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

Marcus W. Beck, PhD

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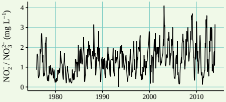
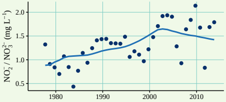
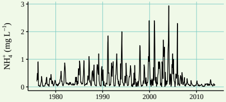
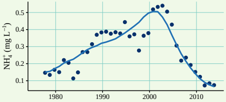
August 30, 2017









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:

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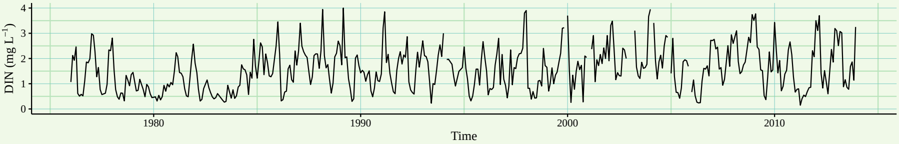
Can we ***develop*** and ***apply*** methods that ***link trends*** with ***causal events***?

Observed data represents effects of many processes



Climate	***Local***	***Regional/historical***
precipitation	light/turbidity	watershed inputs
temperature	residence time	point sources
wind events	invasive species	management actions
ENSO effects	trophic effects	flow changes

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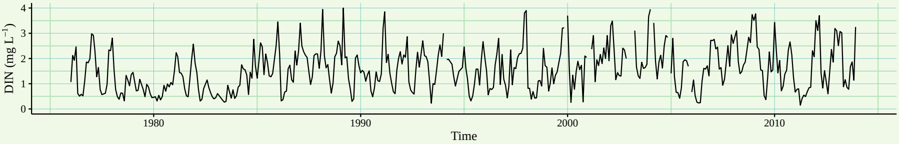

Models should describe components to evaluate effects

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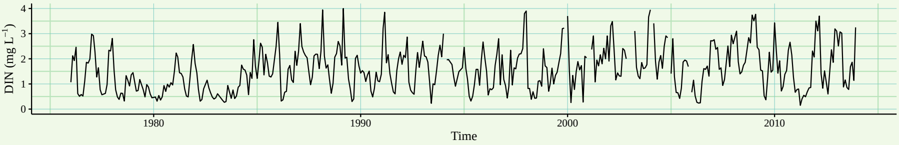

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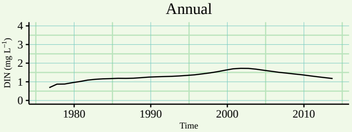

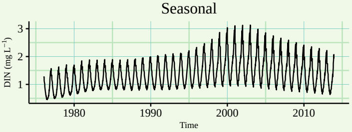

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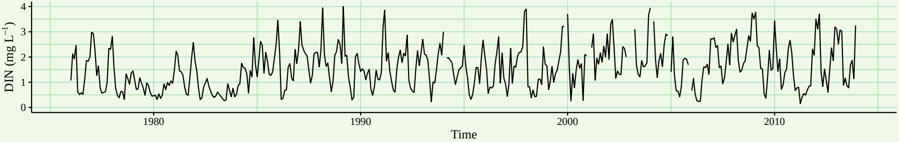

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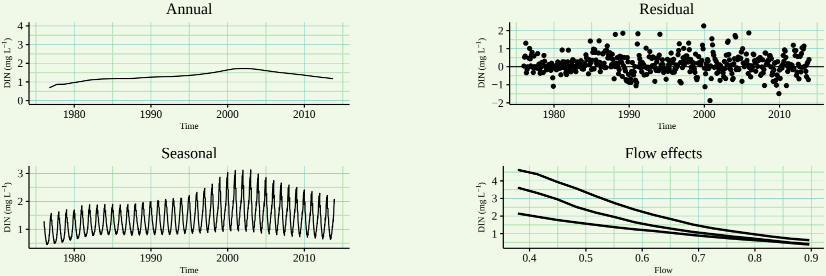

Model theory and background

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*** [Hirsch et al., 2010]

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Adaptation: Applied to Tampa Bay [Beck and Hagy III, 2015], further validated/compared in Patuxent Estuary [Beck and Murphy, 2017]

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)

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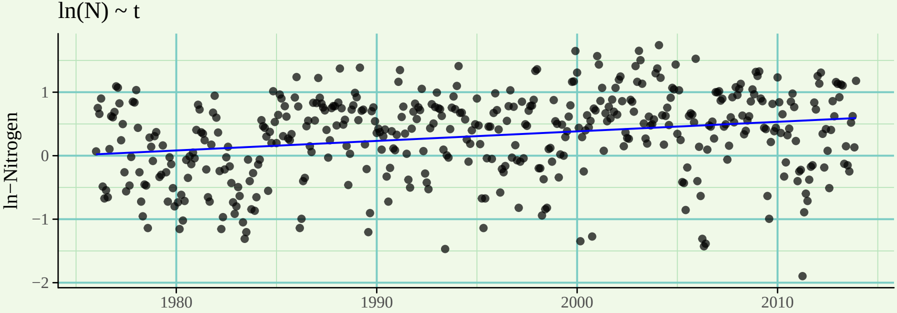

