

Trends in Chesapeake Bay Tidal Water Quality

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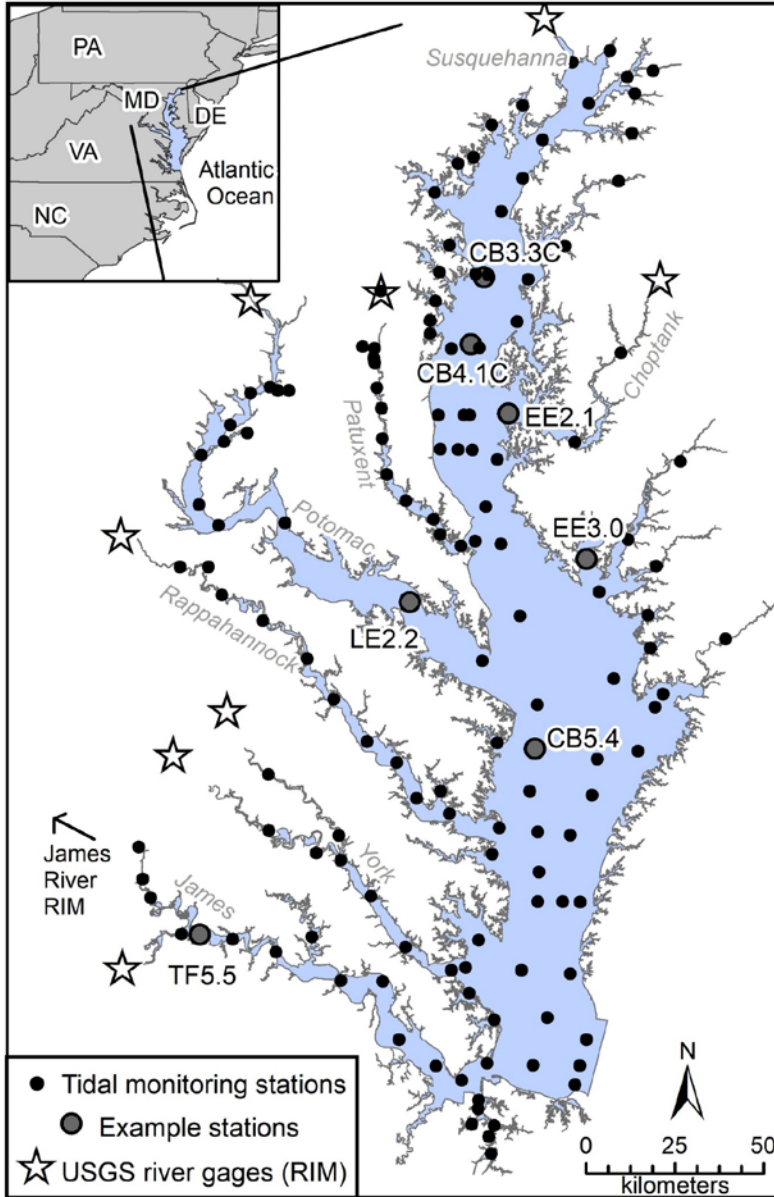
Jeni Keisman

U.S. Geological Survey

Fisheries GIT meeting

June 26, 2019





Extensive long-term coordinated water quality monitoring

- MDDNR, VADEQ and others have been sampling at 150+ stations since the 1980s 1-2 times/month
- Nutrients, chlorophyll-*a*, dissolved oxygen, secchi depth, salinity, temperature, and others, all measured at multiple depths



Matt Rath/Chesapeake Bay Program

Tidal Trends Analysis Collaboration

- Since the mid-1990s, coordinated trends efforts as well
 - Tracking change
 - Visual tool for management audiences
 - Identifying areas for further research
- Recent method revision to use Generalized Additive Models (GAMs)
- Tidal Trends Analysis Team: CBP, MDDNR, VADEQ, ODU, UMCES, USGS, statistical consultants

Approach: Generalized Additive Models (GAMs)

A response variable is modeled as the sum of multiple functions of explanatory variables

$$\text{Water quality} = s(\text{doy}) + s(\text{date}) + \text{Interaction}(\text{doy}, \text{date})$$

Smoothly-
varying non-
linear “spline”
functions

And multi-
dimensional
smooth
functions

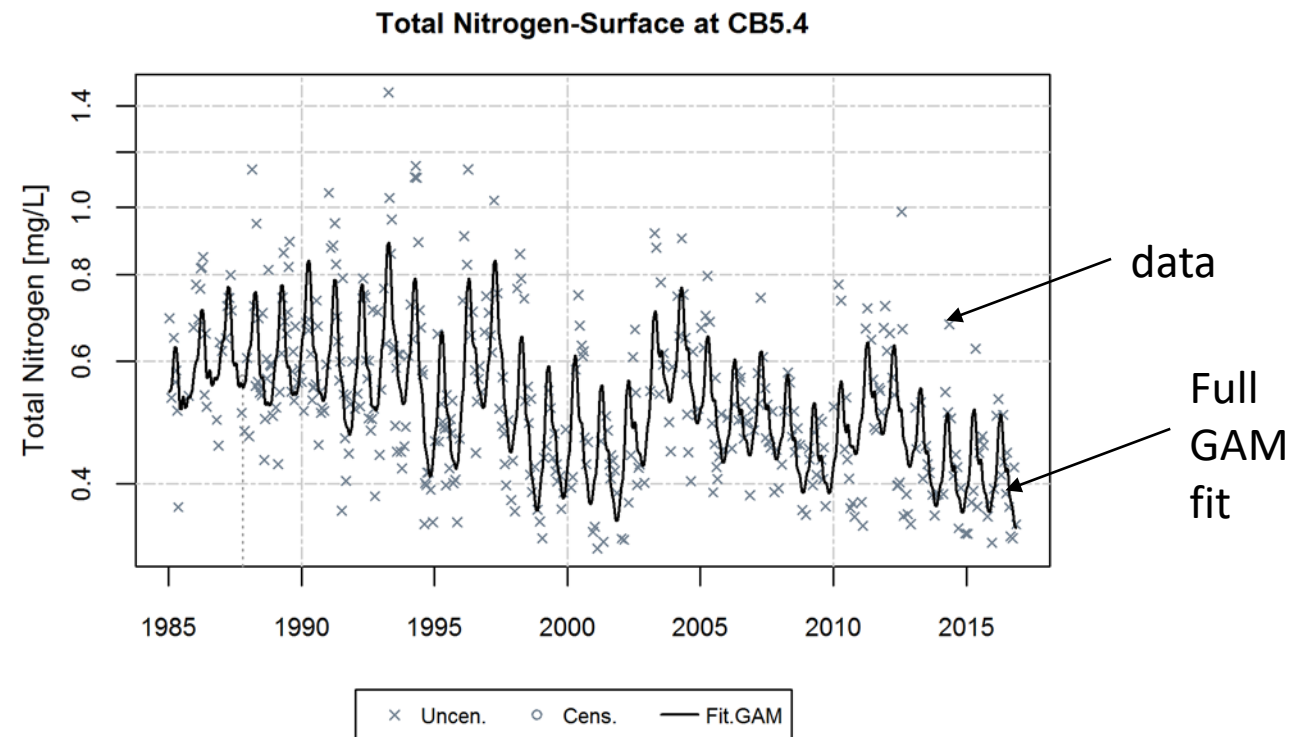
s = spline smooth functions
doy = day of year

We're using: mgcv R package by Simon Wood: (<https://cran.r-project.org/web/packages/mgcv/mgcv.pdf>) and through our separate R package 'baytrends'

