DELTA

Regional Monitoring Program

Delta RMP Nutrient Symposium

Status & Trends in Nutrient Studies

Status & Trends in Nutrient Studies

10:00 to 10:05
Opening Remarks
Janis Cooke, Central Valley Regional Water Quality Board

10:05 to 10:30
Filing in the Blanks: Nutrient Data Gaps and Special Studies in the Delta
Dylan Stern, Delta Stewardship Council

10:30 to 11:05
Sacramento River Nutrient Studies
Lisa Thompson, Regional San

11:05 to 11:55
Nutrients, Phytoplankton, and Harmful Algal Bloom Research by the U.S. Geological Survey
Tamara Kraus and Keith Bouma-Gregson, USGS

11:55 to 12:20
Expanding the Spatial and Seasonal Research on Delta Cyanobacterial Harmful Algal Blooms
Ellen Preece, Robertson-Bryan, Inc.

Opening Remarks

JANIS COOKE, CENTRAL VALLEY REGIONAL WATER QUALITY BOARD

STATUS & TRENDS IN NUTRIENT STUDIES, 10 TO 10:05 AM

DELTA
Regional Monitoring Program

Filing in the Blanks: Nutrient Data Gaps and Special Studies in the Delta

DYLAN STERN, DELTA STEWARDSHIP COUNCIL

STATUS & TRENDS IN NUTRIENT STUDIES, 10:05 TO 10:30 AM

September 2022

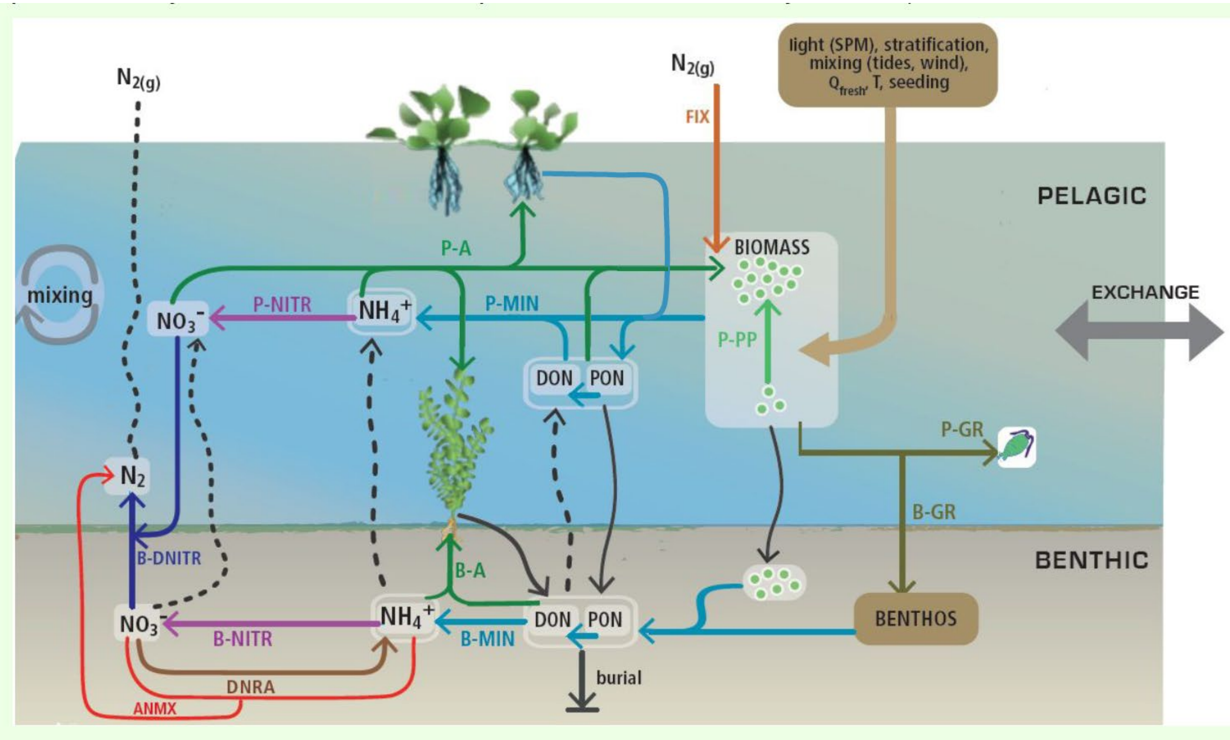
Filling in the blanks: nutrient data gaps and special studies in the Delta

Dylan Stern
Program Manager I
Delta Science Program

Delta Science Program
DELTA STEWARDSHIP COUNCIL

What is the deal with nutrients in the Delta?

- Paradox of nutrients in the Delta
  - Plenty of nutrients – anthropogenic sources
  - No eutrophication
  - Low phytoplankton
- Water quality problems related to nutrients in the Delta impacting **food webs, habitat quality and water management**
  - HABs and their toxins
  - Non-native invasive aquatic macrophytes
  - Low DO
  - Low phytoplankton
- **Is there a water quality problem and are nutrients contributing to the problem?**



Senn et al. 2020

Contents of Talk

- A brief history
- Delta Nutrient Stakeholder & Technical Advisory Group
- “Operation Baseline” pilot studies
- “Operation Baseline” Phase 2
- Competitively Funded nutrient/HABs work
- Science Action Agenda
- Progress Summary
- Data Gaps?
- Future Work
- HABs Workshop!

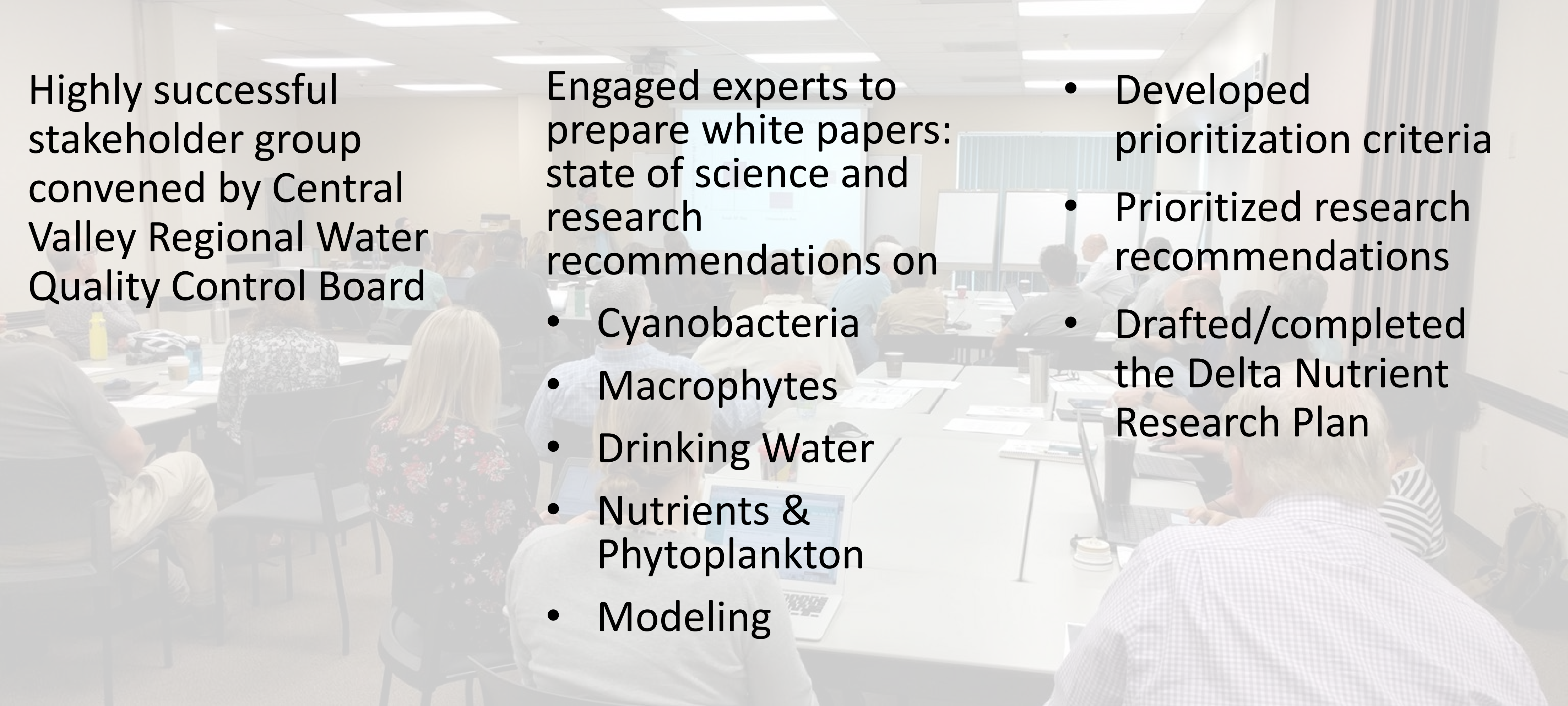
A brief history

2010-present

12 years

- **2010** Permit regulating Regional San for ammonia and nitrate
- **2013** Delta Plan recommendation: the Central Valley Water Board develop a study plan for the development of water quality objectives for nutrients in the Delta.
- **2014** CV Regional Board's Strategic Work Plan
- **2015-2016** Work Groups, white papers, and Stakeholder and Technical Advisory Group
- **2016-2019** Targeted Research funded by Delta Stewardship Council (Operation Baseline pilot studies), Delta RMP, SWC, and others
- **2018** Delta Nutrient Research Plan complete
- **2020** Phase I BNR Complete EchoWater Project
- **2021** Phase 2 BNR Complete EchoWater Project

Delta Nutrient Stakeholder & Technical Advisory Group



Highly successful stakeholder group convened by Central Valley Regional Water Quality Control Board

Engaged experts to prepare white papers: state of science and research recommendations on

- Cyanobacteria
- Macrophytes
- Drinking Water
- Nutrients & Phytoplankton
- Modeling

- Developed prioritization criteria
- Prioritized research recommendations
- Drafted/completed the Delta Nutrient Research Plan

Collaborators

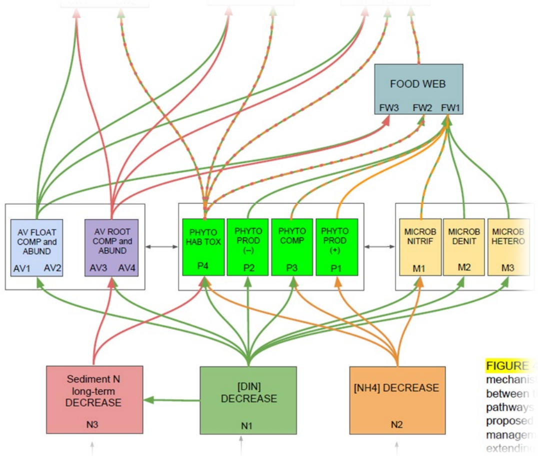
Thank you to all the collaborators!

Operation Baseline: early pilot studies

2016-2019

Operation Baseline Pilot Studies

- Conceptual Framework to identify data needs and knowledge gaps
- Response scenarios:
  - Will the response be detectable? Testable?
  - How likely is the response and at the ecosystem scale?
- **DNRP** What are the gaps in our understanding of the problem, including status and trends?



May 2018 Workshop

Conceptual Framework

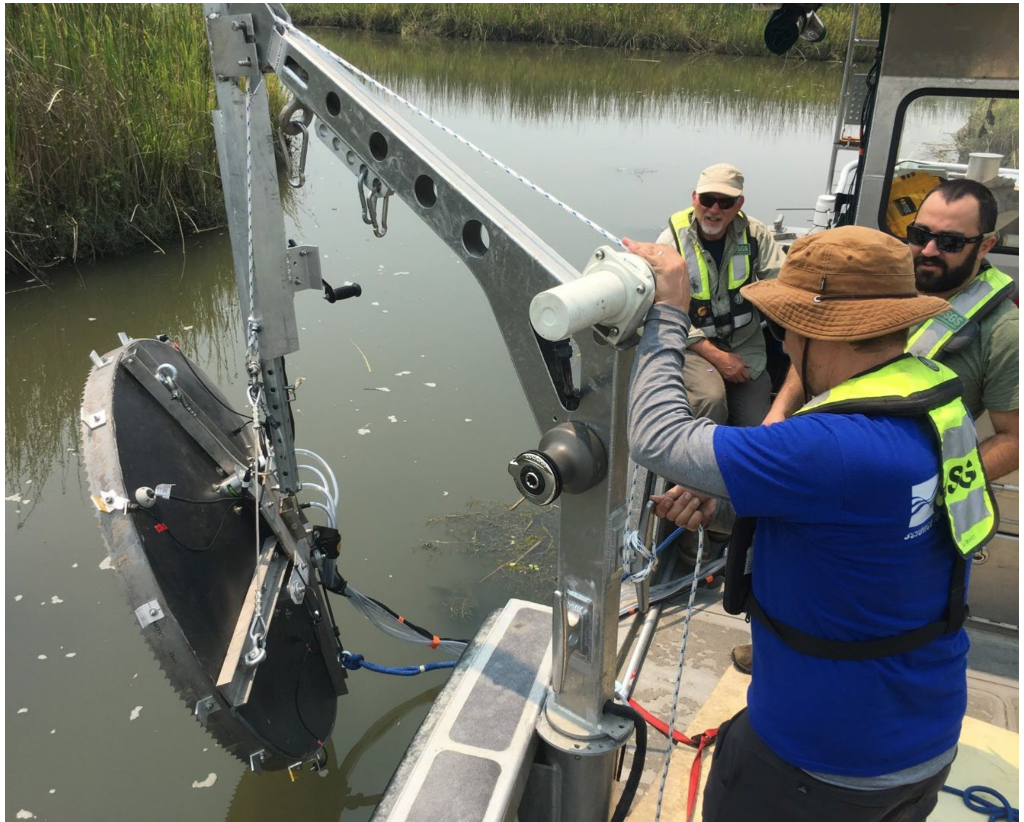
DNRP What are the gaps in our understanding of the problem, including status and trends?

		T1			T2																T3	
	Data / Knowledge Gap	Nutrients			Phytoplankton (incl., HABs)							Microbes				Invasive Aquatic Vegetation					FW	
		N1	N2	N slow	P1a	P1b	P2a	P2b	P12 slow	P 3 a, b	P3 slow	M1	M2	M3	M slow	AV1	AV2	AV3	AV4	AV slow	FW 1b	Necessary Gap-Fills, Dependencies
G1	Quantify ambient nutrient concentrations (higher spatial/temporal resolution, additional habitats)																					
G2	Quantify nutrient transformation rates, space/time (mineral., nitrif., denitrif., uptake)																					G 1,18
G3	Quantify sediment nutrient pools, availability and fluxes																					
G4	Phytoplankton Biomass: discrete + high frequency data; align with nutrient+physical data																					G 1,18
G5	Phytoplankton Community: High&low resolution (space,time): composition, densities, biovolume																					G 1,18
G6	Quantify phytoplankton primary production rates + nutrient requirements alongside other drivers																					G 1,18
G7	Quantify phytoplankton (and microbe) loss rates to grazers (planktonic, benthic)																					G 4,5
G8	Quantify HA abundance/toxins relative to nutrient field/other drivers, incl. in-situ+molecular																					G 1,18
G9	Characterize microbial assemblage (space,time) relation to nutrients, transformation rates, other drivers																					G1,2,18
G10	Quantify contribution of microbial community to the foodweb.																					G 4-7,9
G11	Characterize interactions among primary producers (phyto, AVs, HABs, microbes)																					G 1-5,8-9,15,18
G12	Identify nutrient thresholds affecting AV growth by species (concentrations, form, timing)																					G1,3
G13	Quantify AV nutrient demand to determine effects on water column nutrient concentrations																					G1,2,3
G14	Monitor AV biomass and species composition over space/time																					
G15	Zooplankton sampling at relevant space/time freq, changes to carbon/energy delivery to food web																					G1-7,18
G16	Characterize food source/quality consumed/assimilated by zooplankton and effects on abundance																					
G17	Quantify wetland nutrient demand, transformation rates, net exchange with adjacent habitats																					
G18	Integrated collection of physical data to support multiple investigations (temperature, salinity, light, velocity/flow)																					G 1-3,12-15,18
G19	Develop hydrodynamic/biogeochemical models: test hypotheses, exp'l design, synthesize results																					
G20	Maximize coordination: data + analysis across entities (monitoring, studies, modeling, synthesis																					
G21	Develop/Validate techniques to further enable cost-effective monitoring (discrete ⟷*in situ* | HF⟷RS)																					G 1,3-5,14,18

*AV, Aquatic Vegetation; HAB, Harmful algal blooms; phyto, phytoplankton; FW, Food web; HF, high frequency, RS: remote sensing

Priority

- very high
- high
- moderate
- not relevant



Operation Baseline Pilot Studies

Developing New methods

HF ammonium sensor and fluoroprobe for phytoplankton	Benthic flux chamber "sediment Roomba"	Isotope analyses forensic investigation	Nutrient dynamics modeling

DNRP Data Gaps

Sufficient data coverage over space & time	Sediment flux	Transformation rates	Improve linked models

Operation Baseline Pilot Studies

- Measuring rates of nutrient transformation
  - High frequency measurements
  - Bay-Delta Scale
- **DNRP** What are the gaps in our understanding of the problem, including status and trends?
- **DNRP** What are the important processes that transform nutrients in the Delta and what are the rates at which these processes occur?

Operation Baseline Pilot Studies

- Wetland nutrient cycling
  - Nitrification
  - Uptake by organisms
  - Denitrification
  - Benthic flux
- Tidal flux; nutrient spatial flux over broader spatial/temporal scales
- Phytoplankton taxonomy (fluoroprobe)

- **DNRP** What are the spatial and temporal trends in nutrient-related effects in the Delta:
  - Diatom blooms and adequate phytoplankton production
- **DNRP** How do nutrient concentrations, loads, and cycling affect the growth of aquatic macrophytes?

Diatoms | Dinoflagellates | Chlorophytes | Cryptophytes | Cyanobacteria

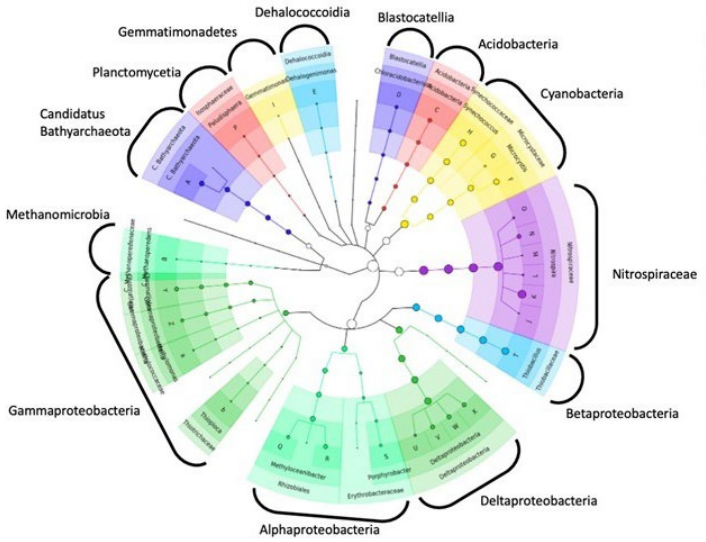
Credit: Alex Parker, Cal Maritime

Operation baseline special studies “phase 2” 2019-present

Directed Action Studies 2019

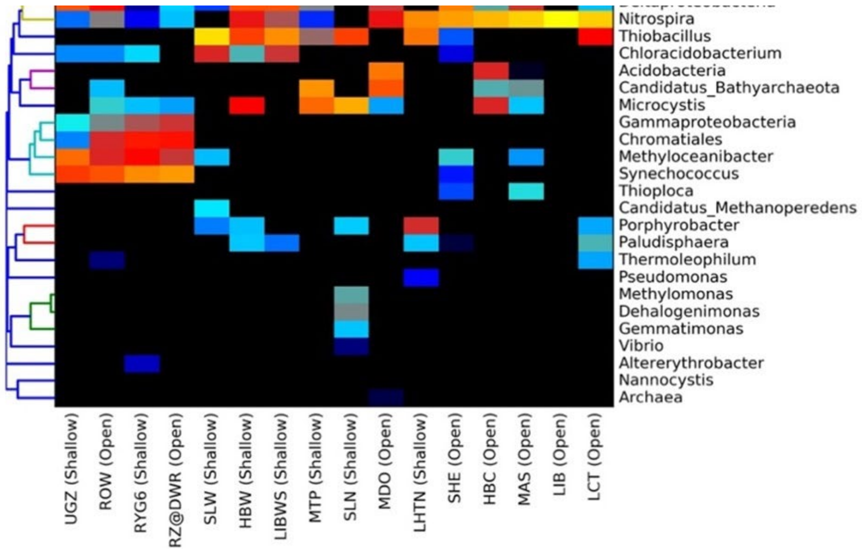
- **USGS**: use new technologies to better understand changes in nutrients and shifts in phytoplankton communities using fixed station and boat measurements
- **USGS and VIMS**: Modeling work in collaboration with DWR
- **BSA Environmental Services, Inc**: analyzing the tiniest phytoplankton, picophytoplankton
- **DNRP** What are the main factors affecting potential nutrient-related effects and how does the relative importance of these factors vary with space and time?

Competitive PSN Projects awarded 2018-2021



1. Assessing sediment nutrient storage and release in the Delta: linking benthic nutrient cycling to restoration, aquatic vegetation, phytoplankton productivity, and harmful algae
    - Tomo Kurobe/Tamara Kraus (2018/2019)

- **DNRP** What are the important processes that transform nutrients in the Delta and what are the rates at which these processes occur?



Competitive PSN Projects awarded 2018-2021

2. Harmful algal blooms and cyanotoxins in the Delta: occurrence, distribution, trends and environmental drivers

- Tamara Kraus/Angela Hansen/Brian Bergamaschi (2020/2021)

- **DNRP** What are the spatial and temporal trends in nutrient-related effects in the Delta:
  - Diatom blooms and adequate phytoplankton production
  - Cyanobacteria blooms and toxins
  - Low dissolved oxygen
- **DNRP** What is the relative importance of nutrients versus other factors in promoting cyanobacteria dominance and/or cyanotoxin production in the San Francisco Bay-Delta?

Conceptual Framework Data Gaps

DNRP What are the gaps in our understanding of the problem, including status and trends?

		T1			T2																T3	
		Nutrients			Phytoplankton (incl., HABs)							Microbes				Invasive Aquatic Vegetation					FW	
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Priority

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- moderate
- not relevant

2017-2021 Science Action Agenda Progress Summary

- **Science Action 4A:** Implement studies to better understand the ecosystem response before, during, and after major changes in the amount and type of effluent from large point sources in the Delta including water treatment facilities
- "Significant Progress": 19 Science Actions
- Feedback during data collection:
    - Importance of measuring ecosystem response to reduced nutrients in Delta
    - Need to examine stressors on benthic and detrital food webs; develop response curves
    - Barriers: funding, coordinated monitoring/science infrastructure
    - Data needs: continuous data for inorganic nitrogen

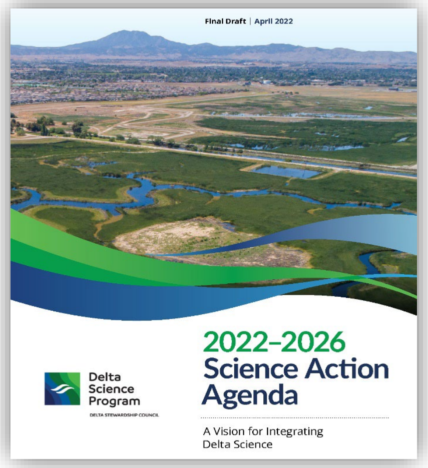
What about the future?

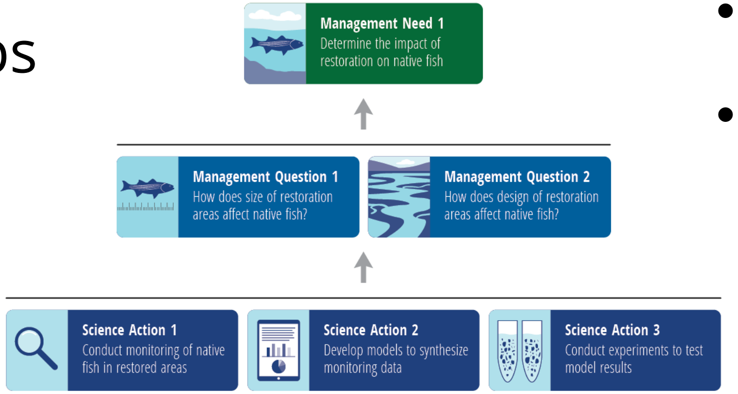
What is the 2022-2026 Science Action Agenda?

A roadmap for science to inform decision-making in the Delta

Addresses key challenges:

- complexity of the Delta
- rapidly changing system
- limited resources
- multiple interest groups and science needs





A four-year science agenda for the Delta that:

- prioritizes and aligns science actions to inform management,
- is collaboratively developed,
- builds science infrastructure, and
- identifies major gaps in knowledge

2022-2026 Science Action Agenda

- **Science Action 5C:** Determine how environmental drivers (e.g., nutrients, temperatures, water residence time) interact to cause HABs in the Delta, identify impacts on human and ecosystem health and well-being, and test possible mitigation strategies
- Management Need 2: Enhance monitoring and model interoperability, integration, and forecasting
  - Management question: What water quality data (e.g., contaminant bioavailability and toxicity, nutrients, water temperature) should be prioritized to add to Delta ecosystem models to evaluate future ecosystem and management changes?
  - Science Action 2B: Develop a framework for monitoring, modeling, and information dissemination in support of operational forecasting and near real-time visualization of the extent, toxicity, and health impacts of harmful algal blooms (HABs)
- Management Need 3: Expand multi-benefit approaches to managing the Delta as a social-ecological system
  - Management question: How can factors (e.g., water flow and residence time, turbidity, water temperature, nutrient concentrations) be managed to encourage productivity in lower trophic food webs while also preventing harmful algal blooms, taste and odor issues, and macrophyte growth?
  - Management question: How do water quality and the multiple elements that contribute to water quality change under different management scenarios, and where is coordinated monitoring needed?

DNRP Data Gaps and Information Needs

DNRP Is there a water quality problem?

- Significant progress
- **Needs:** continue high-frequency map data collection

DNRP Are nutrients contributing to the problem?

- Some progress
- **Needs**: aquatic macrophytes; nutrient transformation rates

DNRP Can nutrient management help address or ameliorate the problem?

- Some Progress
- **Needs**: continue high-frequency map data collection

DNRP Are particular hydrologic, biological, meteorological, or biogeochemical conditions needed for nutrient management to be effective?

- Little Progress
- **Needs**: effects (on phytoplankton, HAB's/toxins, macrophytes) of management actions

DNRP How many anticipated future Delta conditions affect the nutrient-related problem?

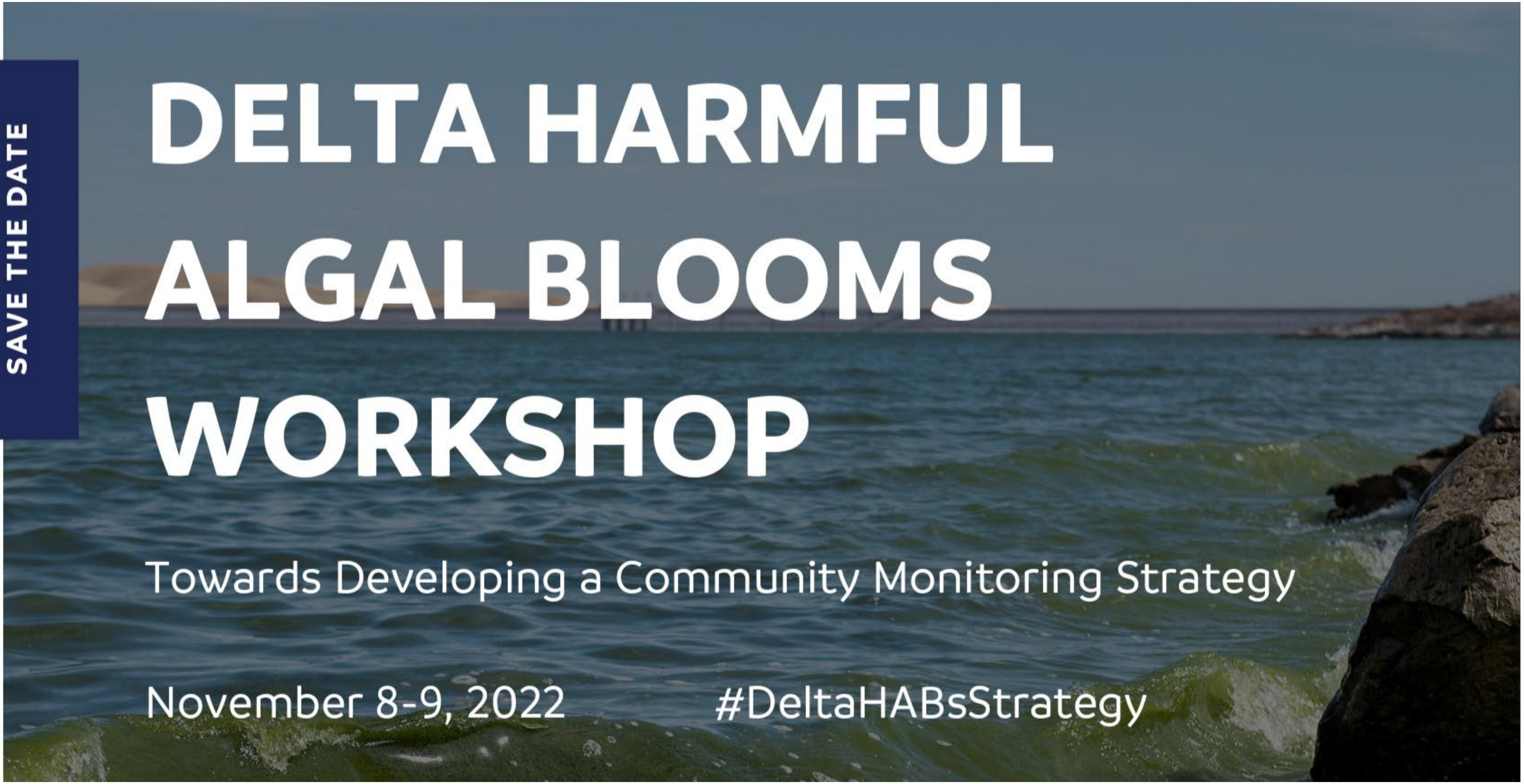
- Little Progress
- **Needs**: continue to improve linked hydrologic/ biogeochemical models for nutrient management under climate change, habitat restoration, etc.

DNRP What management of nutrients is needed to meet beneficial uses now and/or in the future?

- Little Progress
- **Needs**: targeted special studies and modeling

What’s next?