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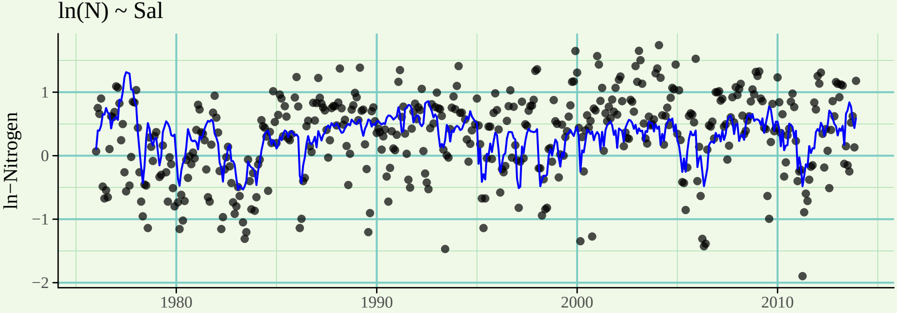

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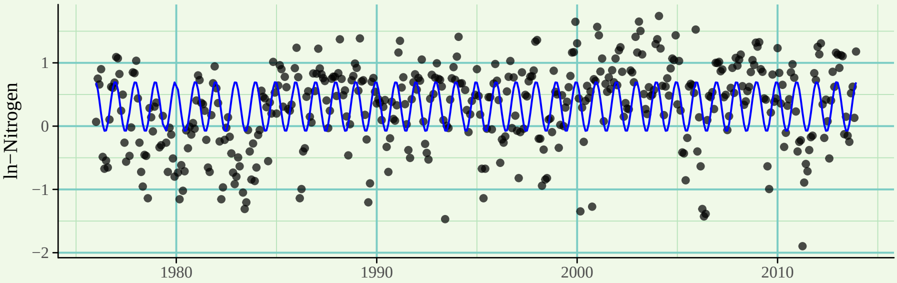
ln(N) ~ cos(2pi * t) + sin(2pi * t)



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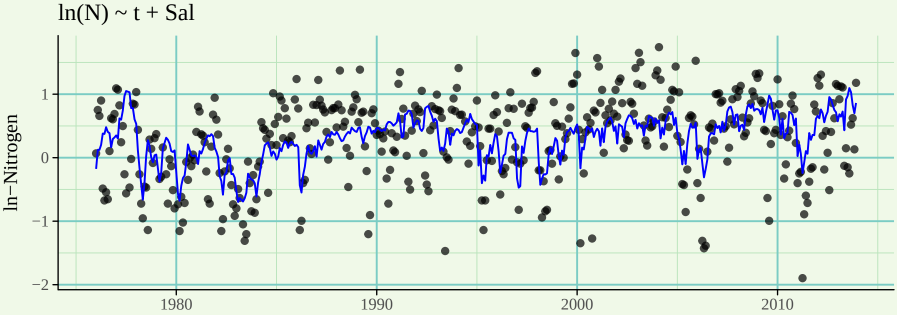

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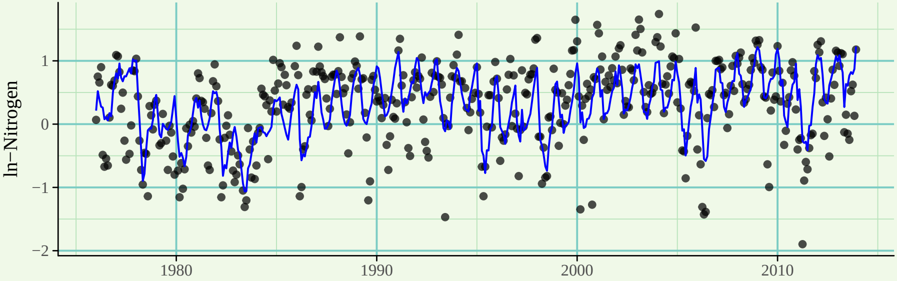
ln(N) ~ t + Sal + cos(2pi * t) + sin(2pi * t)



