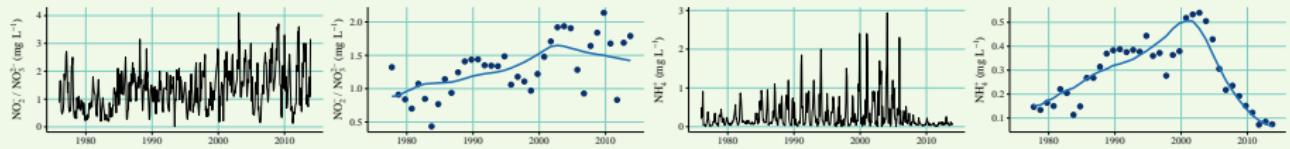


Quantitative approaches to understanding nitrogen pollution: Examples from the upper San Francisco Estuary

Marcus W. Beck, PhD

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

Aug. 26, 2016



Evaluating estuarine condition

How do we collect and use data?

How can we leverage monitoring data to develop our conceptual model of eutrophication?

Eutrophication (noun) - an increase in the rate of supply of organic matter to an ecosystem

– [Nixon, 1995]

Adapted from [Cloern, 2001]

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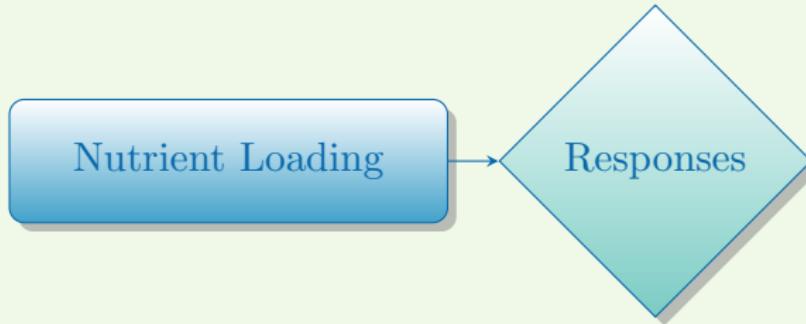
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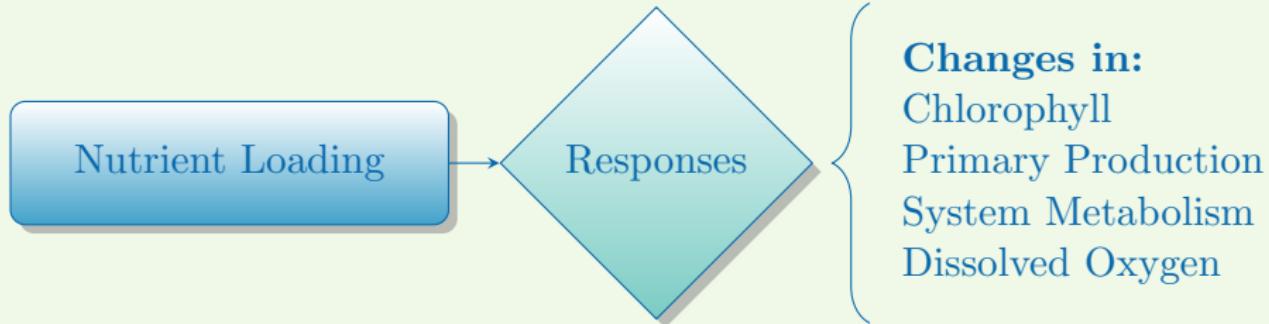
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Water quality trends in the Delta:

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

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Water quality trends in the Delta:

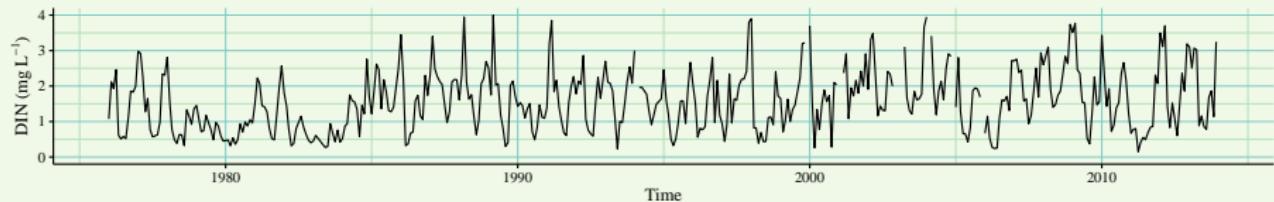
- ***Example 1:*** Model theory and application
- ***Example 2:*** Trends over time
- ***Example 3:*** Selected case studies

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

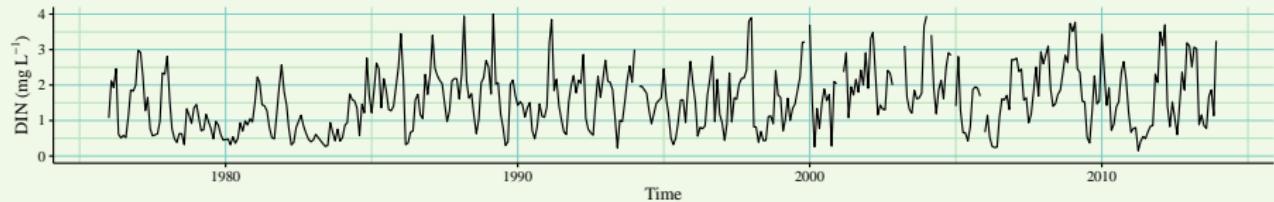
Regional/historical

watershed inputs
point sources
management actions
flow changes

Model theory and background

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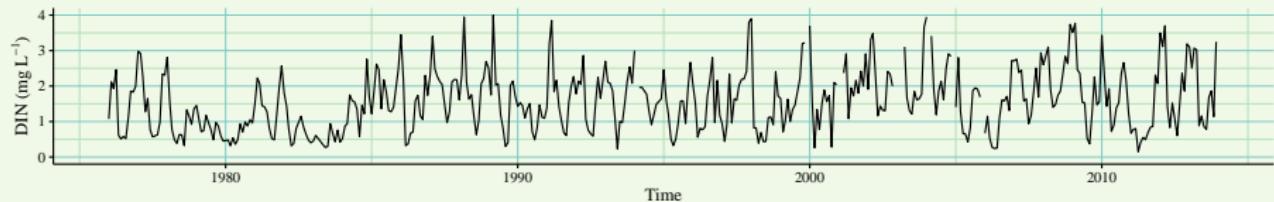