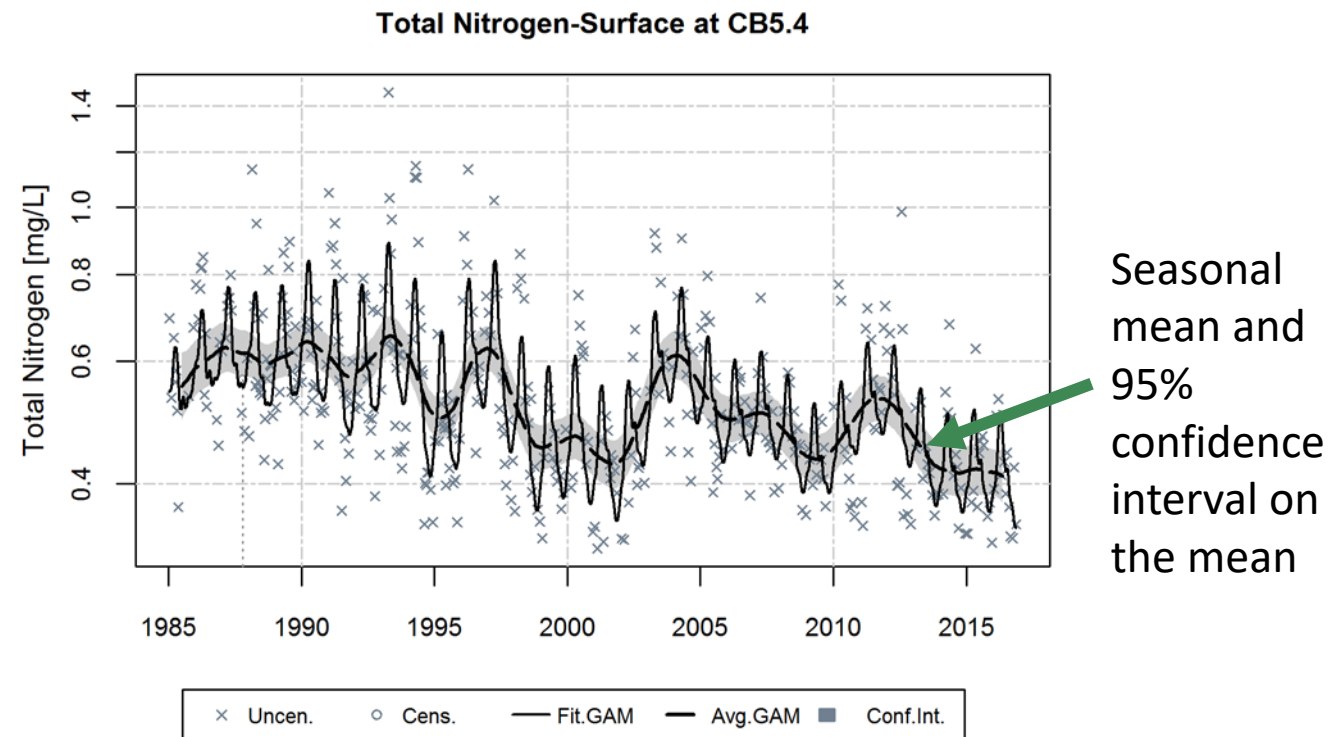
Murphy, R.R., Perry, E., Harcum, J. and Keisman, J. 2019. A Generalized Additive Model approach to evaluating water quality: Chesapeake Bay case study. *Environmental Modelling and Software* 118: 1-13. <https://doi.org/10.1016/j.envsoft.2019.03.027>

GAM Implementation

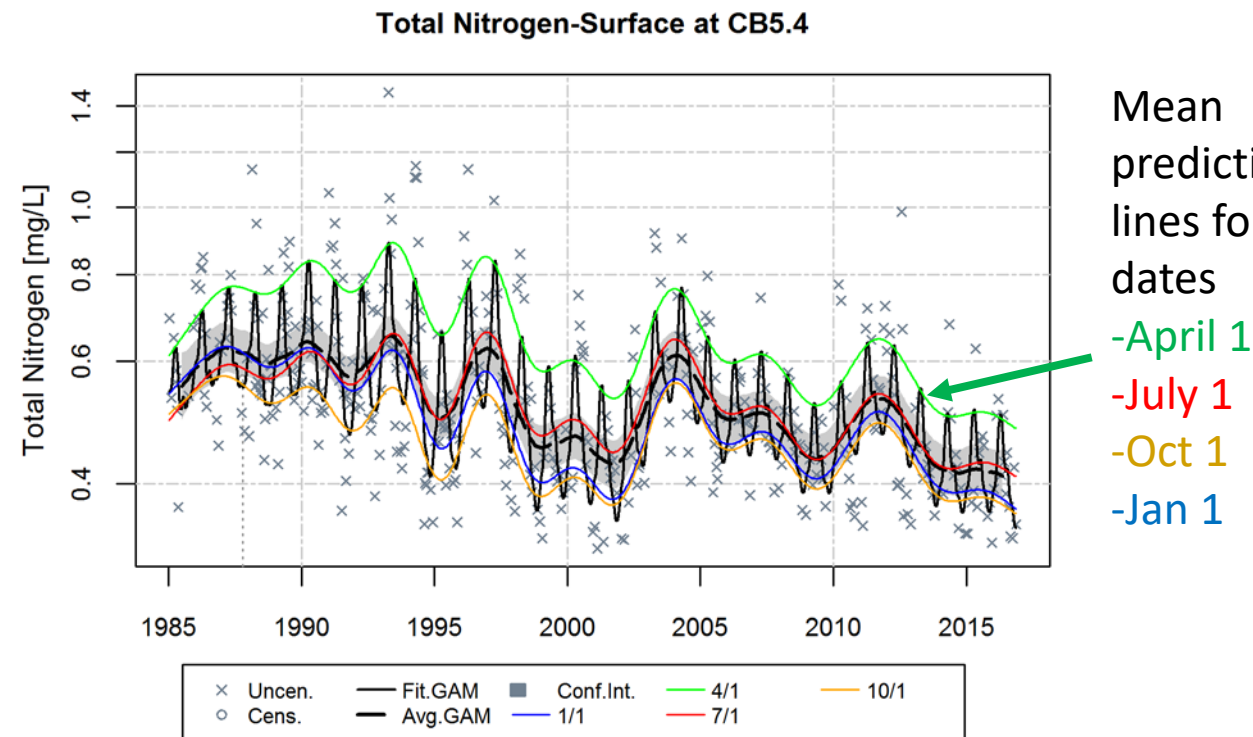
$$\text{TN} = s(\text{doy}) + s(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$



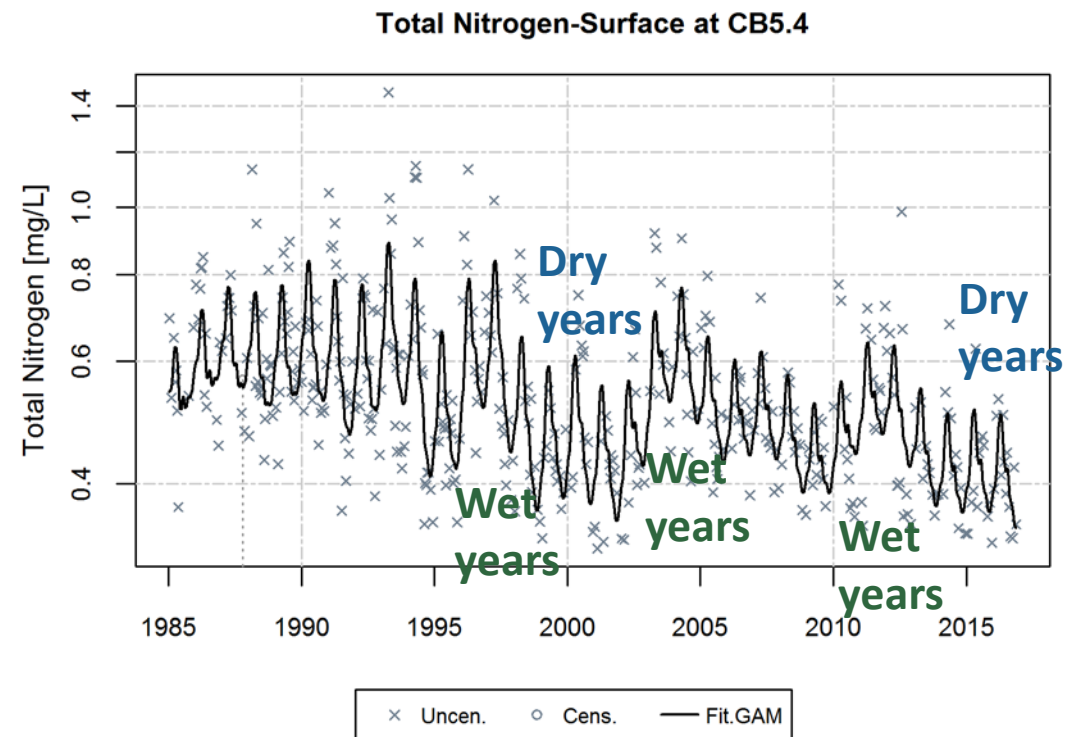
$$\text{TN} = \text{s}(\text{doy}) + \text{s}(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$



