The search for truth in numbers: Quantitative approaches for evaluating trends in water quality data

Marcus W. Beck

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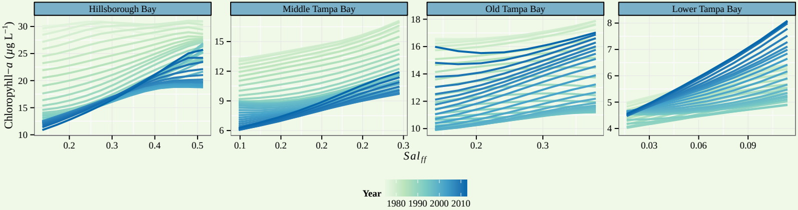
Oct. 24, 2014



The eutrophication paradigm

Research and management in coastal waters

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

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Adapted from [Cloern, 2001]

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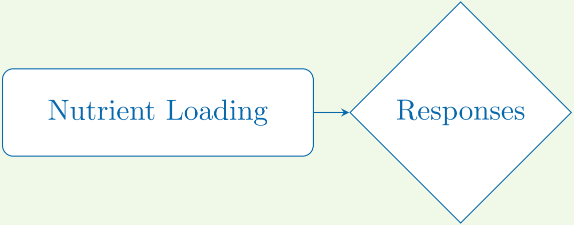

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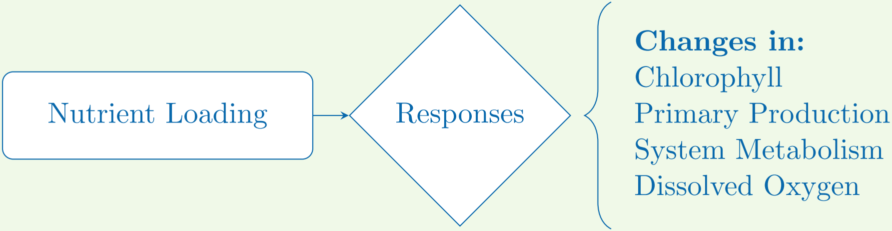

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- Propogated effects to upper trophic levels [Powers et al., 2005]

Red tide off northwest Florida may hit economy

Jason Dearen, Associated Press *2:40 p.m. CDT September 18, 2014*

(Photo: Bruce Graner)

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CLEARWATER –

It's like Florida's version of The Blob. Slow moving glops of toxic algae in the northeast Gulf of Mexico are killing sea turtles, sharks and fish, and threatening the waters and beaches that fuel the region's economy.

Known as "red tide," this particular strain called Karenia brevis is present almost every year off Florida, but large blooms can be particularly devastating. Right now, the algae is collecting in an area about 60 miles wide and 100 miles long, about 5 to 15 miles off St. Petersburg in the south and stretching north to Florida's Big Bend, where the peninsula ends and the Panhandle begins.

MORE STORIES

Forum faces economic realities

Oct. 14, 2014, 8:40 p.m.

Businessman buys block in downtown Pensacola

Oct. 14, 2014, 8:27 p.m.

The eutrophication paradigm

Research and management in coastal waters

Water Quality Act Amendments of 1972

- Federal mandates to protect and restore the chemical, physical, and biological integrity of surface waters
- Protection and restoration requires criteria

The eutrophication paradigm

Research and management in coastal waters

Water Quality Act Amendments of 1972

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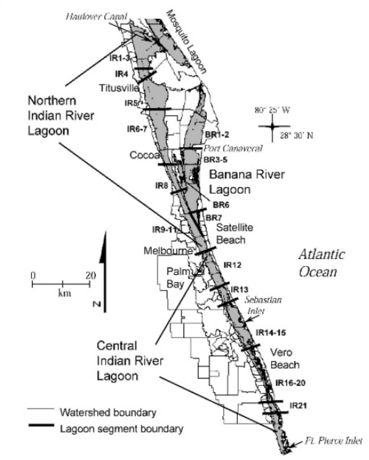
- Protection and restoration requires criteria

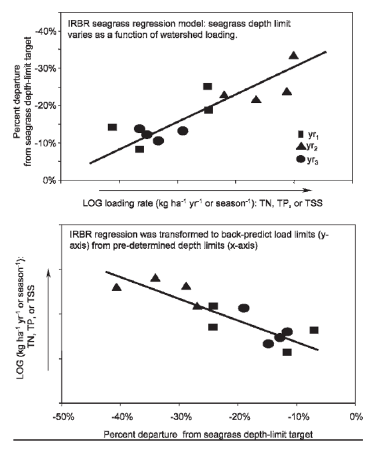
Numeric nutrient criteria

- The amounts of contaminants or pollutants that may be present without impairing aquatic life or human health
- E.g., nutrients limits for seagrass in Indian River Lagoon...

