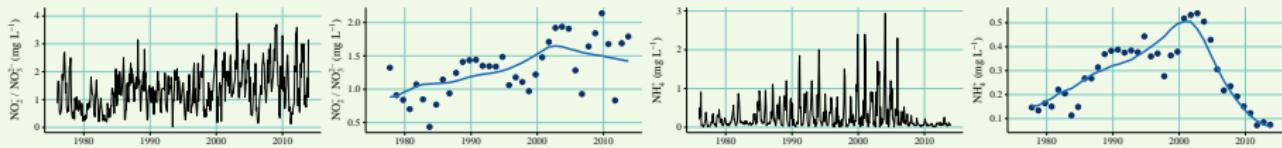


# Evaluation of Delta RMP nutrient data using weighted regression for trend analysis

Marcus W. Beck, PhD

USEPA National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, beck.marcus@epa.gov, Phone: 8509342480

August 30, 2017



# Evaluating Delta RMP data

***Today's talk:*** Evaluation of forty years of Delta RMP nutrient data with weighted regression

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Water quality trends in the Delta:

- ***Part 1:*** Model theory and application
- ***Part 2:*** Trends over time
- ***Part 3:*** Selected case studies

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Water quality trends in the Delta:

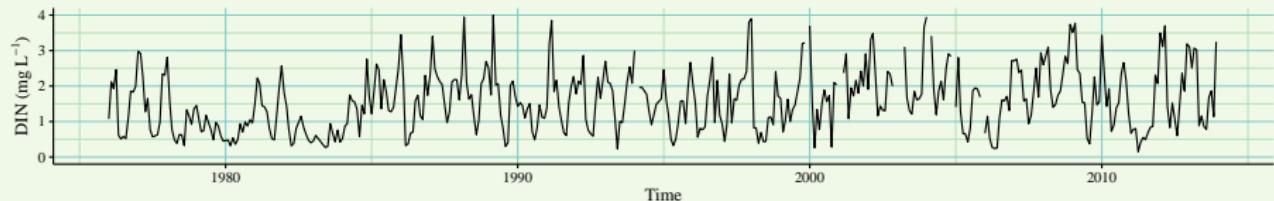
- ***Part 1:*** Model theory and application
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- ***Part 3:*** Selected case studies

Can we *develop* and *apply* methods that *link trends* with *causal events*?

# Model theory and background

WRTDS adaptation for tidal waters

**Observed data represents effects of many processes**



## Climate

precipitation  
temperature  
wind events  
ENSO effects

## Local

light/turbidity  
residence time  
invasive species  
trophic effects

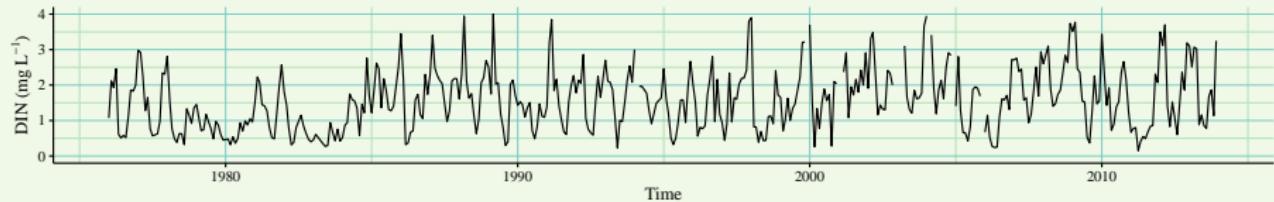
## Regional/historical

watershed inputs  
point sources  
management actions  
flow changes

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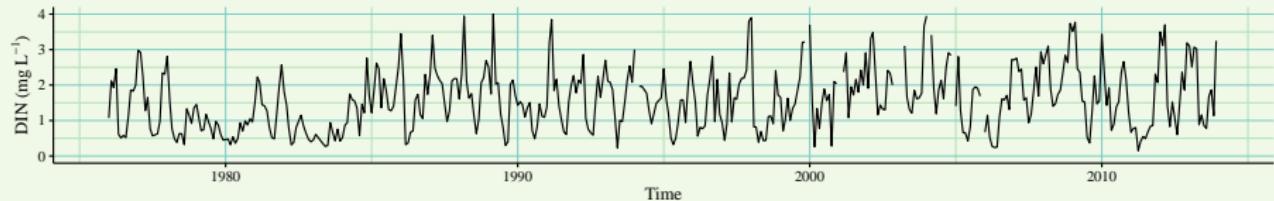


Models should describe components to evaluate effects

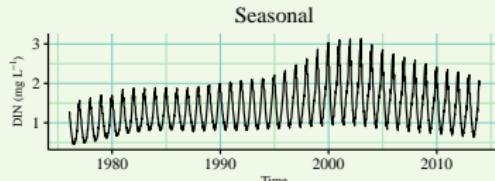
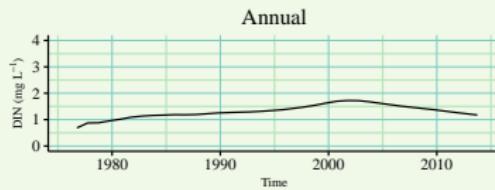
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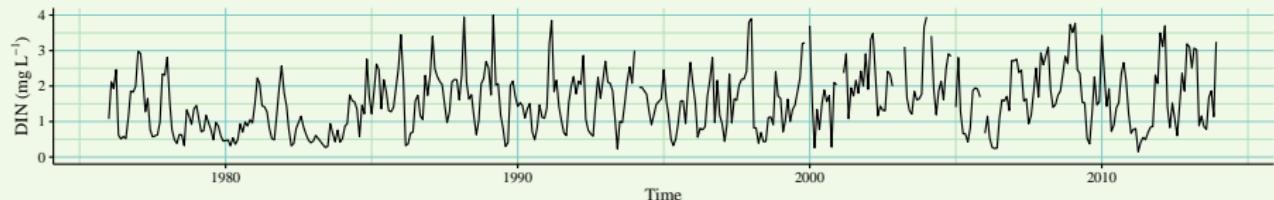
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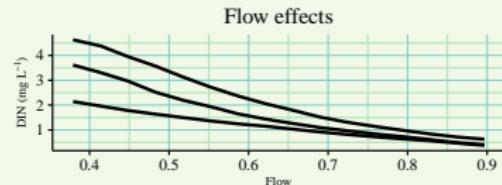
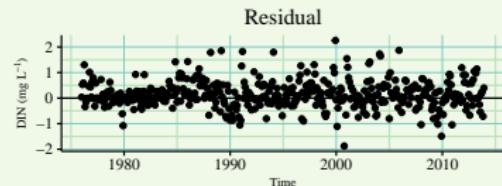
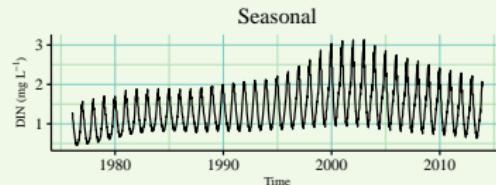
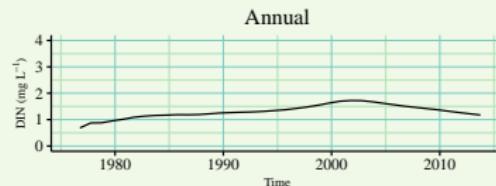
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# Model theory and background

## WRTDS adaptation for tidal waters

**Problem:** Response endpoints of eutrophication vary naturally over time and with discharge or tidal patterns

**Solution:** Develop a model that accounts for changes in relationships between drivers of pollution over time

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The ***weighted regression (WRTDS)*** approach models pollutants in rivers as a function of *time*, *discharge*, and *season*  
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**Adaptation:** Applied to Tampa Bay [Beck and Hagy III, 2015], further validated/compared in Patuxent Estuary  
[Beck and Murphy, 2017]

# Model theory and background

## WRTDS adaptation for tidal waters

How does weighted regression work?

$$\ln(N) = \beta_0 + \beta_1 t + \beta_2 Sal + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t)$$

$N$ : nitrogen (or other response endpoint)

$t$ : time

$Sal$ : Salinity (or other flow-related variable)

