2024 Tidal Trends Summary

Rebecca Murphy (UMCES/CBP)

ITAT meeting, Dec. 17, 2025

Contributing to this year's results:

Renee Karrh (MDDNR); Mike Lane (ODU) and Cindy Johnson (VADEQ);
Efeturi Oghenekaro, Blessing Edje and George Onyullo (DOEE); Mukhtar Ibrahim (MWCOG);
Breck Sullivan (USGS), Kaylyn Gootman (EPA) and Gabriel Duran (CRC)

R package for analysis maintained by:

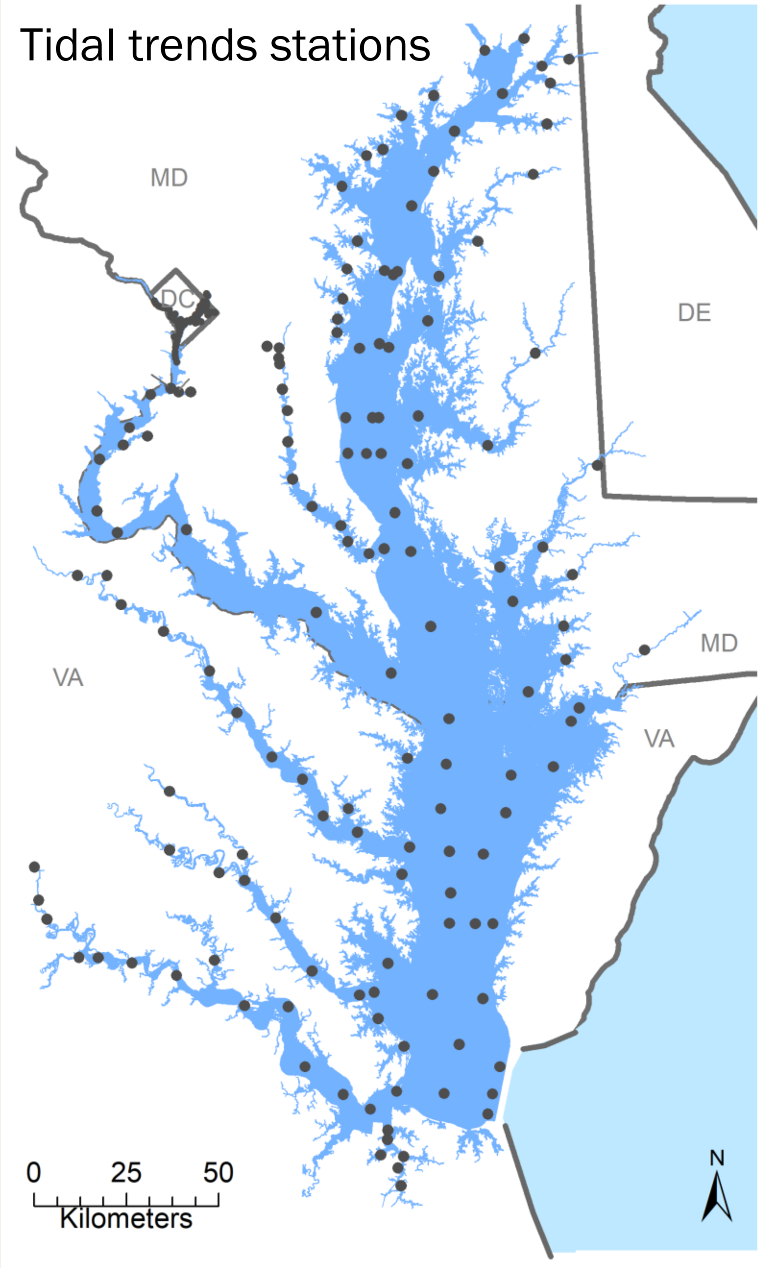
Erik Leppo and Jon Harcum (Tetra Tech)

Data from: *DOEE, MDDNR, and VADEQ*

Chesapeake Bay Program
Science. Restoration. Partnership.

What are the tidal trends?

- Short- and long-term changes, or trends, at about 150 monitoring stations across the Chesapeake Bay mainstem and tidal tributaries for multiple water quality parameters including nutrients, clarity, oxygen, and temperature.
- Uses Generalized Additive Model (GAM) approach to account for seasonal influences, variations in flow or salinity, and changes in methods.
  - *See Murphy et al., 2019 for more details.*
- Successful partnership collaboration to generate consistent, comparable trend results across MD, VA, and DC tidal waters.



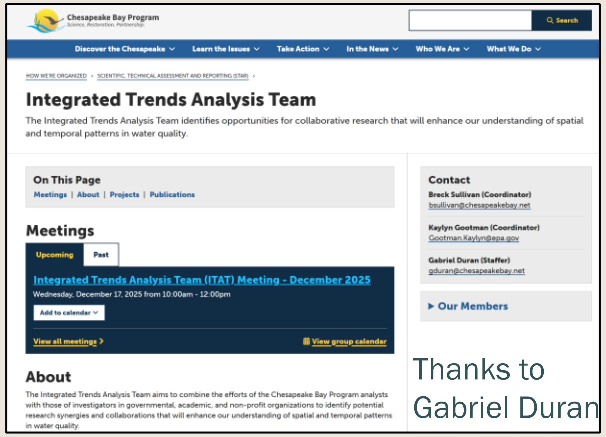
- baytrends: Long Term Water Quality Trend Analysis. R package version 2.0.12. https://cran.r-project.org/web/packages/baytrends/index.html
- Murphy, R.R., E. Perry, J. Harcum, and J. Keisman. 2019. https://doi.org/10.1016/j.envsoft.2019.03.027