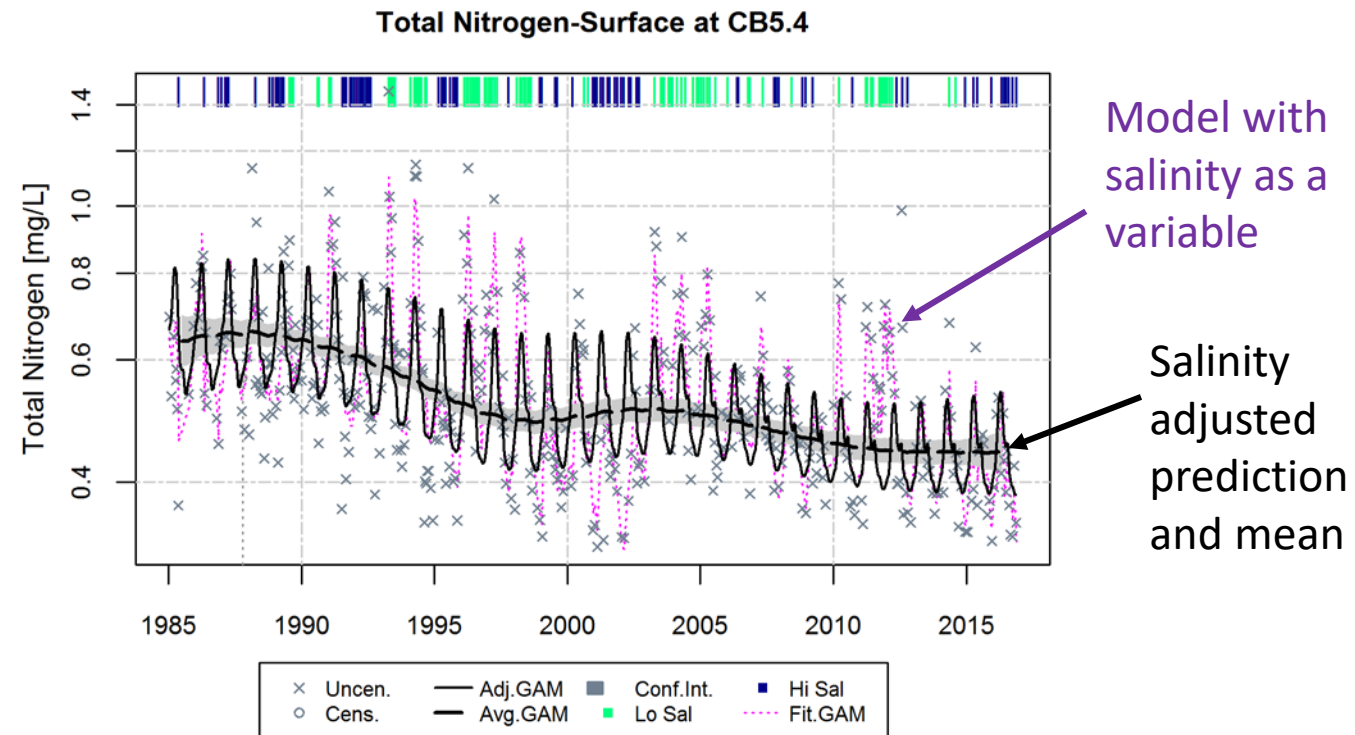
$$TN = s(\text{doy}) + s(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$



Is variability in river flow the cause of year-to-year fluctuations?



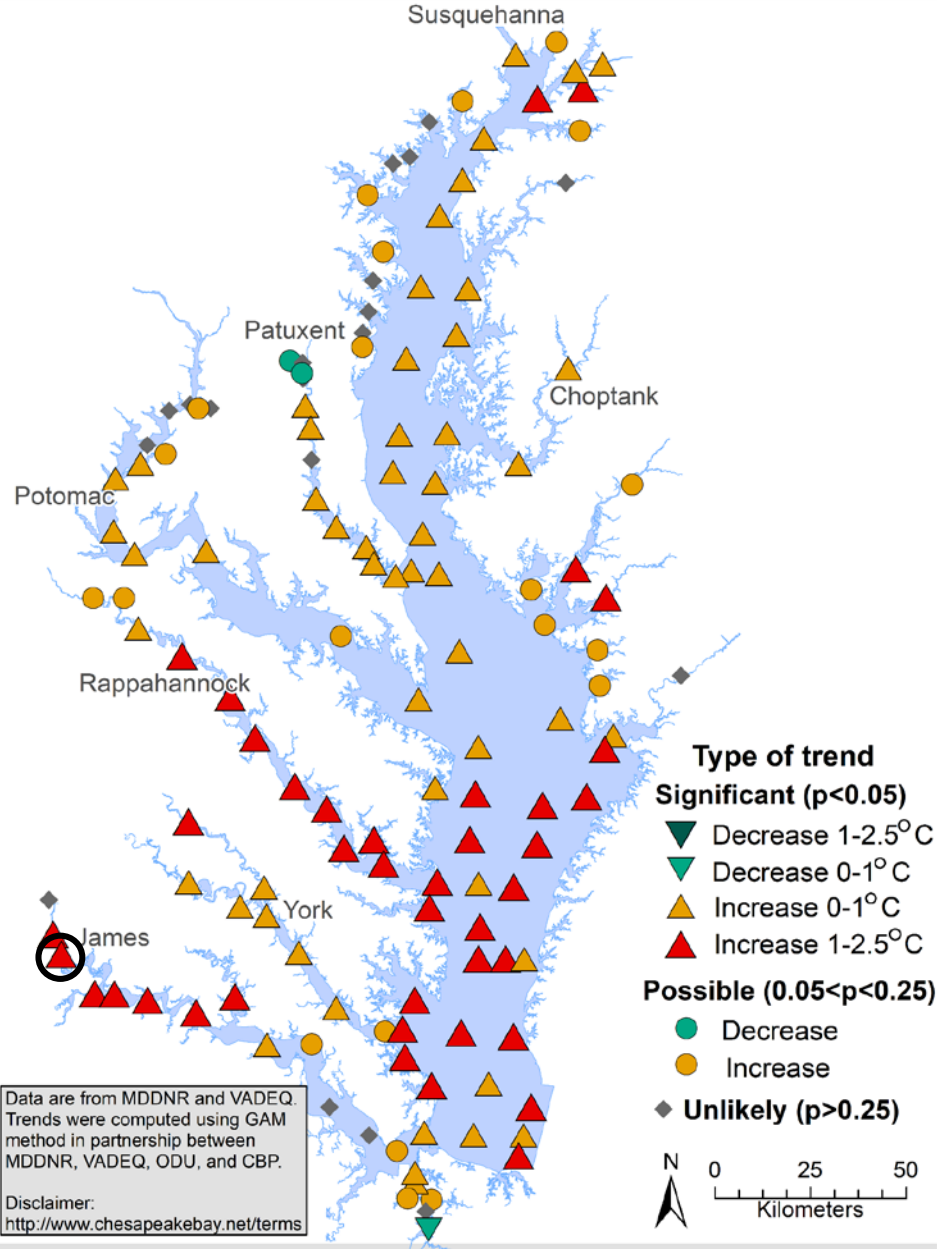
$$\text{TN} = \text{s}(\text{doy}) + \text{s}(\text{date}) + \text{interaction}(\text{doy}, \text{date}) + \text{s}(\text{sal}) + \text{interaction}(\text{sal}, \text{doy}) + \text{interaction}(\text{sal}, \text{date}) + \text{interaction}(\text{sal}, \text{doy}, \text{date})$$