# Model theory and background

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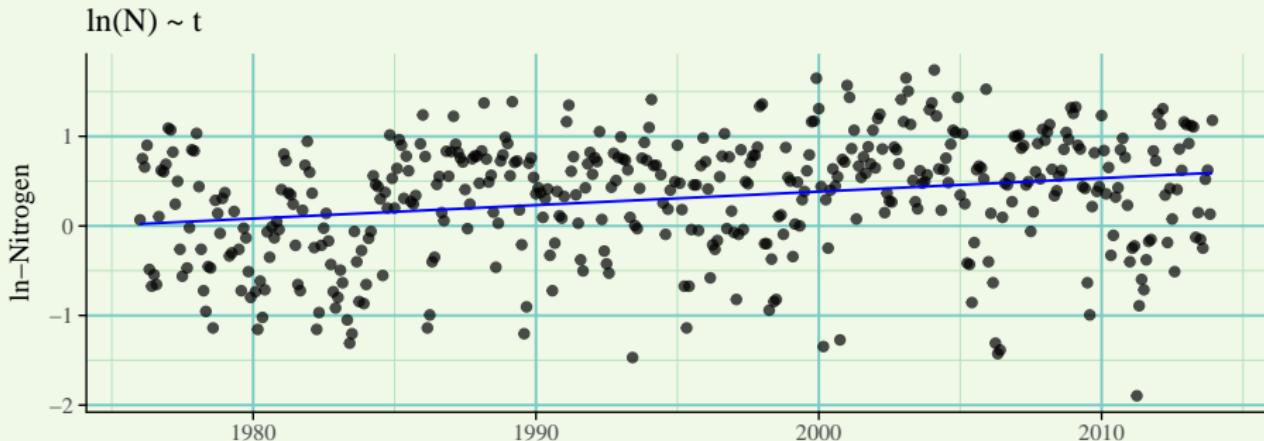
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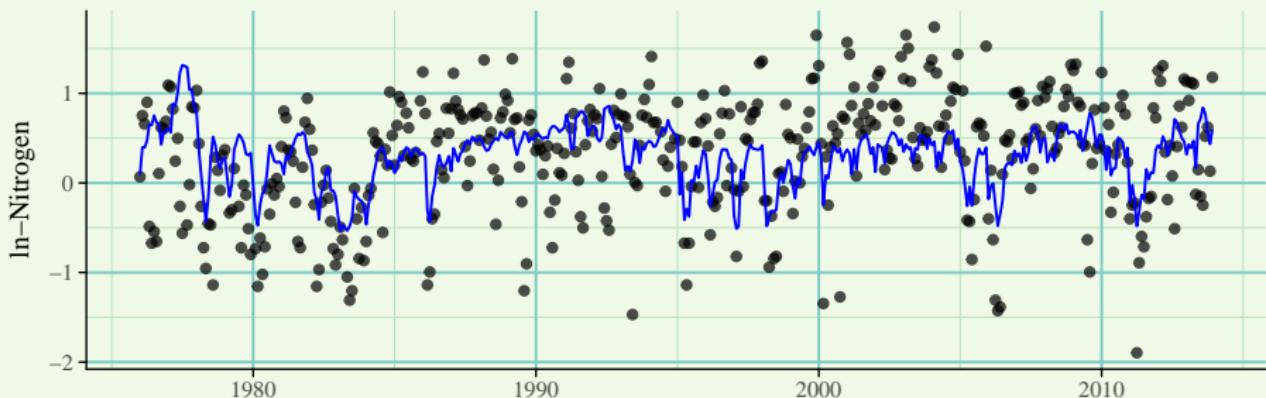
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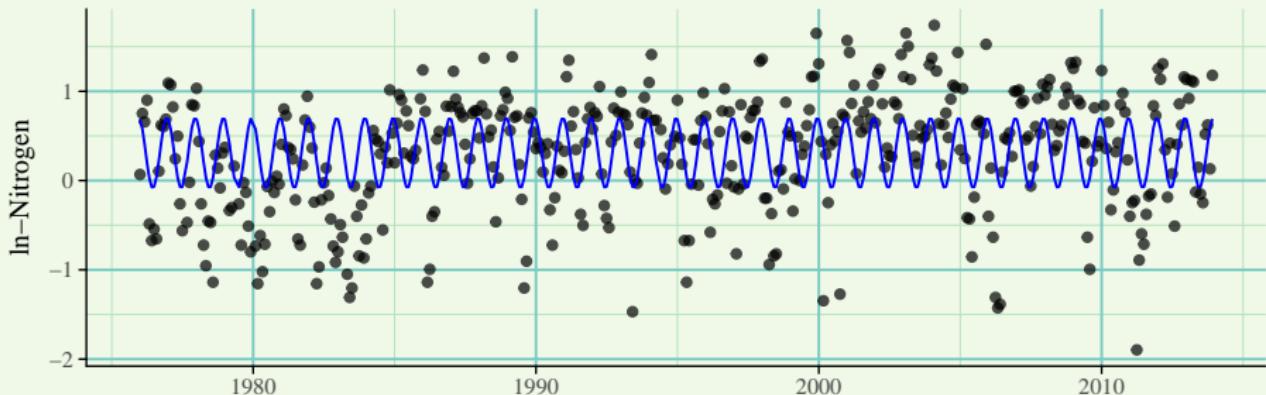
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$$\ln(N) \sim \cos(2\pi * t) + \sin(2\pi * t)$$



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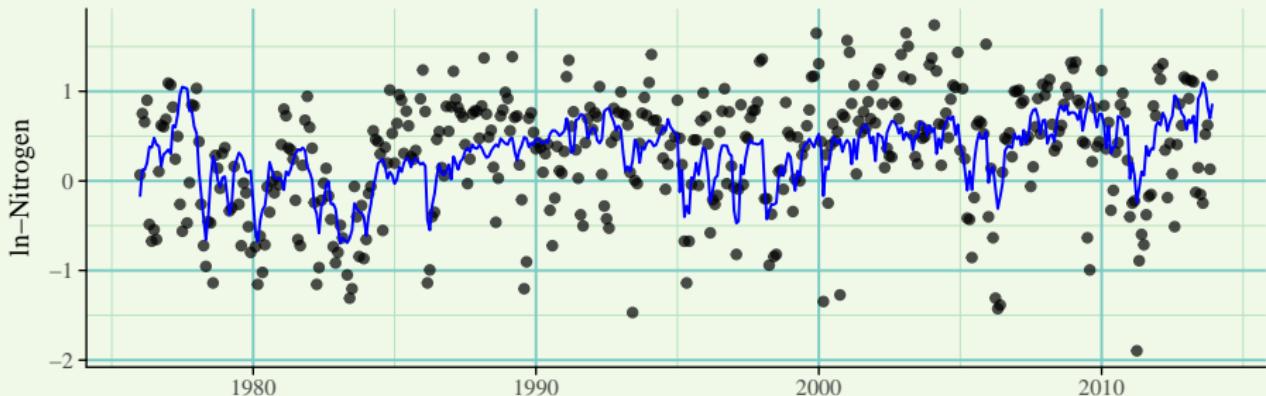
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$$\ln(N) \sim t + Sal$$



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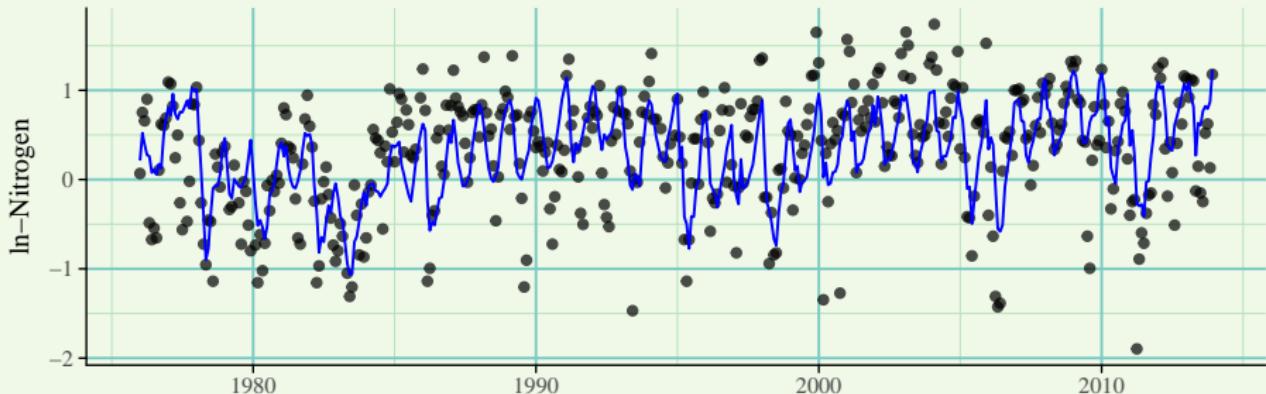
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$$\ln(N) \sim t + Sal + \cos(2\pi * t) + \sin(2\pi * t)$$



# Model theory and background

## WRTDS adaptation for tidal waters

How does weighted regression work?