Annual collaborative effort between partners

2024 Results

ITAT webpage:

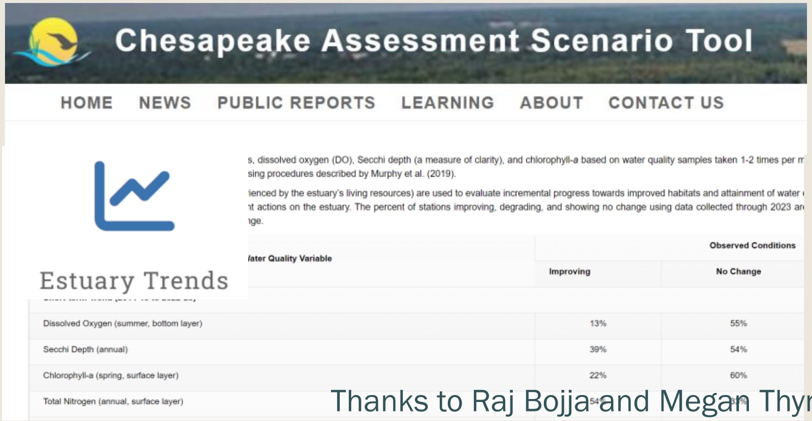
https://www.chesapeakebay.net/who/group/integrated-trends-analysis-team



Thanks to Gabriel Duran

CAST webpage/Trends over time:

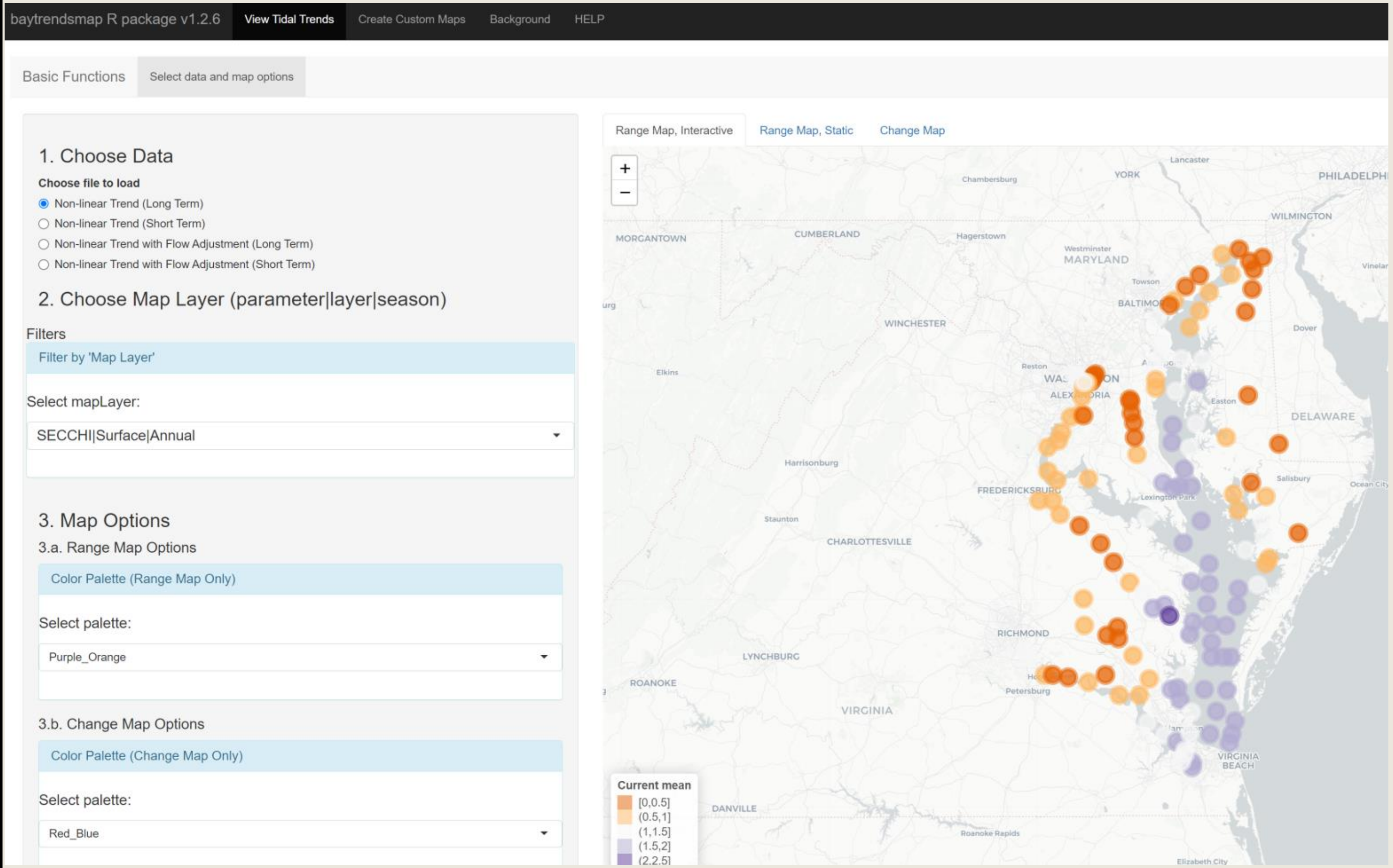
https://cast.chesapeakebay.net/EstuaryTrends



