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

Marcus W. Beck, PhD

Southern California Coastal Water Research Project, marcusb@sccwrp.org, Phone: 7147553217

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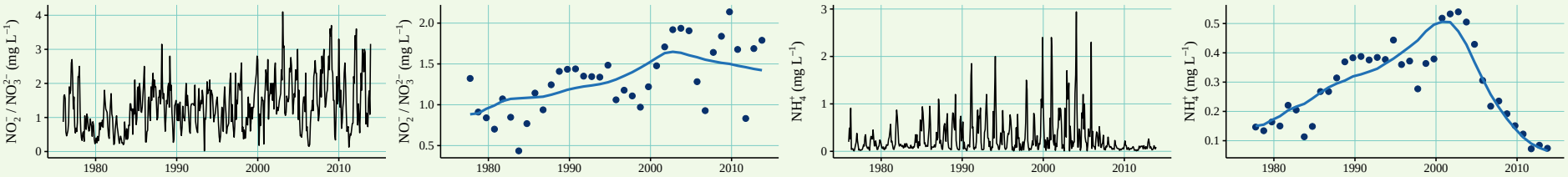

Evaluating Delta RMP data

Today's talk: Evaluation of forty years of Delta water quality data from the Routing Monitoring Program (RMP)

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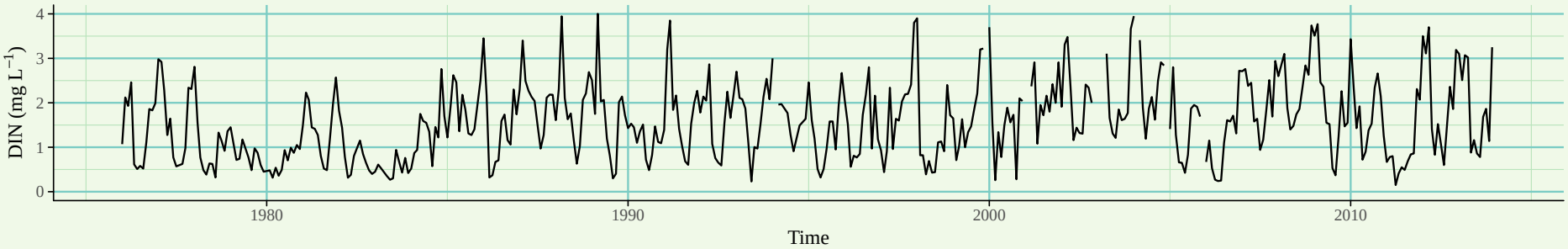
Water quality trends in the Delta:

- ***Part 1***: Model theory and application
- ***Part 2***: Trends over time and selected case study
- ***Part 3***: Use of data science tools to reach environmental managers

Model theory and background

WRTDS adaptation for tidal waters

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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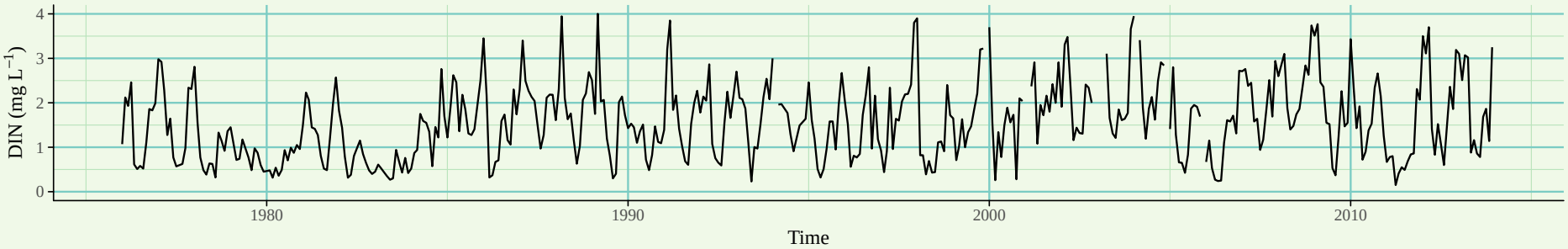

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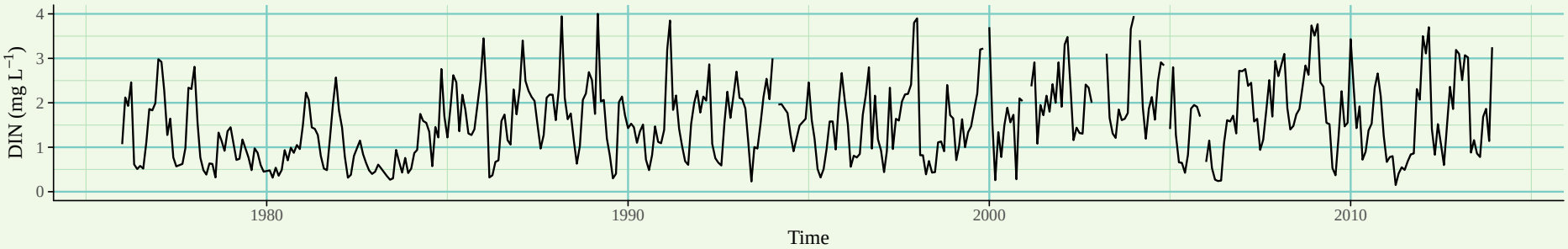

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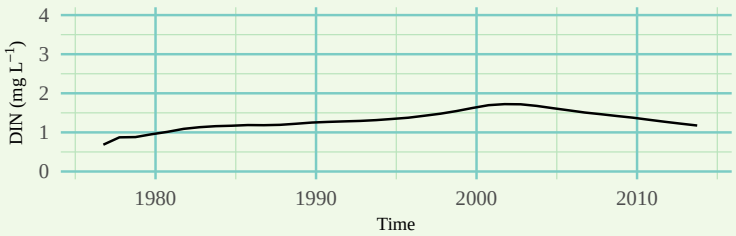
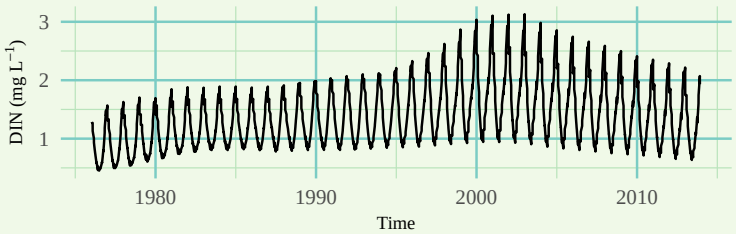


Seasonal



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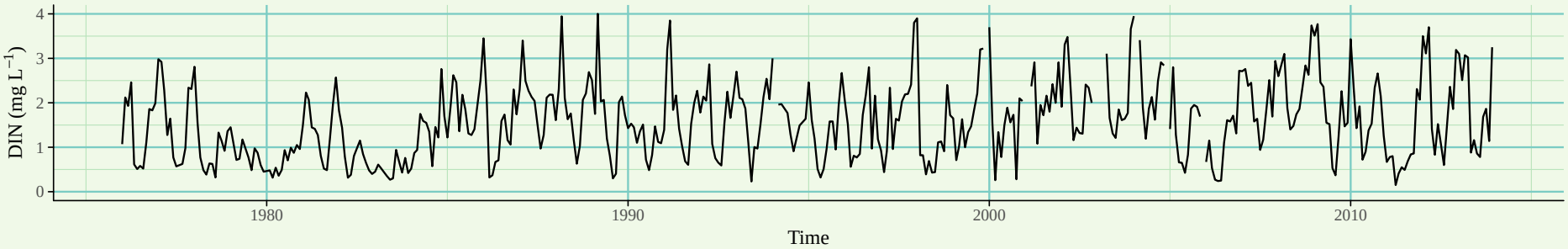

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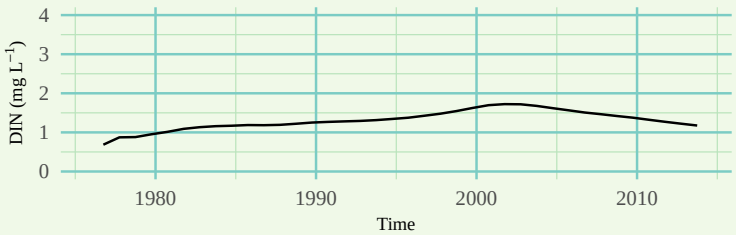
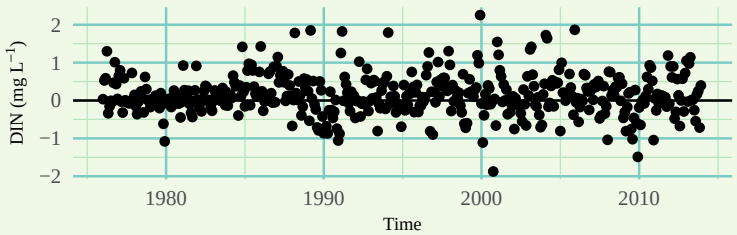


Residual



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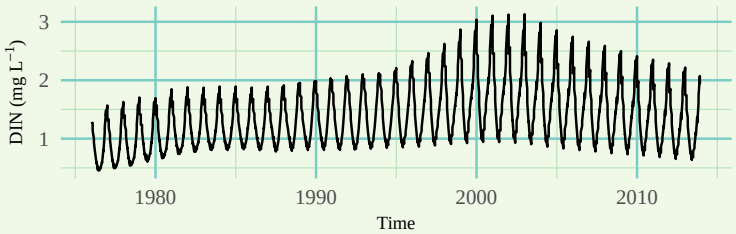
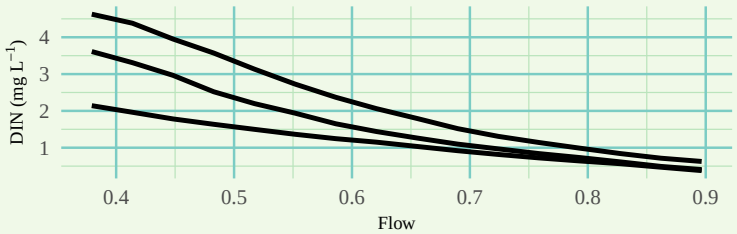


Flow effects



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WRTDS adaptation for tidal waters

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

Solution: Apply a model that accounts for changes in relationships between drivers of pollution over time [Beck et al., 2018]

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

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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)
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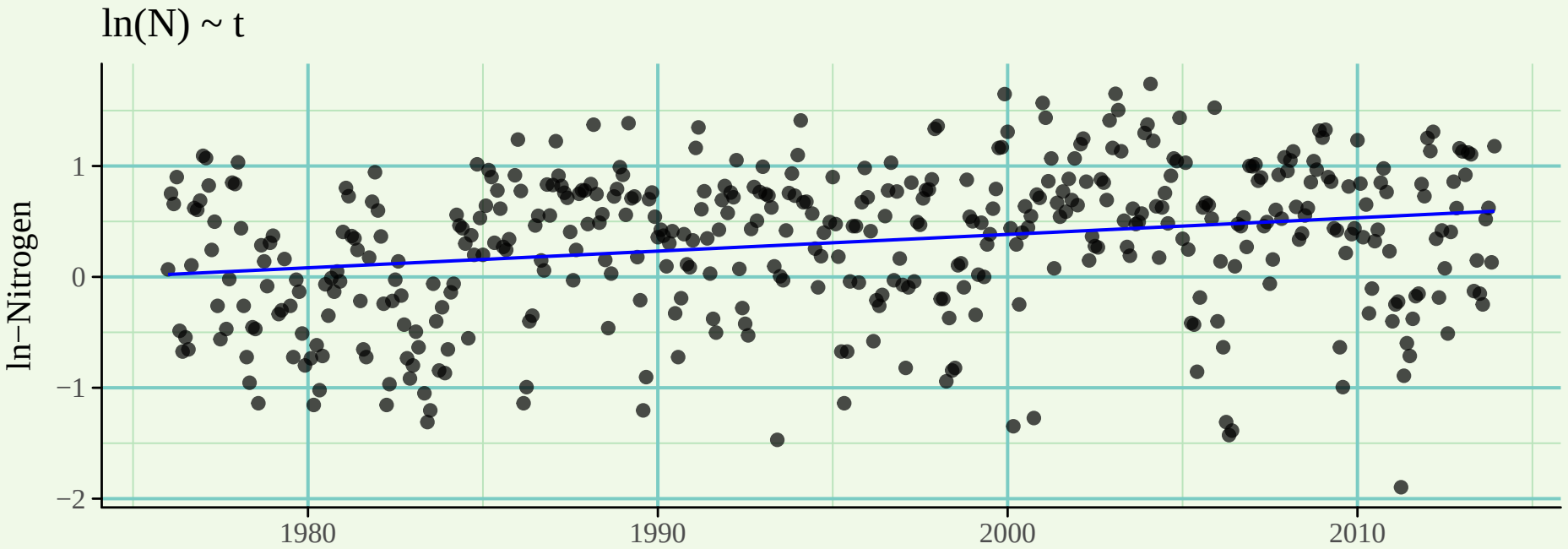