Models should describe components to evaluate effects

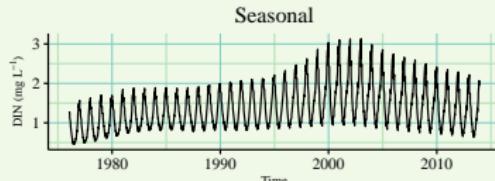
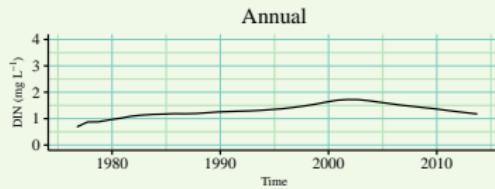
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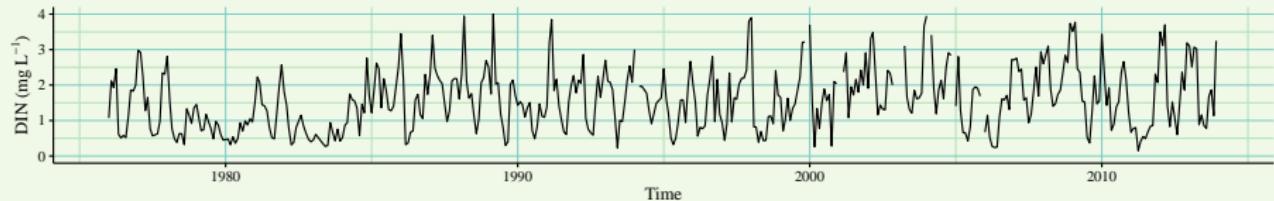
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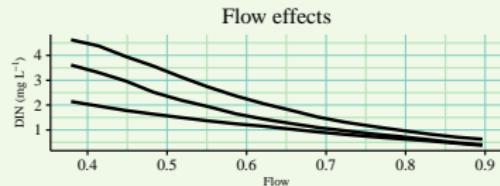
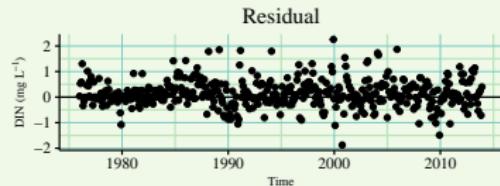
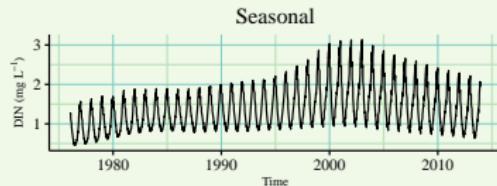
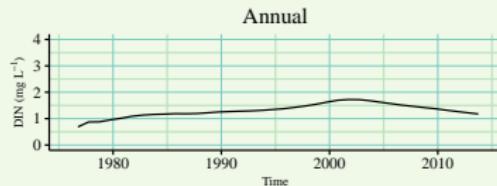
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Model theory and background

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

Model theory and background

WRTDS adaptation for tidal waters

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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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Model theory and background

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

Model theory and background

WRTDS adaptation for tidal waters

How does weighted regression work?