Annual Trend products

- Models fit for every station, surface & bottom:
 - Nutrients: Total Nitrogen, Dissolved Inorganic Nitrogen, Total Phosphorus, Orthophosphate
 - Chlorophyll-a, Dissolved Oxygen, Total Suspended Solids, Secchi Depth
 - Temperature, Salinity
- Post-process analysis possible for time periods and seasons
 - Short-term (last 10 years)
 - Long-term (ideally 1985-present)
 - Spring & Summer chlorophyll-a, summer bottom DO
- Summaries
 - Maps
 - Basin summaries (in the works)

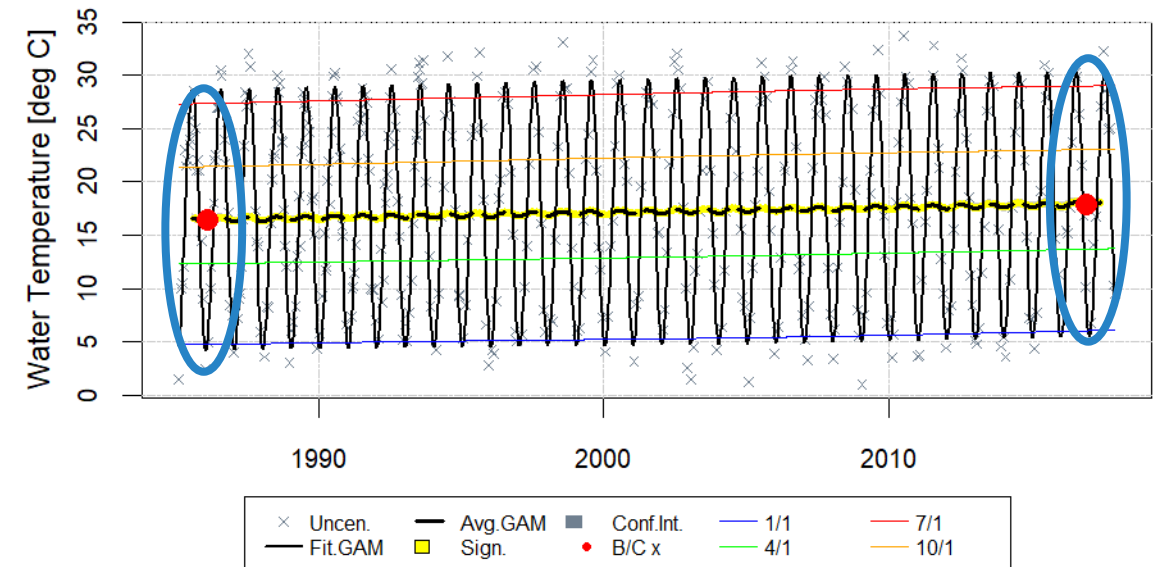
Trends for Surface Water Temperature in the Chesapeake Bay: 1985-2017



Example: Annual Trends in Water Temperature

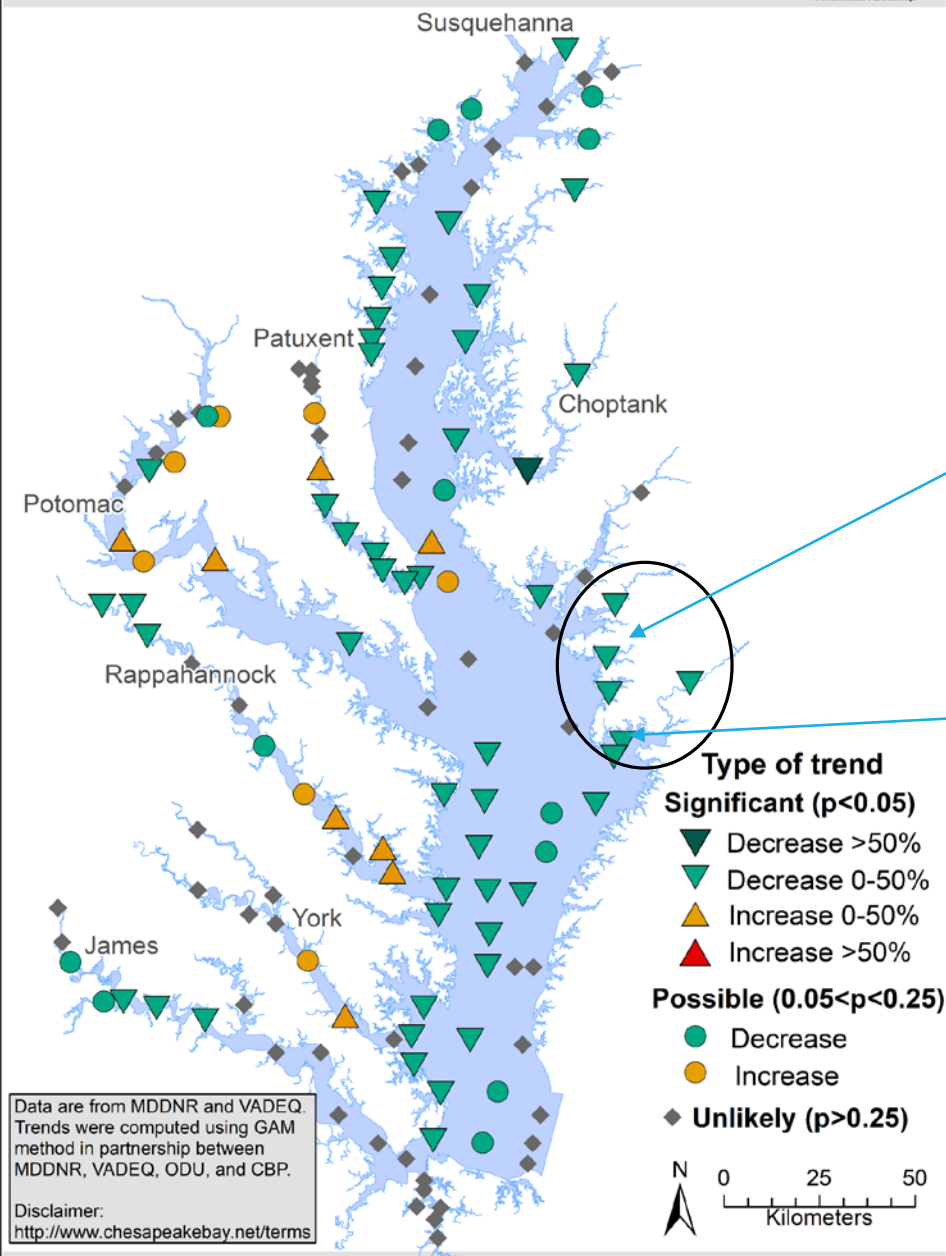
James Tidal Fresh Station

Water Temperature-Surface & Above Pycnocline at TF5.3



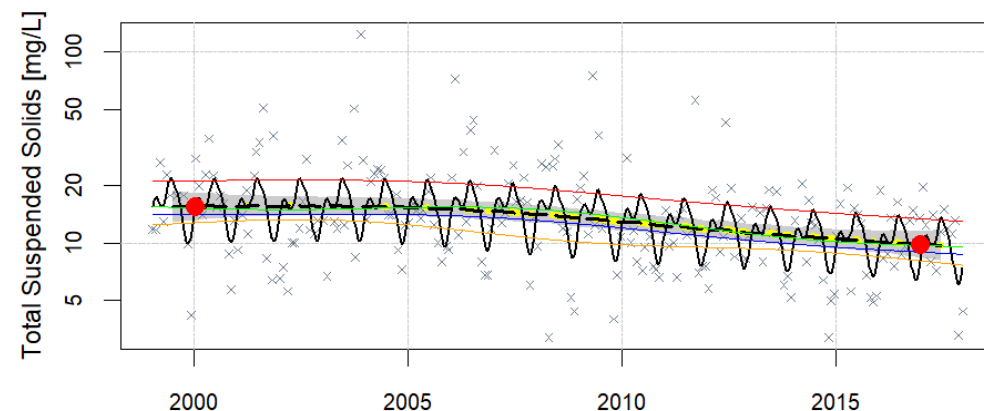
Average 1.5 C (2.7 F) increase ($p < 0.001$)

