

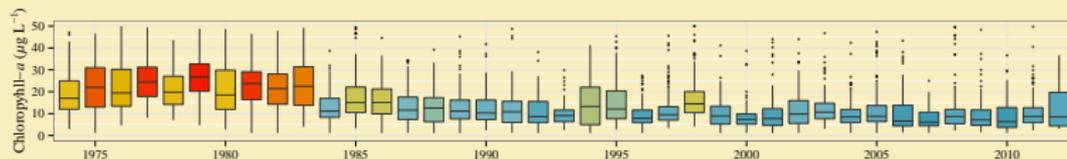
Adaptation of a Weighted Regression Approach to Evaluate Water Quality Trends in Tampa Bay, Florida

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The eutrophication paradigm

Challenges to restore and protect

Change over time is apparent – we have the data but often lack tools to unambiguously and quantitatively characterize

The eutrophication paradigm

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Data without models are chaos, but models without data are fantasy.

– *NWQMC 2014 plenary, R. Hirsch via [Nisbet et al., 2014]*

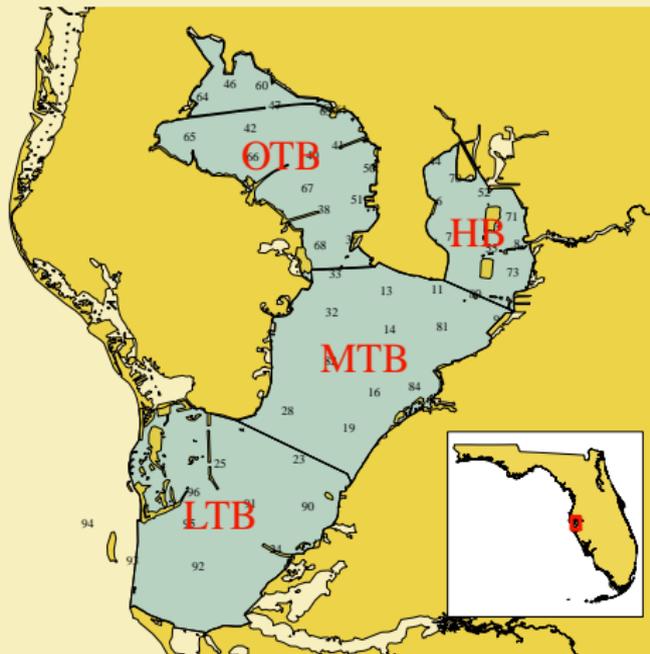
Tampa Bay, Florida

A model system

Second largest estuary on the Gulf Coast

- Four bay segments
- Monthly wq data at 50 stations from 1974 to present

Data from [TBEP (Tampa Bay Estuary Program), 2011]



Tampa Bay, Florida

A model system

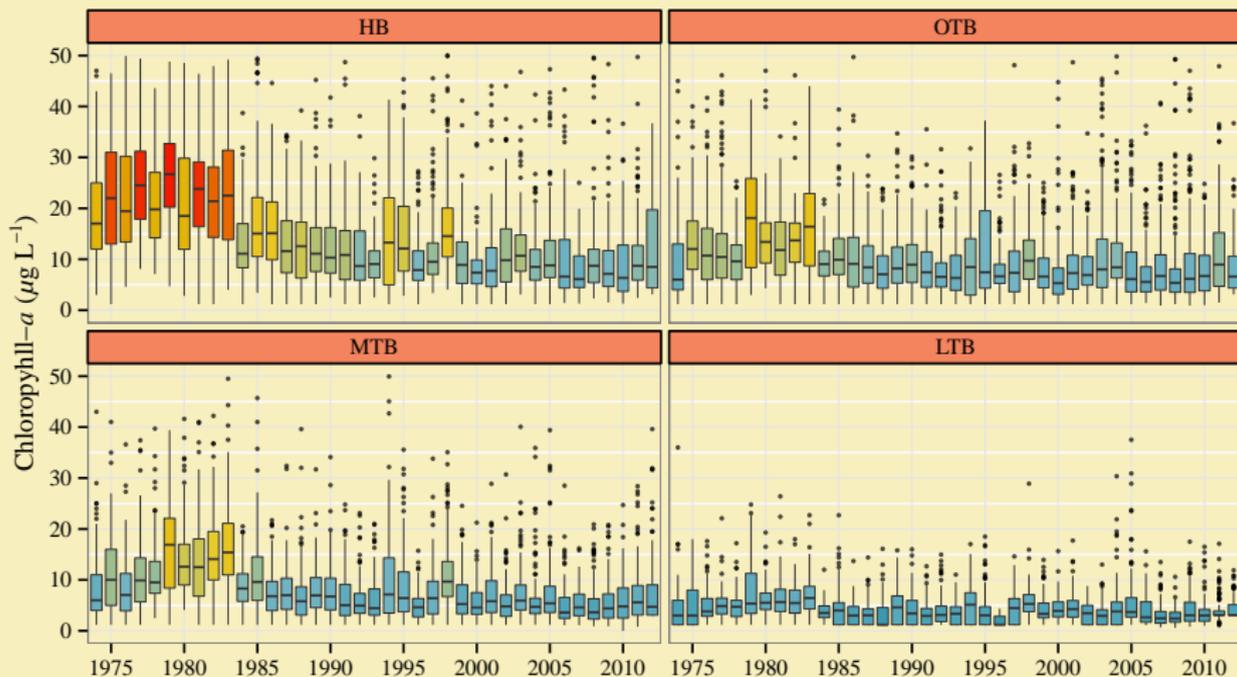


Figure: Annual trends in chlorophyll for each bay segment.

