DELTA

Regional Monitoring Program

Delta RMP Nutrient Symposium

Predicting the Future - Nutrient Modeling

Predicting the Future – Nutrient Modeling

1:20 to 1:25

Opening Remarks

Melissa Turner, DRMP Program Manager

1:25 to 1:55

SFEI Delta-Suisun Biogeochemical Model

David Senn, San Francisco Estuary Institute – Aquatic Science Center

1:55 to 2:25

SPARROW Model of Nutrients in California Streams

Joe Domagalski, USGS California Water Science Center

2:25 to 2:55

Modeling Delta Water Quality Using Coupled Hydrodynamic and Biogeochemical Models

Zhenlin Zhang, Department of Water Resources

Opening Remarks

MELISSA TURNER, DRMP PROGRAM MANAGER

PREDICTING THE FUTURE - NUTRIENT MODELING, 1:20 TO 1:25 PM

DELTA
Regional Monitoring Program

SFEI Delta-Suisun Biogeochemical Model

DAVID SENN, SAN FRANCISCO ESTUARY INSTITUTE – AQUATIC SCIENCE CENTER

PREDICTING THE FUTURE - NUTRIENT MODELING, 1:25 TO 1:55 PM

Development and application of a hydrodynamic-biogeochemical model for the nSFE

1. Background and Science Questions
2. Model details
3. Results & Interpretations
4. Potential Applications and Limitations

Allie King, Sienna White, Pradeep Mugunthan,
Farid Karimpour, David Senn

Delta RMP Nutrient Symposium 9/27/2022

Funding

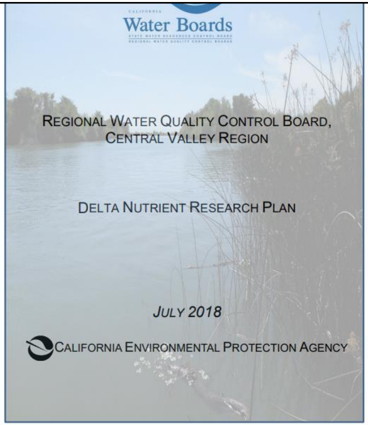
- State Water Board (RB5, RB2)
- Delta RMP
- Delta Science Program
- Regional San
- CCCSD
- SFB Nutrient Management Strategy

Collaborators over several years/projects

- B Bergamaschi, T Kraus, et al., USGS-BGC
- L Lucas, J Thompson USGS
- R Holleman (RMA)
- Z Zhang (DWR)
- Delta RMP Nutrient TAC
- J Cooke, RB5

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

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?
6. What is the status and trends for harmful algal toxins in fish tissue, bivalves, and/or sensitive wildlife?
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
23. What factors drive the growth of benthic phytoplankton species that are associated with taste and odor problems in water conveyance and reservoir system
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 problem
26. How are aquatic organisms, including fish and invertebrates, affected by aquatic macrophyte species in the Delta?



- Develop computer-based, biogeochemical model(s) for the Delta that includes hydrodynamics; nutrient and organic carbon water quality; productivity and nutrient cycling by phytoplankton, vascular plants, non-phytoplankton microalgae, and bacteria; benthic and pelagic grazing, sediment transport, and macrophyte-related processes.
- Develop biogeochemical model and use it to assess relative importance of nutrients and other drivers of aquatic macrophyte growth and to test predictions of effects of possible nutrient and water management changes.
- Develop biogeochemical model(s) and use to assess relative importance of nutrients and other drivers of HAB growth and controls of maximum bloom size.
- Use biogeochemical model to help identify factor(s) is (are) limiting or enhancing the occurrence of the nutrient-related effects, including in different seasons and locations in the Delta where the effect has been observed.
- Perform sensitivity analyses to understand how changes in limiting factor(s) may influence the magnitude of response to nutrient load reductions or increases.
- Use an ecosystem model to predict the effectiveness of management measures to control the initiation, magnitude, and duration of HABs, including at specific Delta locations where HABs affect non-contact recreation.
- Use an ecosystem model to predict the changes in frequency and magnitude of harmful algal blooms in the Delta as a result of climate change and water management changes
- Use biogeochemical models to determine if mechanical, herbicide, and biological control practices could be modified for a greater level of efficacy.
- Use ecosystem model to examine whether turbidity, flow rates, and mixing can be controlled by flow management, habitat restoration, or turbidity inputs. (recommended for understanding options for harmful algal bloom management).
- Use modeling to examine whether non-nutrient drivers of algal blooms (e.g., turbidity, residence time, limited flushing of biomass, stratification) can be controlled by management of flow routes and volumes, suspended sediment inputs, and habitat restoration.
- Establish collaborative relationships between agencies for data management sharing of expertise, and amassing additional funds to meet modeling goals.

NUTRIENTS IN THE NORTHERN SAN FRANCISCO ESTUARY: TRANSPORT, CYCLING, AND FORECASTED CHANGES AFTER NUTRIENT LOAD REDUCTIONS

Sienna White, Allie King, Farid Karimpour, Pradeep Mugunthan, David Senn

San Francisco Estuary Institute
Contribution No. 1035

SFEI 2021a

- How do nutrient concentrations vary spatially and seasonally throughout the northern San Francisco Estuary (nSFE)?
- What physical and biogeochemical processes/mechanisms regulate nutrient transport and fate, and ultimately ambient concentrations or nutrient availability?
- What nutrient sources contribute to nSFE regions that are impacted by HABs or IAVs? What factors influence nutrient fluxes to those regions?
- How will the Regional San upgrade influence…?
  - nutrient fluxes, transformations, concentrations
  - nutrient delivery to downstream systems

For info model development and calibration, see SFEI 2021b

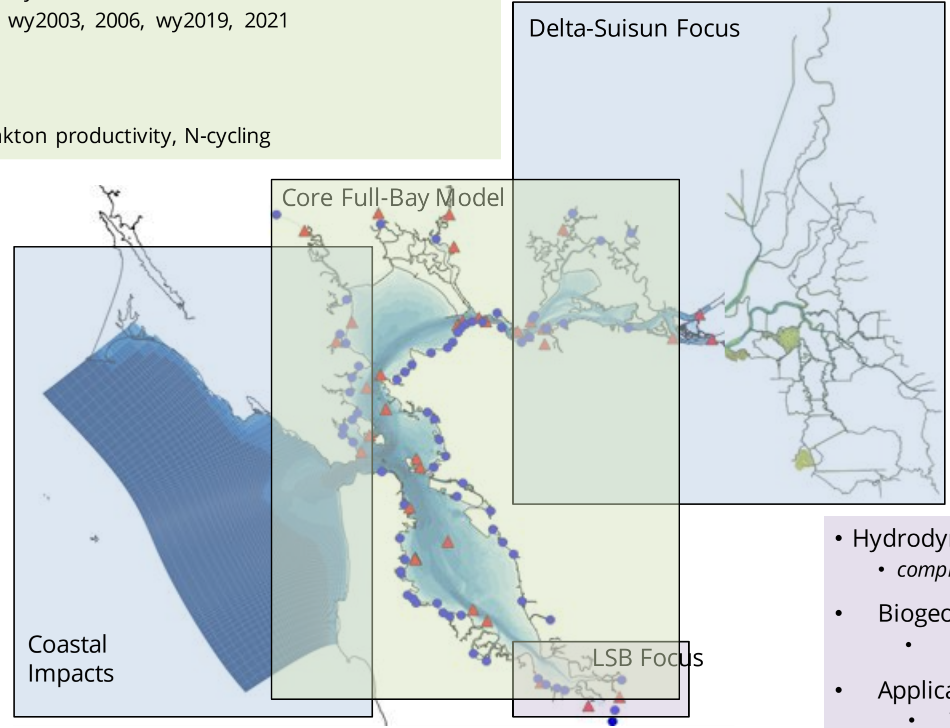
Overview: SFB Nutrient Management Strategy Modeling

Full-Bay Focus

- Hydrodynamics:
  - *complete*: wy2013, 2014, 2015, 2016, 2017, 2018, 2003, 2006
  - *upcoming (fy23)* wy2019, 2020, 2021
- Biogeochemistry
  - Complete: wy2013, 2014, 2015, 2016, 2017, 2018
  - *upcoming (fy23)* wy2003, 2006, wy2019, 2021
- Applications:
  - source apportionment
  - Investigations of phytoplankton productivity, N-cycling

Delta-Suisun Focus

- Hydrodynamics:
  - *complete*: wy2011, 2016
- Biogeochemistry
  - *complete*: wy2011, 2016
- Applications:
  - Investigations of phytoplankton productivity, N-cycling
  - Evaluating influence of Regional San Upgrade



Three Model Domains, used for different regional applications

Coastal Modeling

Led by collaborators:

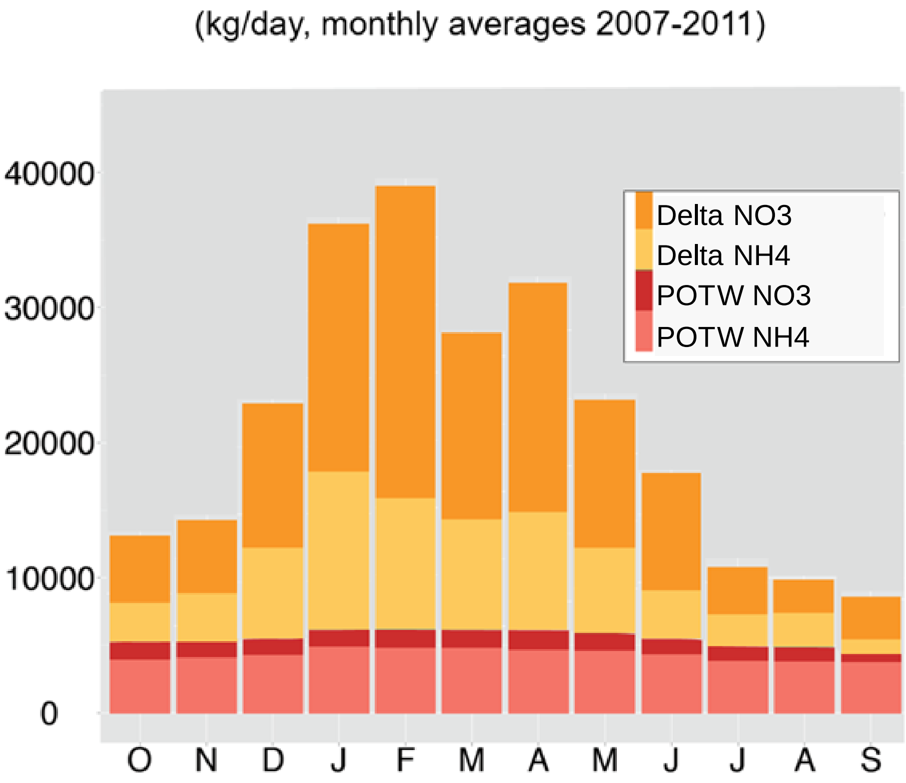
SCCWRP, UCLA, UCSC

- Physical model:
  - *complete*: 2003-2013
- Biogeochemistry
  - *upcoming (2022-2024)*
- Applications:
  - Tracer studies

LSB Focus

- Hydrodynamics:
  - *complete*: seasonal windows, 2015-2017
- Biogeochemistry
  - *complete*: upcoming
- Applications:
  - Tracer studies

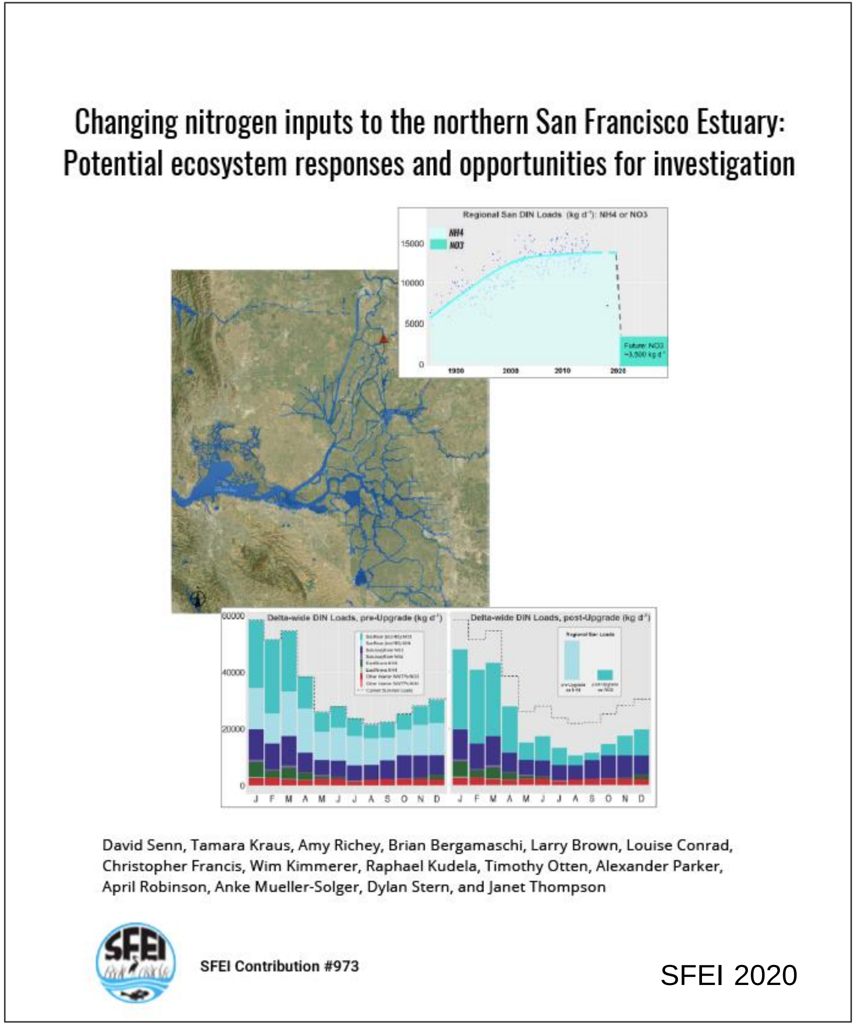
Dissolved Inorganic Nitrogen (DIN) Loads to Suisun Bay



How do Delta→Suisun loads vary seasonally and interannually?

How Delta→Suisun loads change in response to Regional San upgrade?

SFEI 2014, 2015



Changing nitrogen inputs to the northern San Francisco Estuary: Potential ecosystem responses and opportunities for investigation

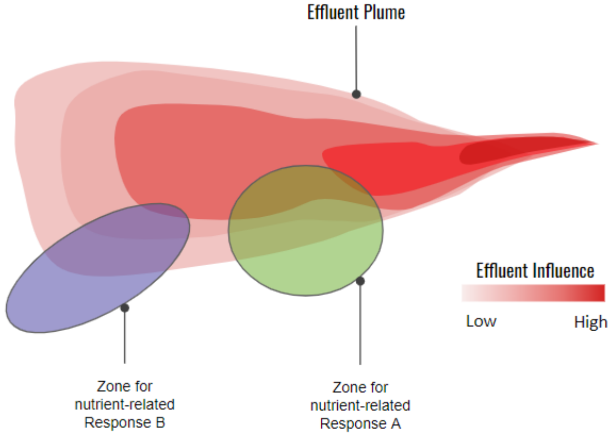
David Senn, Tamara Kraus, Amy Richey, Brian Bergamaschi, Larry Brown, Louise Conrad, Christopher Francis, Wim Kimmerer, Raphael Kudela, Timothy Otten, Alexander Parker, April Robinson, Anke Mueller-Solger, Dylan Stern, and Janet Thompson

SFEI Contribution #973

SFEI 2020

Potential Responses to Regional San upgrade: (examples)

- Decreased phytoplankton productivity (nutrient limitation)
- Decreased HAB frequency/severity
- Decreased IAV density or areal coverage



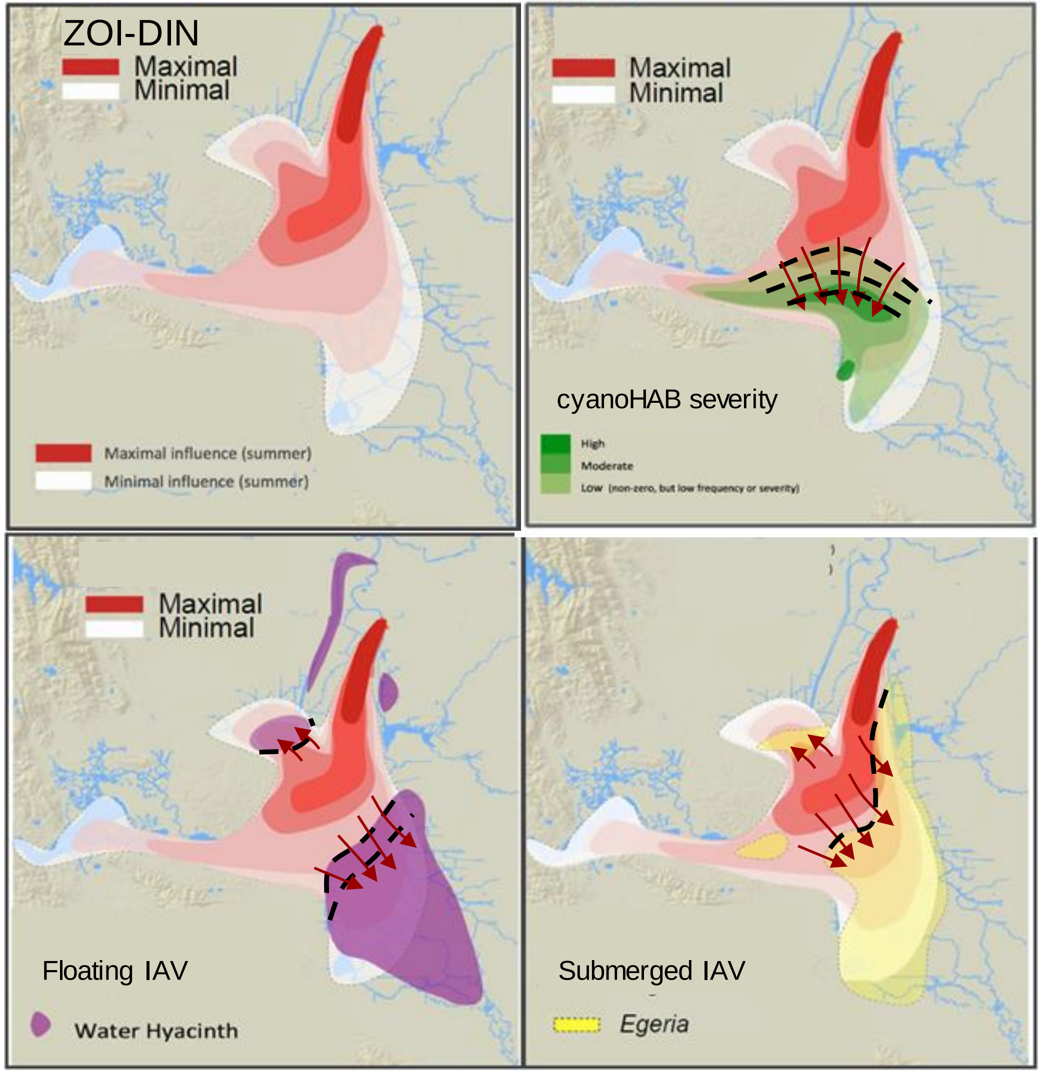
Zone of Influence (ZOI) of Regional San upgrade on DIN levels.

-- and --

Regions where cyanoHABs and IAV issues are most severe

Red arrows:

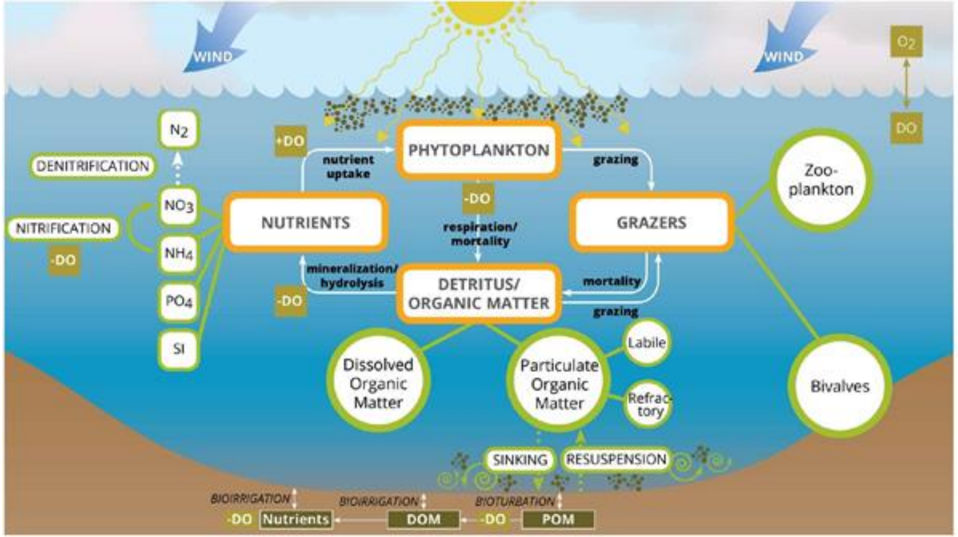
- What are the delivery rates of Sacramento-DIN to regions affected by cyanoHABs and IAV?
- How will those delivery rates change in response to the Regional San upgrade?