Trends for Surface TSS in the Chesapeake Bay: 1999-2017

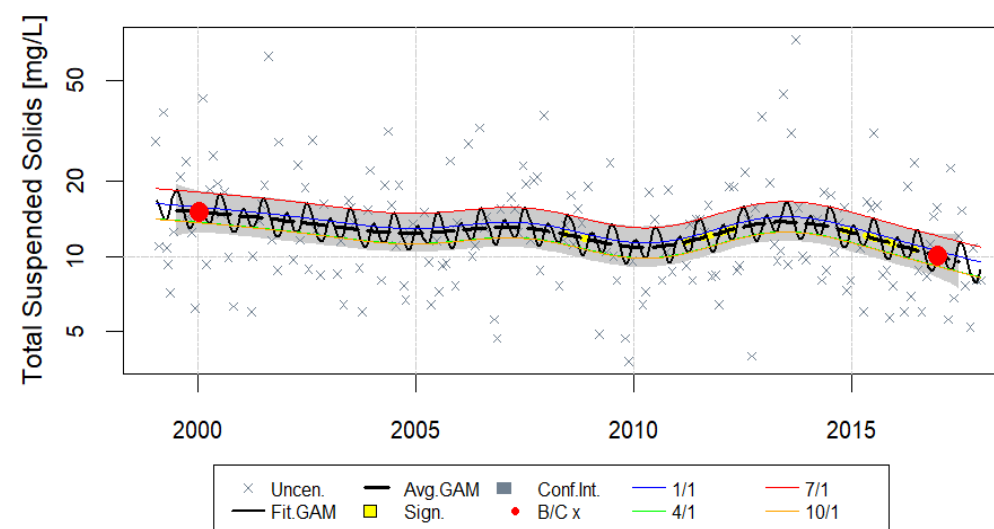


Example: Annual TSS

Total Suspended Solids-Surface & Above Pycnocline at ET8.1



Total Suspended Solids-Surface & Above Pycnocline at EE3.3



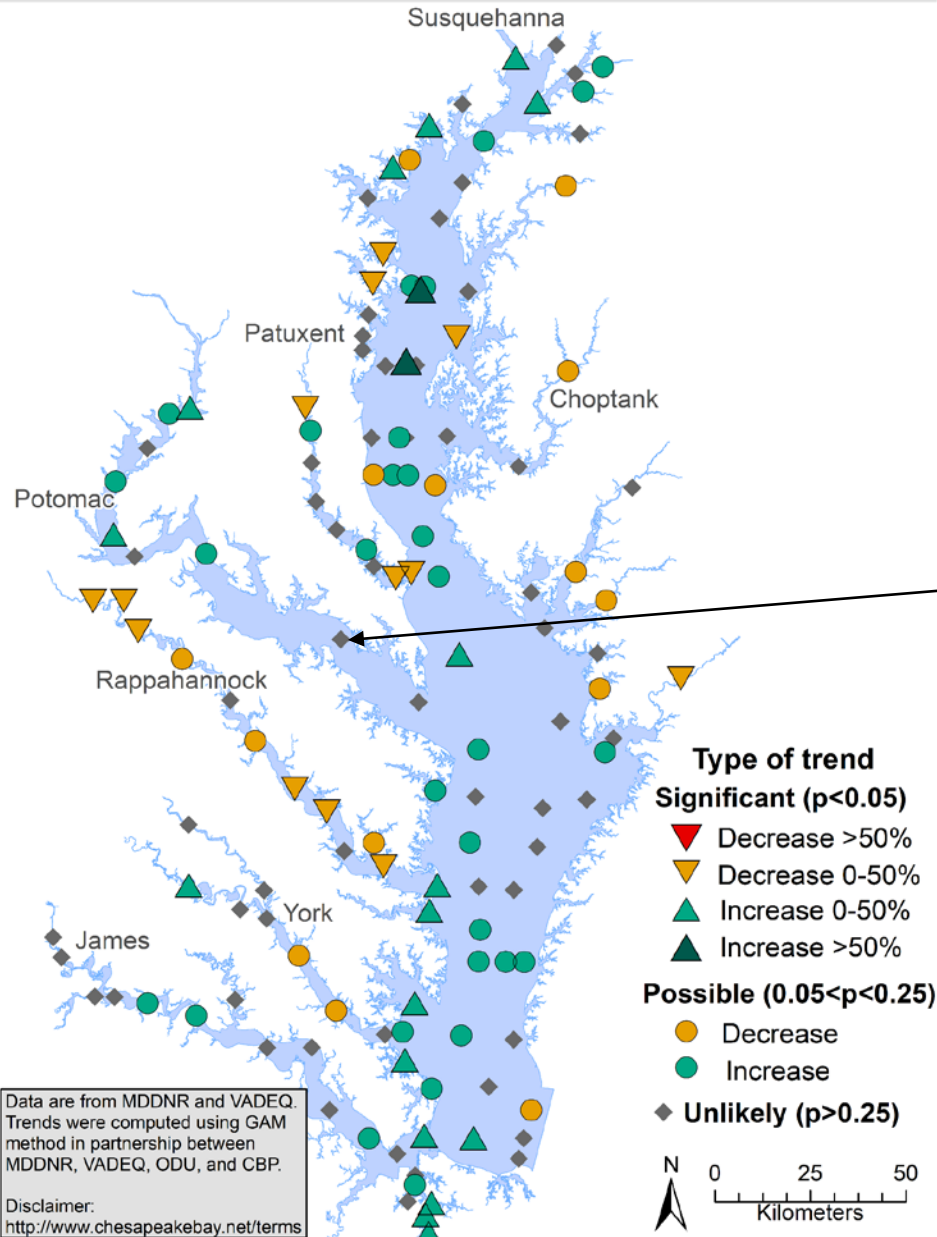
Using the results

All results available:

- Maps at the Integrated Trends Analysis Team website (https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team)
- Any individual station or parameters results available easily (rmurphy@chesapeakebay.net)