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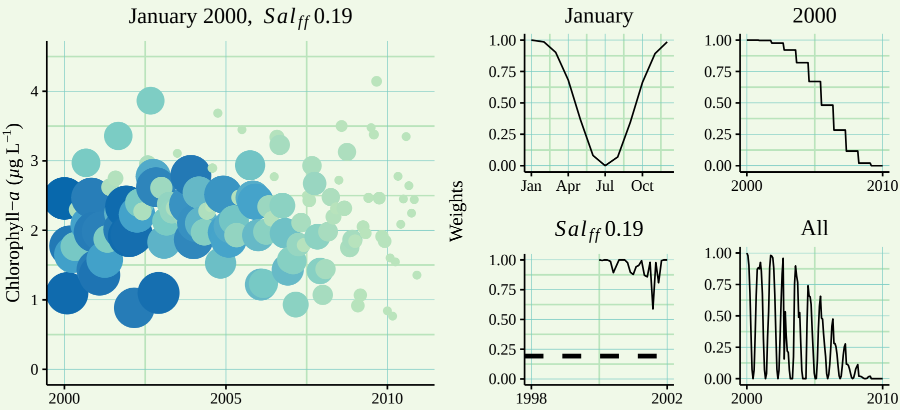
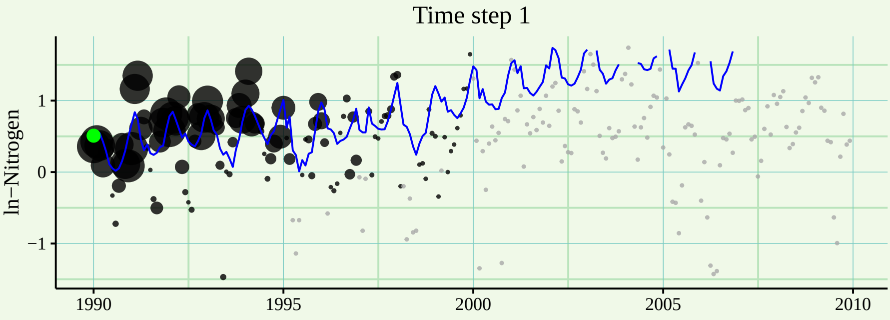


Points: observed time series (black are weighted, grey is zero weight)
Green point: observation at the center of the regression
Blue line: Global model with weights specific to the window
Red line: Accumulated WRTDS model



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

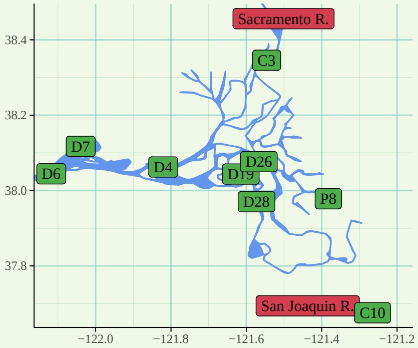
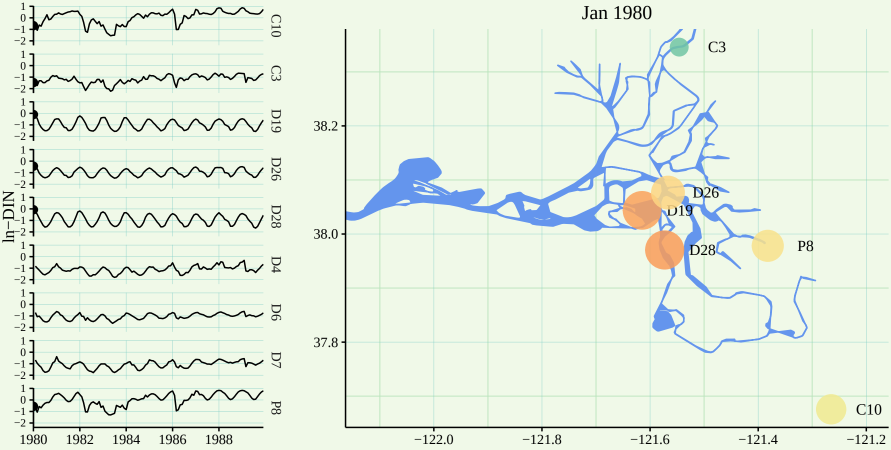


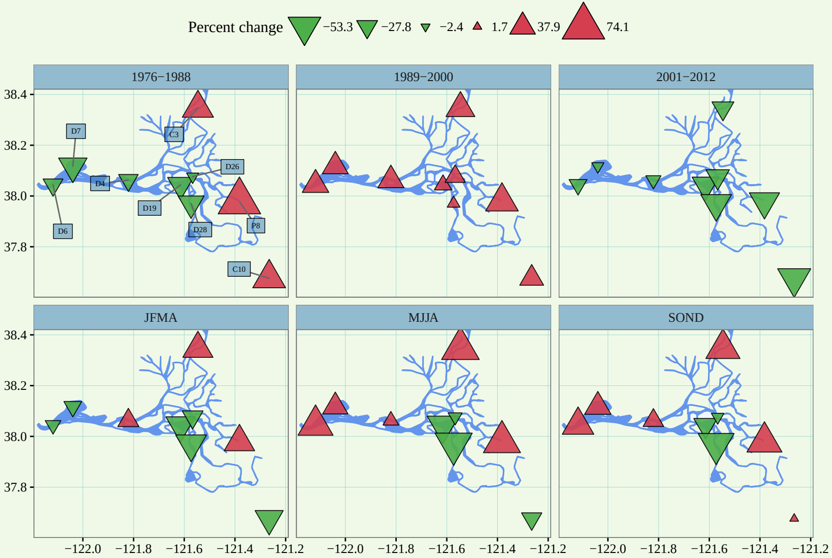
Figure : Stations (green) and flow estimates (red) modelled with WRTDS