The eutrophication paradigm
Research and management in coastal waters

Nutrient limits using seagrass depth-limit targets [Steward and Green, 2007]





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Research and management in coastal waters

USEPA national strategy for the development of regional nutrient criteria

- Aid states' ability to control and reduce nutrient enrichments
- Responsibility of EPA to develop criteria guidance

[USEPA (US Environmental Protection Agency), 1998]

The eutrophication paradigm

Research and management in coastal waters

USEPA Gulf Ecology Division - guidance to Florida DEP and others on criteria development for estuaries

The eutrophication paradigm

Challenges for criteria development

There are challenges to providing guidance...

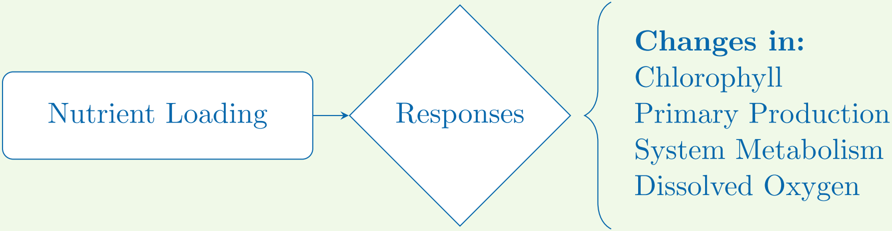
Challenge 1: We don't fully understand eutrophication processes

> *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.



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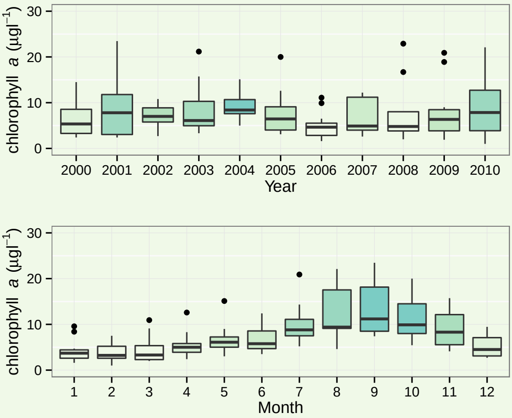
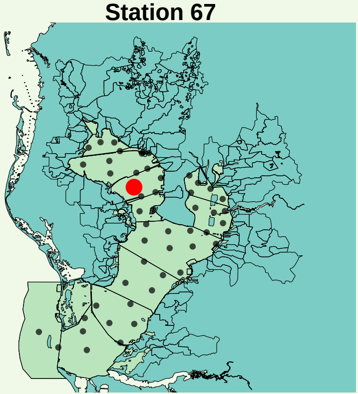
Spatial and temporal variation in chlorophyll for Tampa Bay





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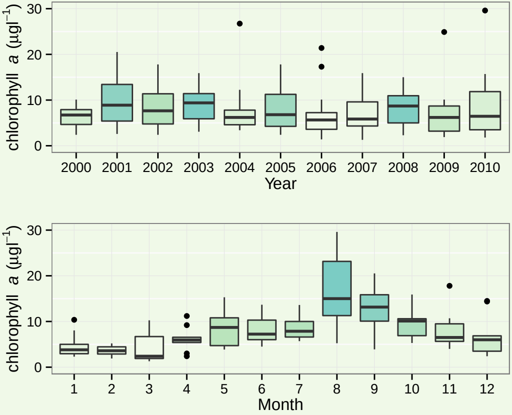