Thanks to Raj Bojja and Megan Thynge

Baytrendsmap :

https://baytrends.chesapeakebay.net/baytrendsmap/



Thanks to Erik Leppo and John Massey

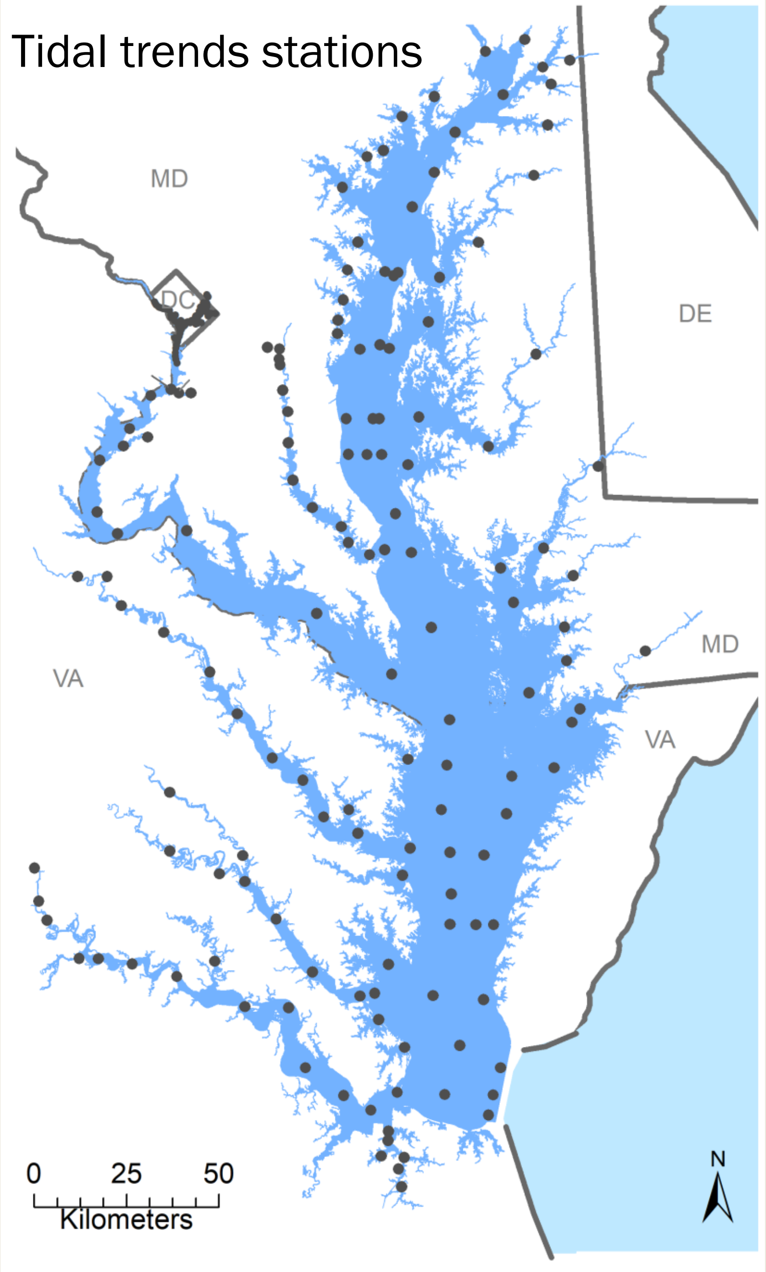
2024 Results

- Long-term (1980s-2024) and short-term (2015-2024) change:
  - *Total Nitrogen (TN)*
  - *Total Phosphorus (TP)*
  - *Secchi depth*
  - *Chlorophyll a*
  - *Water temperature*
  - *Dissolved Oxygen (DO)*

40 year trends!

- 1999-2024 and short-term (2015-2024) change:
  - *Total Suspended Solids (TSS)*
  - *Dissolved Inorganic Nitrogen (DIN)*
  - *Orthophosphate (PO4)*

- Multiple views of each parameter:
  - *Surface & Bottom*
  - *Chla, Secchi, DO: different seasons*
  - *Observed conditions, and flow- or salinity-adjusted conditions*