Specific Science Needs
• Delta-specific HABs effects, transport, and drivers to inform management
• 2022-2026 SAA Implementation
• DNRP Implementation
Synthesis!
More data!
ISB Monitoring Enterprise Review (MER) Recommendations
HABs Workshop


SAVE THE DATE
DELTA HARMFUL ALGAL BLOOMS WORKSHOP
Towards Developing a Community Monitoring Strategy
November 8-9, 2022
#DeltaHABsStrategy

Thank you

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Sacramento River Nutrient Studies

LISA THOMPSON, REGIONAL SAN

STATUS & TRENDS IN NUTRIENT STUDIES, 10:30 TO 11:05 AM

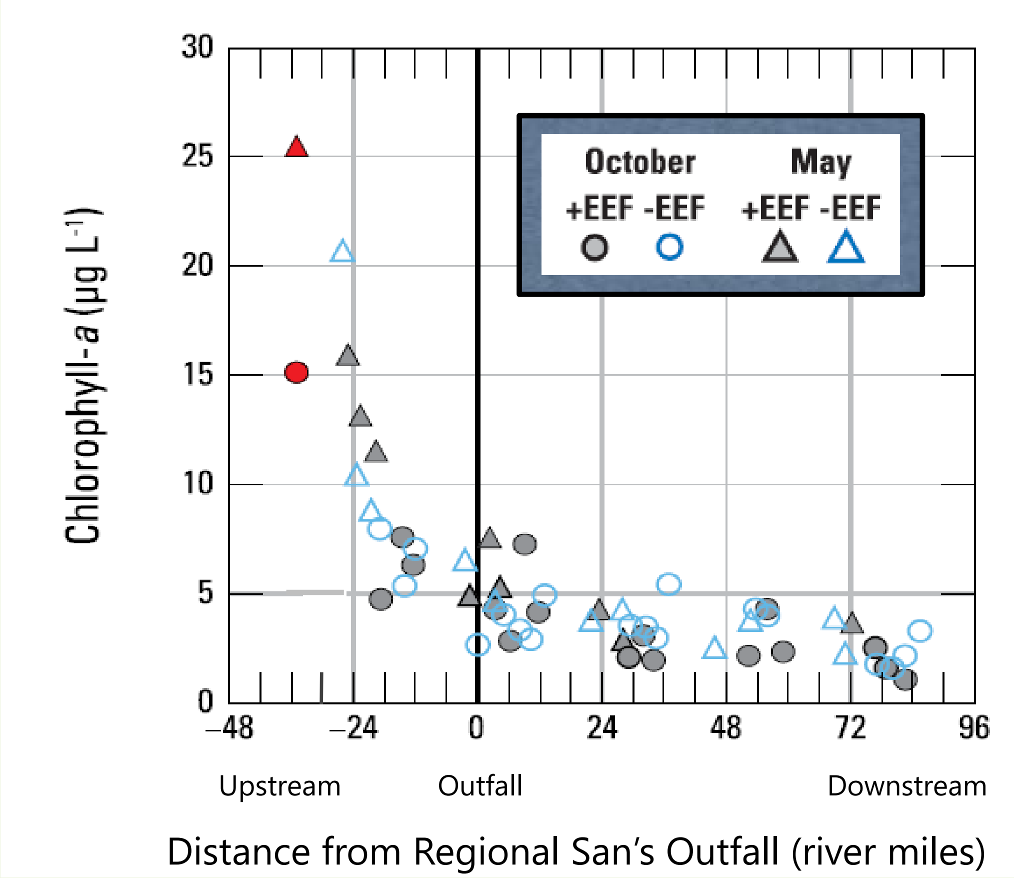
Sacramento River Nutrient Change Study

Conducted by staff from Applied Marine Sciences, Environmental Science Associates, Regional San, Resource Management Associates, San Francisco State University - Estuary and Ocean Science Center, and US Geological Survey

Presentation to the Delta Regional Monitoring Nutrient Symposium, 9/27/2022

Phytoplankton biomass declines in the lower Sacramento River

- USGS experiment tracking water parcels (2013/14)
- Chl-a declined in presence and absence of wastewater
- Sacramento River in this area may be too deep, dark, and fast-flowing to support phytoplankton



Kraus et al. 2017. Limnology and Oceanography, Volume 62, Issue 3 p. 1234-1253

Study objective and design

- Will phytoplankton biomass, phytoplankton productivity, and zooplankton growth rates increase or decline when nitrogen loads from Regional San are absent in North Delta rivers?
- Monitor river conditions before and during a prolonged (48-hour) wastewater diversion in 2019
- Monitor rivers in the east Delta, where flows are slower and water depths are shallower than in the Sac. River, for two-days of wastewater-free exposure
- Measure or model all factors potentially regulating phytoplankton growth

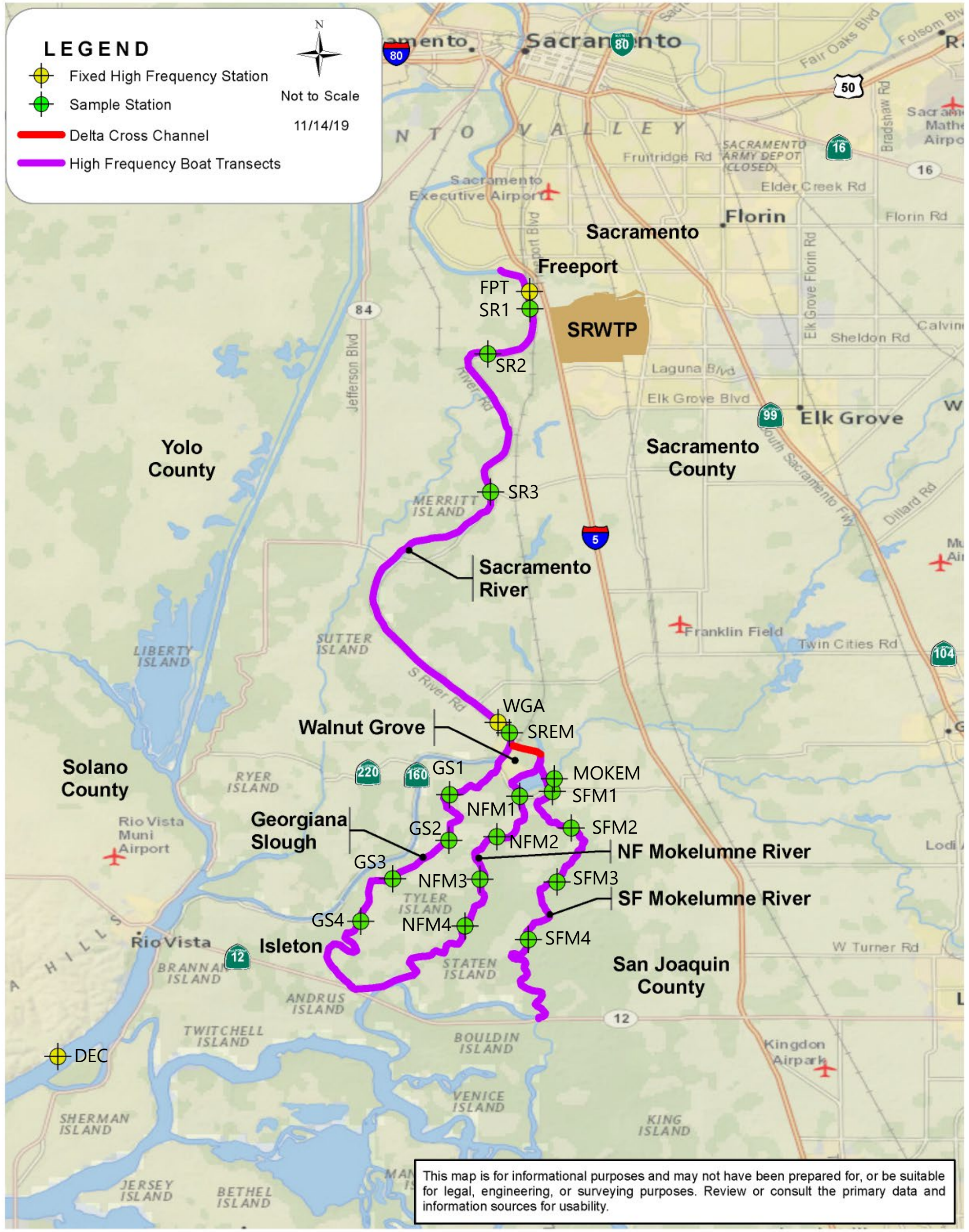
Study area

Fixed sampling sites:
(17 green dots)

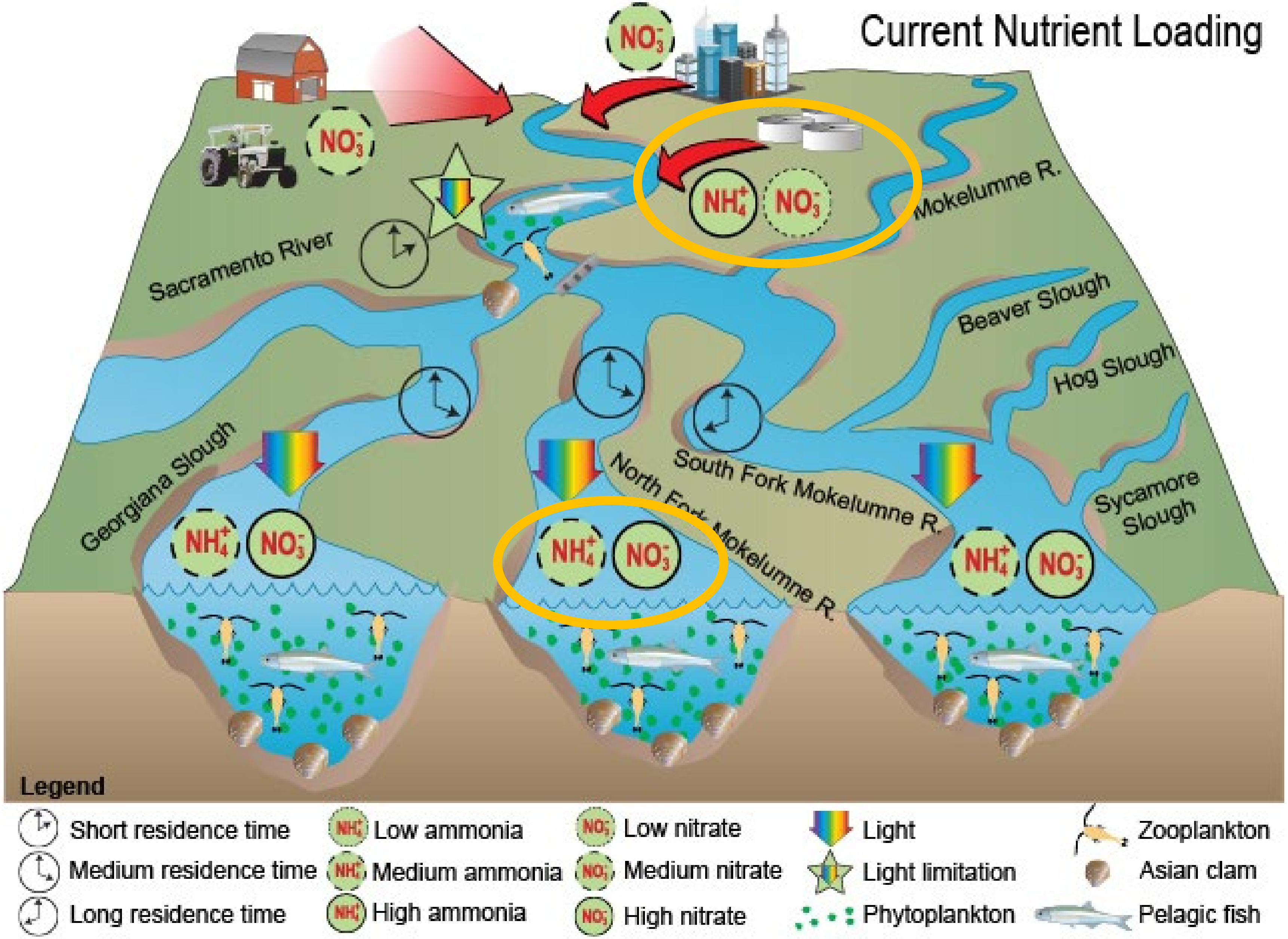
- Lower Sacramento River
- Georgiana Slough
- N. Fork Mokelumne River
- S. Fork Mokelumne River

High resolution boat mapping transects (purple lines)

High resolution water quality stations (3 yellow dots)

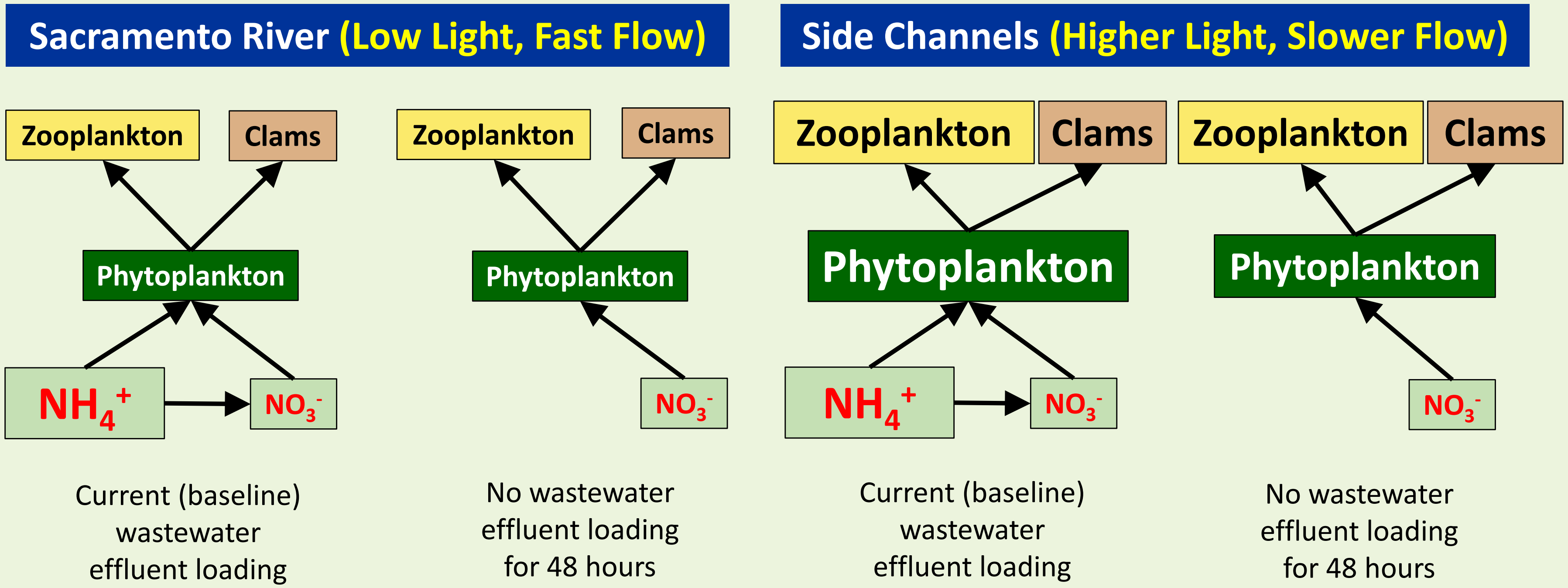


Conceptual Model - current



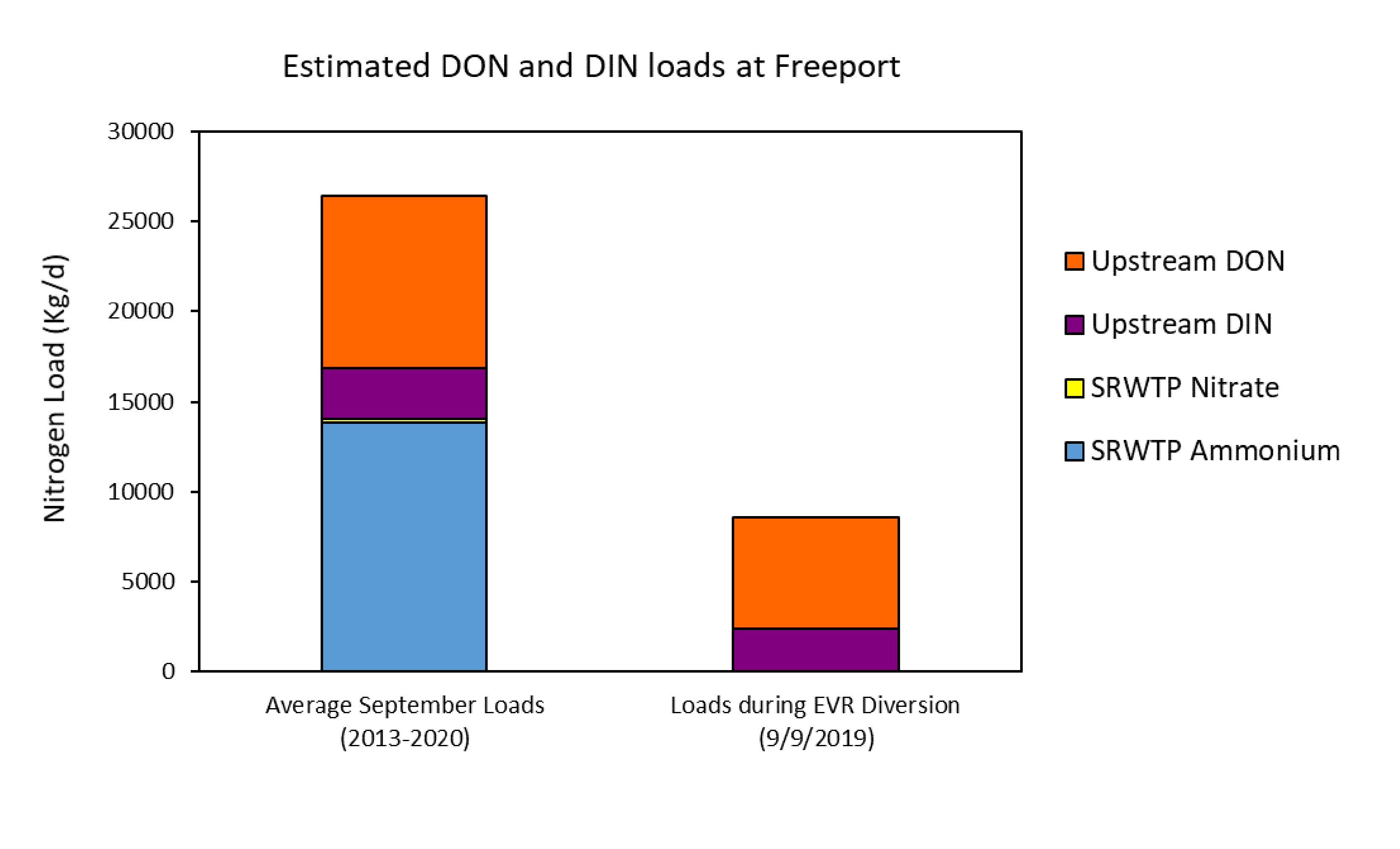
Conceptual Model - predicted

Hypothesized food web interactions in Sacramento River and Side Channels



We expected the side channels to have increased potential for phytoplankton biomass and growth

Nitrogen load in Sacramento River decreased by more than half



Methods

- Hydrodynamic (Water Flow) Modeling
- High Resolution Water Quality Boat Mapping
- Water Quality Sampling & Lab Analysis
- Plankton Enumerations
- Phytoplankton Carbon Uptake
- Zooplankton Growth
- Clam Collection & Analysis

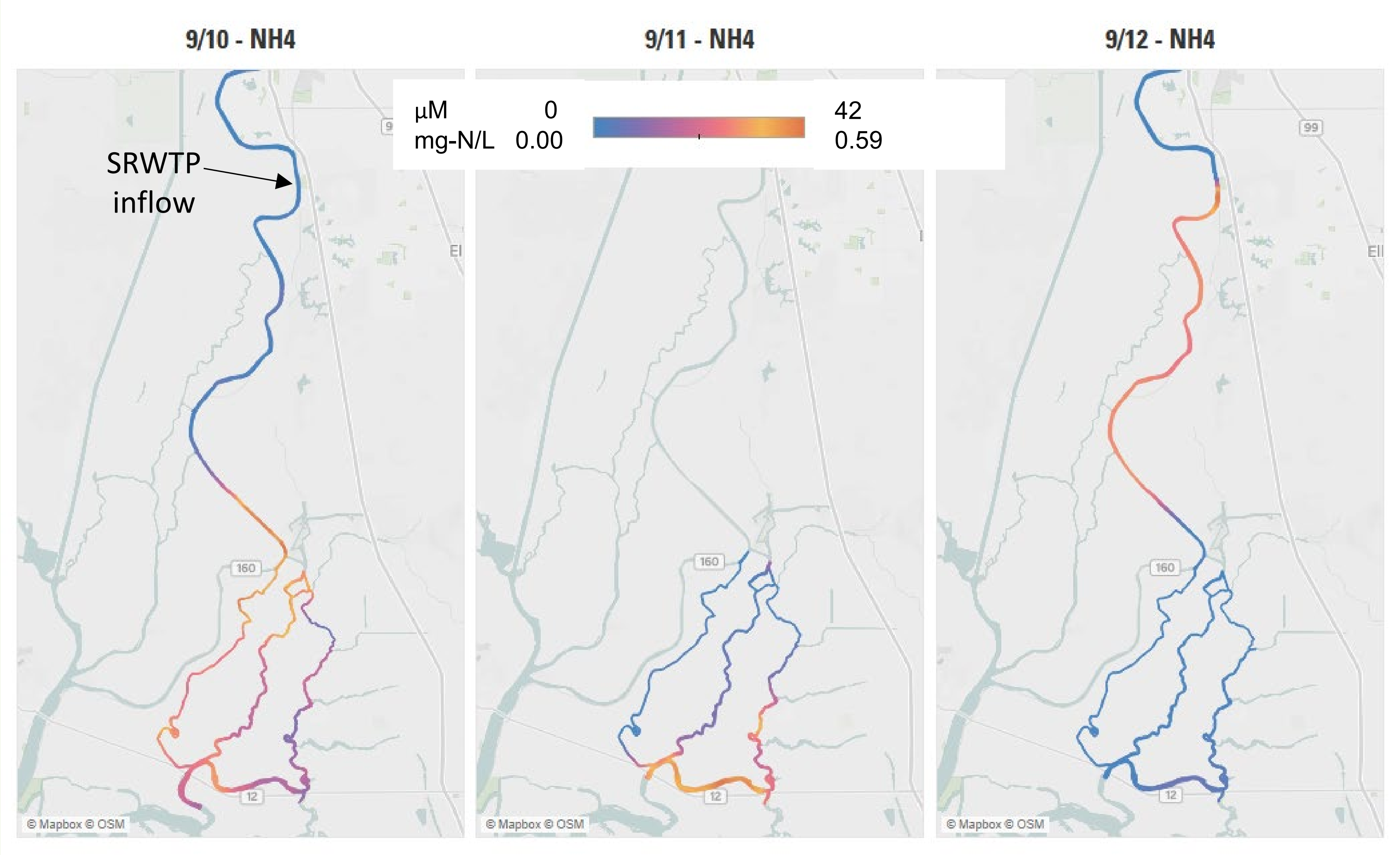
USGS Landsteiner - mapping

USGS Mudslinger – Georgiana Slough

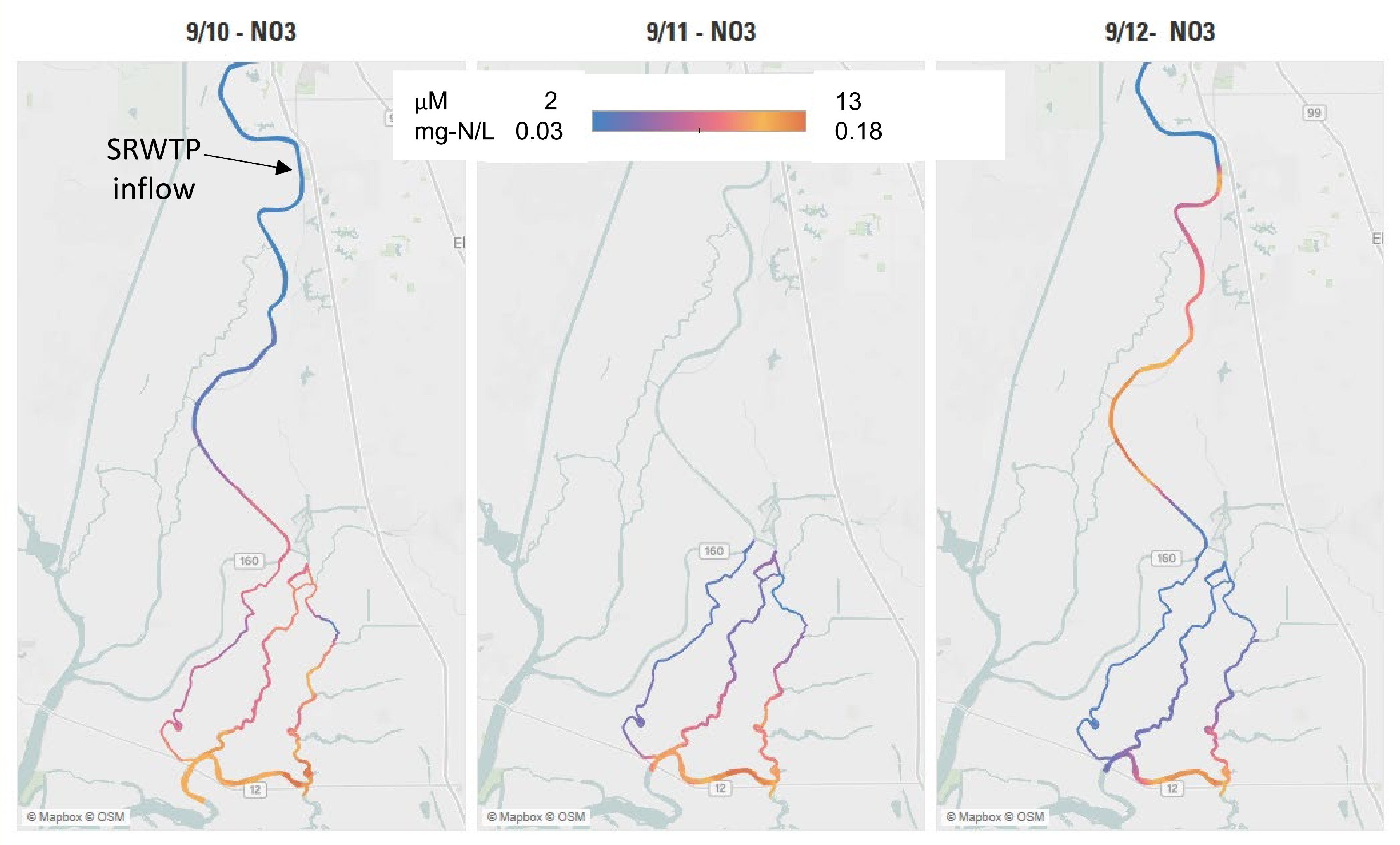

SFSU Twin Vee – S. Fork Mokelumne R.

Regional San Guardian – N. Fork Mokelumne R.

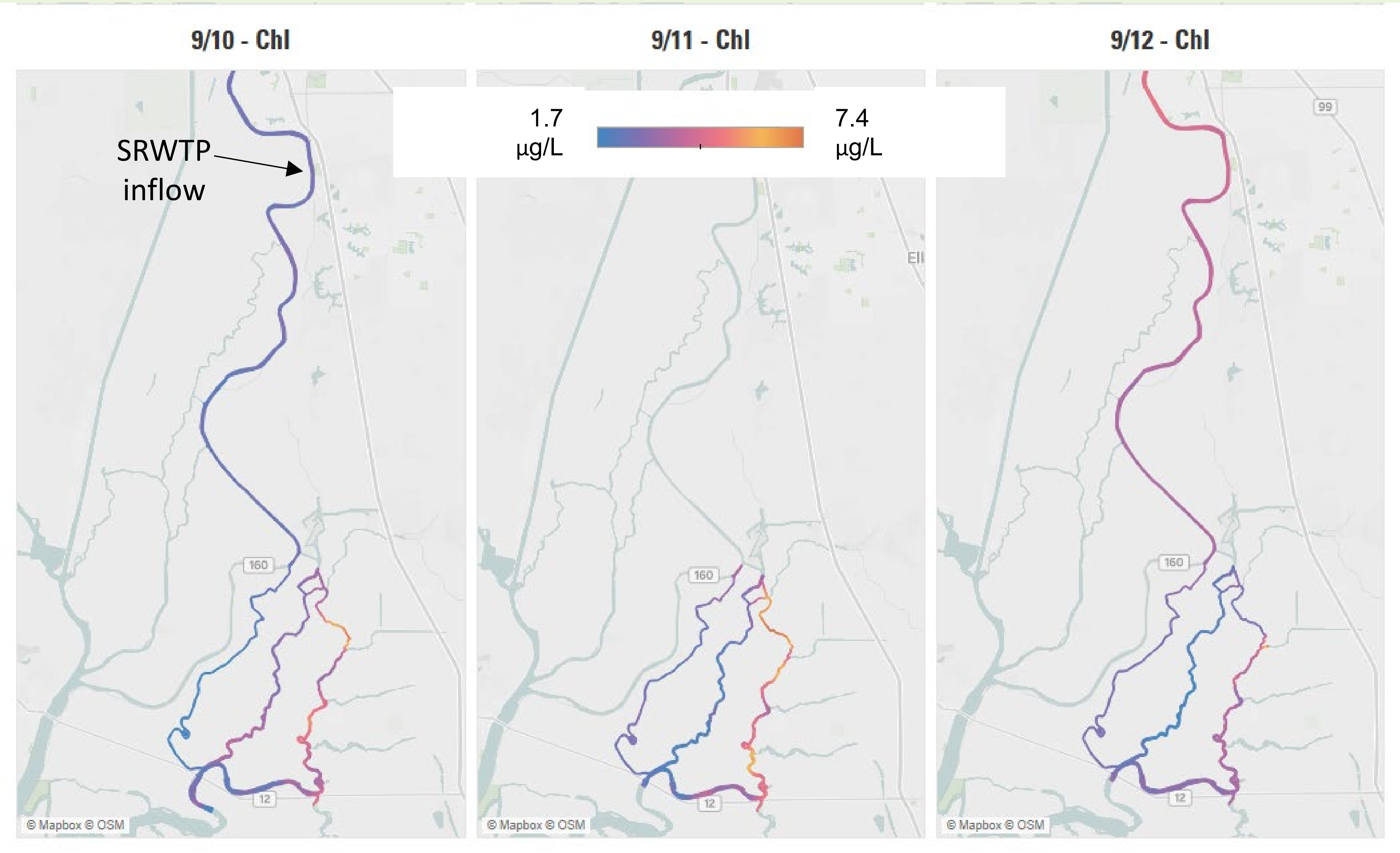
High resolution mapping showed ammonium decreased on days 2 and 3



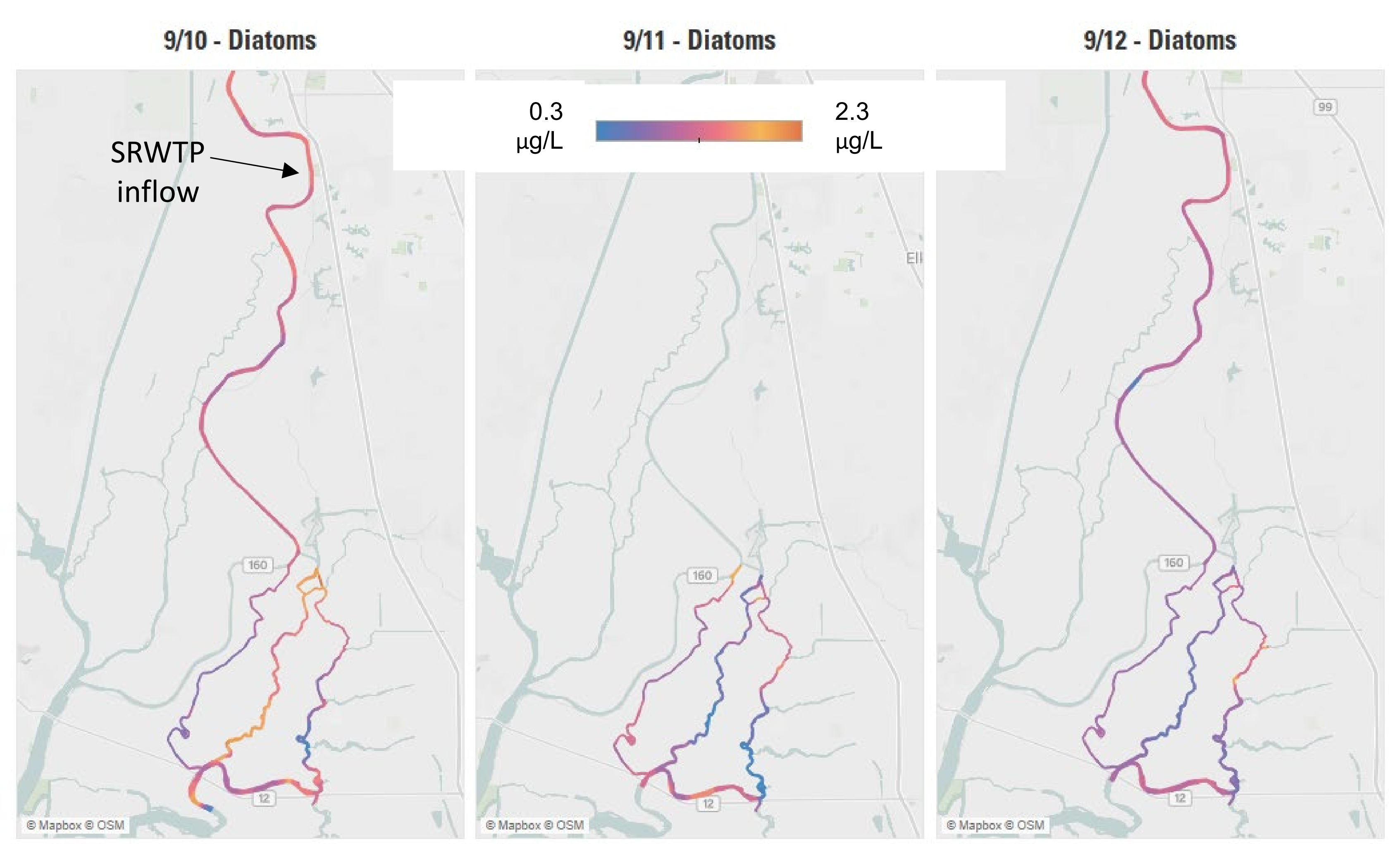
High resolution mapping showed nitrate decreased on days 2 and 3



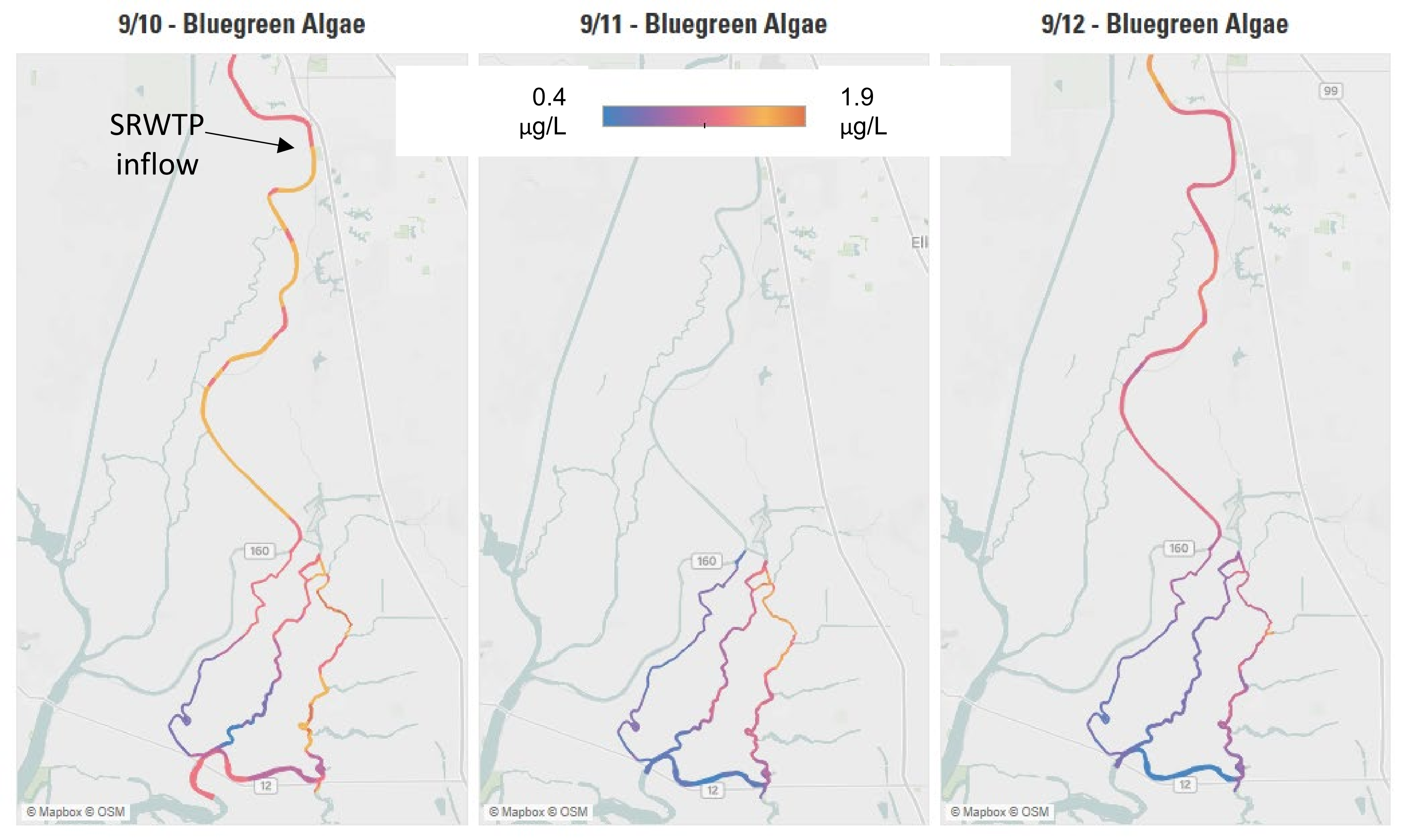
High resolution mapping showed chlorophyll-*a* concentrations changed little



High resolution mapping showed diatom concentrations decreased in the North Fork Mokelumne River