Model set-up

Hydrodynamics: Deltares DFM
calibration/validation WY2016 (SFEI 2019)

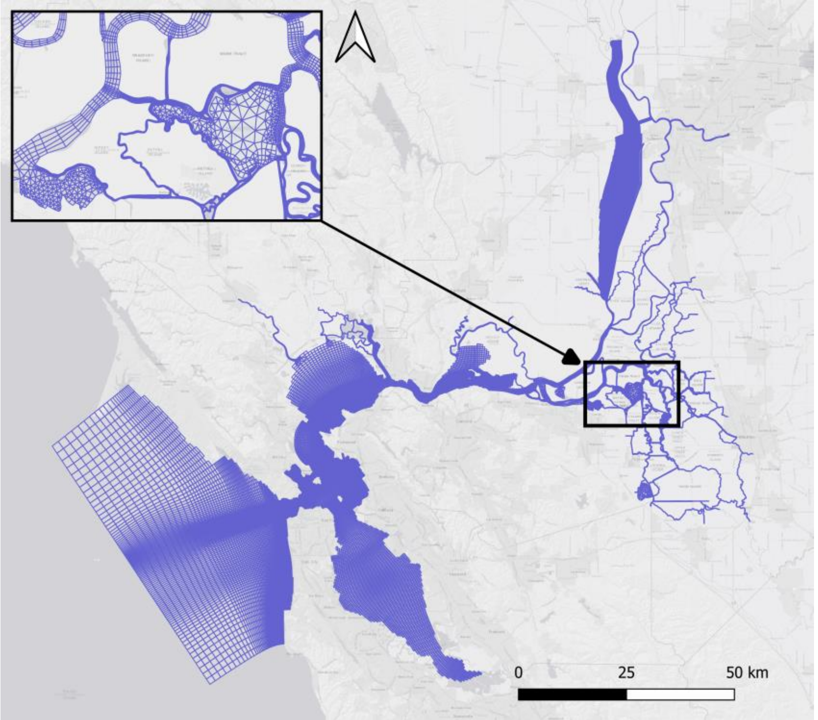
Biogeochemistry: Deltares-DWAQ
Calibration/validation: WY2016 & WY2011 (SFEI (2021b))
Open-source, 'community-modeling' approach



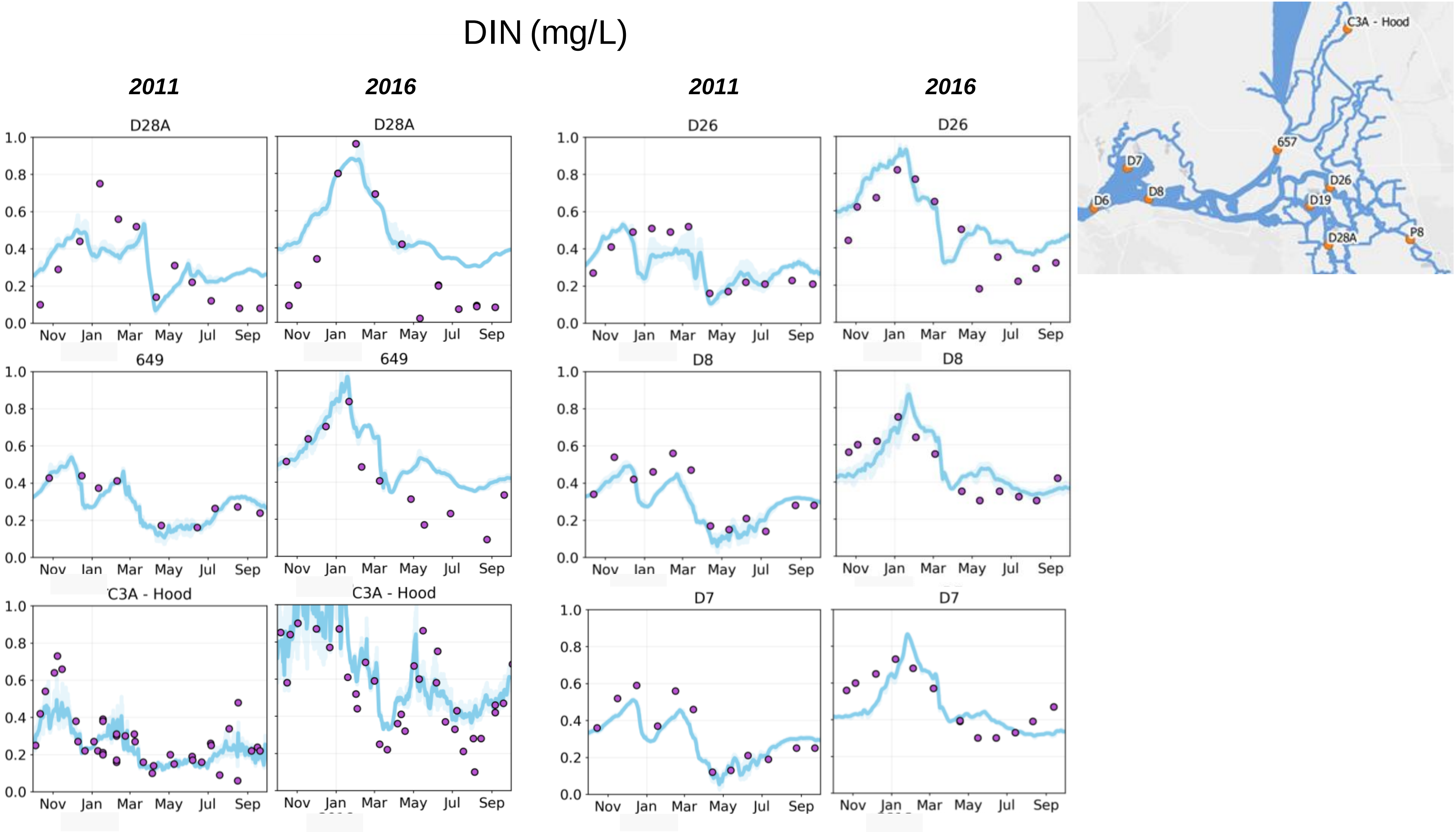
Investments in: empirical K_D, dynamic grazers, sensitivity analysis for calibration, sediment diagenesis, mass balance approaches to assessing model performance and interpretations

Model Domain:
Delta, SFB, coastal ocean

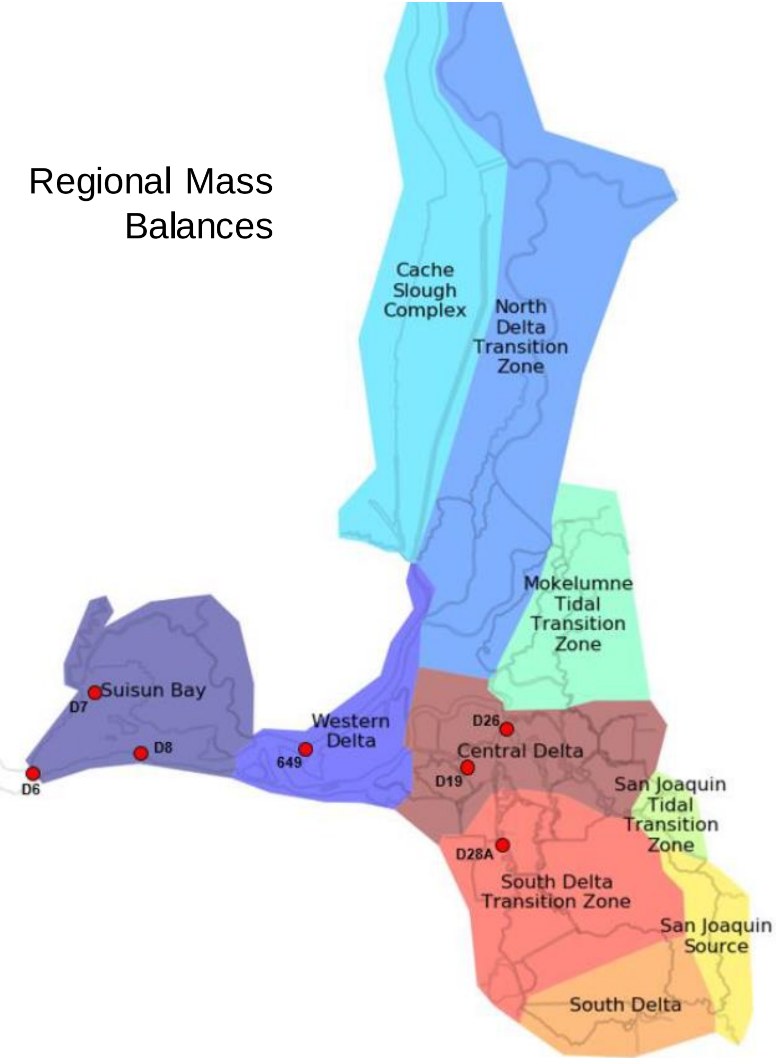
Model Grid:
~75,000 horiz. cells
10 vert. layers

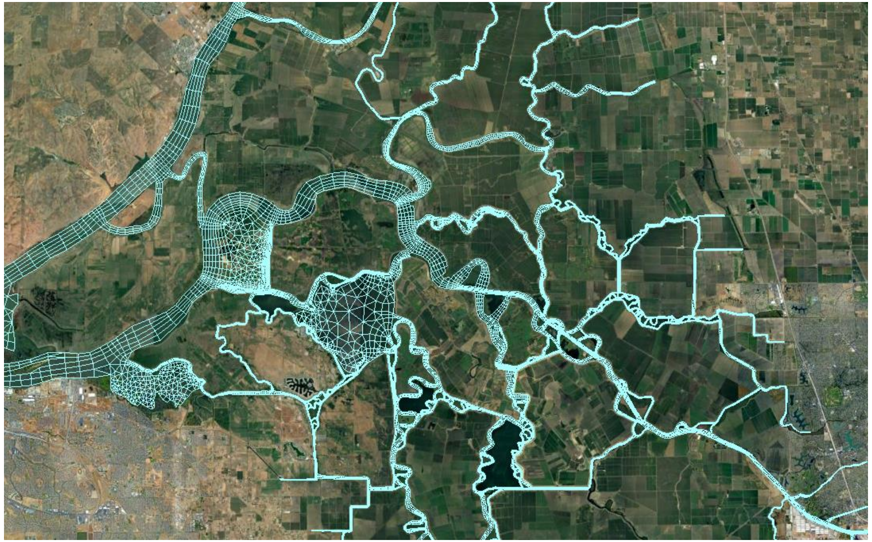


DIN (mg/L)

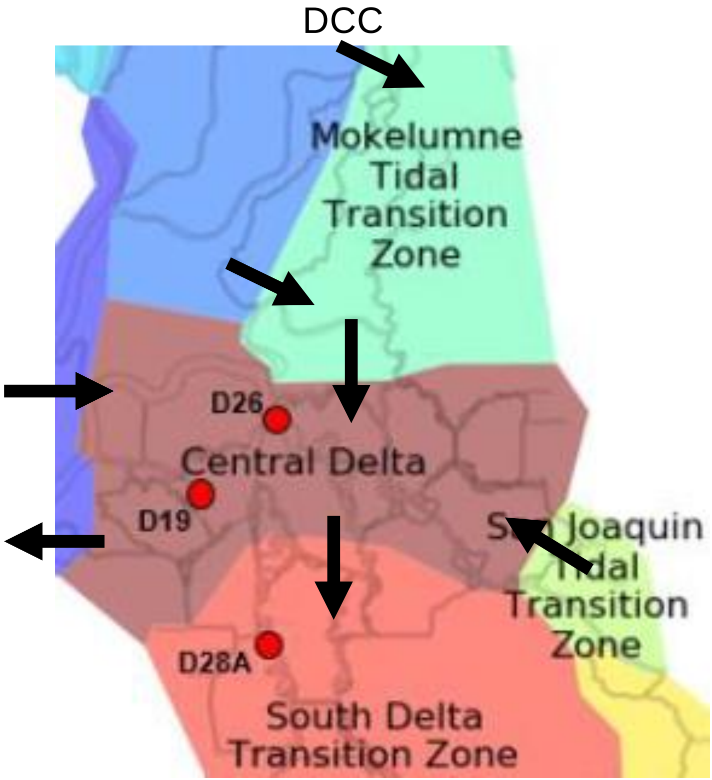

2011
2016
2011
2016
D28A
D28A
D26
D26
649
649
D8
D8
C3A - Hood
C3A - Hood
D7
D7
1.0
0.8
0.6
0.4
0.2
0.0
Nov Jan Mar May Jul Sep
C3A - Hood
657
D7
D8
D6
D26
D19
D28A
P8

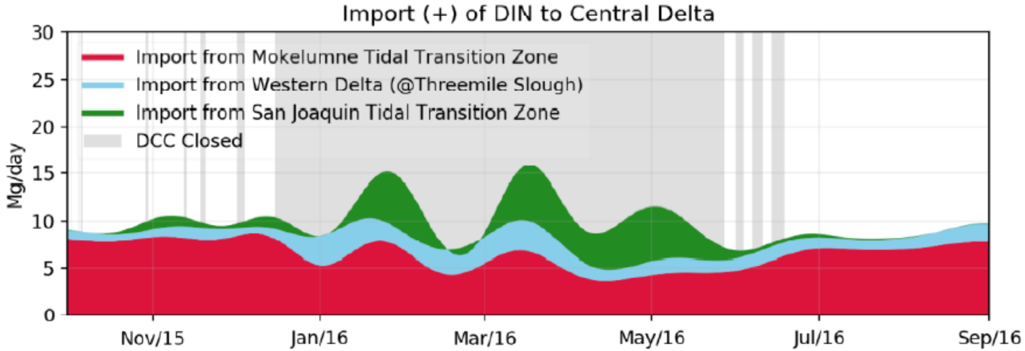
Regional Mass Balances

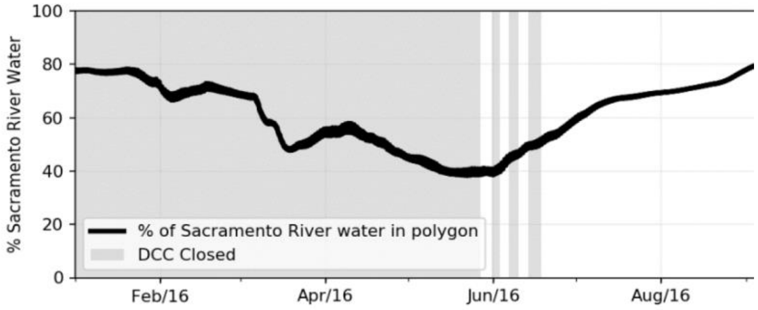




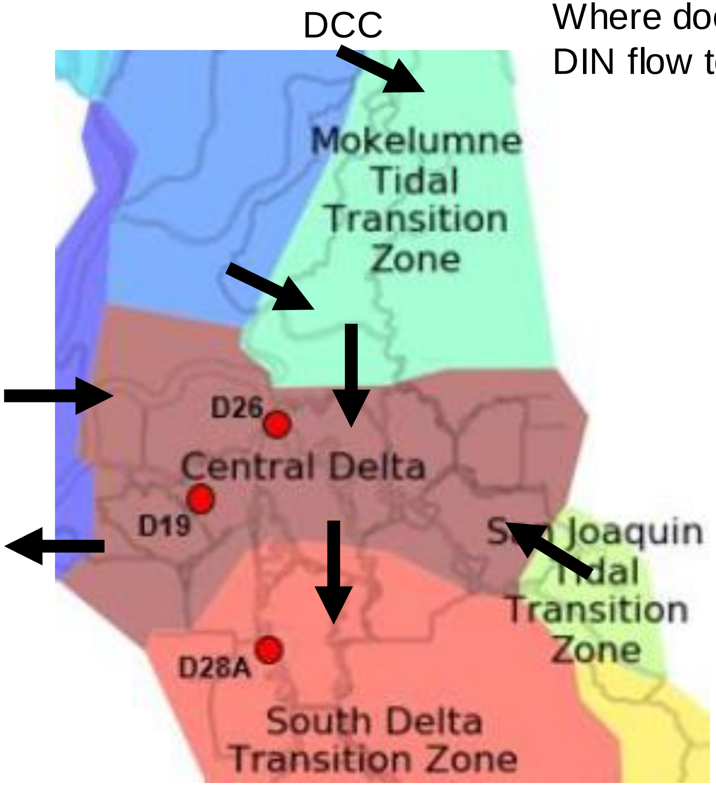
- Biogeochemical simulation
- Source and age tracers



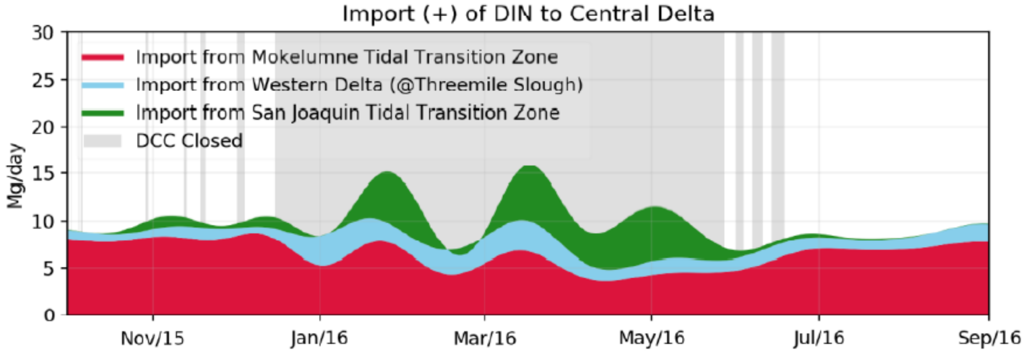




- 50% increase in DIN loads to Central Delta coinciding with DCC opening in Jun 2016
- New DIN loads primarily from Sacramento R
- %Sac increases from 40% to 70% by mid-Jul



Where does the DIN flow to?



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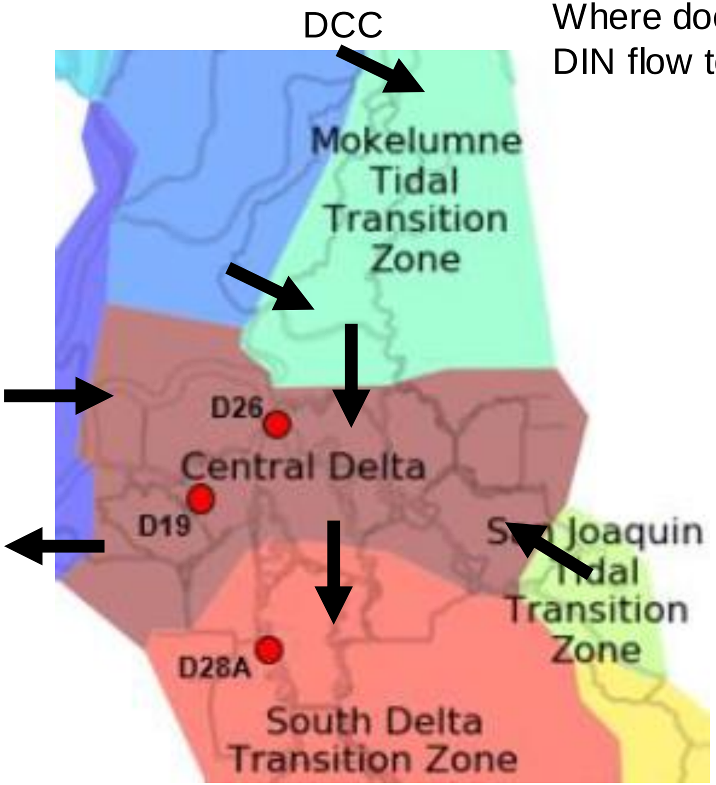
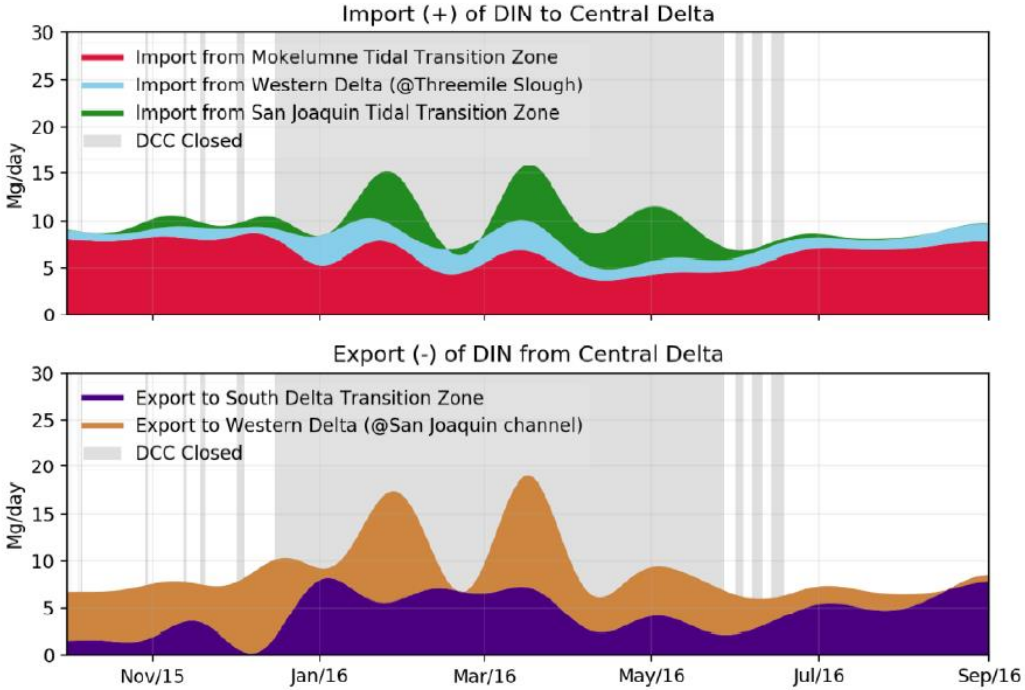




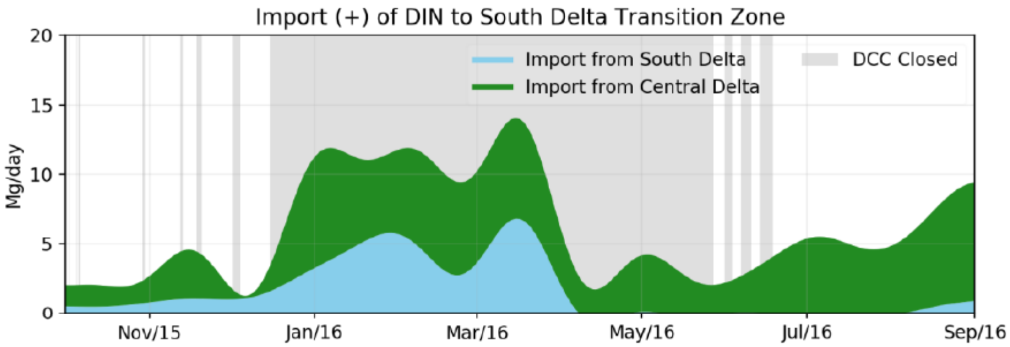
Jun thru Aug 2016

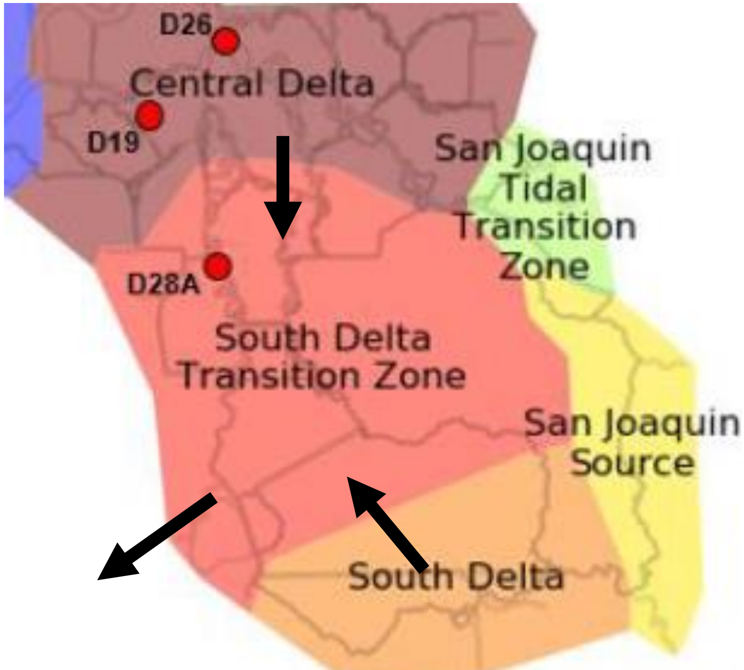
- DCC open
- 30-95% of DIN exports from Central Delta flow to South Delta Transition Zone (SDTZ)