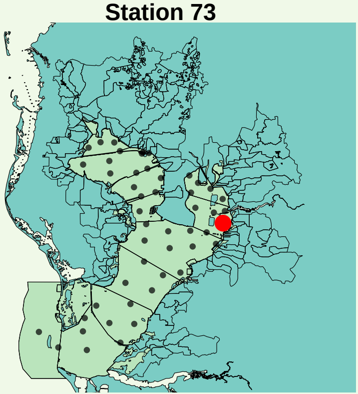

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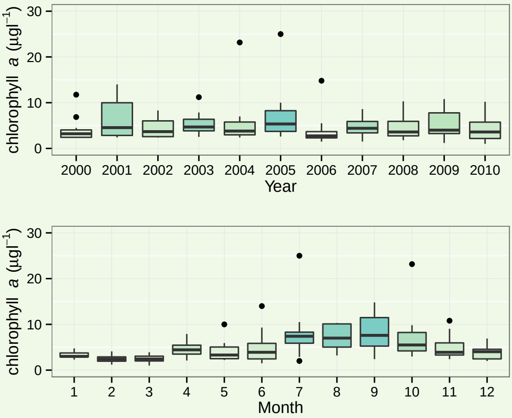

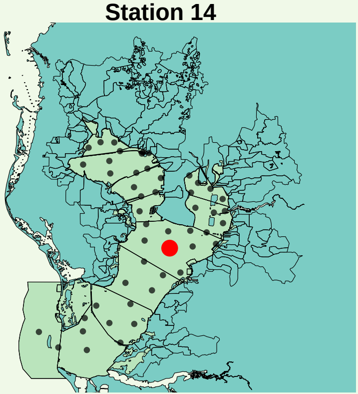

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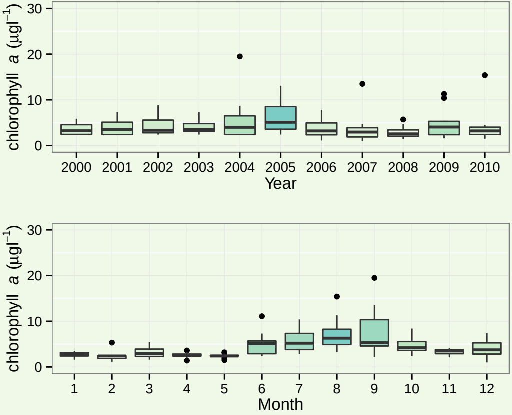

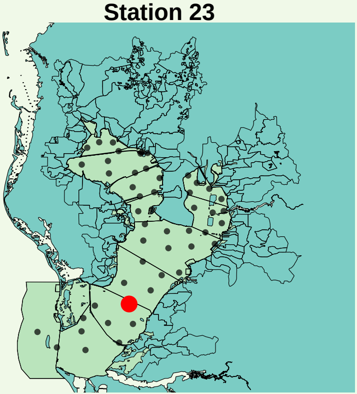

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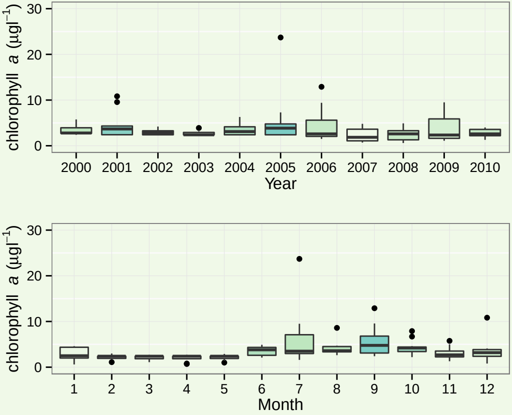

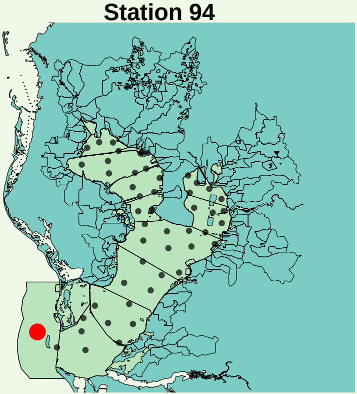

Challenge 2: We have the data but often lack tools to unambiguously and quantitatively characterize

