Adaptation of WRTDS to characterize chlorophyll trends in tidal waters

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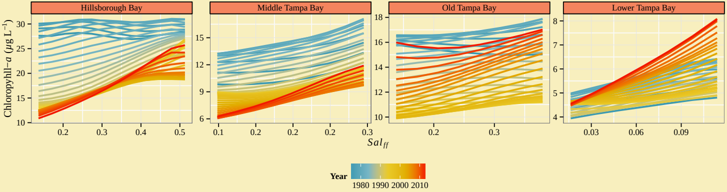
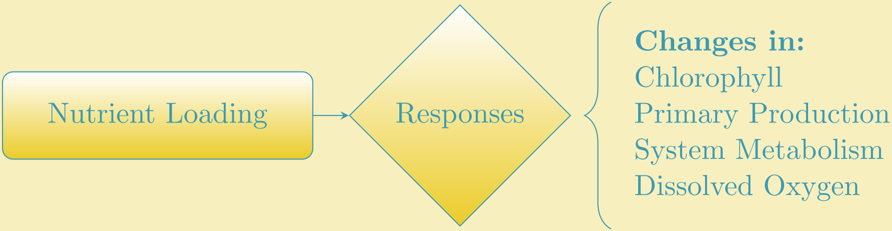


The eutrophication paradigm

Research and management in coastal waters

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

– [Nixon, 1995]



Adapted from [Cloern, 2001]

The eutrophication paradigm

Research and management in coastal waters

Human inputs can greatly accelarate eutrophication... particularly for coastal waters

- Depletion of bottom water dissolved oxygen [Diaz and Rosenberg, 2008]
- Increase in frequency/severity of harmful algal blooms [Glibert et al., 2013]
- Reduction or extirpation of seagrass communities [Tomasko et al., 2005]
- Propogated effects to upper trophic levels [Powers et al., 2005]

There are challenges to providing guidance...

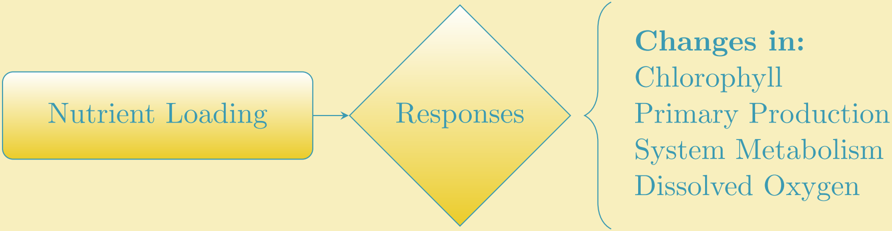
Challenge 1: We don't fully understand eutrophication processes

> *There are good reasons to believe that eutrophication will, in the near future, become a hazard in marine coastal areas in many parts of the world.*
>
> – *[Rosenberg, 1985]*

The eutrophication paradigm

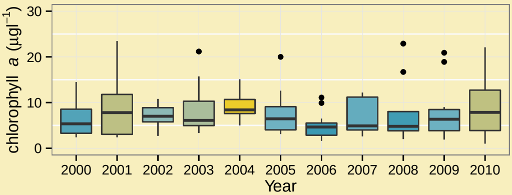
Challenges for criteria development

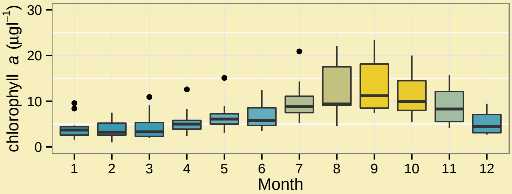
Our conceptual model for understanding the effects of nutrient pollution is adopted from freshwater sciences.

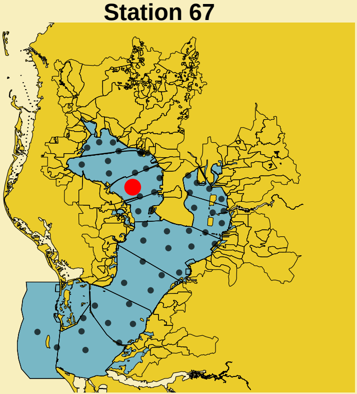


Adapted from [Cloern, 2001]

Spatial and temporal variation in chlorophyll for Tampa Bay







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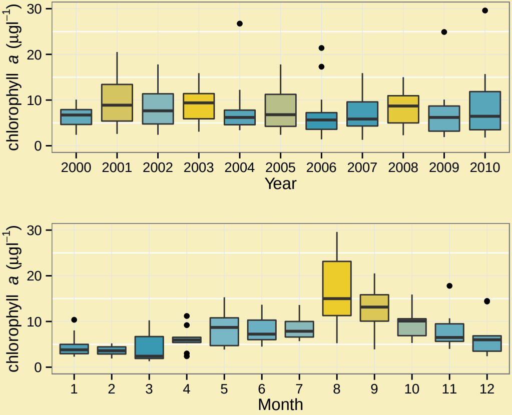