Predicted DIN trends, 1980-1990



Trends over time

Nitrogen dynamics in the Delta - DIN



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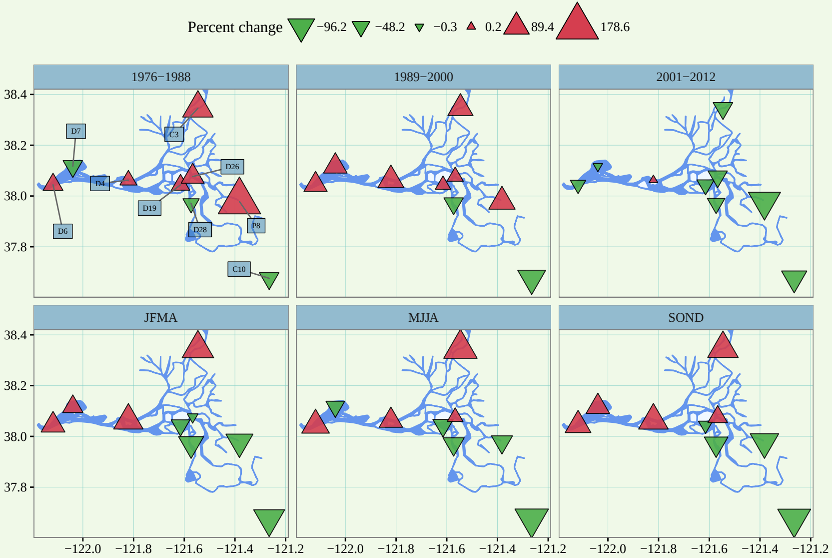
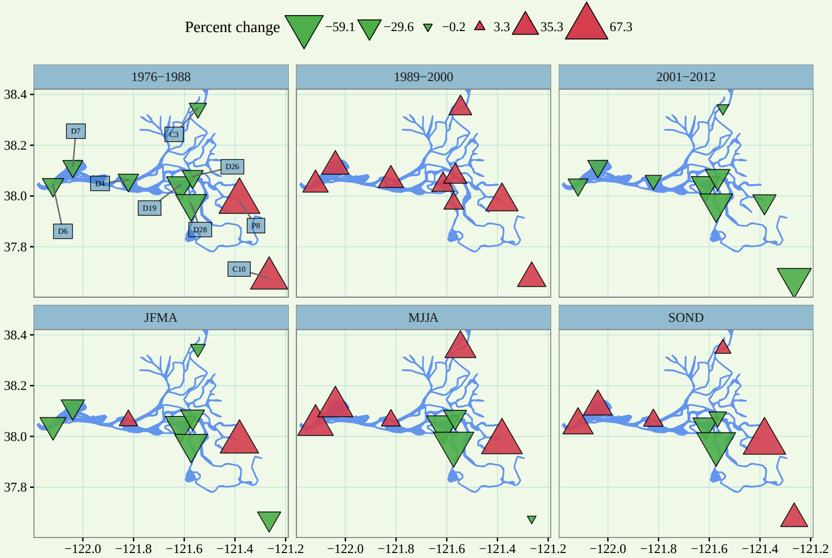
Nitrogen dynamics in the Delta - ammonium