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

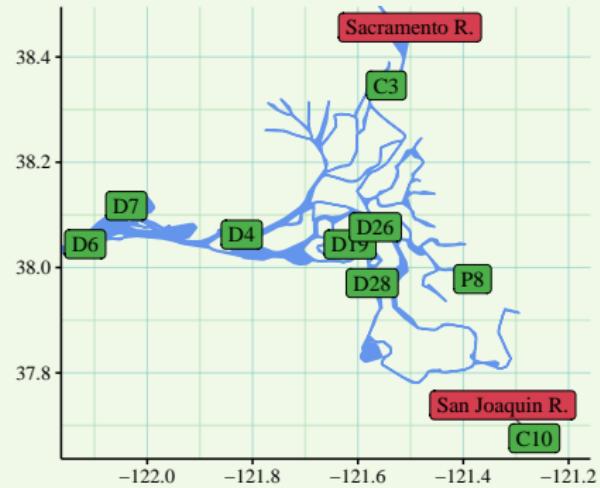


Figure : Stations (green) and flow estimates (red) modelled with WRTDS

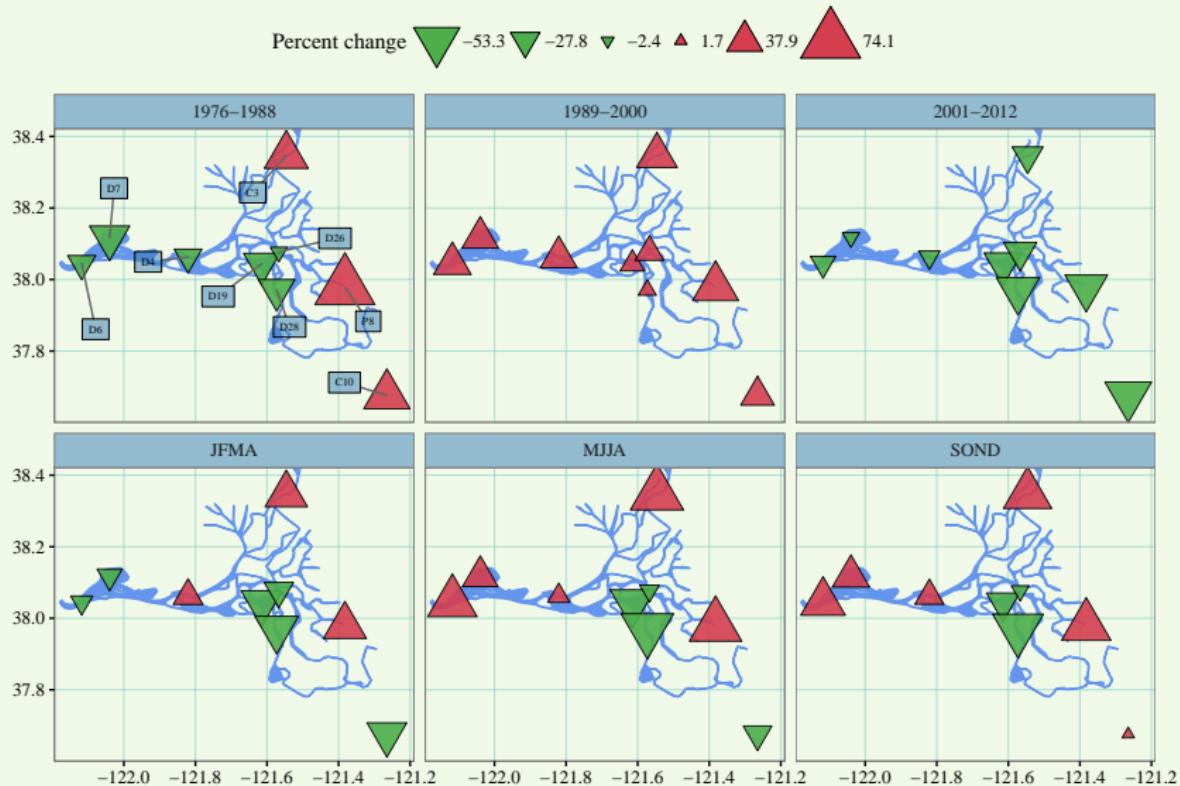
Trends over time

Nitrogen dynamics in the Delta

Predicted DIN trends, 1980-1990

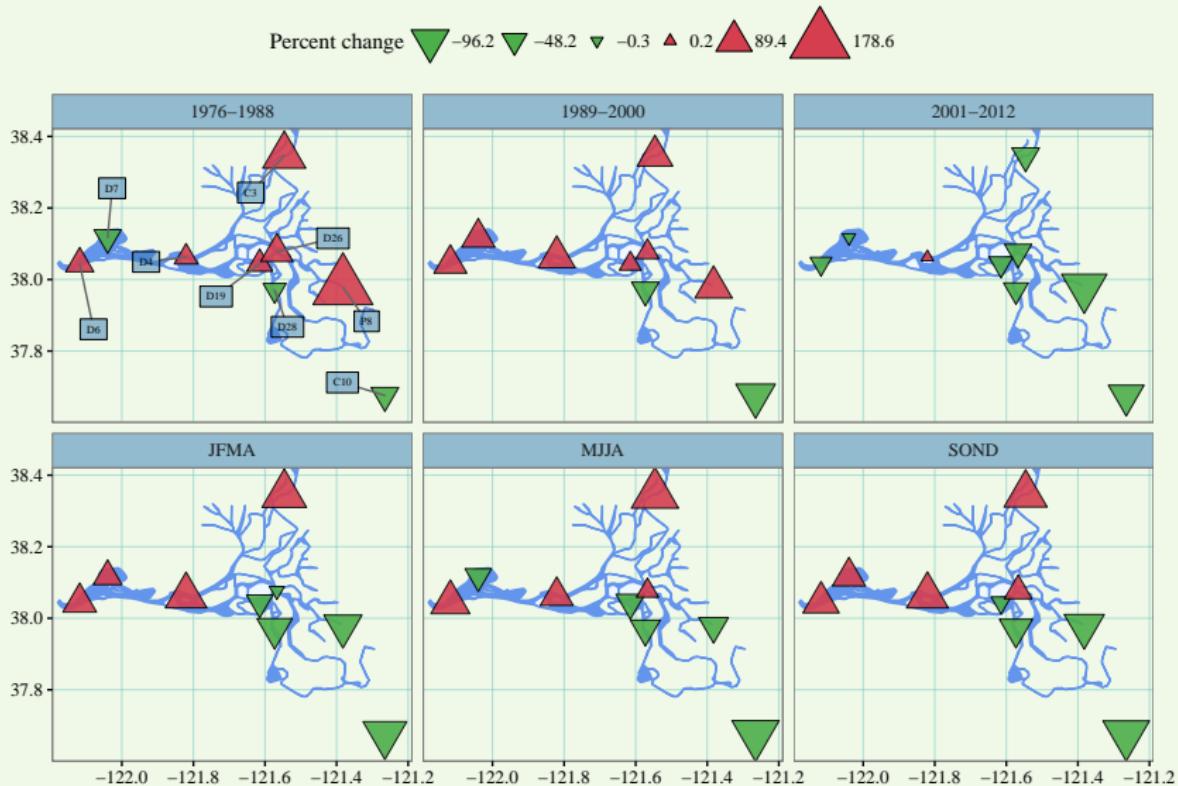
Trends over time

Nitrogen dynamics in the Delta - DIN



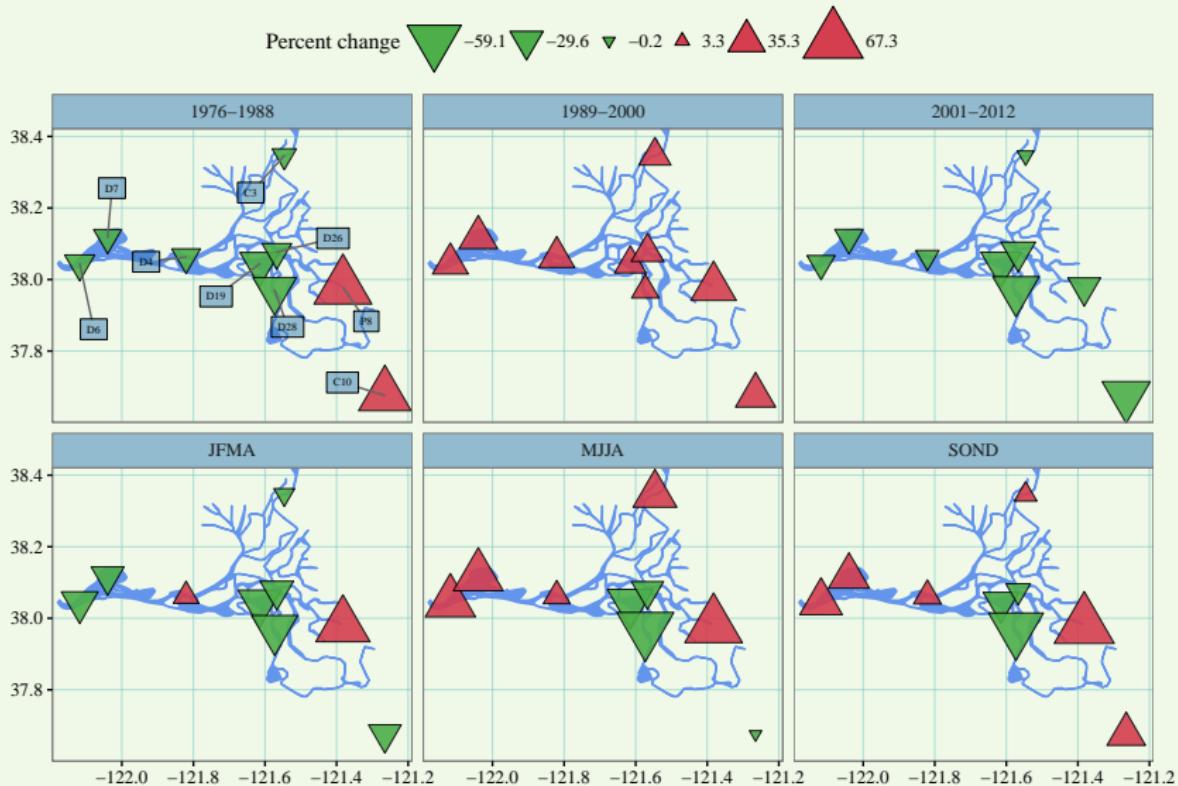
Trends over time

Nitrogen dynamics in the Delta - ammonium



Trends over time

Nitrogen dynamics in the Delta - nitrite/nitrate

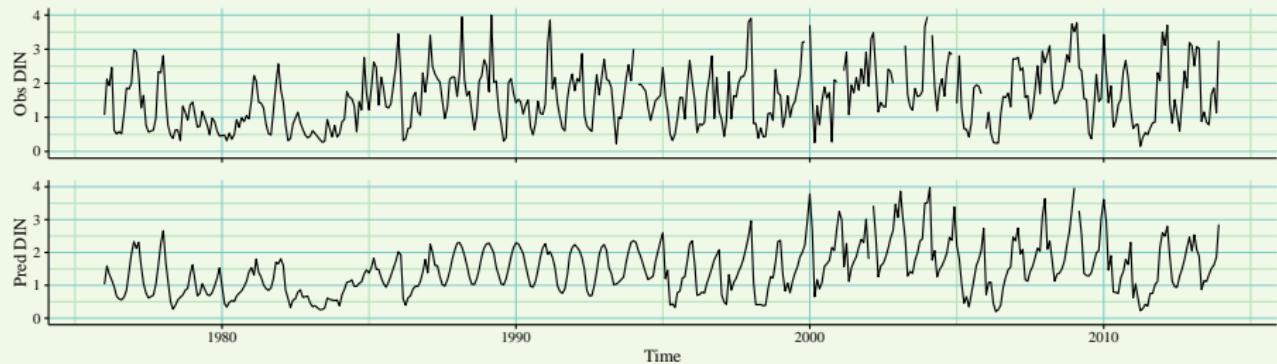


Trends over time

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 tidal waters:

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

Selected case studies

Two examples demonstrate the utility of WRTDS adaptation to tidal waters:

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

Each shows how *model components* describe *processes*

Uses **WRTDStidal** package for R

Selected case studies

Effects of wastewater treatment upgrades

How can model information be linked to causation?