# Model theory and background

## WRTDS adaptation for tidal waters

**Points:** observed time series (black are weighted, grey is zero weight)

**Green point:** observation at the center of the regression

**Blue line:** Global model with weights specific to the window

**Red line:** Accumulated WRTDS model

# Model theory and background

## WRTDS adaptation for tidal waters

### Application to Delta

- Nine stations (three Suisun, three middle, three delta)
- Three analytes (DIN, ammonium, nitrite/nitrate), two flow records
- Four decades of data, 1976-2013

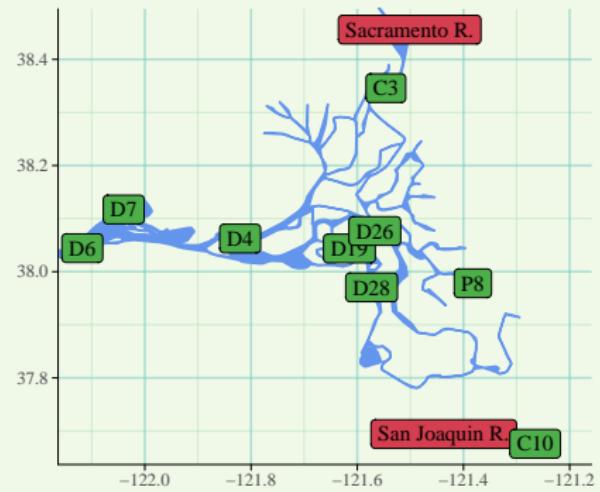


Figure : Stations (green) and flow estimates (red) modelled with WRTDS

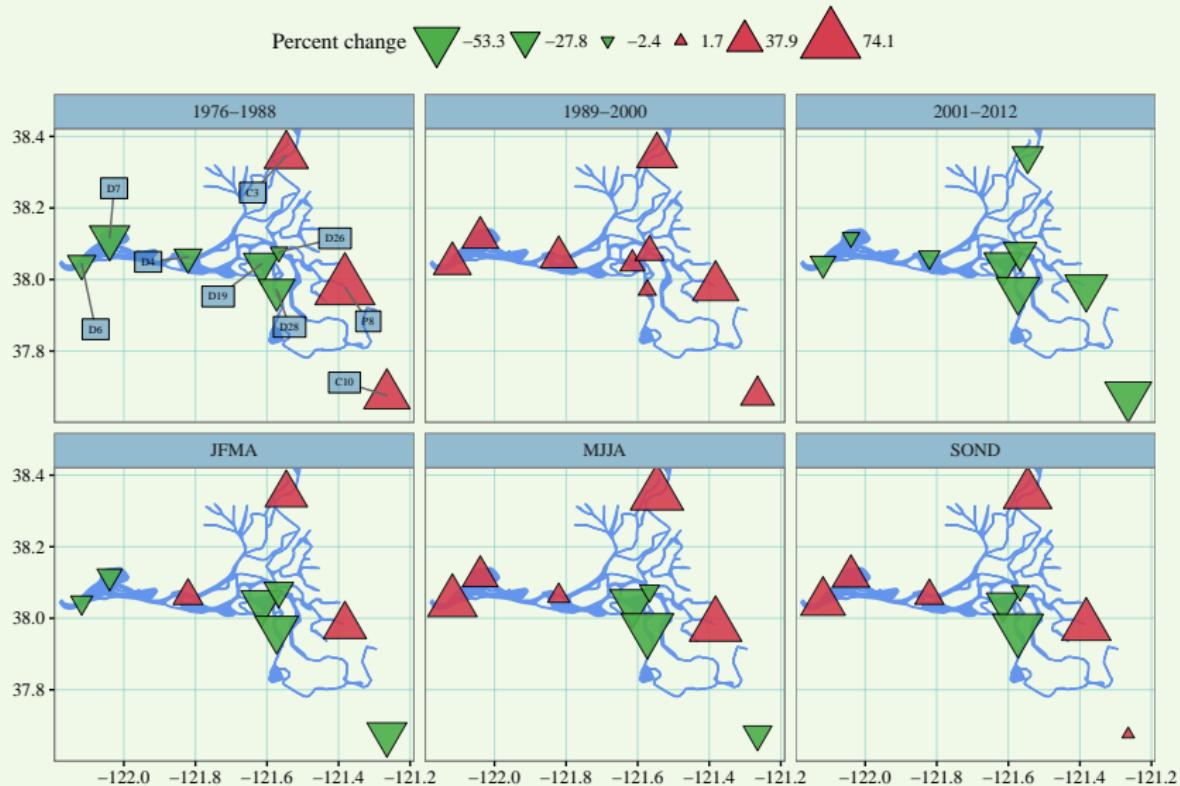
# Trends over time

## Nitrogen dynamics in the Delta

Predicted DIN trends, 1980-1990

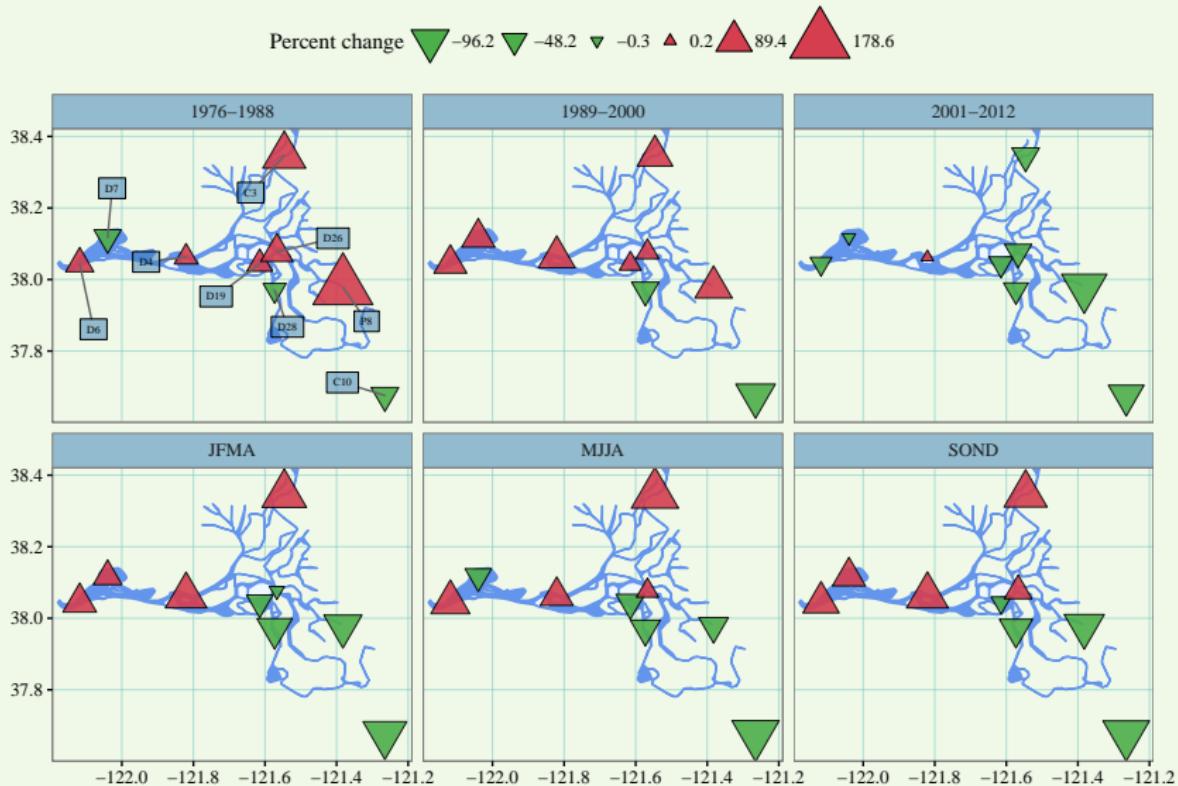
# Trends over time

## Nitrogen dynamics in the Delta - DIN



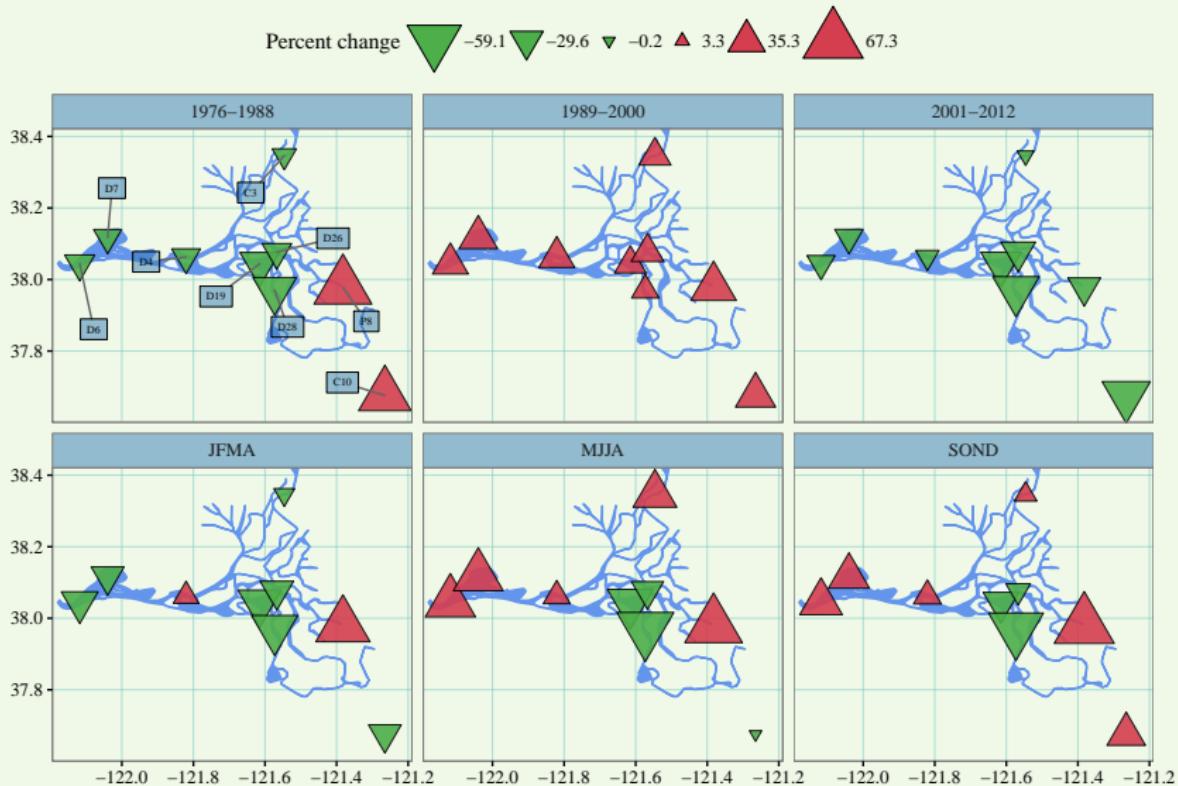
# Trends over time

## Nitrogen dynamics in the Delta - ammonium



# Trends over time

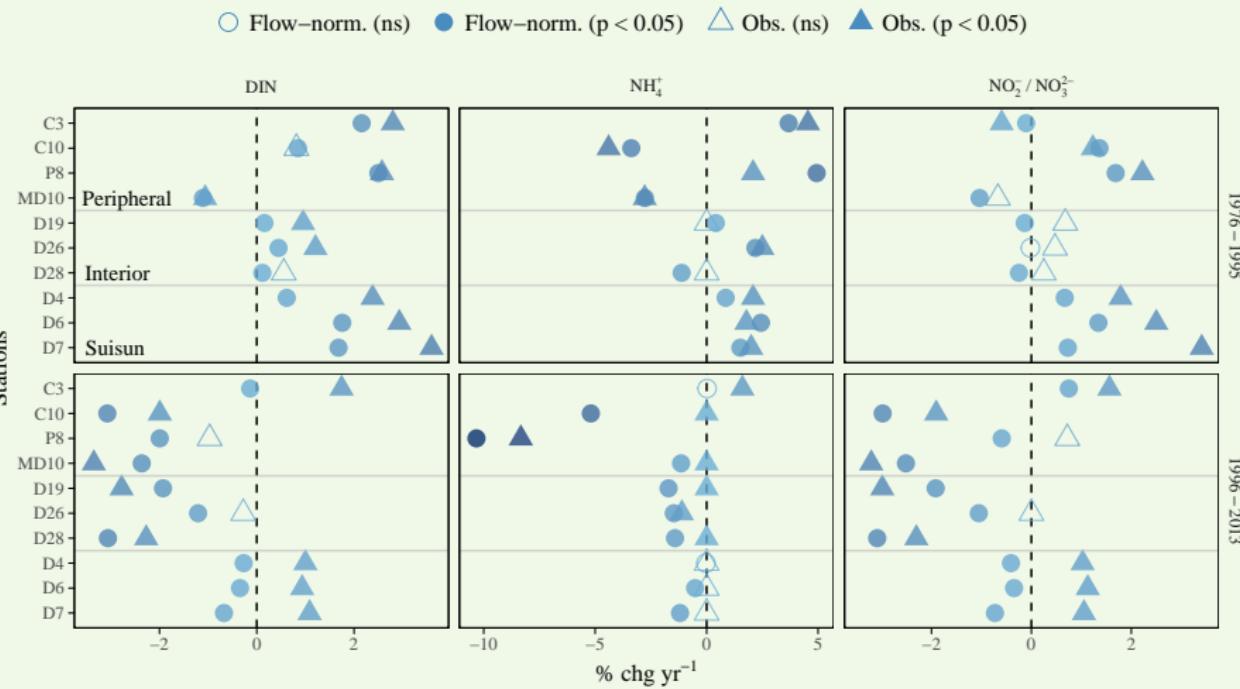