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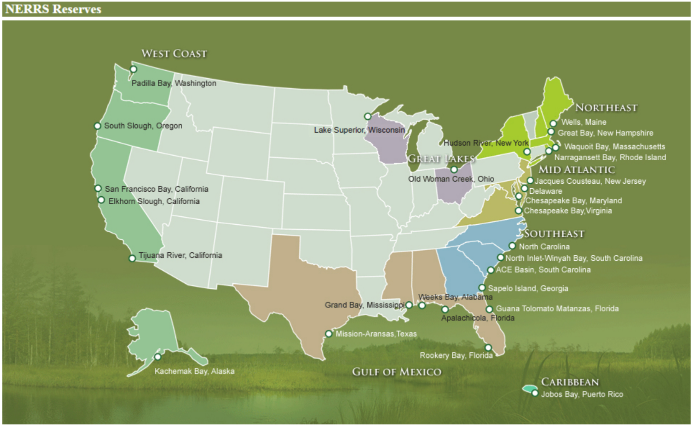
> *Data without models are chaos, but models without data are fantasy.*
>
> *– NWQMC 2014 plenary, R. Hirsch via [Nisbet et al., 2014]*

System Wide Monitoring Program, initiated in 1995 to provide continuous data at over 300 stations in 28 US estuaries



http://nerrs.noaa.gov/ReservesMap.aspx

The eutrophication paradigm

Challenges for criteria development

SWMP - As of this month, over 56 million records

- Weather > 13 million
- Water quality > 43 million
- Nutrients > 93 thousand

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Despite the quantity and quality of the data, very few comparative analyses. Exceptions...

- Comparison of net metabolism [Caffrey, 2003], [Caffrey, 2004]
- DO variation between estuaries [Wenner et al., 2004]
- Synthesis reports [Wenner et al., 2001], [Sanger et al., 2002]

Guidance may come in many forms - not just a number

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Case 1: Chlorophyll drivers in Tampa Bay

The eutrophication paradigm
Challenges for criteria development

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Case 1: Chlorophyll drivers in Tampa Bay

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Case 3: 'Open-science' tools for analysis of water quality

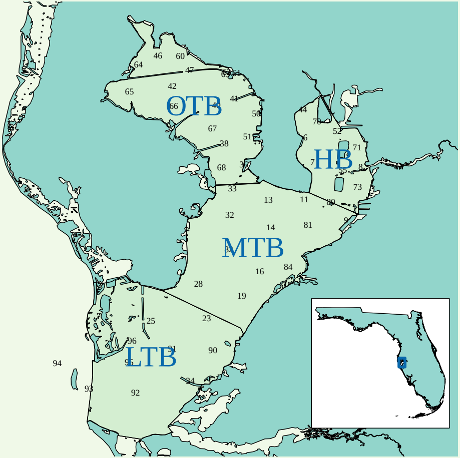
Each provides an example of addressing the dual challenges of understanding nutrient dynamics and developing quantitative tools for trend evaluation

Case 1: 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]



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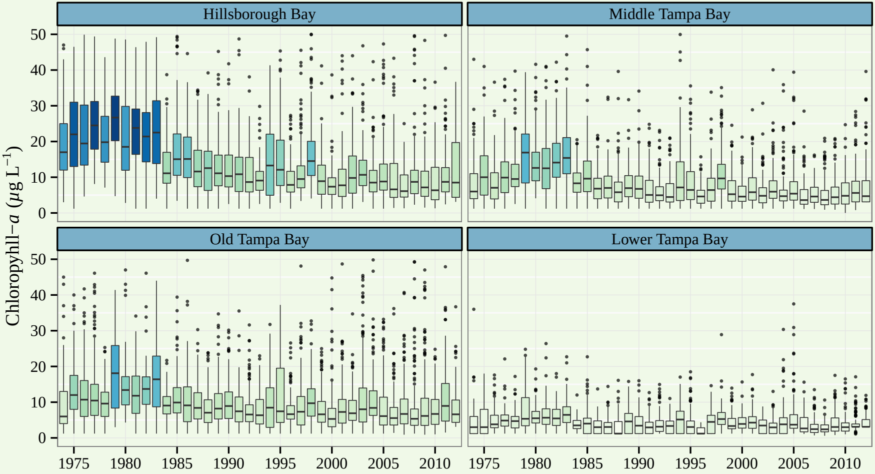

Figure : Annual trends in chlorophyll for each bay segment.

Case 1: Tampa Bay

Understanding chlorophyll response to eutrophication

What affects our interpretation of chlorophyll response to nutrients?