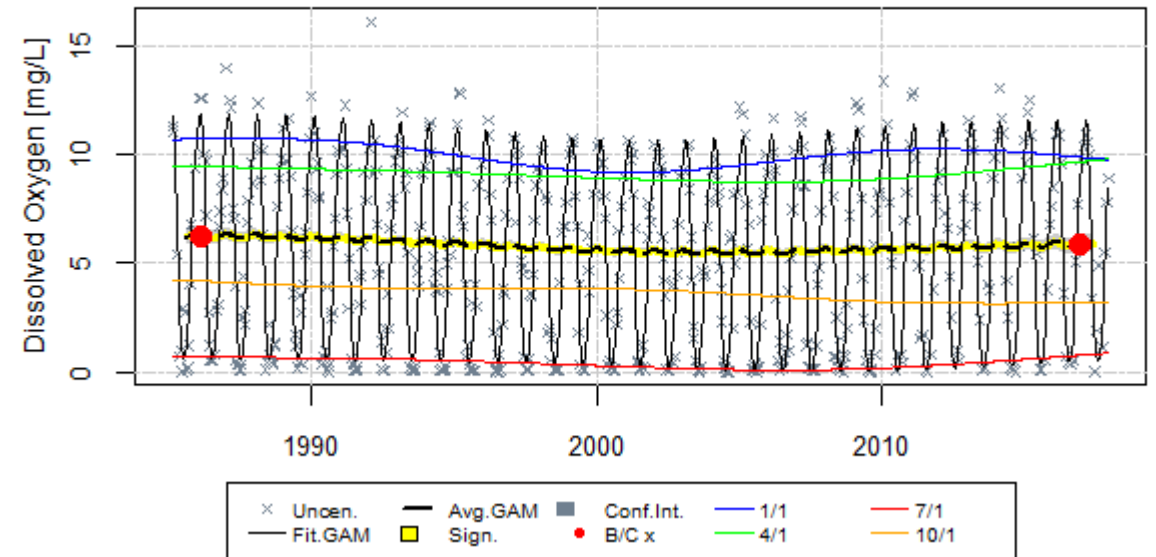
Post-processing tools may be useful for fisheries and habitat comparisons →

Trends for Summer Bottom Dissolved Oxygen: 1985-2017 (June-Sept)

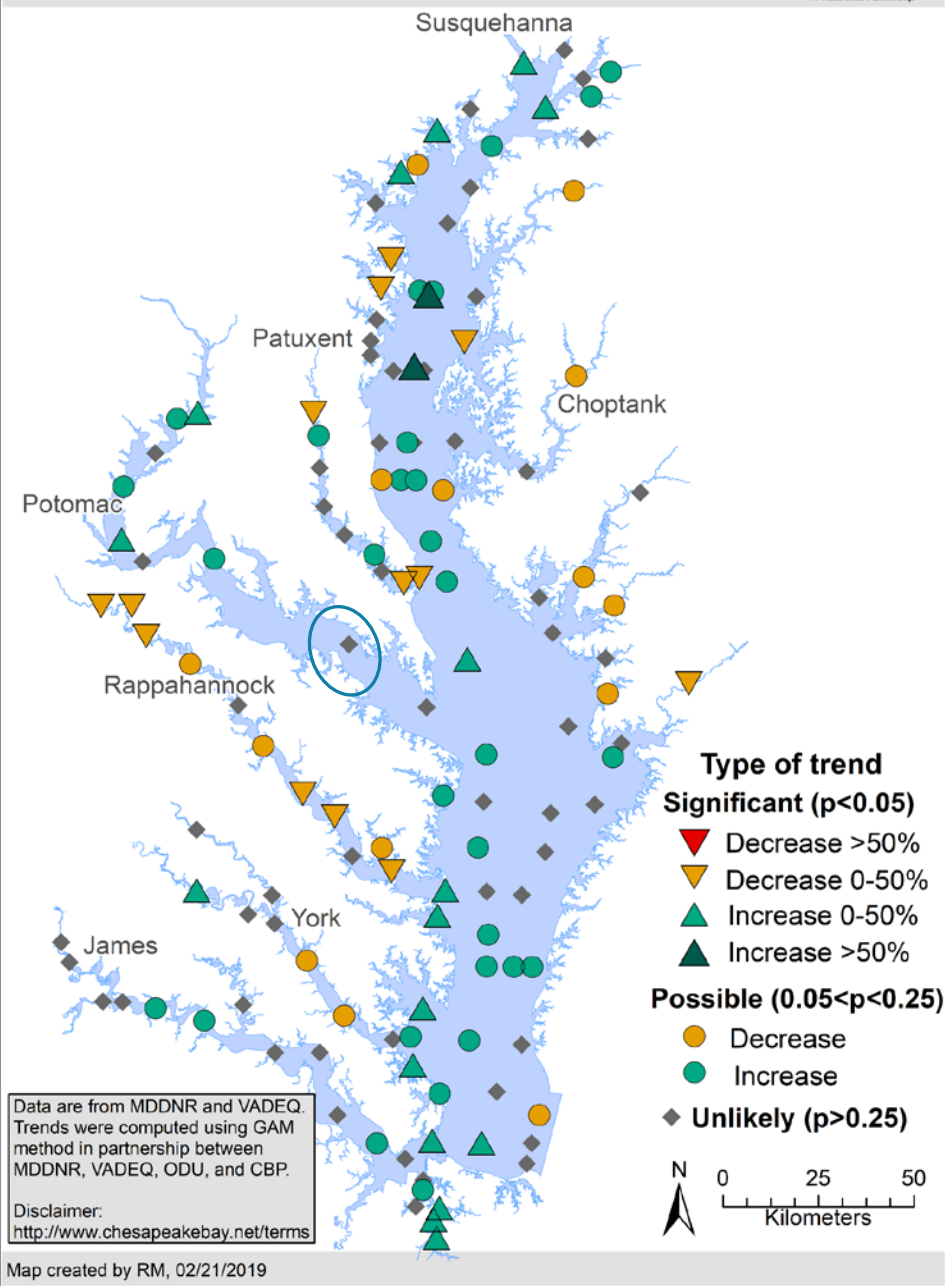


Examine patterns by season and month

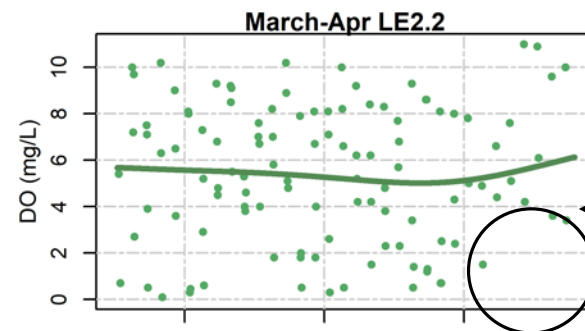
Dissolved Oxygen-Bottom at LE2.2



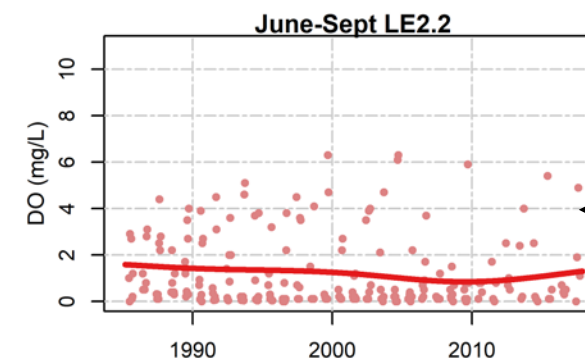
Trends for Summer Bottom Dissolved Oxygen: 1985-2017 (June-Sept)



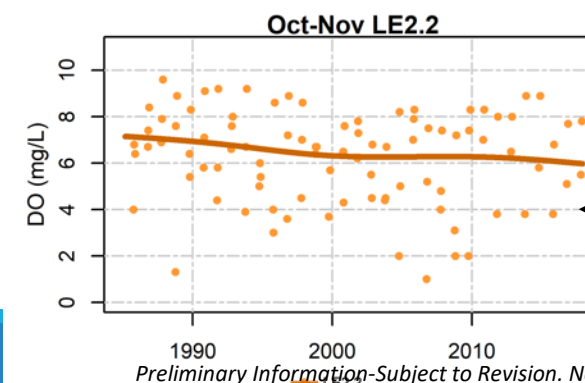
Examine if there are different patterns in different times of the year



Example: Using 4 as a cutoff – better conditions in spring lately.