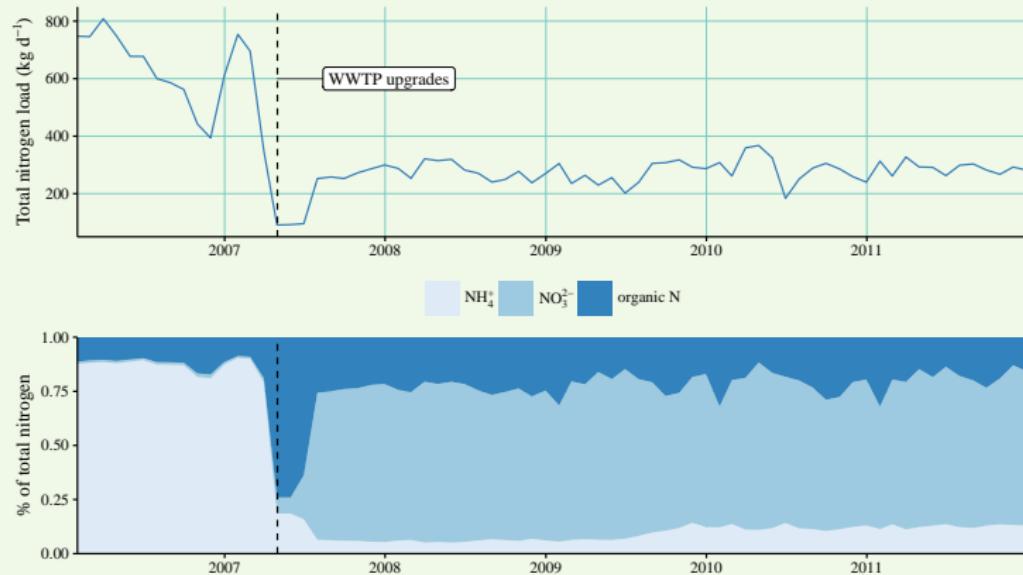


Figure : Nitrogen load measurements (kg d⁻¹) at the Tracy Wastewater Treatment Plant. Wastewater discharge requirements were implemented in May, 2007.

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

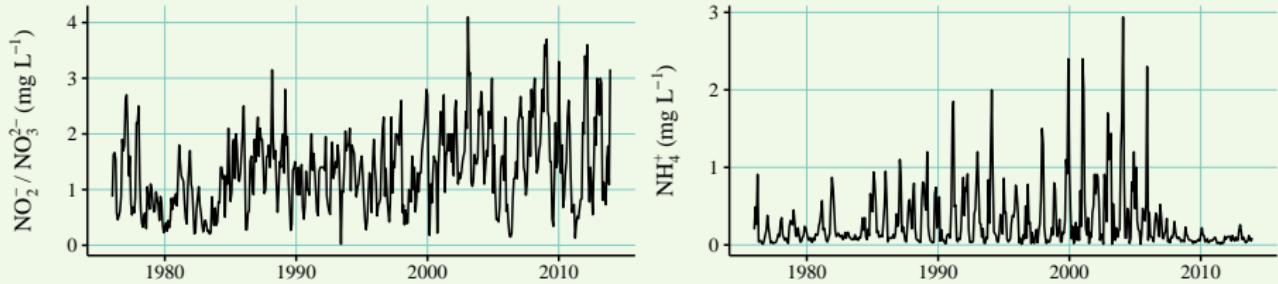


Figure : Observed nitrogen time series at P8

Selected case studies

Effects of wastewater treatment upgrades

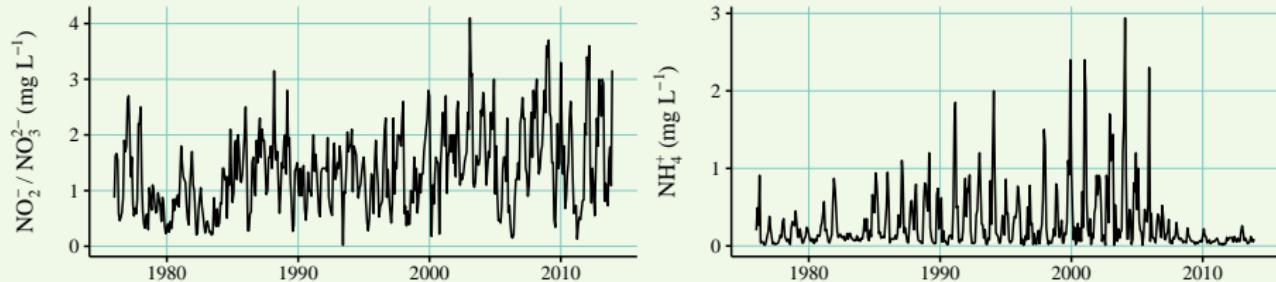


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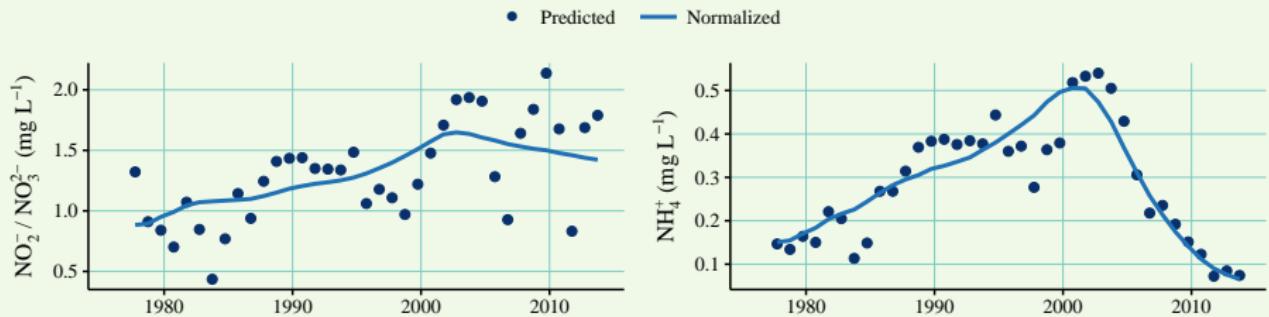


Figure : Annual predicted and flow-normalized nitrogen from WRTDS.