Tampa Bay, Florida

A model system

What affects our interpretation of chlorophyll response to nutrients?

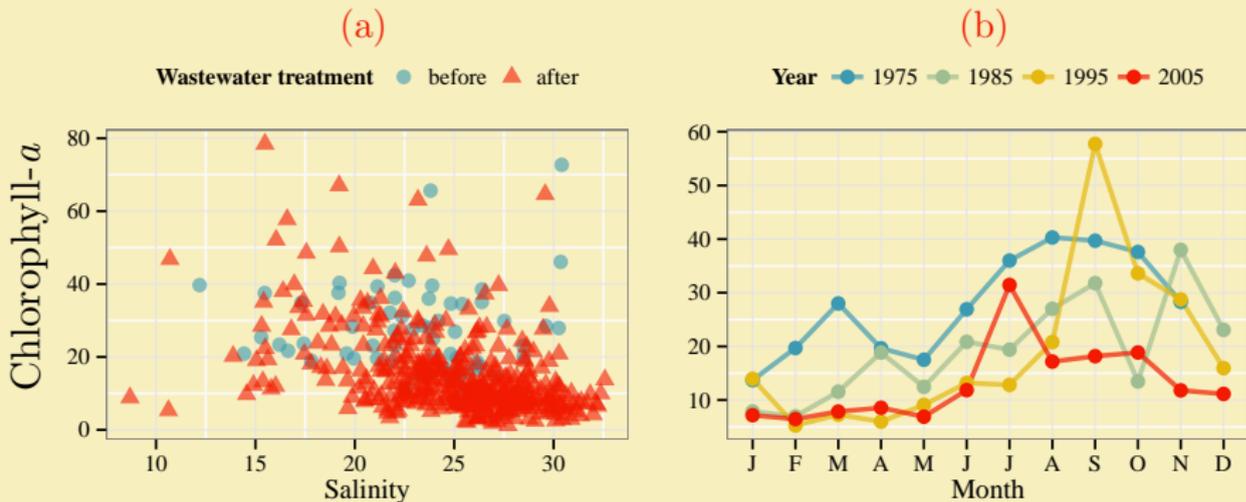


Figure: Variation in chlorophyll by (a) salinity, (b) season, and (b) year in Hillsborough Bay. Panel (a) shows the relationship between salinity and chlorophyll before and after wastewater treatment in 1979.

Analysis approach

Objectives and questions of management interest

Study objective

Adapt and apply nutrient response model for estuaries that leverages the descriptive capabilities of large datasets

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Questions of management concern – Can we...

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Adapt and apply nutrient response model for estuaries that leverages the descriptive capabilities of large datasets

Questions of management concern – Can we...

- ...provide a natural history of water quality that is temporally consistent with drivers of change?
- ...characterize changes in extreme events in addition to describing the mean response?
- ...improve our understanding of the nutrient-response paradigm in estuaries?

Weighted regression approach

Adaptation to estuaries

The **weighted regression (WRTDS)** model is being developed by USGS for pollutant modelling in fluvial systems [Hirsch et al., 2010]

Based on the idea that pollution concentration is a function of **time**, **discharge**, and **season**

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WRTDS functional form

$$\ln(c) = \beta_0 + \beta_1 t + \beta_2 \ln(Q) + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t) + \epsilon$$

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Logical extension to estuary eutrophication

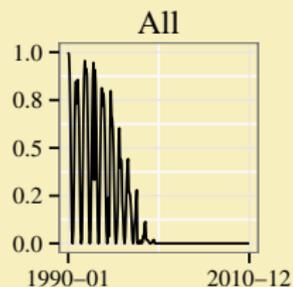
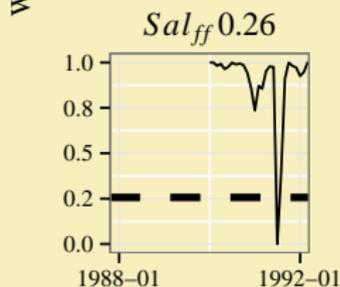
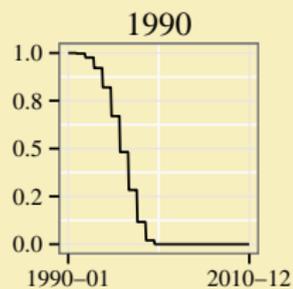
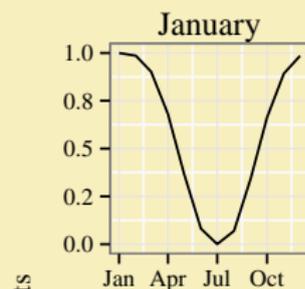
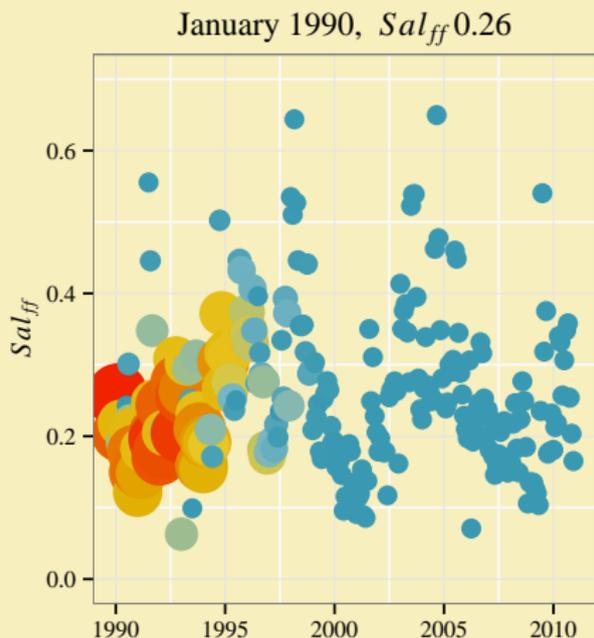
Adapted functional form

$$\ln(\text{Chl}) = \beta_0 + \beta_1 t + \beta_2 \text{Sal}_{ff} + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t) + \epsilon$$