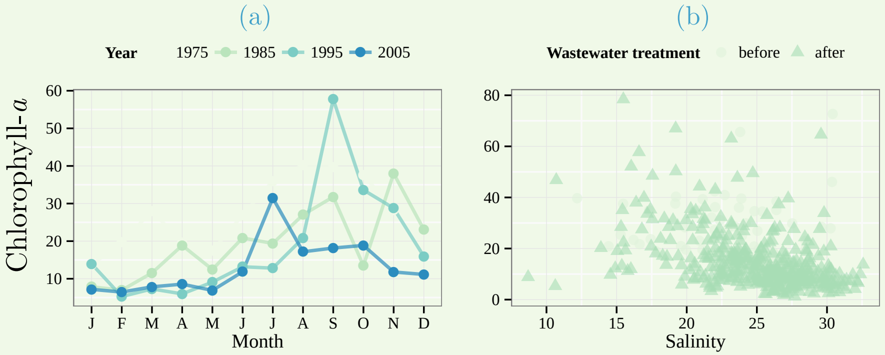

Figure : Variation in chlorophyll by (a) time and (b) salinity and management in Hillsborough Bay. Panel (a) is colored before and after wastewater treatment in 1979.

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Study objective

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

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- ...provide a natural history of water quality that is temporally consistent with drivers of change?

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- ...characterize changes in extreme events in addition to describing the mean response?
- ...improve our understanding of the nutrient-response paradigm in estuaries?

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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

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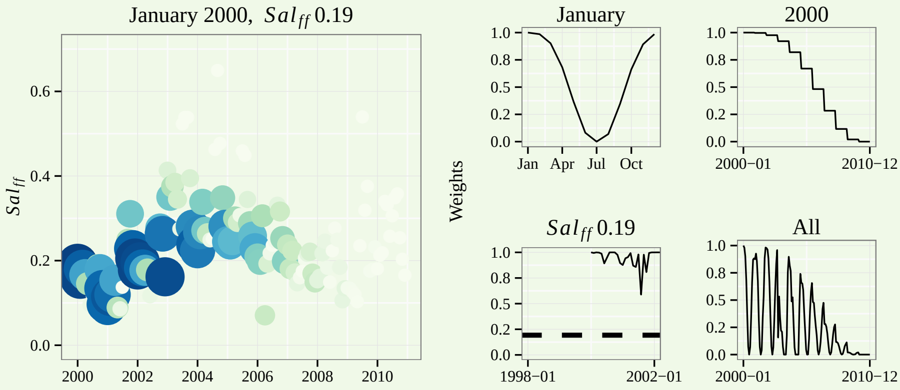
Adaptation: Can this approach be used to evaluate chlorophyll trends in Tampa Bay?

How does weighted regression work?



Case 1: Tampa Bay

Understanding chlorophyll response to eutrophication

This gives us improved predictions of chlorophyll dynamics...

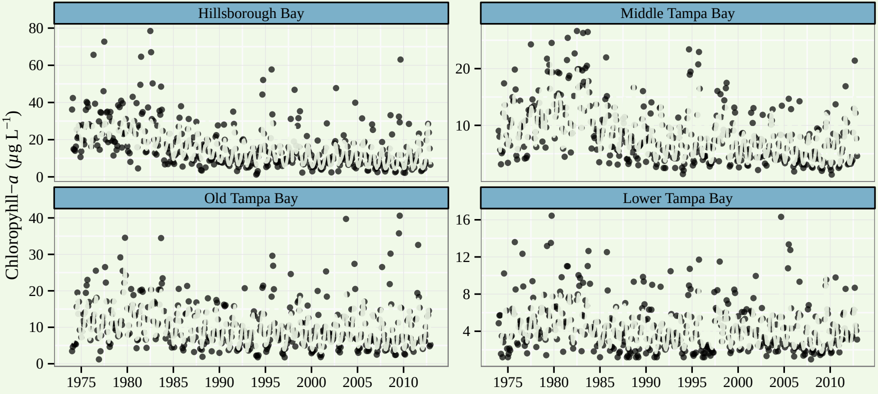


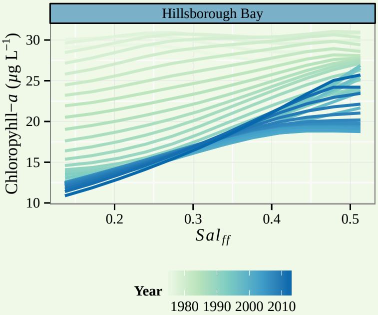
Figure : Predicted and observed monthly chlorophyll by segment.