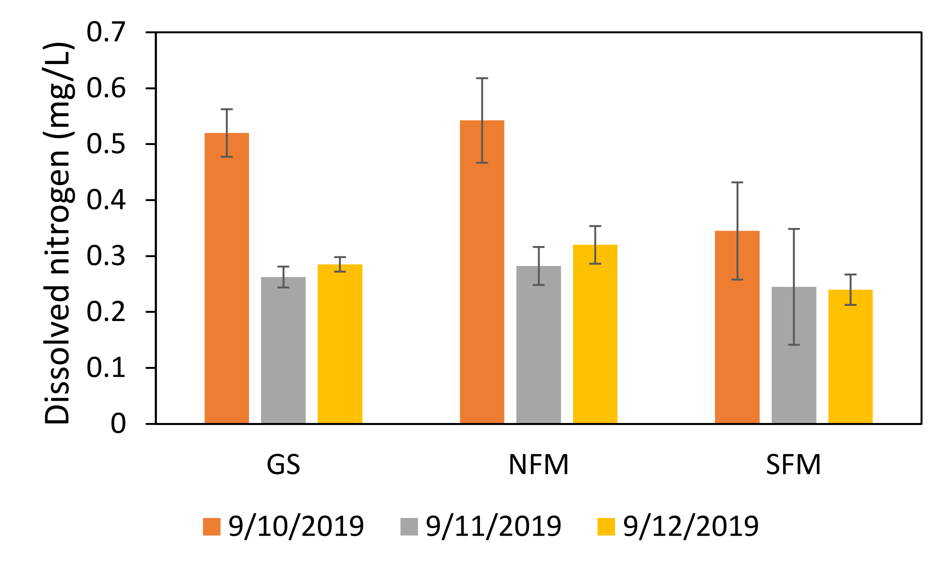
High resolution mapping showed blue-green algae concentrations decreased slightly

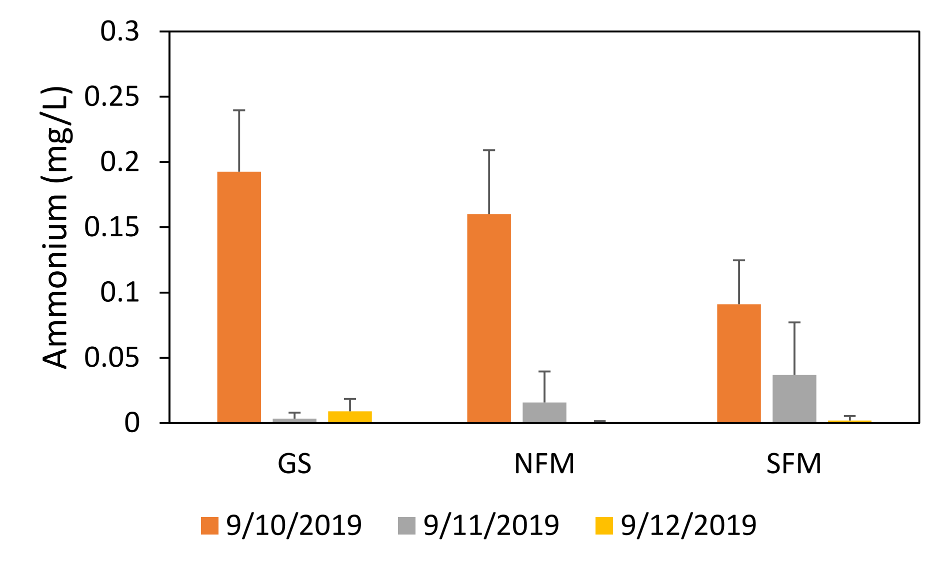


Discrete sampling also showed a decrease in concentrations of various forms of nitrogen

- Discrete water samples
- 2-factor Analysis of Variance:
  - Day (Wastewater present or absent)
  - Channel

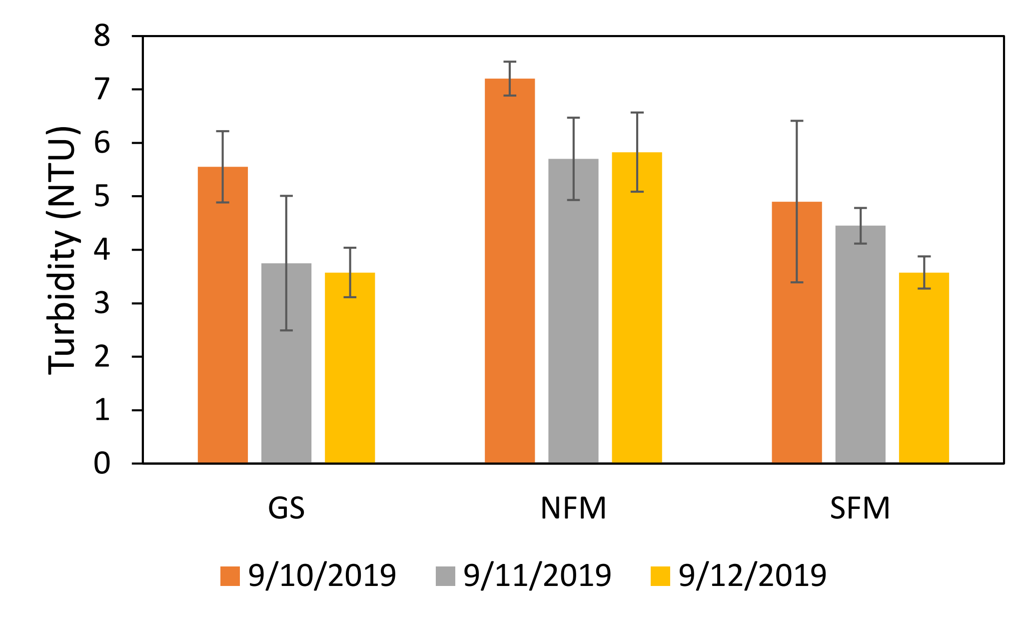
Wastewater-related





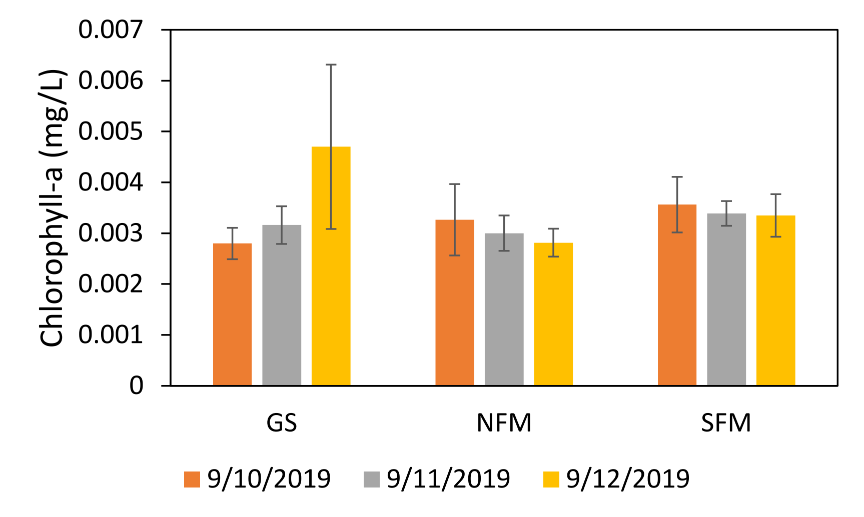
Turbidity decreased (and light availability increased), likely due to changes upstream of the treatment plant

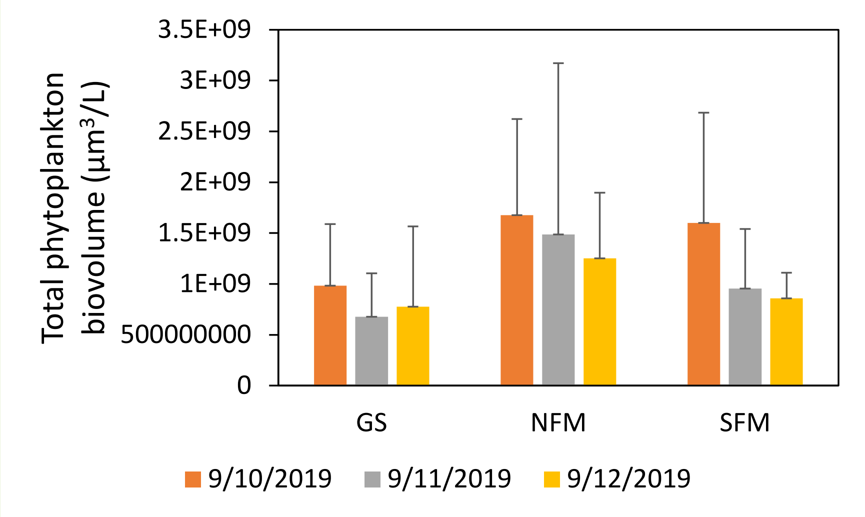
- Discrete water samples
- 2-factor Analysis of Variance:
  - Day (Wastewater present or absent)
  - Channel

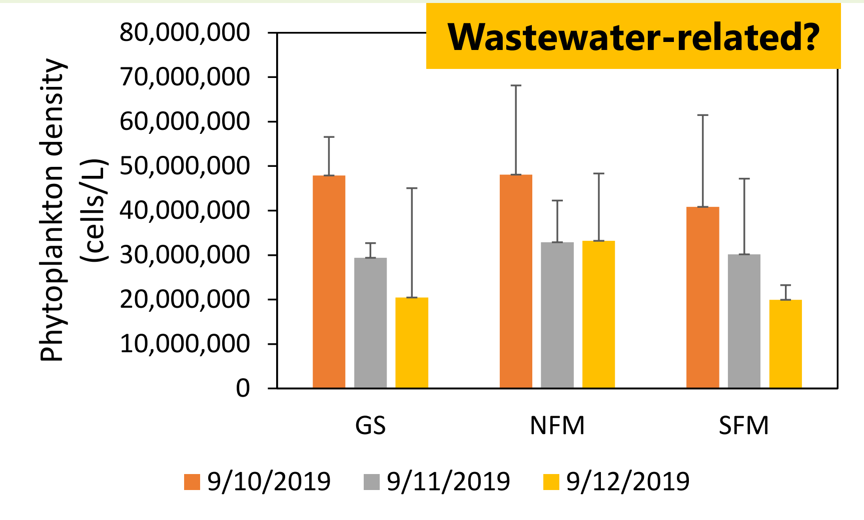


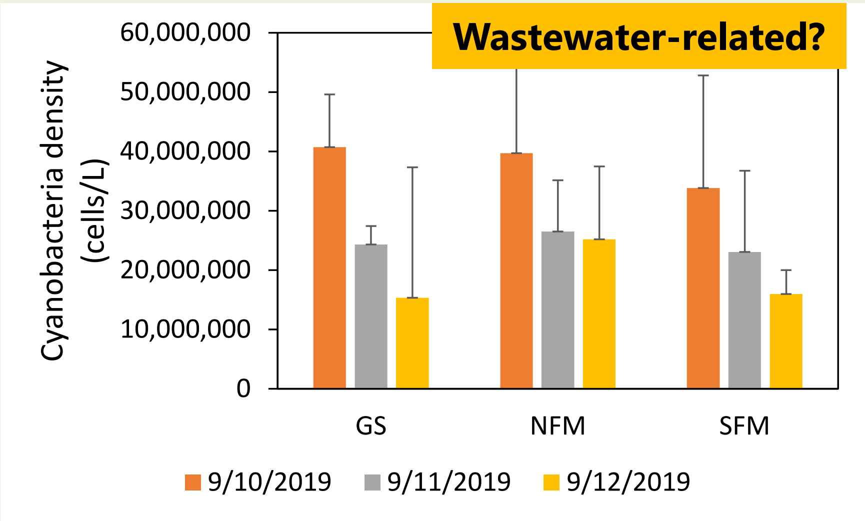
Environment-related

Chlorophyll-*a* and total phytoplankton biovolume were unchanged; total phytoplankton density and cyanobacteria density decreased



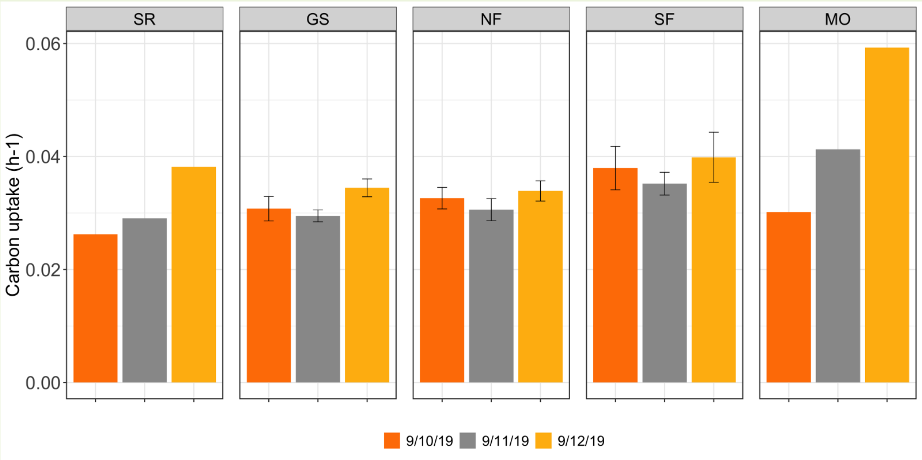


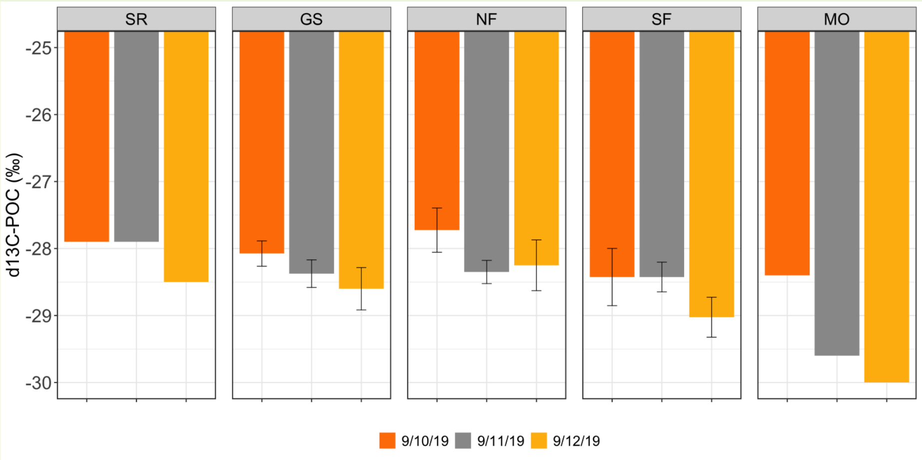




Phytoplankton productivity increased

Environment-related



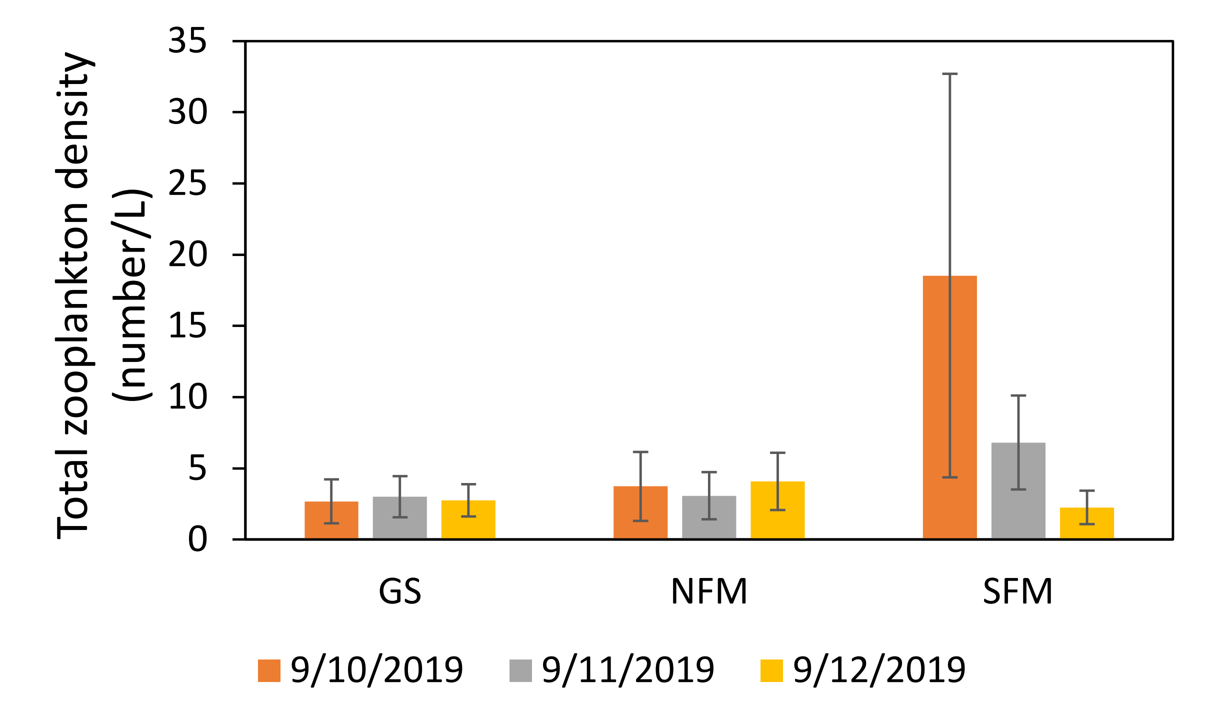


Turbidity decreased and light availability increased, starting upstream of SRWTP on day 2 of effluent hold, resulting in higher Carbon Fixation and lower $\delta^{13}C$-Particulate Organic Carbon in the absence of wastewater. There was also a trend of higher productivity from west to east across the channels.

Zooplankton abundance decreased, but this was driven by the pattern in only one channel

- Discrete samples captured with a zooplankton net
- 2-factor Analysis of Variance:
  - Day (Wastewater present or absent)
  - Channel

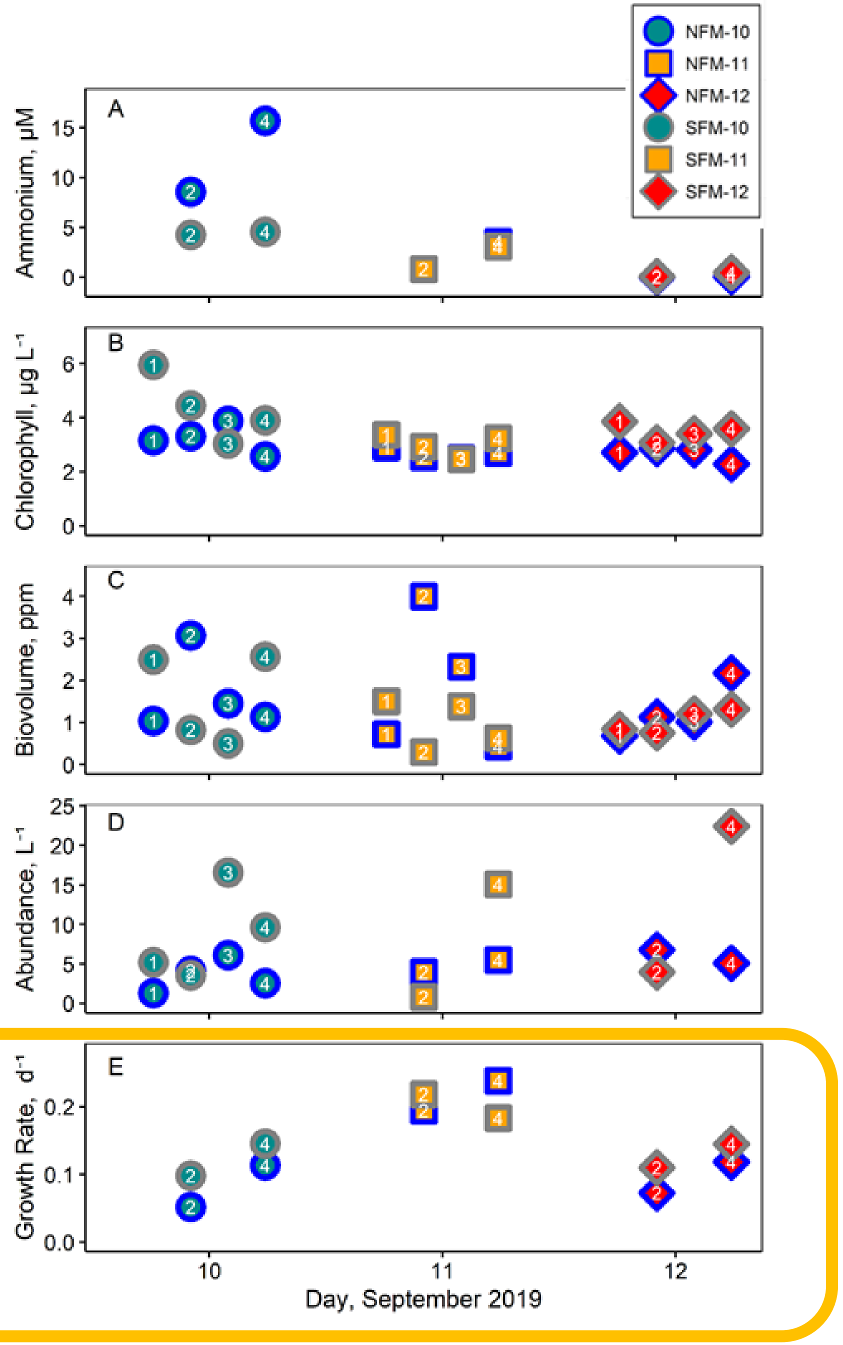
Lack of changes due to nutrient loading was expected over the short time frame



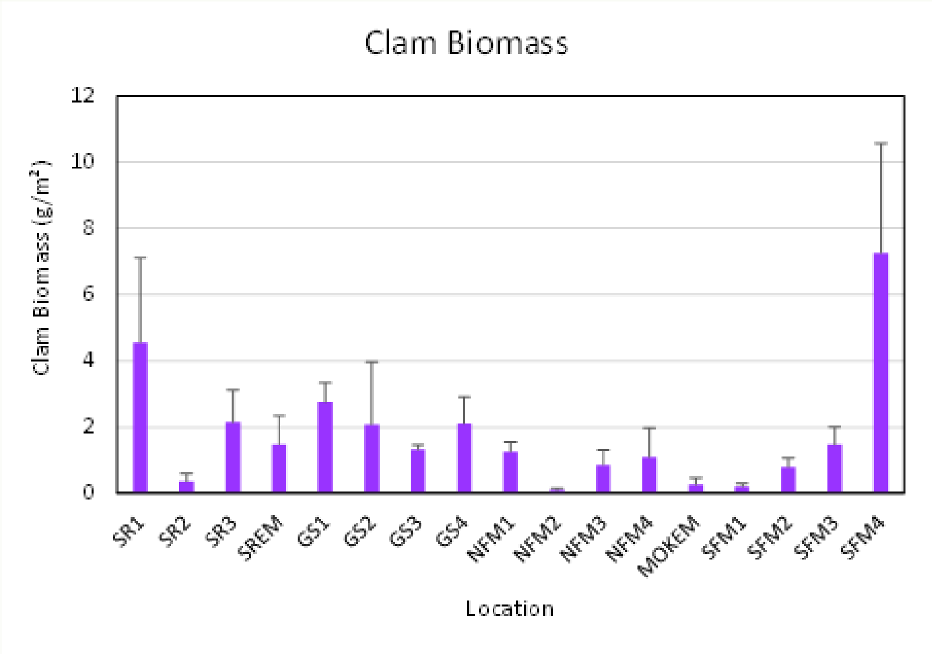
Zooplankton growth metrics appeared to show little or no effect of wastewater

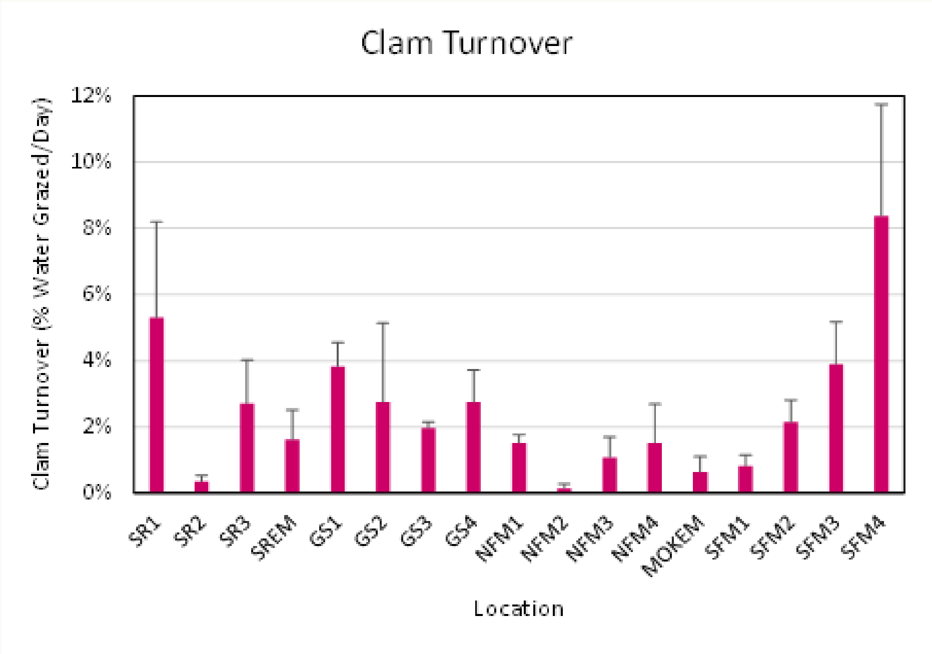
Zooplankton growth rates were generally low, with the values from 9/11 being the highest

Lack of changes due to nutrient loading was expected over the short time frame



Clam biomass was moderate; median grazing (turnover) rate was ~ 2% per day



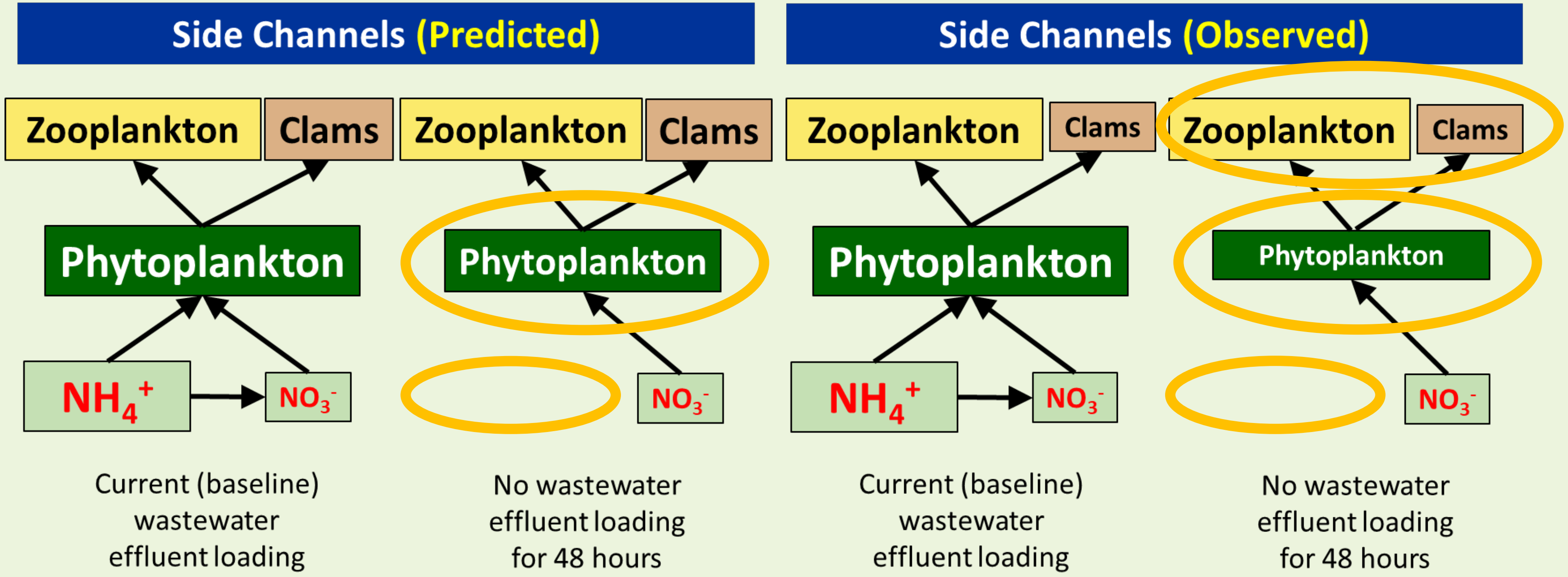


This study was the first to sample clam biomass in the east Delta Rivers. Each bar represents three trawls. We measured the shell width of every clam collected (total = 23,947).

Food web – some predictions were confirmed, but others remain unclear

Predicted phytoplankton abundance decrease with decreased wastewater loading

Observed abundance of some forms of phytoplankton decreased with decreased wastewater loading, but chl-*a* was unchanged, productivity <u>increased</u>, and increased irradiance may have played a role.



Zooplankton and clams remained unchanged

Predicted ammonium decrease with decreased wastewater loading

Observed ammonium decreased with decreased wastewater loading

Conceptual Model - observed

Summary

- We observed a large, short-term (48-hour) removal of wastewater effluent and its associated nutrient load from three Delta river channels
- In the absence of wastewater, we observed statistically significant declines in the density of cyanobacteria and total phytoplankton, but not in phytoplankton biovolume or chlorophyll-*a*
- Phytoplankton productivity increased during the study, but this appeared to be related to decreased turbidity (increased light availability) as well as channel effects

Data gaps identified in the Delta Nutrient Research Plan that were addressed by this study

1. Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?
2. How do physical, chemical, and biological factors affect phytoplankton abundance and growth, including nutrients, phytoplankton growth and species composition, microbial processes related to nutrient release, biological controls of phytoplankton (e.g., grazing), and physical factors, including hydrology, turbidity, turbulence, irradiance, and temperature?
3. How do previous light and nutrient conditions affect nutrient uptake by phytoplankton?
4. What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?

8. How do connections between peripheral habitats (wetlands, floodplains, and macrophyte beds) and open water affect nutrient transformation, nutrient transport rates, and the growth and biomass of primary producers (including phytoplankton, microalgae, vascular plants, bacteria, and detritus)?

15. How do grazers (including grazing by bivalve, zooplankton, and protists) affect phytoplankton biomass, productivity, and composition? Where, when and under what conditions do grazers have the most significant impacts on phytoplankton growth and composition, as well as relationships between nutrients and grazing?

How future research projects can inform data gaps identified in the Delta Nutrient Research Plan

- Future projects could study the potential effects of the smaller but longer-term nutrient loading reductions resulting from the EchoWater Project upgrade to biological nutrient removal at the Sacramento Regional Wastewater Treatment Plant, as well as other nutrient reductions to the Delta that may occur in future
- Look at multiple factors that may be affecting phytoplankton: nutrients, but also light, water residence time, depth, grazing

Acknowledgements

- Jointly funded by
  - Delta Regional Monitoring Program
  - State Water Contractors
  - US Bureau of Reclamation
  - Regional San (in-kind)
  - US Geological Survey (in-kind)
- Project designed with assistance from the Delta RMP Nutrient (Subgroup) Technical Advisory Committee
- We received critical and valued support from many Delta stakeholders, including marina operators, USBR, SFEI, and other sections of USGS and Regional San

Nutrients, Phytoplankton, and Harmful Algal Bloom Research by the U.S. Geological Survey

TAMARA KRAUS, USGS

KEITH BOUMA-GREGSON, USGS

STATUS & TRENDS IN NUTRIENT STUDIES, 11:05 TO 11:55 AM

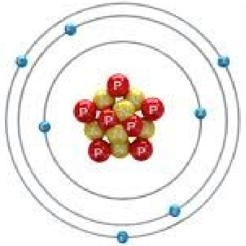
Nutrients, Phytoplankton and Harmful Algal Bloom Research by the U.S. Geological Survey

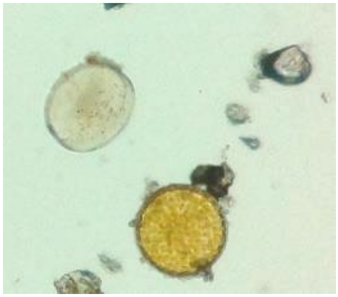
Tamara Kraus, Keith Bouma-Gregson, Angela Hansen, Brian Bergamaschi

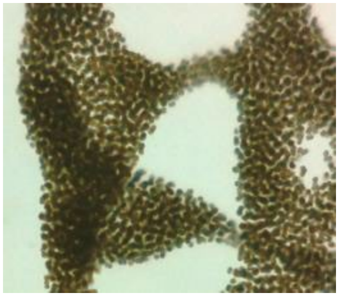
U. S. Geological Survey, California Water Science Center

Delta Regional Monitoring Program Nutrient Symposium

September 27, 2022







U.S. Geological Survey California Water Science Center
USGS CAWSC

https://www.usgs.gov/centers/ca-water

- Provide foundational data and scientific analysis to address the water issues facing the state of California.
- Work in partnership with state, local, and other federal agencies to ensure relevance of our activities.