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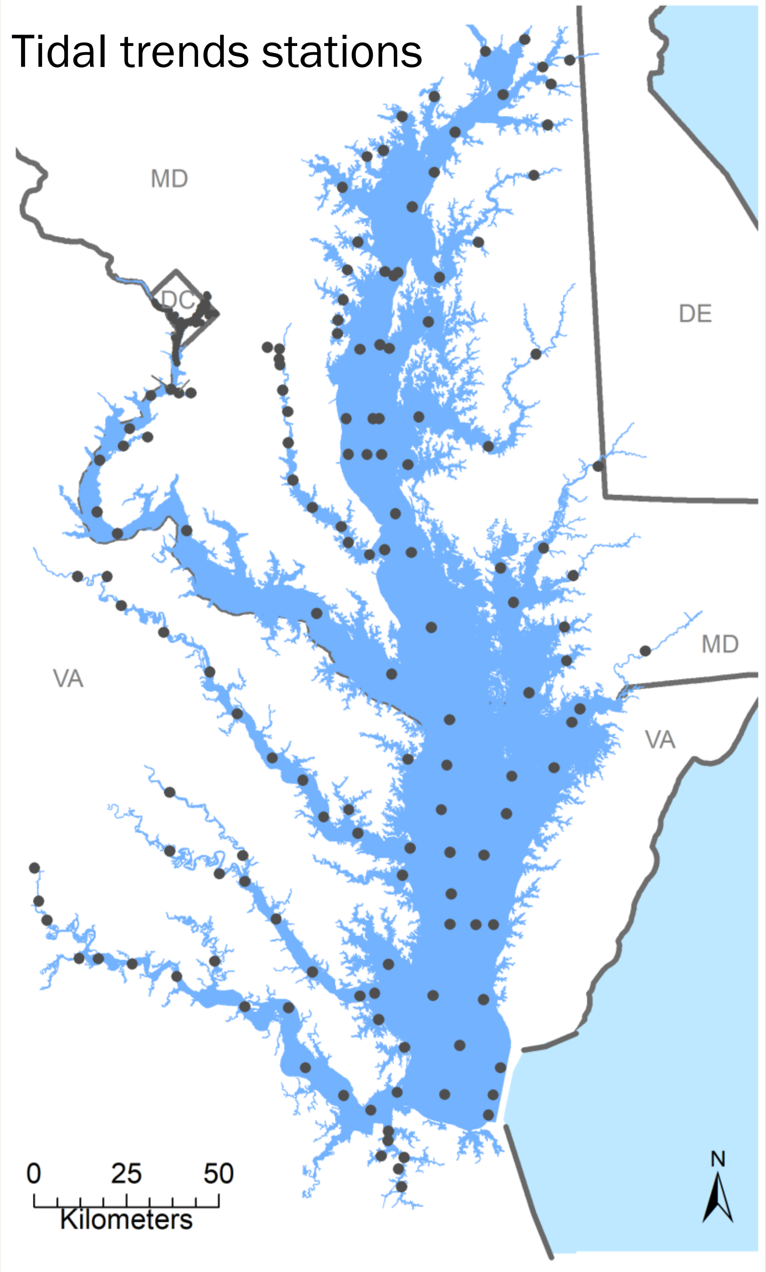
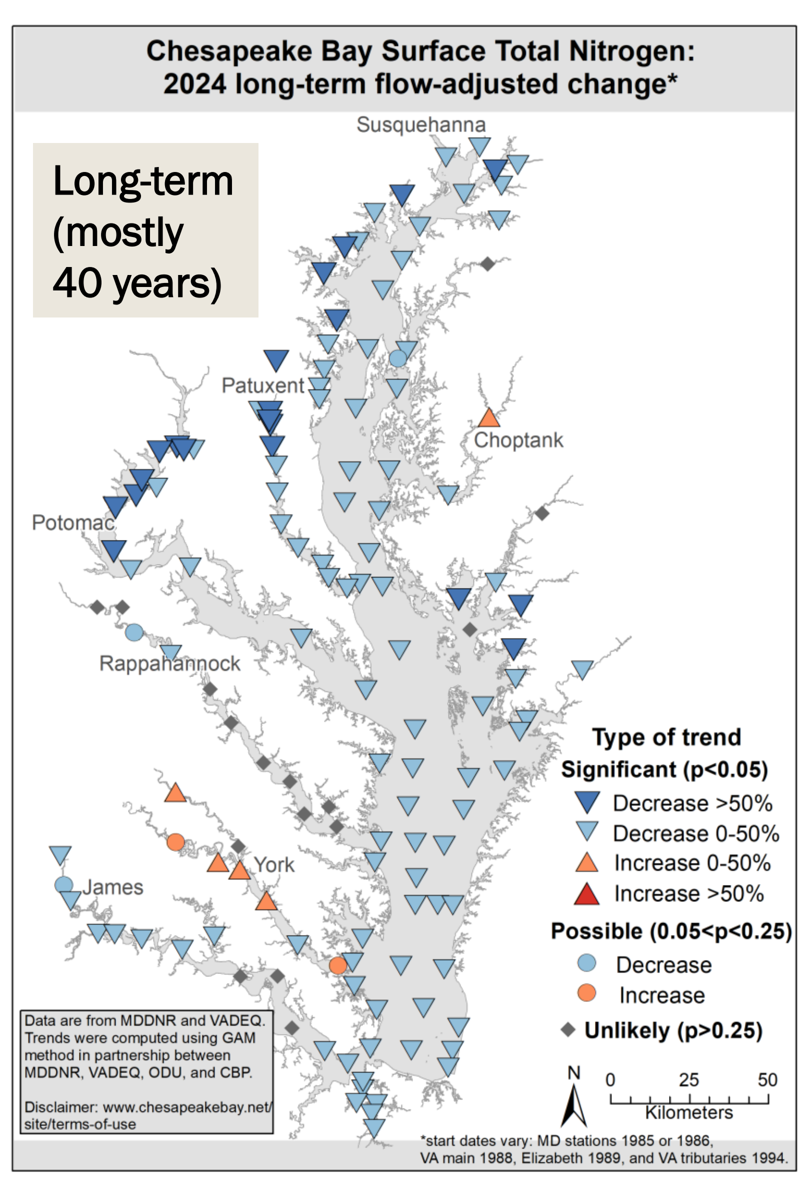


