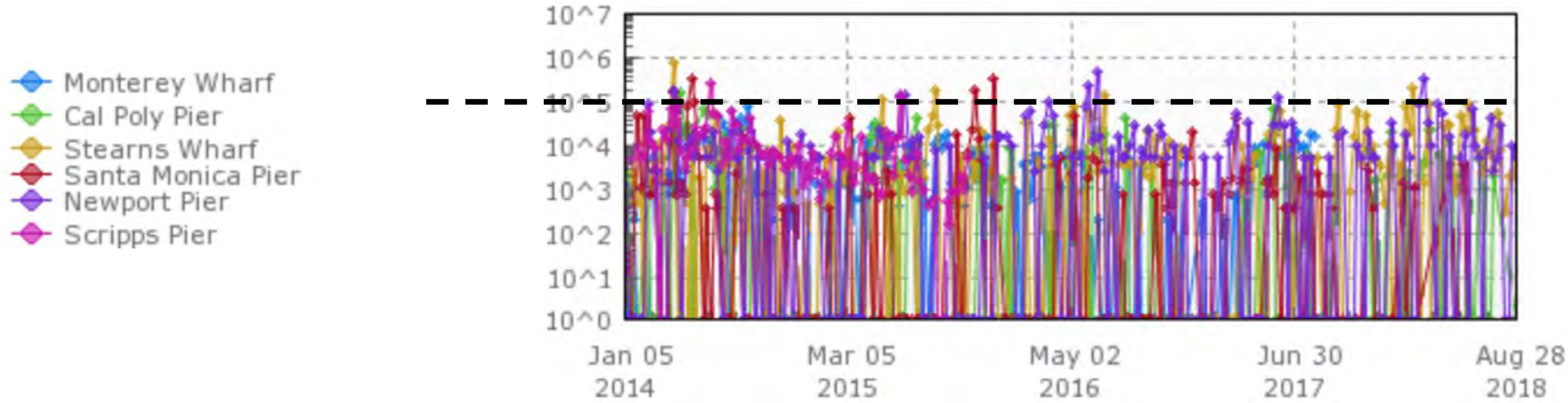
Alexandrium measurements; Coastal CA sites