DIN Sources to SDTZ

May-Aug 2016

- ~100% of DIN inflow from Central Delta

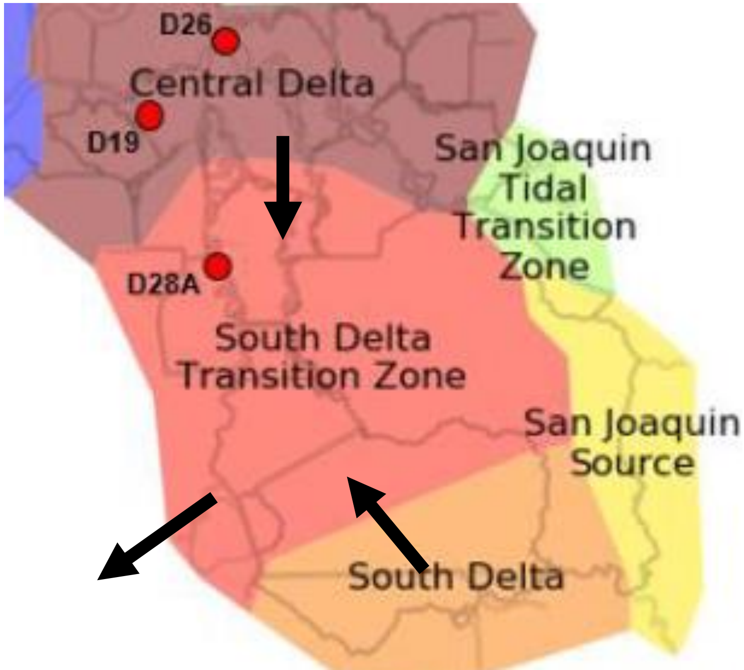


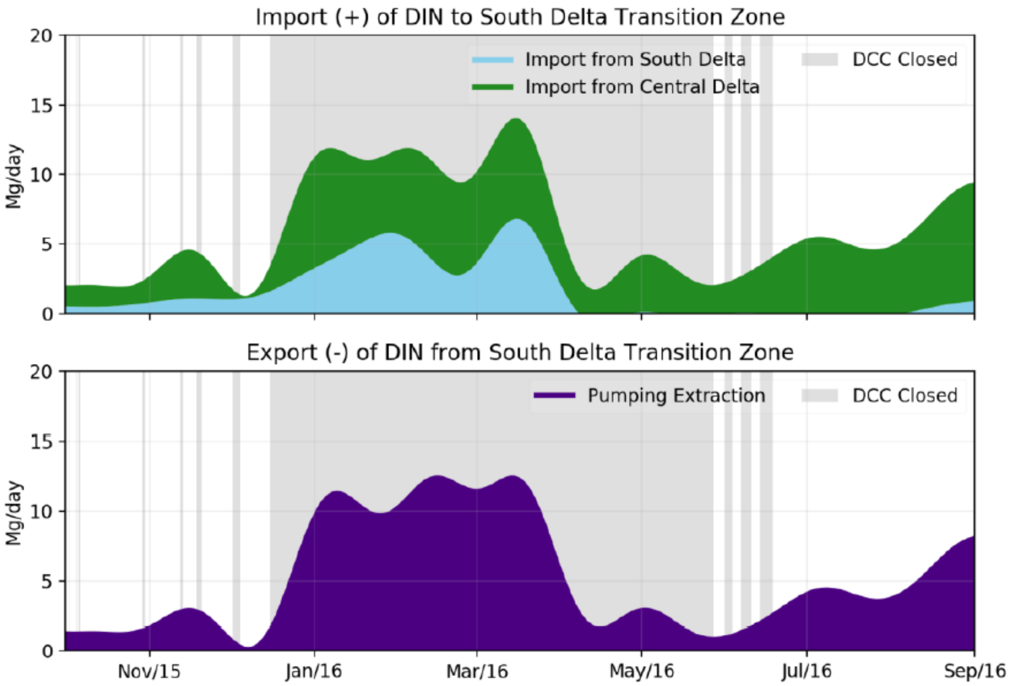


DIN Sources to SDTZ

May-Aug 2016

- ~100% of DIN inflow from Central Delta
- DIN influx from Central Delta (and SacR) driven by DCC and pump operation





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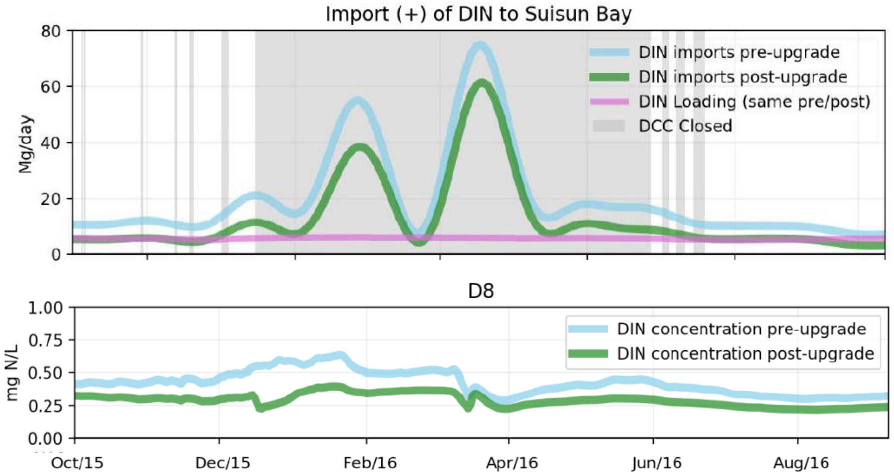
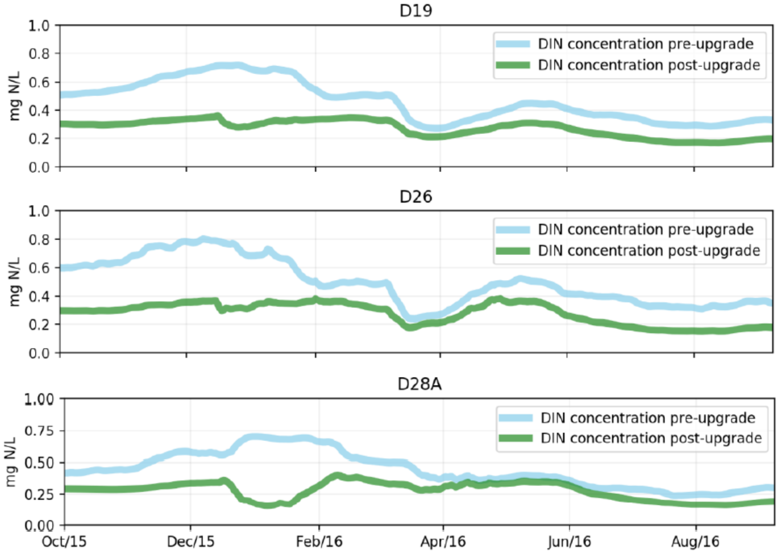
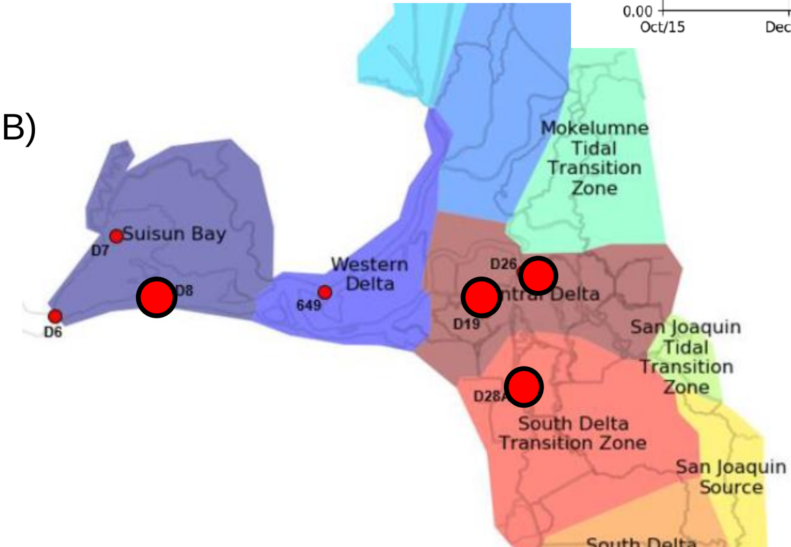
- How will the Regional San upgrade influence…?
  - nutrient fluxes, transformations, concentrations
  - nutrient delivery to downstream systems

Rerun WY2016 using post-upgrade loads



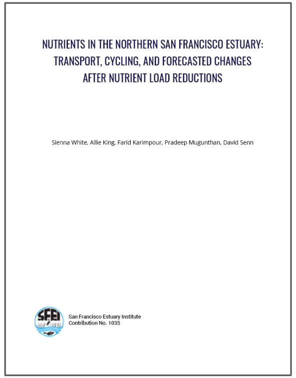


30% DIN load decrease to Suisun Bay (and rest of SFB)



50% decrease in DIN concentrations in the Central Delta (D26, D19)

~30% decrease in SDTZ (D28A)


NUTRIENTS IN THE NORTHERN SAN FRANCISCO ESTUARY:
TRANSPORT, CYCLING, AND FORECASTED CHANGES
AFTER NUTRIENT LOAD REDUCTIONS

Sienna White, Allie King, Farid Karimpour, Pradeep Mugunthan, David Senn

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- How do nutrient concentrations vary spatially and seasonally throughout the northern San Francisco Estuary (nSFE)?

- What physical and biogeochemical processes/mechanisms regulate nutrient transport and fate, and ultimately ambient concentrations or nutrient availability?

  Simulation results indicate that (during wy2016)…
  - DCC operation and pumping play important roles allowing/inducing DIN flux from Sacramento River into the interior Delta.

- What nutrient sources contribute to nSFE regions that are impacted by HABs or IAVs? What factors influence nutrient fluxes to those regions?

  - DIN from the Sacramento River represents a large fraction of the overall DIN influx to the Central Delta and SDTZ during summer months (when HAB events most common, and when the most IAV growth would occur).
  - DCC operation and pumping play a major role inducing/allowing summer influx of Sacramento-DIN to the Central Delta and SDTZ.

- How will the Regional San upgrade influence nutrient fluxes / transformations / concentrations within the nSFE and nutrient delivery to downstream systems?

  - 30-50% decreases in summer DIN concentrations within Central Delta and SDTZ.
  - ~30% decrease in DIN loads to Suisun Bay and ~30% decrease in Suisun Bay DIN concentrations

Model Validation:

Major Take-Homes

- Overall, the model performs well at reproducing spatial and seasonal variability in NO3 and NH4 concentrations (both timing and magnitude).

- Model reproduces Delta-Suisun's generally-low chl-a levels throughout the majority of both wy2016 and wy2011, two years with very different forcings and responses.

- Phytoplankton Blooms:
  - captures meaningful chl-a increases at diverse stations during wy2011
  - does not capture the space/time windows of elevated phytoplankton biomass during wy2016

Limitations

- Not predicting phytoplankton biomass levels as well as nutrients.
  - re-examining importance of short-lived peaks
  - also modeled-observed GPP
- No macrophytes…validation is a bit of catch-22 therefore…if macrophyte uptake is nontrivial, should get nutrients wrong
- Not currently explicitly modeling cyanoHABs
- Improvements needed to CSC (wetting, drying)

Biogeochemical Model Development

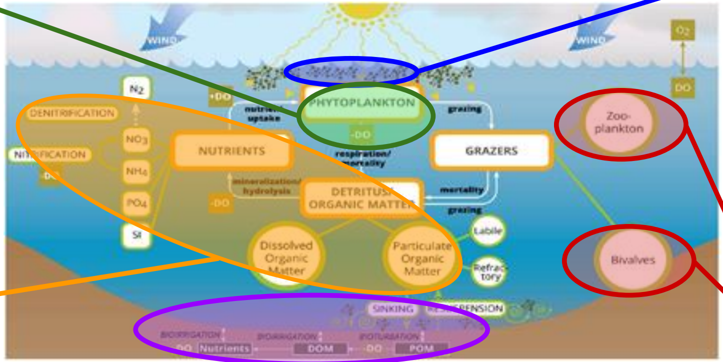
- simulated/tuned across two diverse water years, WY2016 & WY2011
- validated against mooring data – concentrations and fluxes
- best 'global' calibration (wy2016, wy2011)

Phytoplankton

- adjustments/tuning of phytoplankton growth parameters, mortality, etc.

Nutrient transformations

- nitrification and denitrification rates, temperature coefficients, etc.
- org-N mineralization rate (mineralization in w.c. vs. settling/storage in sediments)



Light Attenuation Coefficients

- developed empirical light attenuation input field
- space-time interpolated, network of turbidity sensors (hourly, daily)
- converted turbidity → K_D using Delta-Suisun specific relationships (w/ USGS-BGC)

Grazing (dynamic energy budget)

- refining/tuning zooplankton grazing coeff.
- refining/tuning clam grazing coeff.
- developed spatially-interpolated clam initial conditions, refined/iterated
  - *Corbicula*
  - *Potamocorbula*

Sediment diagenesis, fluxes sediments←→ water-column

- important NH4 recycling/fluxes, O_2 demand, PO4 and Si fluxes
- incorporated updated sediment diagenesis module from SFB model
- customized for Delta-Suisun: initial conditions, rates/coefficients

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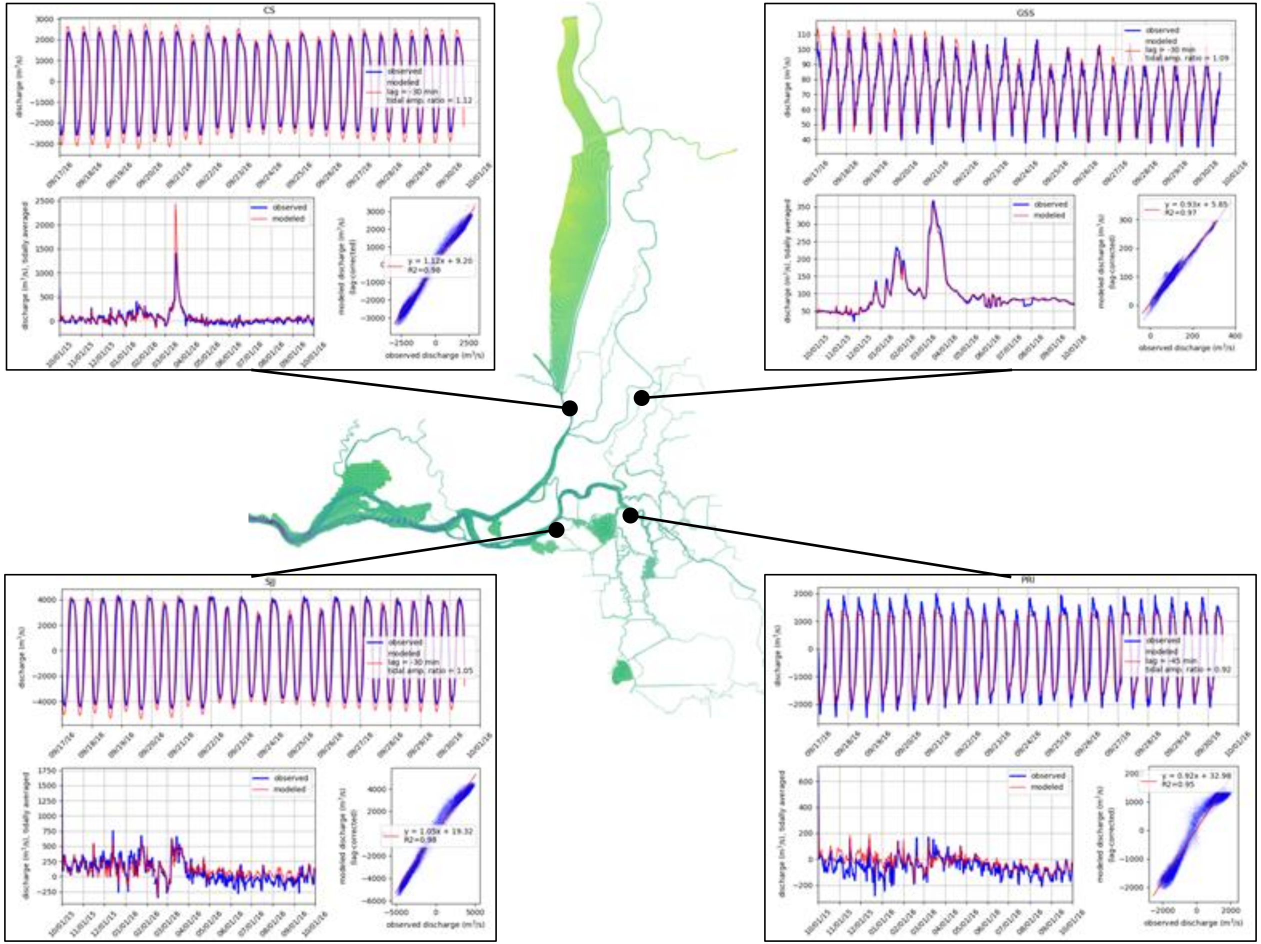
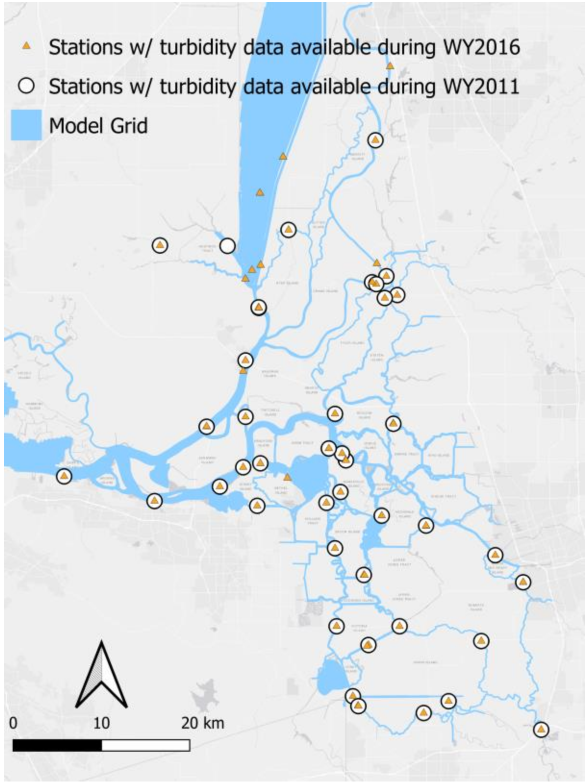
17. What are the nitrogen and phosphorus inputs, sinks, and outputs in the Delta over a breadth of hydrologic conditions and seasons?
18. What are the production and cycling rates for both nutrients and carbon in aquatic plants, pelagic algae, and benthic algae, as determined from biomass, nutrient content, 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?

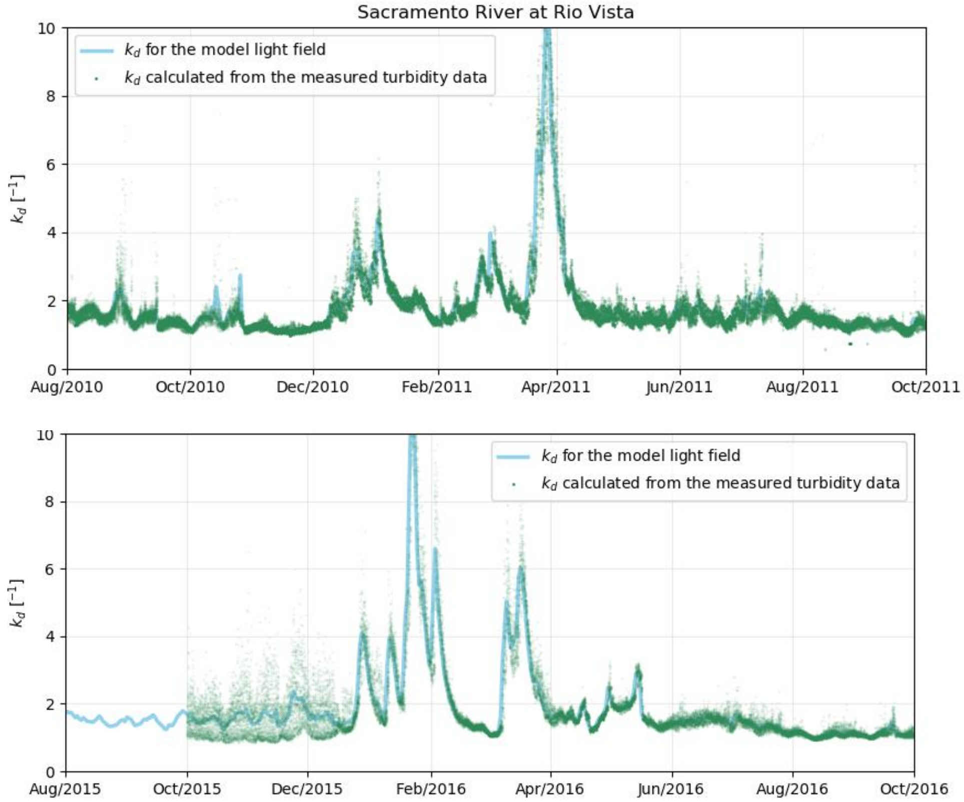
- Develop computer-based, biogeochemical model(s) for the Delta that includes hydrodynamics; nutrient and organic carbon water quality; productivity and nutrient cycling by phytoplankton, vascular plants, non-phytoplankton microalgae, and bacteria; benthic and pelagic grazing, sediment transport, and macrophyte-related processes.
- Develop biogeochemical model and use it to assess relative importance of nutrients and other drivers of aquatic macrophyte growth and to test predictions of effects of possible nutrient and water management changes.
- Develop biogeochemical model(s) and use to assess relative importance of nutrients and other drivers of HAB growth and controls of maximum bloom size.
- Use biogeochemical model to help identify factor(s) is (are) limiting or enhancing the occurrence of the nutrient-related effects, including in different seasons and locations in the Delta where the effect has been observed.
- Perform sensitivity analyses to understand how changes in limiting factor(s) may influence the magnitude of response to nutrient load reductions or increases.
- Use an ecosystem model to predict the effectiveness of management measures to control the initiation, magnitude, and duration of HABs, including at specific Delta locations where HABs affect non-contact recreation.
- Use an ecosystem model to predict the changes in frequency and magnitude of harmful algal blooms in the Delta as a result of climate change and water management changes
- Use biogeochemical models to determine if mechanical, herbicide, and biological control practices could be modified for a greater level of efficacy.
- Use ecosystem model to examine whether turbidity, flow rates, and mixing can be controlled by flow management, habitat restoration, or turbidity inputs. (recommended for understanding options for harmful algal bloom management).
- Use modeling to examine whether non-nutrient drivers of algal blooms (e.g., turbidity, residence time, limited flushing of biomass, stratification) can be controlled by management of flow routes and volumes, suspended sediment inputs, and habitat restoration.
- Establish collaborative relationships between agencies for data management sharing of expertise, and amassing additional funds to meet modeling goals.