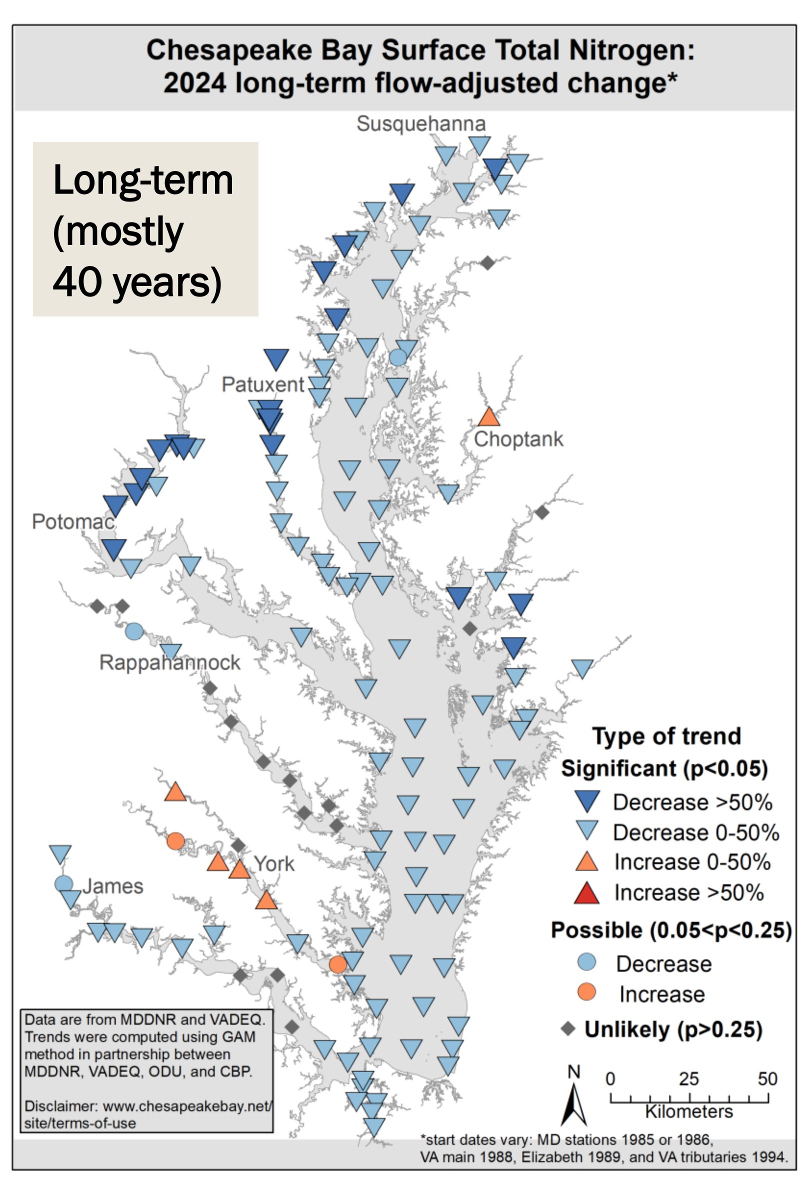
TN

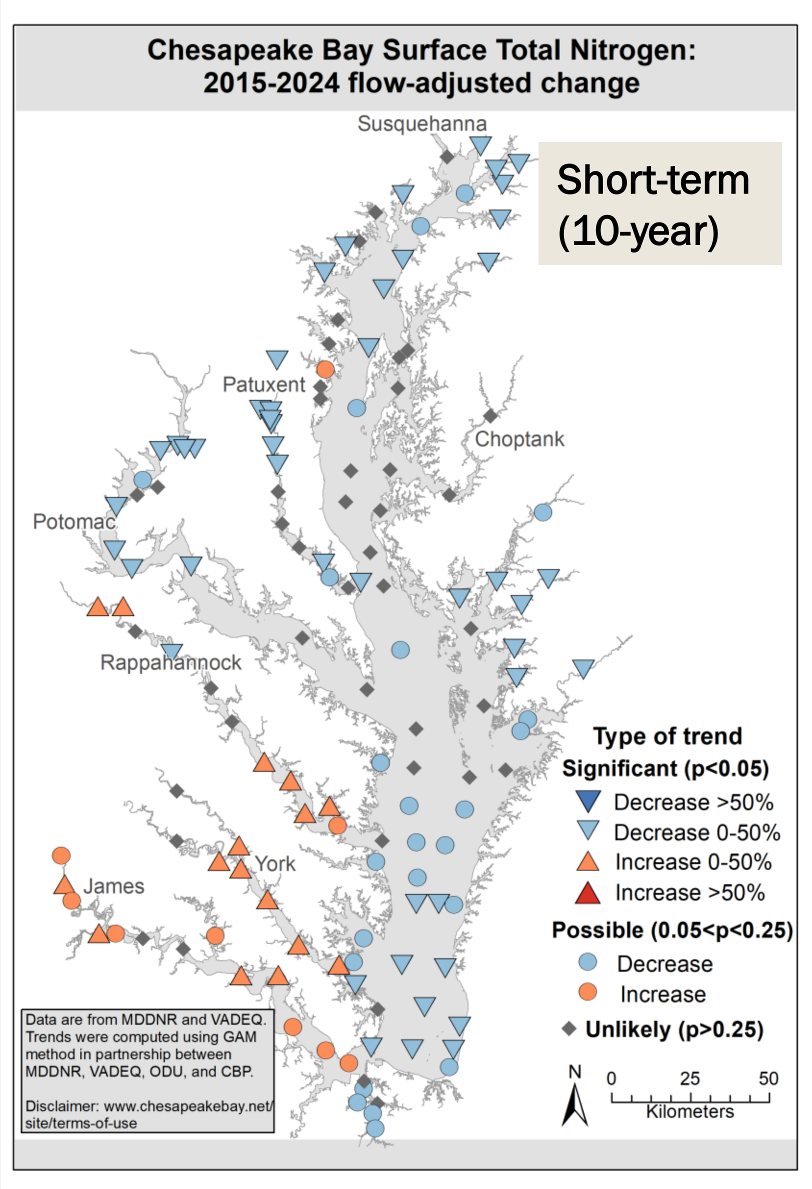
Surface Flow-adjusted