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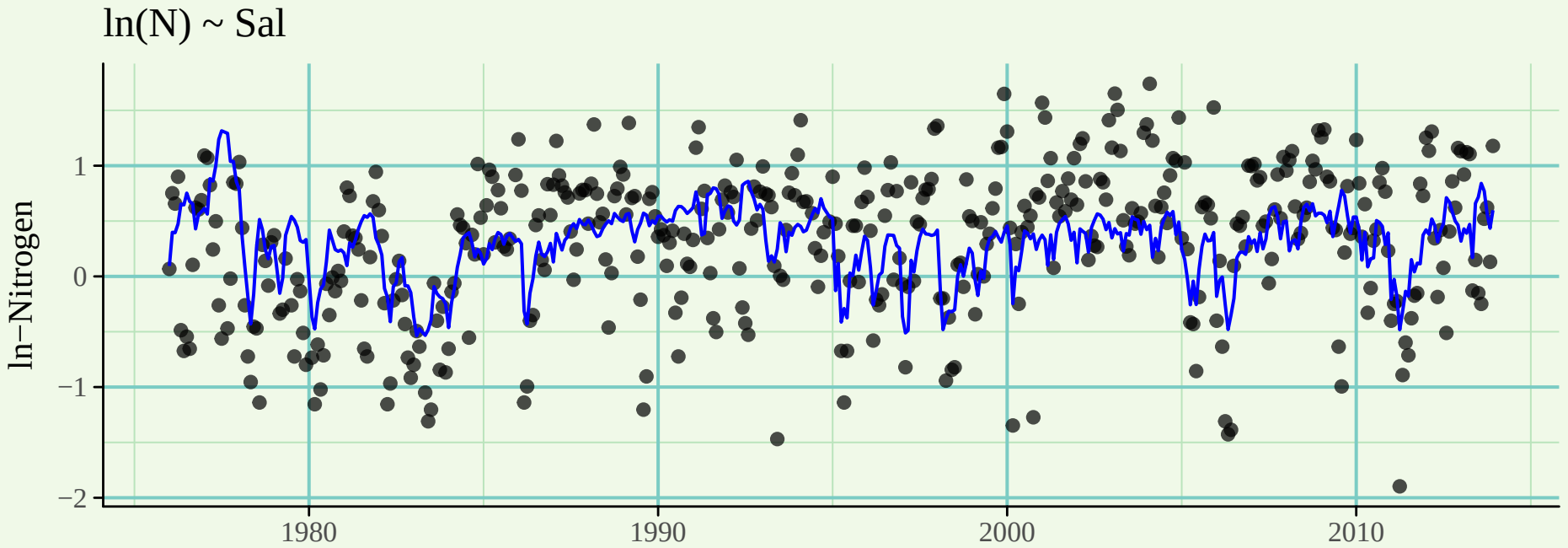

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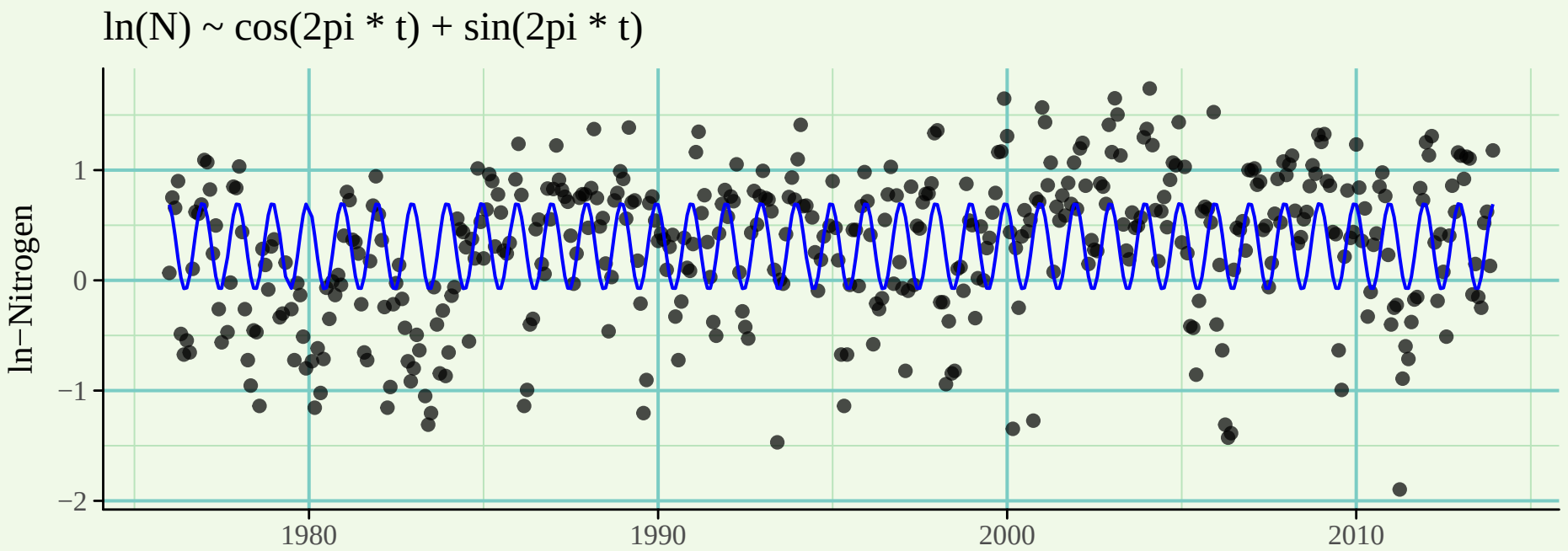

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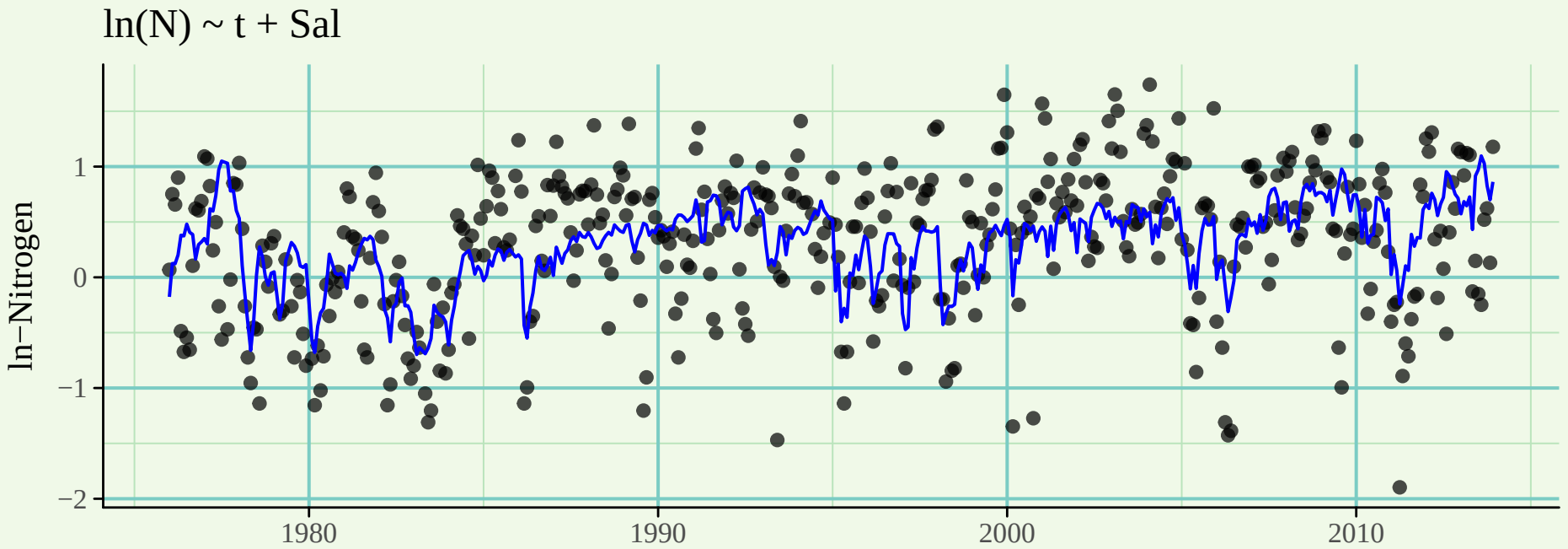

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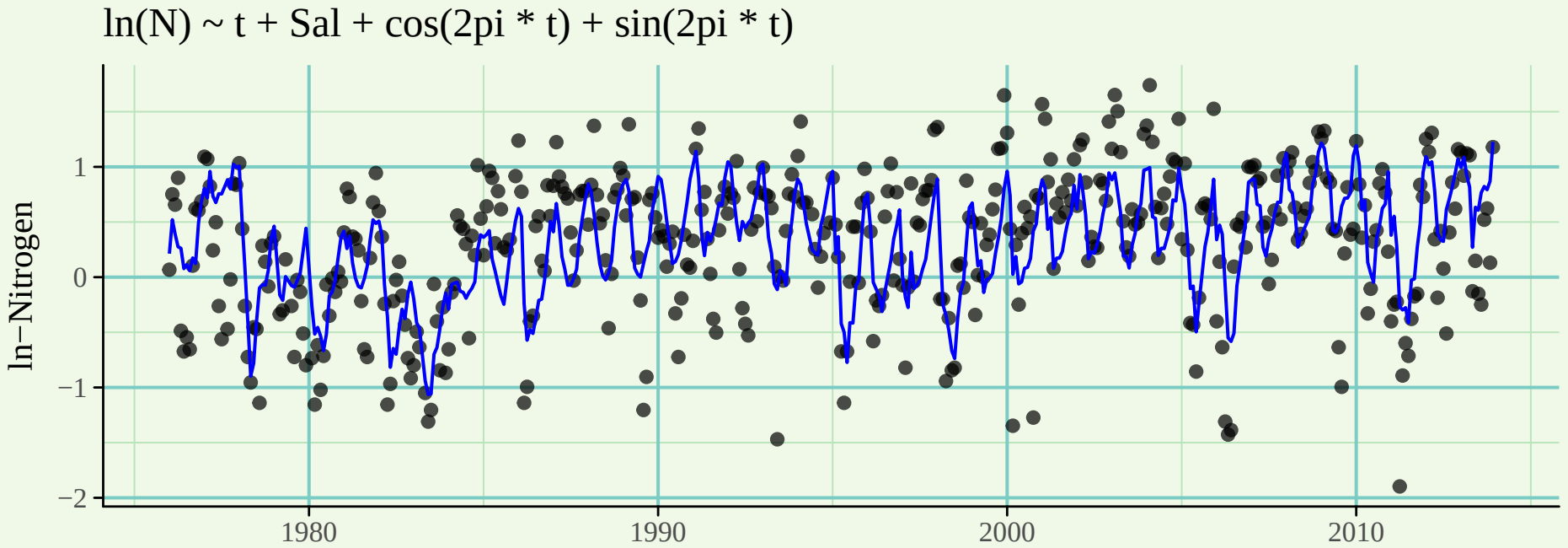