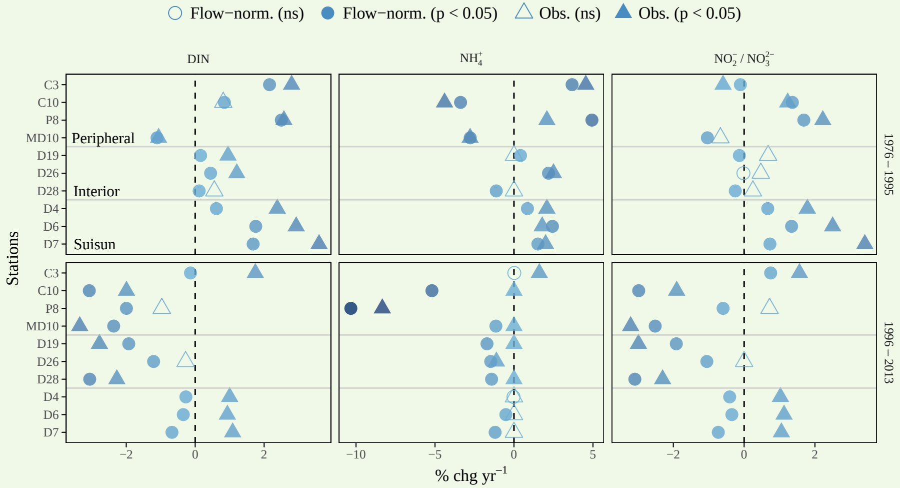


Trends over time

Nitrogen dynamics in the Delta - nitrite/nitate



Better description of nutrient endpoints can change conclusions

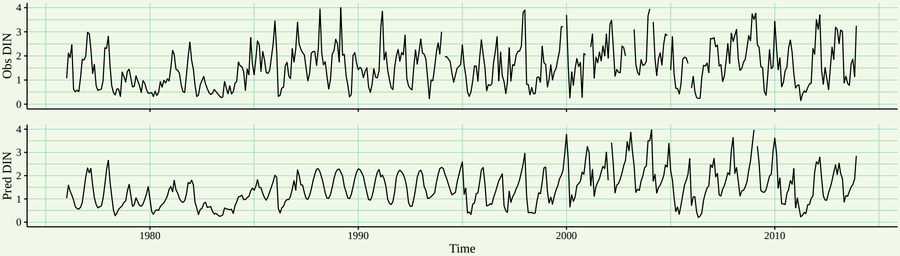


Trends over time

Nitrogen dynamics in the Delta - nitrite/nitate

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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Each shows how ***model components*** describe ***processes***

Uses ***WRTDStidal*** package for R [Beck, 2017]:
`https://cran.rstudio.com/web/packages/WRTDStidal`

How can model information be linked to causation?

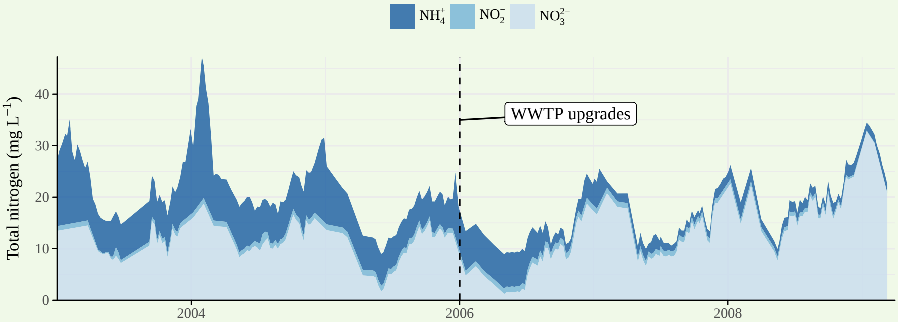

Figure : Nitrogen concentration measurements (mg L^{-1}) from the City of Stockton Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in 2006 for nitrification/denitrification and tertiary filtration to convert ammonium to nitrate.

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

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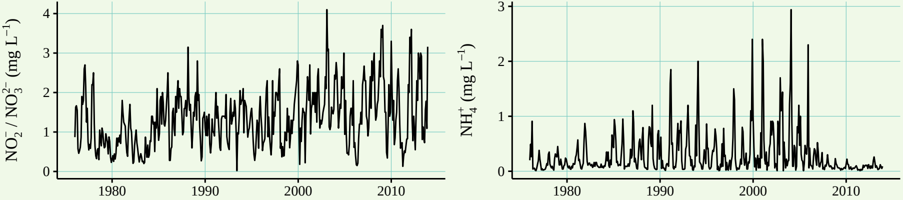

Figure : Observed nitrogen time series at P8

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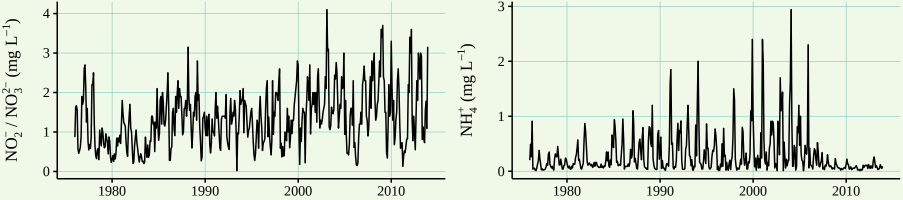

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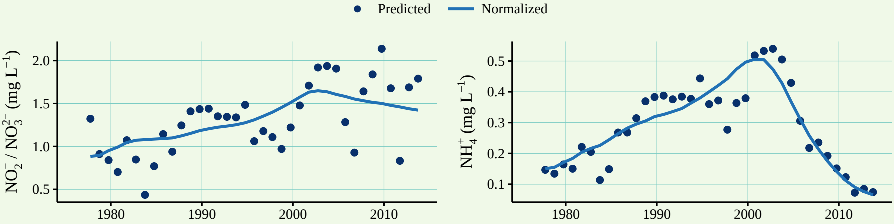

Figure : Annual predicted and flow-normalized nitrogen from WRTDS.