Weighted regression approach

Adaptation to estuaries

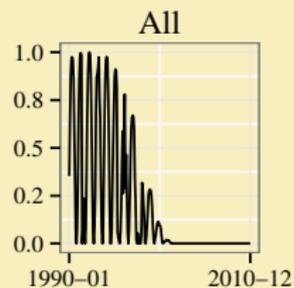
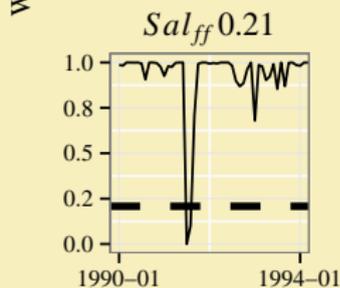
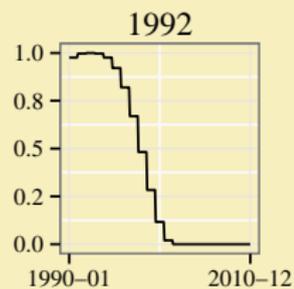
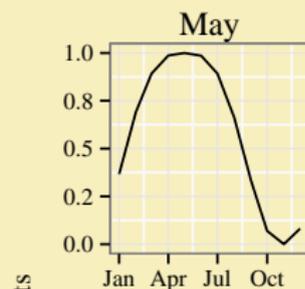
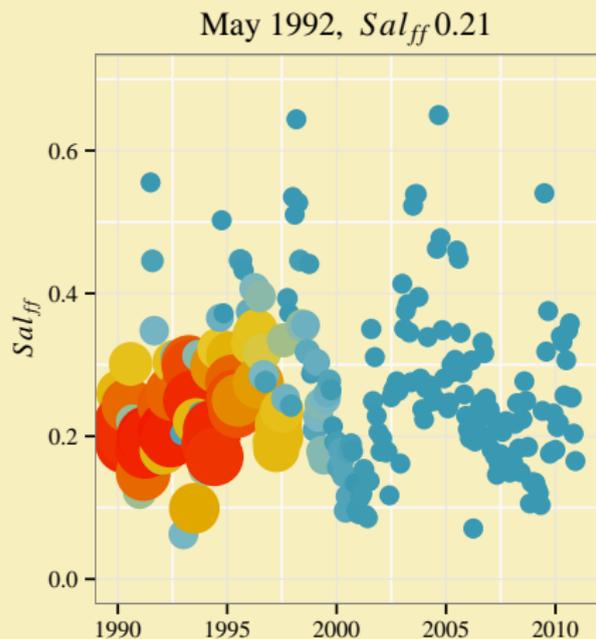
Flexibility through weighted parameterization - a moving window