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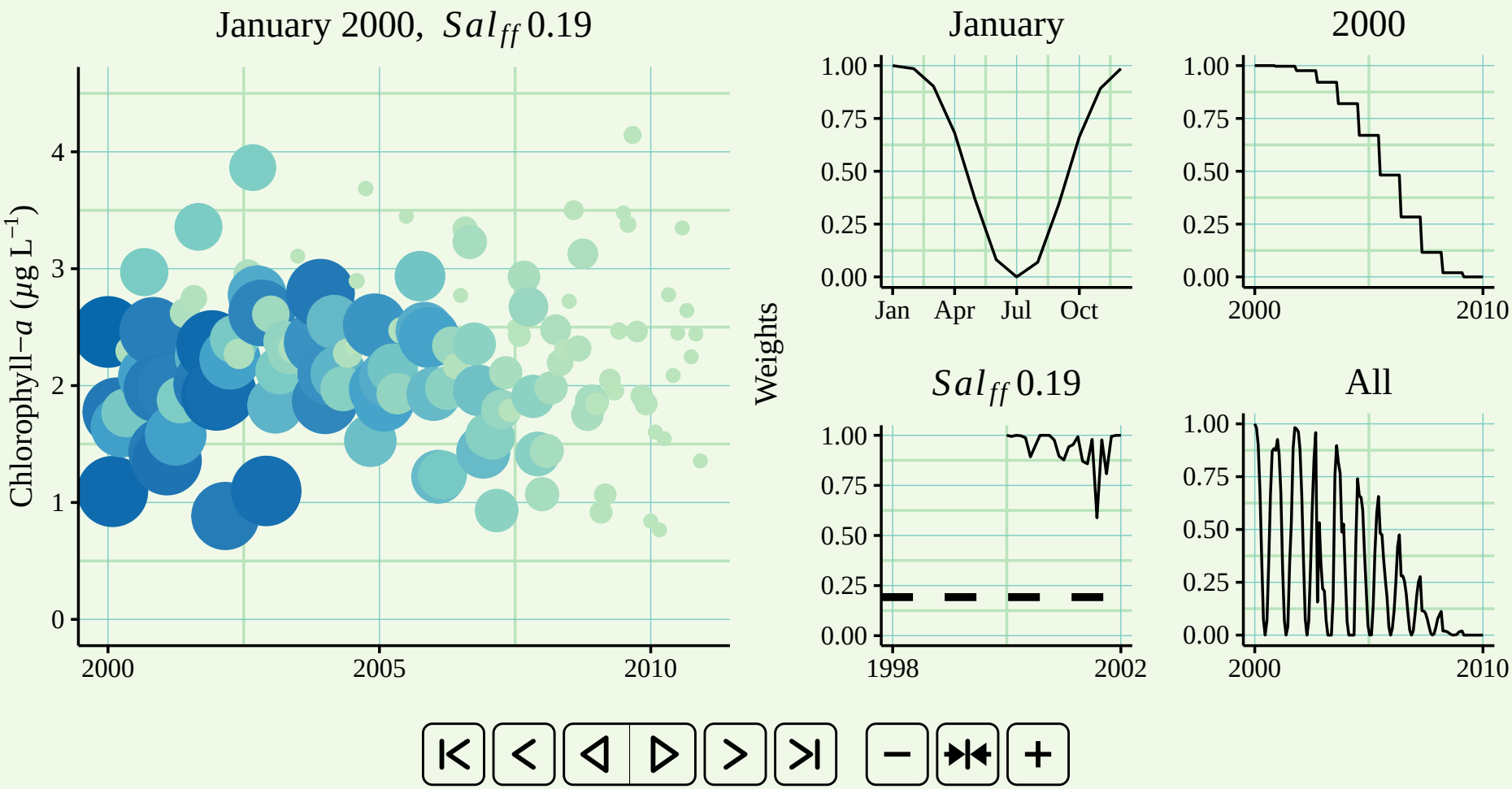

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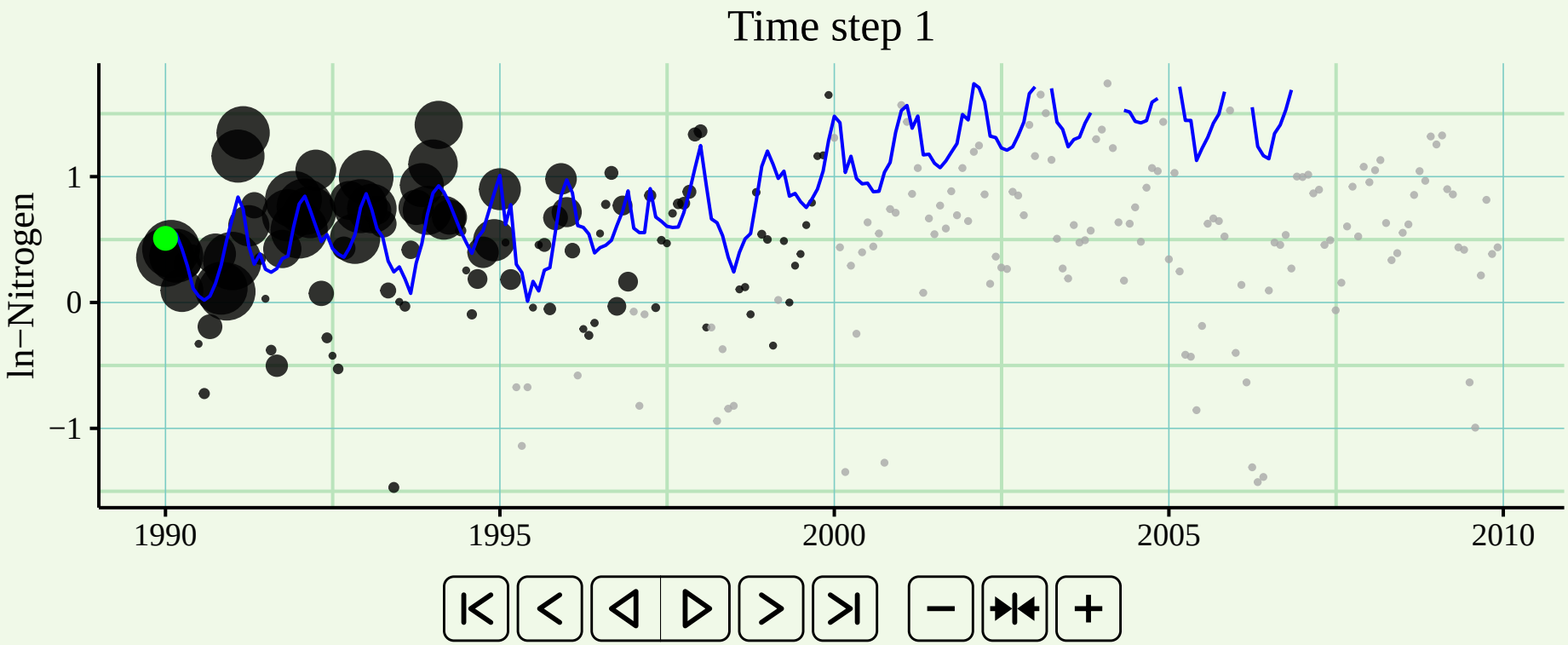
Points: observed time series (black are weighted, grey is zero weight)
Green point: observation at the center of the regression
Blue line: Global model with weights specific to the window
Red line: Accumulated WRTDS model



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

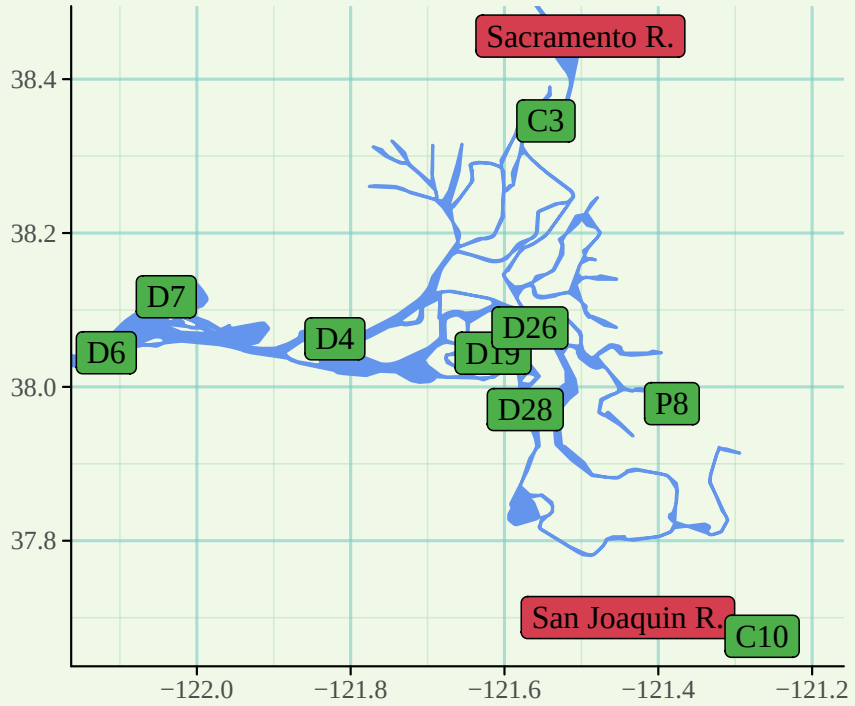
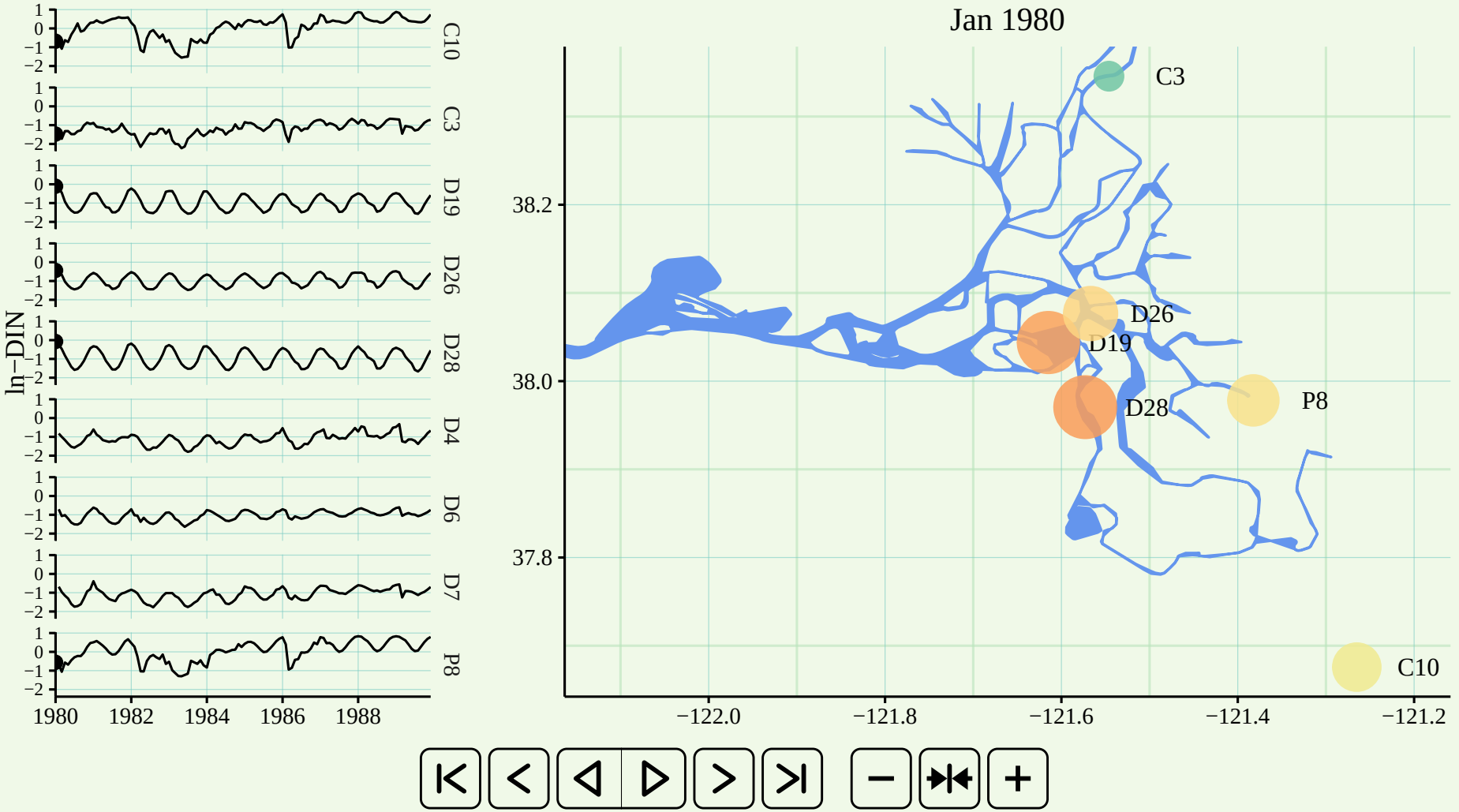