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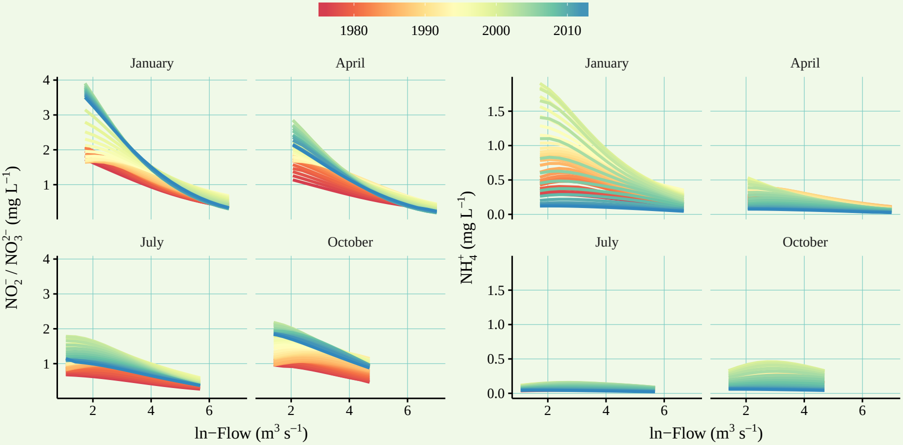
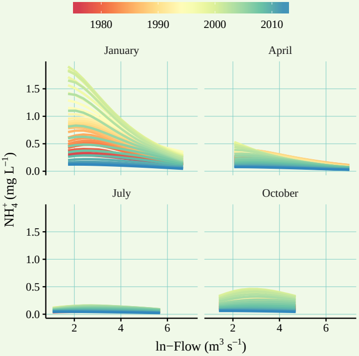


Figure : Nitrogen relationships with flow over time at P8.

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

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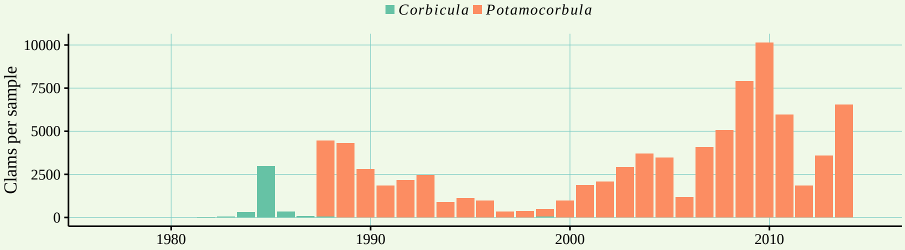

Figure : Clam density by year at D7, Suisun Bay [Crauder et al., 2016].

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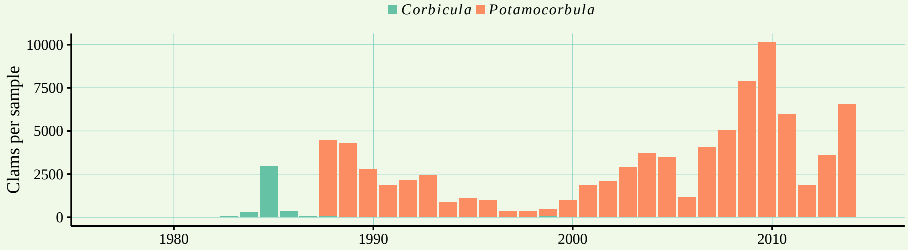

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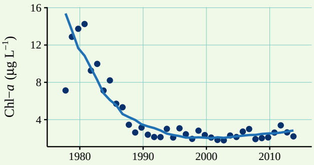
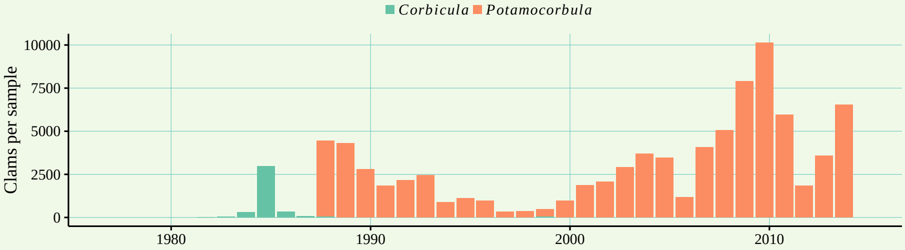


Figure : Annual predicted (points) and flow-normalized (lines) water quality data at D7.