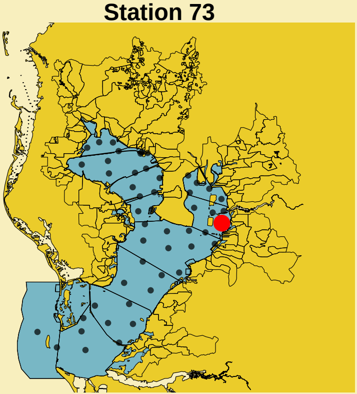

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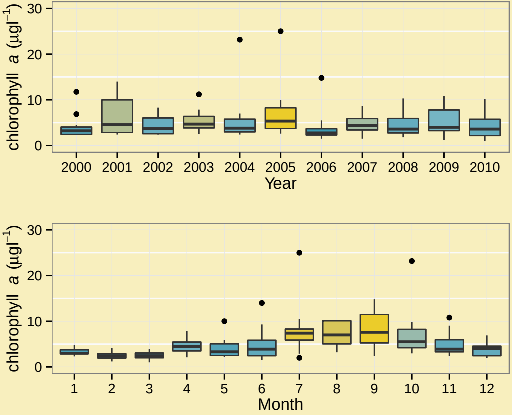

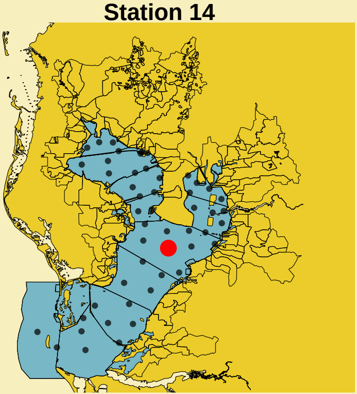

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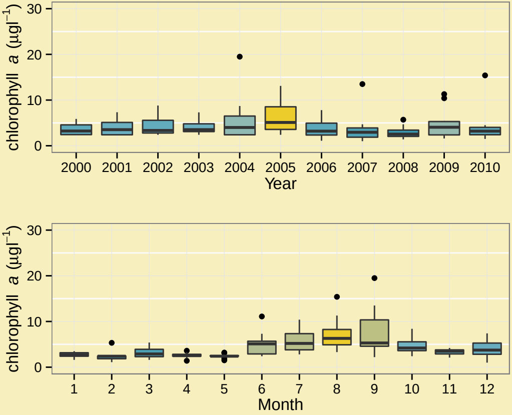

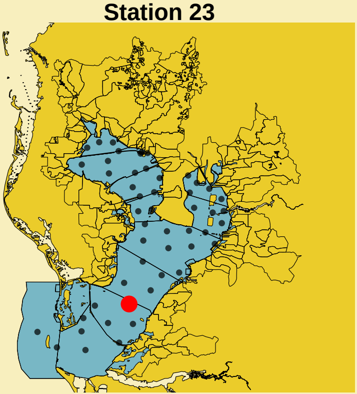

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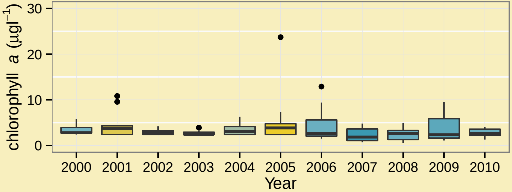
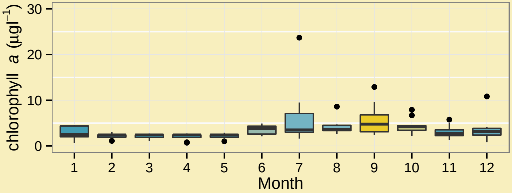
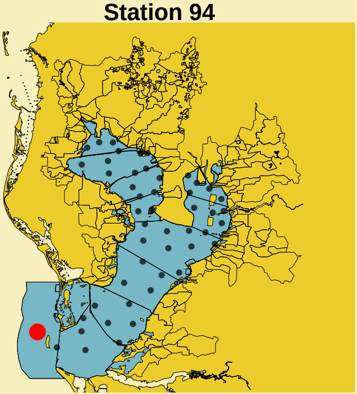






Challenge 2: We have the data but often lack tools to unambiguously and quantitatively characterize

> *Data without models are chaos, but models without data are fantasy.*
>
> *– NWQMC 2014 plenary, R. Hirsch via [Nisbet et al., 2014]*

Study objective

Adapt and apply nutrient response model for estuaries that leverages the descriptive capabilities of large datasets [Beck and Hagy, in review]

Questions of management concern – Can we...