DELTA REGIONAL MONITORING PROGRAM
Delta Science Program
DELTA STEWARDSHIP COUNCIL
BUREAU OF RECLAMATION
SWC STATE WATER CONTRACTORS FOUNDED 1982
CALIFORNIA DEPARTMENT OF WATER RESOURCES
REGIONALSAN
SFEI AQUATIC SCIENCE CENTER
SAN FRANCISCO ESTUARY INSTITUTE & THE AQUATIC SCIENCE CENTER





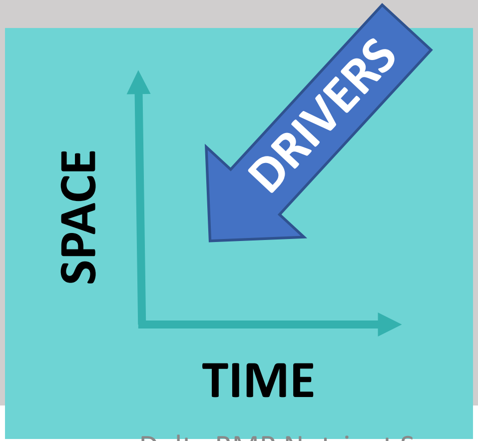

USGS

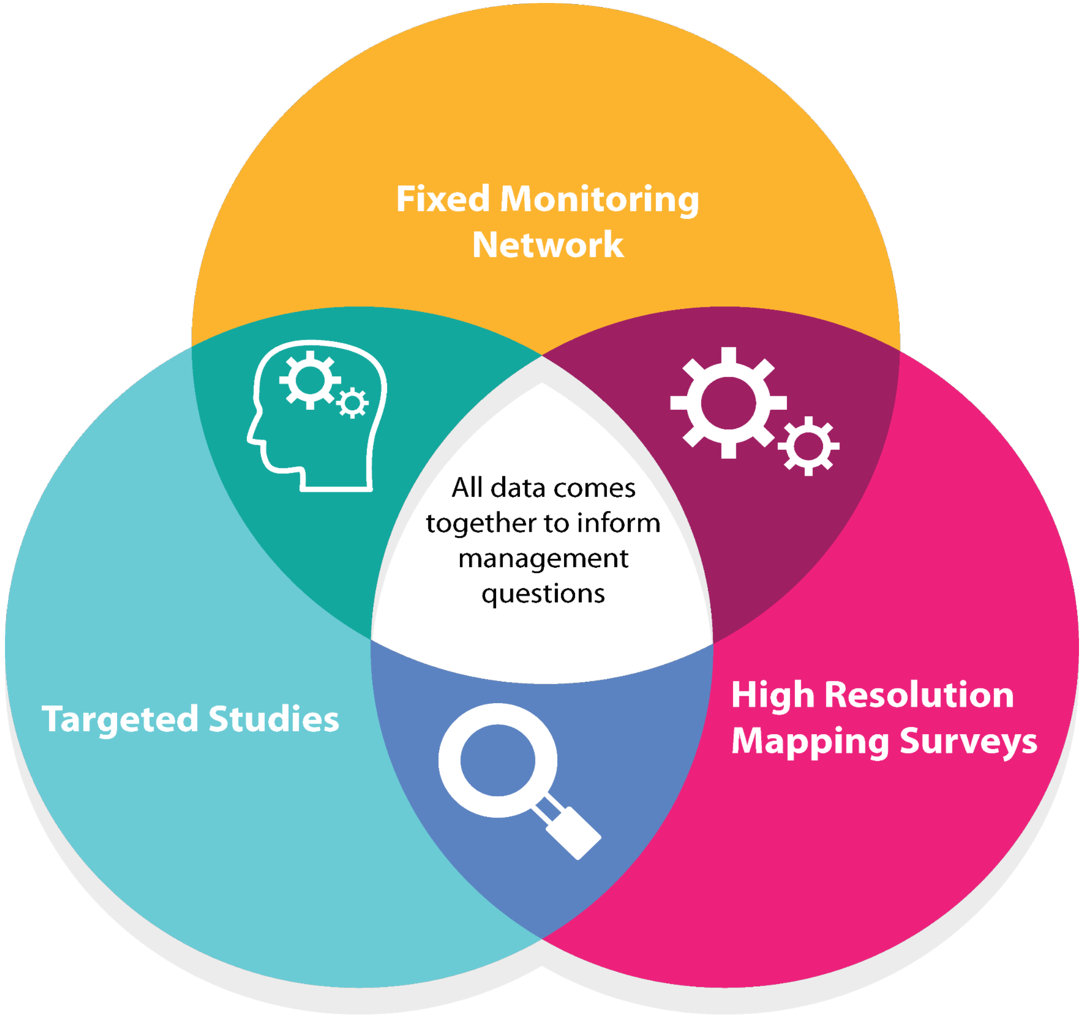
USGS CAWSC – Biogeochemistry Group (BGC)

Study Range of Topics

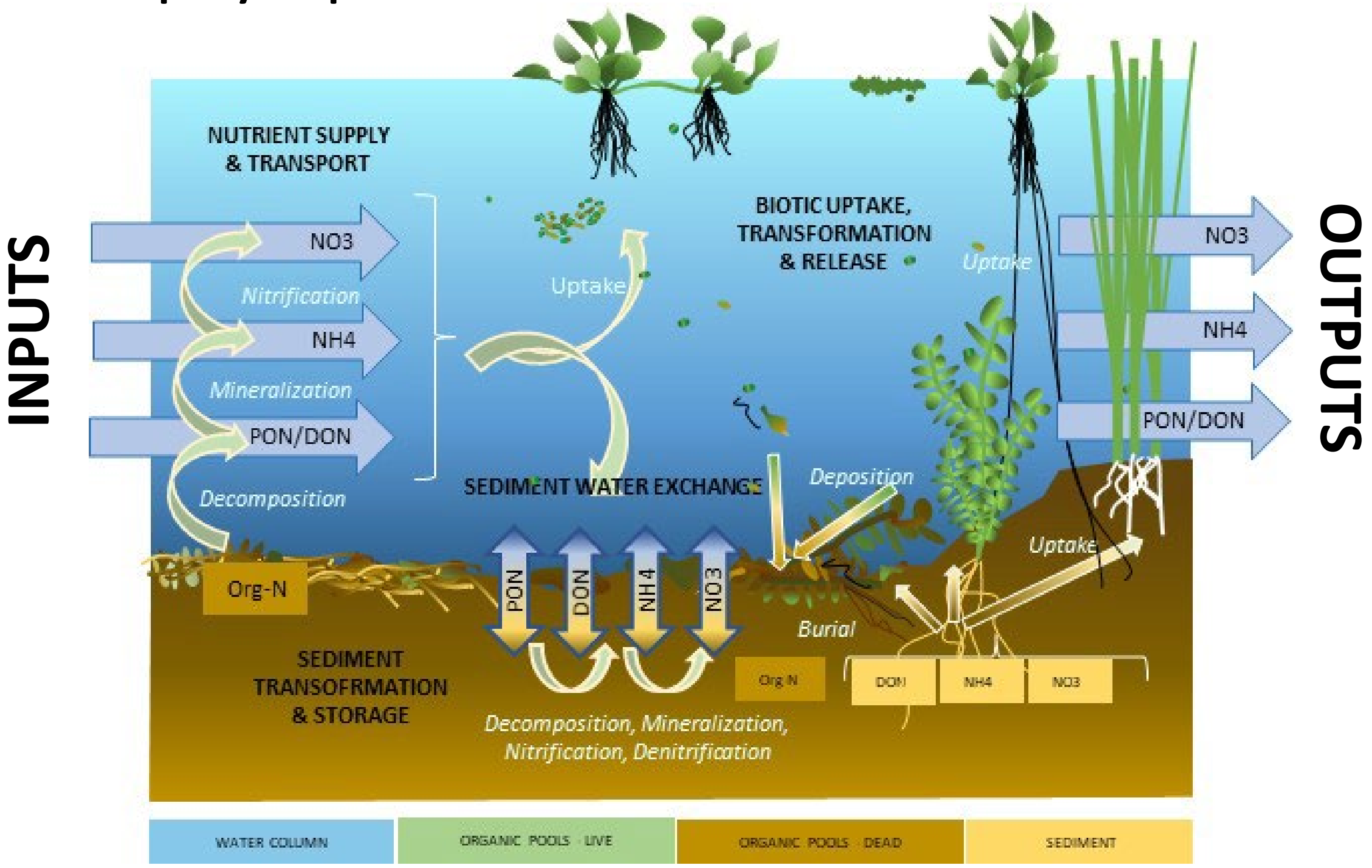
- **<u>Nutrients & Phytoplankton (HABs and BABs)</u>**
  - Sources and Loads (conc & flow)
  - Concentrations/Abundance, Forms/Composition
  - Controls/Drivers:
    - Environmental, Hydrologic, Landscape Scale
    - Management Actions
  - Aquatic-Terrestrial Linkages
  - Benthic-Water Column Exchange
  - Wetland Restoration
  - Contaminants (mercury, pesticides)
  - Drinking Water Quality

  - New tools and approaches
  - Remote Sensing
  - Data Access,
    Integration
    Visualization





Numerous studies related to nutrients and phytoplankton



***f*(Location, Season, WRTime)**

Environmental Complexity

Multiple Environmental Drivers

- Flow/Turbulence
- Temperature
- Radiation/Light
- Salinity
- Depth/Geomorphology
- Sediment Properties
- Biotic Community
  - Microbes, Phytoplankton, Macrophytes, Zooplankton, Fish

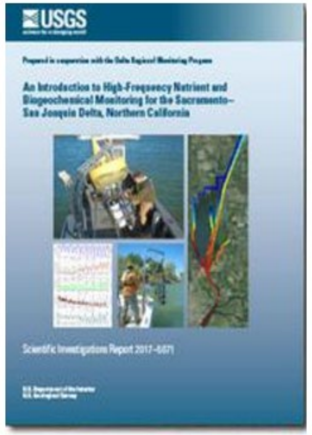
Hydrologic Complexity

Landscape Complexity

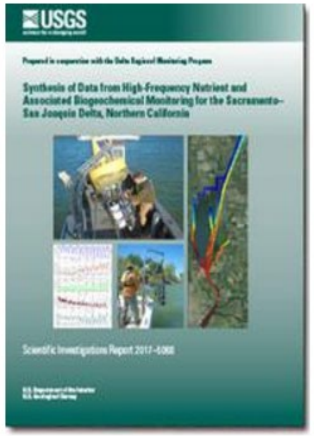
Seasonal Patterns

Delta RMP USGS BGC Funded Studies

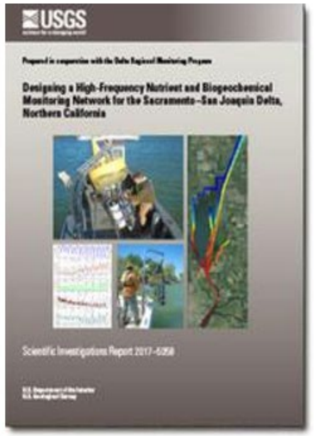
- 2016 High Frequency Reports (three publications)
- 2018 Delta Mapping Surveys (Spring, Summer, Fall)
- 2020 Delta Mapping Survey (Spring)
- 2021-22 Cyanotoxin monitoring (2 USGS & 2 DWR stations
- 2022-23 MDM Cyanotoxins and Fluoroprobe
- Participated in Chlorophyll Intercalibration Study
- Participated in SRiNC study led by Regional San (Lisa Thompson presenting)
- Participated in SFEI's WY2016 Report (David Senn presenting)



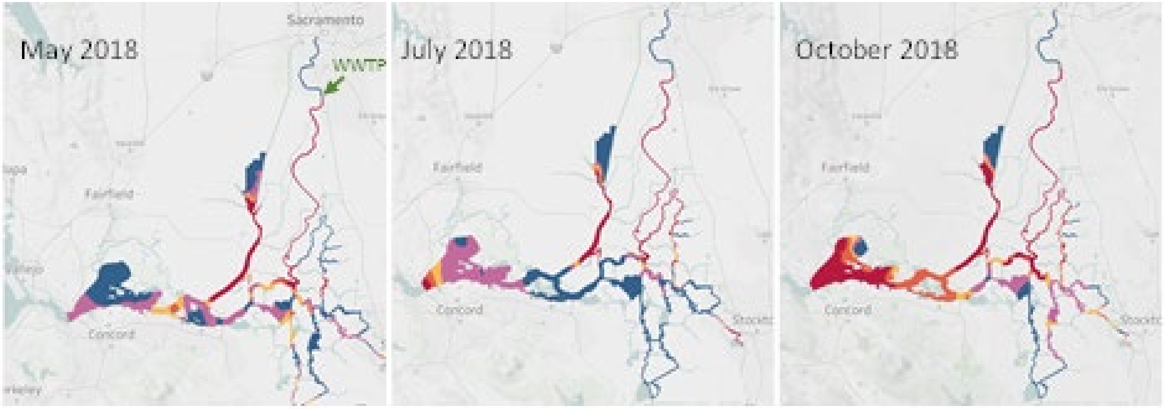
Introduction

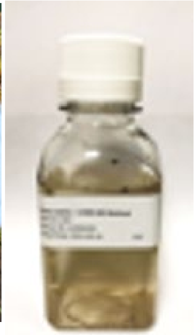


Data Synthesis



Monitoring Design Considerations





What are the data gaps identified in the DNRP addressed by USGS studies?

DELTA Regional Monitoring Program

26 QUESTIONS

1. Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?
2. How do physical, chemical, and biological factors affect phytoplankton abundance and growth, including nutrients, phytoplankton growth and species composition, microbial processes related to nutrient release, biological controls of phytoplankton (e.g., grazing), and physical factors, including hydrology, turbidity, turbulence, irradiance, and temperature?
3. How do previous light and nutrient conditions affect nutrient uptake by phytoplankton?
4. What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?
5. What is the status and trends of floating and submersed invasive macrophytes in Delta habitats and how are they affected by nutrient concentrations?
7. How do nutrients and other drivers control the growth rate, maximum biomass, and toxin production of HABs?
8. **How do connections between peripheral habitats (wetlands, floodplains, and macrophyte beds) and open water affect nutrient transformation, nutrient transport rates, and the growth and biomass of primary producers (including phytoplankton, microalgae, vascular plants, bacteria, and detritus)?**
9. What factors control the instantaneous, annual, and interannual production rates of submersed and floating aquatic macrophytes over a range of Delta habitats?
10. Are there predictable relationships between tissue growth, nutrient uptake rates, and nutrient concentrations in invasive aquatic macrophytes and nutrient levels in the water or sediment?
11. Can controlled studies and data syntheses confirm key drivers of cyanoHABs identified in field studies and determine rate measurements that can be used in modeling?
12. Do environmental conditions, including herbicides and grazing pressure, selectively enhance the growth of cyanobacteria in the Delta?
13. Can changes in nutrients or physical drivers be used to reduce the frequency and magnitude of HAB blooms and cyanotoxins?
14. Do environmentally-relevant concentrations of herbicides, fungicides, and mixtures thereof affect aquatic macrophytes, harmful algal species, or phytoplankton species composition?
15. How do of grazers (including grazing by bivalve, zooplankton, and protists) effect phytoplankton biomass, productivity, and composition? Where, when and under what conditions do grazers have the most significant impacts on phytoplankton growth and composition, as well as relationships between nutrients and grazing?
16. **How much nitrification and other nitrogen transformation processes are occurring in benthic and pelagic zones and what nutrient fluxes occur between these zones?**
17. **What are the nitrogen and phosphorus inputs, sinks, and outputs in the Delta over a breadth of hydrologic conditions and seasons?**
18. What are the production and cycling rates for both nutrients and carbon in aquatic plants, pelagic algae, and benthic algae, as determined from biomass, nutrient content, and instantaneous and net tissue growth?
19. Do predictive relationships exist between cyanobacteria (bloom occurrence and toxin concentrations) and readily available data (e.g., nitrogen forms, chlorophyll, and other pigments) from continuous sensors or other sources?
20. **How do nutrient concentrations vary at increasing distance from and into aquatic macrophyte beds?**
21. **Are there seasons or locations in the Delta when nutrient concentrations might be restricting aquatic macrophyte growth?**
22. What is the potential for Delta nutrient sources, cycling, and other conditions to manage problems of HAB occurrence and toxins in water conveyance and drinking water systems downstream of the Delta?
23. What factors drive the growth of benthic phytoplankton species that are associated with taste and odor problems in water conveyance and reservoir systems downstream of the Delta?
24. Would lower nutrient concentrations increase the effectiveness of macrophyte management strategies (mechanical, herbicide, and biological)?
25. Would changes in nutrients or physical drivers reduce the frequency and magnitude of benthic and planktonic cyanobacteria causing taste and odor problems?
26. How are aquatic organisms, including fish and invertebrates, affected by aquatic macrophyte species in the Delta?

8. How do connections between peripheral habitats (wetlands, floodplains, and macrophyte beds) and open water affect nutrient transformation, nutrient transport rates, and the growth and biomass of primary producers (including phytoplankton, microalgae, vascular plants, bacteria, and detritus)?

16. How much nitrification and other nitrogen transformation processes are occurring in benthic and pelagic zones and what nutrient fluxes occur between these zones?

17. What are the nitrogen and phosphorus inputs, sinks, and outputs in the Delta over a breadth of hydrologic conditions and seasons?

Status and Trends

- Nutrient concentrations, forms, ratios
- Phytoplankton – abundance, species composition
- Cyanotoxins – presence/absence, concentrations

Transformation, Drivers and Interactions

- Nutrient transformation f(time, env drivers, habitat)
- Nutrients ←→ Water Quality, Environment, Management
- Nutrients ←→ Phytoplankton
- Nutrients ←→ Macrophytes

USGS

Delta RMP initial assessment questions -

Status and trends (ST)

ST-1	How do concentrations of nutrients (and nutrient-associated parameters) vary spatially and temporally?
ST-1A	Are trends similar or different across subregions of the Delta?
ST-1B	How are ambient levels and trends affected by variability in climate, hydrology, and ecology?
ST-1C	Are there important data gaps associated with particular water bodies within the Delta subregions?
ST-2	What is the current status of the Delta ecosystem as influenced by nutrients?
ST-2A	What is the current ecosystem status of habitat types in different types of Delta waterways, and how are the conditions related to nutrients?

Sources, pathways, loadings, and processes (SPLP)

SPLP-1	Which sources, pathways, and processes contribute most to observed levels of nutrients?
SPLP-1A	How have nutrient or nutrient-related source controls and water management actions changed ambient levels of nutrients and nutrient-associated parameters?
SPLP-1B	What are the loads from tributaries to the Delta?
SPLP-1C	What are the sources and loads of nutrients within the Delta?
SPLP-1D	What role do internal sources play in influencing observed nutrient levels?
SPLP-1E	Which factors in the Delta influence the effects of nutrients?
SPLP-1F	What are the types and sources of nutrient sinks within the Delta?
SPLP-1G	What are the types and magnitudes of nutrient exports from the Delta to Suisun Bay and water intakes for the State and Federal Water Projects?

Forecasting scenarios (FS)

FS-1	How will ambient water quality conditions respond to potential or planned future source control actions, restoration projects, and water resource management changes?

Two core data collection efforts

Continuous Fixed Station Network

Temporally Dense

In situ data: **15 mins, all year**
Discrete: **approx. monthly**

Boat-based High-Resolution Mapping

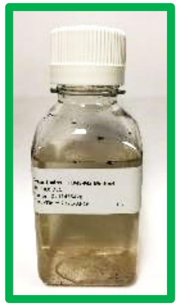
Spatially Dense

In situ data: **1 second, project based**
Discrete: **~30 stations**

PARAMETERS MEASURED

in situ
- ✓ Flow
- ✓ Temperature
- ✓ Specific Conductance
- ✓ Turbidity
- ✓ DO
- ✓ pH
- ✓ **fChlorophyll-a**
- ✓ **fDOM (DOC and DON proxy)**
- ✓ **Nitrate (SUNA)**
- ✓ **Phytoplantkon Composition** (subset)
- ✓ *Ammonium (Mapping only)*
- ✓ other

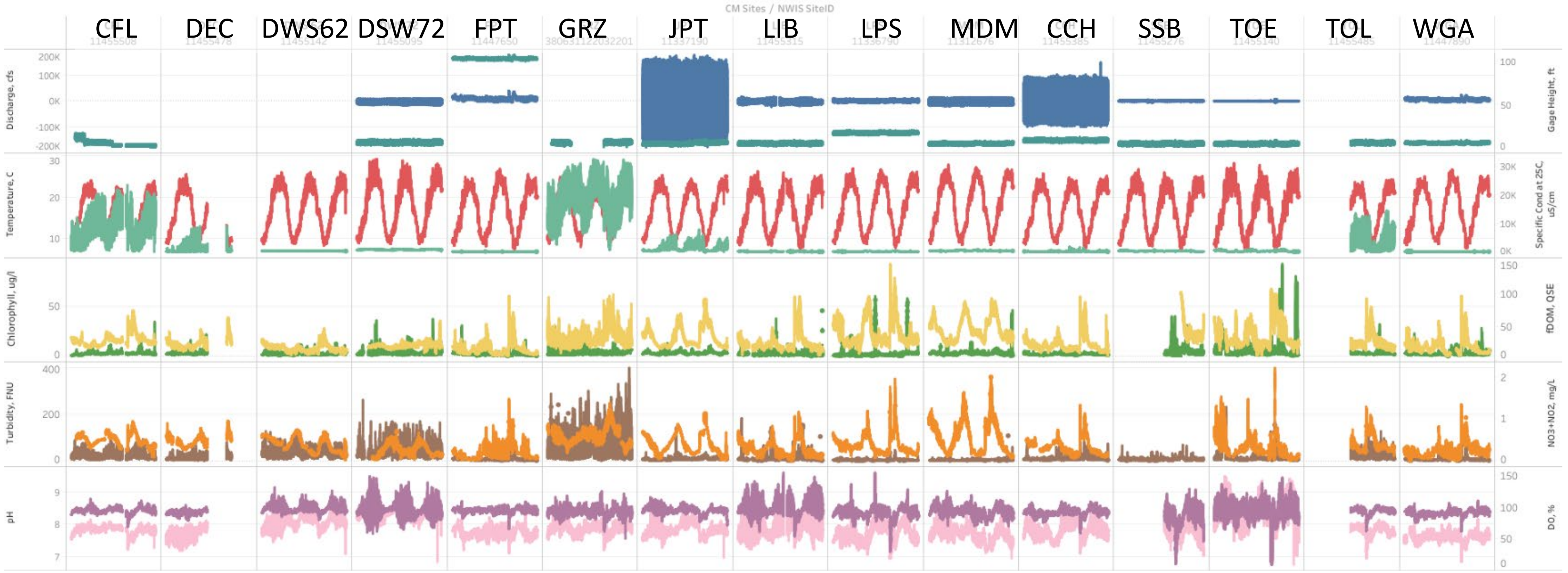
Discrete Samples
- ✓ Nutrients
  - ✓ Nitrate, Nitrite
  - ✓ Ammonium
  - ✓ Phosphate
  - ✓ TDN
  - ✓ DOC
- ✓ Chlorophyll-a Conc
- ✓ Phyto. Enumeration (BSA)
- ✓ Picoplankton (BSA)
- ✓ **Cyanotoxins Whole Water**
- ✓ **Cyanotoxins SPATT**
- ✓ Other



Continuous Monitoring Stations

3 years of data shown

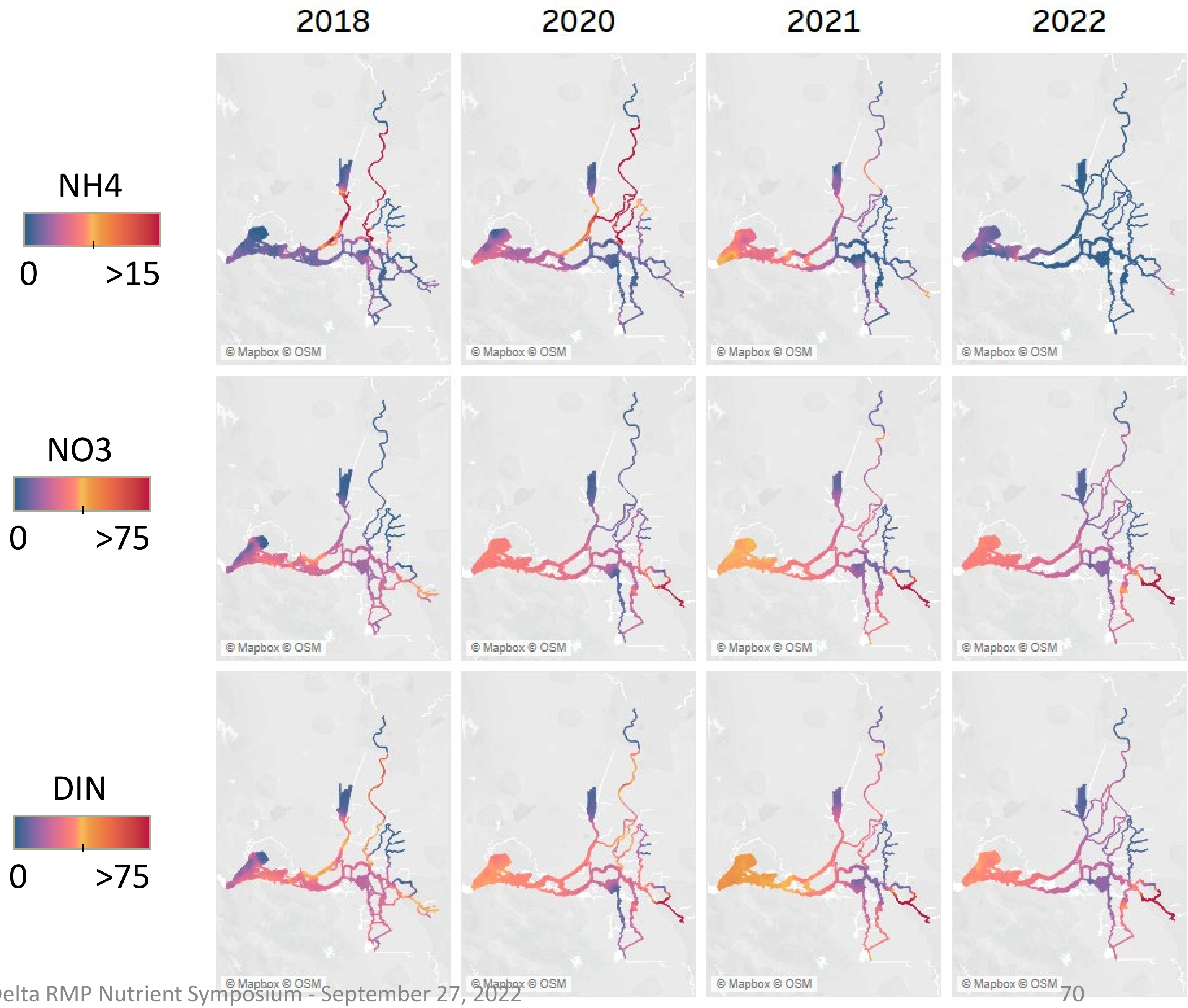
- Discharge, ft^3/s
- Gage Height, ft
- Temperature, C
- Specific Cond at 25C, uS
- Chlorophyll, ug/l
- fDOM, QSE
- fDOM, QSE
- Turbidity, FNU
- NO3+NO2, mg/L
- pH
- DO, %

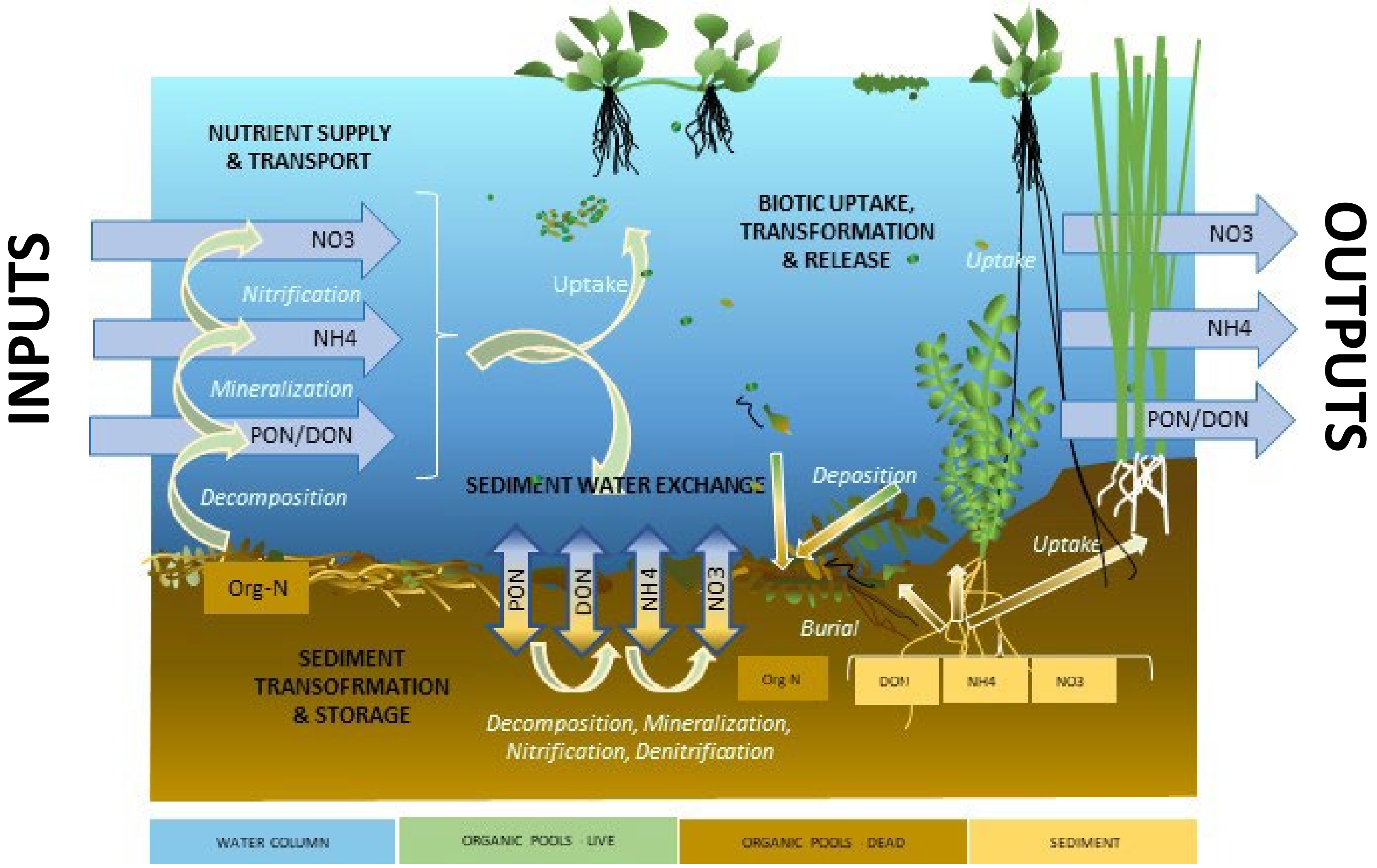


Delta Wide Mapping
SPRING

Longitudinal Gradients
- ➢ Over Space
- ➢ Over Time

Data Can Be Queried for:
- ❑ Status and Trends
- ❑ Relationships between Parameters
- ❑ Environmental Drivers
  (e.g., Drought. Temperature)
- ❑ Impacts of Management Actions
  (e.g. WWTP Upgrade, Barriers, Flow Actions)





***f*(Location, Season, WRTime)**

Environmental Complexity

Multiple Environmental Drivers

- Flow/Turbulence
- Temperature
- Radiation/Light
- Salinity
- Depth/Geomorphology
- Sediment Properties
- Biotic Community
  - Microbes, Phytoplankton, Macrophytes, Zooplankton, Fish

Hydrologic Complexity

Landscape Complexity

Seasonal Patterns

HYDROLOGIC CONTEXT

- Water Year Type
- Timing of ppt/snowmelt
- Management Actions
  - Reservoir Releases
  - Barriers
  - Gate Operations

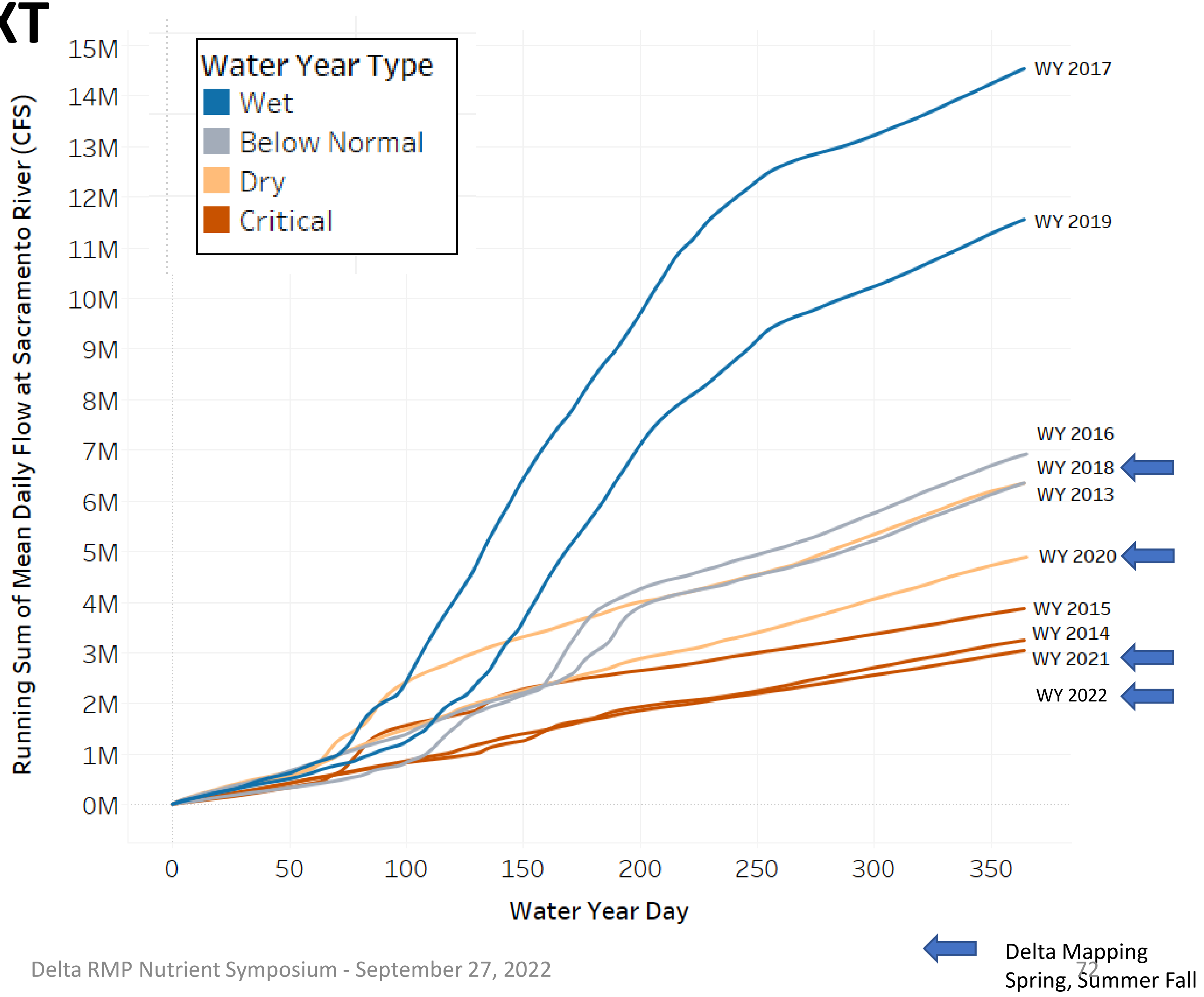
Impacts

Water Quality

Water Residence Time (Age)

Mixing

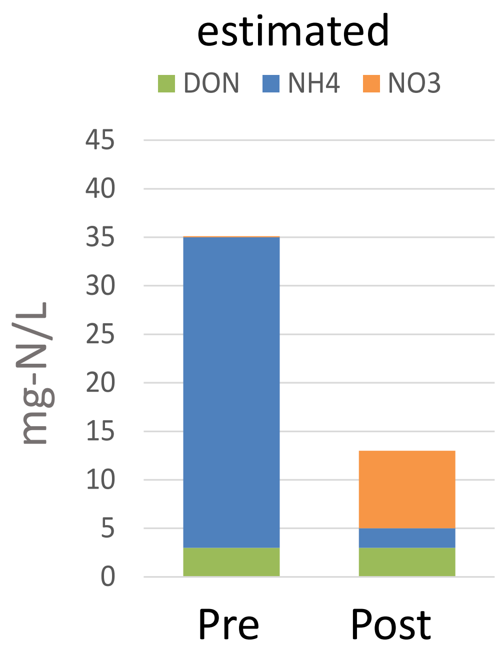
Transport



Sacramento's WWTP Upgrade

	Typical/Anticipated Concentration		
	Current (mg-N/L)	Future (mg-N/L)	Estimated Reduction
Ammonium, NH_4-N (Apr-Oct)	35	<1.5	>95%
Ammonium, NH_4-N (Nov-Mar)	35	<2.4	>93% NH4
Nitrate, NO_3-N	<1	≤10	Increase NO3
TOTAL Inorganic-N	36	<12.4	>65% DIN