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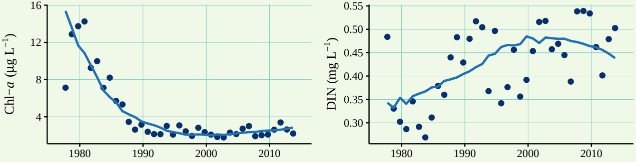

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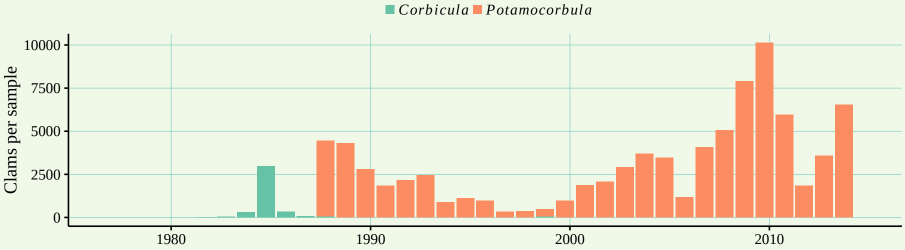

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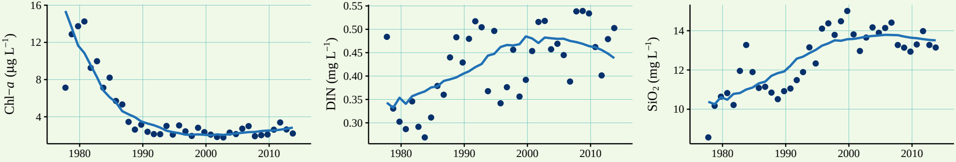

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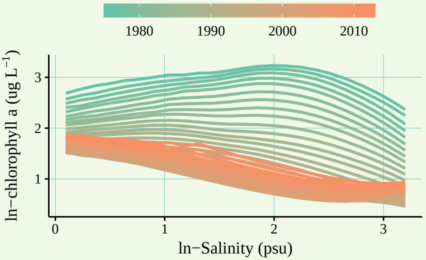

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- Later: Flow-stimulation

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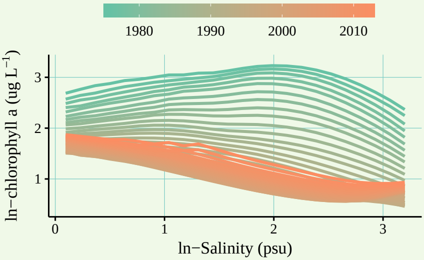

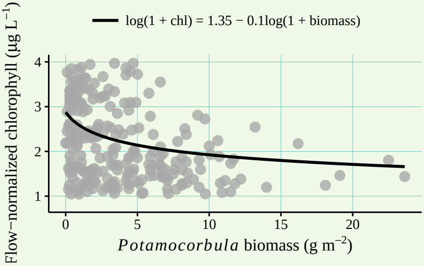

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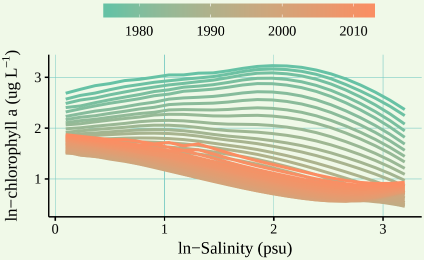

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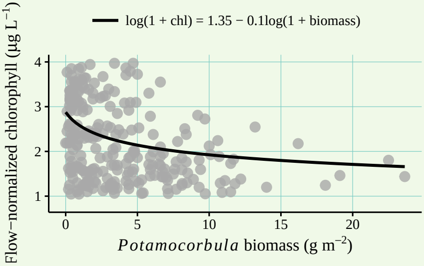

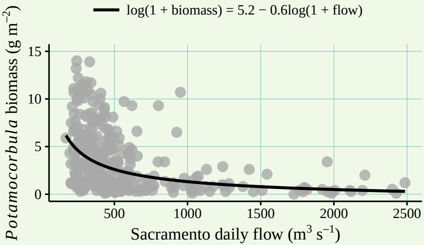

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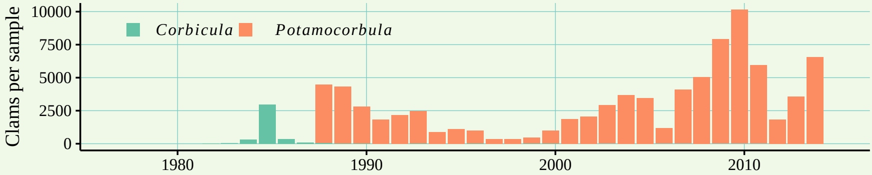