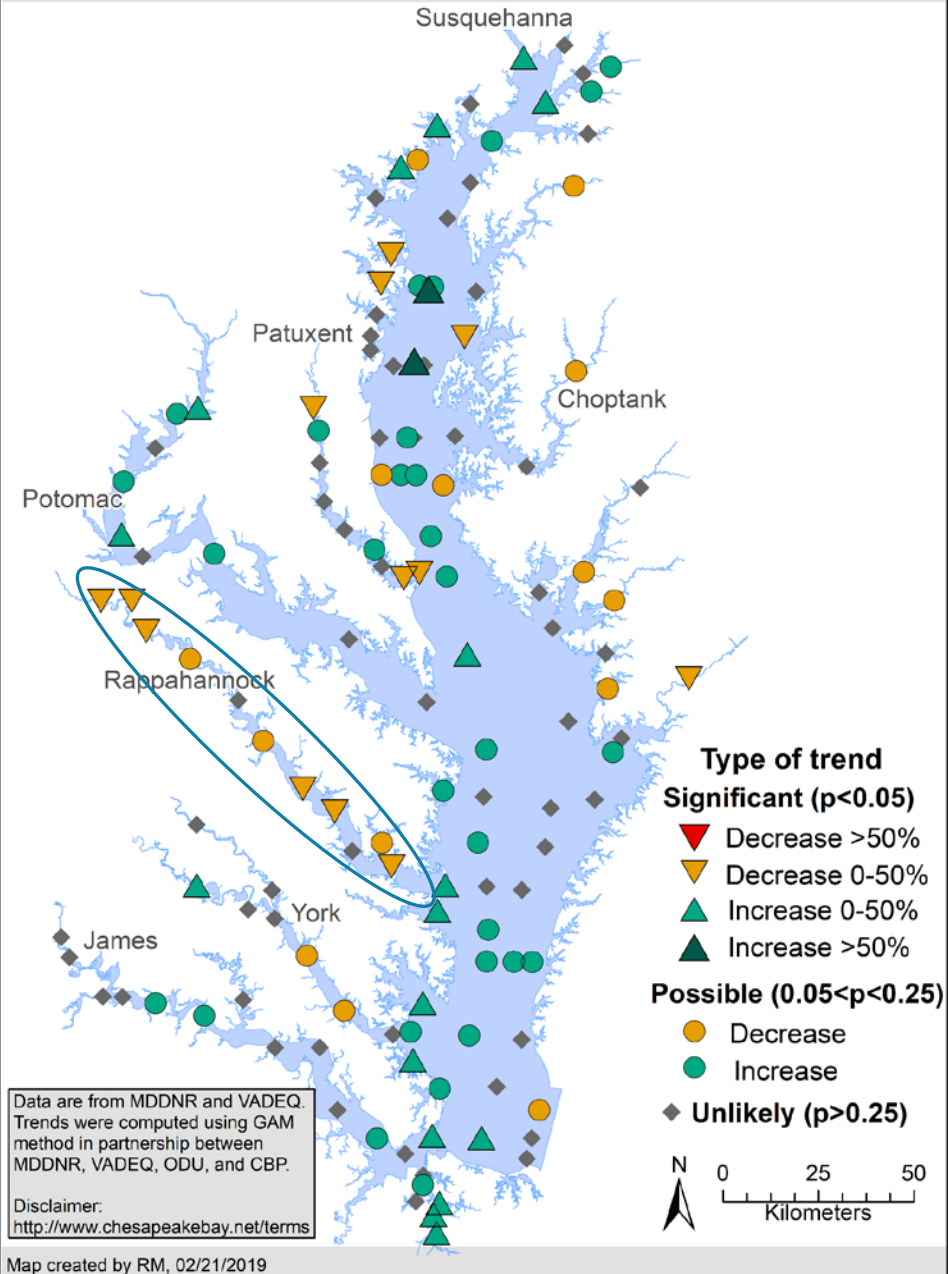
Summer is very low, but possibly improving.



But fall trend appears to be degrading.

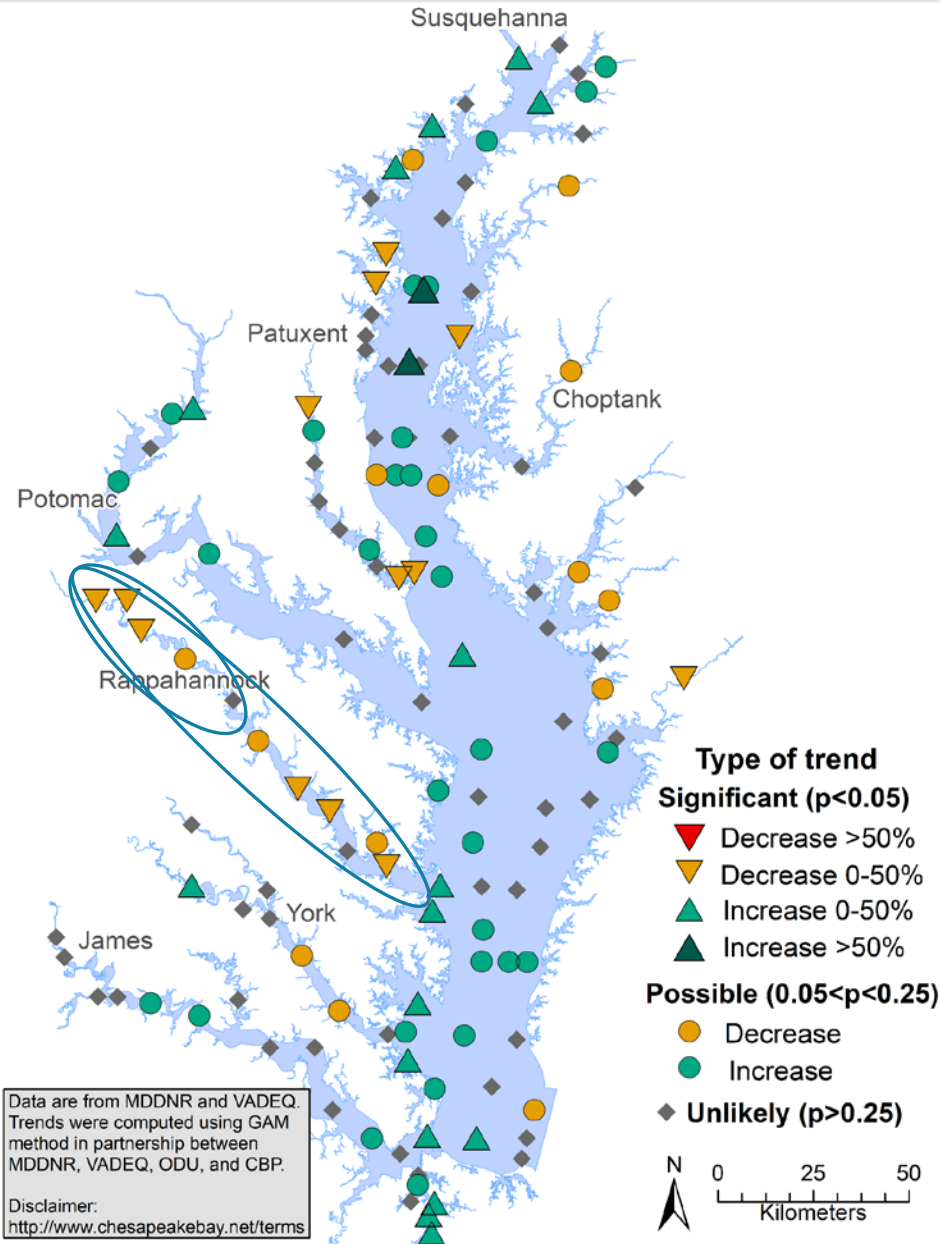
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Trends for Summer Bottom Dissolved Oxygen: 1985-2017 (June-Sept)