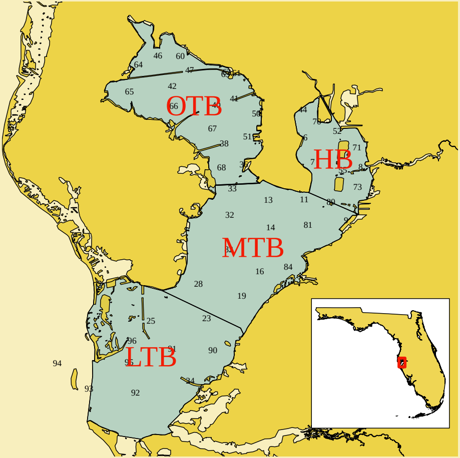
- ...provide a natural history of water quality that is temporally consistent with drivers of change?
- ...characterize changes in extreme events in addition to describing the mean response?
- ...improve our understanding of the nutrient-response paradigm in estuaries?

Tampa Bay

Understanding chlorophyll response to eutrophication

- Four bay segments
- Monthly wq data at 50 stations from 1974 to present
- Longitudinal profile of nutrient load and salinity

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



Tampa Bay

Understanding chlorophyll response to eutrophication

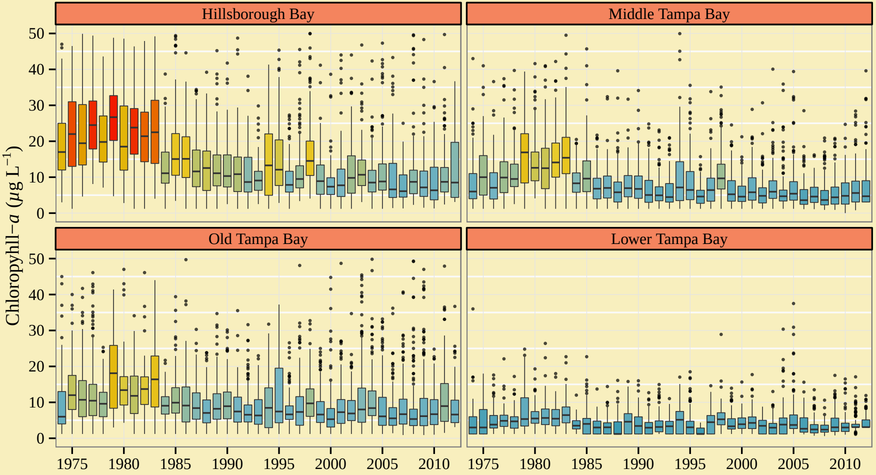


Figure : Annual trends in chlorophyll for each bay segment.

What affects our interpretation of chlorophyll response to nutrients?

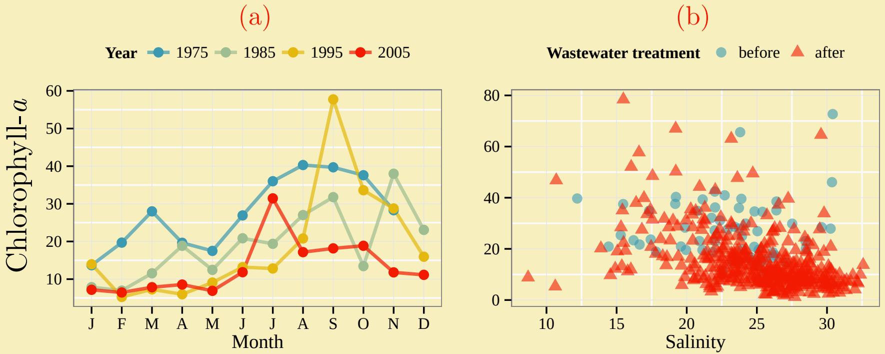


Figure : Variation in chlorophyll by (a) time and (b) salinity and management in Hillsborough Bay. Panel (a) is colored before and after wastewater treatment in 1979.

Tampa Bay

Understanding chlorophyll response to eutrophication

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

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

Problem: We want to see if management has an effect on reducing pollutant load over time, but pollutant load varies with discharge.

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

Adaptation: Can this approach be used to evaluate chlorophyll trends in Tampa Bay?

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

WRTDS functional form

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

Logical extension to estuary eutrophication

Adapted functional form

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

How does weighted regression work?

Tampa Bay

Understanding chlorophyll response to eutrophication

This gives us improved predictions of chlorophyll dynamics...