Weighted regression approach

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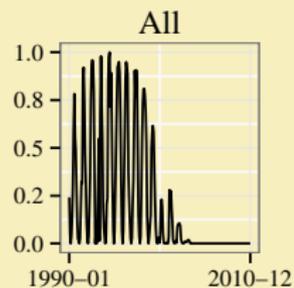
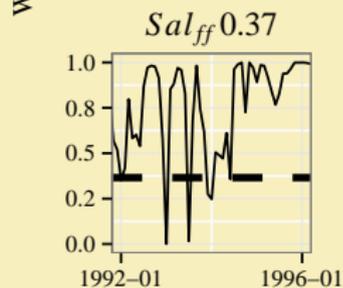
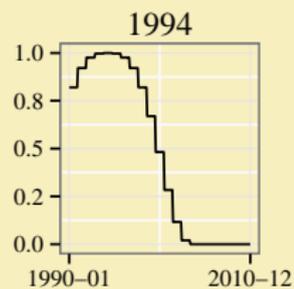
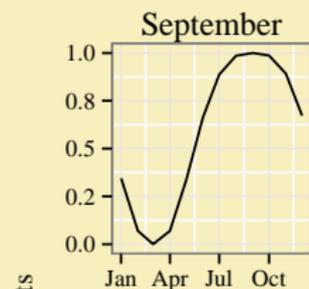
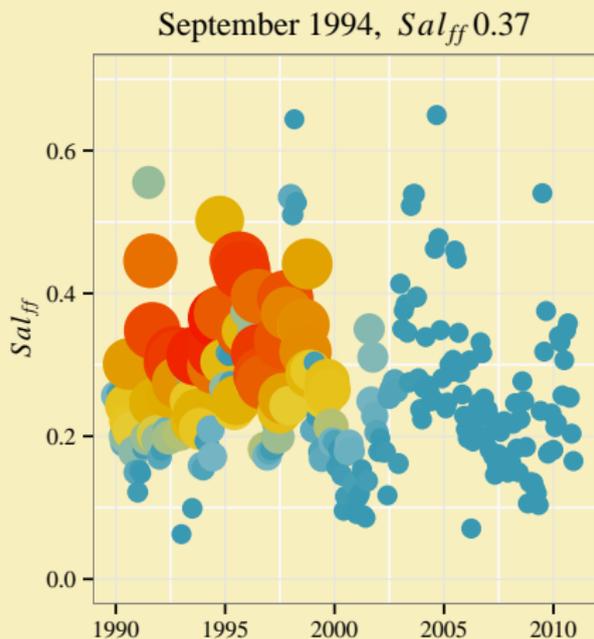
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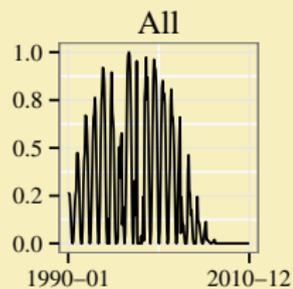
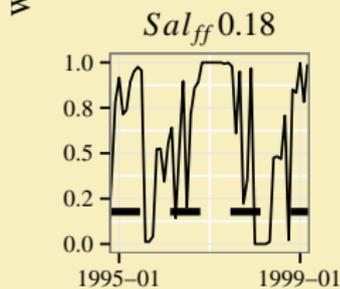
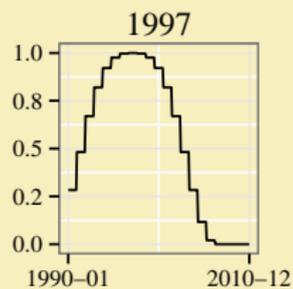
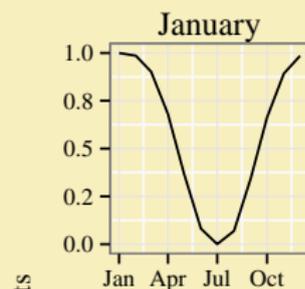
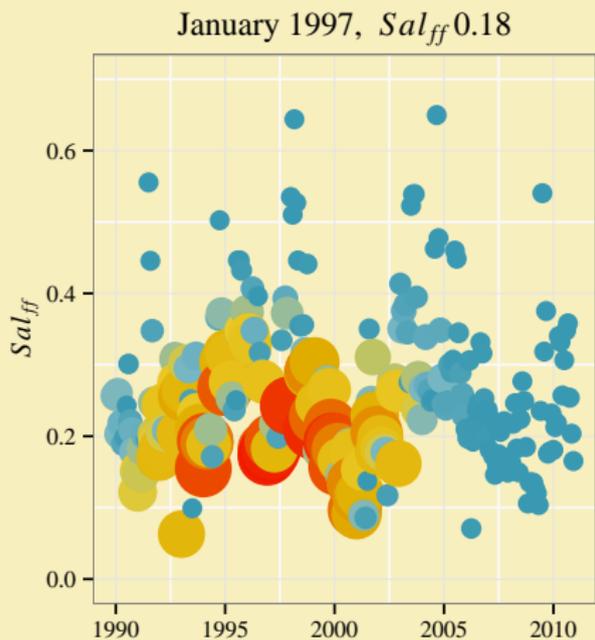
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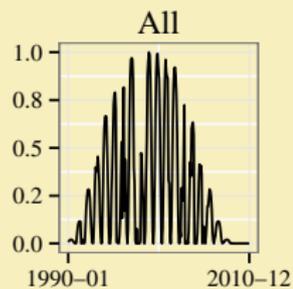
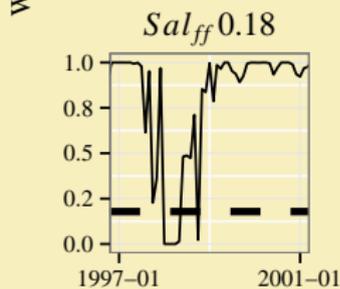
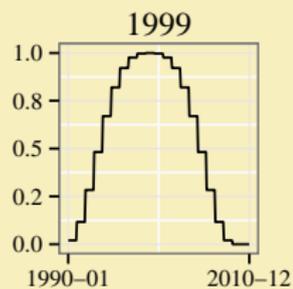