pdf 2

Case 1: Tampa Bay

Understanding chlorophyll response to eutrophication

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

Case 1: 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

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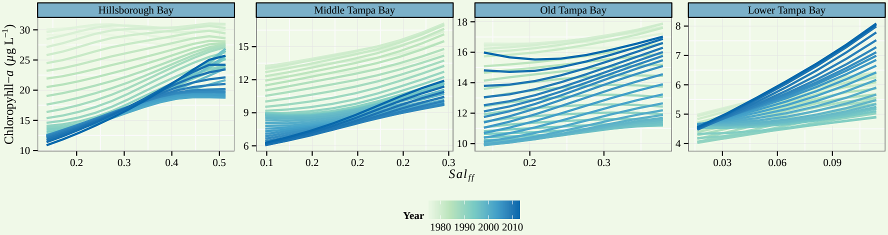
The model parameters show us a picture...



Case 2: Seagrass and water quality
Making the most of existing data

Case 3: Open-source science

Analysis tools for water quality data

Progress in science is incremental and builds on past work

This requires accurate reproduction of methods

The ability to reproduce methods will always be a challenge...

Case 3: Open-source science

Analysis tools for water quality data

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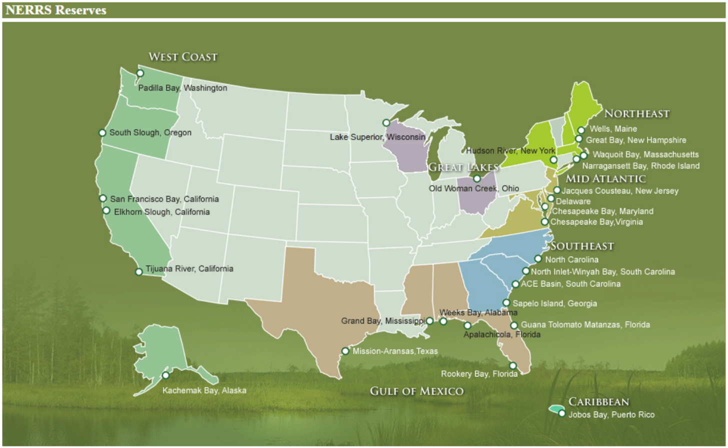
The ability to reproduce methods will always be a challenge...

...digital tools have proliferated to facilitate sharing

Returning back to the System Wide Monitoring Program...



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Problem: These data are numerous and not easily compared

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The benefits include:

- Free for use by anyone
- Free to collaborate
- Facilitation of analysis with 'under-the-hood' functionality

Case 3: Open-source science

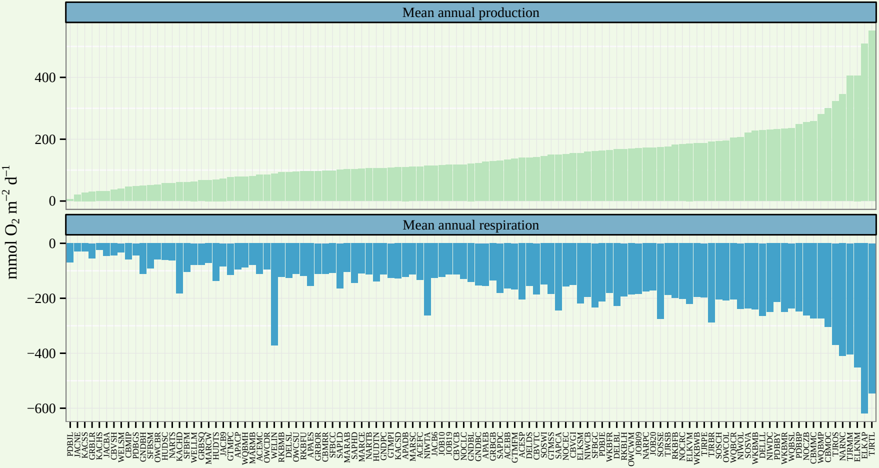
Analysis tools for water quality data

SWMPr is a freely available package for use with R

Designed to facilitate the analysis of SWMP data by providing functions that...