Figure: Stations (green) and flow estimates (red) modelled with WRTDS

Trends over time

Nitrogen dynamics in the Delta

Predicted DIN trends, 1980-1990



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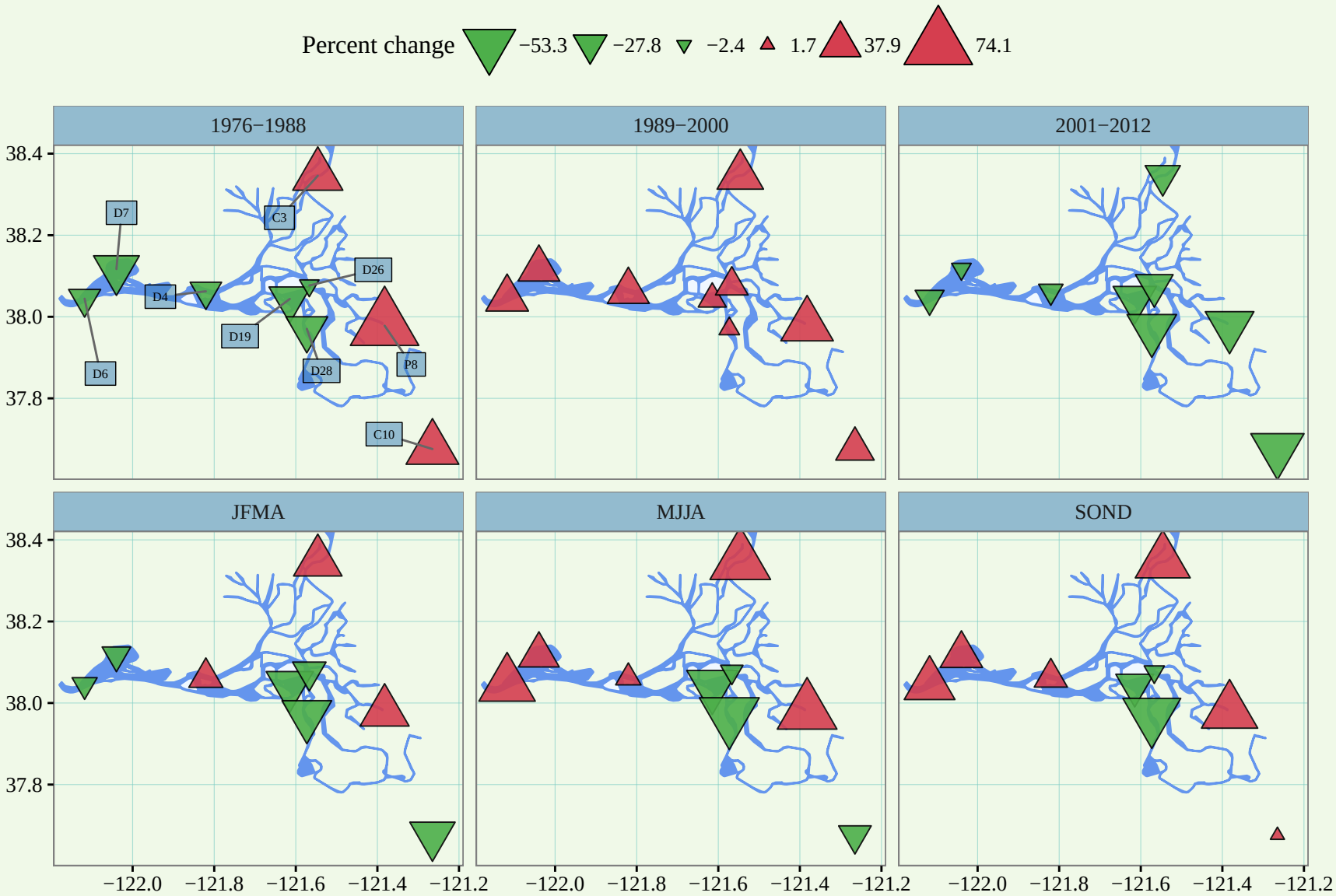
Nitrogen dynamics in the Delta - DIN



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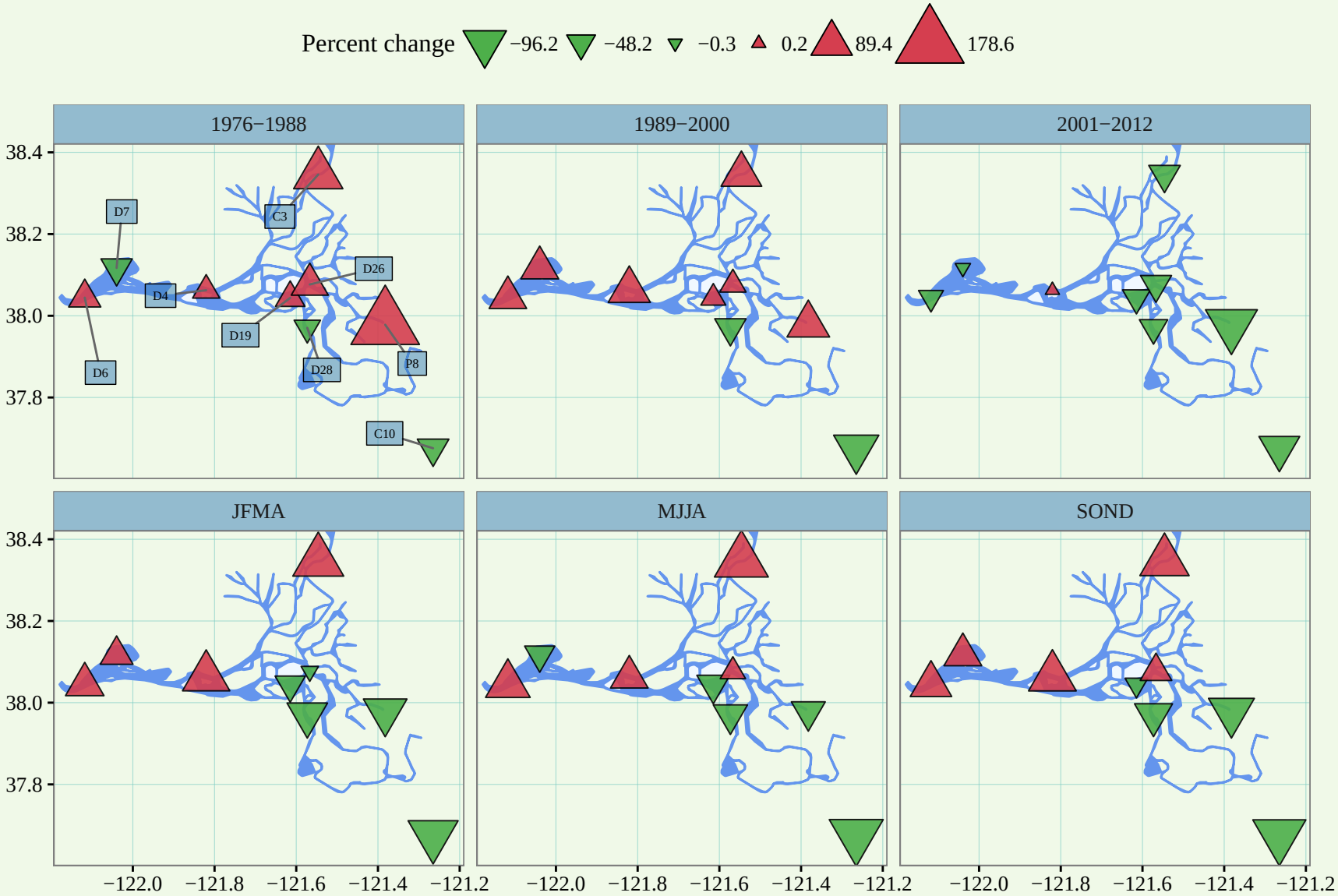
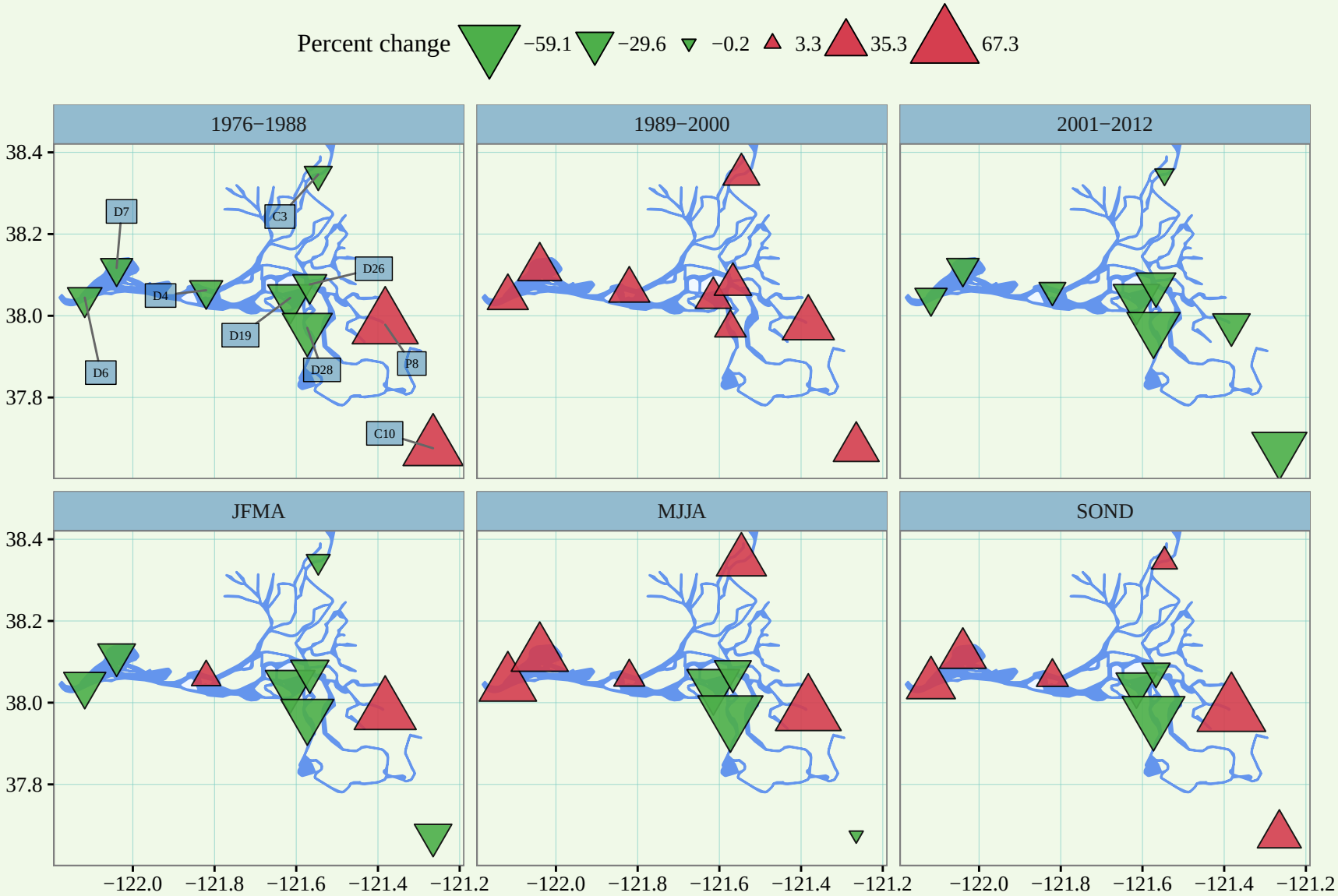
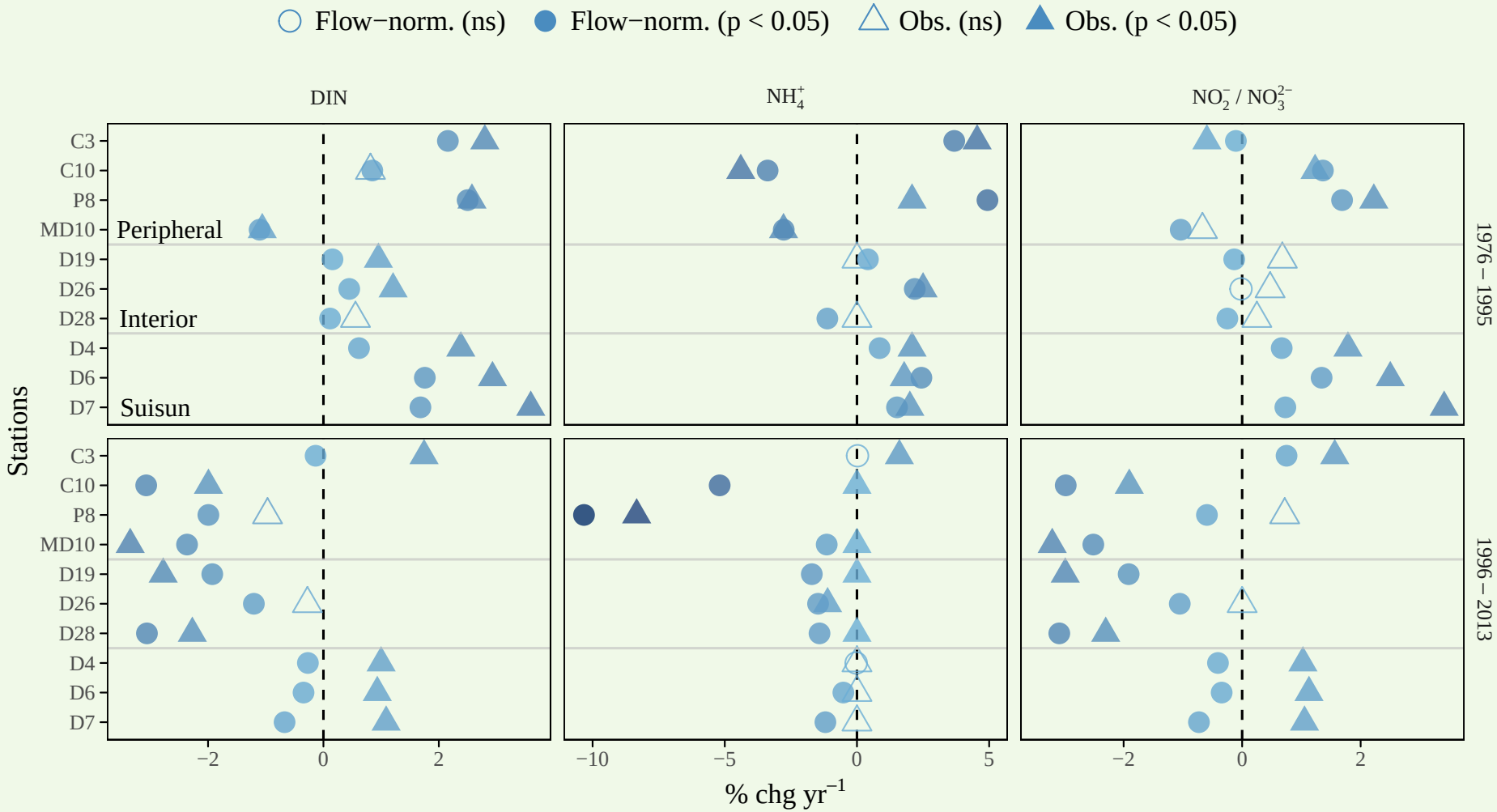