Selected case studies

Effects of wastewater treatment upgrades

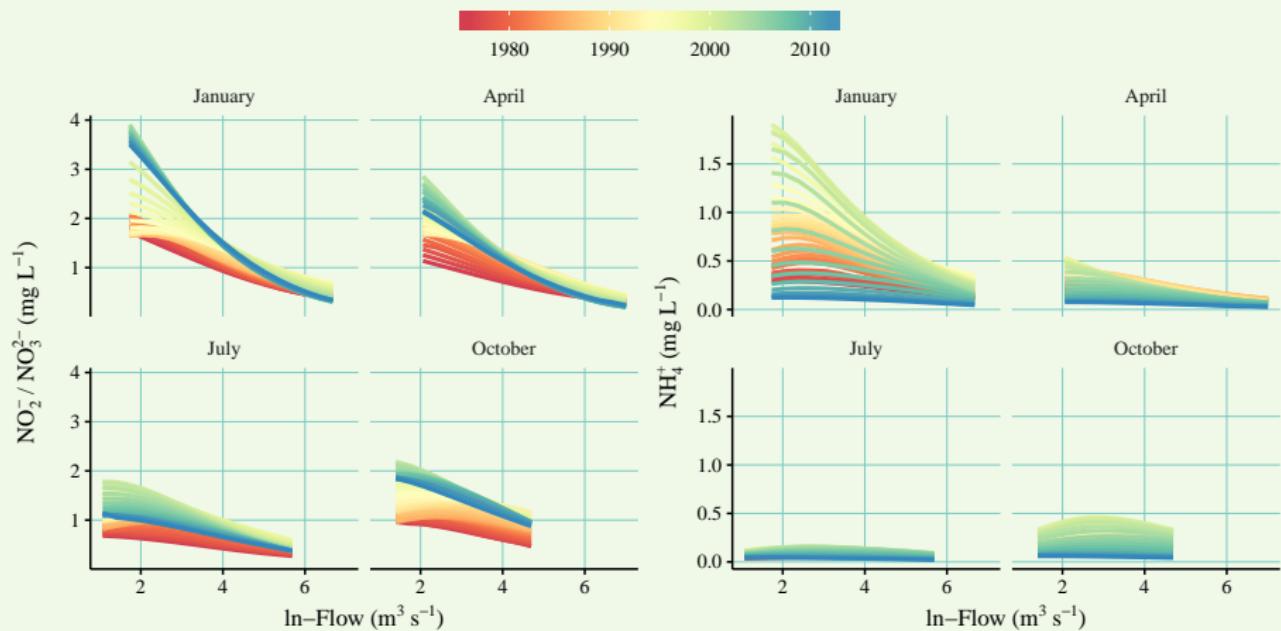


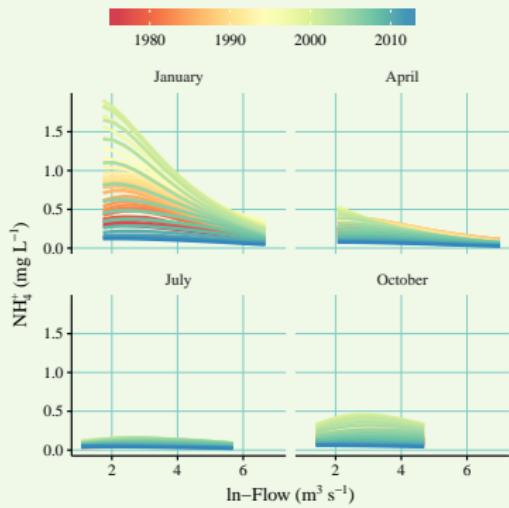
Figure : Nitrogen relationships with flow over time at P8.

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

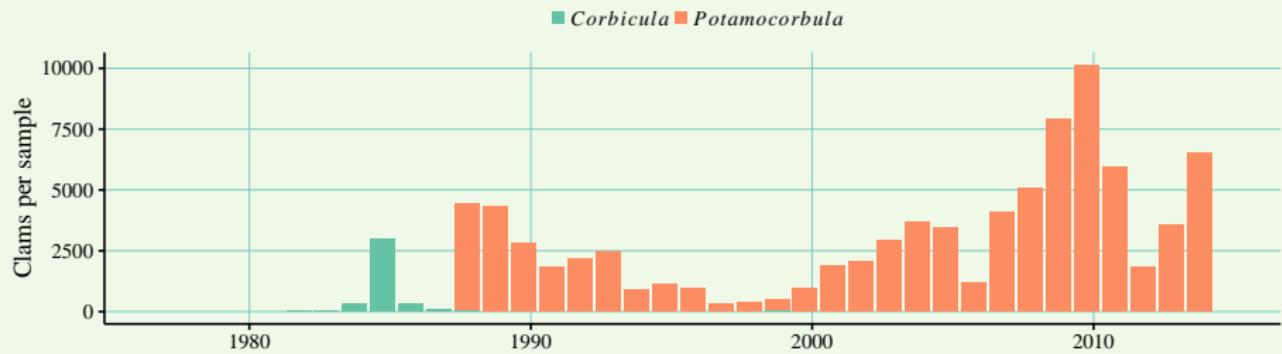


Figure : Clam density by year at D7, Suisun Bay [Crauder et al., 2016].

Selected case studies

Effects of biological invasion in Suisun Bay

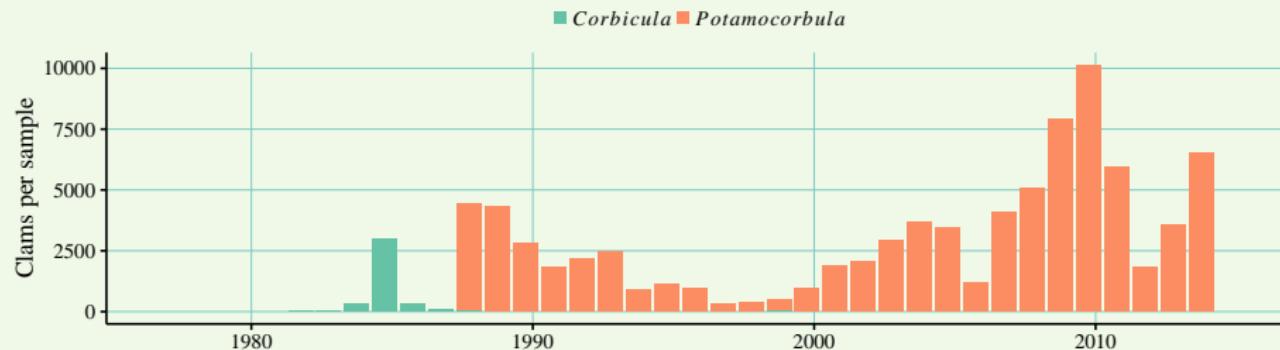


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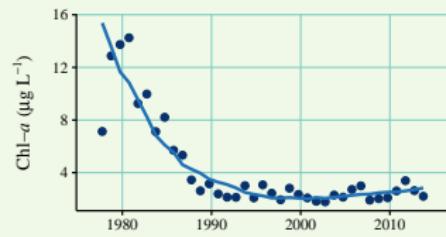


Figure : Annual predicted (points) and flow-normalized (lines) water quality data at D7.