- Retrieve SWMP data for any site and date combination
- Organize the data using standard pre-processing techniques
- Analyze the data using a suite of exploratory and graphical analysis tools

What we've done so far... estimates of ecosystem metabolism



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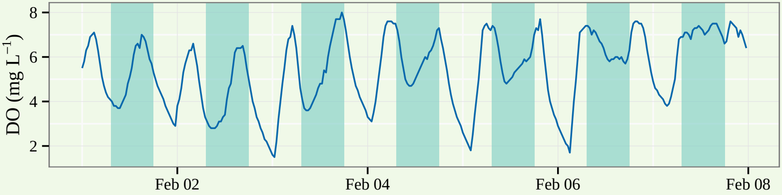
What we've done so far... detiding dissolved oxygen data



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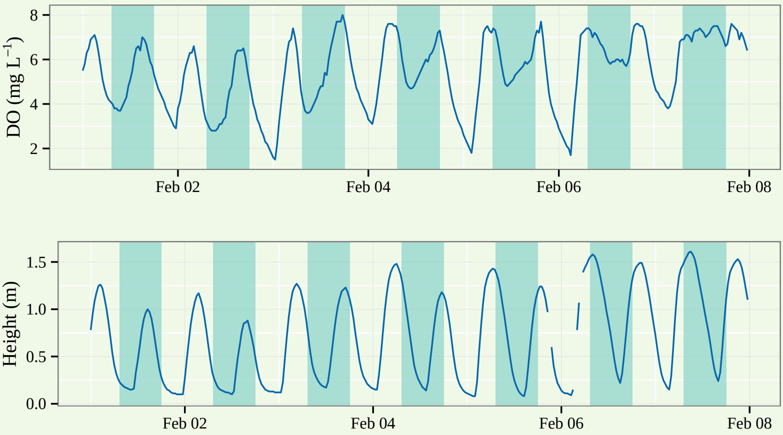

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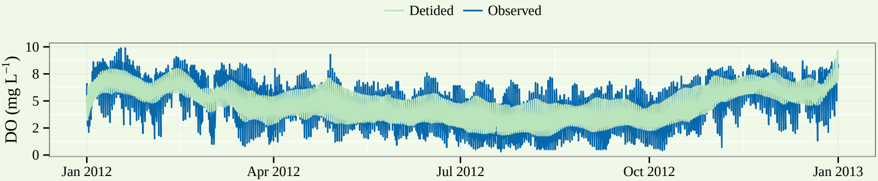

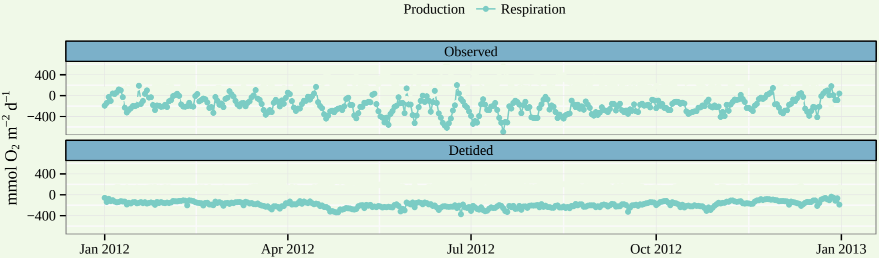

Case 3: Open-source science

Analysis tools for water quality data

Tools in the SWMPr package (or that will be included) have facilitated comparative analyses of millions of water quality records from NERRS

These tools can help improve our understanding of nutrient pollution and eutrophication

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Analysis tools for water quality data

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These tools can help improve our understanding of nutrient pollution and eutrophication

Potential for many other applications... actively being developed

Conclusions

The analysis of water quality will continue to require the use of novel tecniques to interpret the data

These needs are motivated by:

- The continued relevance of stressors that influence ecosystem conditions
- Our increasing ability to gather raw, uninterpreted data

Our methods must be able to make sense of historical trends, as well as predict future conditions

Conclusions

Our ability to share, reproduce, and collaborate is essential

SWMPr package: https://github.com/fawda123/SWMPr

Seagrass applications: https://beckmw.shinyapps.io/sg_depth

Ecosystem metabolism and detiding:
http://spark.rstudio.com/beckmw/detiding_cases/

This presentation: https://github.com/fawda123/wqtrends_pres

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Research staff and employees at USEPA Gulf Ecology Division - especially J. Hagy, M. Murrell

Field staff and data managers at Hillsborough County Environmental Protection Commission

Research coordinators, technicians, and field staff of the National Estuarine Research Reserve System

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

Image credit: Stephen Morrow

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Github: github.com/fawda123/

Blog: beckmw.wordpress.com/

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