Table courtesy of Regional San



↓ NH4
↑ NO3
↓ DIN

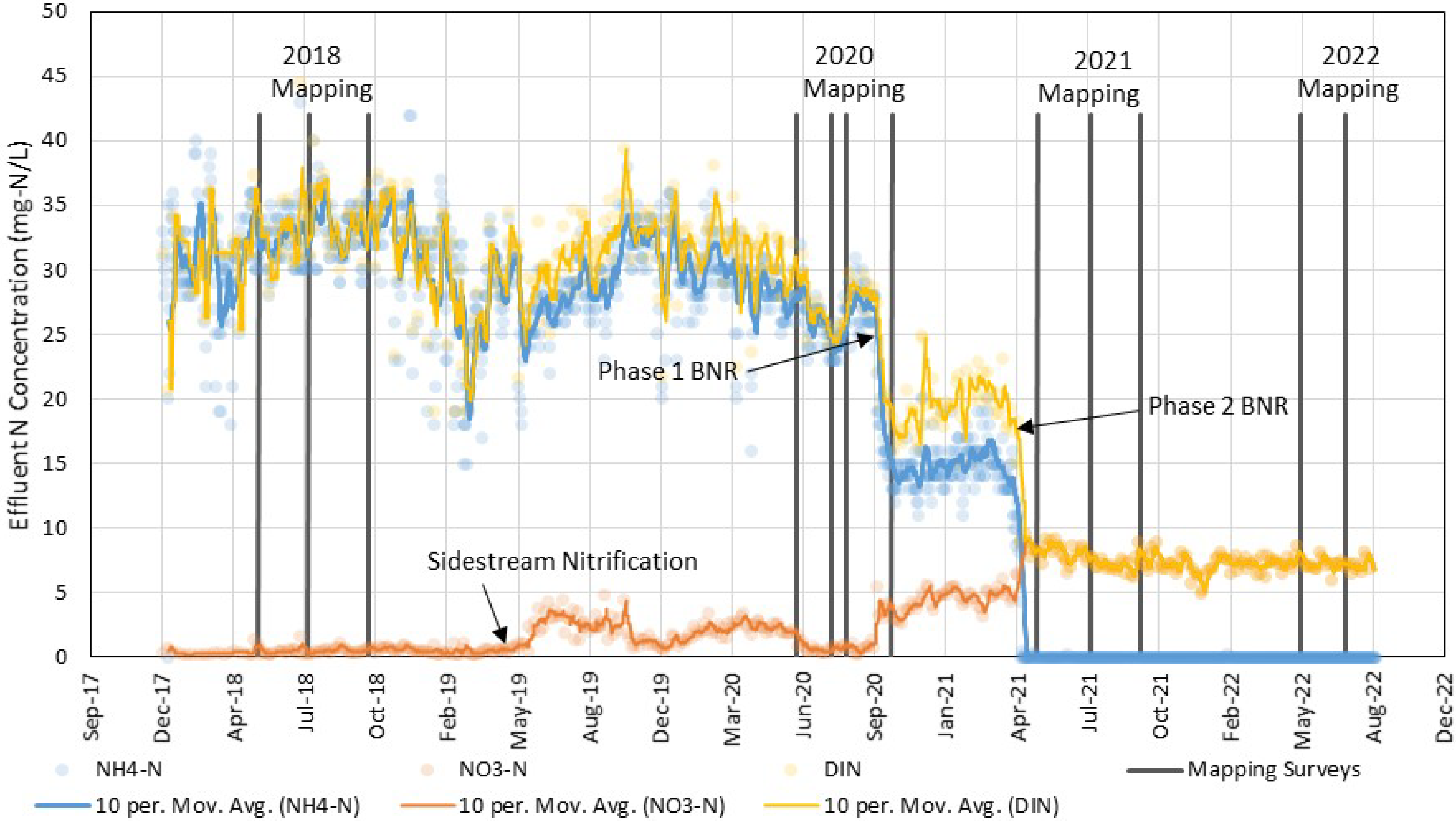
EchoWater Project
Bringing Water Back

Biological Nutrient Removal (BNR)
- Nitrification ($NH_4 \rightarrow NO_3$)
- Denitrification ($NO_3 \rightarrow N_{2(g)}$)

Filtration and enhanced disinfection

- **Shift the dominant form ($NH_4 \rightarrow NO_3$)**
- **Reduction in Nitrogen Inputs**

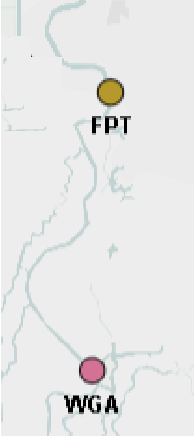
Regional San's Effluent Nutrient Concentrations & USGS Delta Wide Mapping Surveys

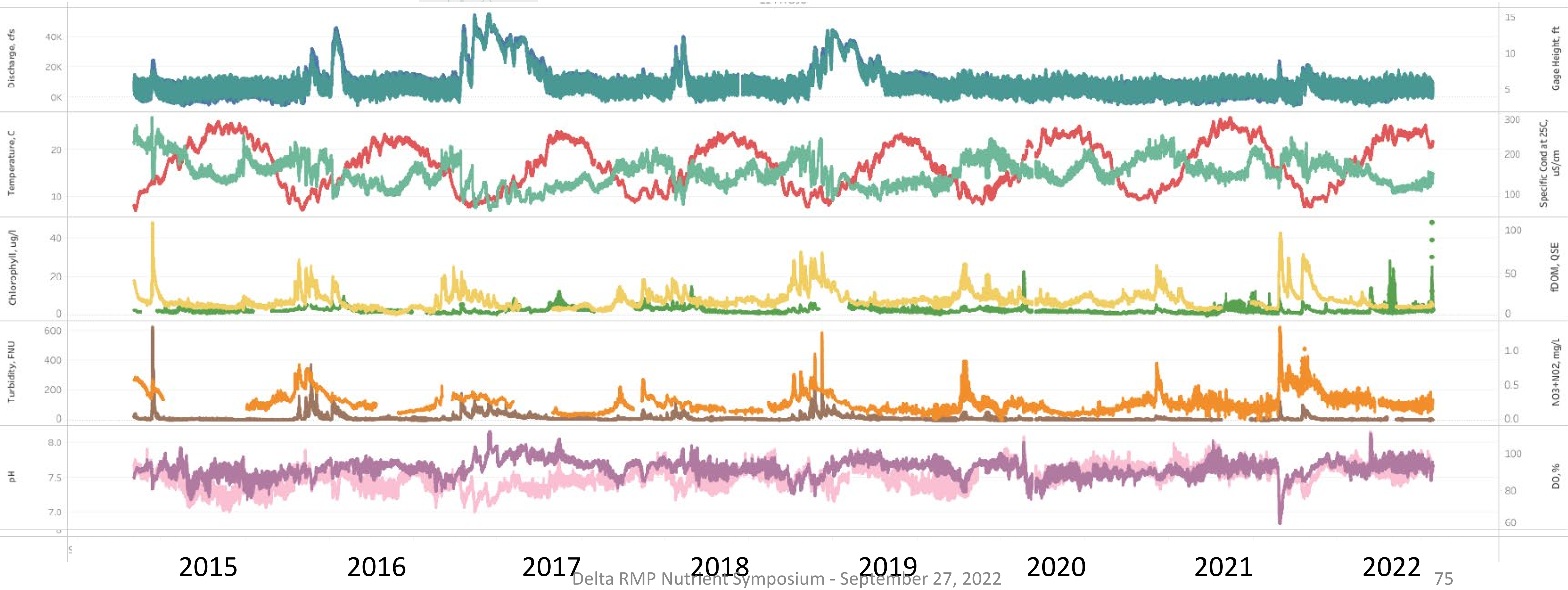


Data courtesy of Regional San

Walnut Gove

8 years of data





Delta Wide Mapping
SPRING

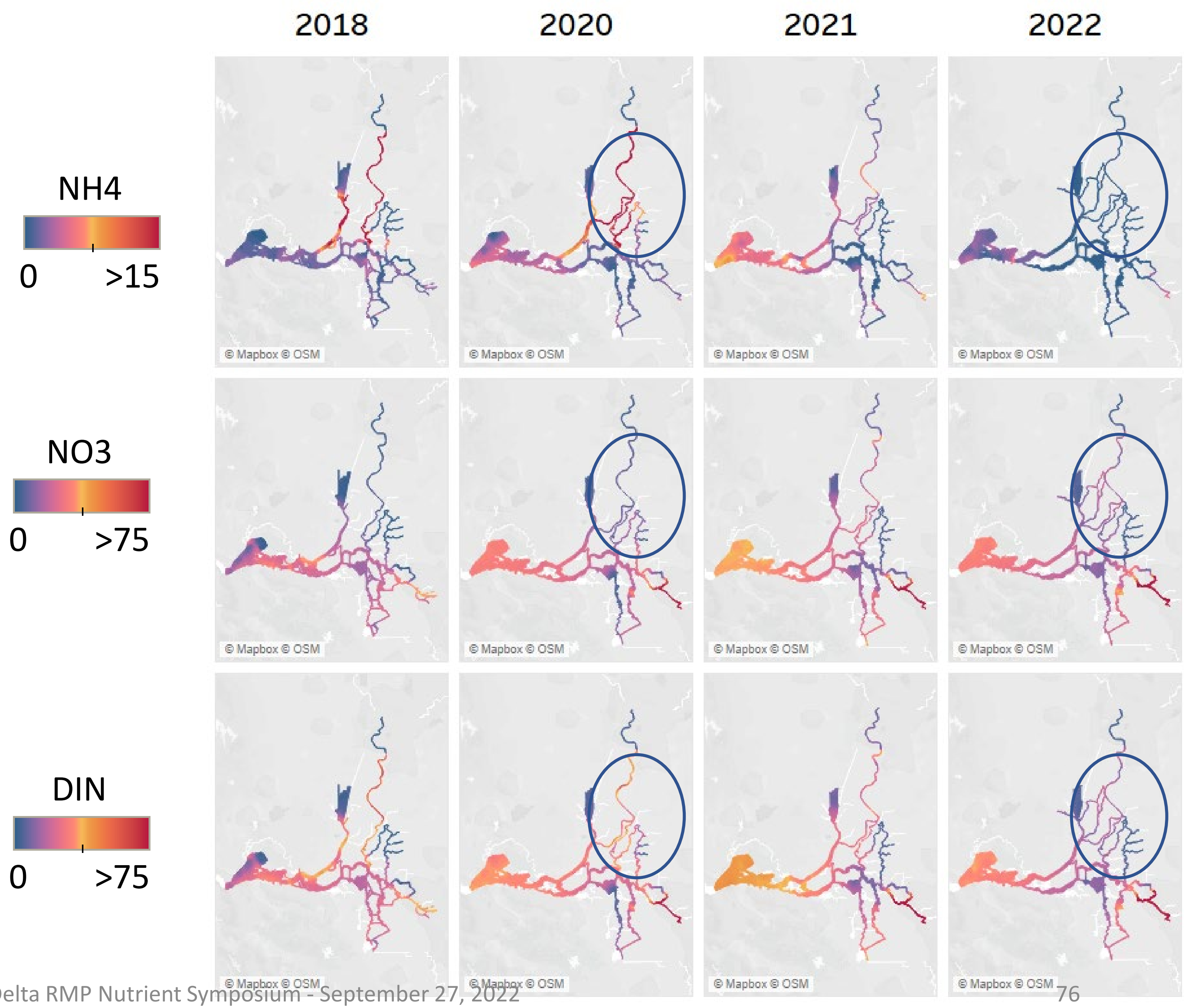
Longitudinal Gradients
- Over Space
- Over Time

Environmental Complexity

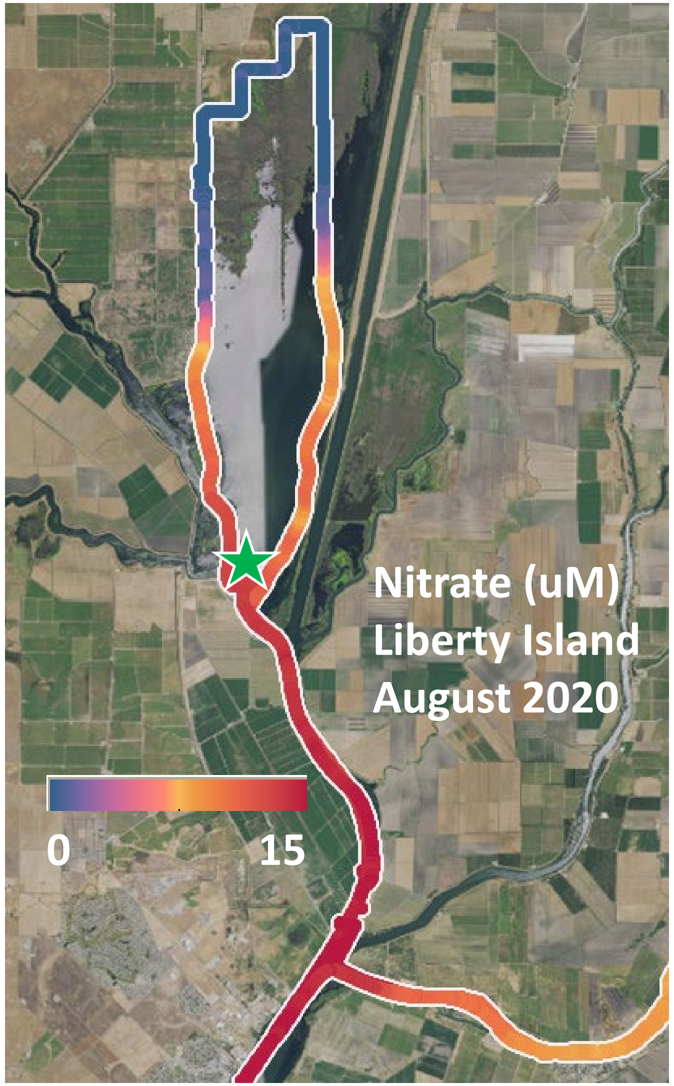
Hydrologic Complexity

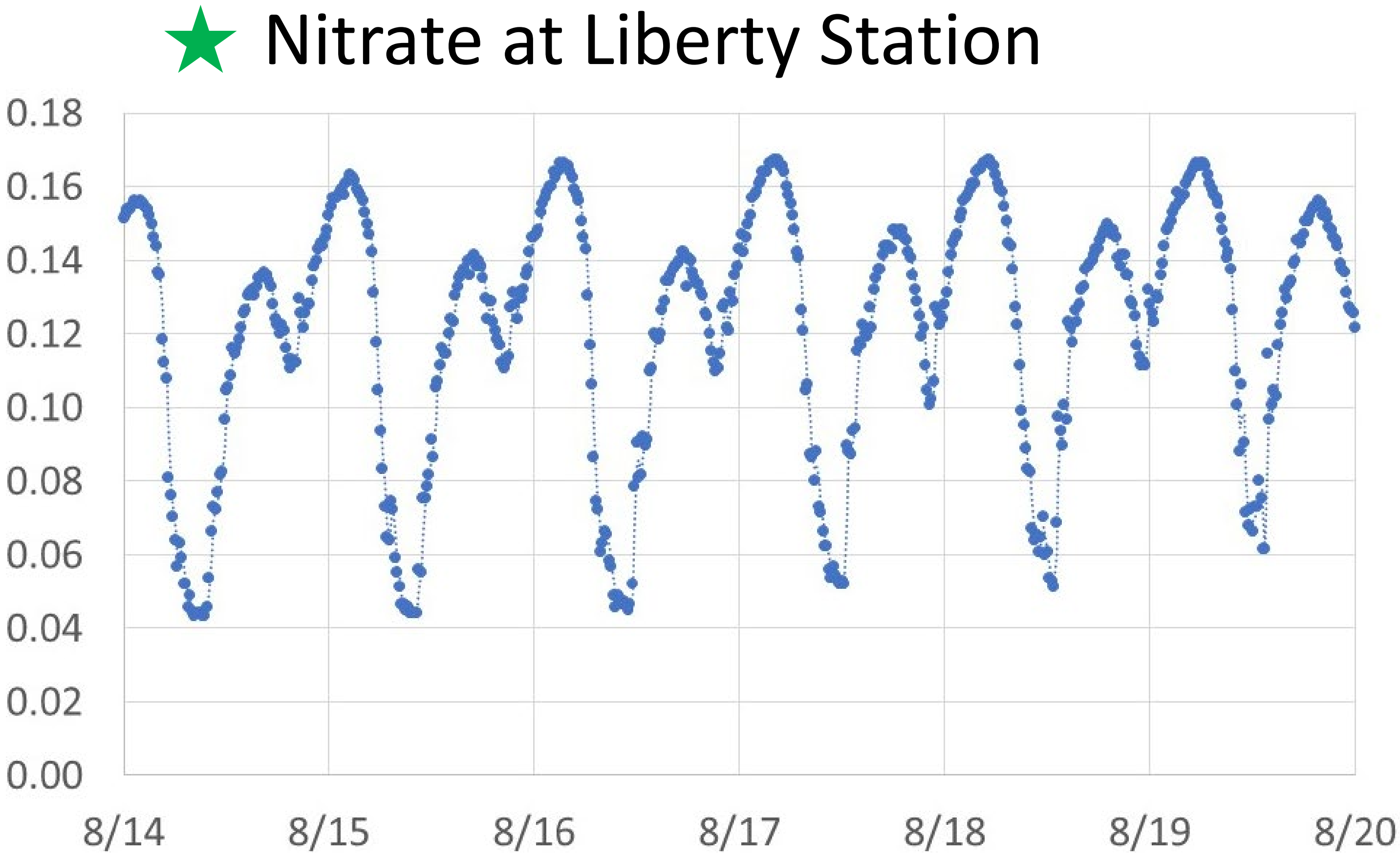
Landscape Complexity

Seasonal Patterns

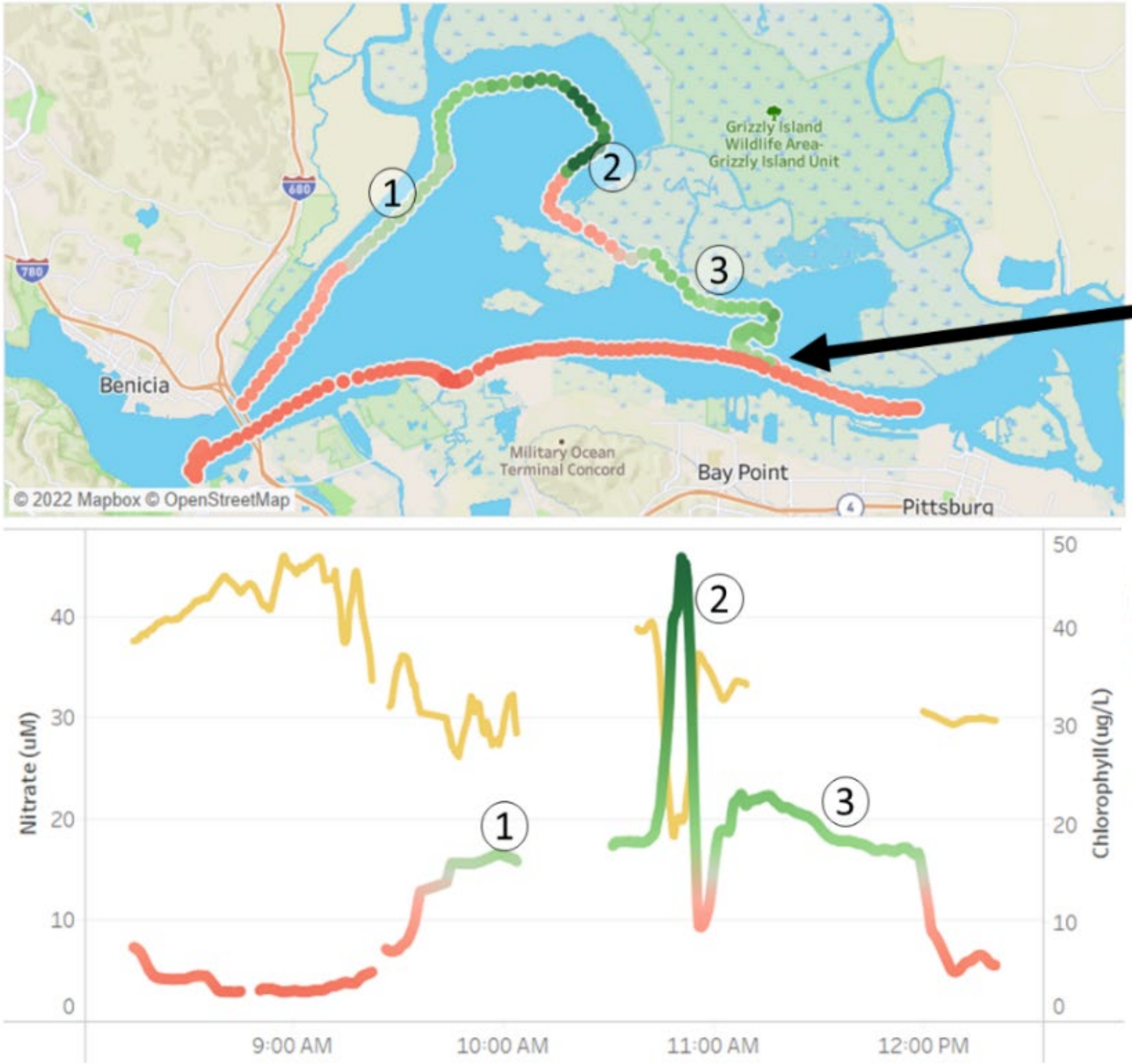


Gradients are Frequently Steep – Spatially / Temporally



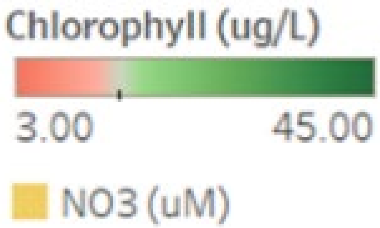


Phytoplankton can be a major sink for Nutrients

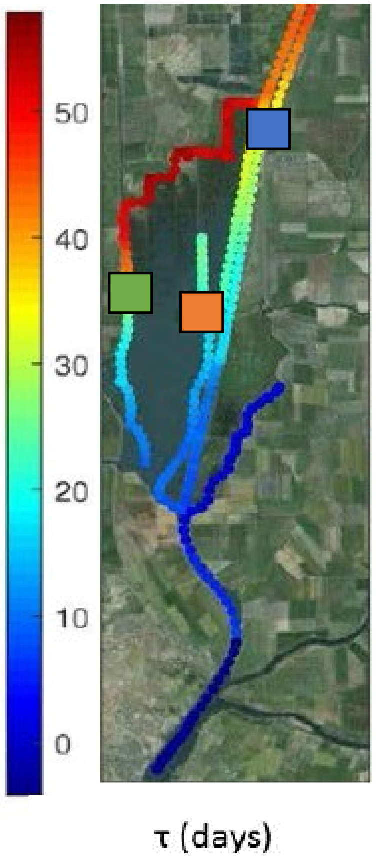


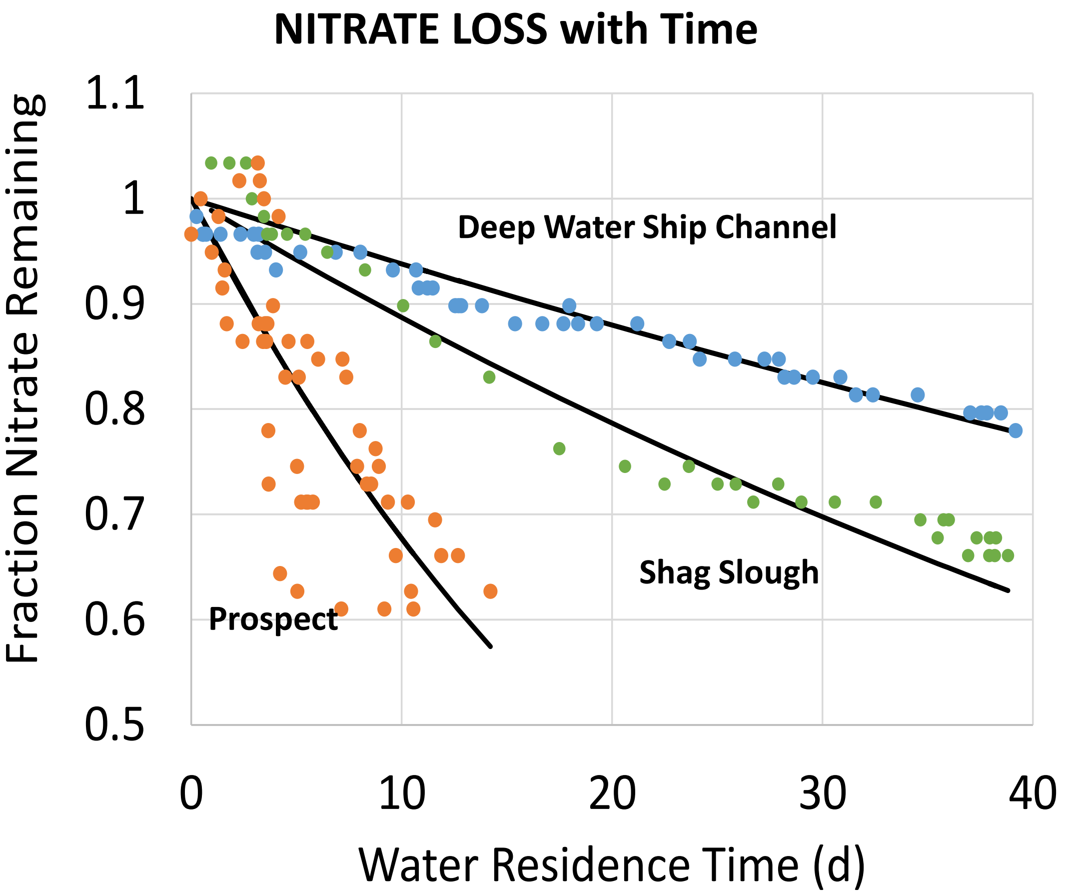
Mapping survey track May 17, 2018.

Track color corresponds to chlorophyll concentrations in graph below



TIME is a Major Control On Nutrients
but also Landscape Scale Factors





Why are rates different?

- Phytoplankton Uptake ?
- Nitrification ?
- Benthos ?
- Aquatic Vegetation ?
- Wetlands vs. Channel ?

Downing et al. 2016; ES&T

How can future research projects inform data gaps identified in the DNRP?

DELTA Regional Monitoring Program

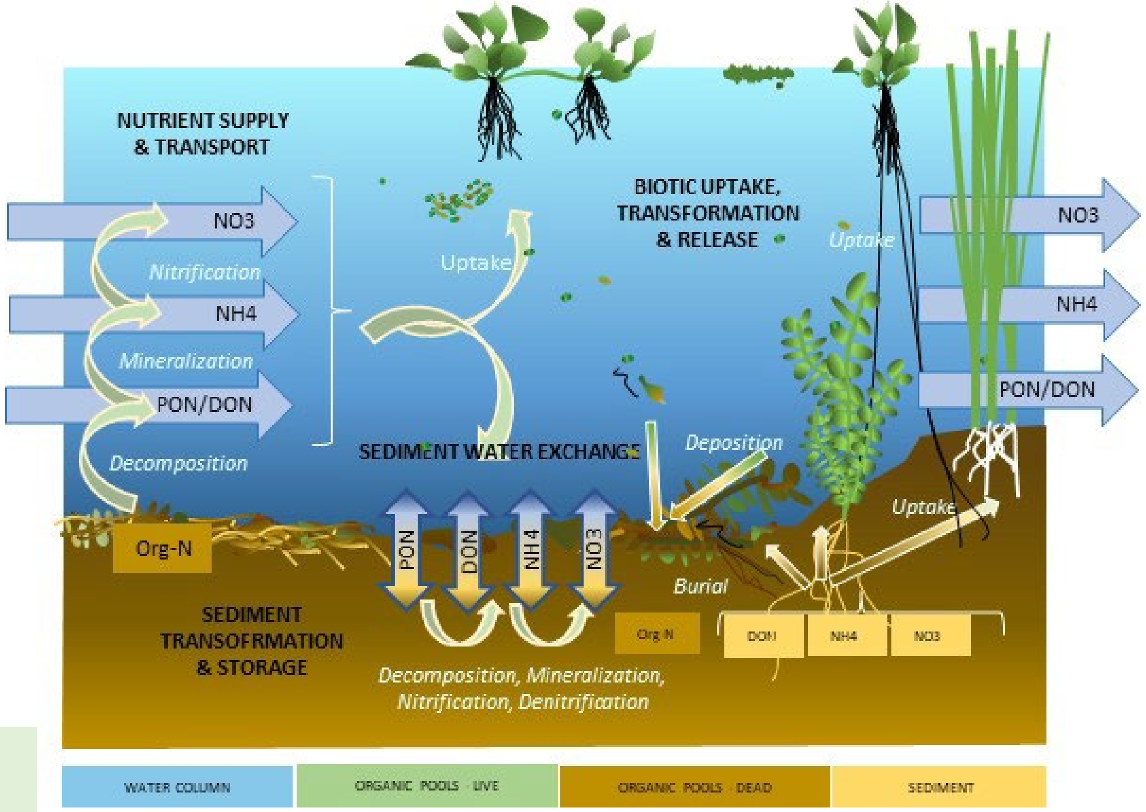
Status and Trends

- Nutrient concentrations, forms, ratios
- Phytoplankton abundance, species composition
- Cyanotoxin concentrations

Drivers and Interactions

- Nutrient transformation
- Nutrients ←→ Phytoplankton
- Nutrients ←→ Macrophytes

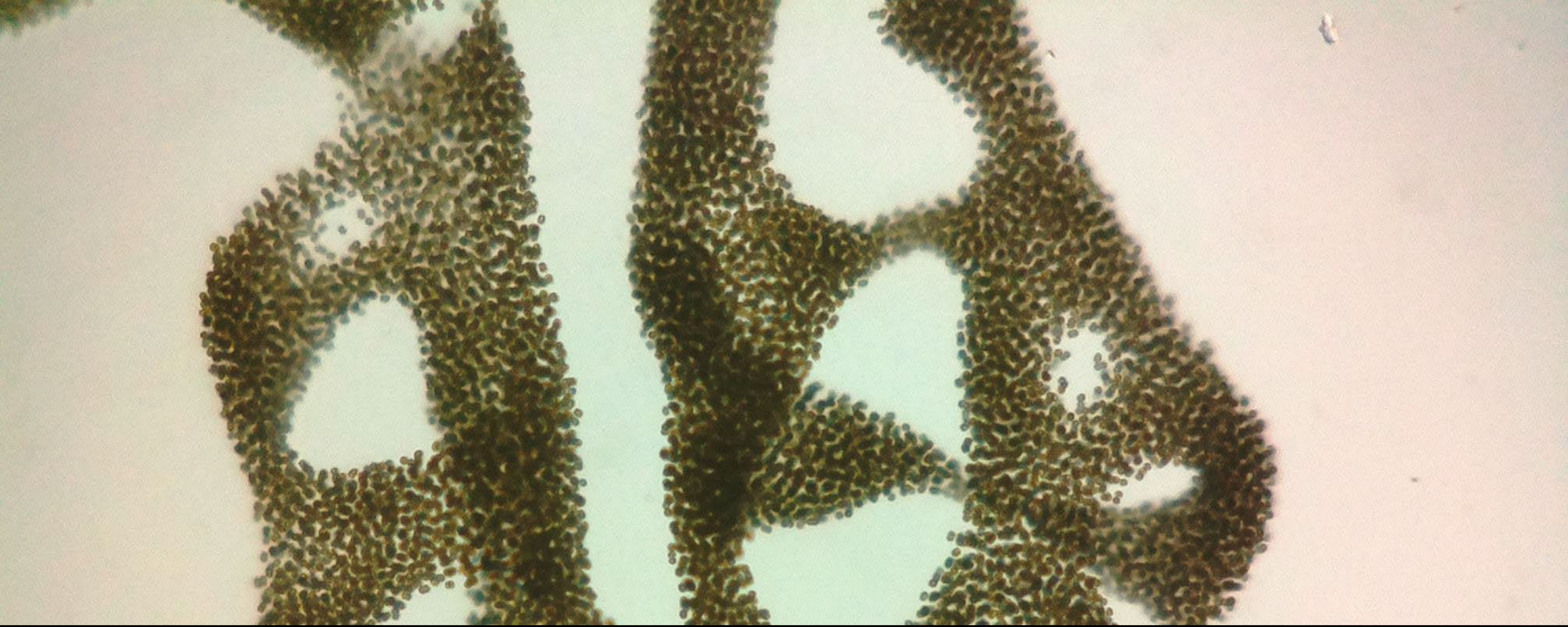
Environmental Complexity	Landscape Complexity
Hydrologic Complexity	Seasonal Patterns



f(location, season, WRTime)

USGS

Photo courtesy of USGS CAWSC Hydrodynamics Group



Cyanobacterial blooms in the Delta

USGS: Keith Bouma-Gregson, Tamara Kraus, Angela Hansen, Brian Bergamaschi
Dept. of Water Resources: Ted Flynn, Jared Frantzich, Scott Waller, Rosemary Hartman, Peggy Lehman (retired)
Funding: Delta Regional Monitoring Program, Delta Science Program, U.S. Bureau of Reclamation, USGS

Cyanobacteria

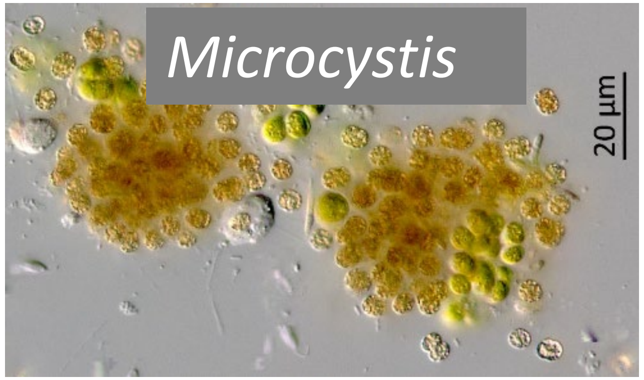
- Photosynthetic bacteria
- Evolved >2 billion years ago
- Globally distributed and found in almost all aquatic environments