## Nitrogen dynamics in the Delta - nitrite/nitrate



# The ORISE experience

## Additional WRTDS applications

Better description of nutrient endpoints can change conclusions

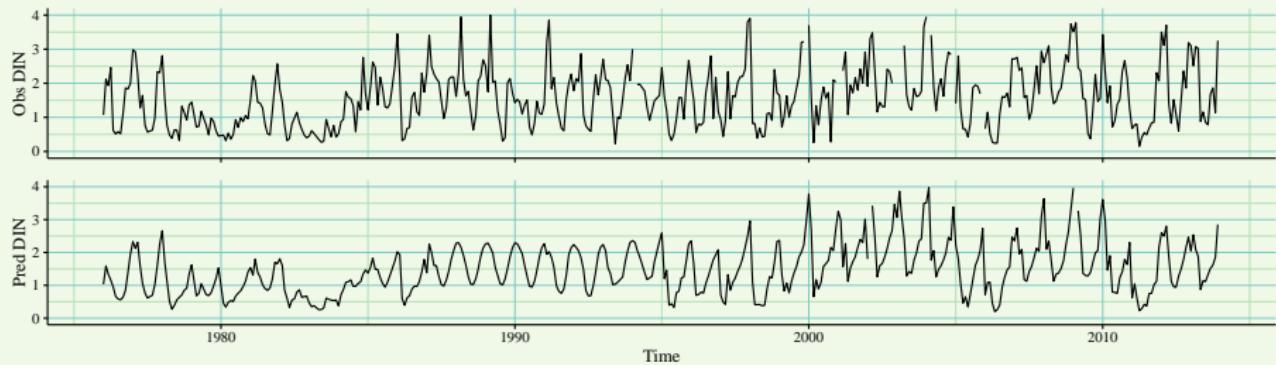


# Trends over time

## Nitrogen dynamics in the Delta - nitrite/nitrate

The **WRTDS** approach lets us model historical trends in relation to *time, discharge, and season*

Predicted trends follow observed... how can we leverage the results to better understand important processes?



## Selected case studies

Two examples demonstrate the utility of WRTDS adaptation to Delta RMP data:

- Effects of wastewater treatment at P8
- Effects of biological invasion in Suisun Bay

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Two examples demonstrate the utility of WRTDS adaptation to Delta RMP data:

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- Effects of biological invasion in Suisun Bay

Each shows how *model components* describe *processes*

Uses **WRTDStidal** package for R [Beck, 2017]:

<https://cran.rstudio.com/web/packages/WRTDStidal>

# Selected case studies

## Effects of wastewater treatment upgrades

How can model information be linked to causation?