Trends over time

Nitrogen dynamics in the Delta - nitrite/nitrate



Better description of nutrient endpoints can change conclusions



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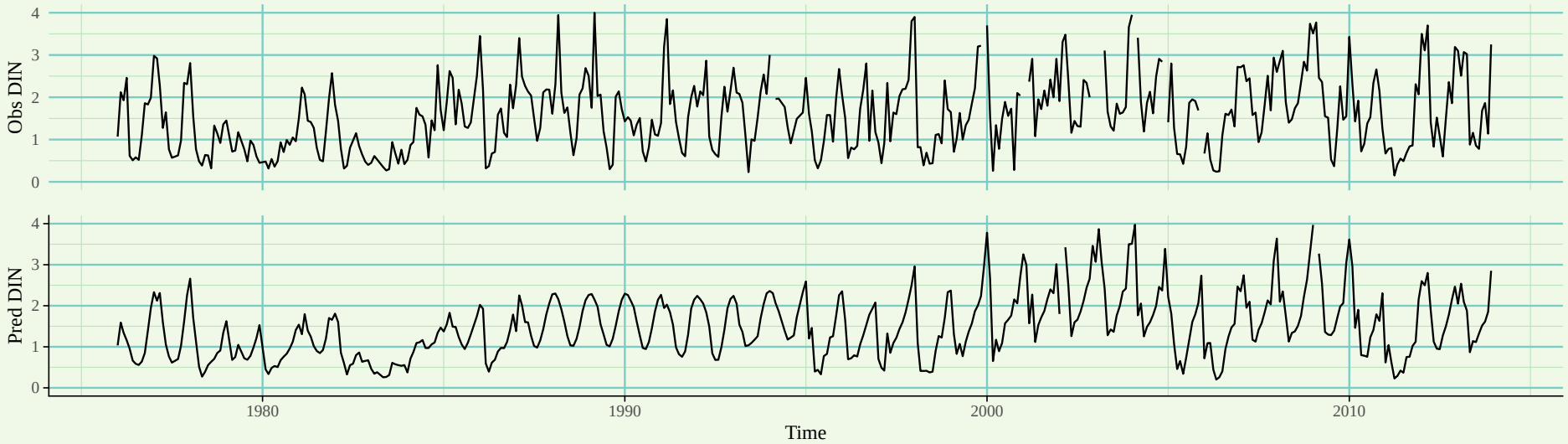
The ***WRTDS*** approach lets us model historical trends in relation to ***time***, ***discharge***, and ***season***

Predicted trends follow observed... how can we leverage the results to understand drivers of environmental change?



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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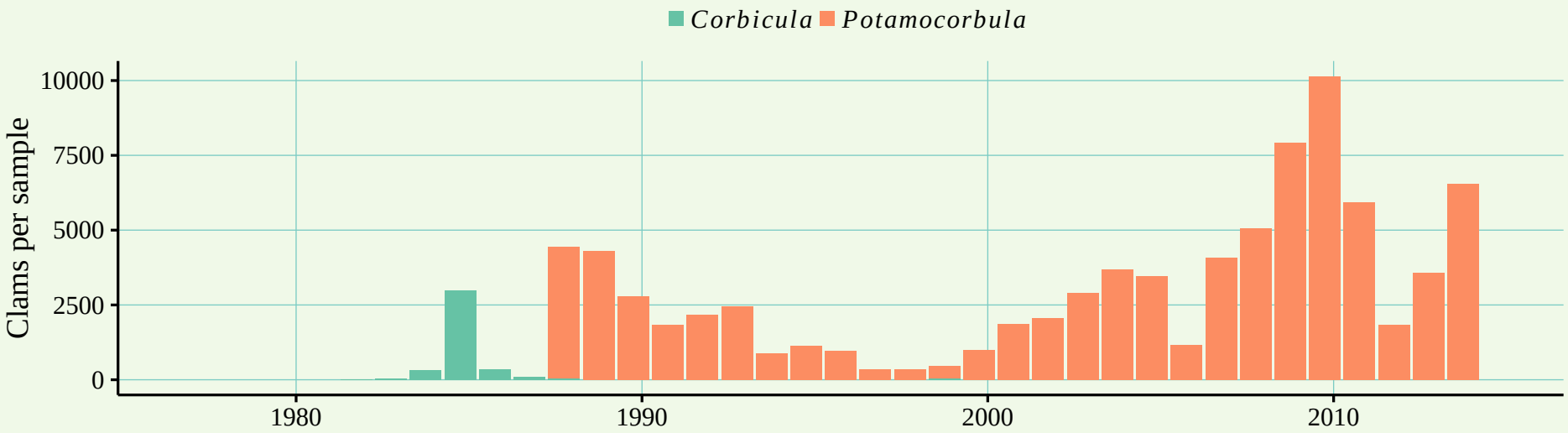

Figure: Clam density by year at D7, Suisun Bay [Crauder et al., 2016].

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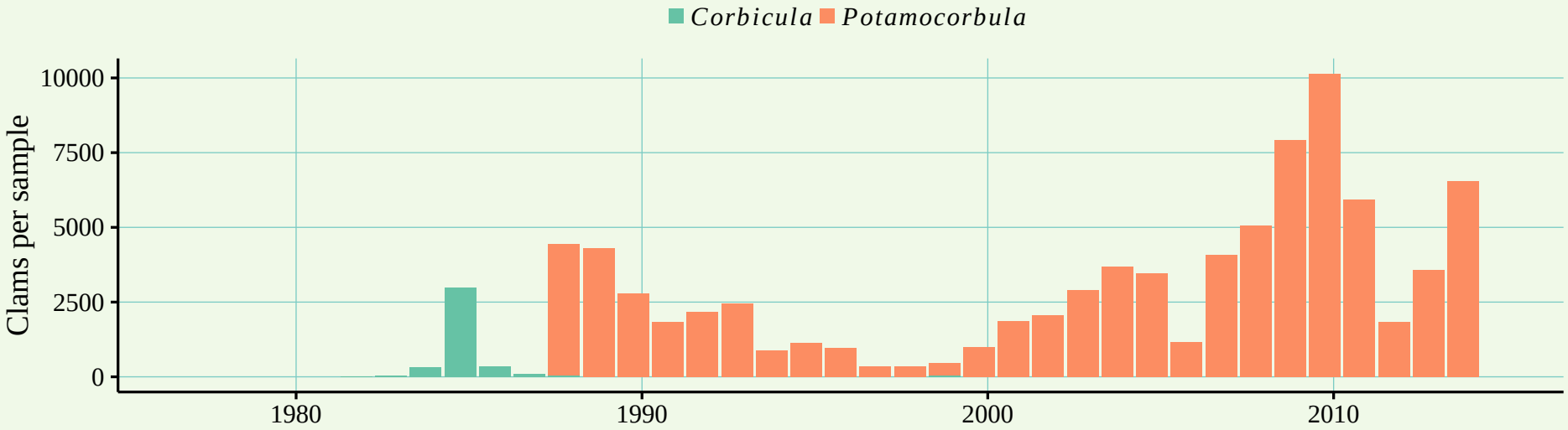

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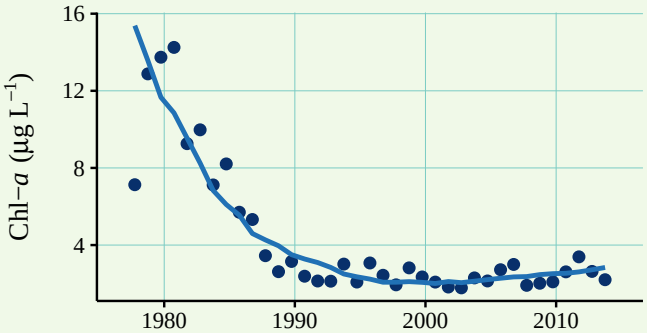

Figure: Annual predicted (points) and flow-normalized (lines) water quality data at D7.

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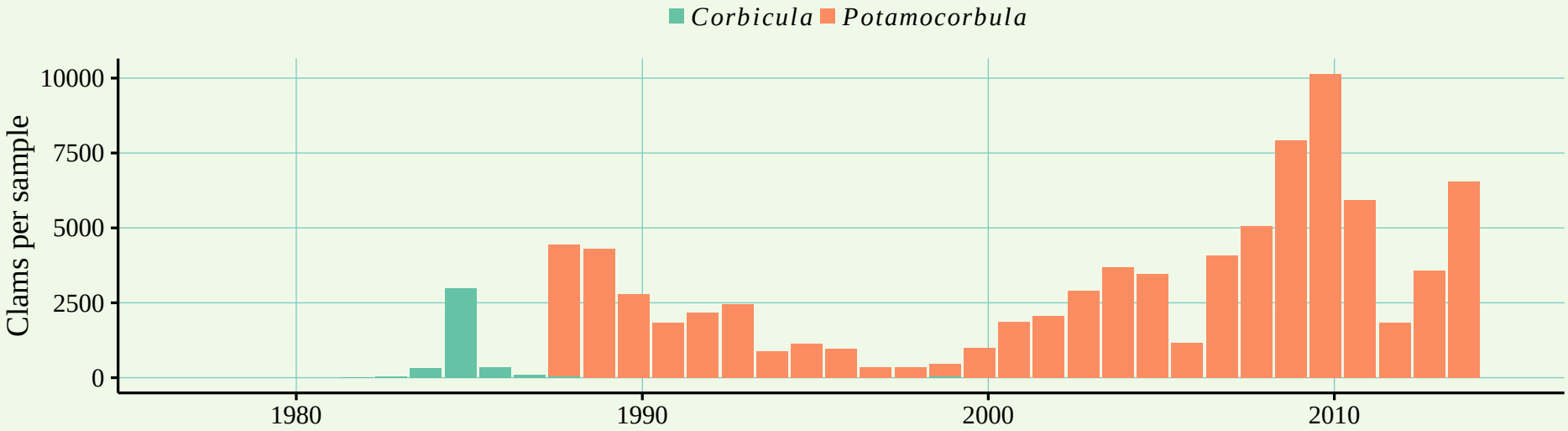