WY2016 Hydrodynamics calibration/validation

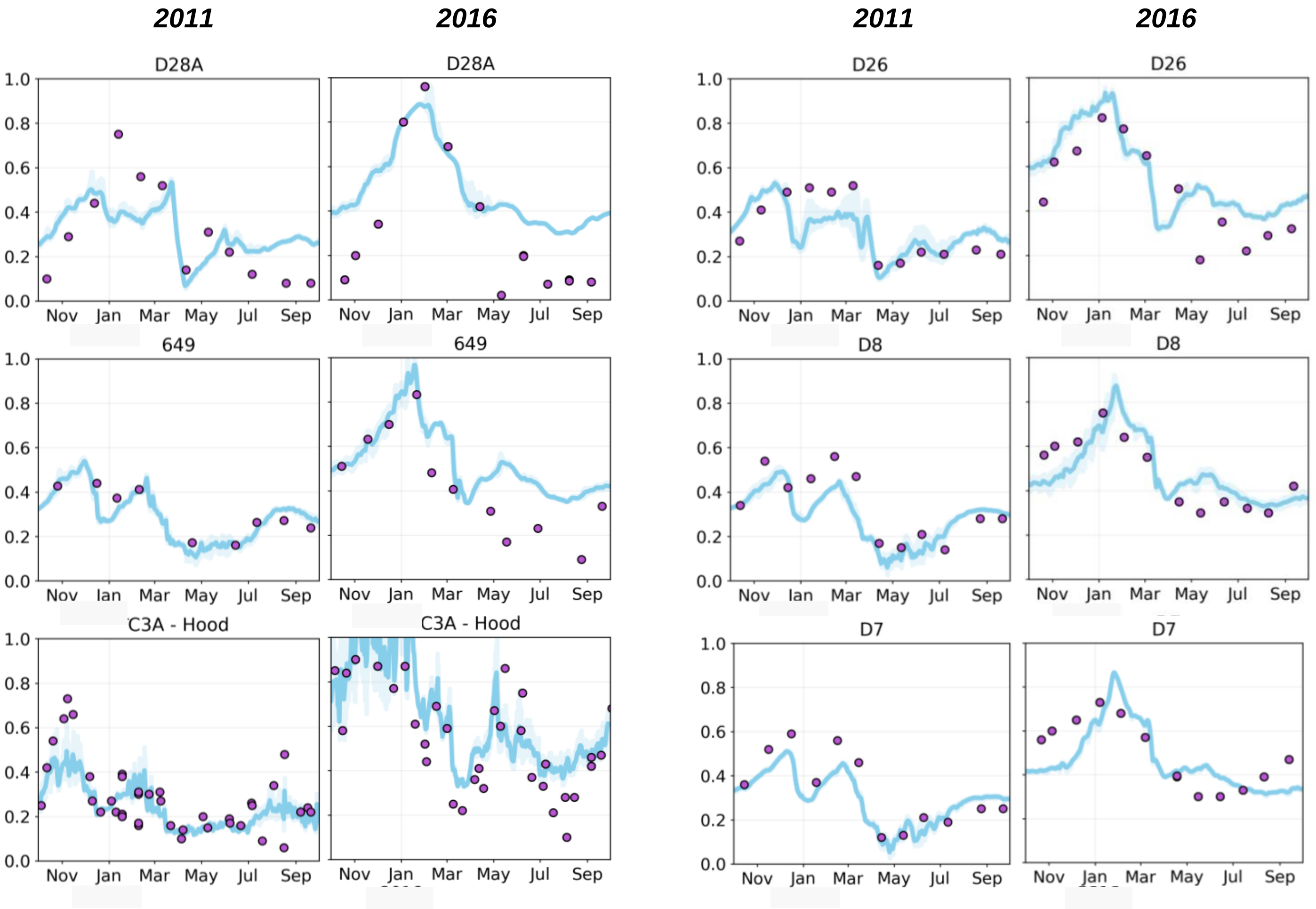
SFEI 2019 (link)



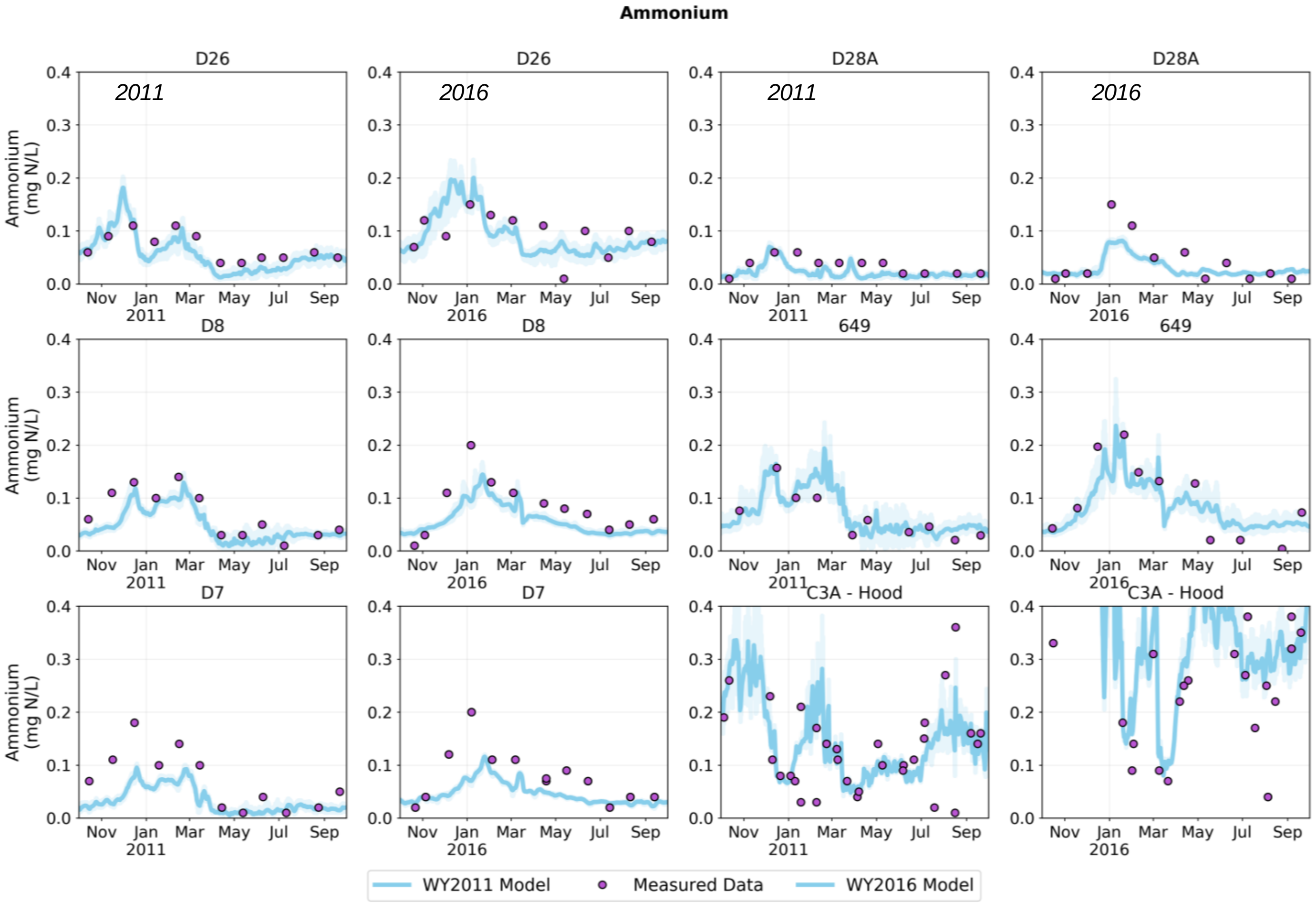

Stations w/ turbidity data available during WY2016
Stations w/ turbidity data available during WY2011
Model Grid
0
10
20 km


Sacramento River at Rio Vista
k_d for the model light field
k_d calculated from the measured turbidity data
k_d [$^{-1}$]
0
2
4
6
8
10
Aug/2010
Oct/2010
Dec/2010
Feb/2011
Apr/2011
Jun/2011
Aug/2011
Oct/2011
k_d for the model light field
k_d calculated from the measured turbidity data
k_d [$^{-1}$]
Aug/2015
Oct/2015
Dec/2015
Feb/2016
Apr/2016
Jun/2016
Aug/2016
Oct/2016

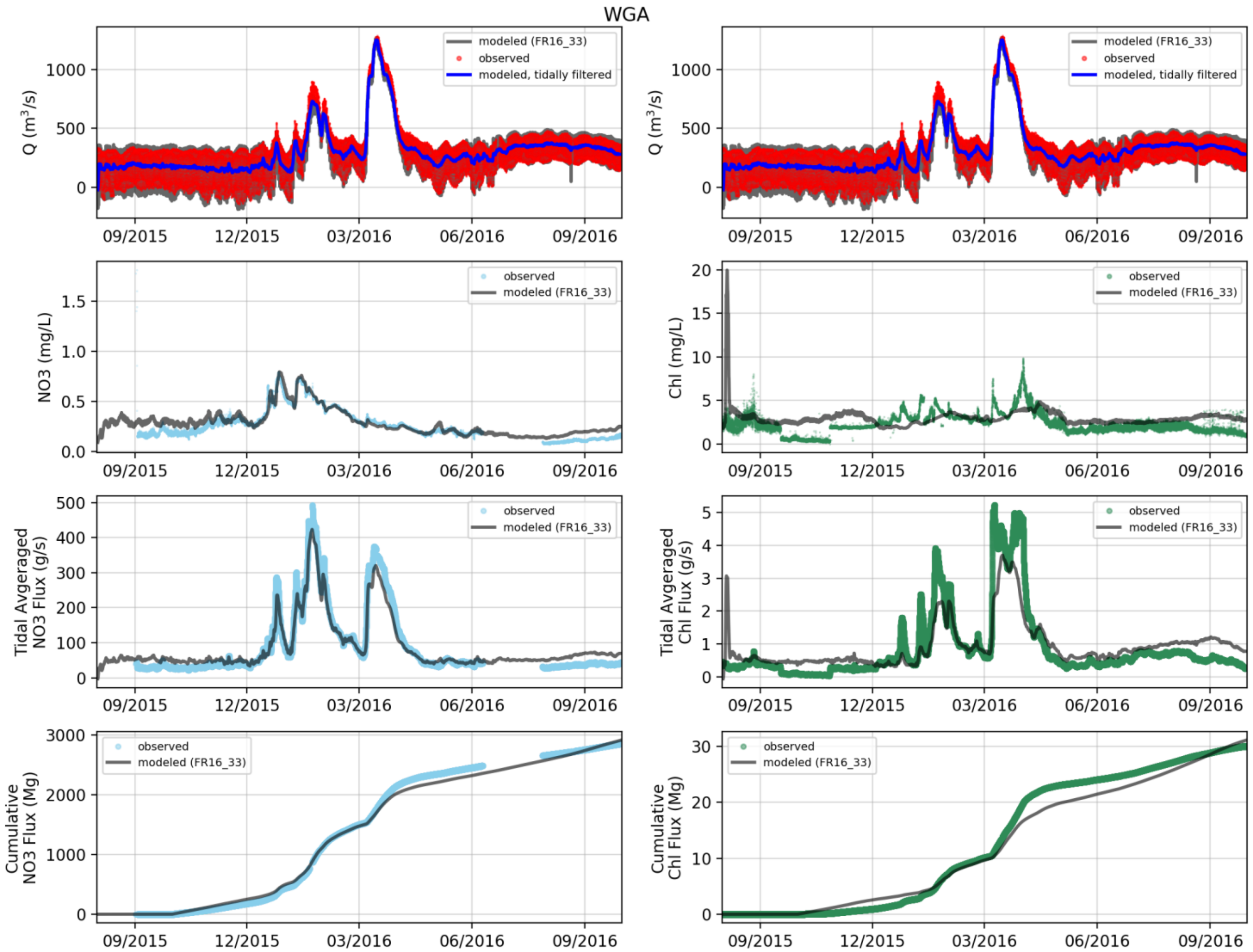
DIN (mg/L)

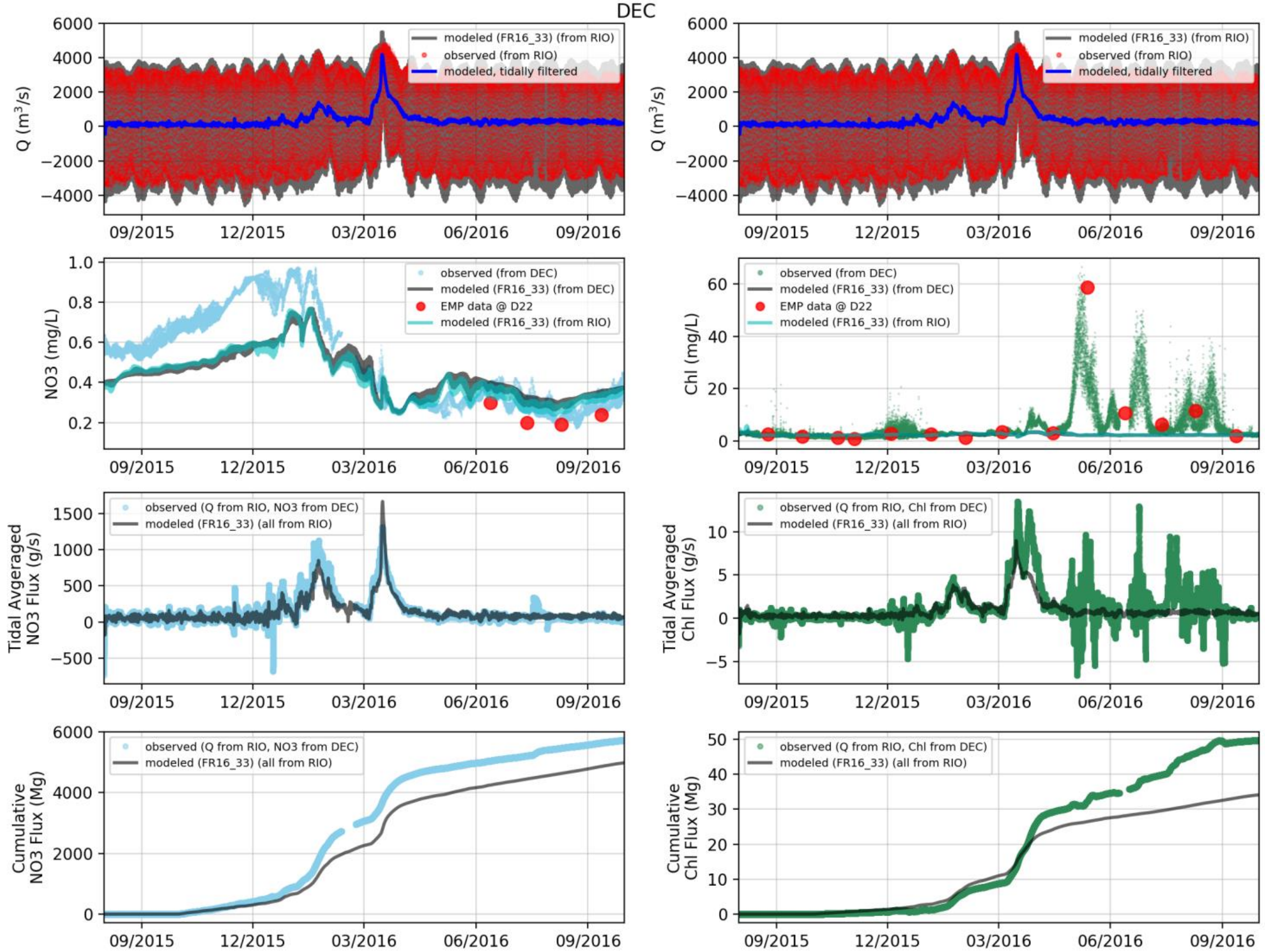


2011
2016
2011
2016
D28A
D28A
D26
D26
649
649
D8
D8
C3A - Hood
C3A - Hood
D7
D7
1.0
0.8
0.6
0.4
0.2
0.0
Nov
Jan
Mar
May
Jul
Sep



Ammonium
D26
2011
D26
2016
D28A
2011
D28A
2016
D8
D8
649
649
D7
D7
C3A - Hood
C3A - Hood
Ammonium (mg N/L)
0.0
0.1
0.2
0.3
0.4
Nov
Jan
Mar
May
Jul
Sep
2011
2016
WY2011 Model
Measured Data
WY2016 Model


WGA
Q (m³/s)
modeled (FR16_33)
observed
modeled, tidally filtered
NO3 (mg/L)
Chl (mg/L)
Tidal Avgeraged NO3 Flux (g/s)
Tidal Avgeraged Chl Flux (g/s)
Cumulative NO3 Flux (Mg)
Cumulative Chl Flux (Mg)
09/2015
12/2015
03/2016
06/2016
09/2016


DEC
modeled (FR16_33) (from RIO)
observed (from RIO)
modeled, tidally filtered
Q (m³/s)
observed (from DEC)
modeled (FR16_33) (from DEC)
EMP data @ D22
modeled (FR16_33) (from RIO)
NO3 (mg/L)
Chl (mg/L)
observed (Q from RIO, NO3 from DEC)
modeled (FR16_33) (all from RIO)
Tidal Avgeraged NO3 Flux (g/s)
observed (Q from RIO, Chl from DEC)
Tidal Avgeraged Chl Flux (g/s)
Cumulative NO3 Flux (Mg)
Cumulative Chl Flux (Mg)
09/2015
12/2015
03/2016
06/2016
09/2016

SPARROW Model of Nutrients in California Streams

JOE DOMAGALSKI, USGS CALIFORNIA WATER SCIENCE CENTER

PREDICTING THE FUTURE - NUTRIENT MODELING, 1:55 TO 2:25 PM

Delta RMP Nutrient Symposium

SESSION: PREDICTING THE FUTURE – NUTRIENT MODELING

SPARROW MODELS OF NUTRIENTS IN CALIFORNIA STREAMS

SPARROW Models of Nutrients in California Streams

Joseph Domagalski

U.S. Geological Survey, California Water Science Center

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

SOURCES OF NUTRIENTS IN CENTRAL VALLEY WATERSHED AND NUTRIENT LOADS FROM UPSTREAM TO ESTUARINE LOCATIONS

What and why is SPARROW?
Spatially-Referenced Regression on Watershed Attributes

The SPARROW model was developed by the U.S. Geological Survey National Water Quality Assessment Program **to address data gaps** : Specifically, how can a monitoring program with limited financial and personnel resources understand and predict sources of nutrients in large watersheds and provide information to managers on possible types of source control.

It is impossible to monitor all streams, so a model based on discharge and possible sources along with hydrological and biogeochemical simulation was needed to assess source, transport, and load.

The model was to designed to help understand factors affecting water quality; Simulate water quality response to climate and land-use change (historical, future)

Predict mean-annual flux, yield and concentration for unmonitored stream reaches and watersheds

$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-\delta_m^s T_{i,j,m}) \prod_l 1/(1 + \lambda^r q_{i,j,l}^{-1}) \right\} \exp(\varepsilon_i)$$

Annual Stream Load

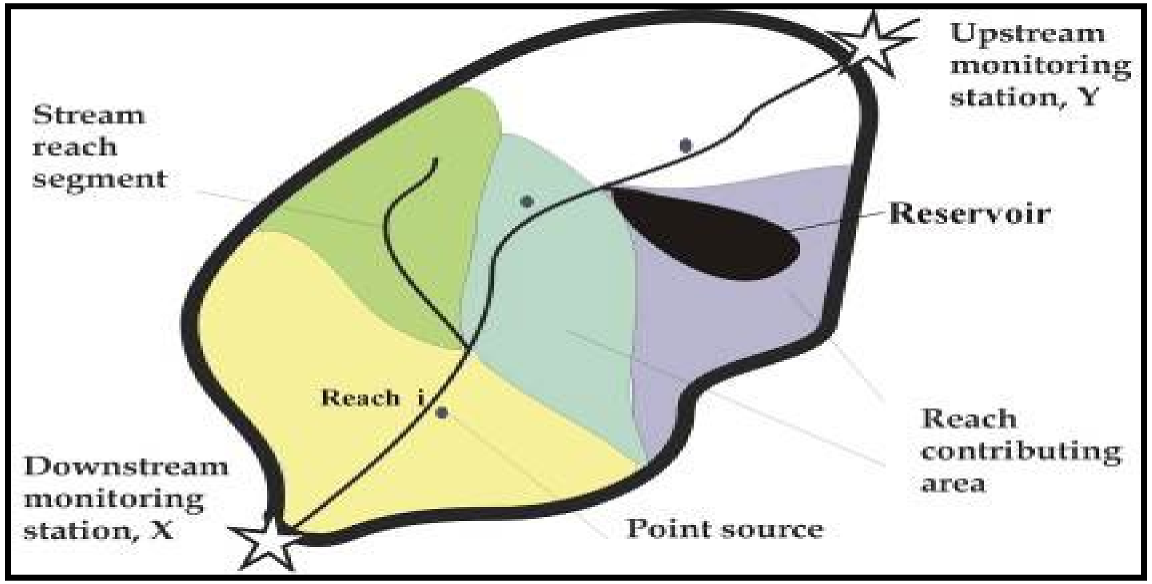
Sources

Land-to-water transport

Aquatic transport

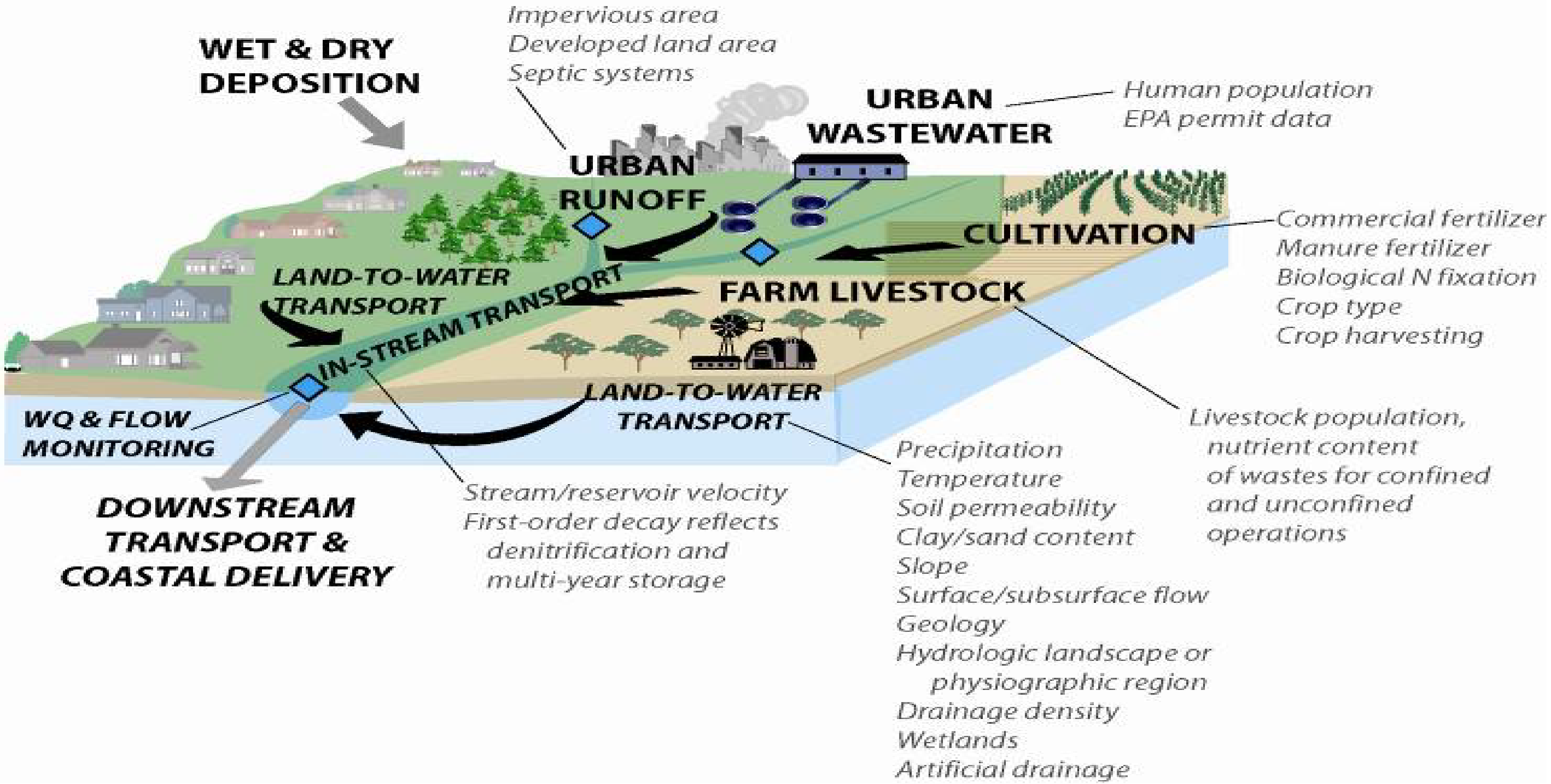
Error

- **Spatial reference frame is stream network**
- **Fundamental spatial element is stream reach and associated catchment**
- **SPARROW estimates the optimal set of rate coefficients that balance material mass (source inputs, stream loads, and storage/loss)**