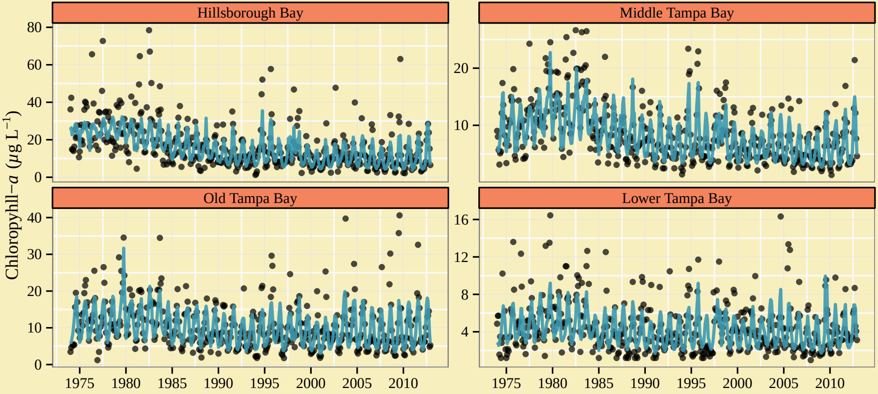


Figure : Predicted and observed monthly chlorophyll by segment.

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

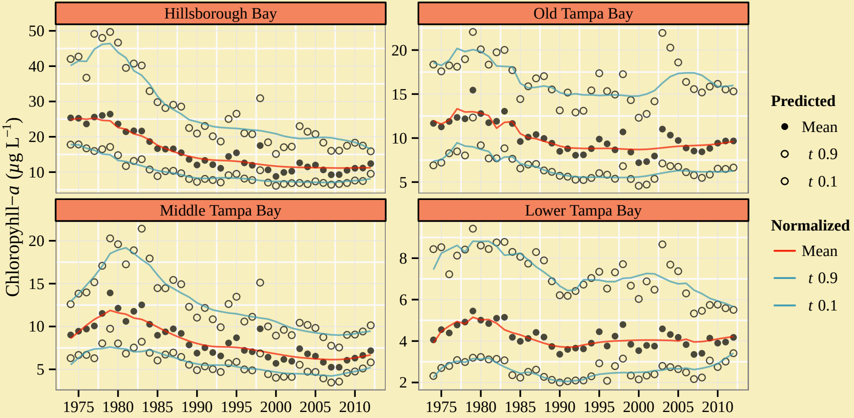
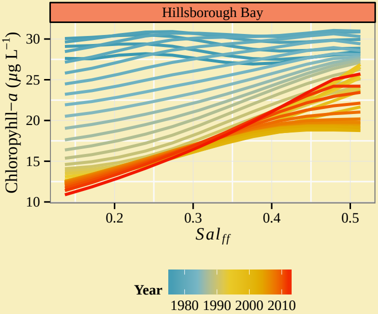


Figure : Predicted and salinity-normalized annual chlorophyll by segment.

Because the model is dynamic, we have parameters describing the relationship of chlorophyll with other factors specific to different time periods



- Early period (blue) - point-sources
- Late period (red) - non-point sources
- Chlorophyll shows increasing response to freshwater input in recent years

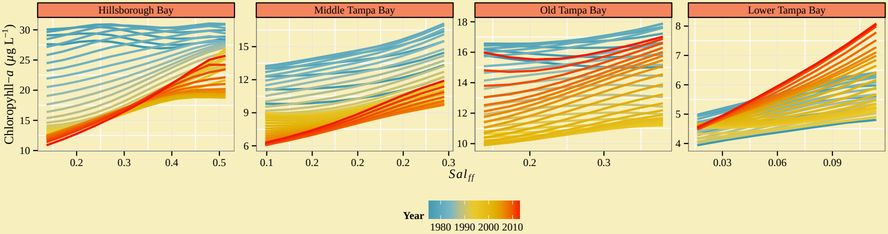
Tampa Bay

Understanding chlorophyll response to eutrophication

What does this mean for Tampa Bay and elsewhere?

- Predictions followed observed chlorophyll – but increased clarity in the description
- More detailed evaluation of trends allows greater insight into drivers of change

The model parameters show us a picture...

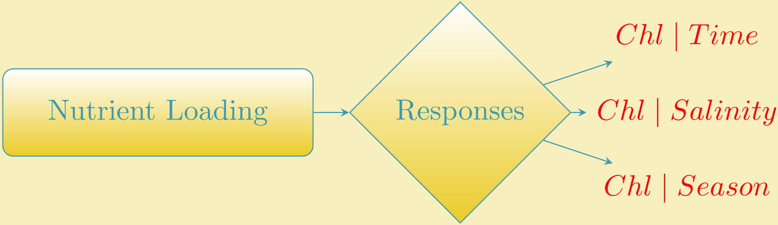


Weighted regression approach
General conclusions

Adaptation of freshwater modelling approaches to estuaries suggests improved interpretation of trends is possible

A data-driven process for investigational analysis - can't ask 'why' without the 'what'

Results can improve our understanding of the coastal model of eutrophication



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

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Blog: beckmw.wordpress.com/

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