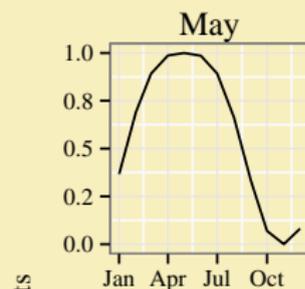
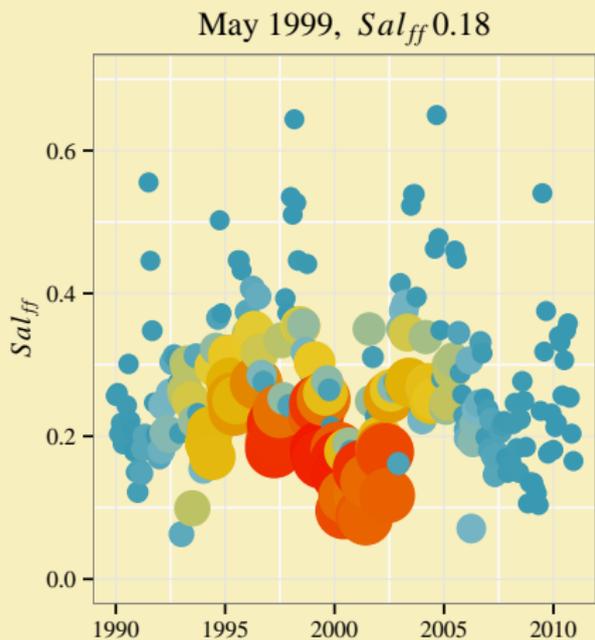
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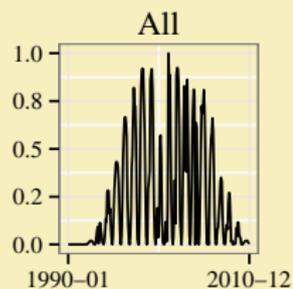
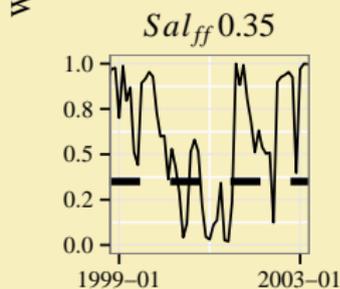
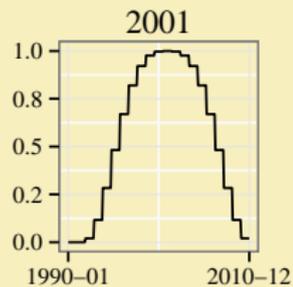
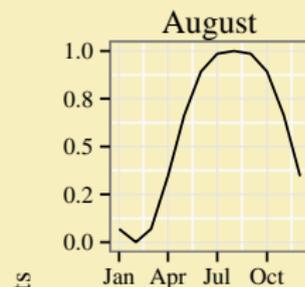
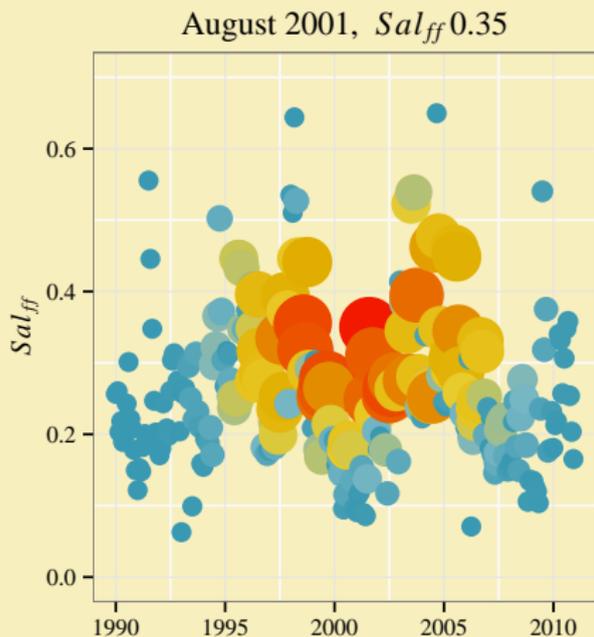
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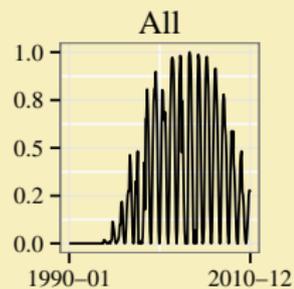
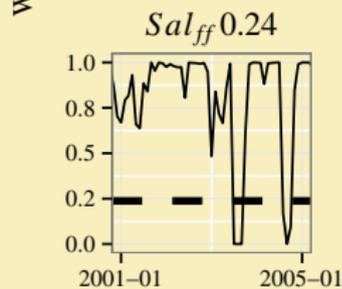
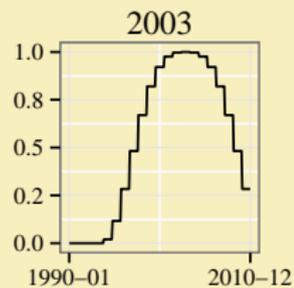
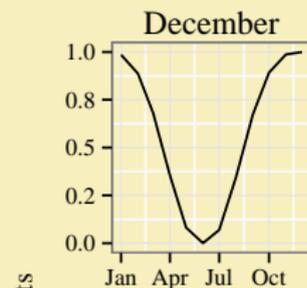
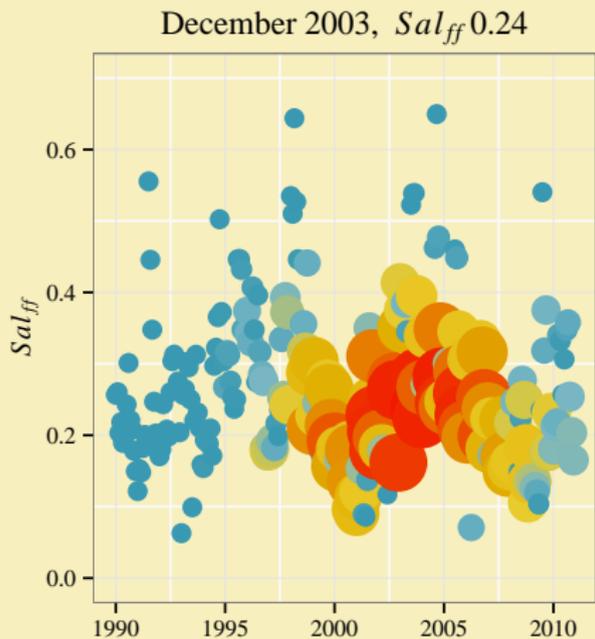
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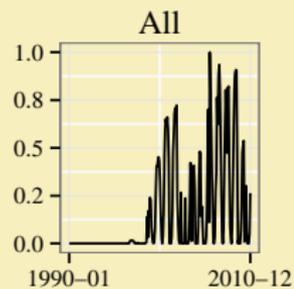
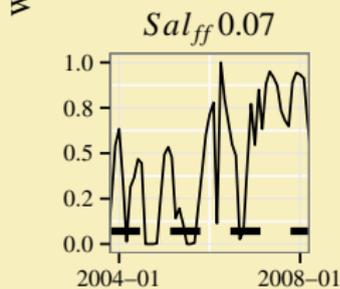