SPARROW: A Spatially-Explicit Mass-Balance Watershed Model

Quantifies nutrient sources and sinks for annual time periods



SPARROW, pros, cons, strengths, weaknesses

Pros:

- Helps to identify options for reducing loads of nutrients or sediment
- Design strategies for WQ protection or to meet regulatory requirements
- Predict changes in water quality that might result from management actions
- Identify gaps and priorities in monitoring network design
- Predictions of sources of nutrients in specific locations based on a hydrological framework
- Model takes into account natural and human altered hydrology

Cons:

- Data intensive, must have accurate information which is sometimes difficult to obtain, such as amounts of fertilizer, manure used in specific locations
- Model is based on “average” conditions. SPARROW de-trends changes in streamflow and climate over a calibration period to achieve this
- Transport/decay equations are for Total Nitrogen, Total Phosphorus, and Suspended Sediment only
- Must have water quality matching different types of land uses, hydrogeology, etc.
- Model is based on annual loads and does not provide information on seasonal variability

SPARROW Data Layers Used

Base Flow Index

Climate: Annual Precipitation, Temperature

Bedrock Geology

Surficial Geology

Hydrologic Landscape Regions

Population Density

Nutrient EcoRegions

National Land Cover DataBase

Percent Impervious Surface

2001 Percent Canopy

Mean Annual R-factor

Physiography

STATSGO Soils

Recharge

Atmospheric Deposition

Nutrient Inputs from Fertilizer and Manure (N&P)

Nutrient Application for Fertilizer and Manure Applied to Crops

Tile Drains, Irrigated Lands, Agricultural modifications, water diversions

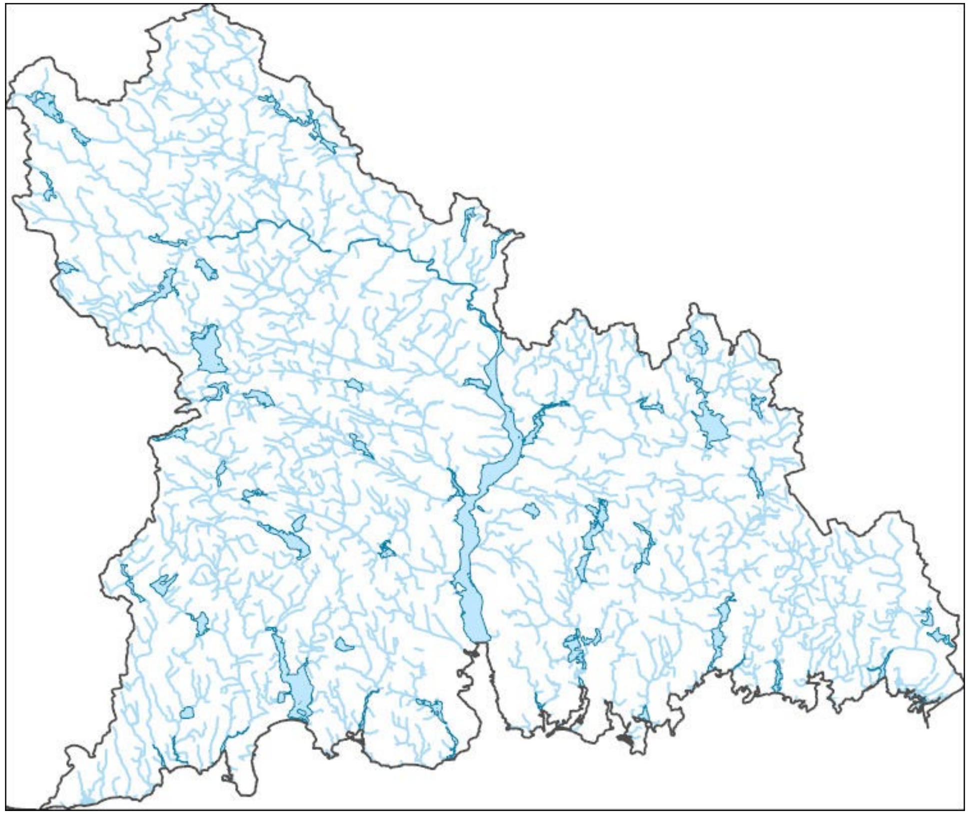
Wastewater facility locations and average annual discharges

Physical Measures, Drainage area, Basin Shape Index, Sinuosity, Slope, Stream Density, Stream Length, Road Density etc

Average streamflow (in cfs) for the modeled period estimated using the Unit Runoff Method (UROM)

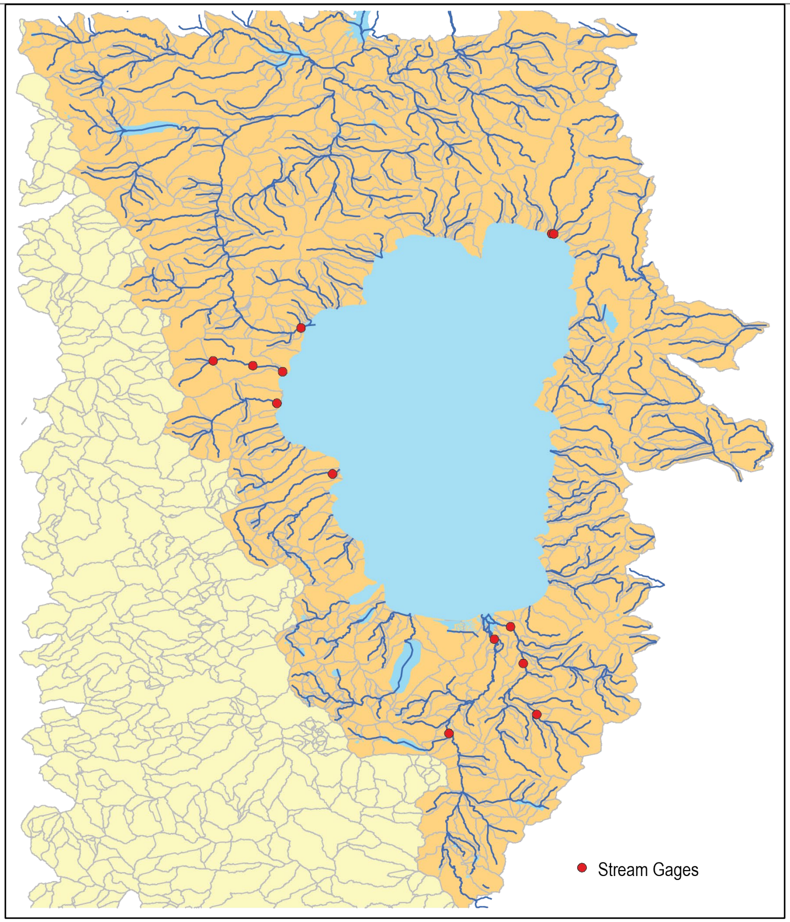
Water quality sites: locations with sufficient data to calculate an annual load

SPARROW Uses National Hydrography Dataset_Plus V2 for stream network



This is the most detailed coverage of the national stream network. NHD+ contains information on location, direction of flow and sub-watersheds within a larger.

Streams and Catchments



Each segment of a stream reach is within a labeled polygon (catchment)

The model input data-frame has a row for each catchment (142,000 in 2002 model)

Data such as soil types, fertilizer, atmospheric deposition, wastewater treatment load, land-use, etc. are included for each polygon where applicable.

If a diversion occurs along a flowline, the average amount of the diverted water on an annual basis is included

Calibration Sites

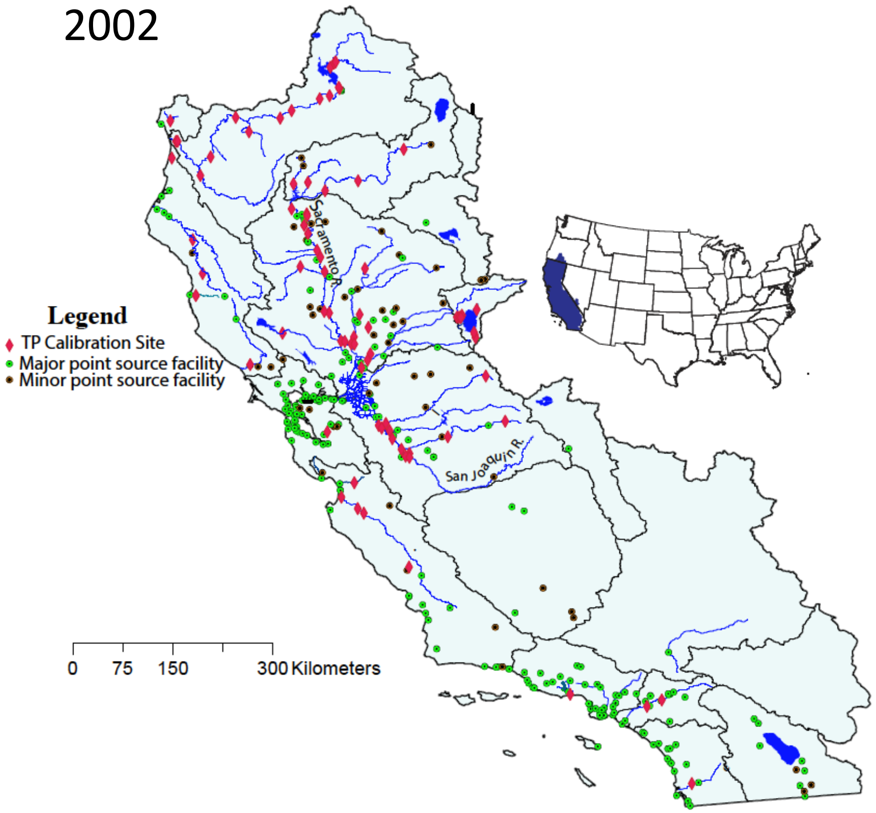
Calibration sites must be co-located with stream gaging stations

A sufficient number of samples must be collected over the year to calculate an annual load using a model such as LOADEST ; 89 locations for 2002 California model

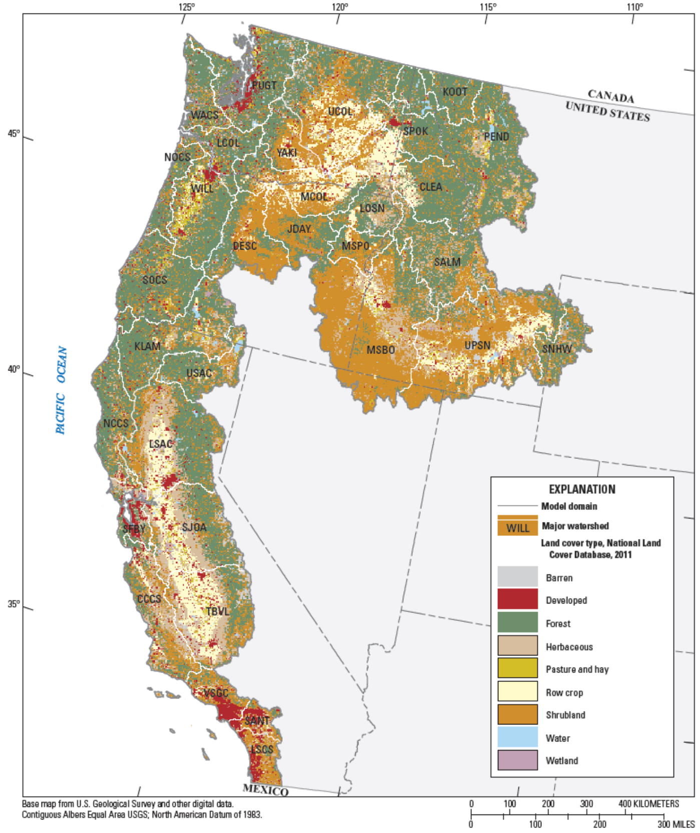
Calibration sites must be located near important land uses or hydrologic regions in order to build a statistically significant relationship between stream load, land use, land to water transfer, and aquatic decay

2002 and 2012 Model Domains

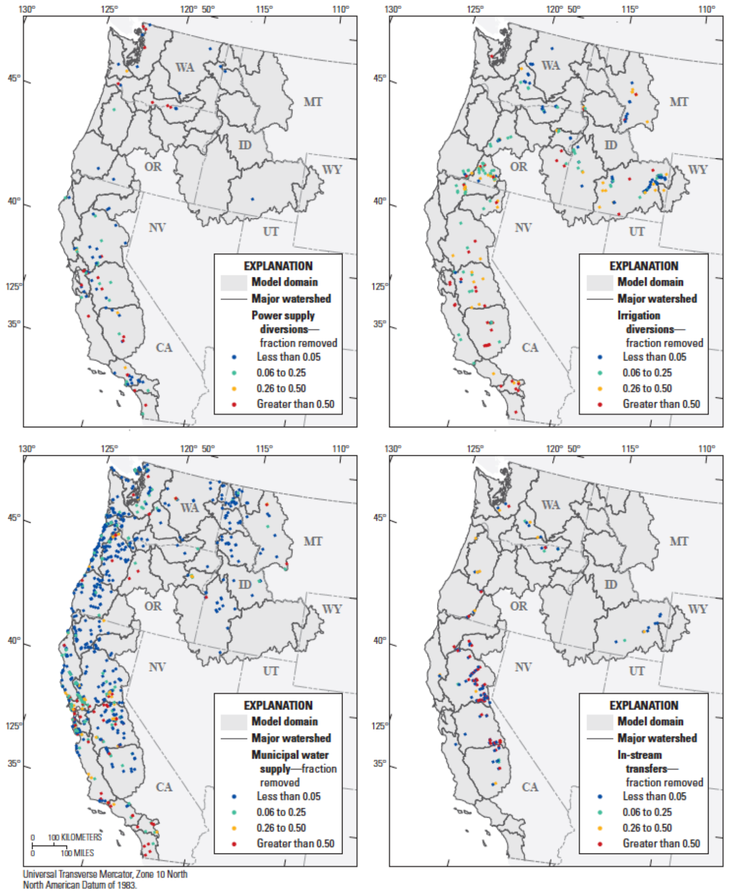
2002



2012



Water Diversions—2012 model was the most comprehensive and provided better mass balance on water.



Diversions Included:

- 91 for Power Supply
- 248 for Irrigation
- 642 for Municipal Water Supply
- 72 for other In-stream transfers

Model Evaluation and Statistical Summary

TABLE 2. SPARROW Model Statistics for Total Nitrogen.

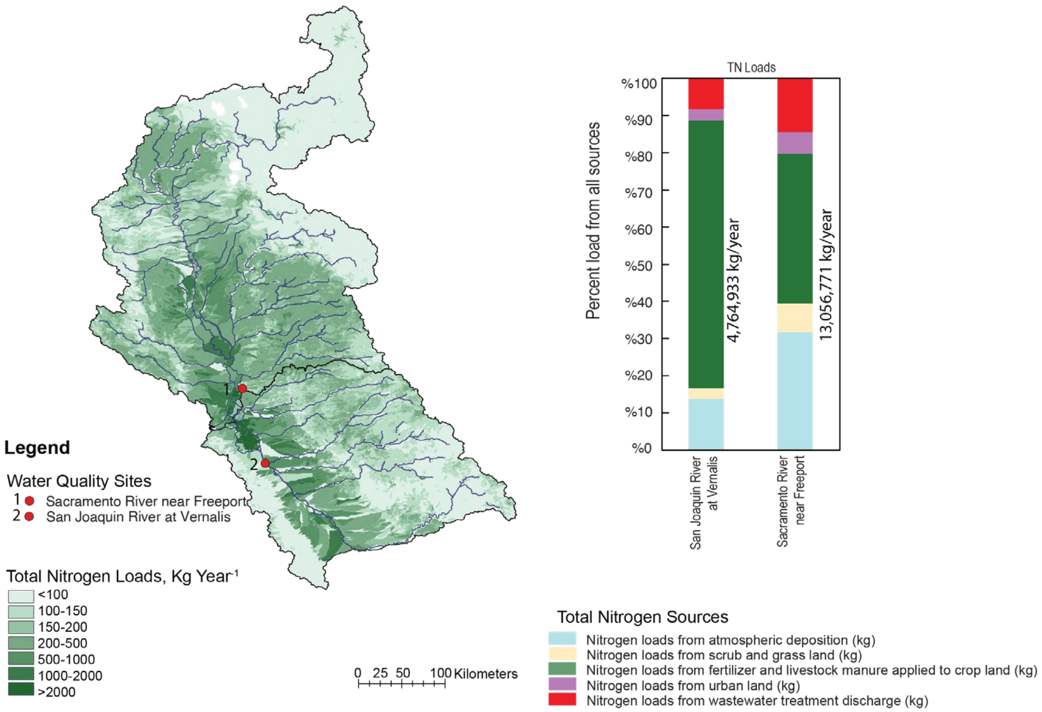
Parameters (explanatory variable units)	Estimated Model Coefficient Units	90% Confidence Interval for Model Coefficient: Lower	90% Confidence Interval for Model Coefficient: Upper	Estimated Model Coefficient	Standard Error	p*	Nonparametric Bootstrap Estimate of Coefficient (mean)
Nitrogen sources							
Forested land[1] (km^2)	kg/km^2/year	280.11	654.88	450.08	190.36	0.021	452.64
Developed land[2] (km^2)	kg/km^2/year	442.68	1253.52	844.24	526.59	0.113	853.48
Point sources[3] (kg)	Dimensionless	0.99	1.53	1.18	0.389	0.004	1.26
Farm fertilizer and confined manure[4] (kg)	Dimensionless	0.07	0.22	0.14	0.05	0.007	0.14
Unconfined manure[5] (kg)	Dimensionless	0.27	0.87	0.46	0.24	0.063	0.54
Atmospheric deposition[6] (kg)	Dimensionless	0.53	1.38	0.89	0.37	0.019	0.94
Land-to-water delivery**							
Precipitation[7] (mm)	Log (mm)	0.24	0.83	0.40	0.26	0.129	0.51
Sand[8] (share of catchment)	Dimensionless	−0.03	−0.02	−0.03	0.01	0.0003	−0.02
Tiles[9] (share of catchment)	Dimensionless	0.04	0.26	0.05	0.01	<0.0001	0.09
Wetlands[10] (share of catchment)	Dimensionless	0.03	0.08	0.06	0.01	<0.0001	0.05
Aquatic loss							
Instream loss1[11] (where $Q < 14.0\ m^3/s$)	$(days)^{-1}$	1.38	2.09	1.67	0.32	<0.0001	1.70
Instream loss2 (where $Q \geq 14.0\ m^3/s$)	$(days)^{-1}$	0.17	0.39	0.25	0.09	0.0049	0.27
Intermittent stream[12] (m^3/s)	$(days)^{-1}$	2.22	3.53	2.69	0.66	<0.0001	2.84
MSE: 0.27		R^2 load:		0.94			
RMSE: 0.52		R^2 yield:		0.81			
Number of observations: 89							

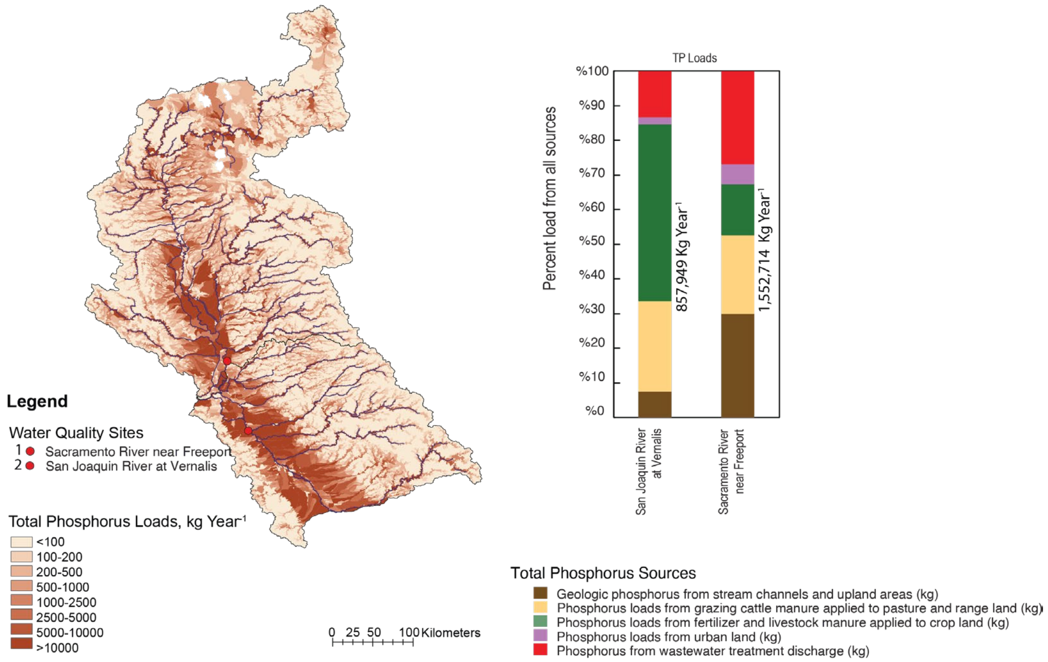
A statistical summary is provided with the model output

A *p* value above 0.1 for a source, land to water delivery, or aquatic decay term is considered insignificant and is taken out of subsequent model runs