Figure : Nitrogen concentration measurements ( $\text{mg L}^{-1}$ ) from the City of Stockton Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in 2006 for nitrification/denitrification and tertiary filtration to convert ammonium to nitrate.

# Selected case studies

## Effects of wastewater treatment upgrades

***Hypothesis:*** Response of nutrient concentrations at P8 is linked to upstream WWTP upgrades

We should be able to ***predict:***

- A flow-normalized annual trend concurrent with WWTP upgrades
- Variation in nitrogen species response depending on change in load outputs

# Selected case studies

## Effects of wastewater treatment upgrades

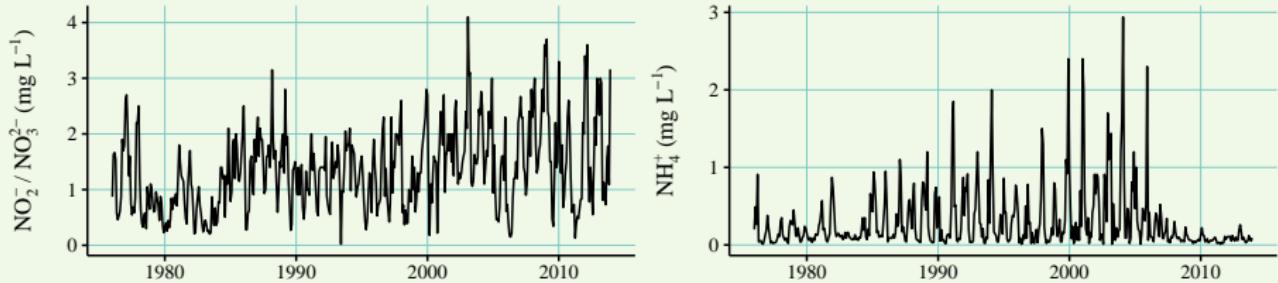


Figure : Observed nitrogen time series at P8

# Selected case studies

## Effects of wastewater treatment upgrades

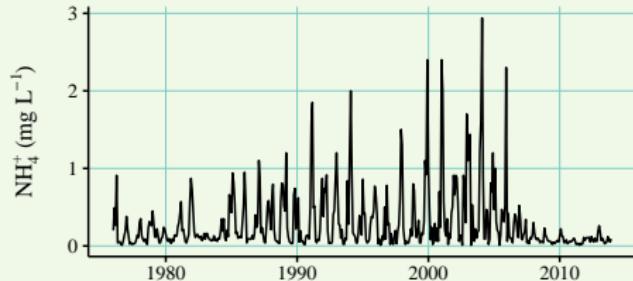
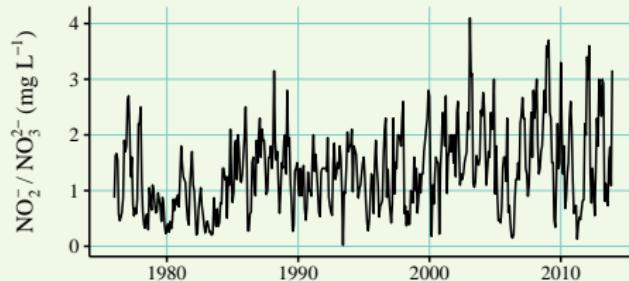


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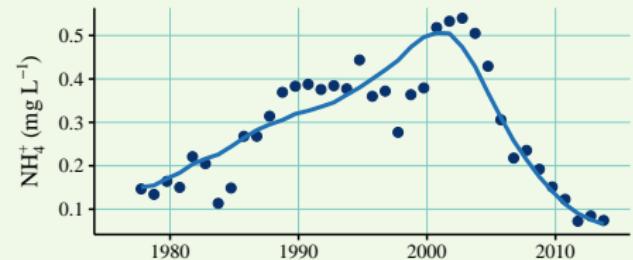
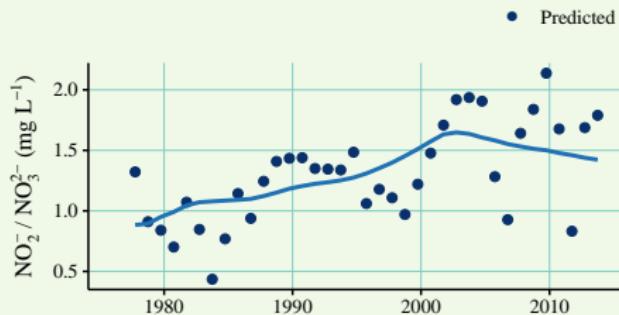


Figure : Annual predicted and flow-normalized nitrogen from WRTDS.

# Selected case studies

## Effects of wastewater treatment upgrades

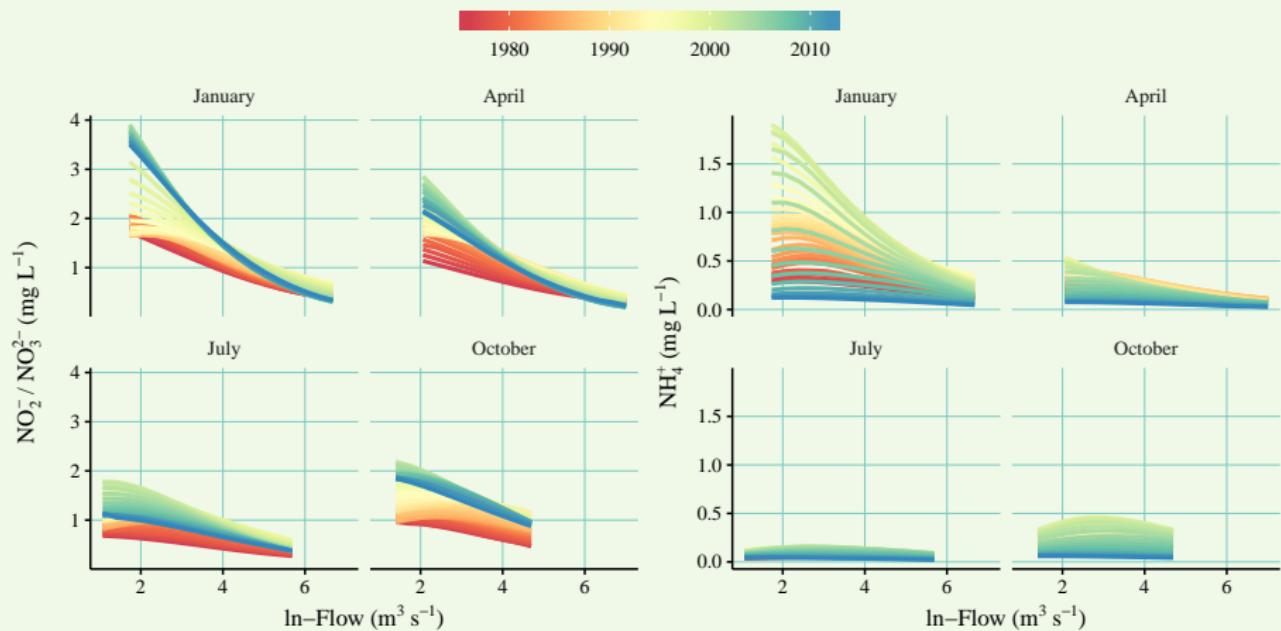


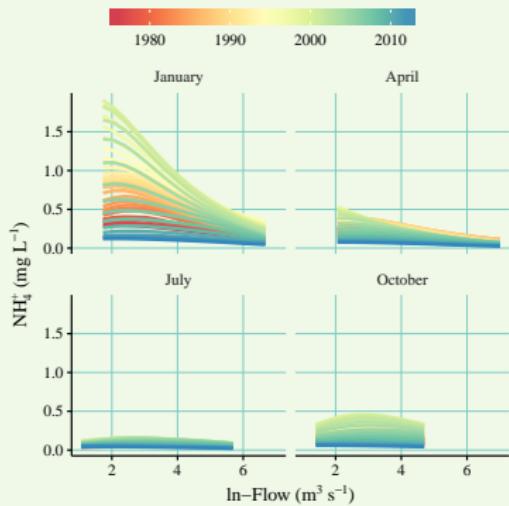
Figure : Nitrogen relationships with flow over time at P8.