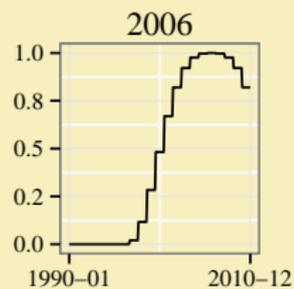
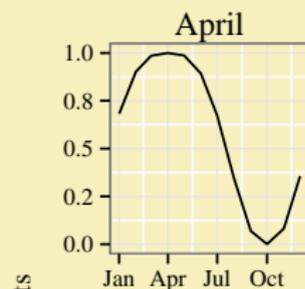
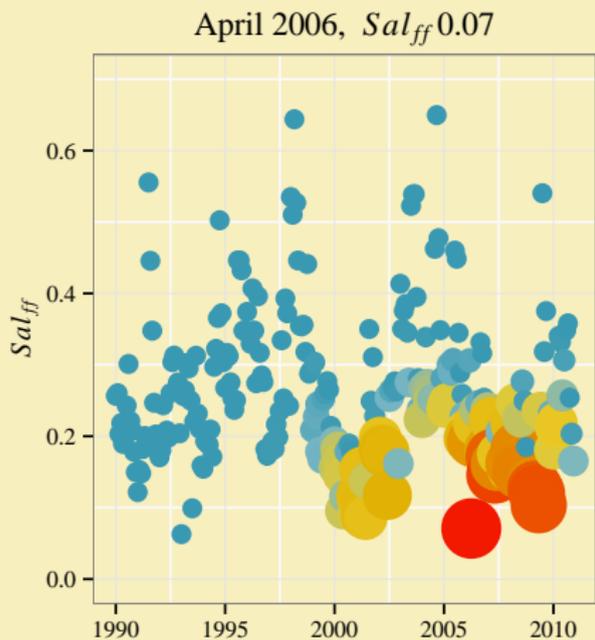
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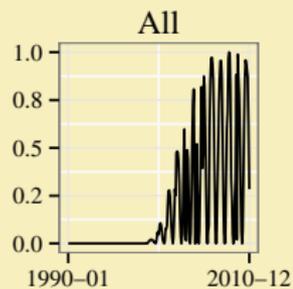
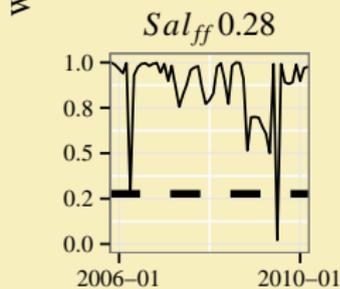
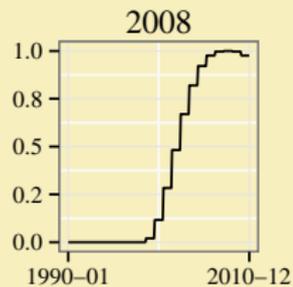
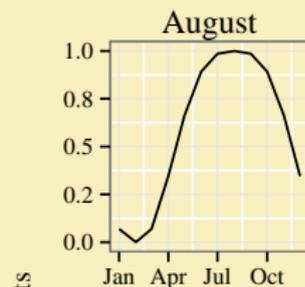
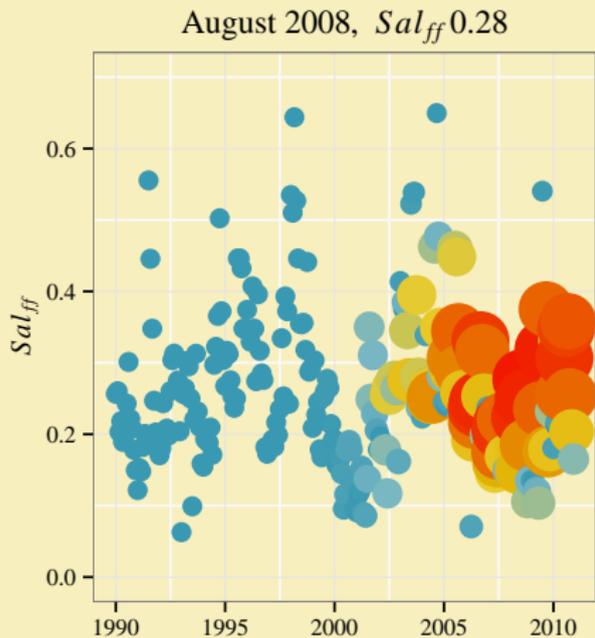
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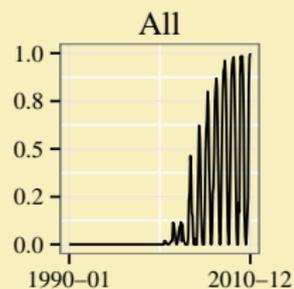
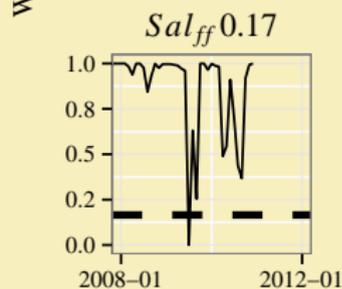
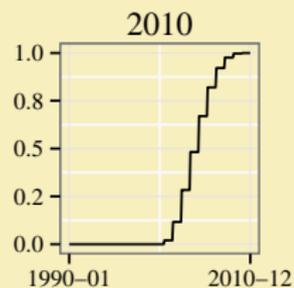
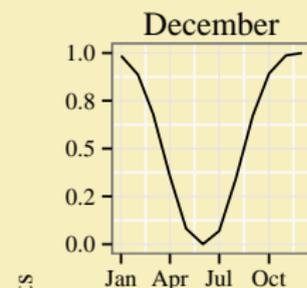
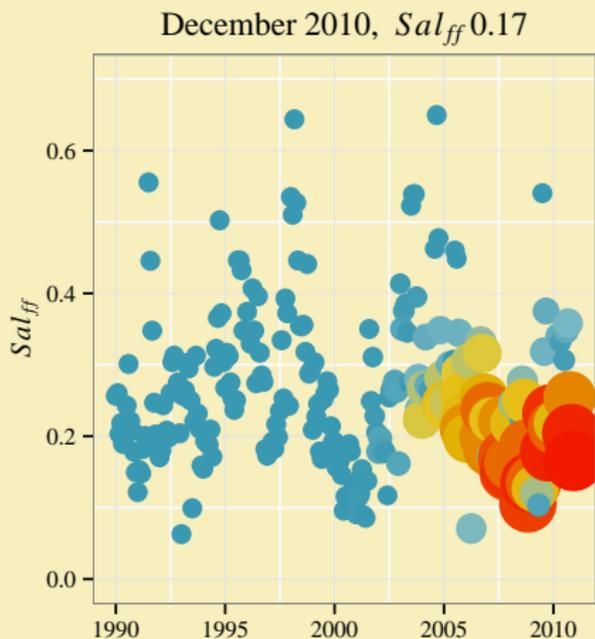
Flexibility through weighted parameterization - a moving window