Alexandrium measurements: SFB, 1992-2013

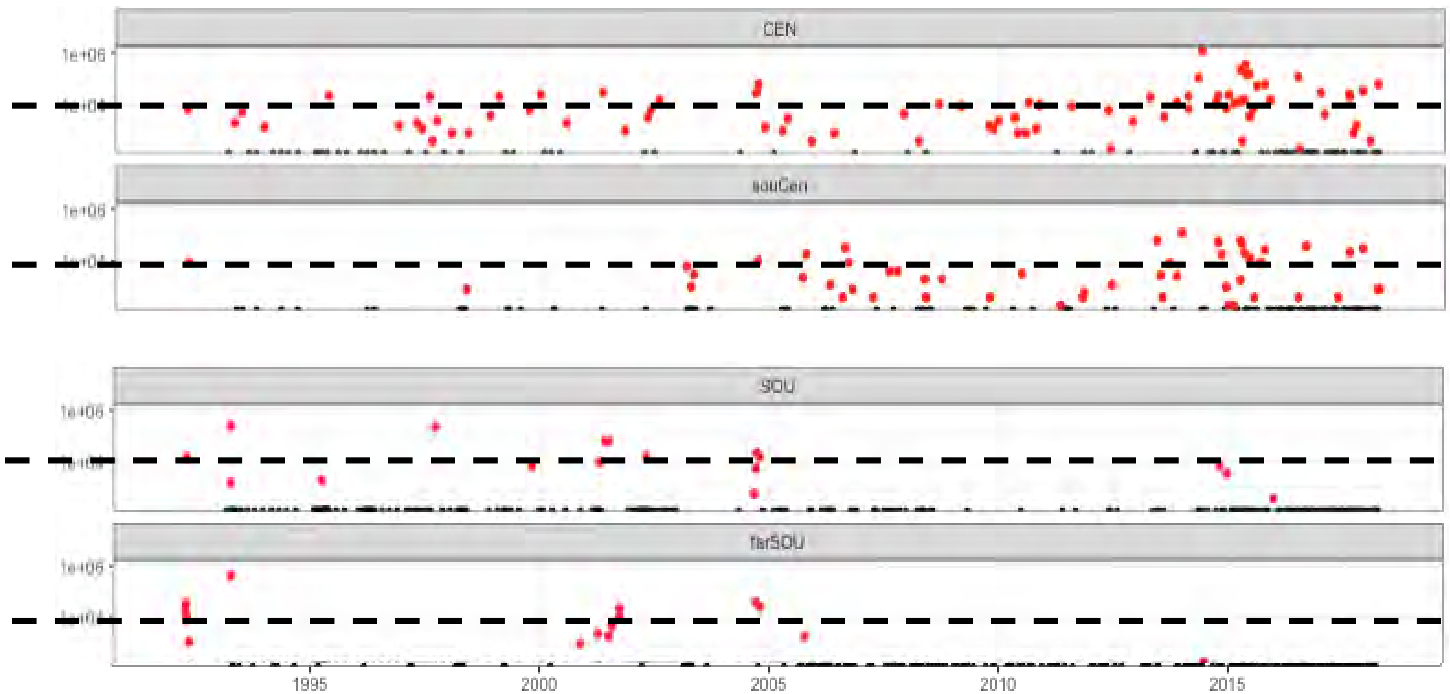


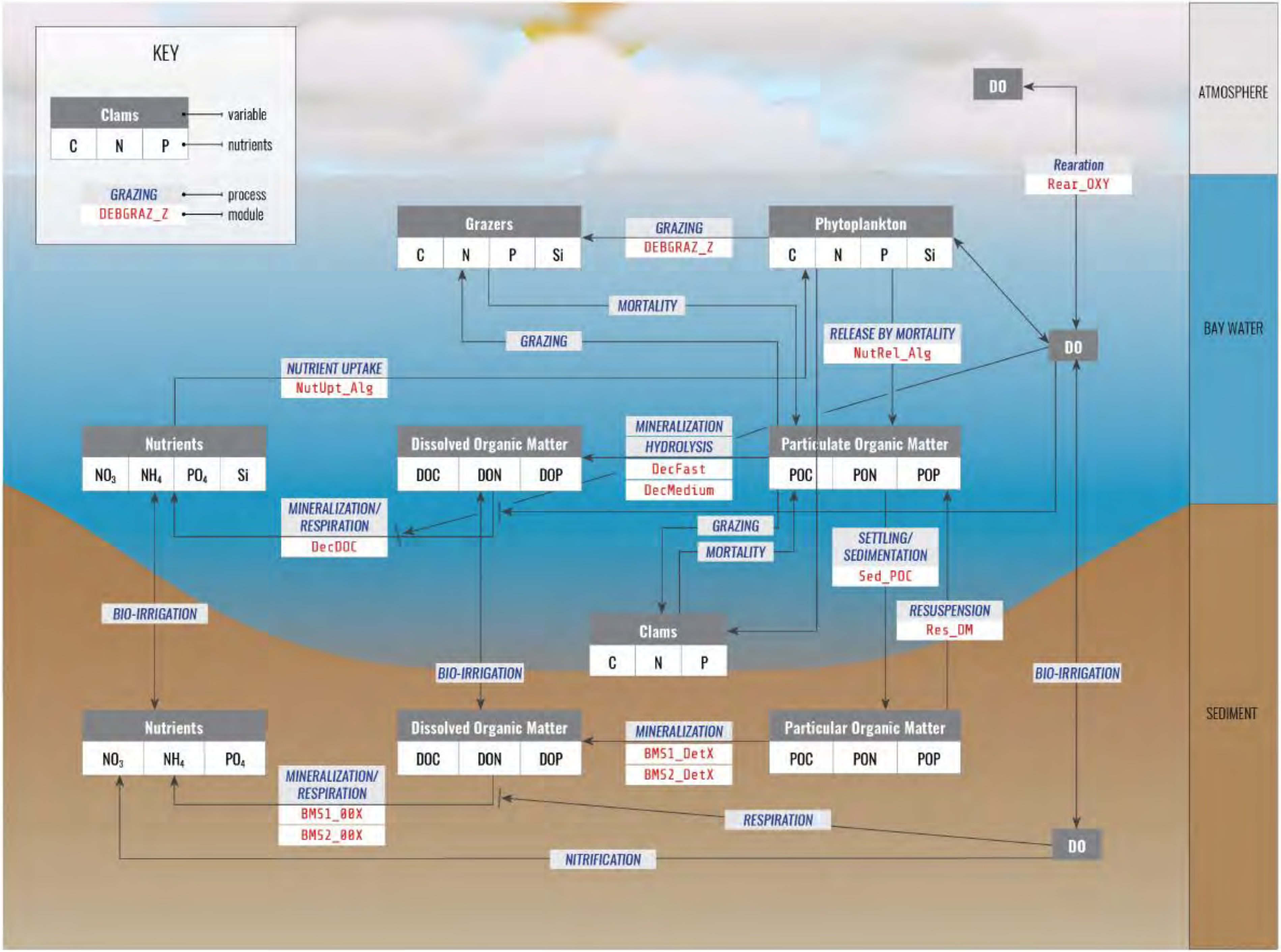
Pseudo-nitzchia: Coastal CA sites, Jan2014-Aug2018