TN

Surface Flow-adjusted





TN
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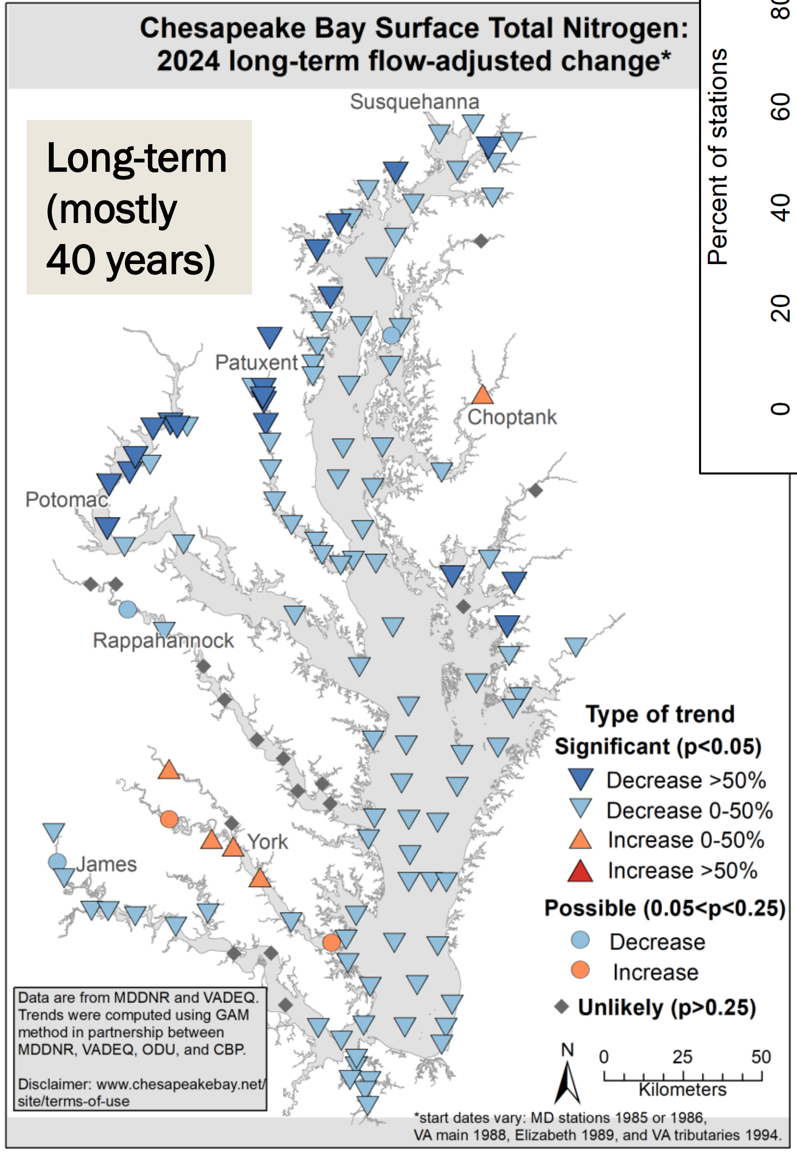
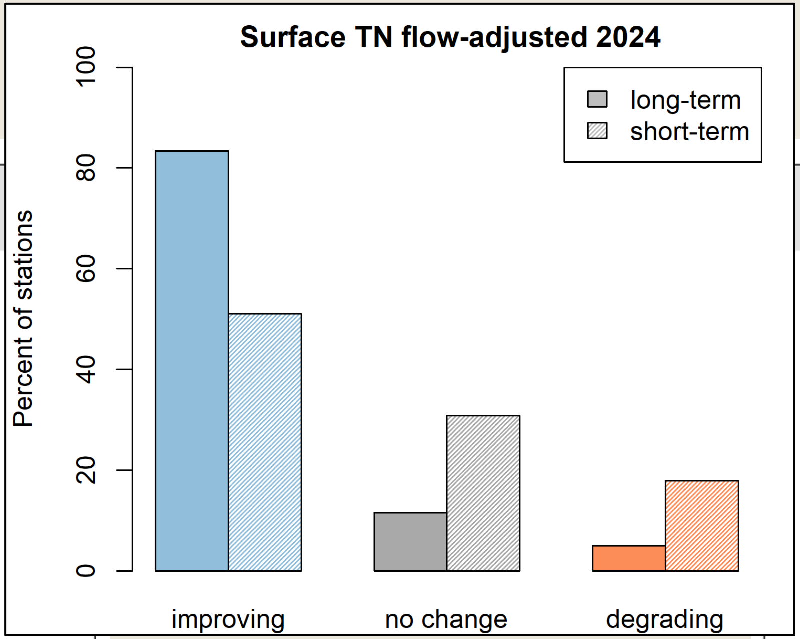
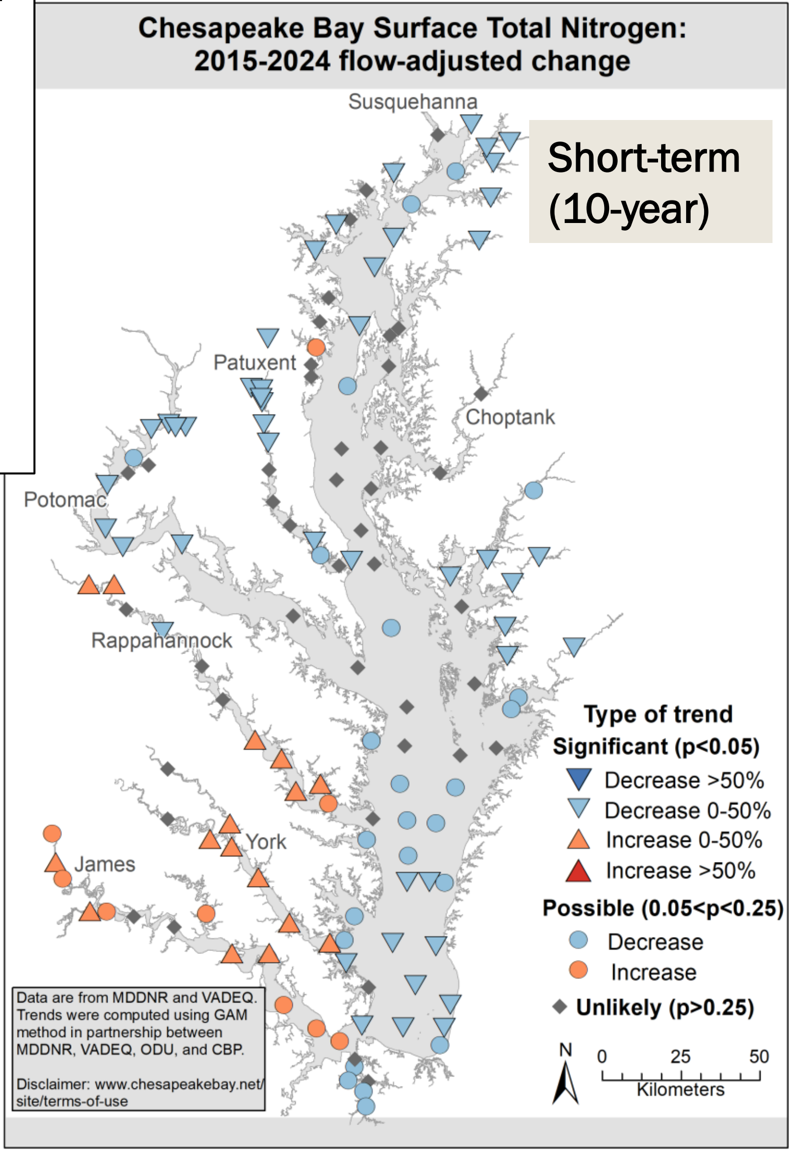