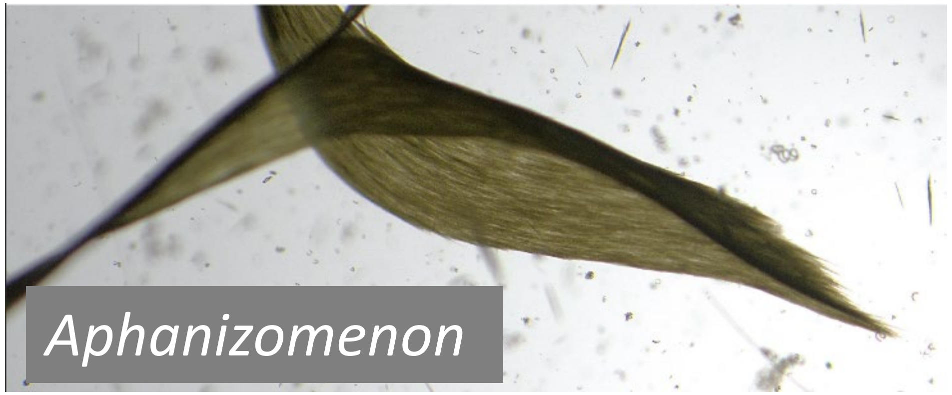
Nuisance and harmful blooms

- *Microcystis*
- *Aphanizomenon*
- *Dolichospermum*

Bloom impacts

Taste & odor compounds, filter clogging, aesthetics, low dissolved oxygen, food web, toxin production





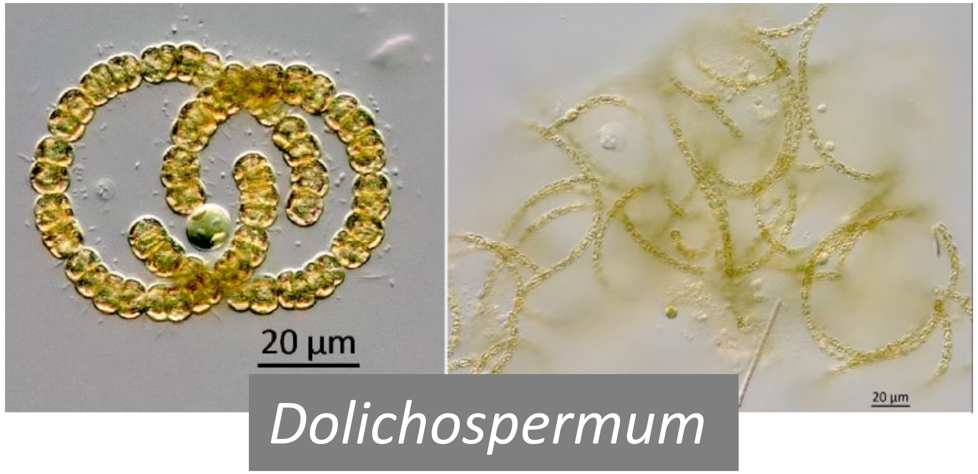


Photo credits: Barry Rosen

Cyanotoxins

Cyanotoxins are secondary metabolites: molecules NOT used for normal growth, development, and reproduction

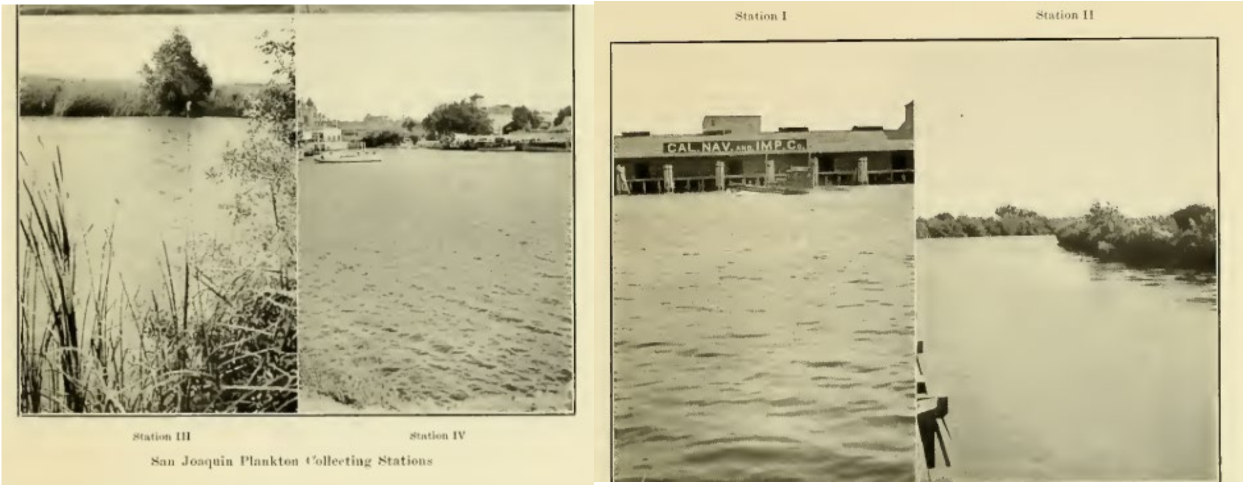
Types of effects

- Skin
- Kidneys
- Liver
- Nervous system

Toxin	Toxicity
Microcystin	Liver
Nodularin	Liver
Anatoxin	Nervous system
Cylindrospermopsin	Liver & kidney
Saxitoxin	Nervous system
Anabaenopeptins	(enzyme inhibition)

Cyanobacteria in the Delta

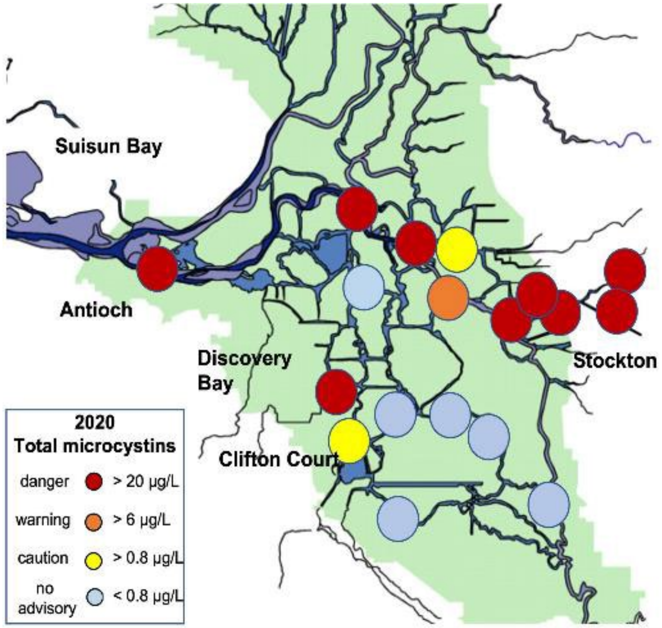
- 1913: W. E. Allen surveys San Joaquin River around Stockton and observes cyanobacteria
- 1999: First report of a “bloom” in the Delta (Hayes and Waller, 1999)
- Most research has focused on genus *Microcystis* and toxin microcystin
- 2016: DWR first detects anatoxins and saxitoxins in Delta (Lehman et al. 2021)
- Highest toxins Stockton, Discovery Bay, & marinas



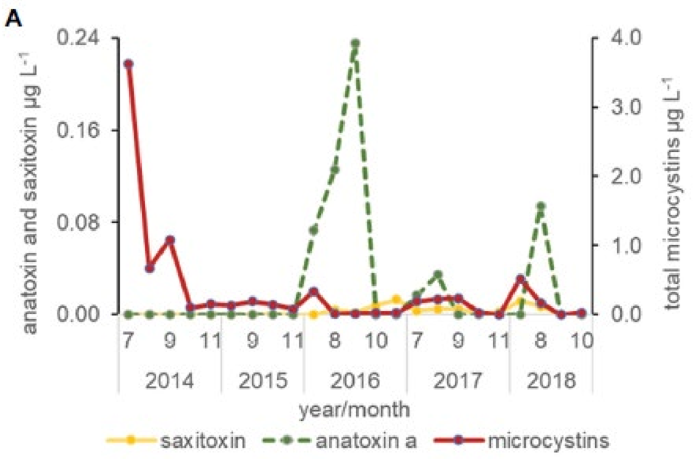
Allen 1920, *University of California Publications in Zoology*

Hayes and Waller 1999, *IEP Newsletter*

Figure 1 ***Microcystis aeruginosa*** **(side view in solution)**



Peggy Lehman, DWR, (2022 IEP workshop). Data Source: State Water Board FHAB Program, mywaterquality.ca.gov/habs



Lehman et al. 2021, *Frontiers in Microbiology*

USGS cyanoHAB projects

Two core data collection efforts

Continuous Fixed Station Network

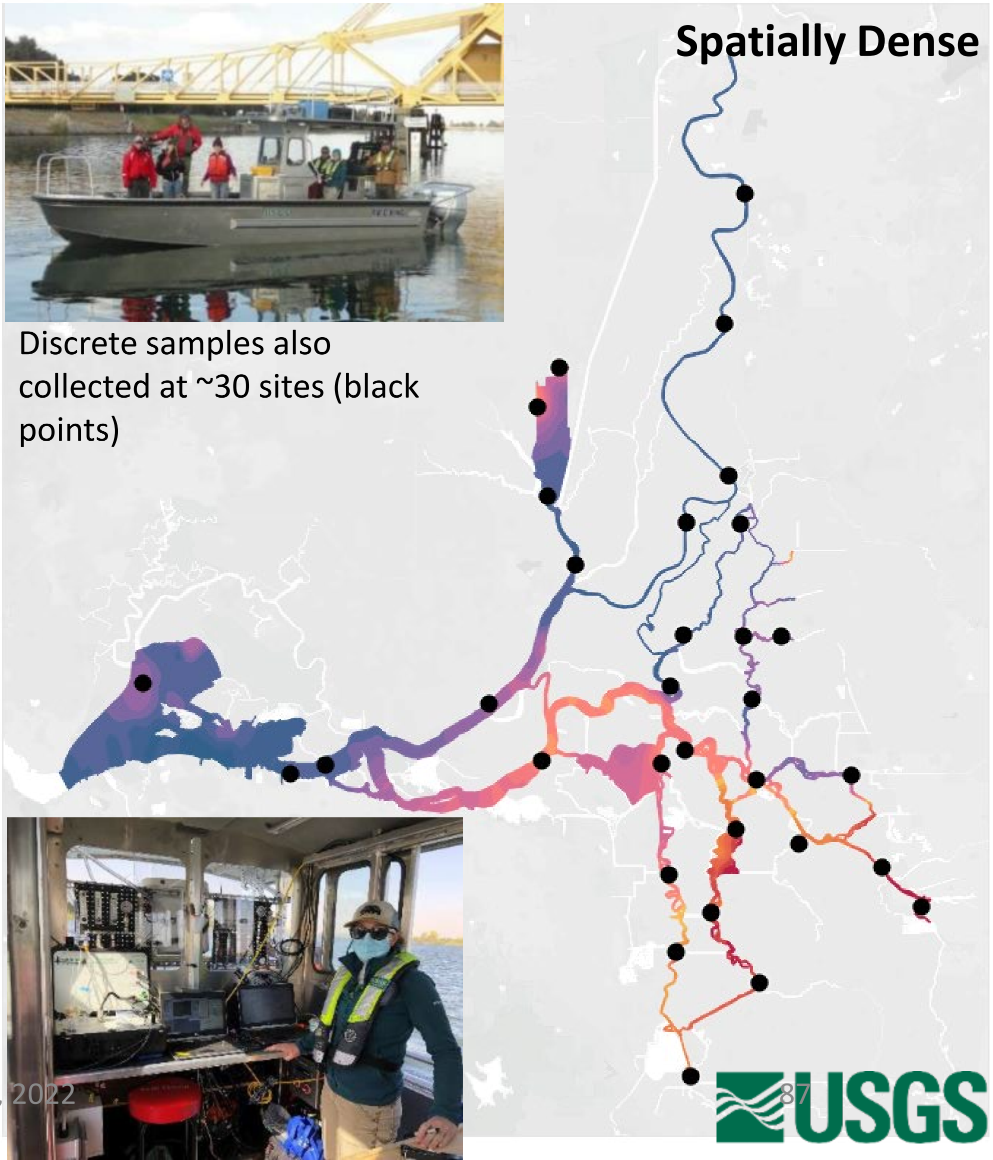
Temporally Dense

Funding

- Fixed station network funded by U.S. Bureau of Reclamation and Regional San (Freeport site)
- Mapping surveys (without addition of cyanotoxins) funded by
  - Delta RMP (2018, Spring 2020)
  - Delta Science Program (2020, 2021)
  - State Water Contractors (2022)

Boat-based High-Resolution Mapping

Spatially Dense



Discrete samples also collected at ~30 sites (black points)

Cyanotoxin monitoring

Year	Mapping toxins	Fixed station toxins	Funding
2020	Yes	2	DRMP, DSP, USGS
2021	Yes	6	DRMP, DSP, USGS
2022	Yes	6	DRMP, DSP
2023-2024	No	5	DSP

SITES

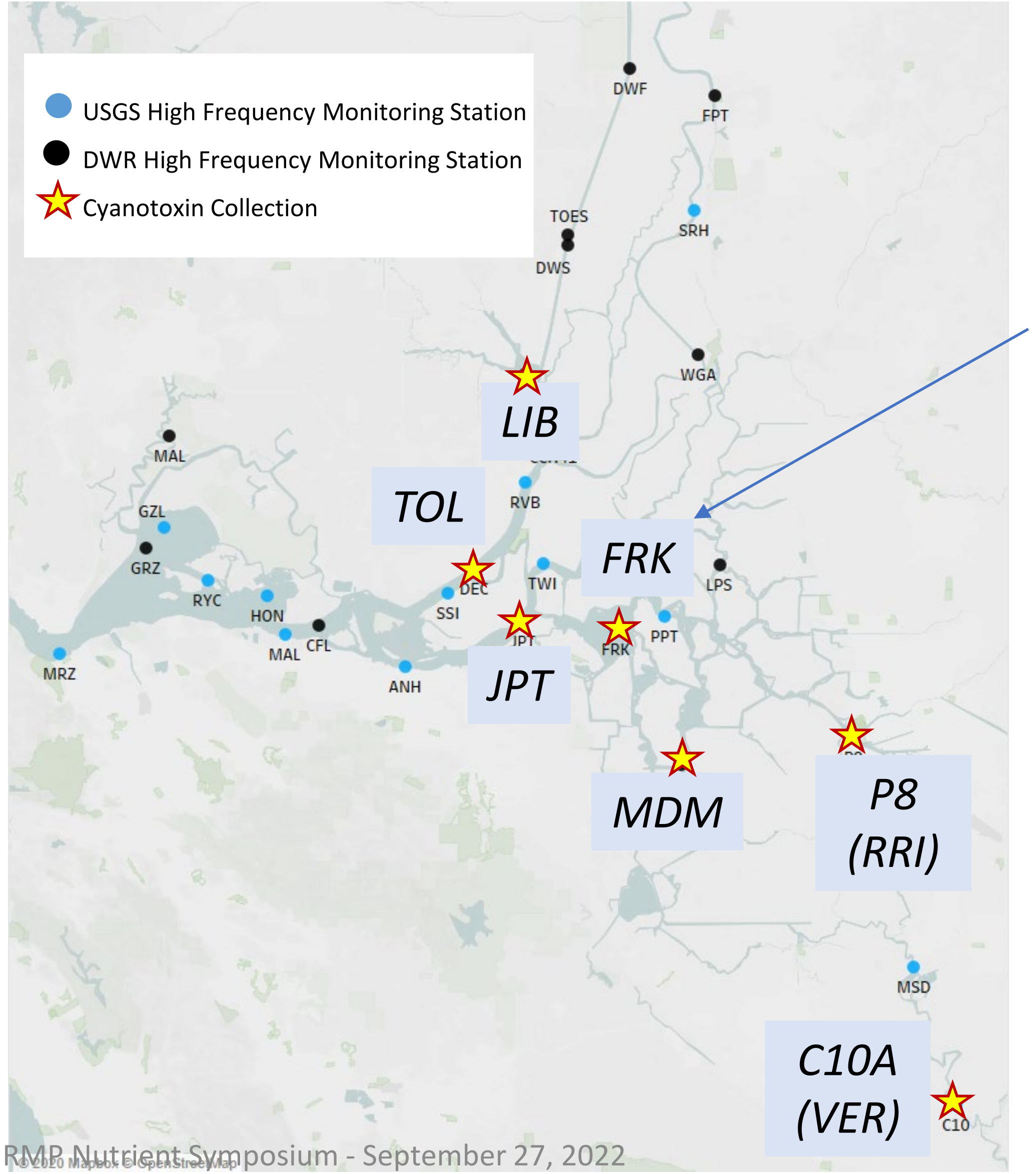
- Liberty Island (LIB)
- Sac. River Decker Isl. (DEC/TOL)
- SJ River, Jersey Point (JPT)
- SJ River, Rough & Ready (P8) – DWR site
- SJ River, Vernalis (C10A) – DWR site
- Middle River (MDM)

WHEN

- 18X per year
  - Oct-March, monthly
  - April-Sept, 2 weeks

SAMPLES

- Cyanotoxin analyses (LC-MS/MS)
  - Whole water
  - SPATTs



DWR project in 2022 to study HABs in Franks Tract related to Emergency Drought Barrier

SPATT samplers

SPATT: Solid Phase Adsorption Toxin Tracking

- Made of adsorption resin sandwiched in mesh
- Concentrates dissolved cyanotoxins onto resin
- Integrates over time
    - useful in flowing systems (rivers and estuaries)
- Very sensitive
- Semi-quantitative (not easily compared with grab samples)

USGS

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

What are the data gaps identified in the Delta Nutrient Research Plan addressed by this study?

1) Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?

4) What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?

7) How do nutrients and other drivers control the growth rate, maximum biomass, and toxin production of HABs?

19) Do predictive relationships exist between cyanobacteria (bloom occurrence and toxin concentrations) and readily available data (e.g., nitrogen forms, chlorophyll, and other pigments) from continuous sensors or other sources?

25) Would changes in nutrients or physical drivers reduce the frequency and magnitude of benthic and planktonic cyanobacteria causing taste and odor problems?

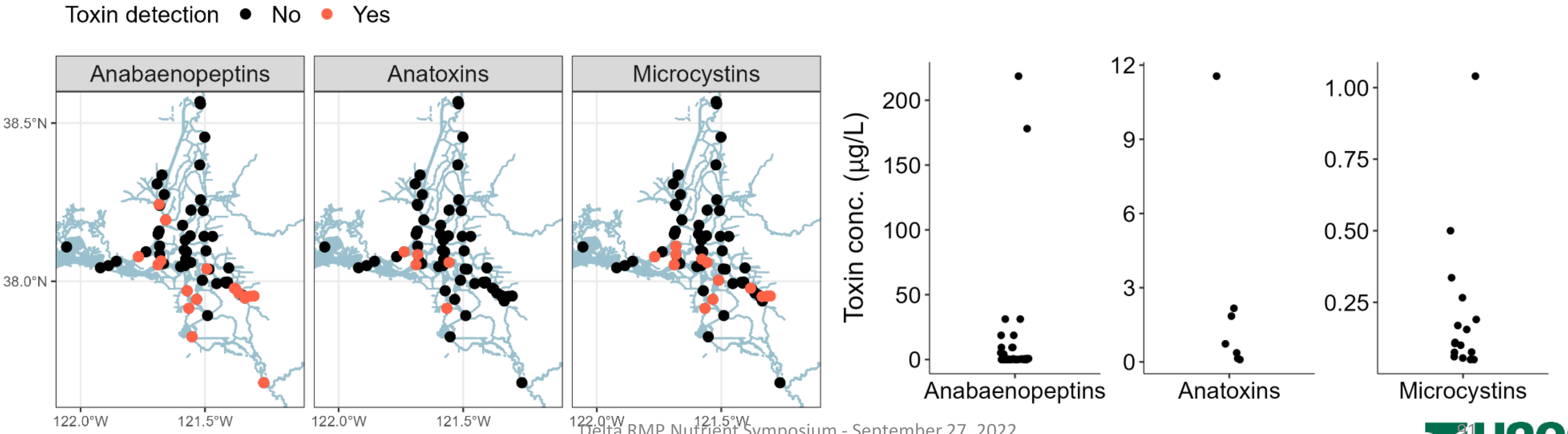
Water results

- Anabaenopeptins most frequently detected
- Detections in Central and South Delta
- Microcystins and anatoxins detected below recreational advisory concentrations

  CA Rec. Warning level (µg/L)

  Anabaenopeptins: N/A, Anatoxins: 20, Microcystin: 6

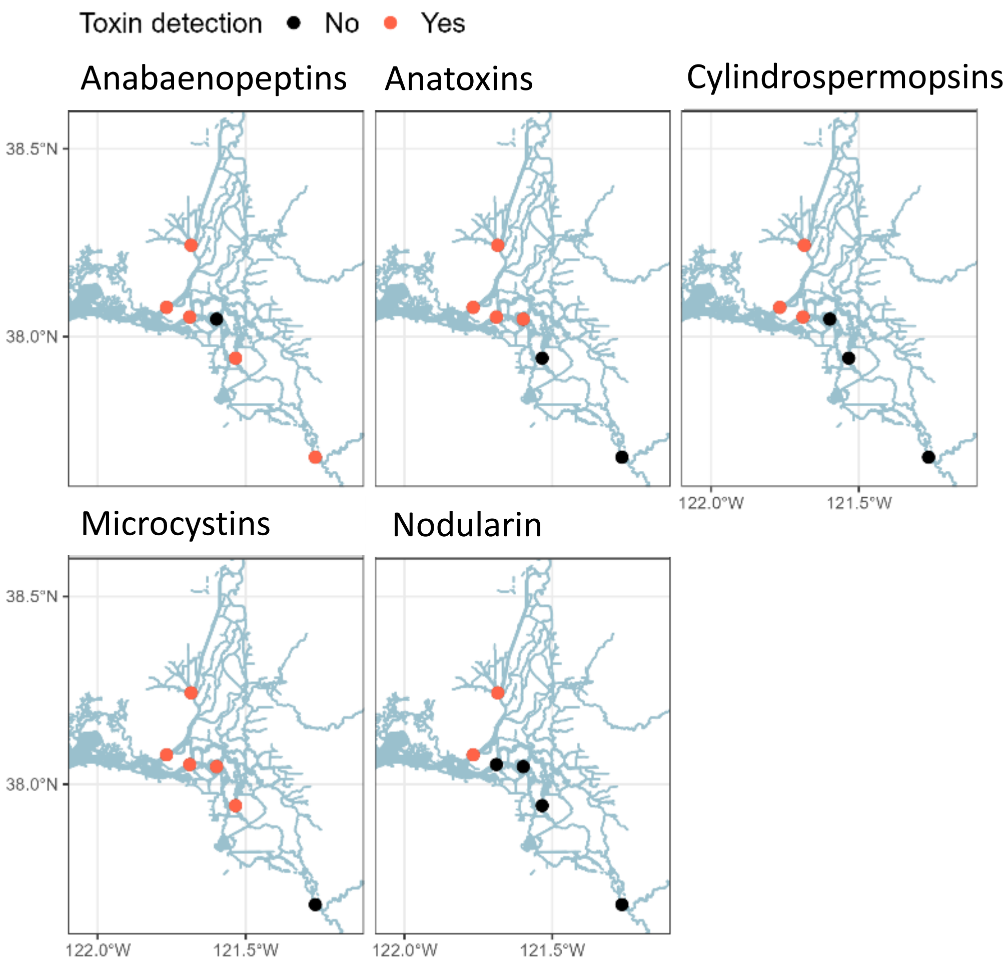
Toxin class	Whole water detections (LC-MS/MS)
Anabaenopeptins	44 (N = 386)
Microcystins	16 (N = 405)
Anatoxins	7 (N = 405)
Cylindrospermopsins	0 (N= 386)
Nodularin	0 (N = 376)



SPATT results

- More toxin classes detected than with discrete grab samples
- More frequent detections of cyanotoxins than with discrete grab samples
- Anatoxins detected earlier in the year

Toxin class	**Whole water detections (LC-MS/MS)**
Anabaenopeptins	30 (N = 174)
Microcystins	84 (N = 236)
Anatoxins	32 (N = 288)
Cylindrospermopsins	9 (N = 174)
Nodularin	5 (N = 174)

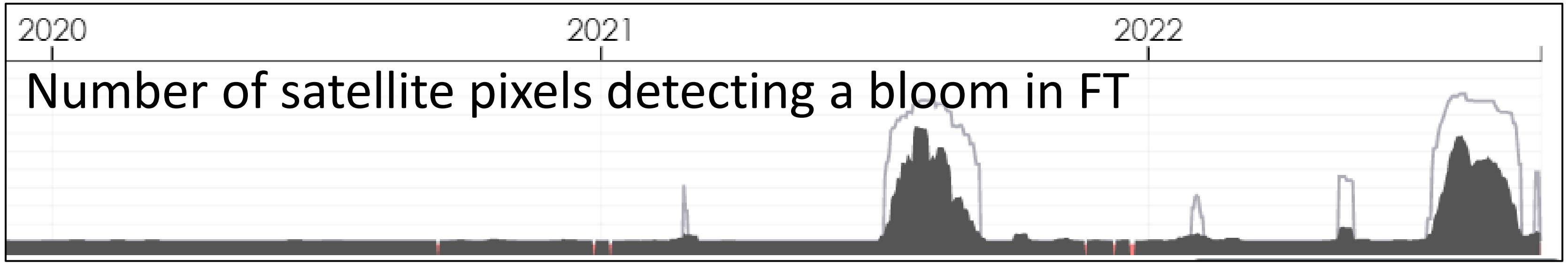


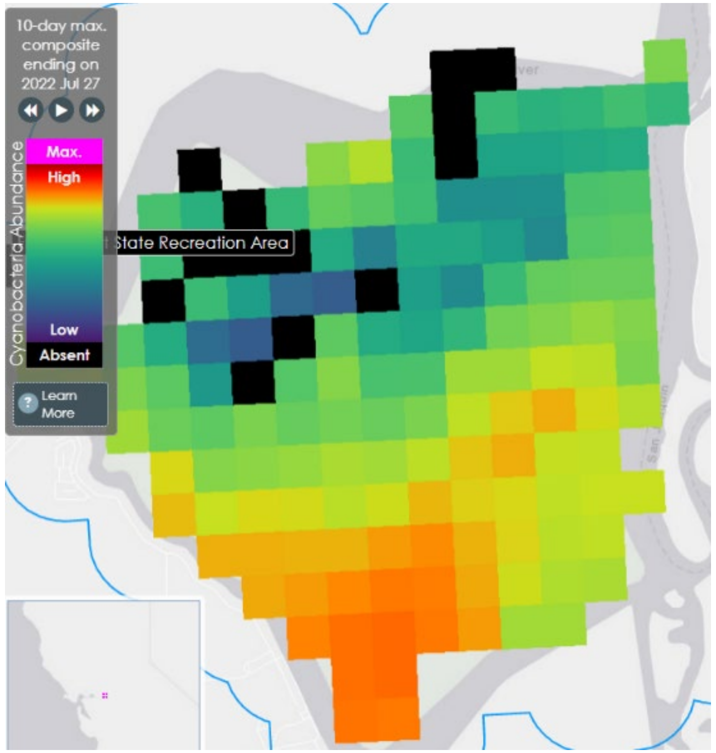
Months with detections

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MC SPATT	1			1	4	11	12	26	3	24	1	1
MC WW					1		12	3				
ATX SPATT	1		4	4		5	3	7	3	5		
ATX WW				4	1		2					

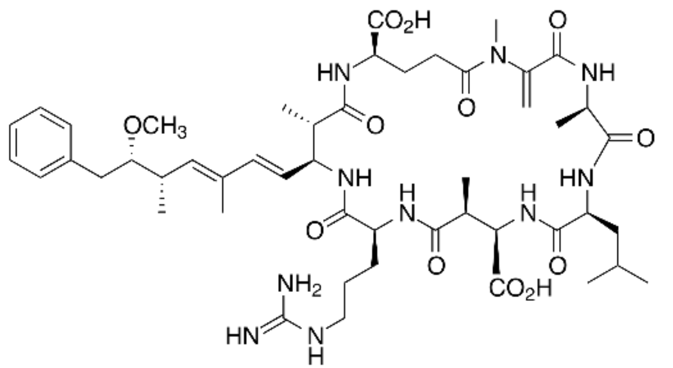
Franks Tract blooms

- Blooms in Franks Tract in 2021 and 2022
- 2022 bloom dominated by *Dolichospermum and Aphanizomenon* (both N fixers), not *Microcystis.*
- No water toxins detected in FT in 2022 (SPATT detected MC & ATX)



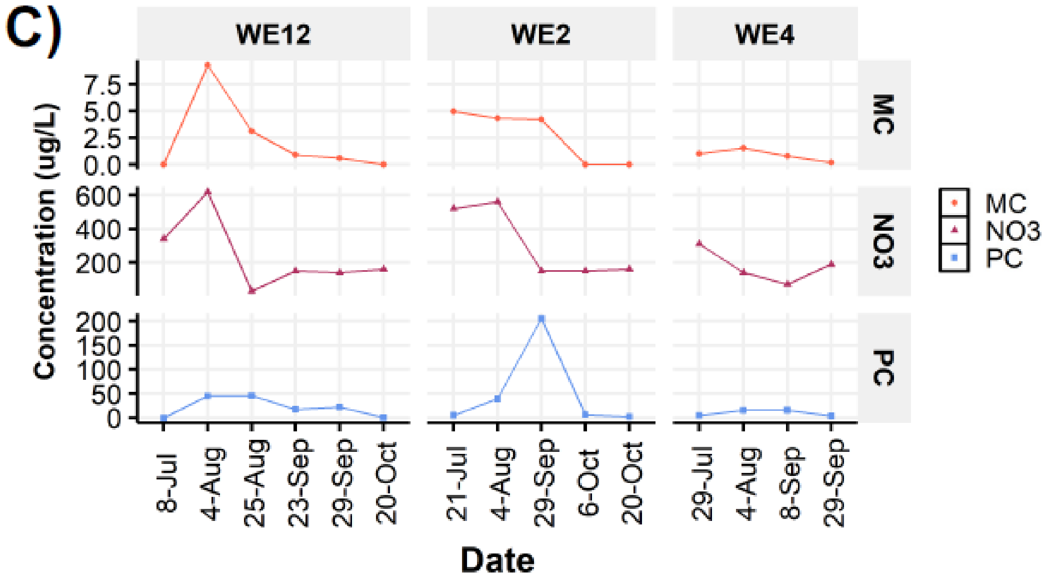


Microcystin and nitrogen

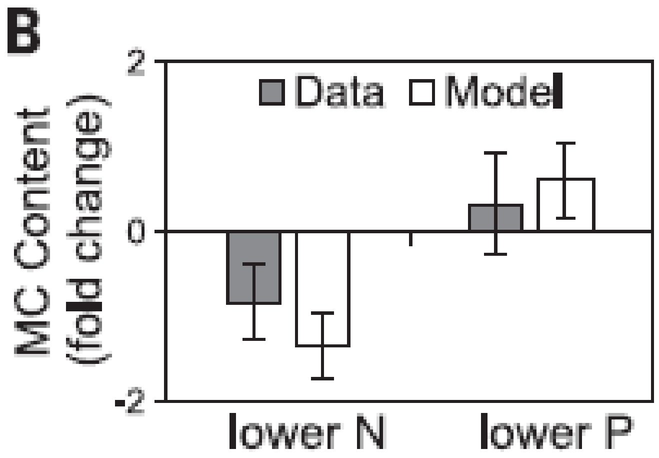


- Microcystin molecule has 10 nitrogen atoms ($C_{49}H_{74}\mathbf{N_{10}}O_{12}$)

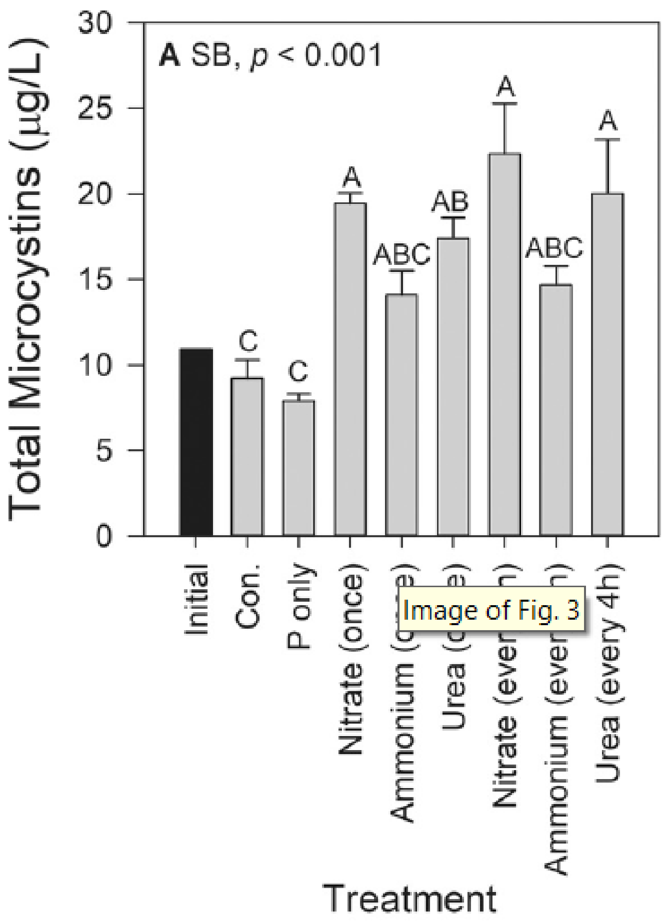
- Research has shown a decrease in microcystin producing *Microcystis* strains and microcystin production when N is low (Gobler et al. 2016).