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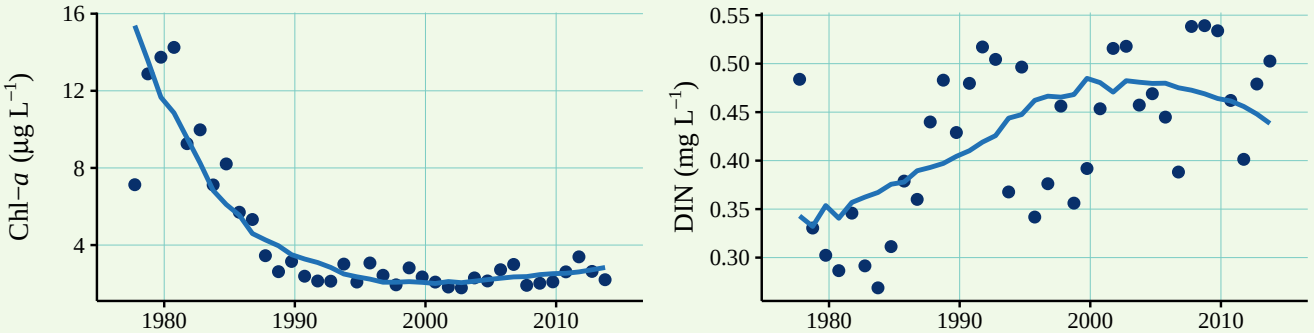

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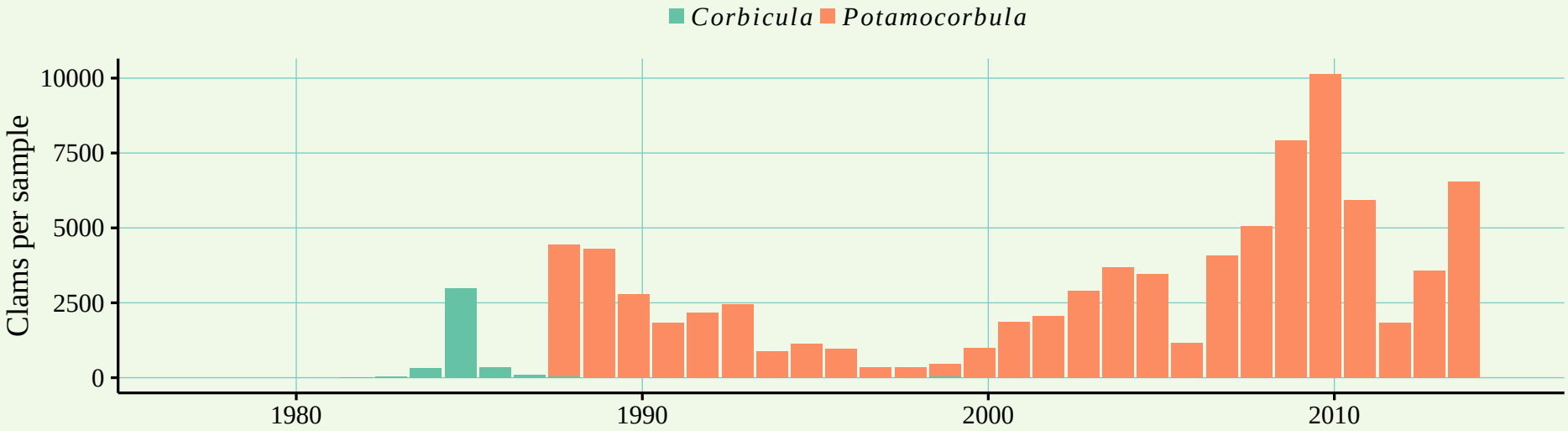

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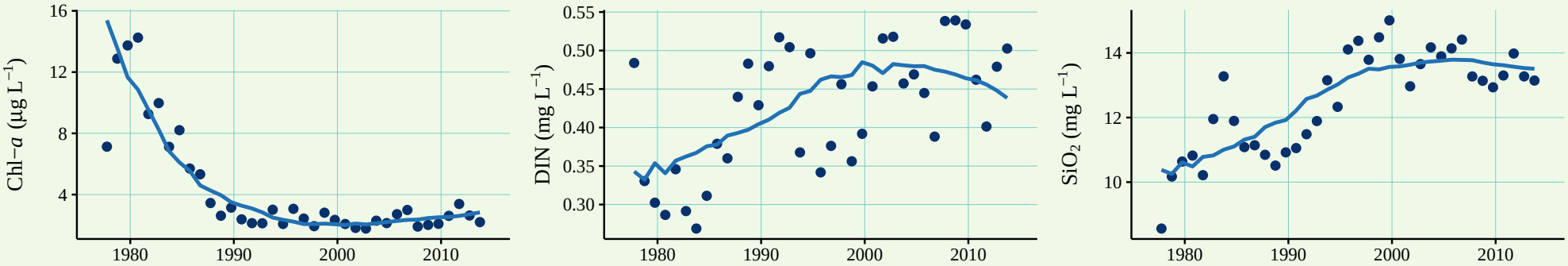

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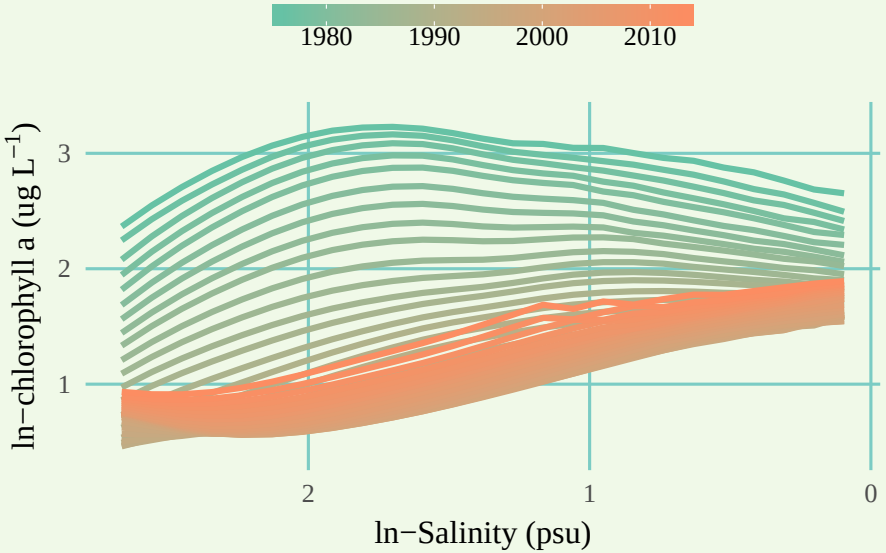

- Early: Flushing
- Later: Flow-stimulation

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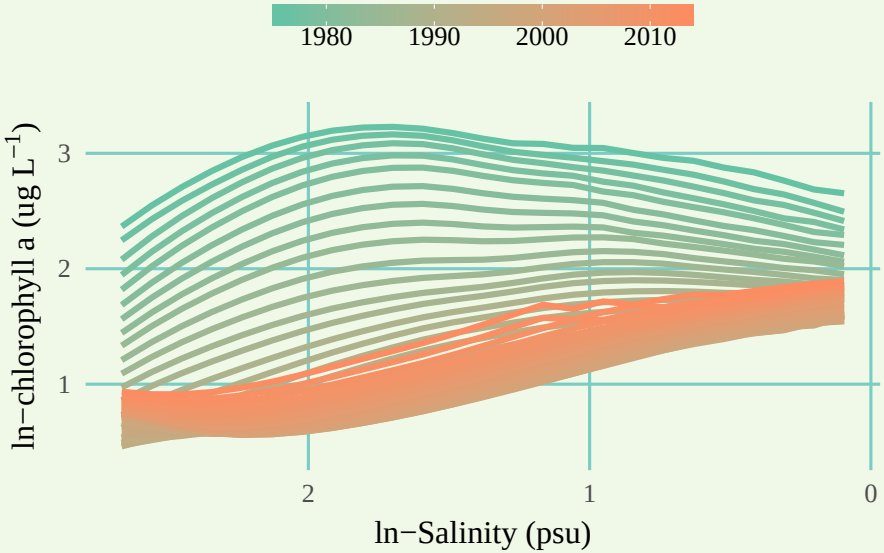

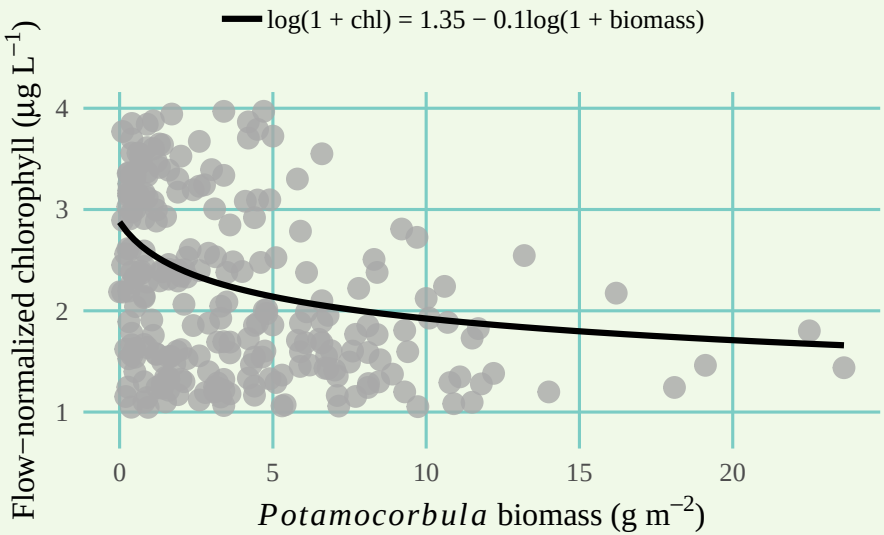

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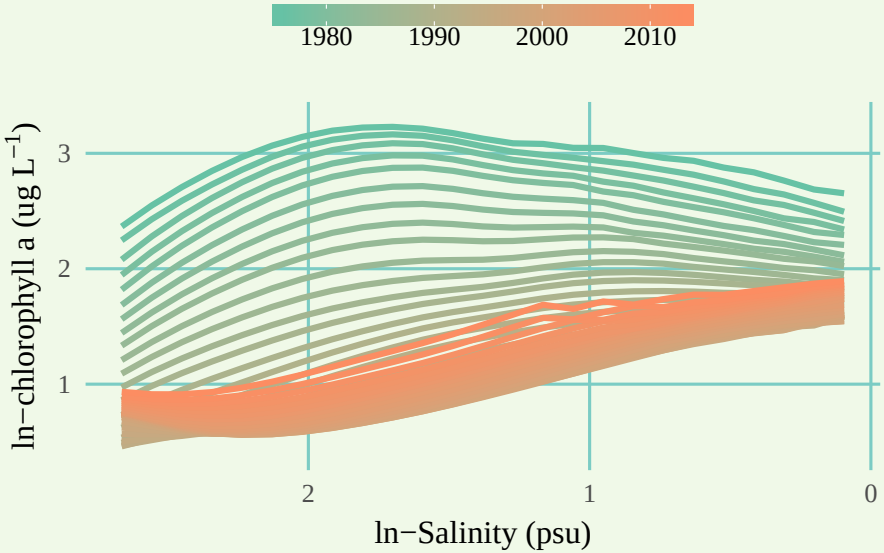

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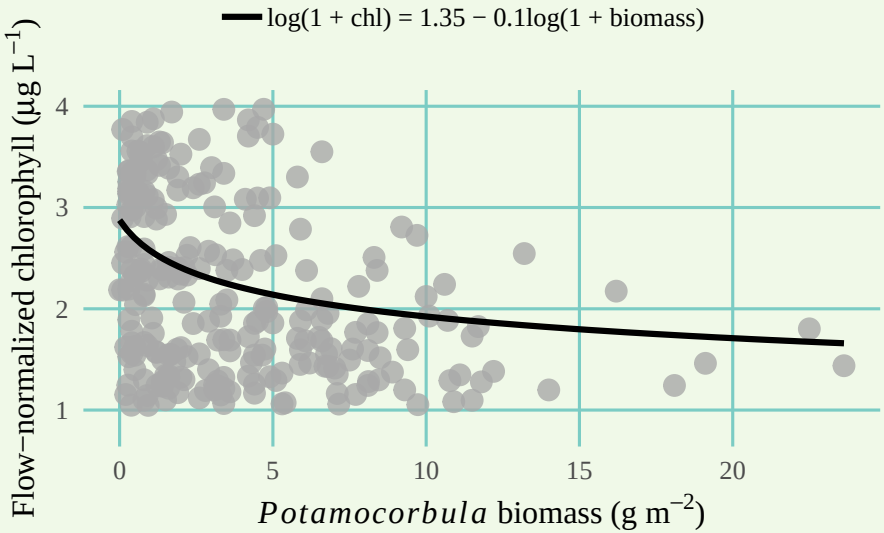