cells/L

Pseudo-nitzchia: SFB, 1992-2013

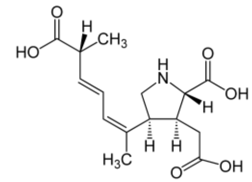




KEY
Clams
variable
C
N
P
nutrients
GRAZING
process
DEBGRAZ_Z
module
ATMOSPHERE
BAY WATER
SEDIMENT
DO
Rearation
Rear_OXY
Grazers
C
N
P
Si
GRAZING
DEBGRAZ_Z
Phytoplankton
C
N
P
Si
MORTALITY
GRAZING
RELEASE BY MORTALITY
NutRel_Alg
DO
NUTRIENT UPTAKE
NutUpt_Alg
Nutrients
NO_3
NH_4
PO_4
Si
Dissolved Organic Matter
DOC
DON
DOP
MINERALIZATION
HYDROLYSIS
DecFast
DecMedium
Particulate Organic Matter
POC
PON
POP
MINERALIZATION/
RESPIRATION
DecDOC
GRAZING
MORTALITY
SETTLING/
SEDIMENTATION
Sed_POC
RESUSPENSION
Res_DM
BIO-IRRIGATION
Clams
C
N
P
BIO-IRRIGATION
BIO-IRRIGATION
Nutrients
NO_3
NH_4
PO_4
Dissolved Organic Matter
DOC
DON
DOP
MINERALIZATION
BMS1_DetX
BMS2_DetX
Particular Organic Matter
POC
PON
POP
MINERALIZATION/
RESPIRATION
BMS1_OOX
BMS2_OOX
RESPIRATION
DO
NITRIFICATION

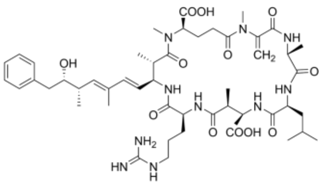
Example Harmful Algal Bloom (HAB) forming species and toxins

Domoic Acid
(Amnesic Shellfish Poisoning)



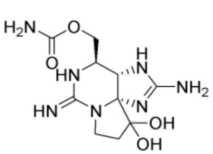
Pseudo-nitzschia spp.

Microcystin toxins
(hepatotoxin)



Microcystis spp.