Yancey et al., 2022, *Appl. Env. Bio*



Hellweger et al., 2022, *Science*

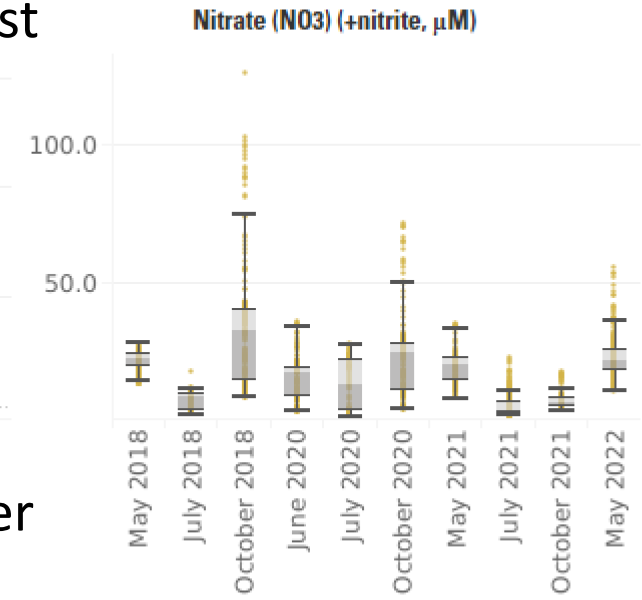


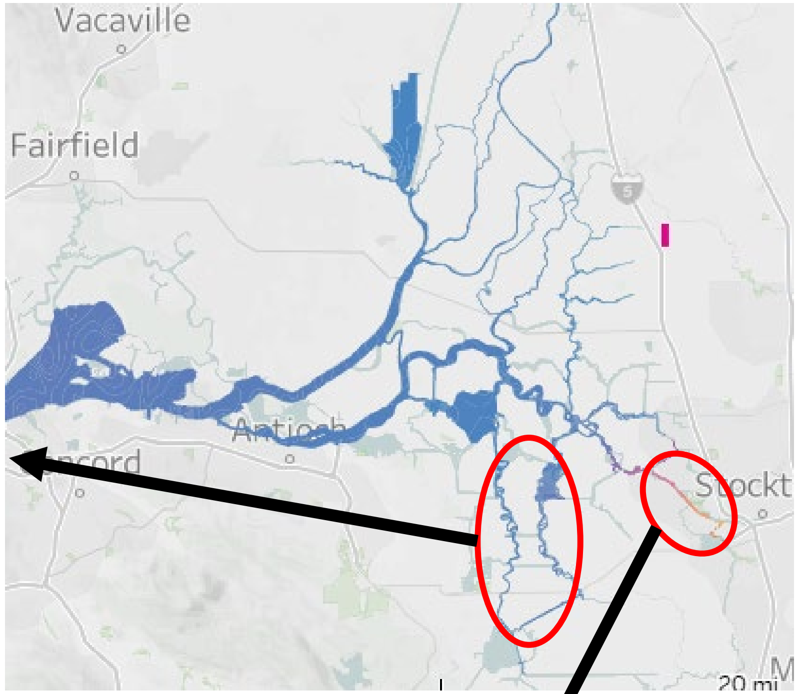
Chaffin et al., 2018, *Harmful Algae*

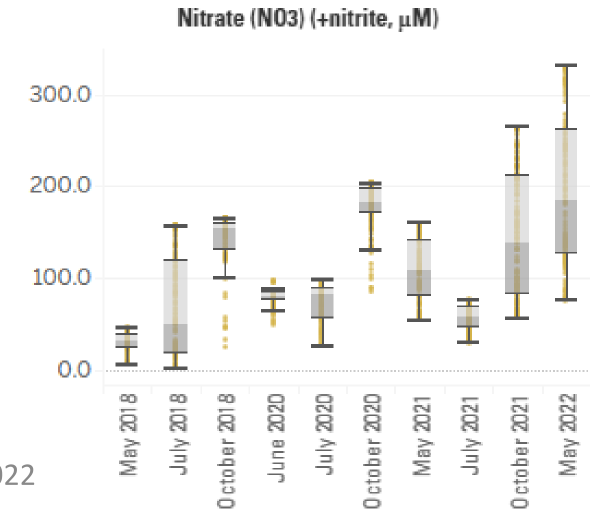
Microcystin and nitrogen

- Nitrogen gradients exist in the Delta. Highest nitrate in SJR Deep Water Shipping channel near Stockton

- Nitrate concentrations decrease moving westward
  - Phytoplankton uptake and dilution/dispersion with Sac. River water







Are lower *Microcystis* abundances and microcystin concentrations related to lower dissolved inorganic nitrogen concentrations?

What are the data gaps identified in the DNRP addressed by this study?

1) Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?
   - South and Central Delta, though lower abundances in Cache Slough Complex
   - Impacts to drinking water intakes in 2021 and 2022

4) What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?
   - Microcystins, anatoxins, cylindrospermopsin, anabaenopeptins, and possibly more

7) How do nutrients and other drivers control the growth rate, maximum biomass, and toxin production of HABs?
   - Is there a relationship between nitrogen and microcystin production?

19) Do predictive relationships exist between cyanobacteria (bloom occurrence and toxin concentrations) and readily available data (e.g., nitrogen forms, chlorophyll, and other pigments) from continuous sensors or other sources?

25) Would changes in nutrients or physical drivers reduce the frequency and magnitude of benthic and planktonic cyanobacteria causing taste and odor problems?

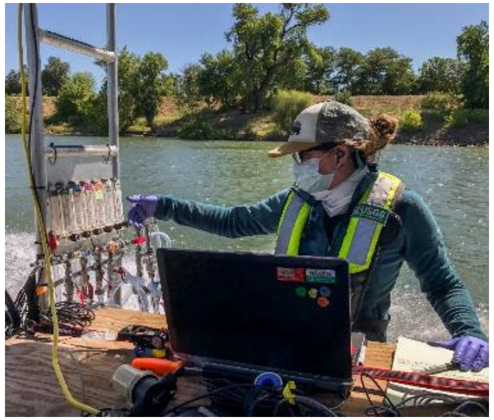
Stay tuned for first set of reports once we get all the summer 2022 data back

How can future research projects inform data gaps identified in the DNRP?

1. Research on anatoxin producers and timing of anatoxin production and other toxins being produced
2. Monitoring or studies to compare cyano *hot spots* to conditions at long-term monitoring stations by USGS or EMP
3. Targeted research on relationship between nitrogen and microcystin production and *Microcystis* strains
4. Targeted research on differences in ecology of *Dolichospermum* and *Aphanizomenon* compared to *Microcystis*

USGS

Acknowledgements



Thanks to all the staff (USGS & DWR) out collecting and processing data/samples. It could not be done without you!

Acknowledgements

Funding from

Delta Regional Monitoring Program
Delta Science Program
U.S. Bureau of Reclamation
Sacramento Regional Sanitation District
State Water Contractors
SFEI/Aquatic Science Center
U.S. Geological Survey
…others

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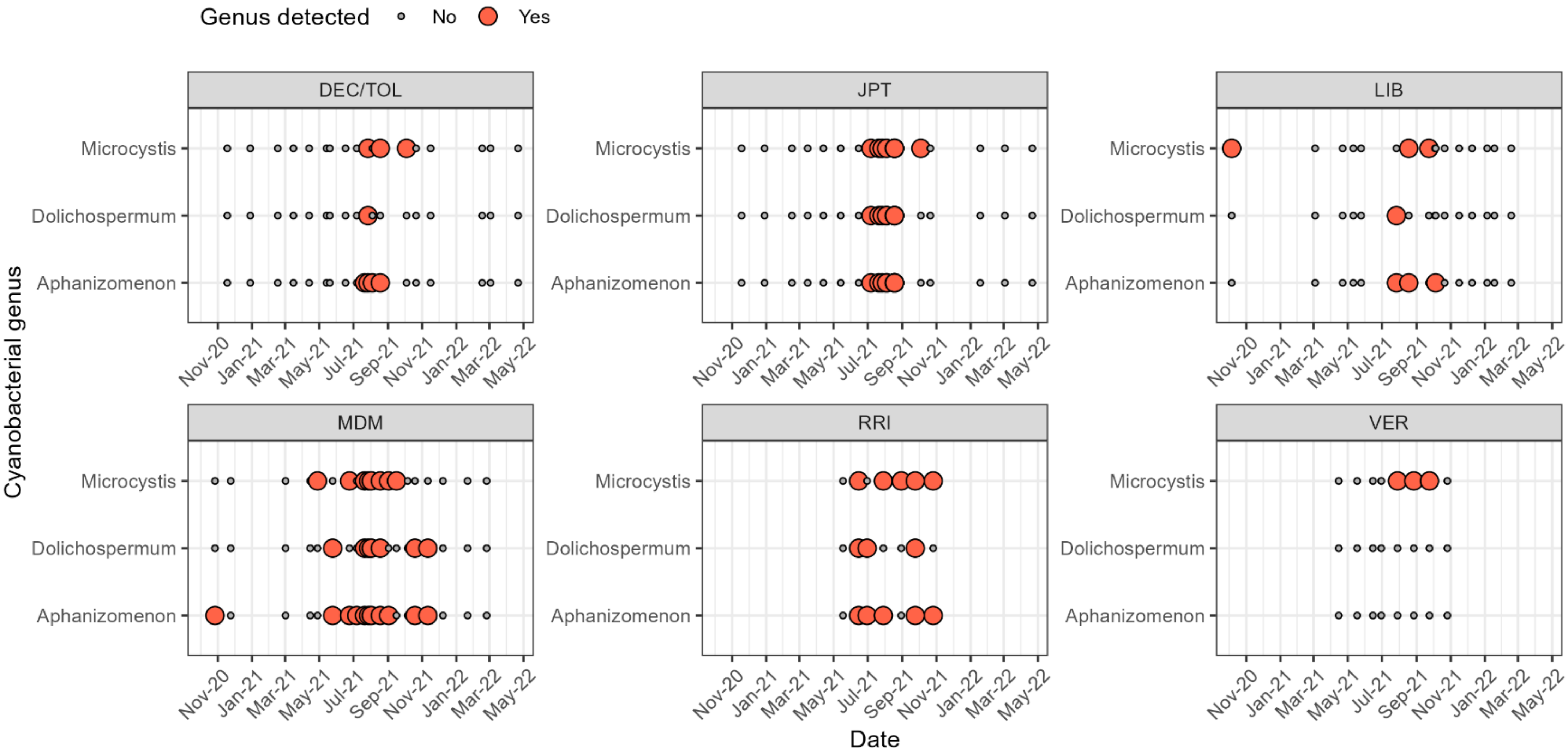
Hellweger, et al. (2022). Models predict planned phosphorus load reduction will make Lake Erie more toxic. *Science* 376, 1001–1005. doi: 10.1126/science.abm6791.

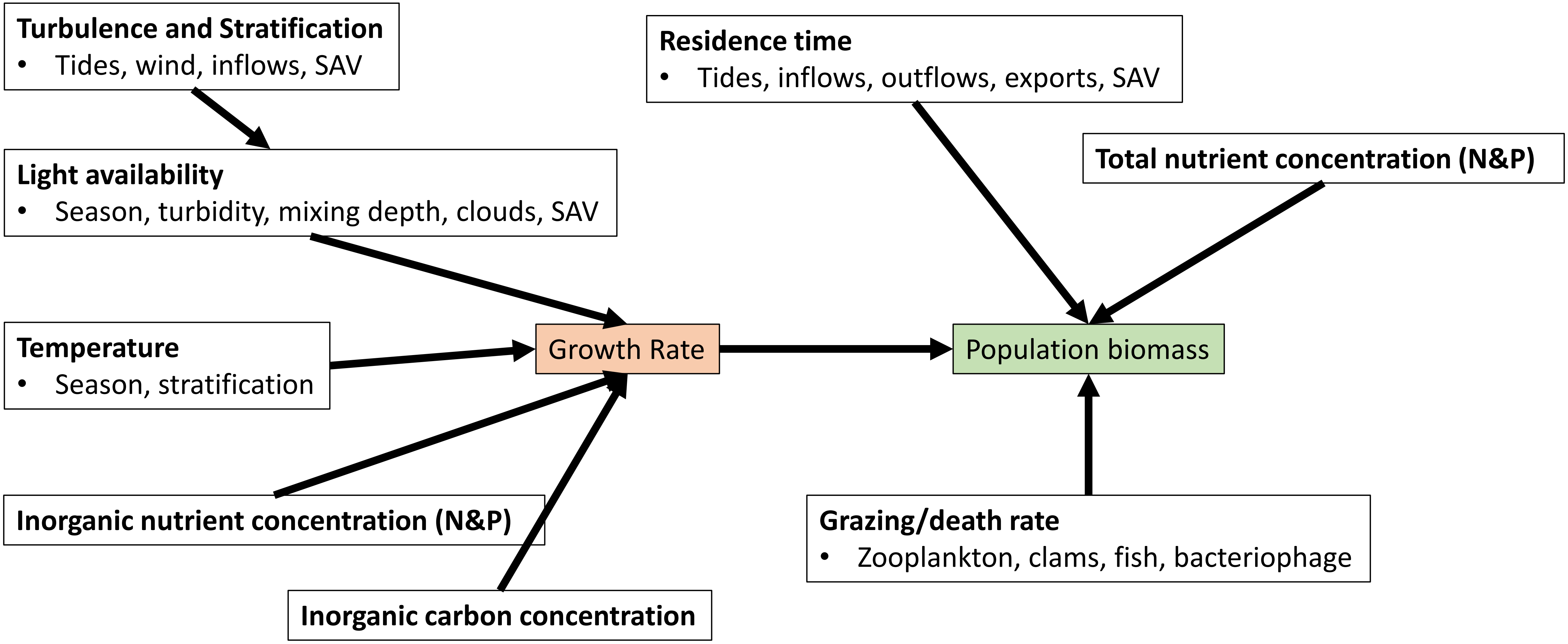
Lehman, et al. (2021). Covariance of phytoplankton, bacteria, and zooplankton communities within *Microcystis* blooms in San Francisco Estuary. *Front. Microbiol.* 12, 632264. doi: 10.3389/fmicb.2021.632264.

Mioni, et al. (2011). Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). Rancho Cordova, CA: Central Valley Regional Water Quality Board Available at: https://www.lakecountyca.gov/Assets/Departments/WaterResources/Algae/2011+Cyanobacteria+Report.pdf.

Yancey, et al. (2022). Metagenomic and Metatranscriptomic Insights into Population Diversity of *Microcystis* Blooms: Spatial and Temporal Dynamics of *mcy* Genotypes, Including a Partial Operon That Can Be Abundant and Expressed. *Appl Environ Microbiol*. e02464-21. doi: 10.1128/aem.02464-21.

Phytoplankton results





Turbulence and Stratification
• Tides, wind, inflows, SAV
Light availability
• Season, turbidity, mixing depth, clouds, SAV
Temperature
• Season, stratification
Growth Rate
Inorganic nutrient concentration (N&P)
Inorganic carbon concentration
Residence time
• Tides, inflows, outflows, exports, SAV
Total nutrient concentration (N&P)
Population biomass
Grazing/death rate
• Zooplankton, clams, fish, bacteriophage

Expanding the Spatial and Seasonal Research on Delta Cyanobacterial Harmful Algal Blooms

ELLEN PREECE, ROBERTSON-BRYANT, INC.

STATUS & TRENDS IN NUTRIENT STUDIES, 11:55 AM TO 12:20 PM

Delta Regional Monitoring Program

Robertson - Bryan, Inc.
Solutions for Progress

Delta RMP Nutrient Symposium
STATUS AND TRENDS IN NUTRIENT STUDIES

EXPANDING THE SPATIAL AND SEASONAL RESEARCH ON DELTA CYANOBACTERIAL HARMFUL ALGAL BLOOMS

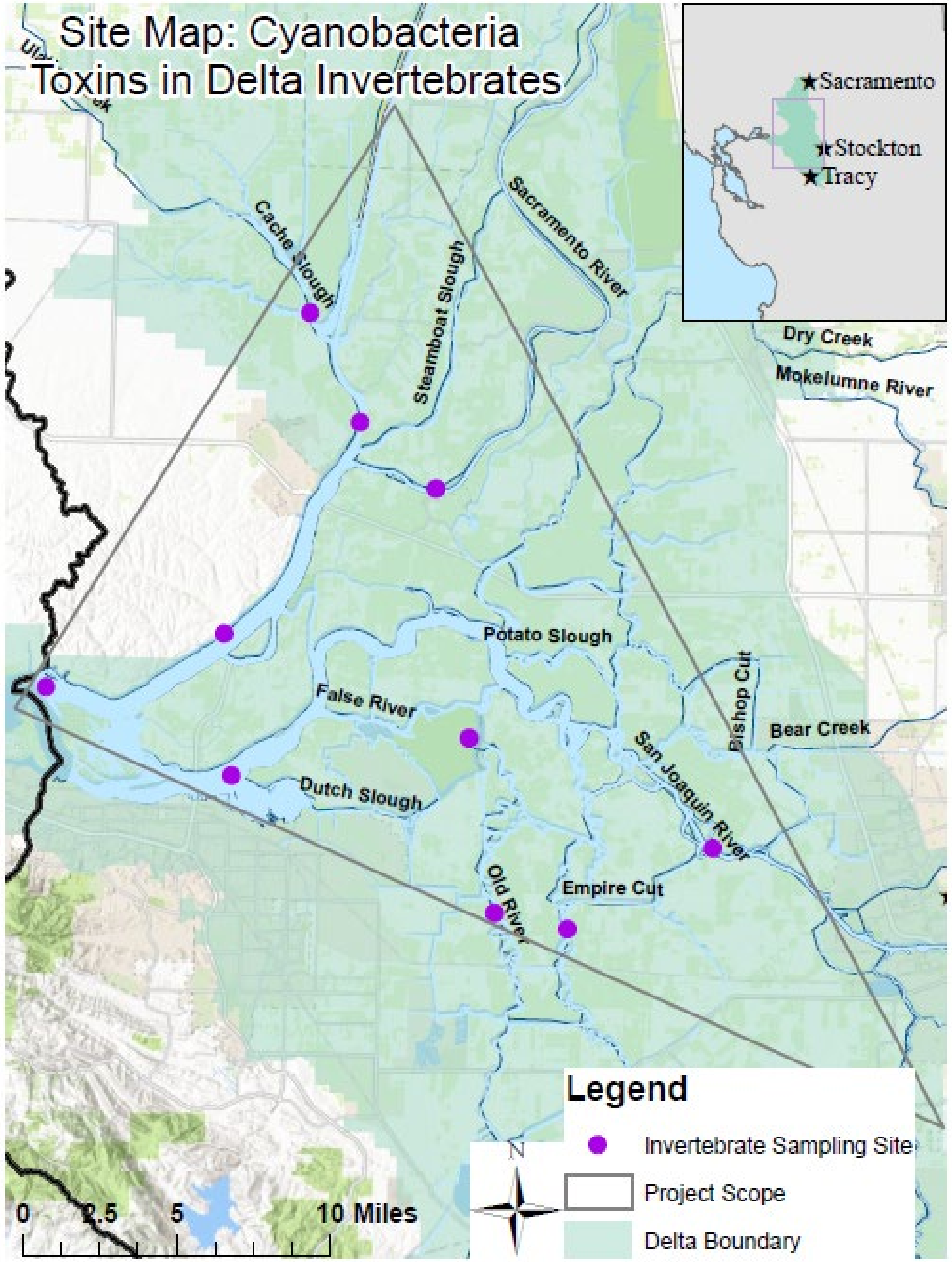
Ellen P. Preece

Robertson-Bryan, Inc.

Stockton Waterfront August 2020
Photo Cred: Janis Cooke

Overview

- Introduction to ongoing cyanobacteria harmful algal bloom (CHAB) research projects
- Spatial findings
- Seasonal/temporal findings
- Project findings and DNRP knowledge gaps
- How future research address DNRP knowledge gaps



Shellfish Study

Identifying Cyanobacterial harmful Algal Bloom Toxins in Delta Invertebrates: Implications for Native Species and Human Health

Project Goal

Determine if HAB toxins (MC/STX) are stressors on food webs and native fish including managed species

- **Sample from 2020 – 2022**
- **Collect Asian clams from sediments at 10 sites**
- **Opportunistically collected crayfish**
- **Measure microcystin (MC) and saxitoxin (STX) in shellfish and water**
- **Funded by Proposition 1**

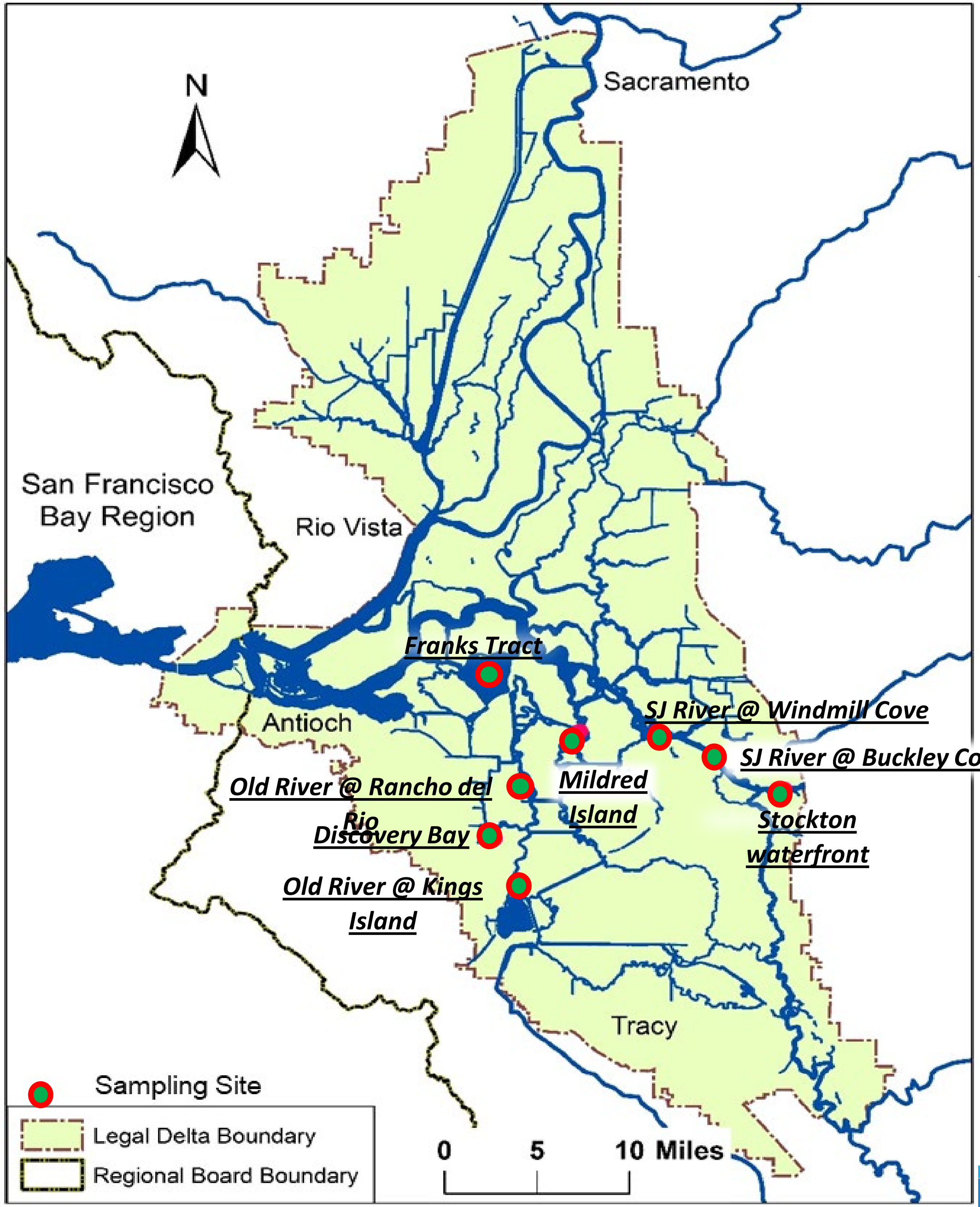


Figure 1. Map of the sites impacted by CHABs to be sampled.

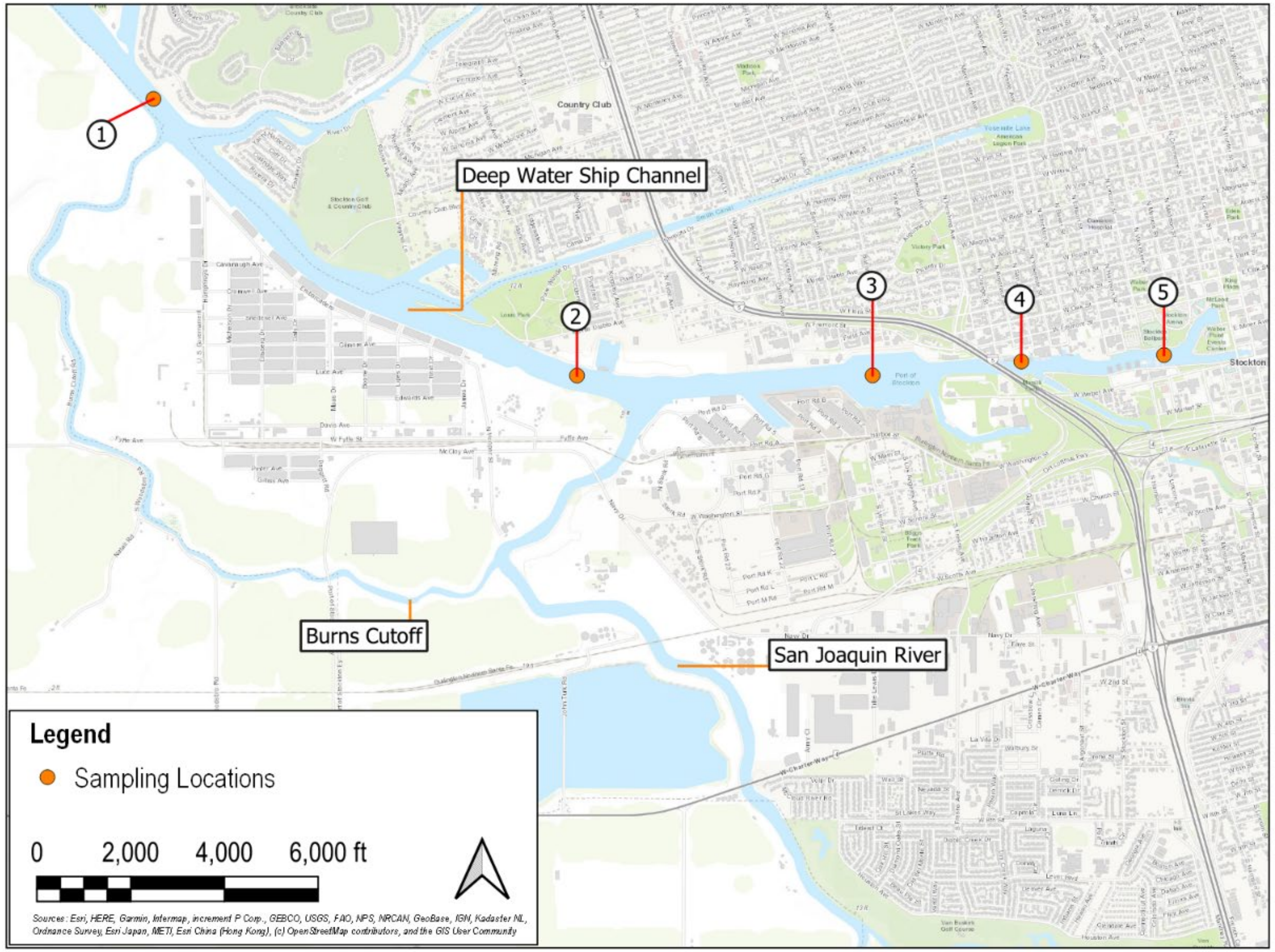
Sediment Study

MAPPING BENTHIC OVERWINTERING *MICROCYSTIS SP.* WITHIN THE SACRAMENTO-SAN JOAQUIN DELTA

Project Goal

Determine if *Microcystis* blooms throughout the Delta are generated by benthic resting cells from a few select locations

- **Sample from 2020 – 2022**
- **Collect sediment samples at 8 sites**
  - **November (end of bloom season) and April (beginning of bloom season)**
  - **Dead end sloughs and sites with greater hydrologic connectivity**
- **Use QPCR to quantify *Microcystis* seedstock in sediments**
- **Funded by Delta RMP Supplemental Environmental Project funds, State FHAB funds, Central Valley Water Board**



Stockton Study

2022 Stockton Cyanobacteria Harmful Algal Bloom Monitoring Project

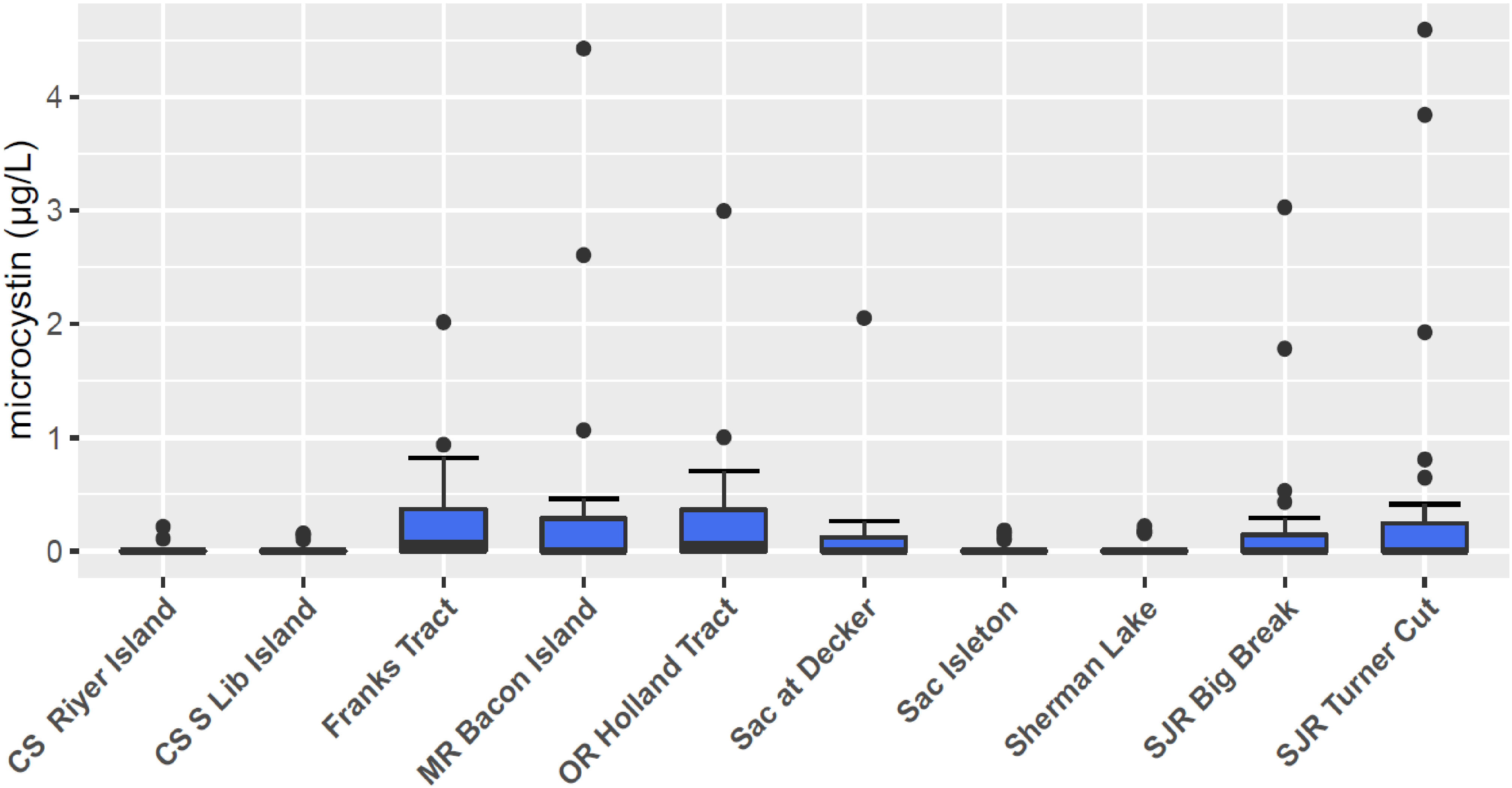
Project Goal

Characterize CHABs and associated cyanotoxins across the Stockton Deep Water Ship Channel

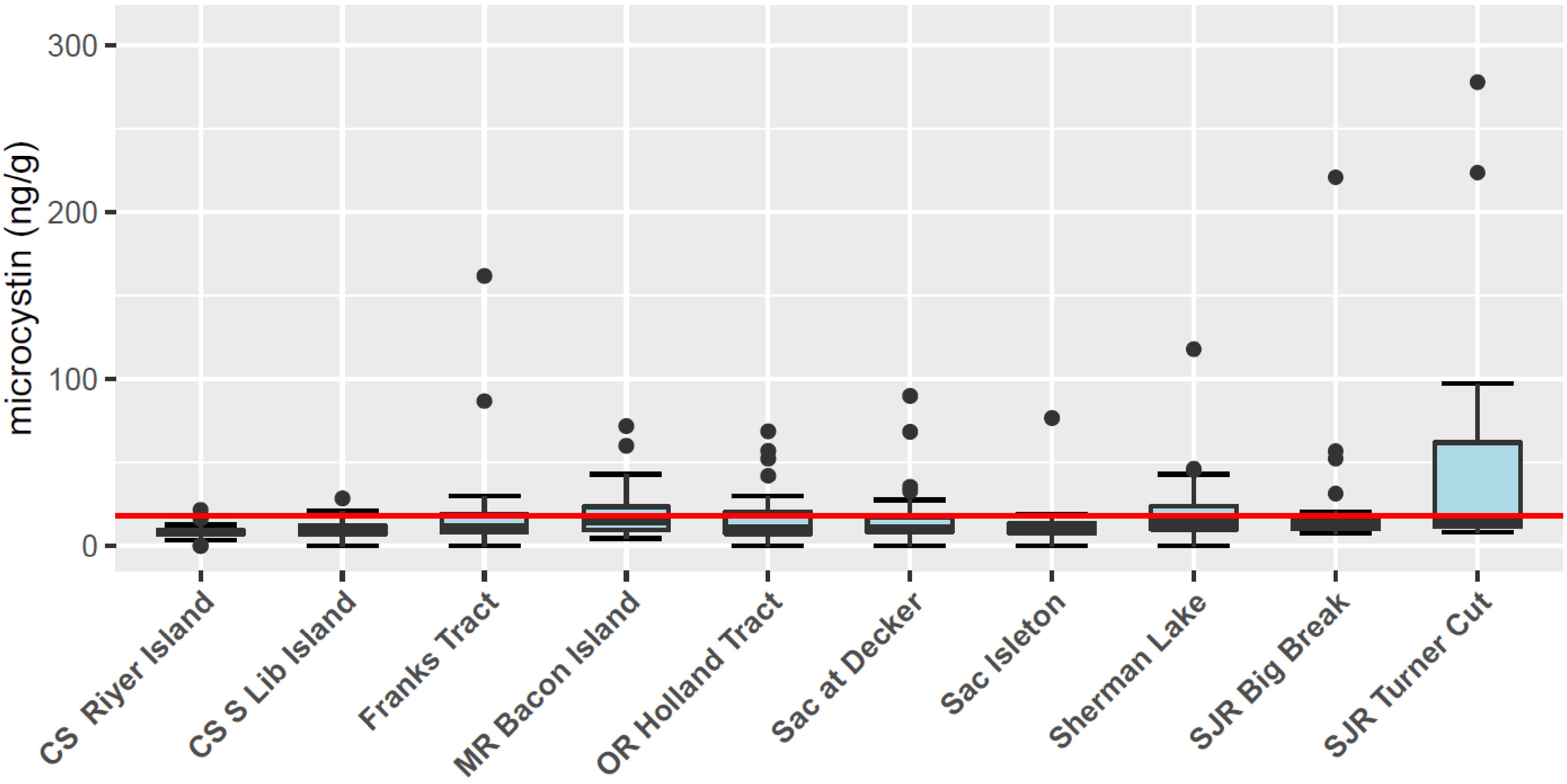
- **Sample at 5 sites on 11 dates**
- **Collect water samples to determine fluctuations in water quality across time, depth and space**
- **Collect sediment samples to characterize legacy phosphorus**
- **Funded by Central Valley Water Board, State FHAB funds, City of Stockton, Port of Stockton**