Weighted regression approach

Adaptation to estuaries

Flexibility through weighted parameterization - a moving window



Weighted regression approach

Results for Tampa Bay

Provides internally consistent estimates of change independent of confounding variables – improved precision

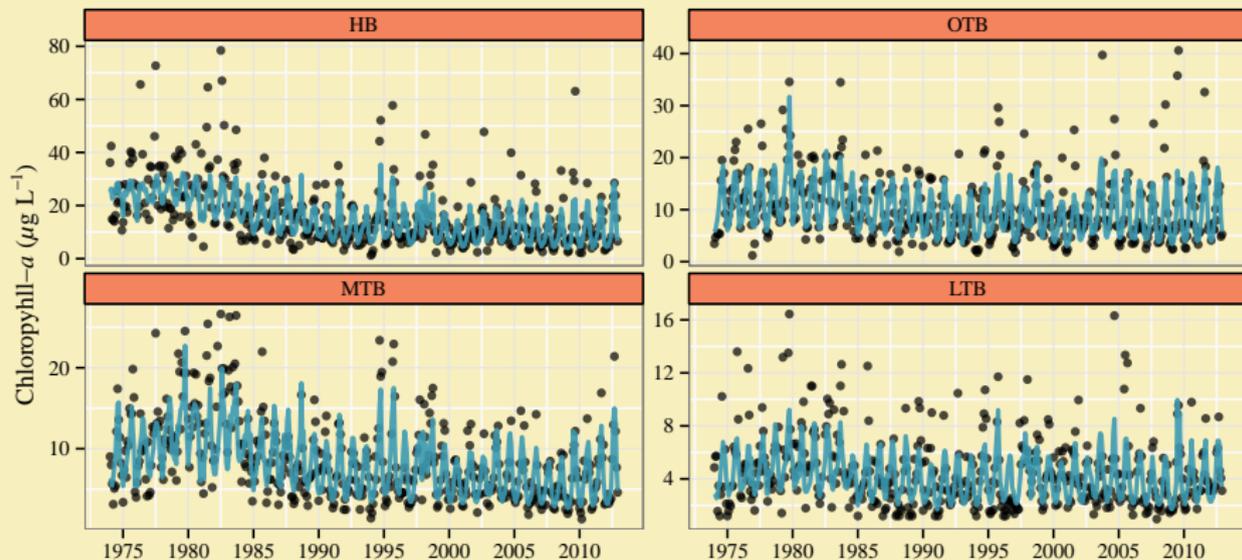


Figure: Predicted and observed monthly chlorophyll by segment.

Weighted regression approach

Results for Tampa Bay

Table: Fit statistics by bay segment comparing non-weighted and weighted regression.

Statistic	mean		0.9 τ		0.1 τ	
	Non-wtd	Wtd	Non-wtd	Wtd	Non-wtd	Wtd
HB						
R^2	0.54	0.66	0.32	0.47	0.31	0.45
$RMSE$	0.48	0.41	0.78	0.66	0.74	0.67
OTB						
R^2	0.54	0.65	0.29	0.45	0.34	0.47
$RMSE$	0.41	0.36	0.65	0.61	0.67	0.59
MTB						
R^2	0.60	0.71	0.34	0.51	0.38	0.51
$RMSE$	0.37	0.31	0.60	0.52	0.61	0.52
LTB						
R^2	0.40	0.51	0.26	0.37	0.18	0.34
$RMSE$	0.45	0.40	0.72	0.65	0.77	0.68