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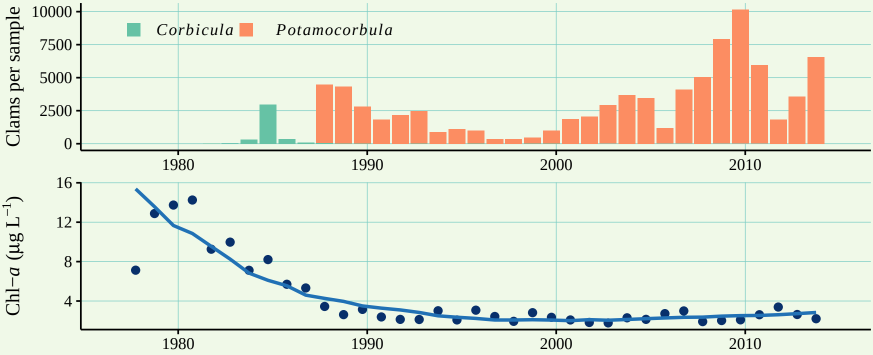

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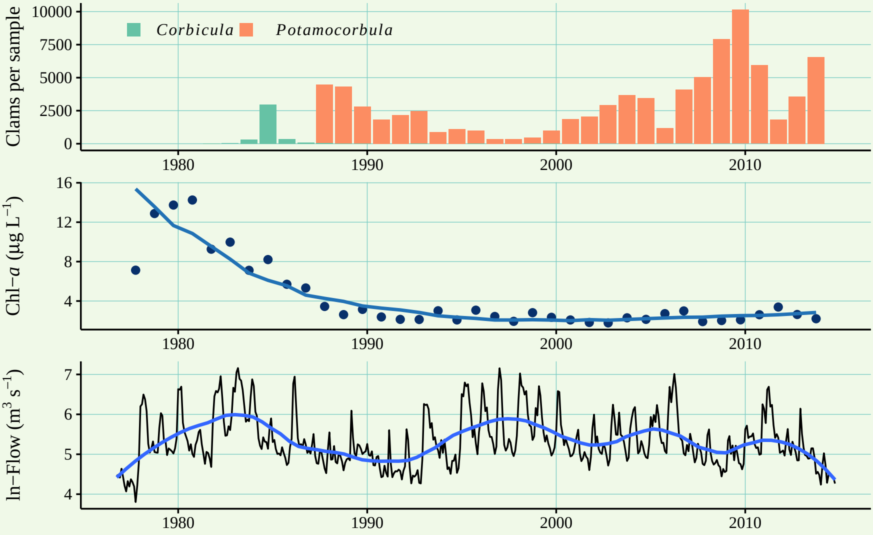

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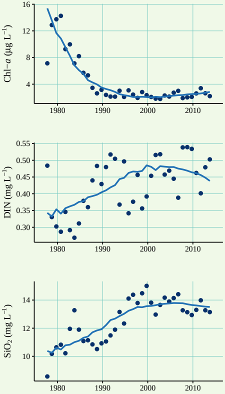

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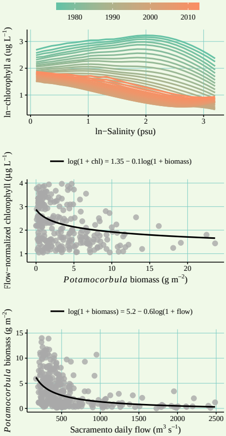
- Increase in DIN... but also increase in SiO_2
- Relationship with flow changed depending on physical or biological forcing



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

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WRTDStidal package for R, active development
`https://github.com/fawda123/WRTDStidal`

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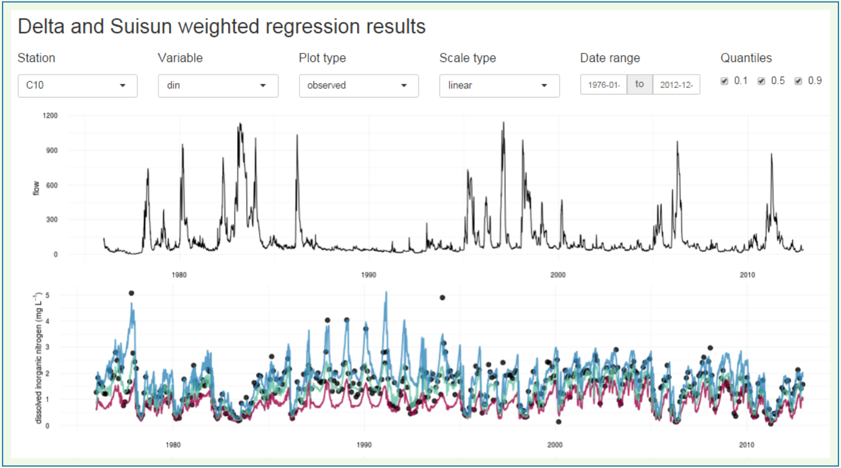
Shiny app: `https://beckmw.shinyapps.io/sf_trends/`



Acknowledgments and contact info:

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Links:

This presentation: `https://github.com/fawda123/sfei_pres`
Shiny app: `https://beckmw.shinyapps.io/sf_trends/`
Detailed results: `http://fawda123.github.io/sf_trends/README`
Draft manuscript: `http://fawda123.github.io/sftrends_manu`

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