Selected case studies

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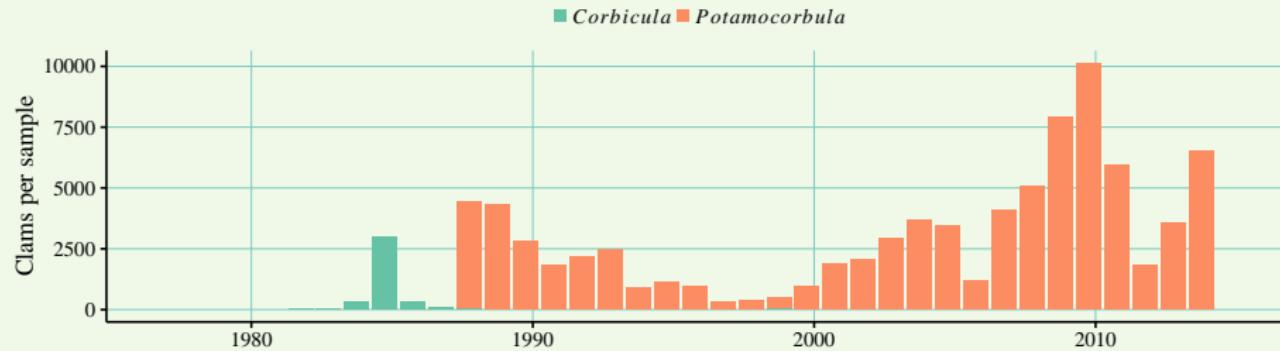


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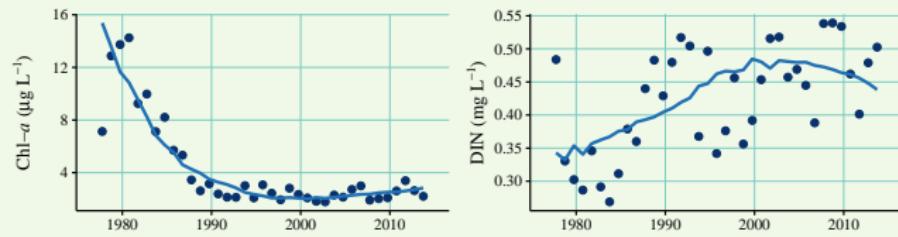


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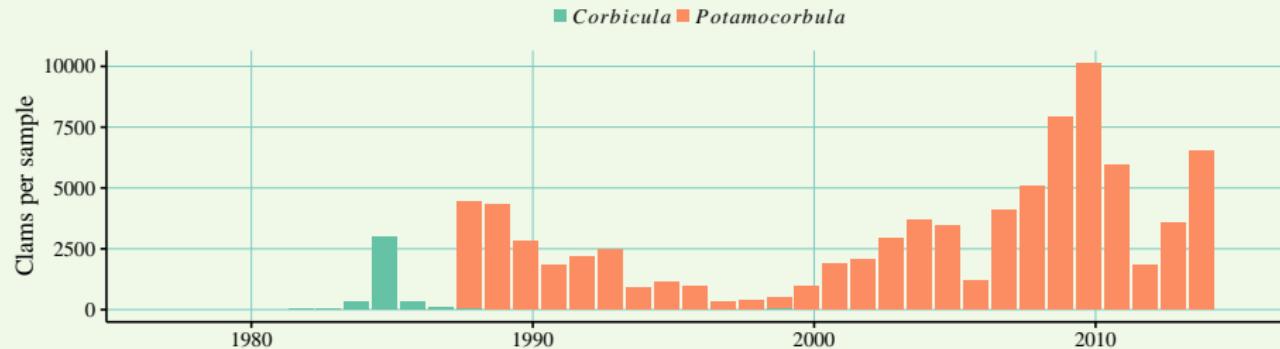


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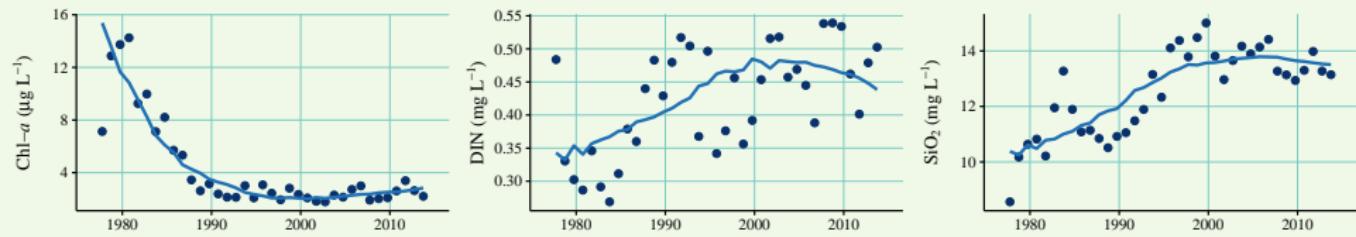
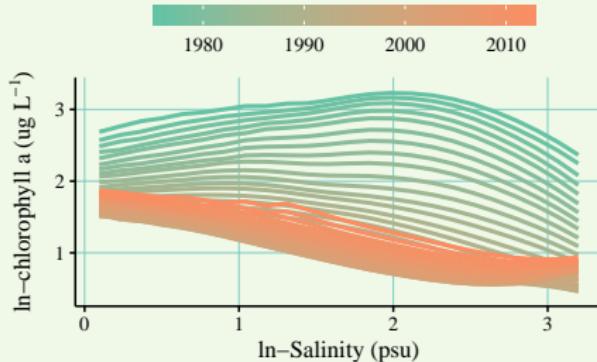


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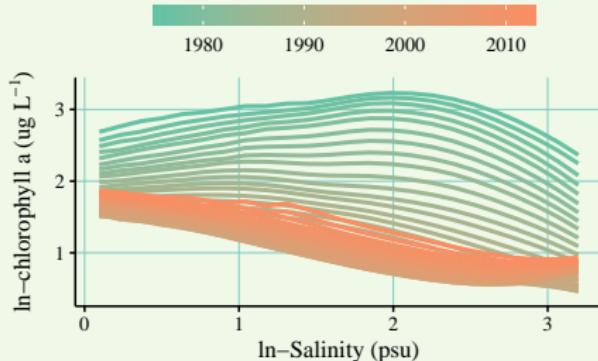
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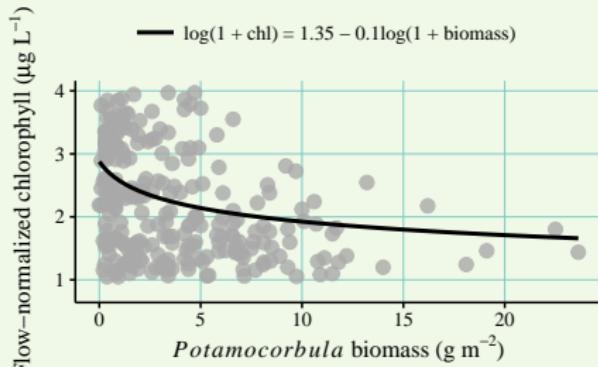
- Early: Flow-stimulation, then flushing
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Selected case studies

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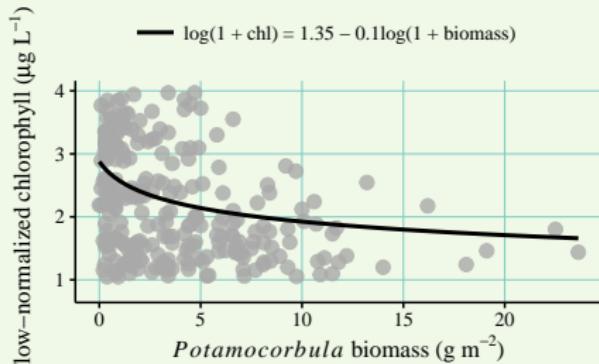
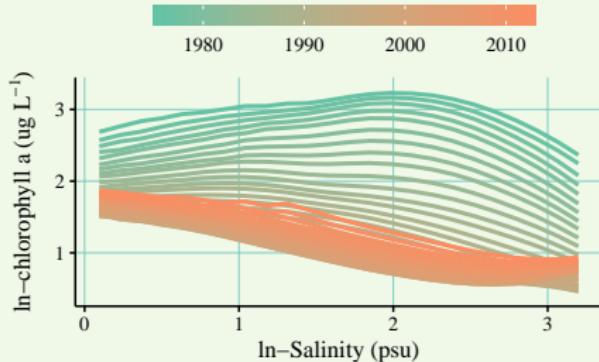