# Selected case studies

## Effects of wastewater treatment upgrades

Results at P8 were linked to WWTP upgrades:

- Flow-normalized changes in ammonium, also nitrite/nitrate
- Ammonium reductions occurred in winter
- Largest response of ammonium at low flow... but not in summer



# Selected case studies

## Effects of biological invasion in Suisun Bay

**Hypothesis:** Biological invasions by benthic filter feeders have shifted abundance and composition of phytoplankton in Suisun Bay

We should be able to *predict*:

- A decline in annual, flow-normalized chlorophyll following increase in invaders
- Varying effects of flow given complex relationships between chlorophyll and invaders

# Selected case studies

## Effects of biological invasion in Suisun Bay

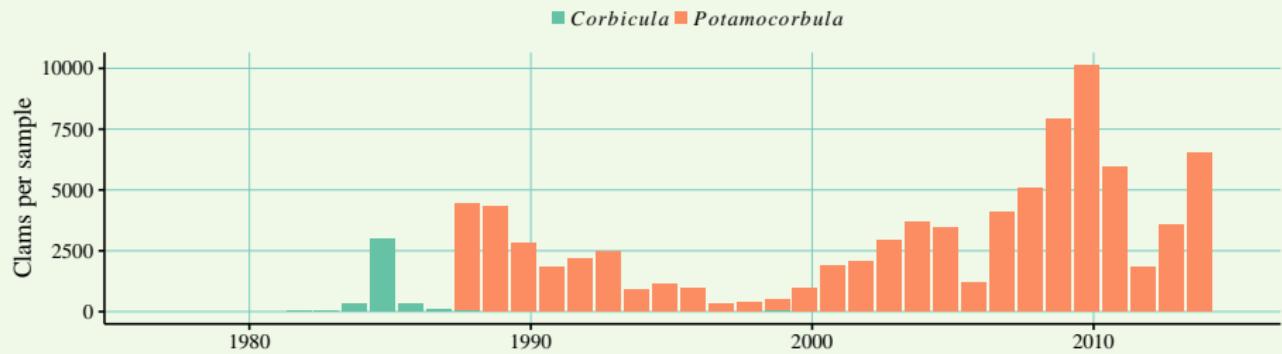


Figure : Clam density by year at D7, Suisun Bay [Crauder et al., 2016].

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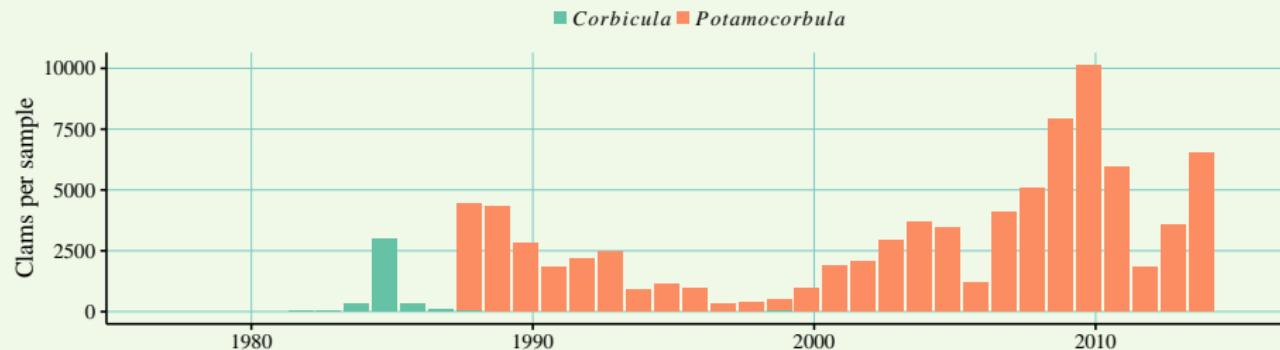


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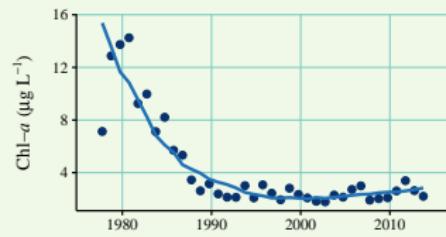


Figure : Annual predicted (points) and flow-normalized (lines) water quality data at D7.

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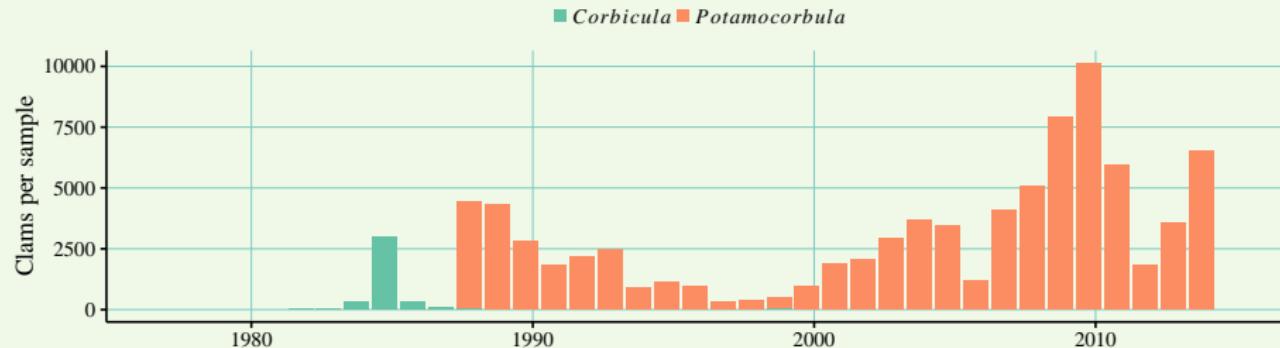


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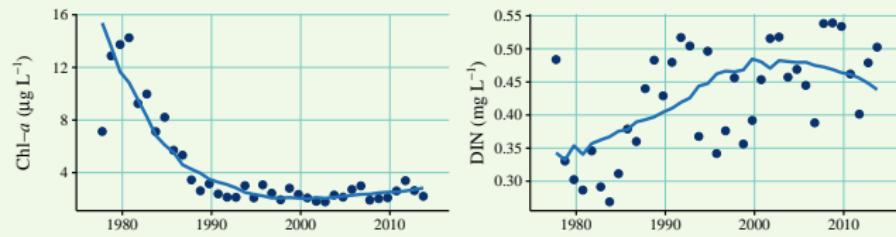


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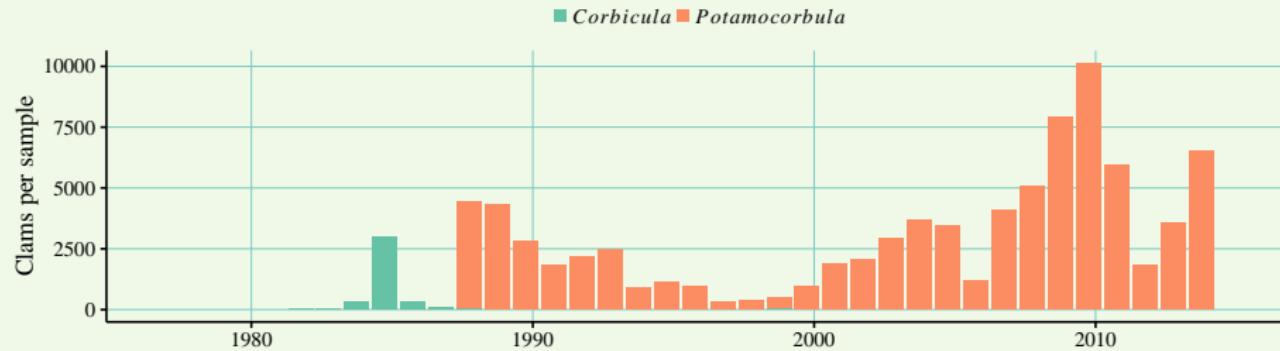