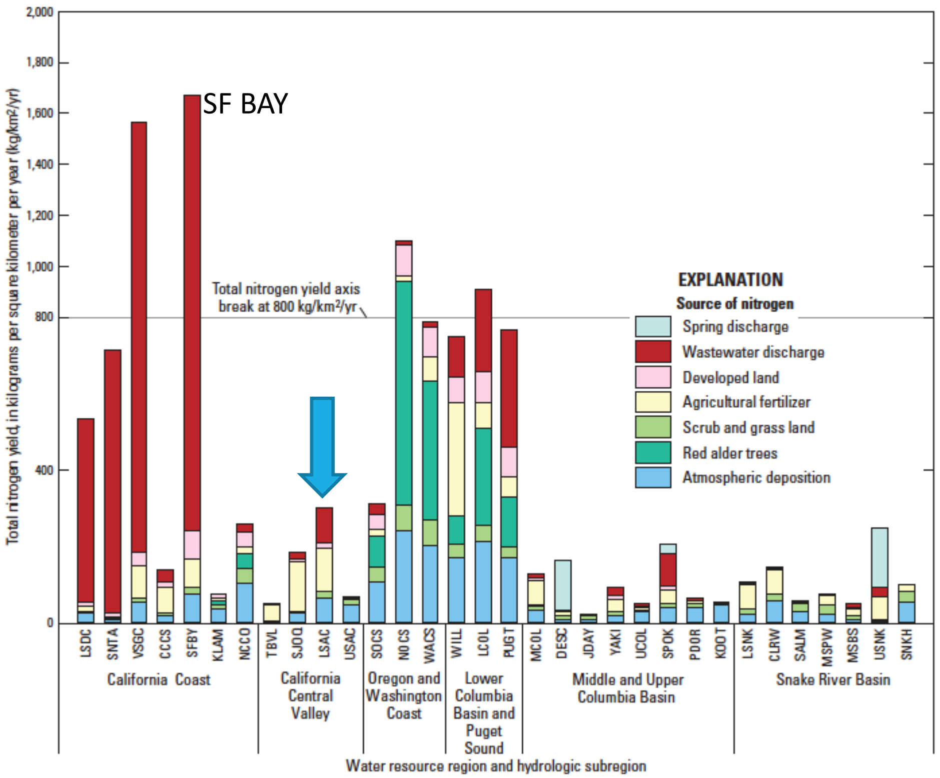
In this TN model, the over value of R^2 of the load is 0.94 and that for the yield is 0.84

TN and TP Loads at Freeport and Vernalis, from 2012 Model





TN Loads in Other Areas



Highest yields of TN in California coastal waters include:

Highest yield for San Francisco Bay

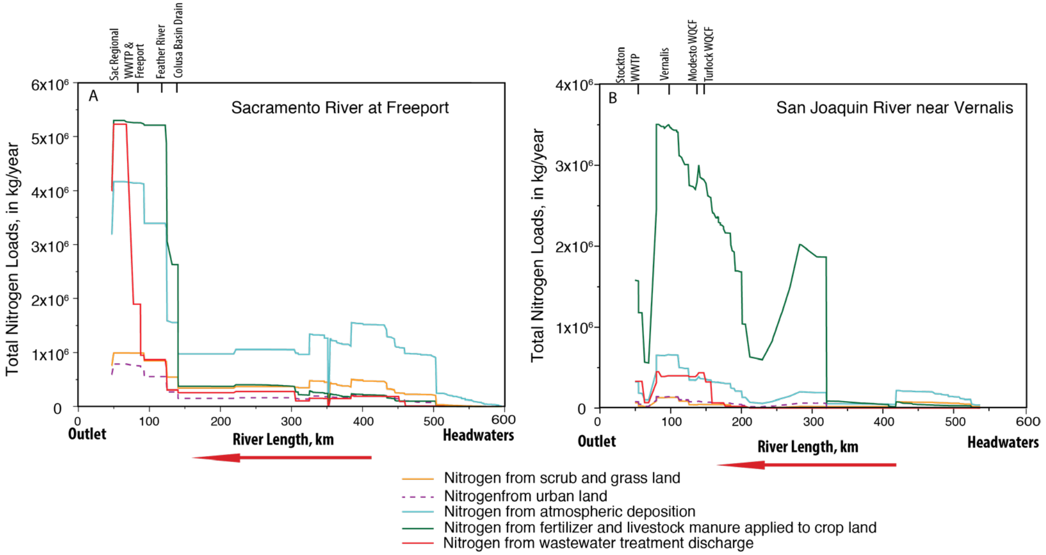
Second highest for Ventura-San Gabriel

Third highest for Santa Ana

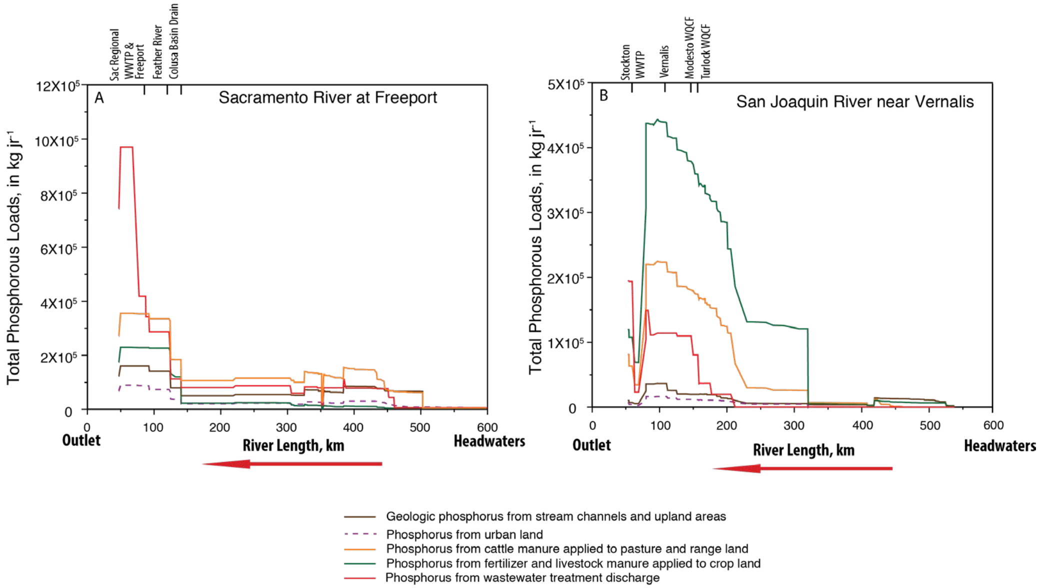
Fourth highest for Laguna-San Diego

“Canoe” trip down major rivers

Total Nitrogen



Total Phosphorus



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

NEW APPROACHES TO SPARROW MODELING ARE BEING DEVELOPED AND TESTED

New Approaches to SPARROW Modeling

Original SPARROW models invoked annual loads with de-trended discharge and climate data in order to provide information on “average” years

A Dynamic model, is being tested at several watersheds nation-wide, including one in California

Improvements in this model include a storage term which allows for an understanding of stream loads after a lag time and more accurately predicts stream loading on a seasonal basis. De-trending is not used in this case

Predictions of hydrologic changes in future scenarios can be used in the stream network to show how loading, transport, and aquatic decay may change with changing land uses and potential sources

Modeling Delta Water Quality Using Coupled Hydrodynamic and Biogeochemical Models

ZHENLIN ZHANG, DEPARTMENT OF WATER RESOURCES

PREDICTING THE FUTURE - NUTRIENT MODELING, 2:55 TO 3:10 PM

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Modeling Delta water quality using coupled hydrodynamic and biogeochemical models

September 27, 2022

Delta Modeling Section

Zhenlin Zhang and Eli Ateljevich

Acknowledgements

- DWR Delta Modeling Section staff
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- Regional Water Board

  Janis Cooke
- Reginal San

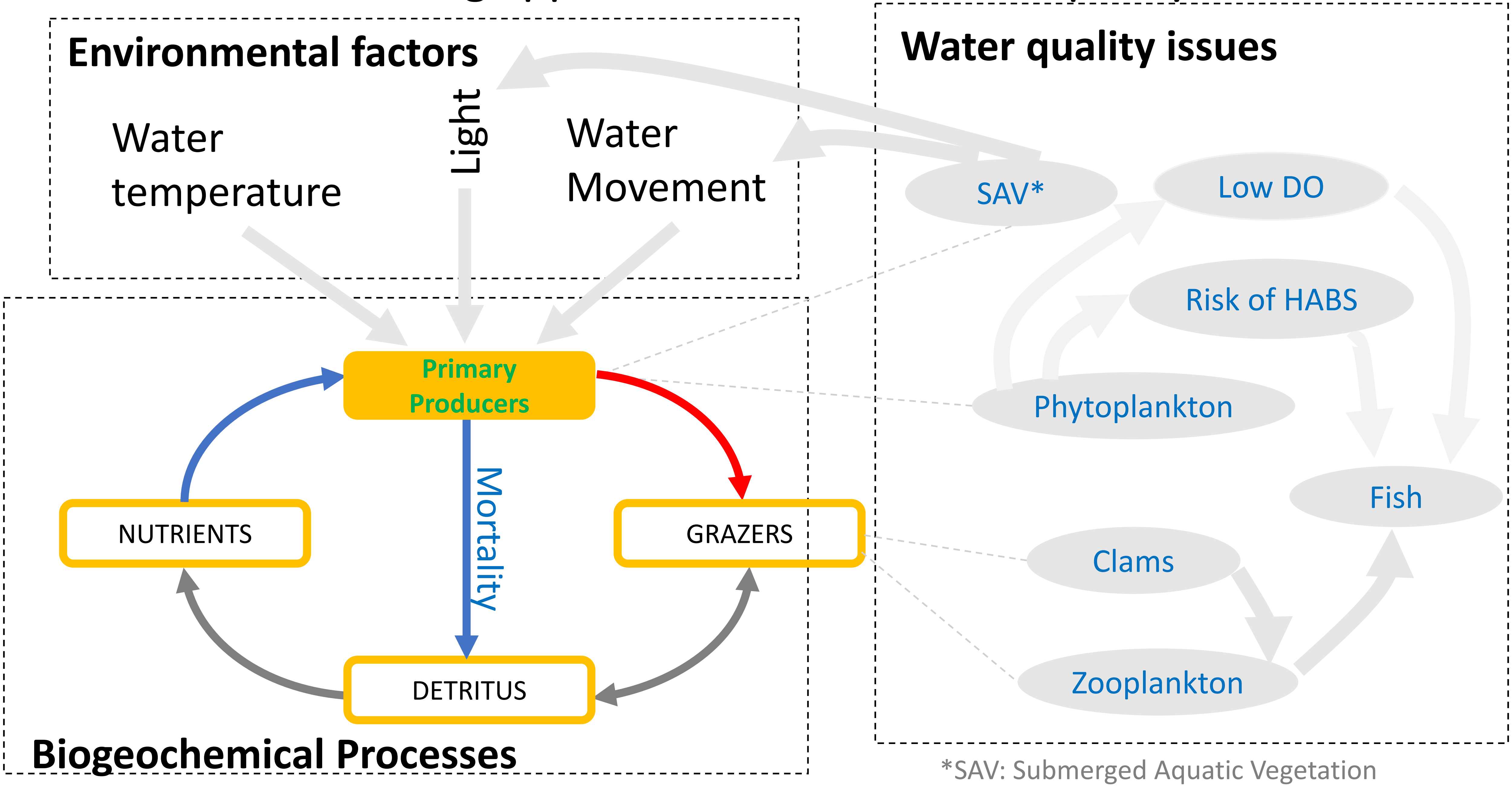
  Timothy Mussen, Lisa Thompson
- DWR

  Elizabeth Wells, Rosemary Hartman
- USGS

  Brian Bergamaschi, Tamara Kraus, Keith Bouma-Gregson
- SFSU

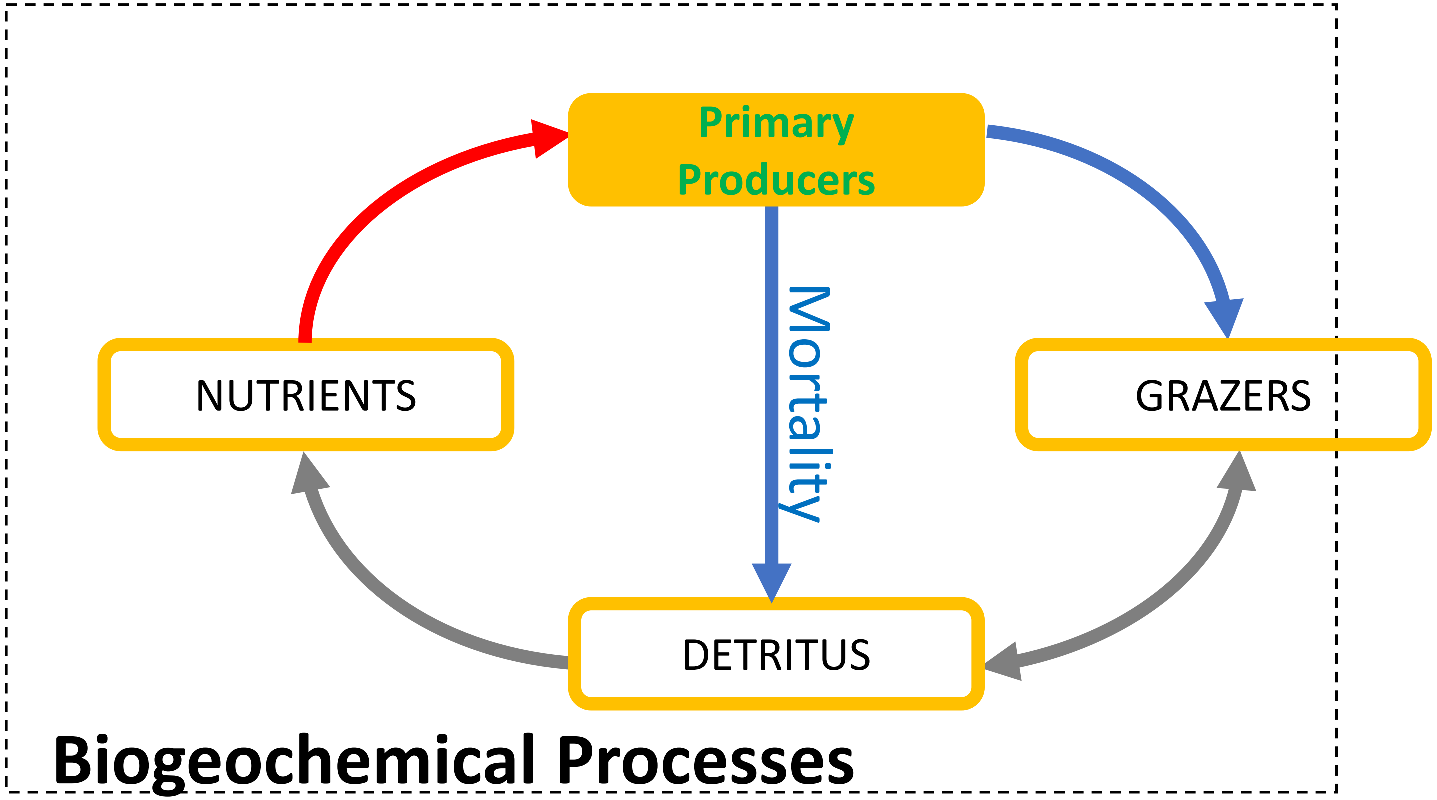
  Frances Wilkerson, Richard Dugdale

A mechanistic modeling approach to address water quality issues

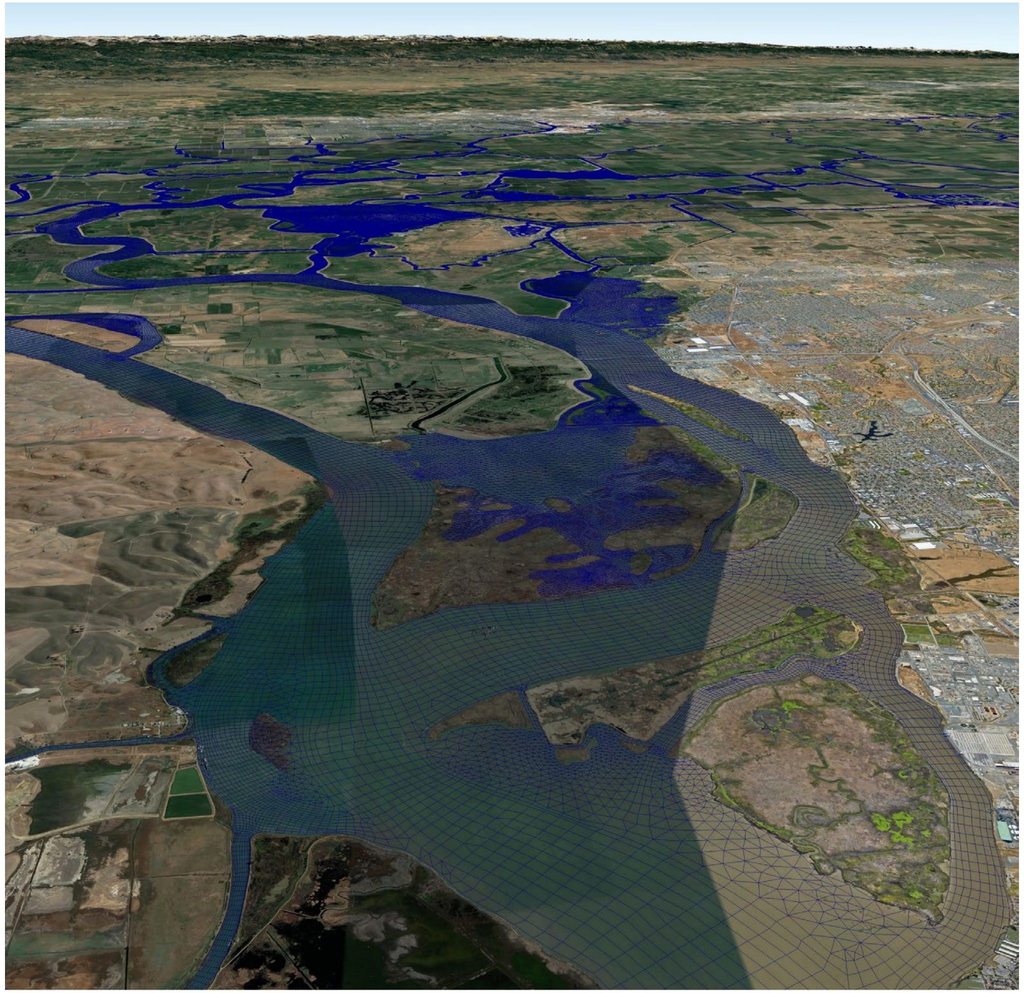


*SAV: Submerged Aquatic Vegetation

A coupled hydrodynamic and biogeochemical processes



Hydrodynamic Processes



Models: SCHISM* & CoSiNE (Carbon, Silicate, Nitrogen Ecosystem)

- ✓Open-source, unstructured-grid model, well-supported community model
- ✓Extensively calibrated for the Delta → Developing operational model
- ✓Peer-reviewed journal articles using SCHISM & biogeochemical models.
- ✓Coupled to FABM (Framework for Aquatic Biogeochemical Models), which includes ~20 different biogeochemical models.

*SCHISM stands for Semi-implicit Cross-scale Hydroscience Integrated System Model

CoSiNE (Carbon, Silicate, Nitrogen Ecosystem)