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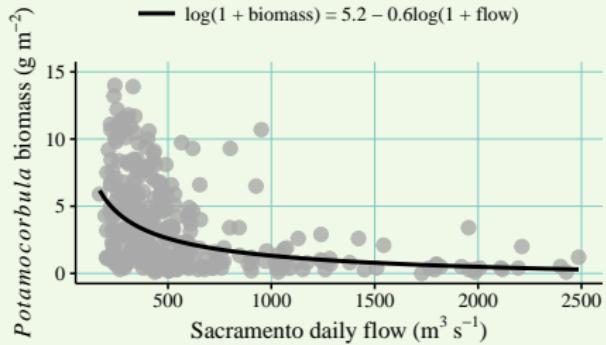


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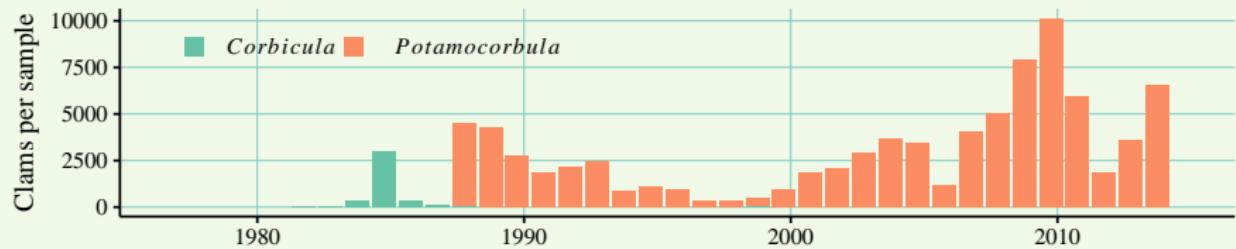


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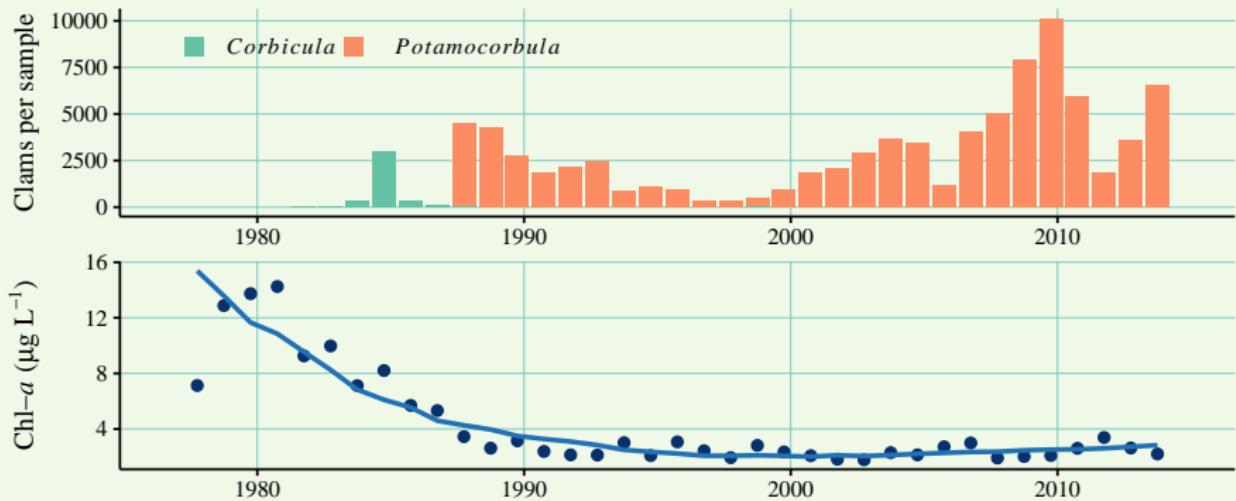
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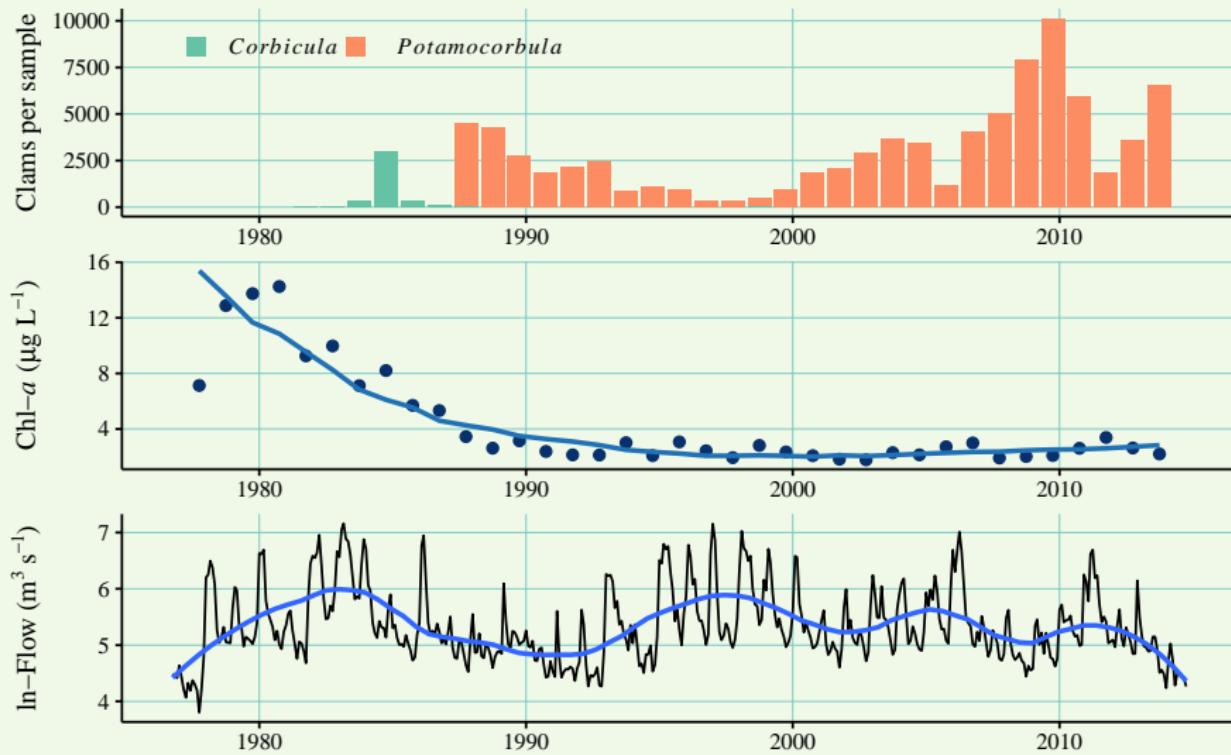
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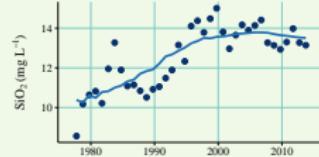
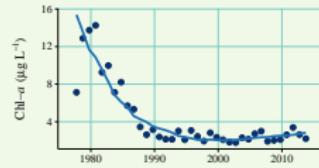