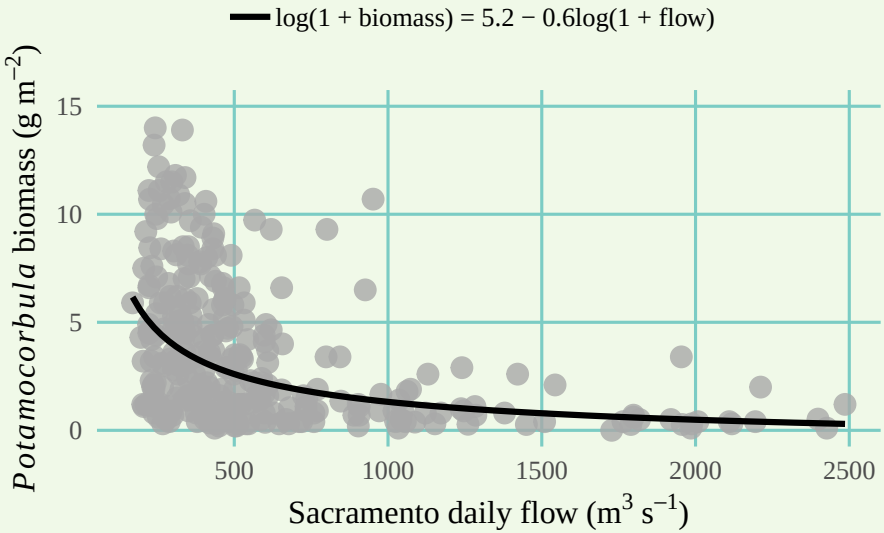

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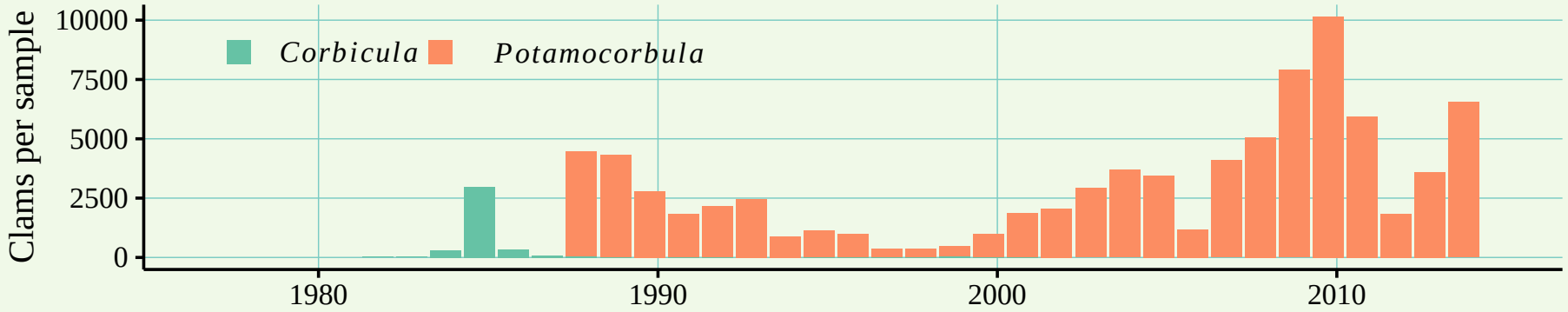

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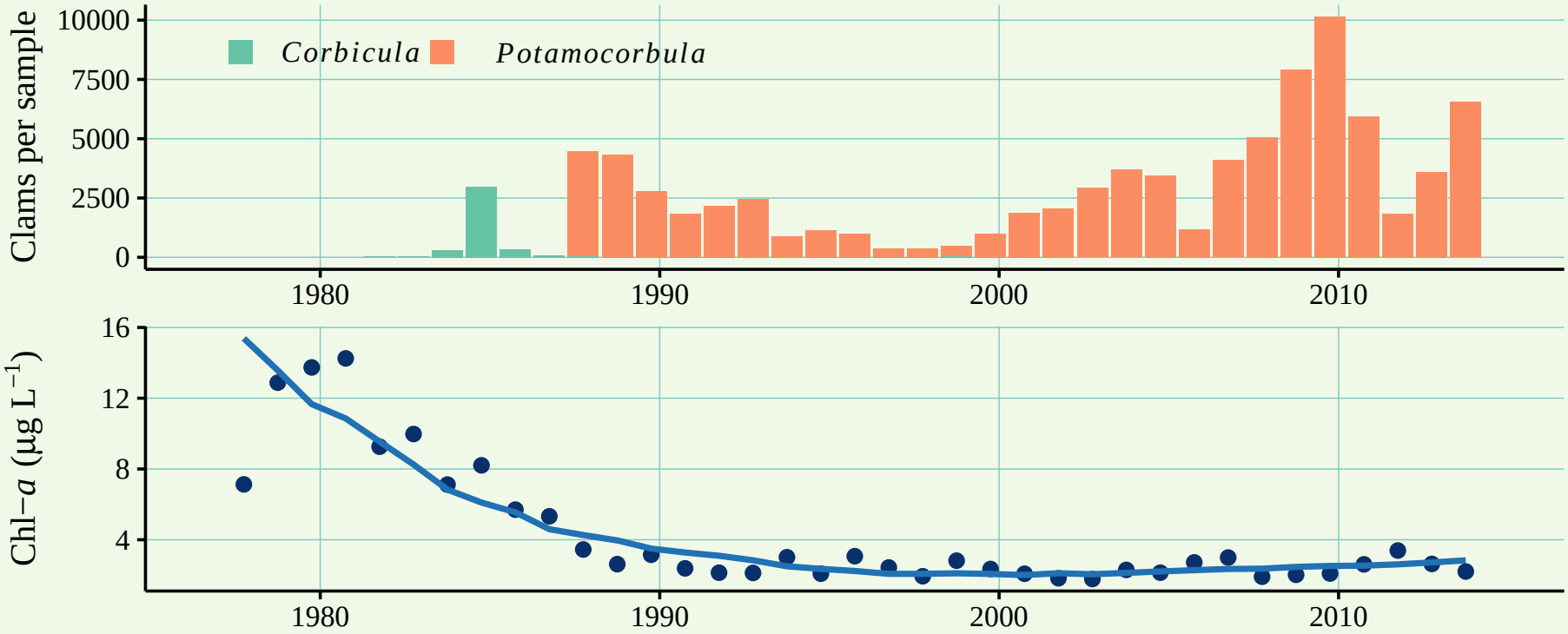

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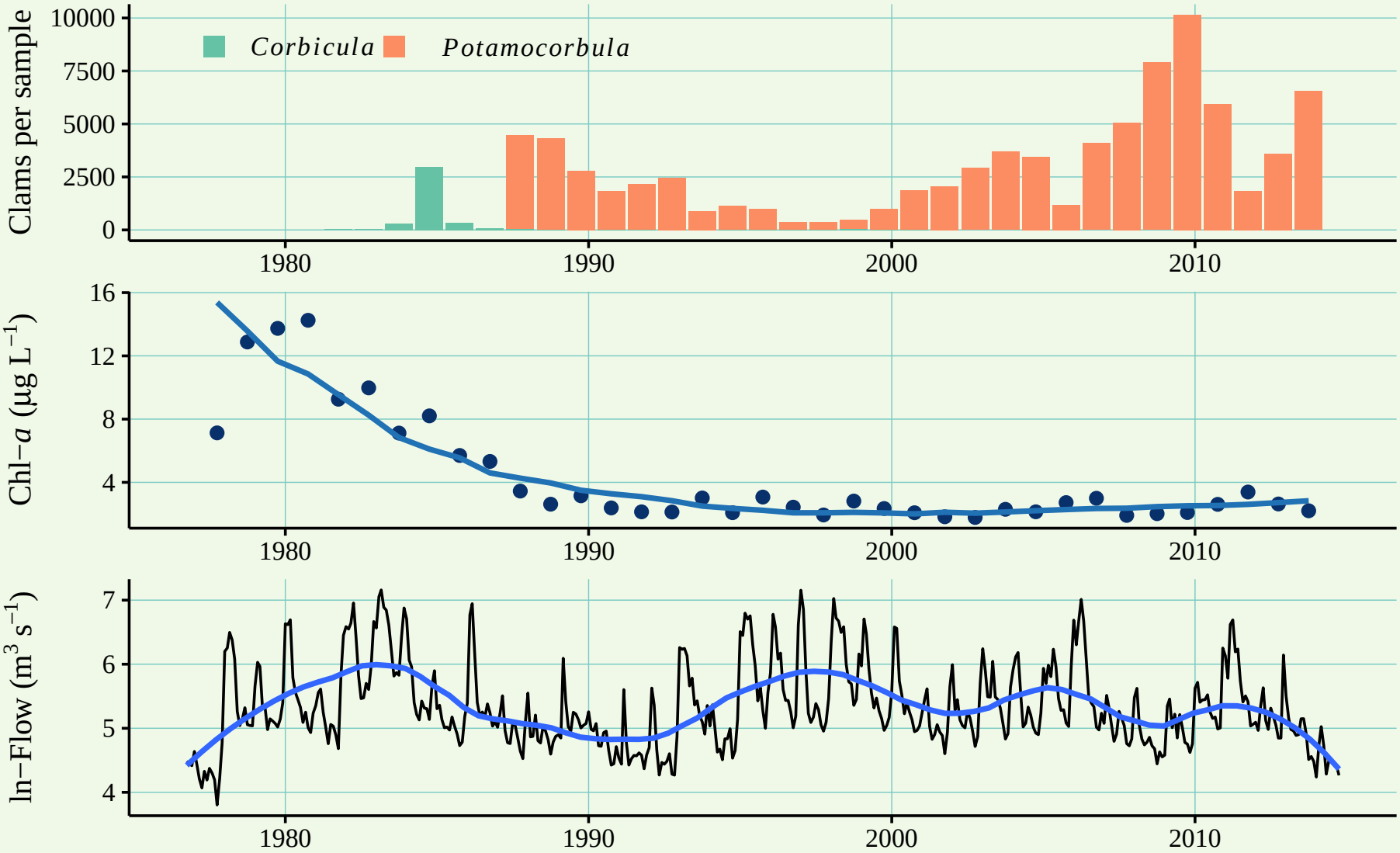

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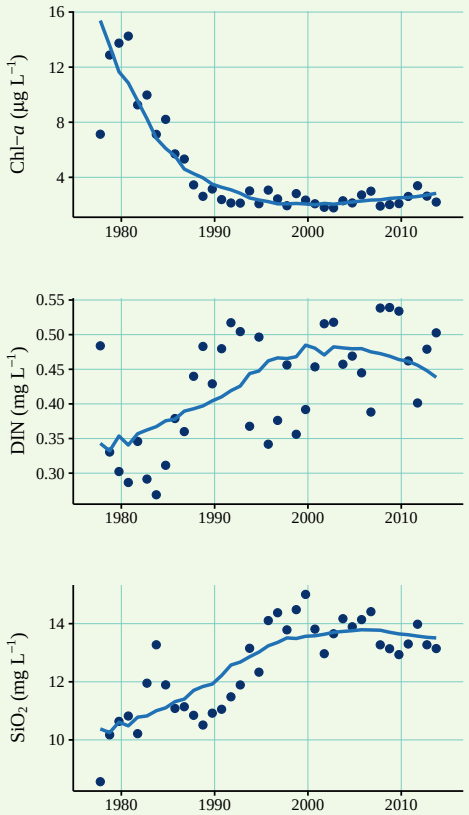

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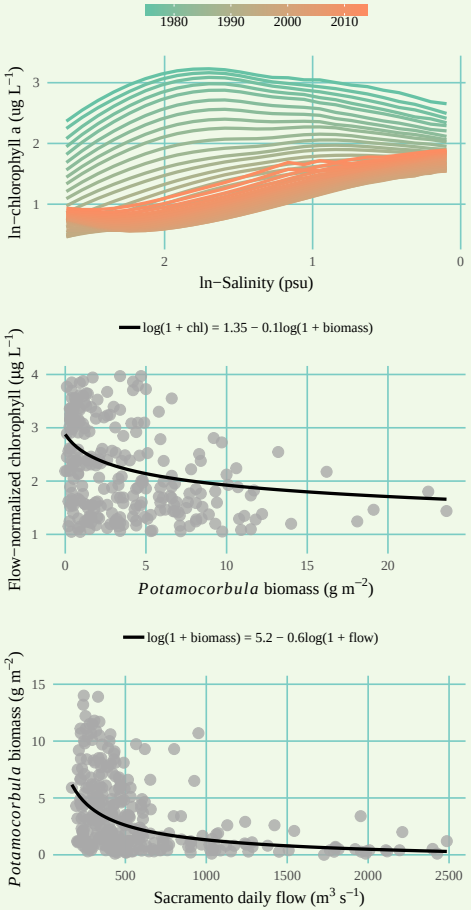