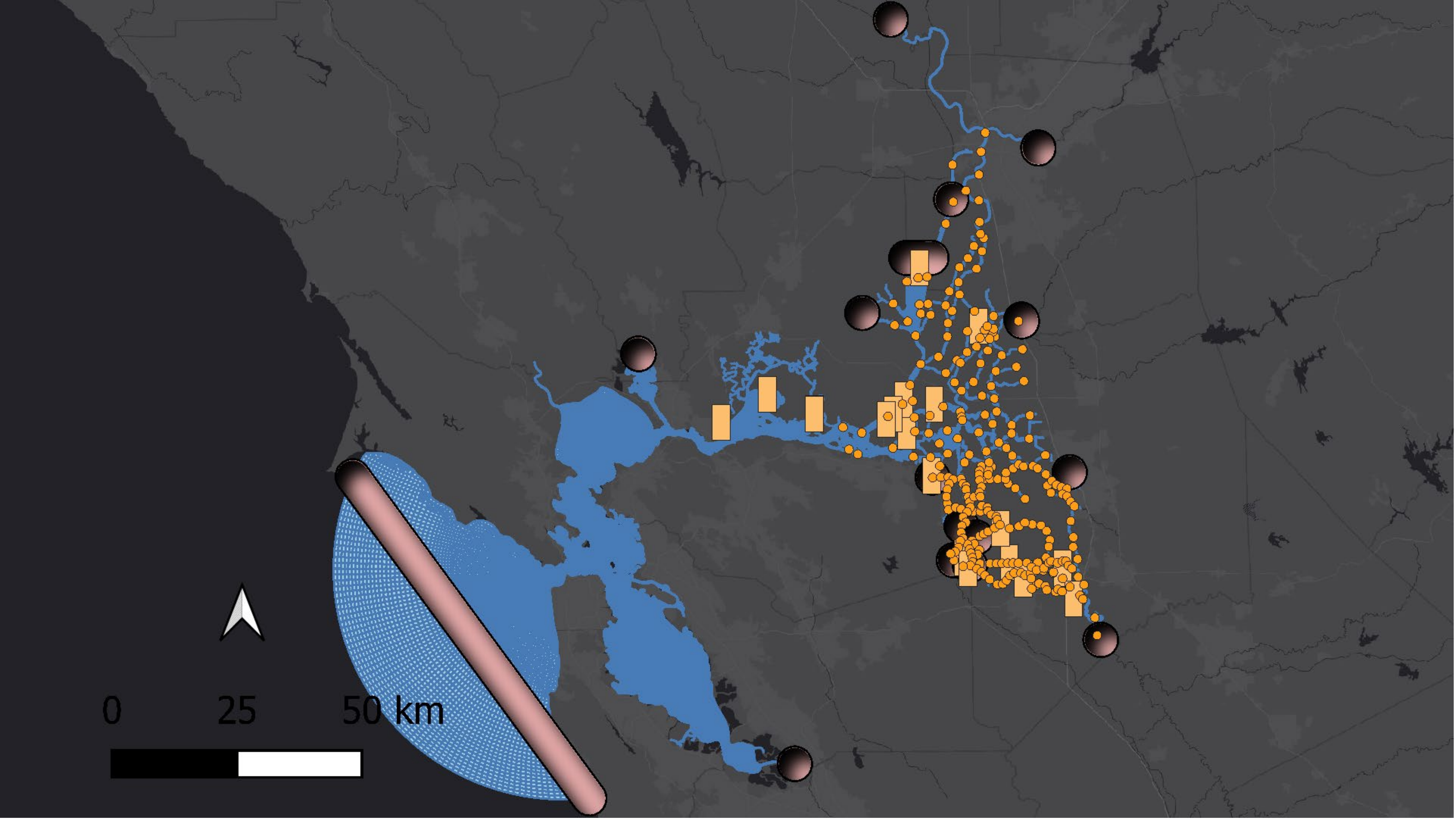
Nutrients

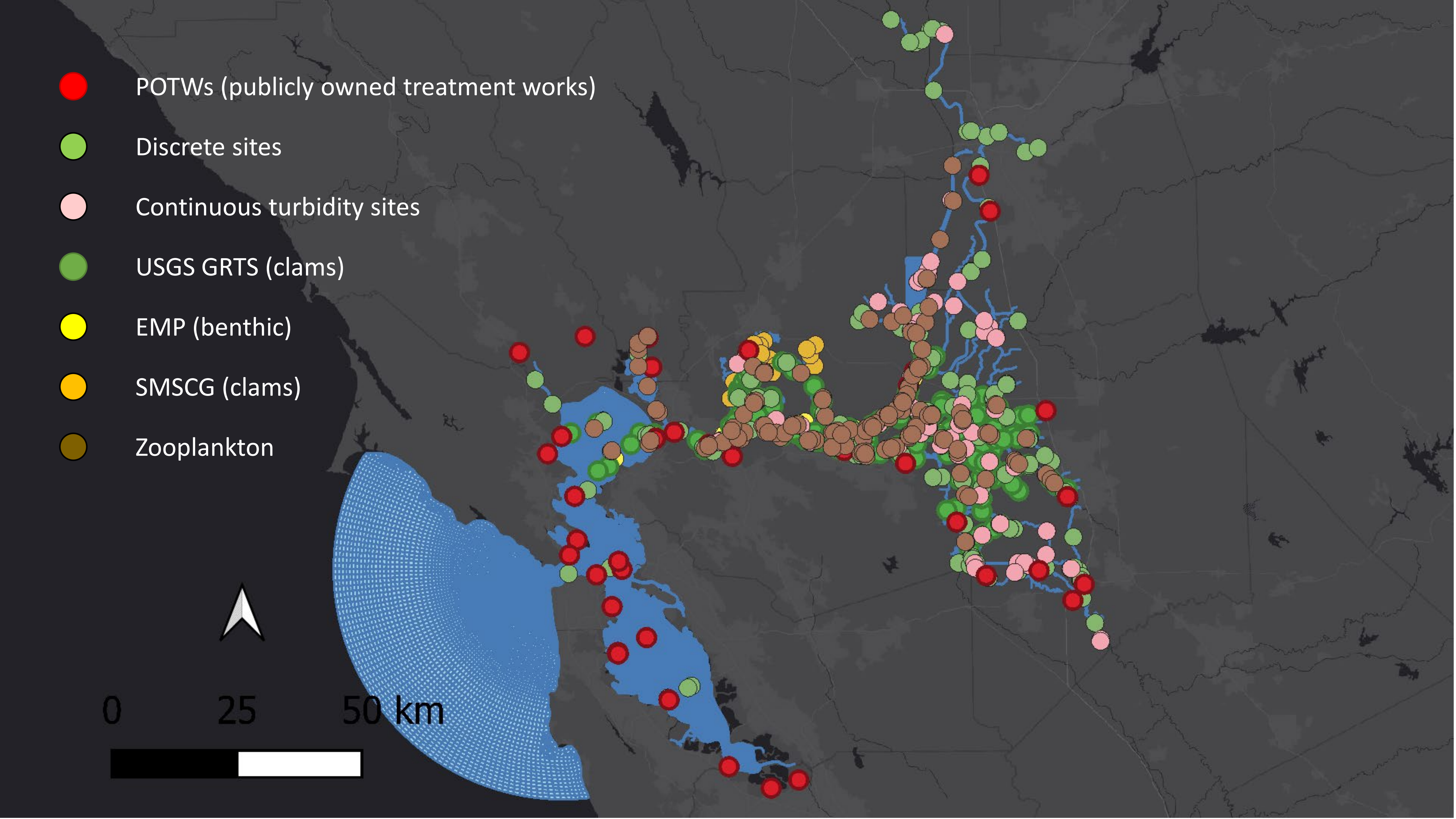
Phytoplankton

Zooplankton

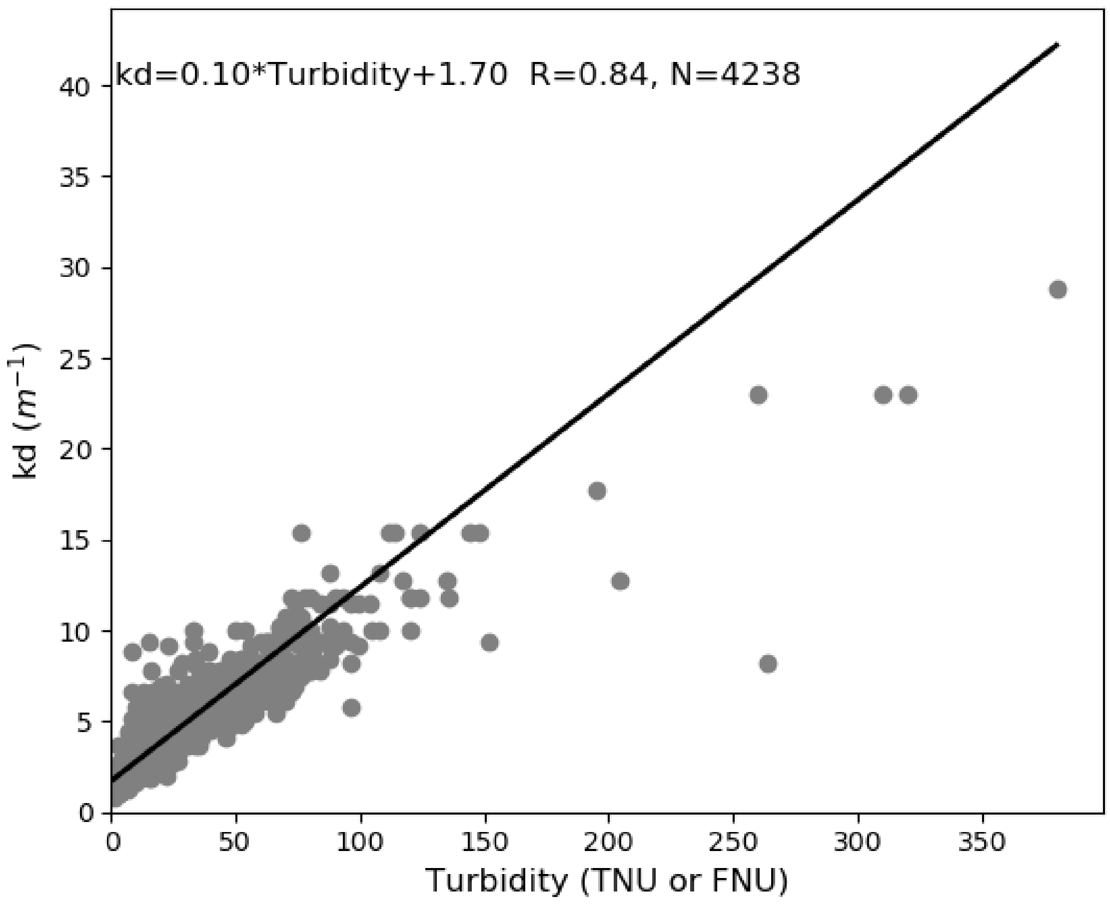
Detritus

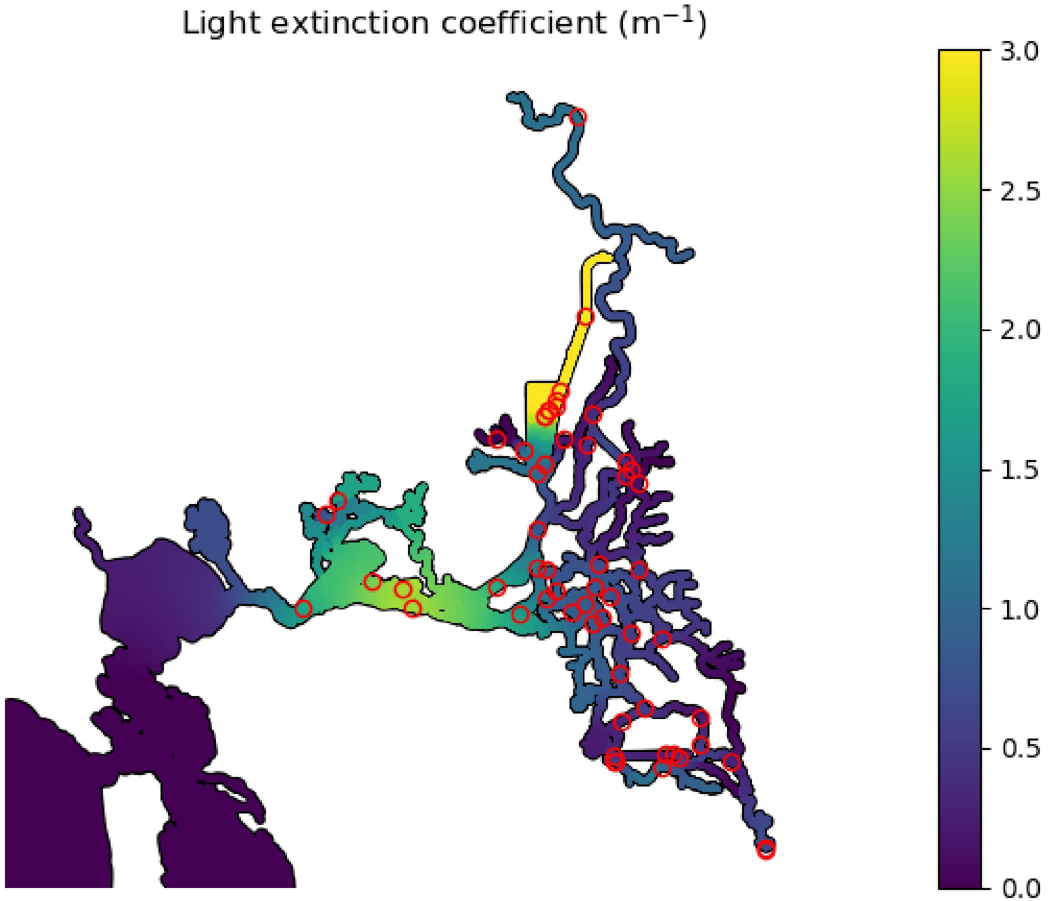
Name of State Variables	Symbol	Tracer Numbering in SCHISM (within CoSiNE module)	Unit
Nitrate	NO3	1	$mmol/m^3$
Silicate	SiO4	2	$mmol/m^3$
Ammonium	NH4	3	$mmol/m^3$
Small Phytoplankton	S1	4	$mmol/m^3$
Diatom	S2	5	$mmol/m^3$
Microzooplankton	Z1	6	$mmol/m^3$
Mesozooplankton	Z2	7	$mmol/m^3$
Detritus Nitrogen	DN	8	$mmol/m^3$
Detritus Silicon	DSi	9	$mmol/m^3$
Phosphate	PO4	10	$mmol/m^3$
Dissolved Oxygen	DOX	11	$mmol\ m^{-3}$
Dioxide Carbon	CO2	12	$mmol\ m^{-3}$
Alkalinity	ALK	13	meq/m^3


0
25
50 km


POTWs (publicly owned treatment works)
Discrete sites
Continuous turbidity sites
USGS GRTS (clams)
EMP (benthic)
SMSCG (clams)
Zooplankton
0
25
50 km

Turbidity and Light field





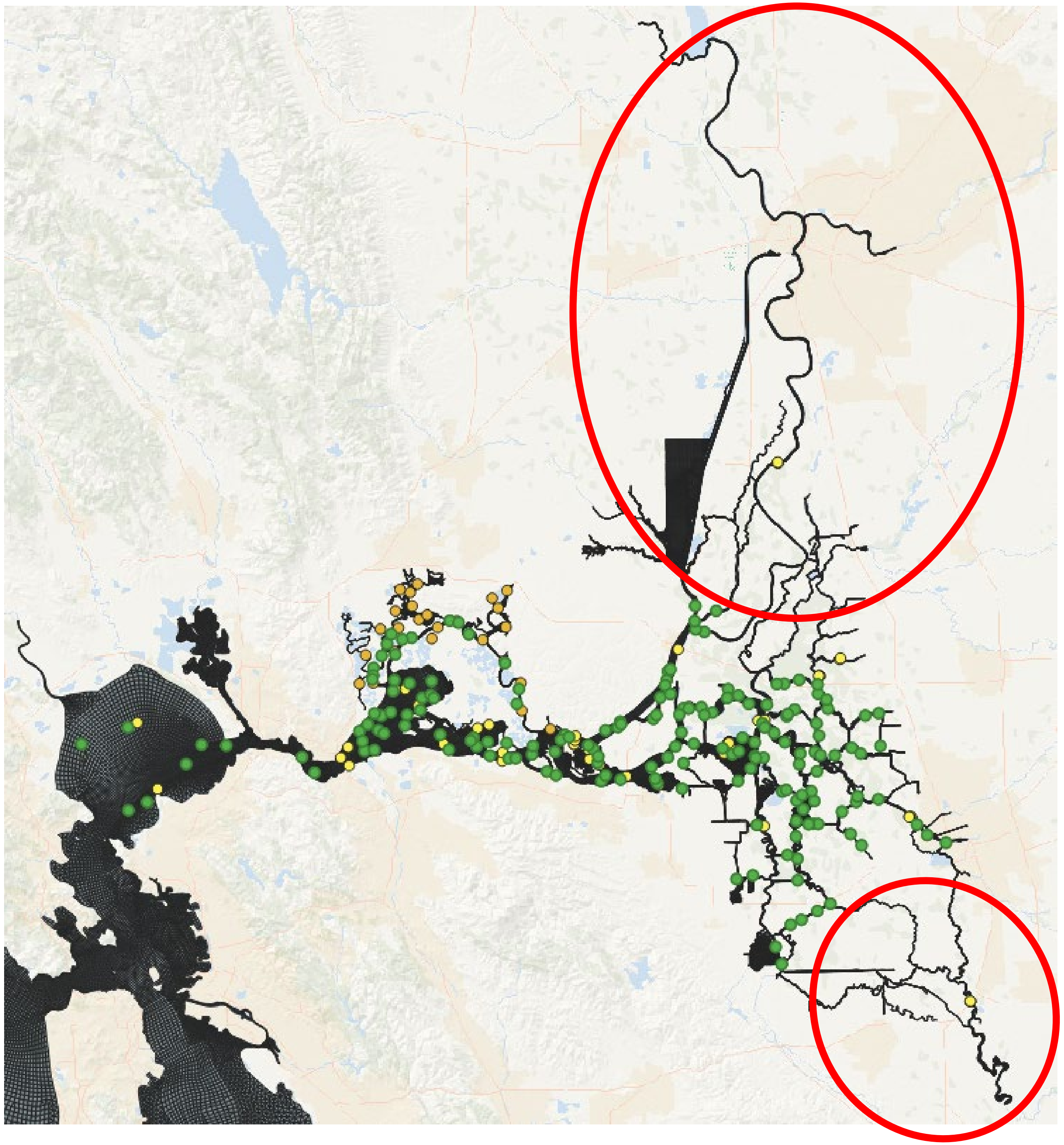
Light extinction coefficient (Kd) ~ 0.1 FNU or TNU
Data source: EMP (Environmental Monitoring Program)

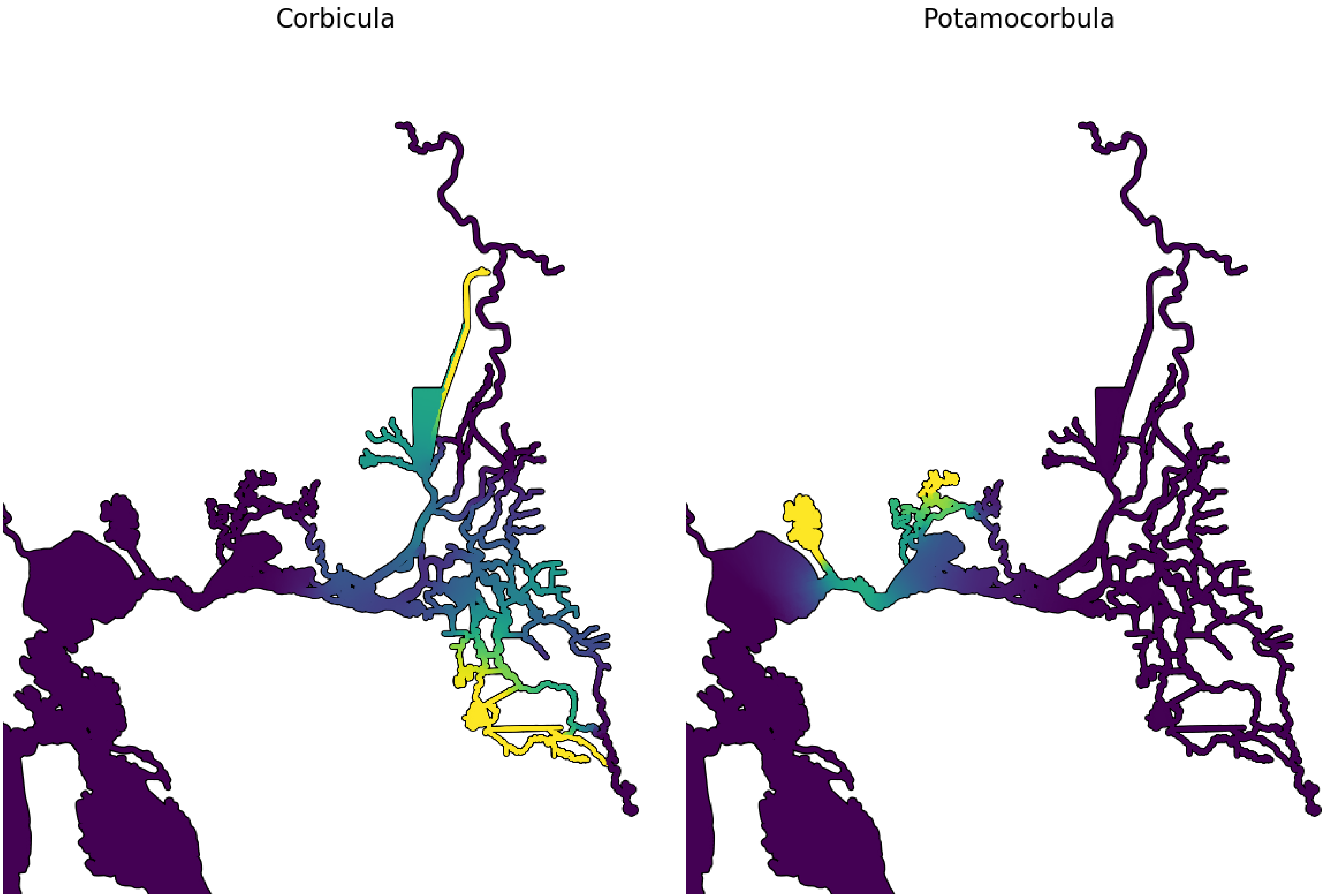
Spatial interpolation using fdaPDE (Functional Data Analysis and Partial Differential Equations)
https://cran.r-project.org/web/packages/fdaPDE/index.html

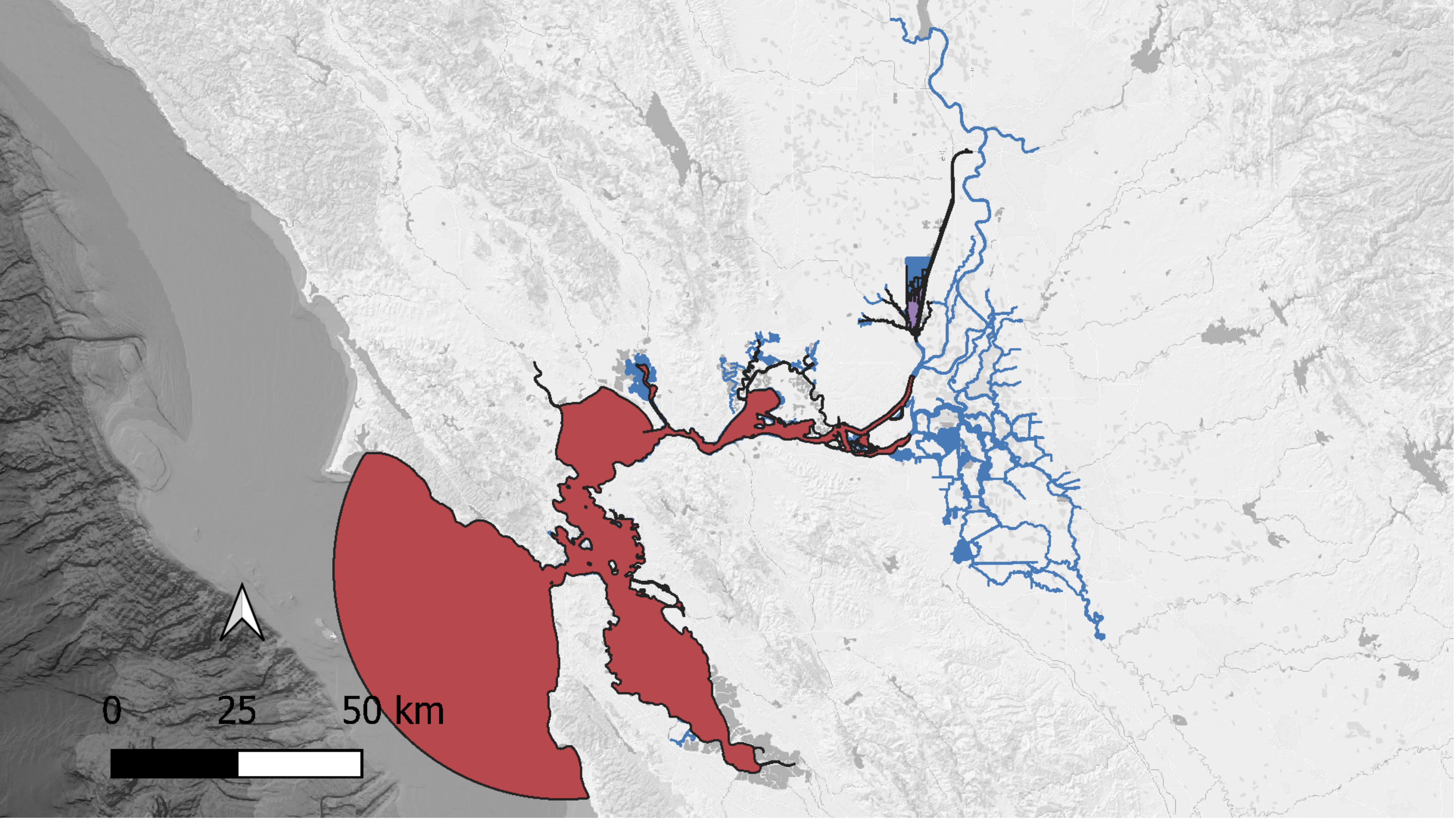
Clam grazing data

- EMP: monthly 2014 - 2019 https://doi.org/10.5066/P9Q57NL0
- USGS GRTS: May, Oct 2007 – 2019 https://www.sciencebase.gov/catalog/item/5fe575f7d34ea5387deb52ee
- SMSCG: July, Sep 2018-2020 https://portal.edirepository.org/nis/mapbrowse?packageid=edi.876.1