Saxitoxin
(Paralytic Shellfish Poisoning)

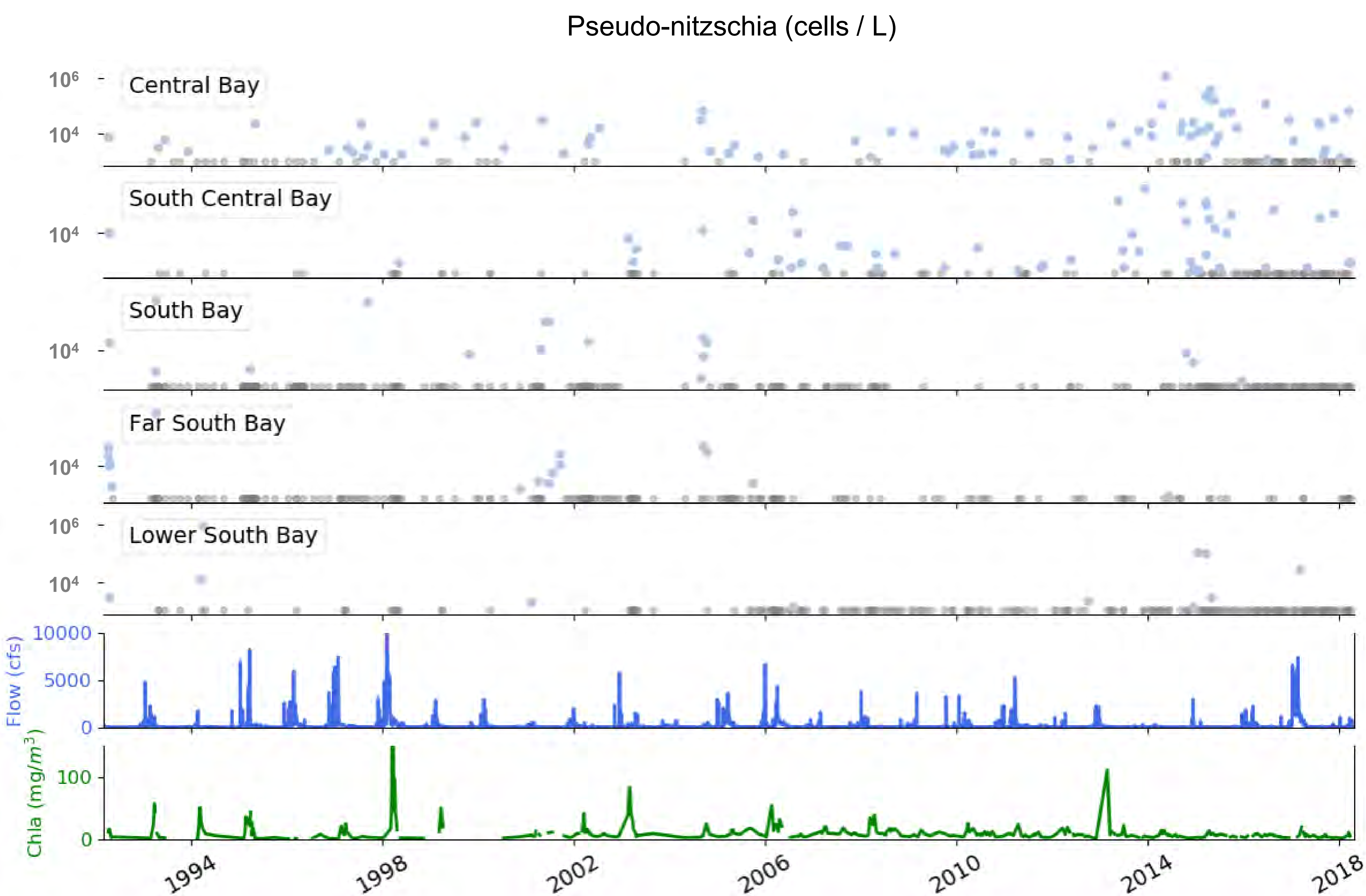


Alexandrium spp.

When are toxins produced?

When they are stressed…e.g.,

- Salinity, Temperature
- Nutrients (e.g., ± P, - Si, ±N)
- Light conditions



Pseudo-nitzschia (cells / L)
Central Bay
South Central Bay
South Bay
Far South Bay
Lower South Bay
10^6
10^4
Flow (cfs)
10000
5000
0
Chla (mg/m^3)
100
0
1994
1998
2002
2006
2010
2014
2018

NMS Modeling Focus Areas