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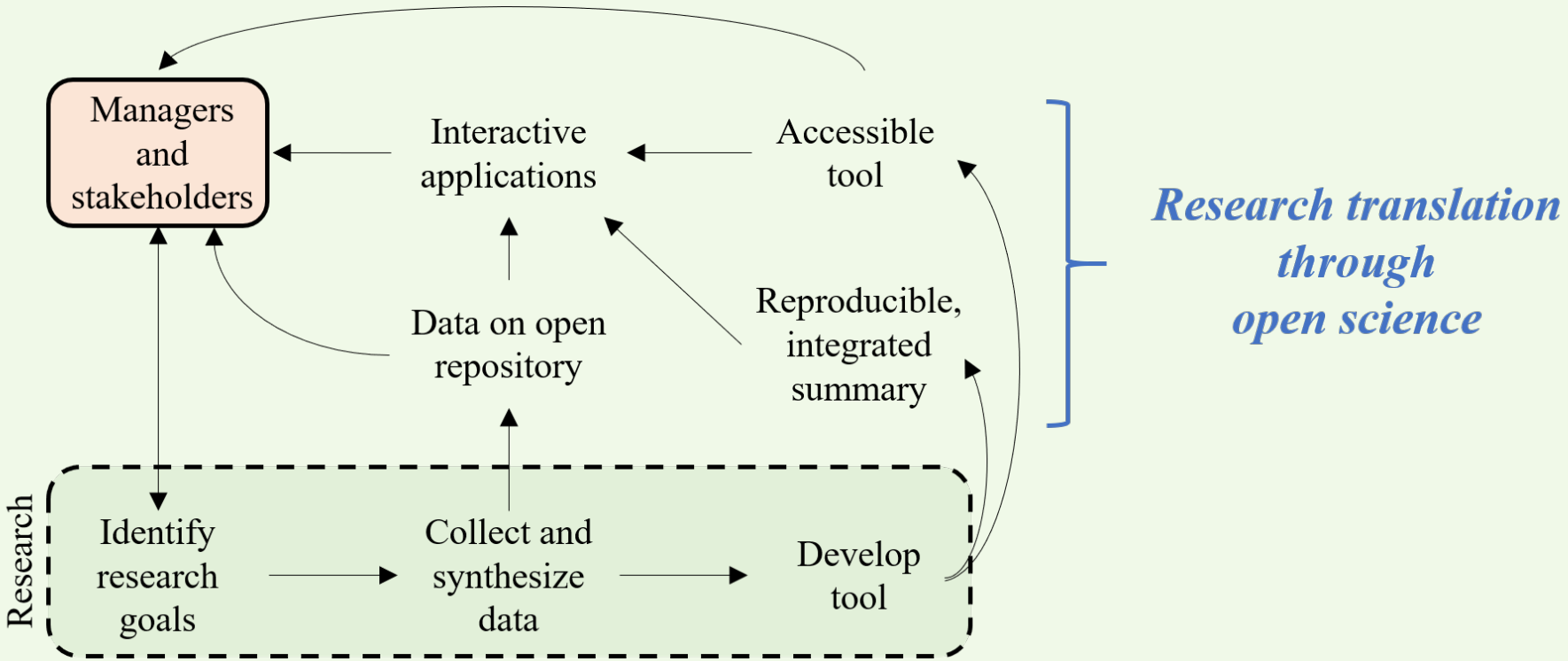
> "Don't give me another 500-page report, I won't read t."
>
> — Overheard at recent meeting

An Open Science paradigm

Bridge the research-management divide



An Open Science paradigm

Bridge the research-management divide

Make your methods accessible!

https://cran.r-project.org/web/packages/WRTDStidal/index.html

WRTDStidal: Weighted Regression for Water Quality Evaluation in Tidal Waters

An adaptation for estuaries (tidal waters) of weighted regression on time, discharge, and season to evaluate trends in water quality time series.

Version:	1.1.1
Depends:	R (≥ 3.1.2), ggplot2
Imports:	caret, dplyr, fields, foreach, forecast, gridExtra, lubridate, purrr, quantreg, RColorBrewer, survival, tidyr
Suggests:	doParallel, grDevices, magrittr
Published:	2018-07-16
Author:	Marcus W. Beck [aut, cre]
Maintainer:	Marcus W. Beck <marcusb at sccwrp.org>
BugReports:	https://github.com/fawda123/wtreg_for_estuaries/issues
License:	CC0
NeedsCompilation:	no
In views:	Hydrology
CRAN checks:	WRTDStidal results

Downloads:

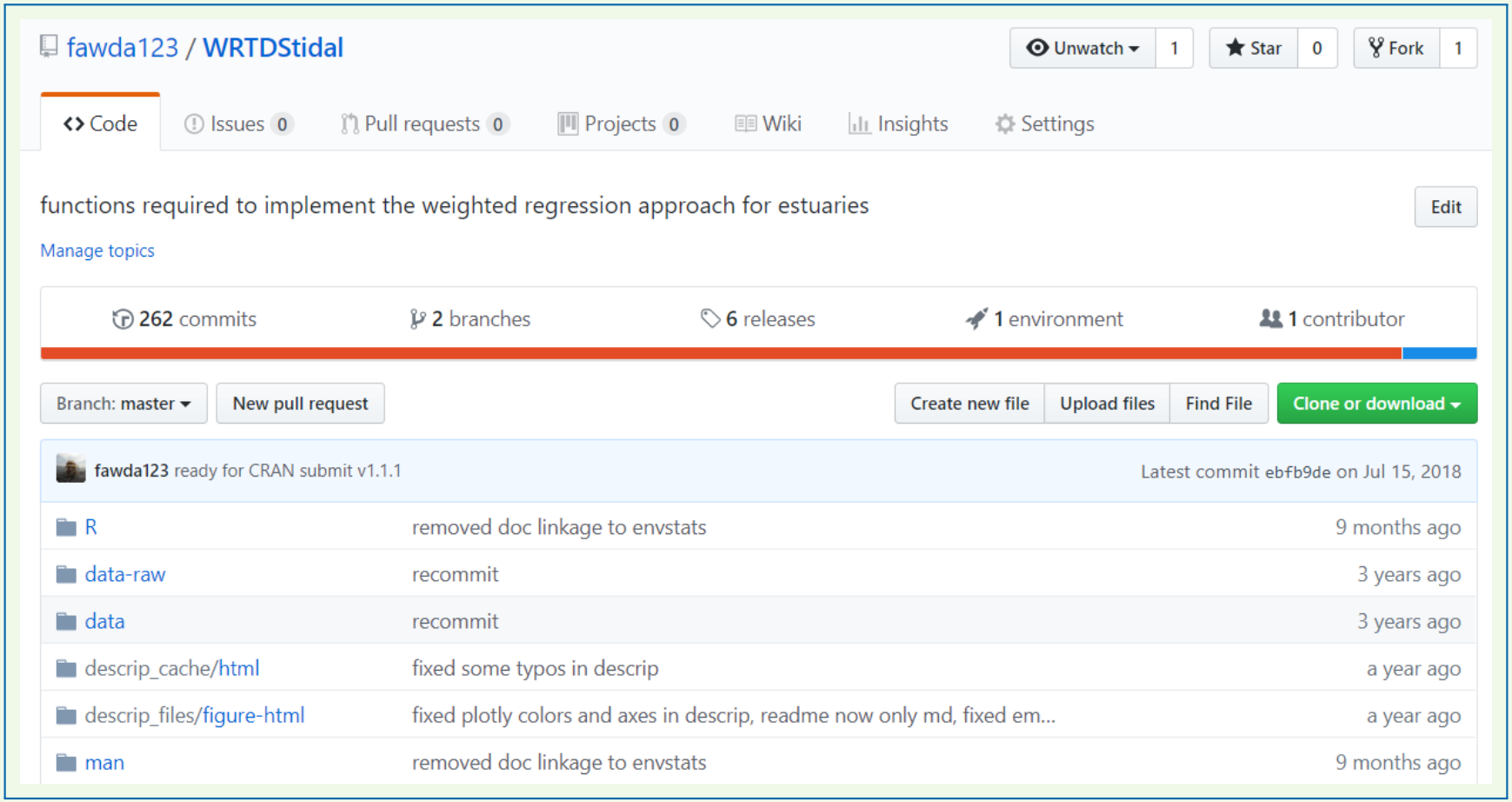
Reference manual:	WRTDStidal.pdf
Package source:	WRTDStidal_1.1.1.tar.gz
Windows binaries:	r-devel: WRTDStidal_1.1.1.zip, r-release: WRTDStidal_1.1.1.zip, r-oldrel: WRTDStidal_1.1.1.zip
OS X binaries:	r-release: WRTDStidal_1.1.1.tgz, r-oldrel: WRTDStidal_1.1.1.tgz
Old sources:	WRTDStidal archive

An Open Science paradigm

Bridge the research-management divide

Make your methods transparent!

`https://github.com/fawda123/WRTDStidal`



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Communicate your results!

https://beckmw.shinyapps.io/sf_trends/

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Communicate your results!

https://sccwrp.shinyapps.io/sfbaytrends/

GAM evaluation - SF South Bay

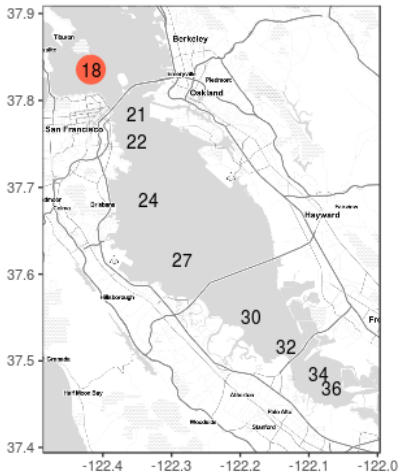
Exploratory plots

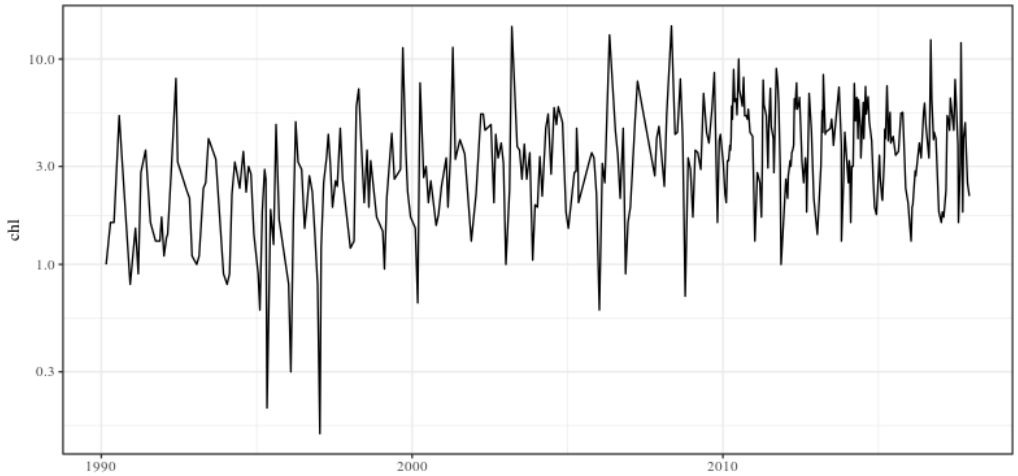
The following plots show the raw data for all monitoring stations and parameters in South Bay, 1990 - 2017. Select the parameter, plot type (total time series, by year, or by month), and variable transformation. The year and month plots are aggregated boxplots of all observations at a station for each selected time period. The variable transformation can be used to show the observations in arithmetic or logarithmic space.

Choose station: 18

Choose plot type: tot

Log-space: TRUE





Conclusions

Lessons for data scientists

Science (and data science) is a tool that is a means to an end...
...it is not an end in itself

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Lessons for data scientists

Science (and data science) is a tool that is a means to an end...
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How do you use your products to reach those that need it?

- Use relevant methods within the scope of your question
- Strive for transparency, reproducibility, and accessibility
- Use open source tools with vibrant user communities
- Be a champion within your institution to promote open science

Acknowledgments and contact info:

Research staff and employees at USEPA Gulf Ecology Division, San Francisco Estuary Institute, Southern California Coastal Water Research Project

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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`
Manuscript: `http://fawda123.github.io/sftrends_manu`

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