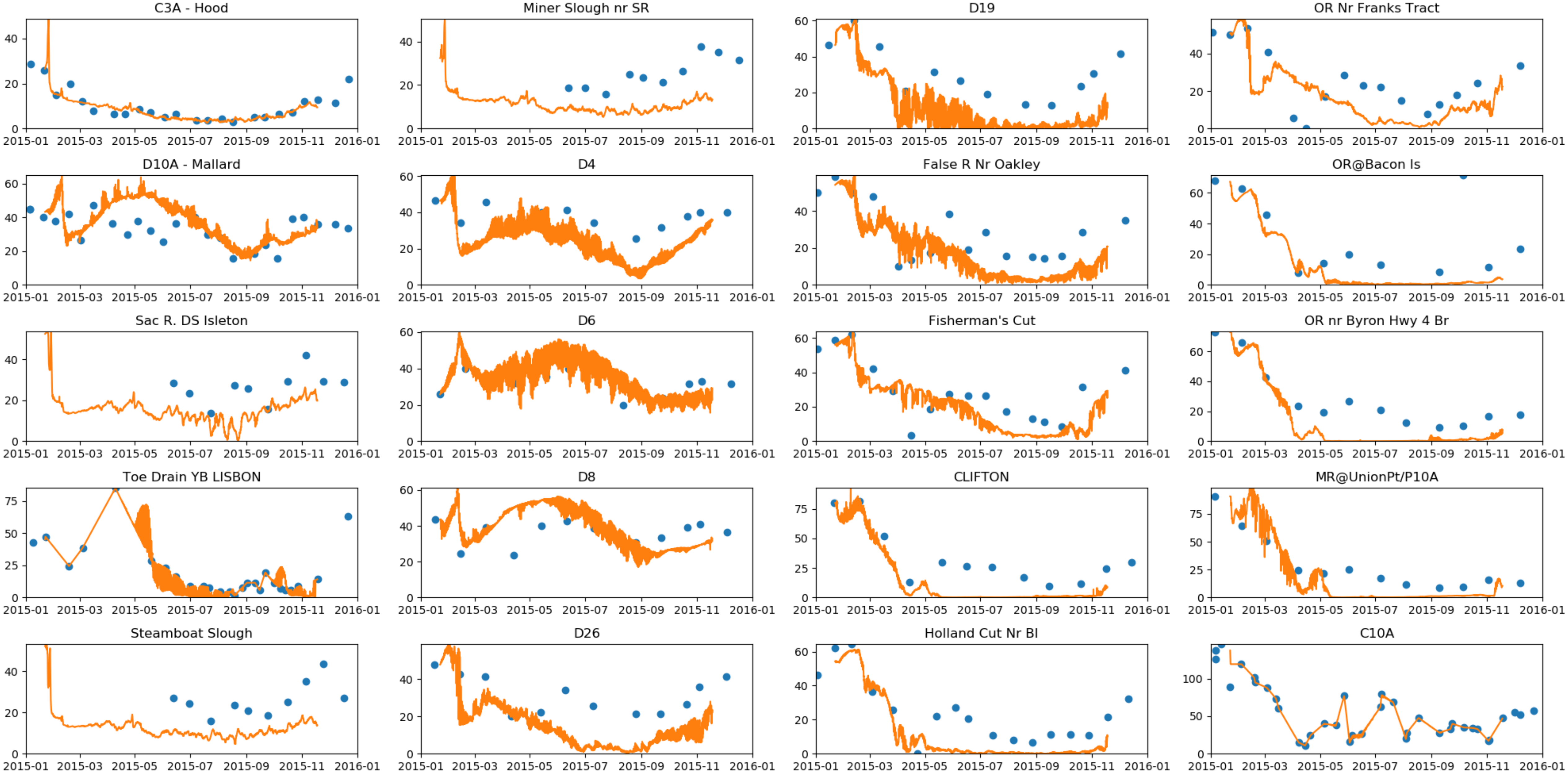
GRTS: Generalized Random Tessellation Stratified Program
EMP: Environmental Monitoring Program
SMSCG: The Suisun Marsh Salinity Control Gates



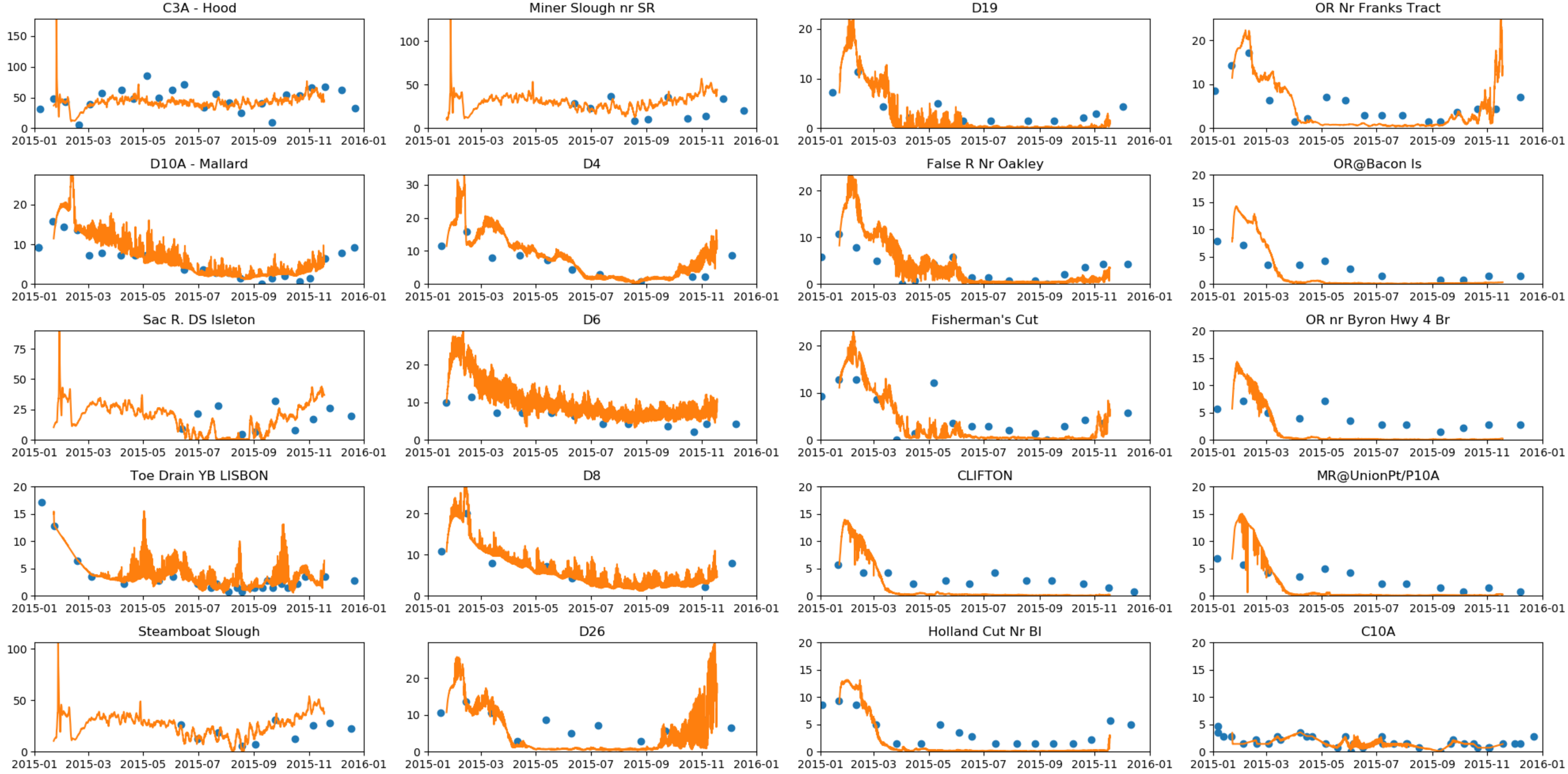

Corbicula
Potamocorbula


0
25
50 km

Nitrate + Nitrite (μM)

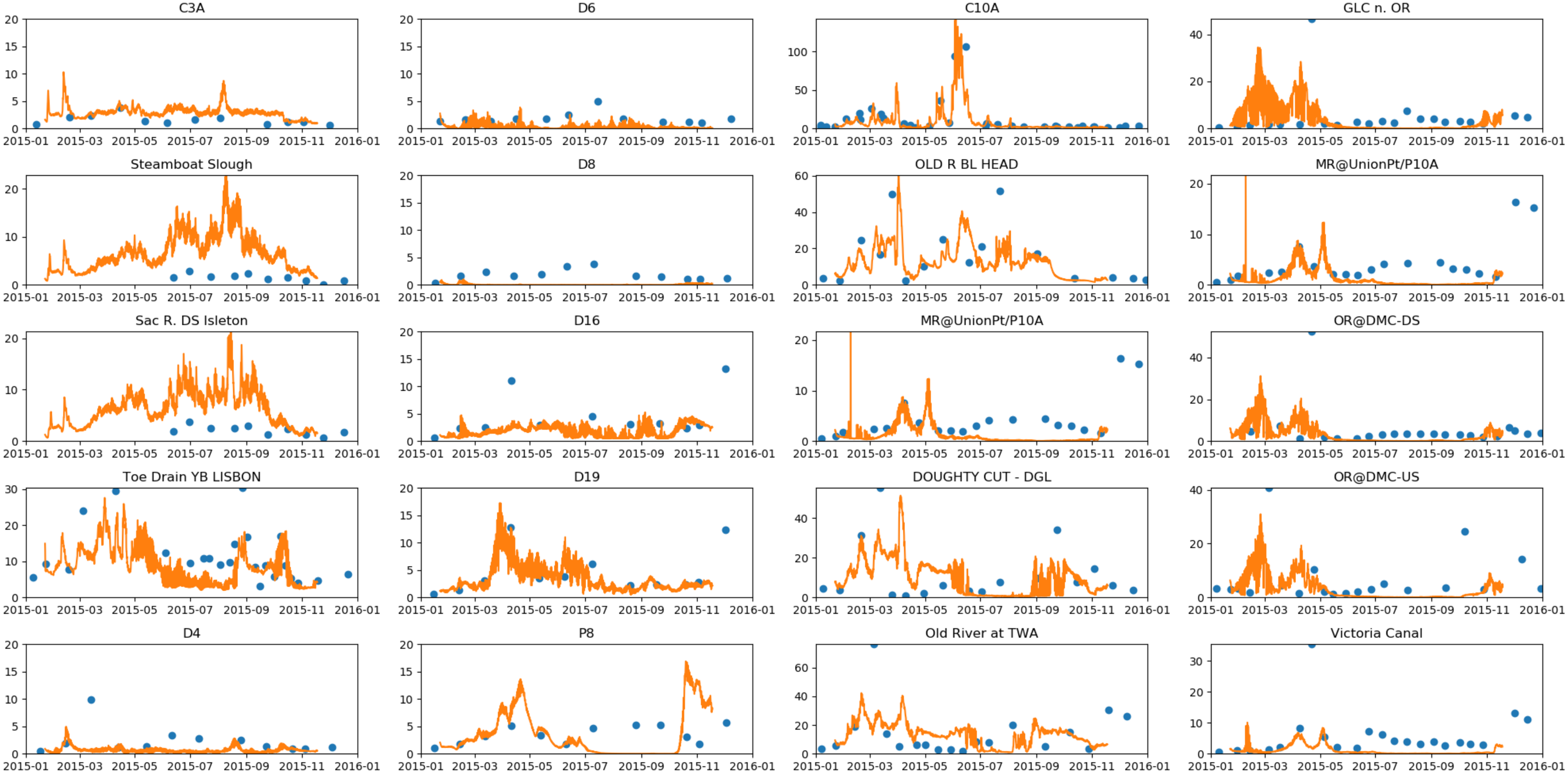


Ammonia (μM)



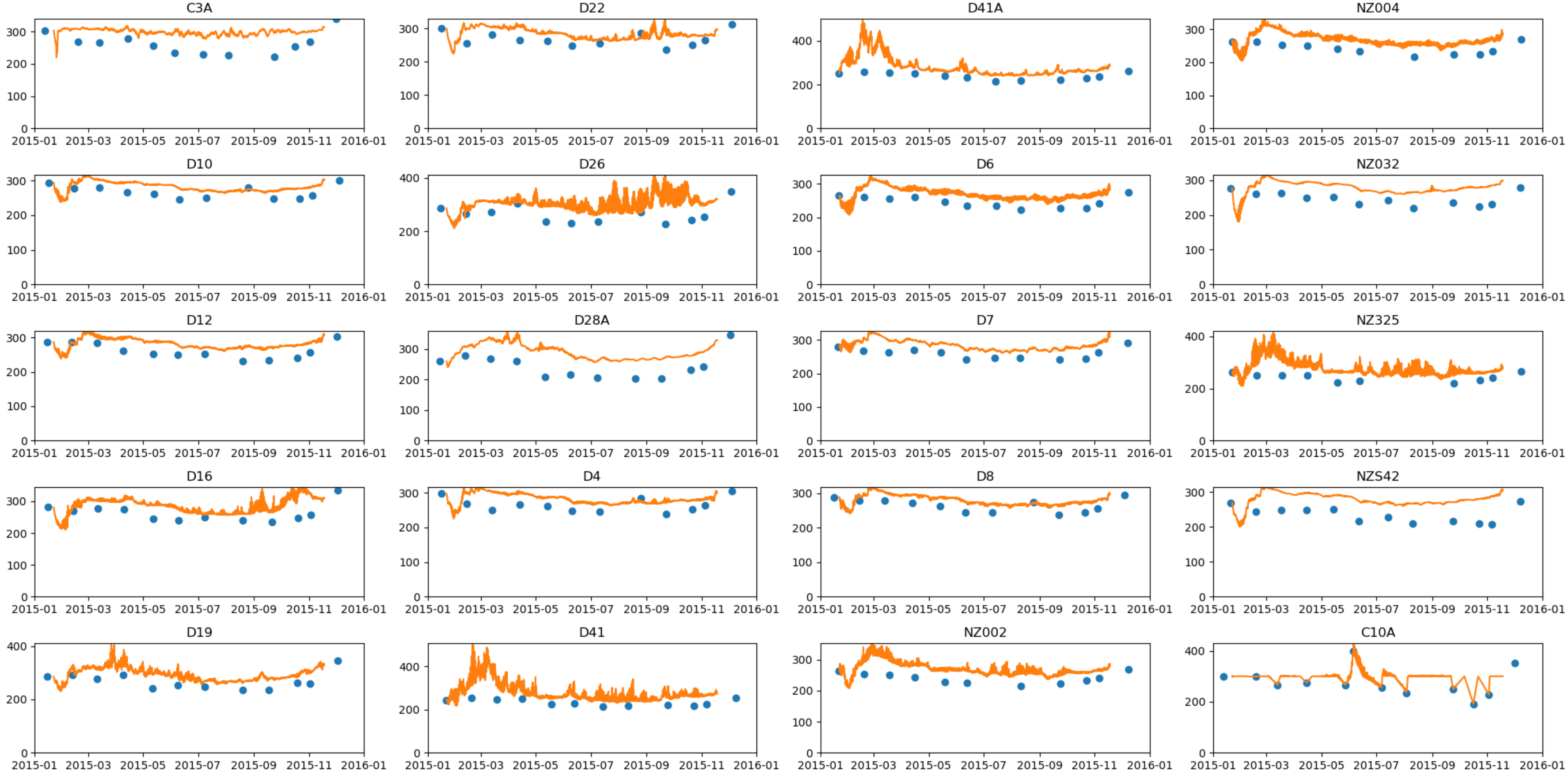
C3A - Hood
Miner Slough nr SR
D19
OR Nr Franks Tract
D10A - Mallard
D4
False R Nr Oakley
OR@Bacon Is
Sac R. DS Isleton
D6
Fisherman's Cut
OR nr Byron Hwy 4 Br
Toe Drain YB LISBON
D8
CLIFTON
MR@UnionPt/P10A
Steamboat Slough
D26
Holland Cut Nr BI
C10A
2015-01
2015-03
2015-05
2015-07
2015-09
2015-11
2016-01

Chlorophyll a (μg/l)



Phosphate (μM)

DO (μM)


C3A
D22
D41A
NZ004
D10
D26
D6
NZ032
D12
D28A
D7
NZ325
D16
D4
D8
NZS42
D19
D41
NZ002
C10A
2015-01
2015-03
2015-05
2015-07
2015-09
2015-11
2016-01

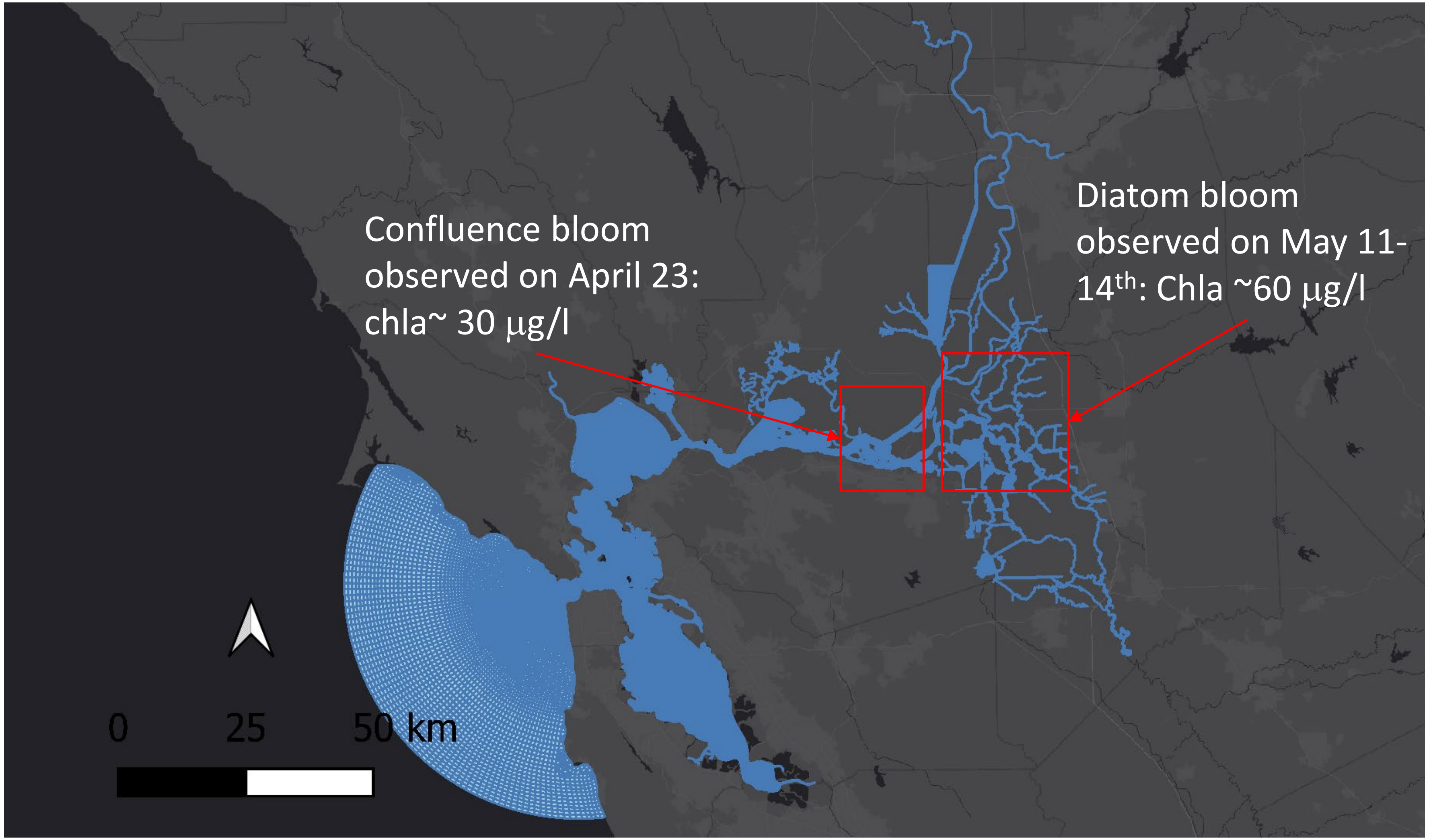
Conclusions

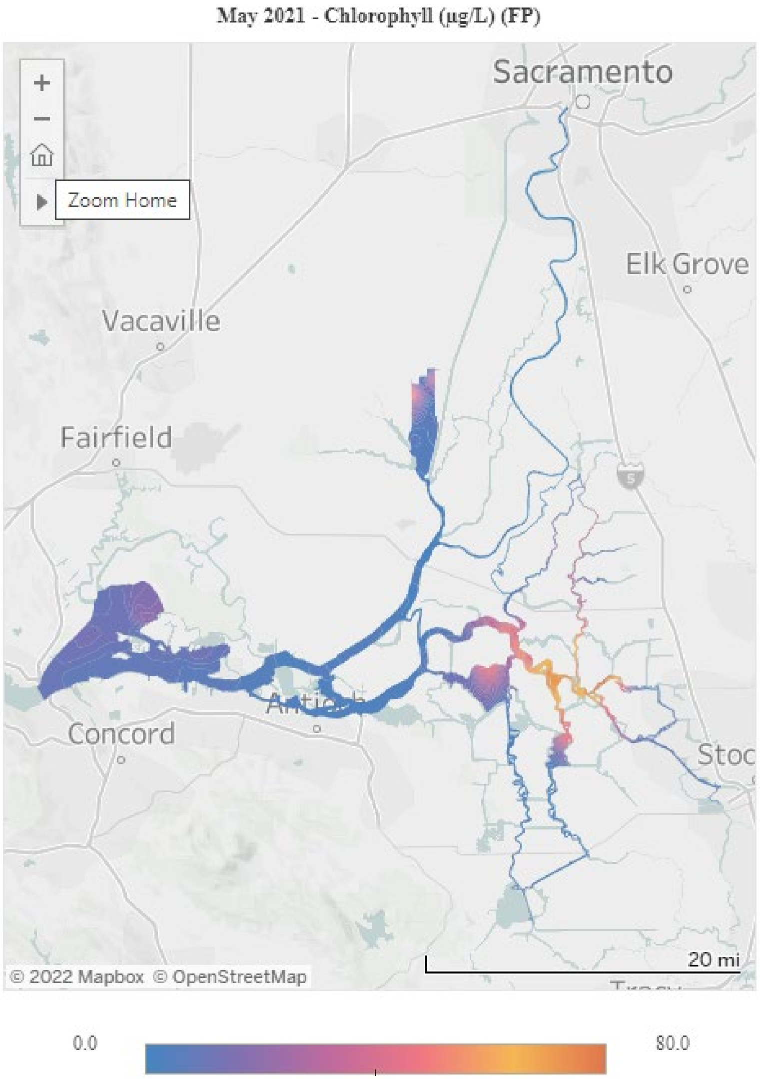
- This project is an infrastructural level of modeling effort and a working progress: a test run for 2015 showed that SCHISM & CoSiNE is capable of modeling the seasonal variability of observed nutrients, Chlorophyll a, and DO for most part of the domain.
- Further tuning is required to improve the model.

Future work

- Model calibration for other years (particularly 2021).
- Long-term model calibration (2008 to 2018, particularly for 2016 and 2018).
- Zooplankton model validation.
- Further data validation using USGS high resolution mapping data.
- Dynamic clam grazing model: modeling clam growth and mortality based on food availability.
- HABs modeling.

Why is 2021 our next target year?





USGS Delta survey by Bergamaschi et al.

Other important events in 2021

- Upgrade of Regional San (Sacramento Regional Wastewater Treatment Plant) in May.
- Emergency Drought Barrier on False River.
- HAB event observed in July and August 2021 in Franks Tract.

Delta RMP Nutrient Symposium

"Status and Trends in Nutrient Studies" &
"Predicting the Future – Nutrient Modeling":
Presenter Questions to Address

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

- Clam grazing rate.
- Better data on light attenuation.
- Calibration of continuous Chl-a data.

Questions and Comments

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Questions and Discussion

PREDICTING THE FUTURE - NUTRIENT MODELING, 2:55 TO 3:10 PM