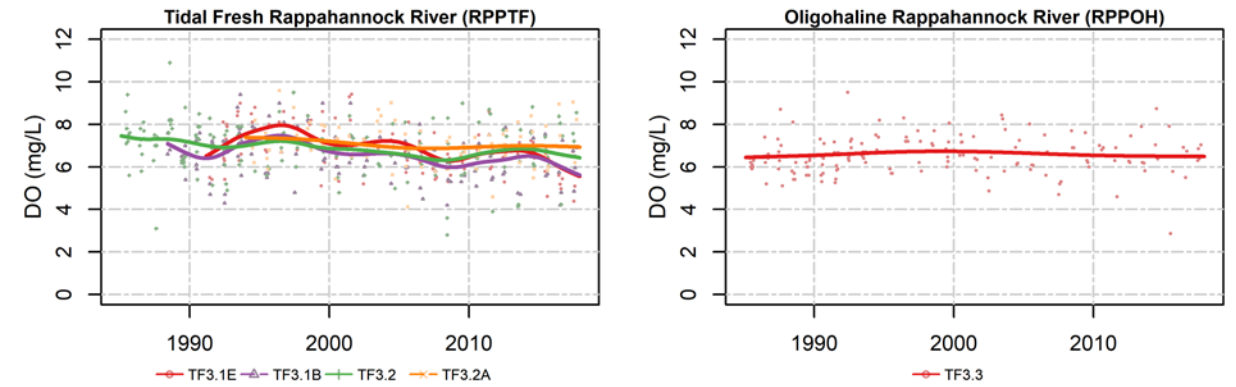


Examine patterns along a tributary

Trends for Summer Bottom Dissolved Oxygen: 1985-2017 (June-Sept)

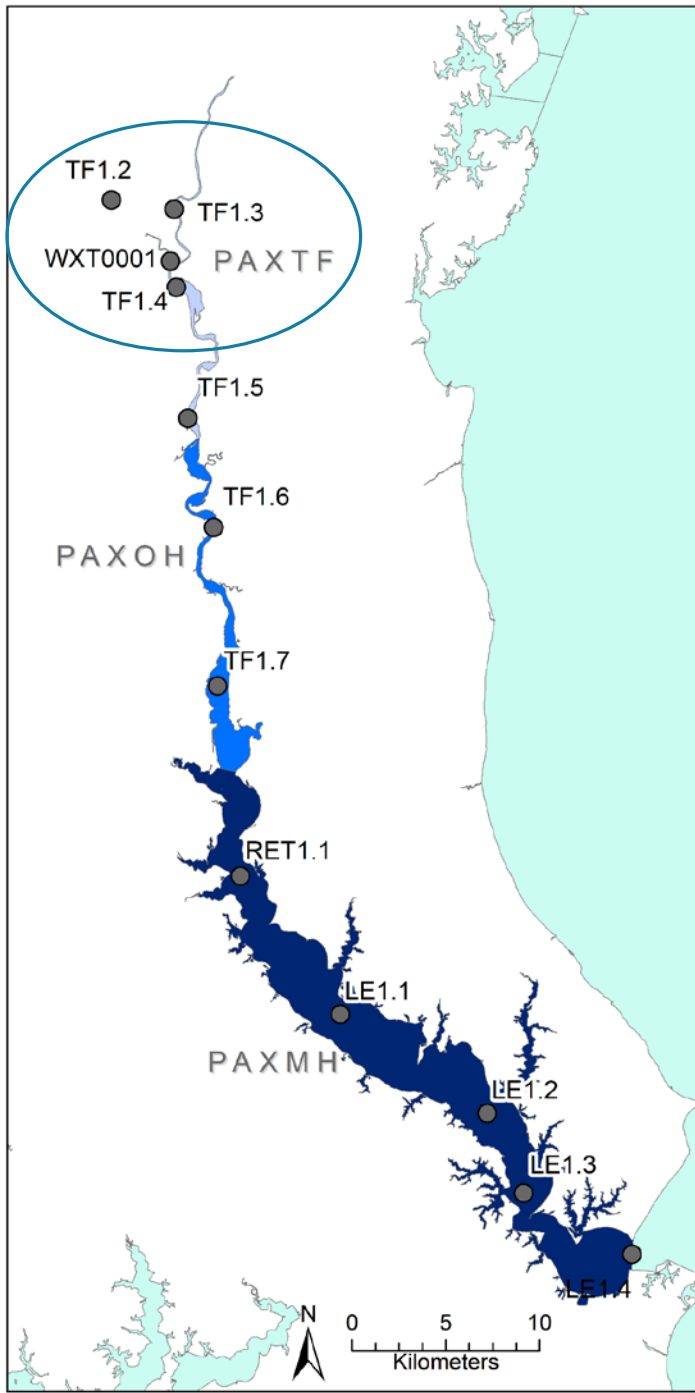


Summer (June-Sept) Bottom DO Data and Average Predictions

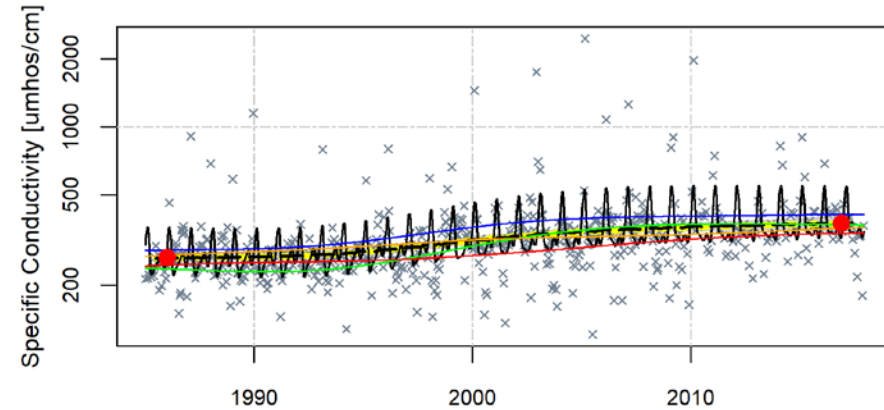


Use the technique on other data

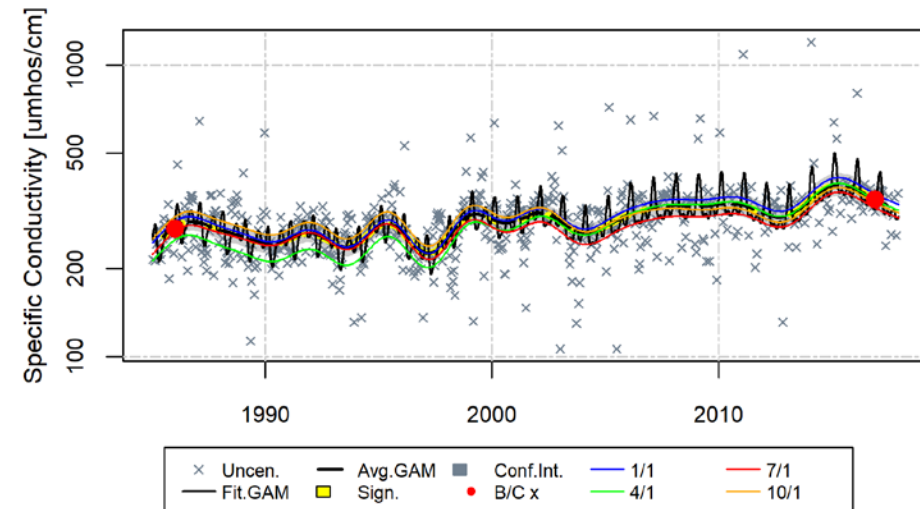
- Is conductivity increasing in Patuxent river?
- CBL student report suggested it was
- So ran GAMs on tidal fresh data:



Specific Conductivity-Surface at TF1.2



Specific Conductivity-Surface at TF1.3



Summary

- Annually-produced water quality trend maps and detailed pattern graphics available bay-wide.
- Additional post-processing tools and graphics can help examine season and location-specific trends.
- Possible further analyses with GAMs include ability to combine variables for hypothesis testing.

GAM team:

- Jeni Keisman (USGS)
- Elgin Perry
- Jon Harcum (Tetra Tech)
- Renee Karrh (MDDNR)
- Mike Lane (ODU)
- Cindy Johnson and Amanda Shaver (VADEQ)

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