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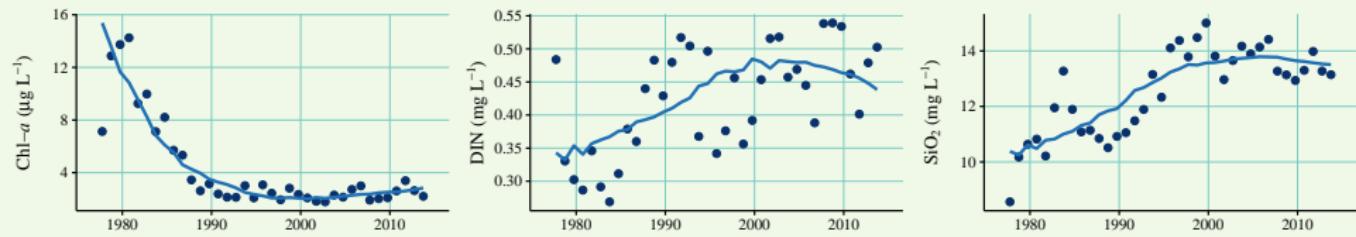
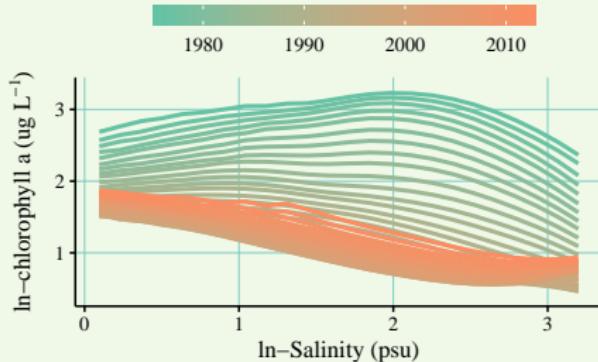


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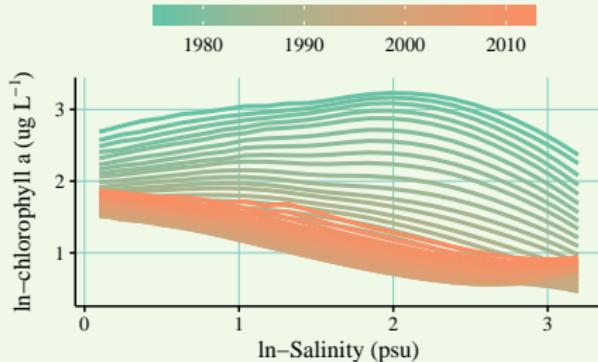
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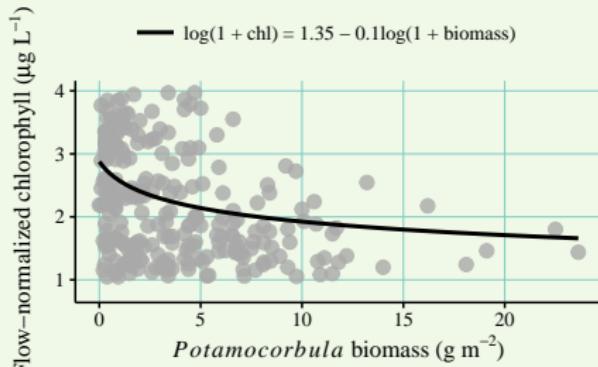
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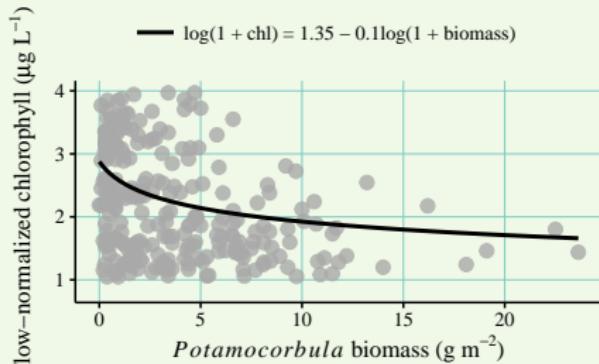
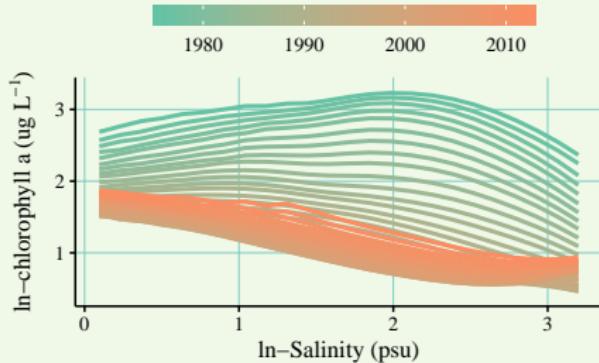


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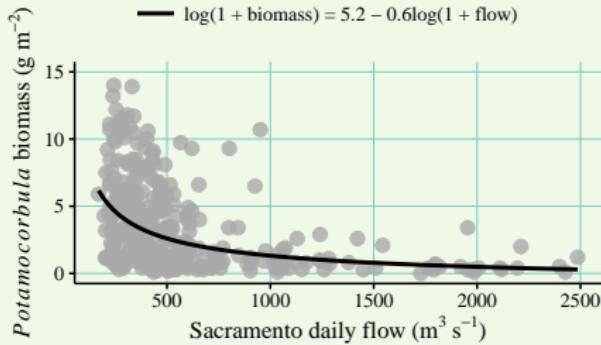


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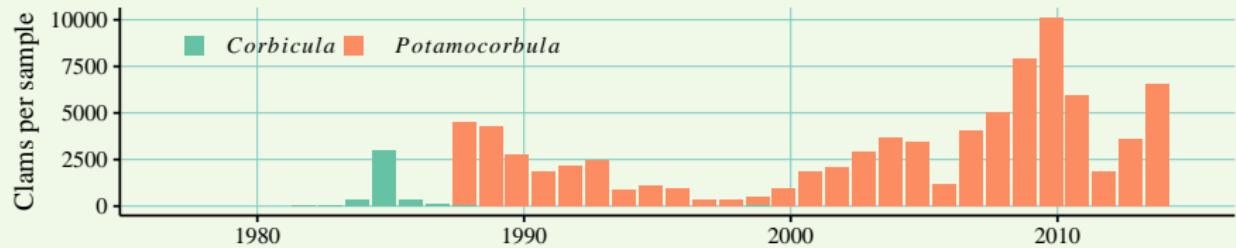