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Effects of biological invasion in Suisun Bay

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- Increase in clam abundance, decrease in chlorophyll
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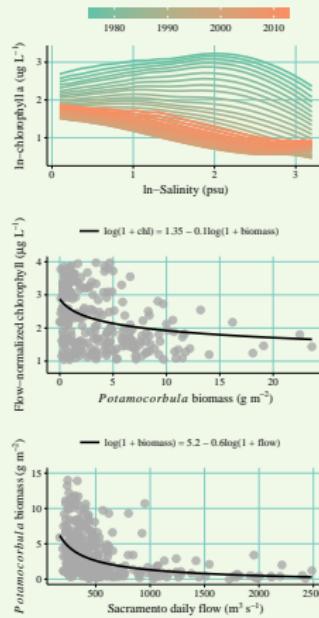


Selected case studies

Effects of biological invasion in Suisun Bay

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- 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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- Better link to causal events
- More comprehensive evaluation of site-specific issues
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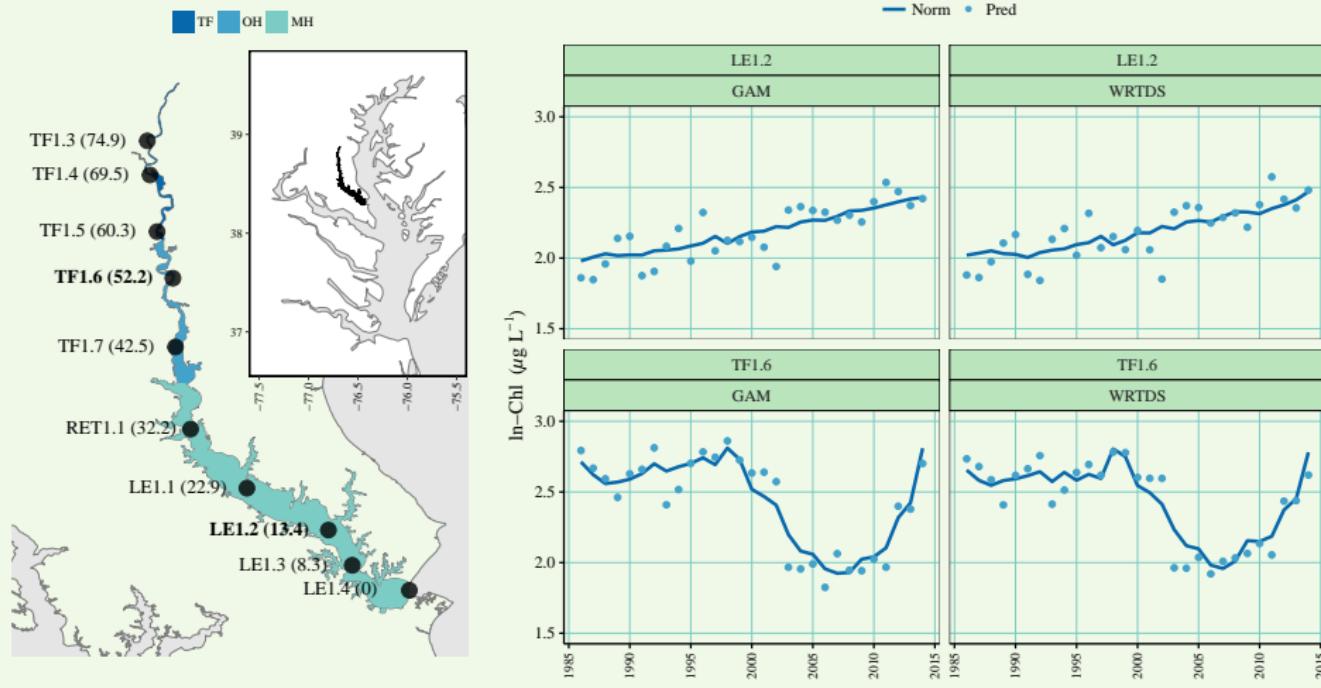
WRTDStidal package for R, active development

<https://github.com/fawda123/WRTDStidal>

Conclusions

Lessons for monitoring and future work

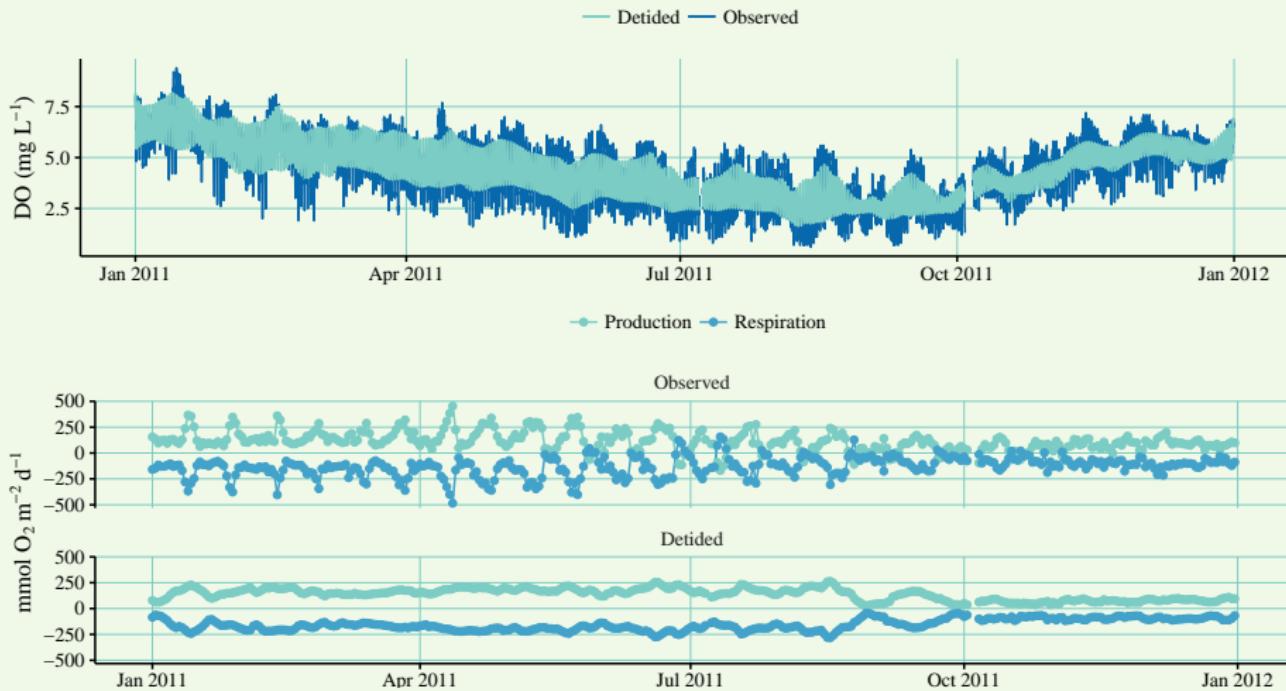
Comparing WRTDS and GAMs for trend evaluation



Conclusions

Lessons for monitoring and future work

DO time series and ecosystem metabolism [Beck et al., 2015]



Conclusions

Lessons for monitoring and future work

Data management and analysis tools



Acknowledgments and contact info:

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

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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

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