Spatial Findings

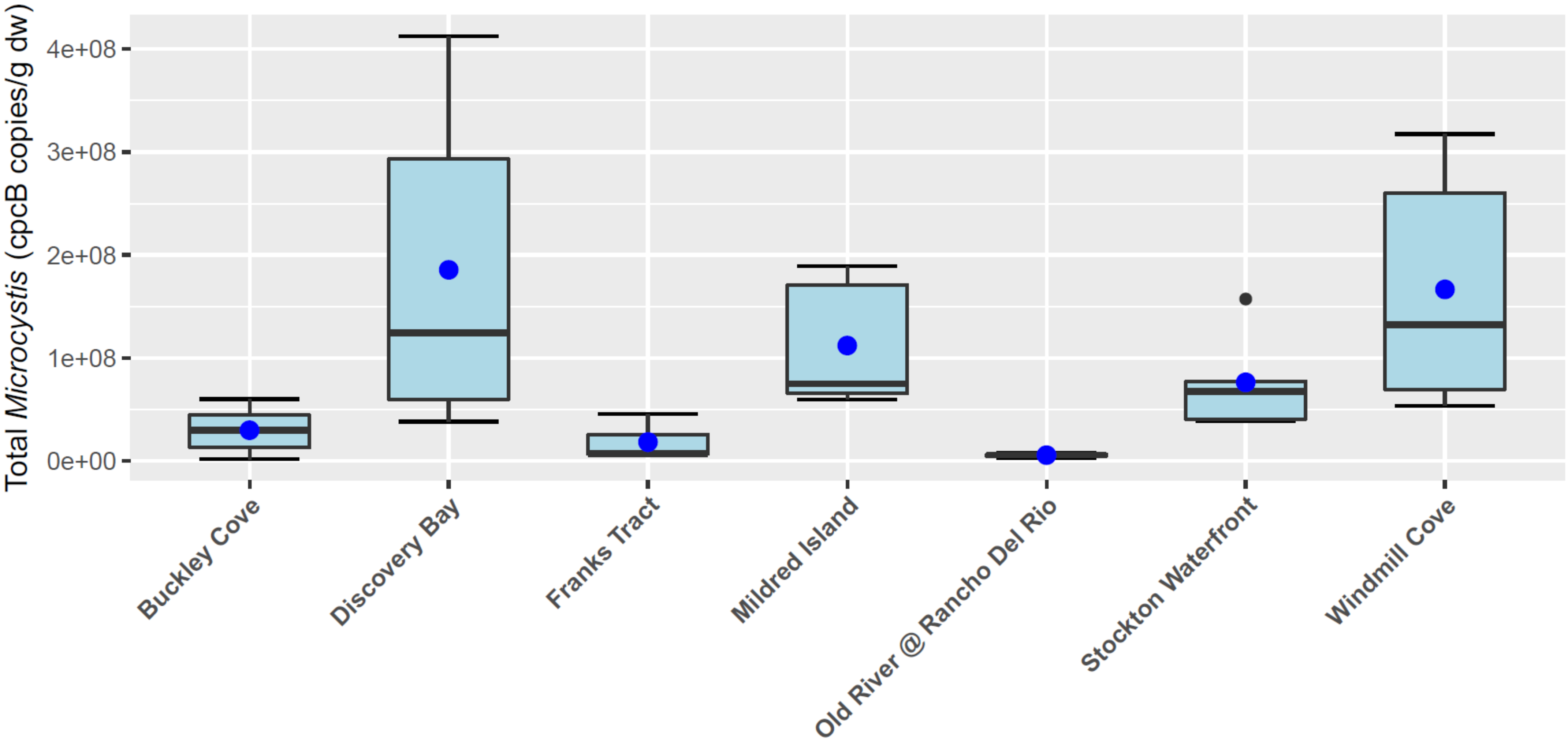
Shellfish Study - Microcystin in water

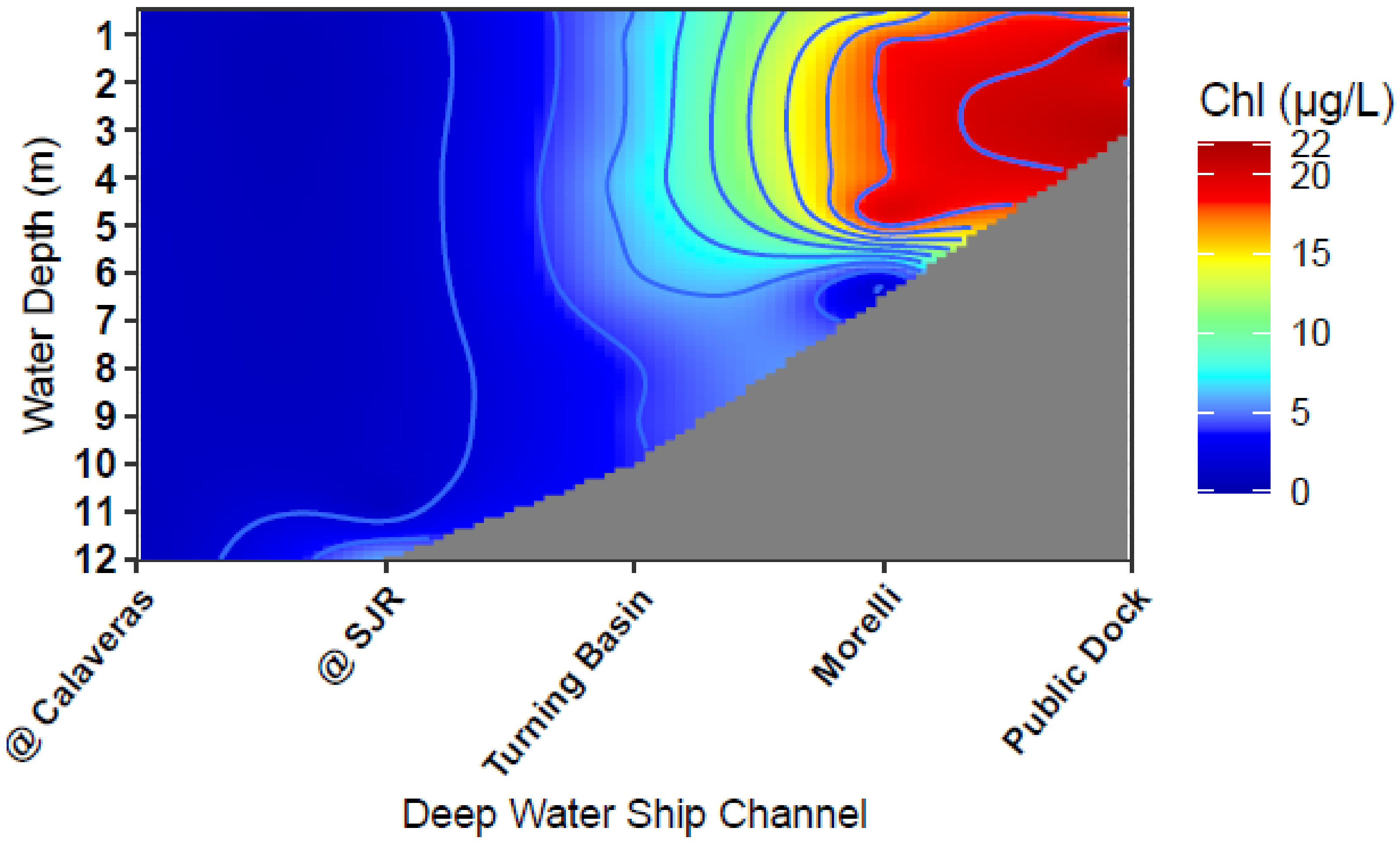


Shellfish Study - Microcystin in Asian Clams (*Corbicula Fluminea*)



Sediment Study – *Microcystis* seedstock in November



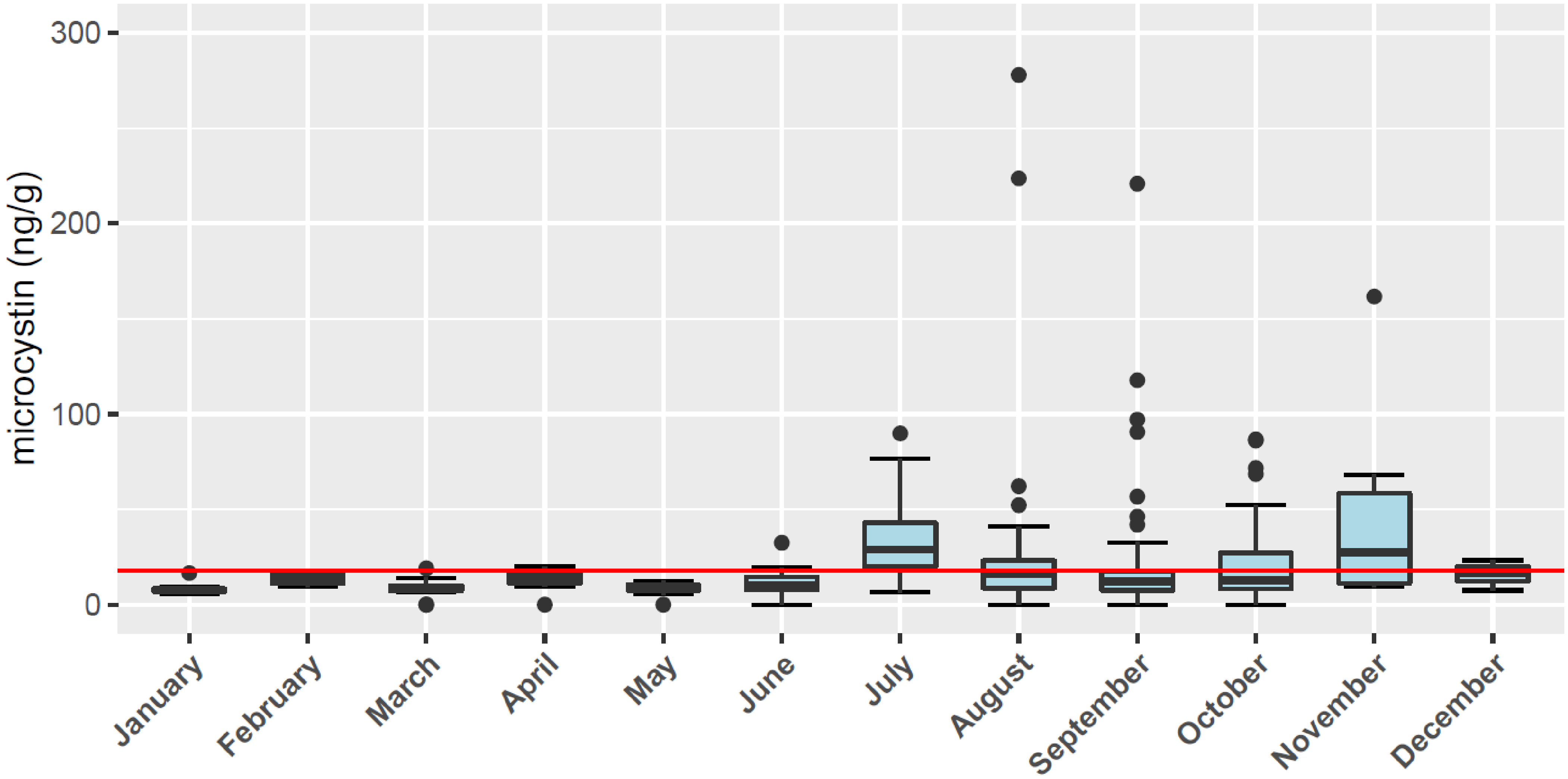


Stockton Study

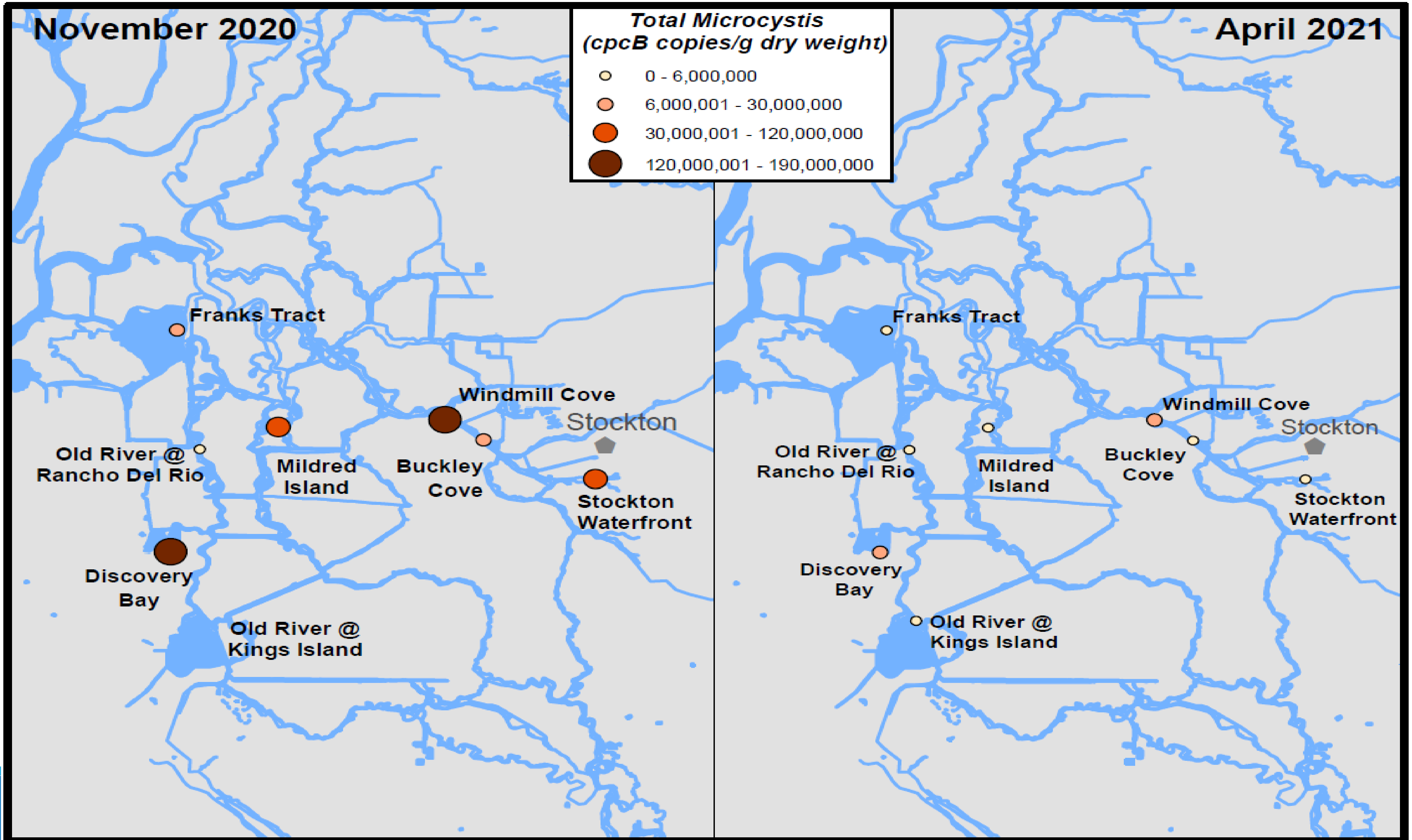
- Isopleth from June 13
- Similar findings from each sampling event
  - Chlorophyll increases in the turning basin to a maximum at the public dock
  - MC increases along the same gradient as chlorophyll

Seasonal/Temporal Findings

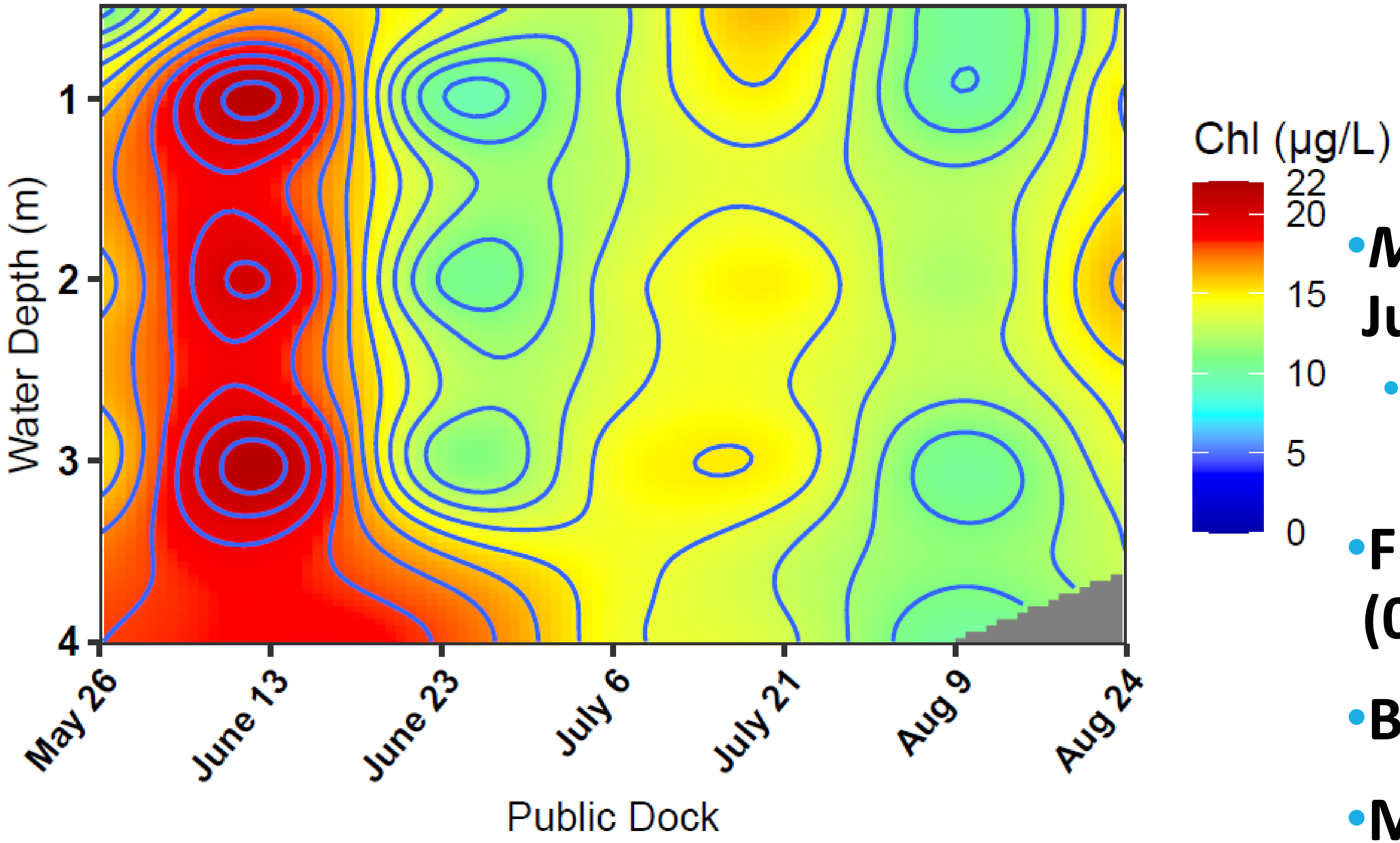
Shellfish Study – Microcystin in Asian Clams



Sediment Study - *Microcystis* Seedstock

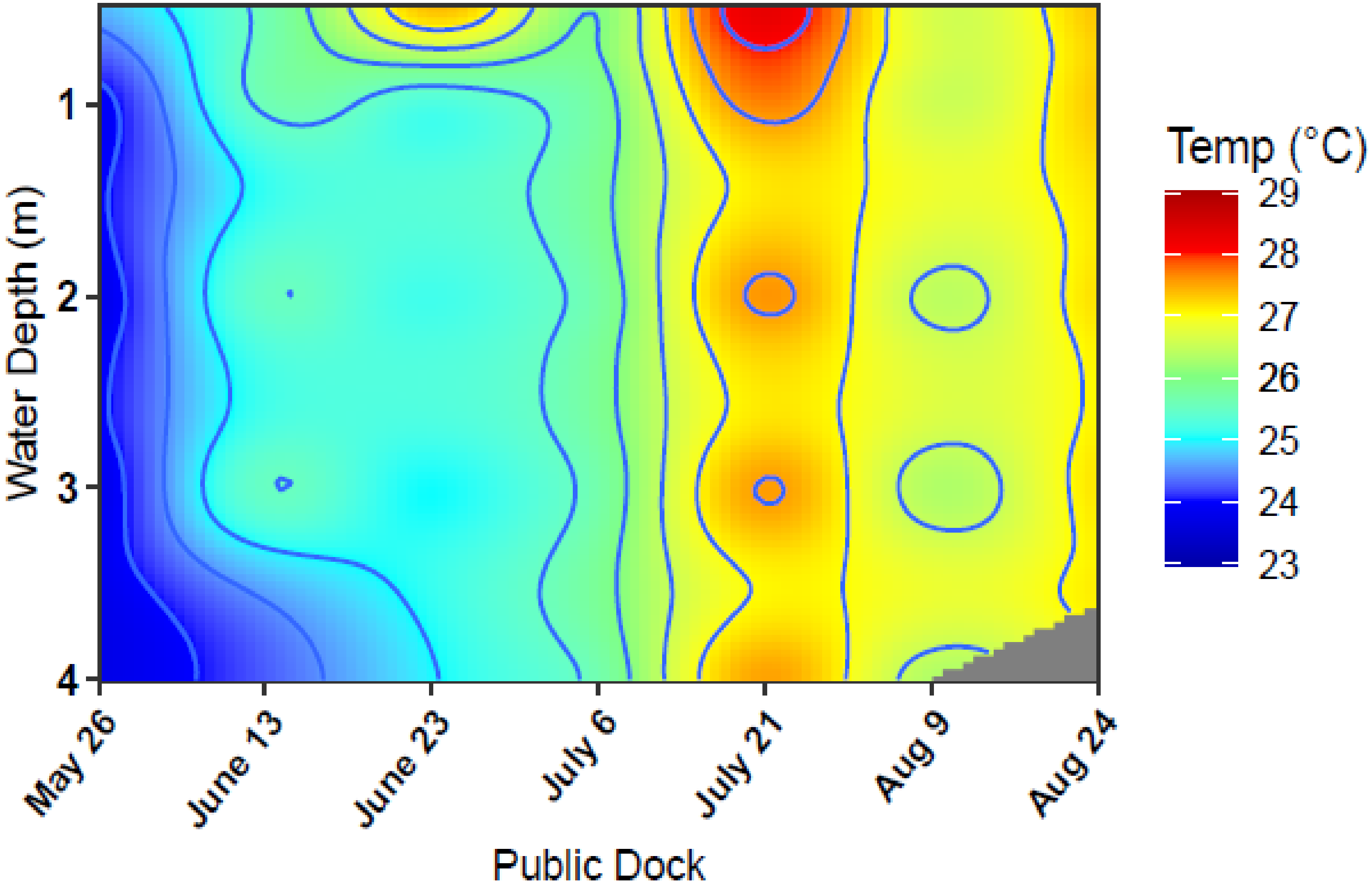


Stockton Study



- ***Microcystis* present in early June**
  - **Densest surface accumulation in late June**
- **First MC detection July 7 (0.24 µg/L)**
- **By July 21 MC = 59.1 µg/L**
- **MC still present but decreased by early August**

Stockton Study



- Peak MC measured on the date that temperature was highest
- Densest bloom (visually and measured via chlorophyll) occurred when temperatures were cooler

What are the data gaps identified in the DNRP addressed by this study?

Relevant DNRP Key Research Gaps

Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?

- Location and timing play a key role in CHABs within the Delta
- **Dense *Microcystis* blooms can occur with no toxins present**
- **In 2022,** MC greatest when temperatures 27°C or higher
- *Microcystis* seedbanks are greatest in back water areas (e.g., Discovery Bay, Stockton Waterfront, Windmill Cove).

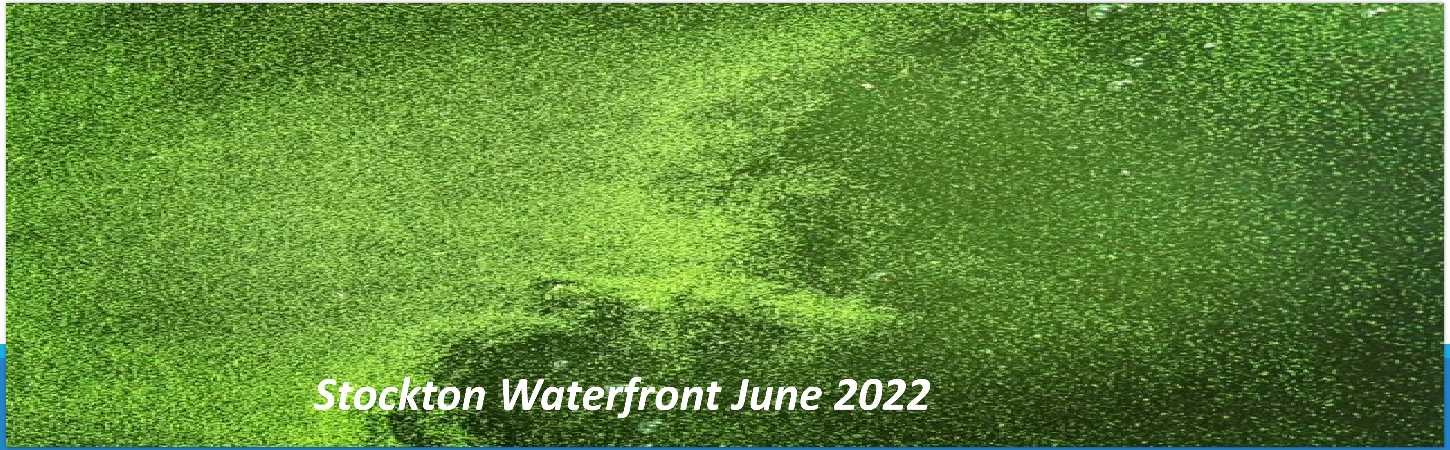
Stockton Waterfront July 2022

Stockton Deep Water Ship Channel July 2022

Relevant DNRP Key Research Gaps

What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?

- Although other toxins can be present, **MC continues to be the most prevalent toxin in the Delta**
- Outside of the dead-end sloughs and low velocity are**as, MC concentrations generally remain below 4 µg/L**
- MCs tend to be highest in water when temperatures are greater than 27°C



Relevant DNRP Key Research Gaps

What is the status and trends for harmful algal toxins in fish tissue, bivalves, and/or sensitive wildlife?

- **Identified MC concentrations in shellfish in areas of the Delta where sturgeon may feed**
- **Identified:**
  - **Temporal patterns in MC accumulation in Asian clams**
    - **MC generally present from July – Nov**
  - **Spatial patterns in MC accumulation in Asian clams and crayfish**
    - **Highest concentrations generally in the South Delta**

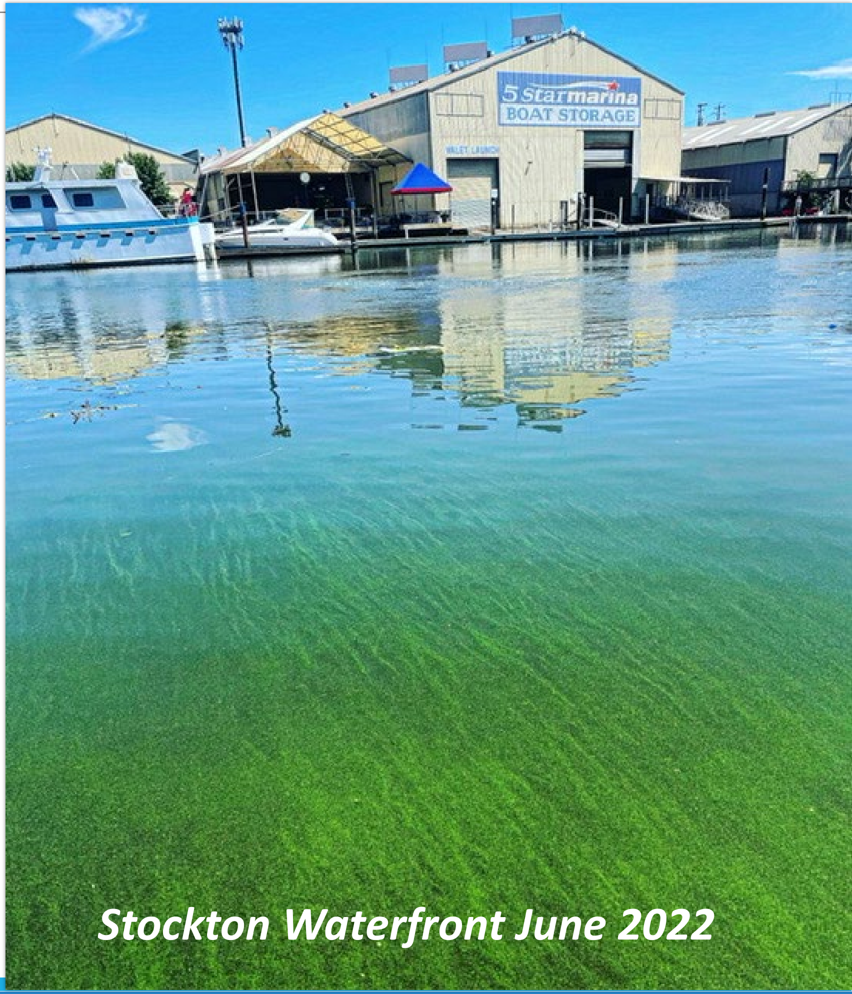
How can future research projects inform data gaps identified in the DNRP?

Relevant DNRP Key Research Gaps

Where, when, and under what conditions do cyanobacteria blooms occur in the Delta over a range of habitats (particularly near natural and restored wetlands, drinking water intakes, and recreational areas)?

- **What do we know now?**
  - **Certain locations in the Delta experience more severe bloom events**
  - **Hotter and drier conditions typically result in the most severe CHABS**
- **What do we need?**
  - **Identify trends over time and space**
  - **Further characterize conditions, including nutrients, in habitats where cyanobacteria blooms are most prevalent**
  - **Prioritize and characterize areas for mitigation**
  - **Identify short and long-term control options feasible for application in the Delta**

Filling these gaps will take both consistent monitoring and special studies.

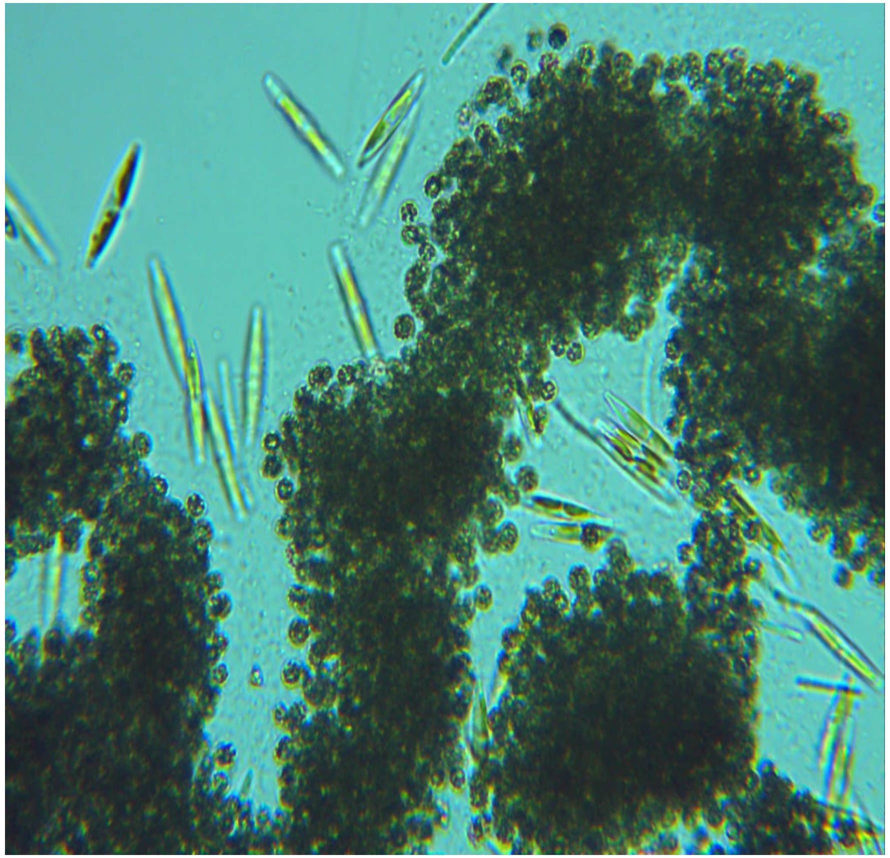


Stockton Waterfront June 2022

Relevant DNRP Key Research Gaps

What range in harmful algal toxins occur across different Delta habitats, particularly in natural and restored wetlands, drinking water intakes, and recreational areas?

- **What do we know now?**
  - To date MC remains the most commonly detected cyanotoxin
  - MC can be present at low levels in many Delta locations
  - Highest MC concentrations generally occur in dead end sloughs
  - June – November is most likely time for MC to be present
- **What do we need?**
  - Assess the different factors/drivers that influence toxin concentrations & monitor how these factors change over time
  - Analyze toxins in multiple matrices to accurately determine risks to biota and humans in different areas of the Delta
  - Prioritize areas to monitor for toxins
    - Areas of greatest recreational exposure, areas of greatest exposure to sensitive species, and/or areas where toxins are expected to be highest



Relevant DNRP Key Research Gaps

What is the status and trends for harmful algal toxins in fish tissue, bivalves, and/or sensitive wildlife?

- **What do we know now?**
  - **MCs are entering the food-web through filter feeders and crayfish**
  - **To date, cyanotoxins in the Delta have not reached a concentration level at which we have seen acute toxicity**
- **What do we need?**
  - **Prioritize food-web questions/knowledge gaps for study over the next five years**
  - **Determine potential impacts to the food-web from:**
    - **Chronic exposure to toxins/presences of HABs**
    - **Examining organisms that feed in the food web for subchronic effects**

Acknowledgements

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Central Valley Regional Water Quality Control Board

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Solutions for Progress

QUESTIONS?

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Stockton Waterfront August 2020
Photo Cred: Janis Cooke

Questions and Discussion

STATUS & TRENDS IN NUTRIENT STUDIES, 12:20 TO 12:35 PM