Weighted regression approach

Results for Tampa Bay

Results can also be normalized by predictors – salinity

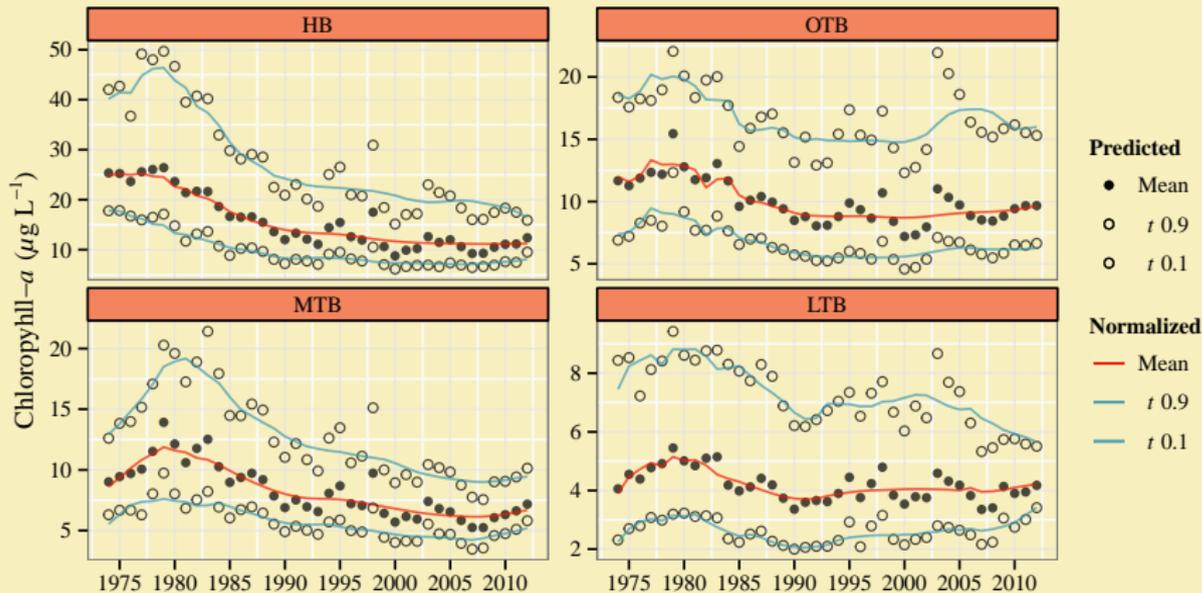


Figure: Predicted and salinity-normalized annual chlorophyll by segment.

Weighted regression approach

Conclusions for Tampa Bay

What new information is obtained from the results?

- Trends generally followed observed chlorophyll – but increased clarity in the description
- Mean response does not show the whole picture – frequency of ‘high’ or ‘low’ chlorophyll events could be changing

Weighted regression approach

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How can this information be used?

- More detailed evaluation of trends allows greater insight into drivers of change
- The model parameters show us a picture...

Weighted regression approach

Conclusions for Tampa Bay

Changes in model parameters help generate hypotheses

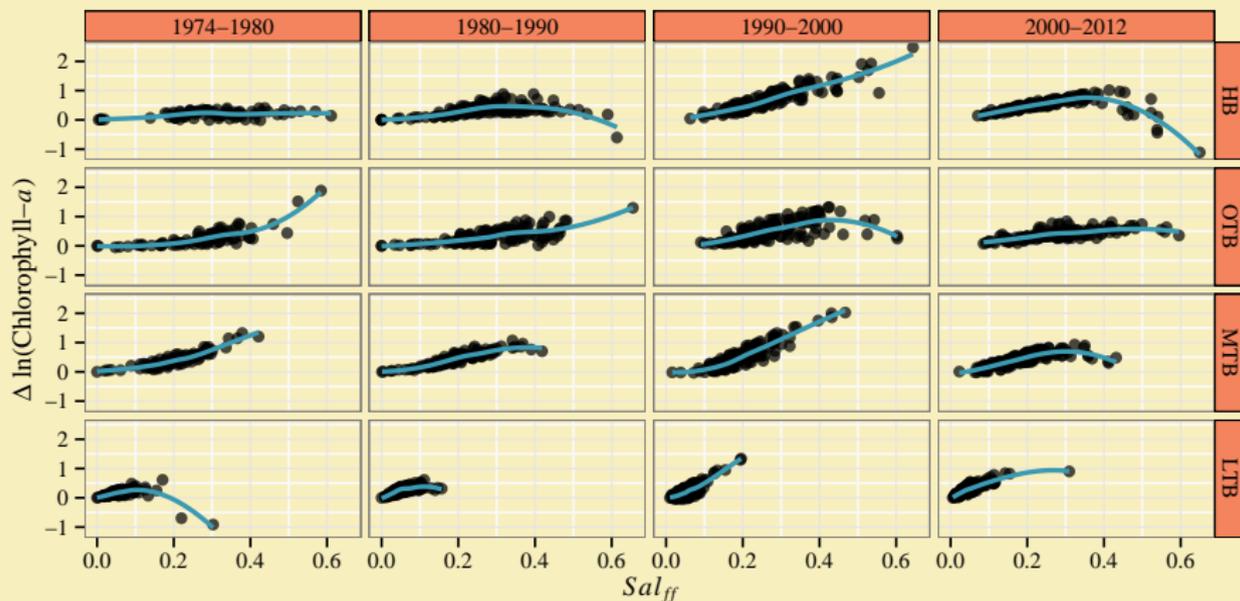


Figure: Relationship between chlorophyll and salinity by decade and bay segment. Y-axis is expected changes in chlorophyll for a given salinity.

Acknowledgments:

Research staff and employees at USEPA Gulf Ecology Division

Field staff and data managers at Hillsborough County Environmental Protection Commission

Tampa Bay Estuary Program for supporting data

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Wes Anderson Zissou color theme borrowed and adapted from github.com/karthik



Image credit: Stephen Morrow



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