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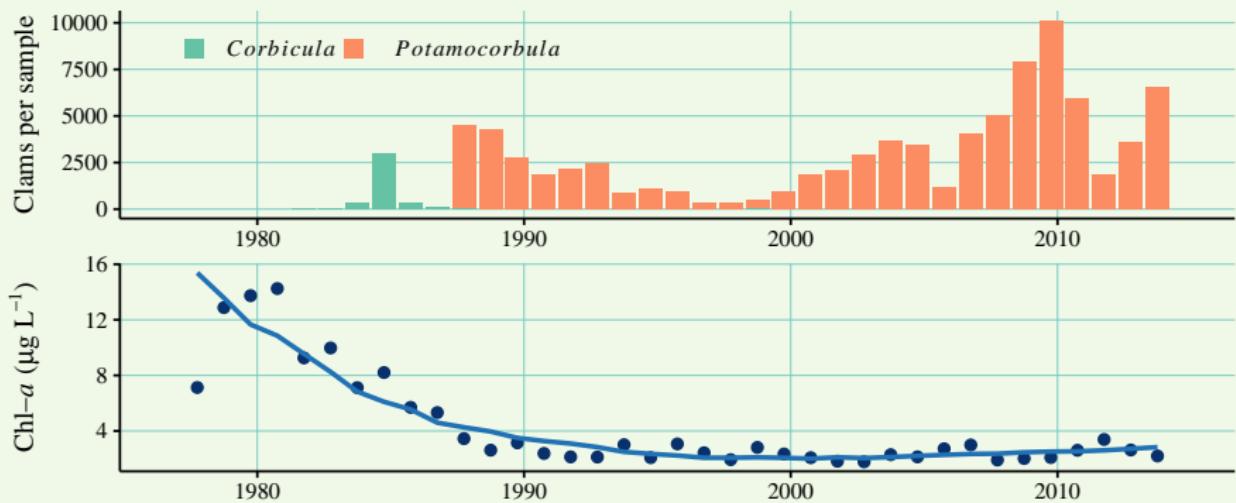
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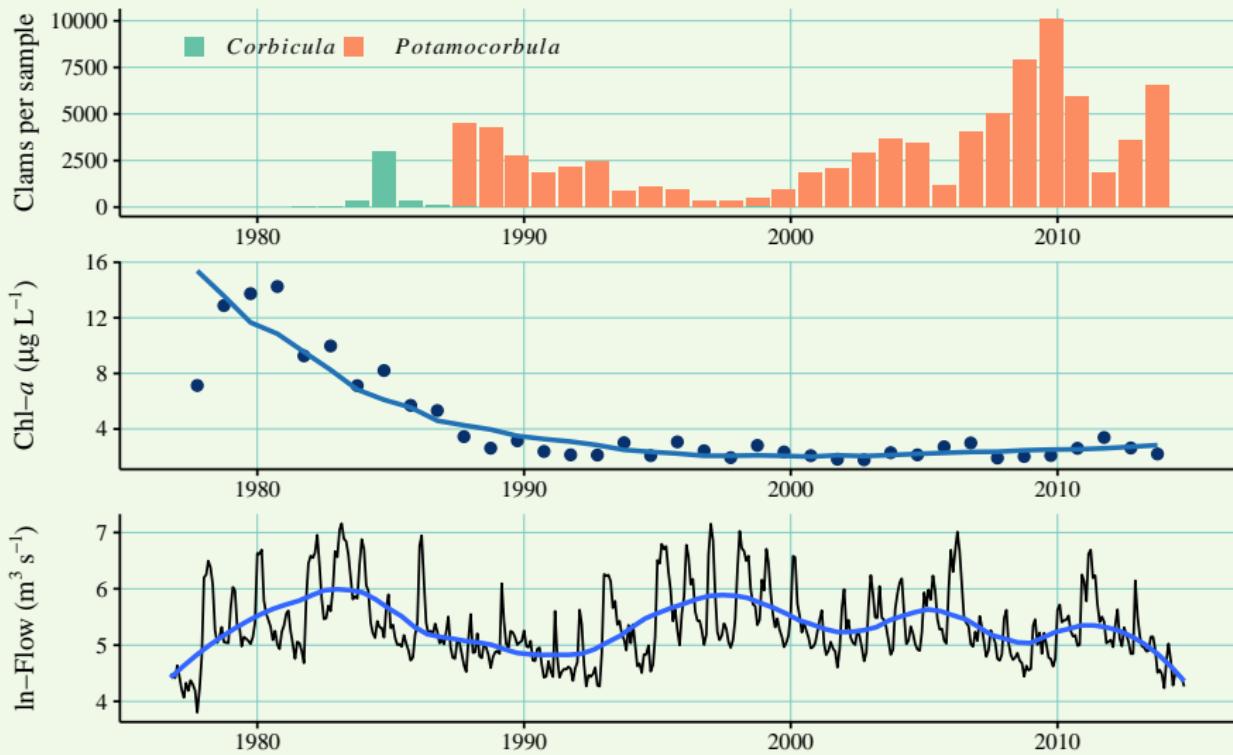
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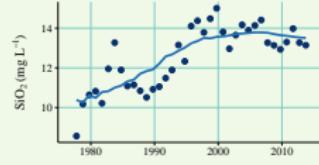
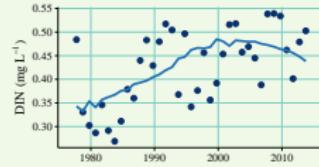
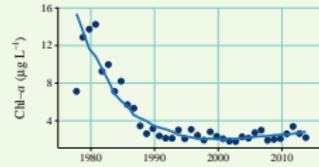


# Selected case studies

## Effects of biological invasion in Suisun Bay

Results at D7 show complex response of chlorophyll:

- Increase in clam abundance, decrease in chlorophyll
- Increase in DIN... but also increase in SiO<sub>2</sub>

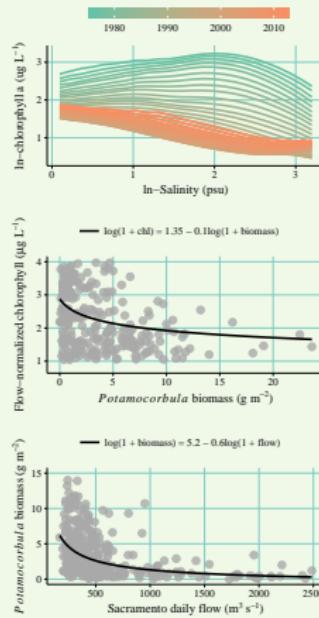


# Selected case studies

## Effects of biological invasion in Suisun Bay

Results at D7 show complex response of chlorophyll:

- Increase in clam abundance, decrease in chlorophyll
- Increase in DIN... but also increase in SiO<sub>2</sub>
- Relationship with flow changed depending on physical or biological forcing



# Conclusions

## Lessons for monitoring and future work

Monitoring data are not particularly telling...

...so we use models or other methods to *decompose* the observations

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Chosen method depends on the question: WRTDS because water quality varies with time, season, and flow

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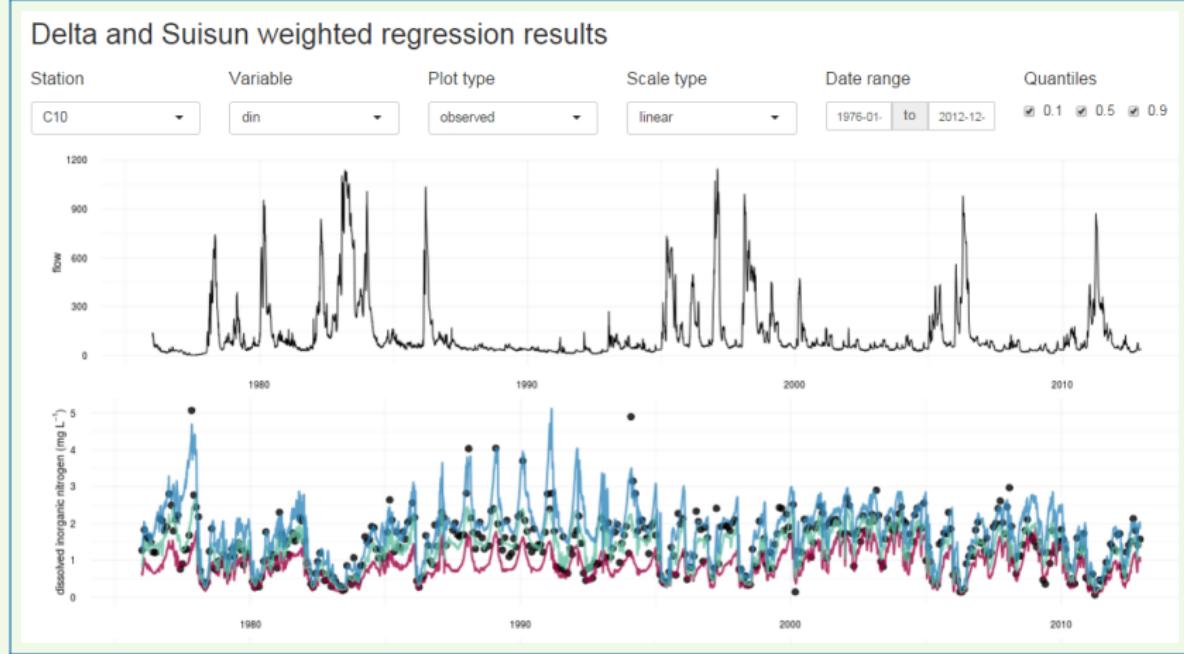
Chosen method depends on the question: WRTDS because water quality varies with time, season, and flow

- More complete description of trends
- Better link to causal events
- More comprehensive evaluation of site-specific issues
- Deconstruct the past to predict the future

# Conclusions

Lessons for monitoring and future work

Shiny app: [https://beckmw.shinyapps.io/sf\\_trends/](https://beckmw.shinyapps.io/sf_trends/)



## Acknowledgments and contact info:

Research staff and employees at USEPA Gulf Ecology Division, San Francisco Estuary Institute

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Phone (SCCWWRP):  
7147553217

## Links:

This presentation: [https://github.com/fawda123/sfei\\_pres](https://github.com/fawda123/sfei_pres)

Shiny app: [https://beckmw.shinyapps.io/sf\\_trends/](https://beckmw.shinyapps.io/sf_trends/)

Detailed results: [http://fawda123.github.io/sf\\_trends/README](http://fawda123.github.io/sf_trends/README)

Draft manuscript: [http://fawda123.github.io/sftrends\\_manu](http://fawda123.github.io/sftrends_manu)

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