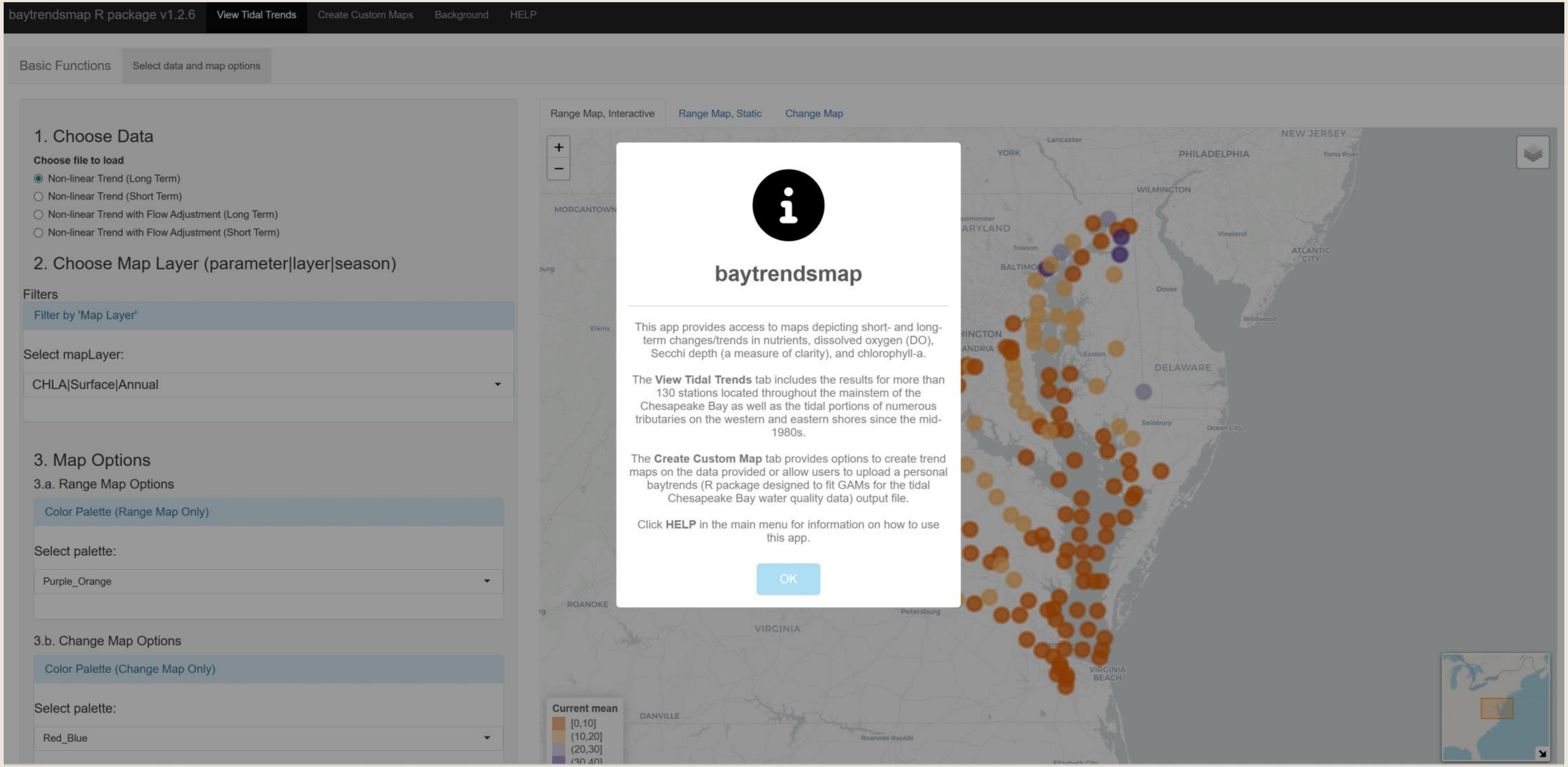




Summary for TN

- Long-term trends decreasing at majority of stations (bottom is similar).
- Short-term trends are more mixed, but the largest group is improving.

Explore more with baytrendmap: https://baytrends.chesapeakebay.net/baytrendsmap/



TN

Surface

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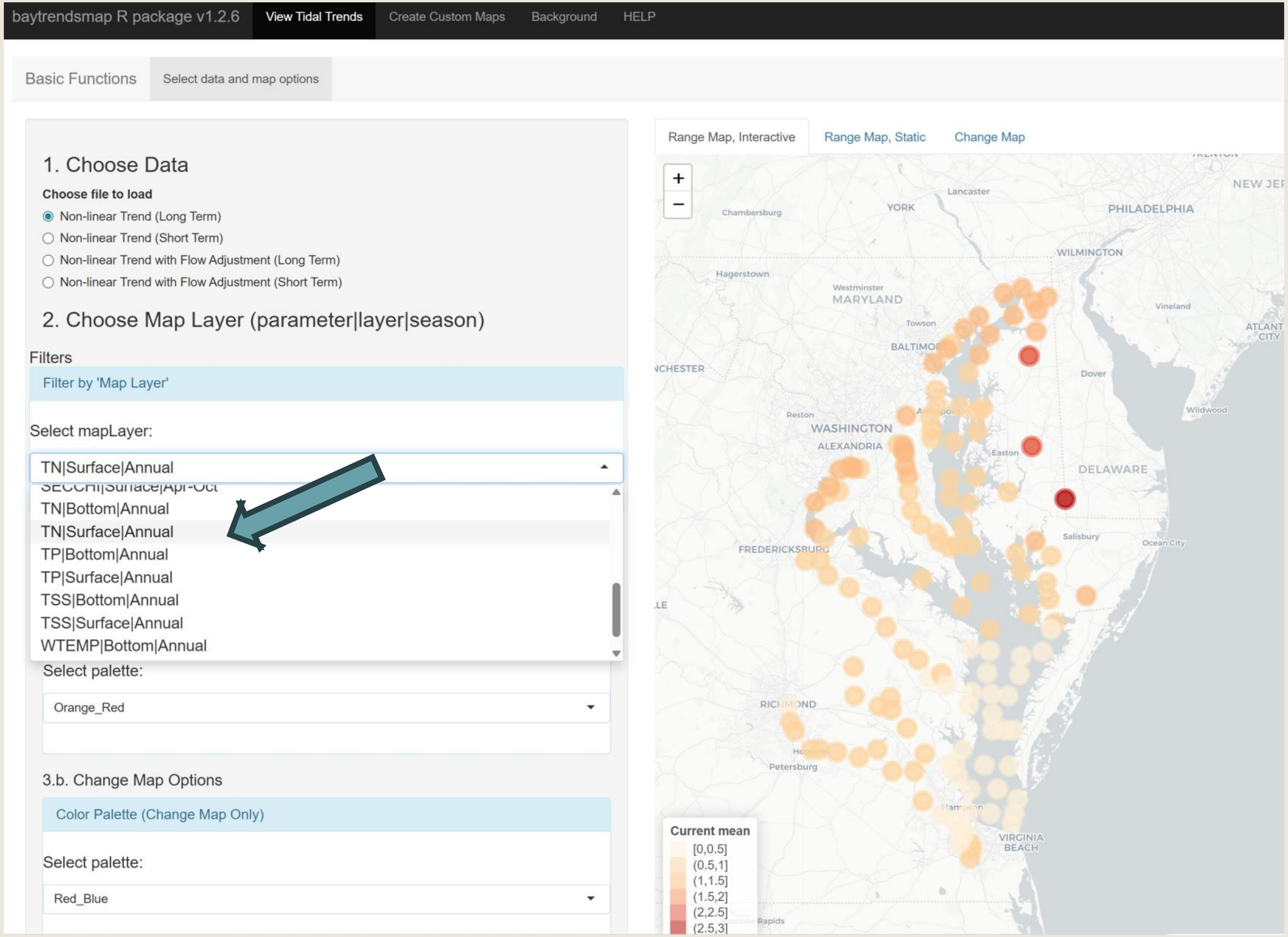

TN
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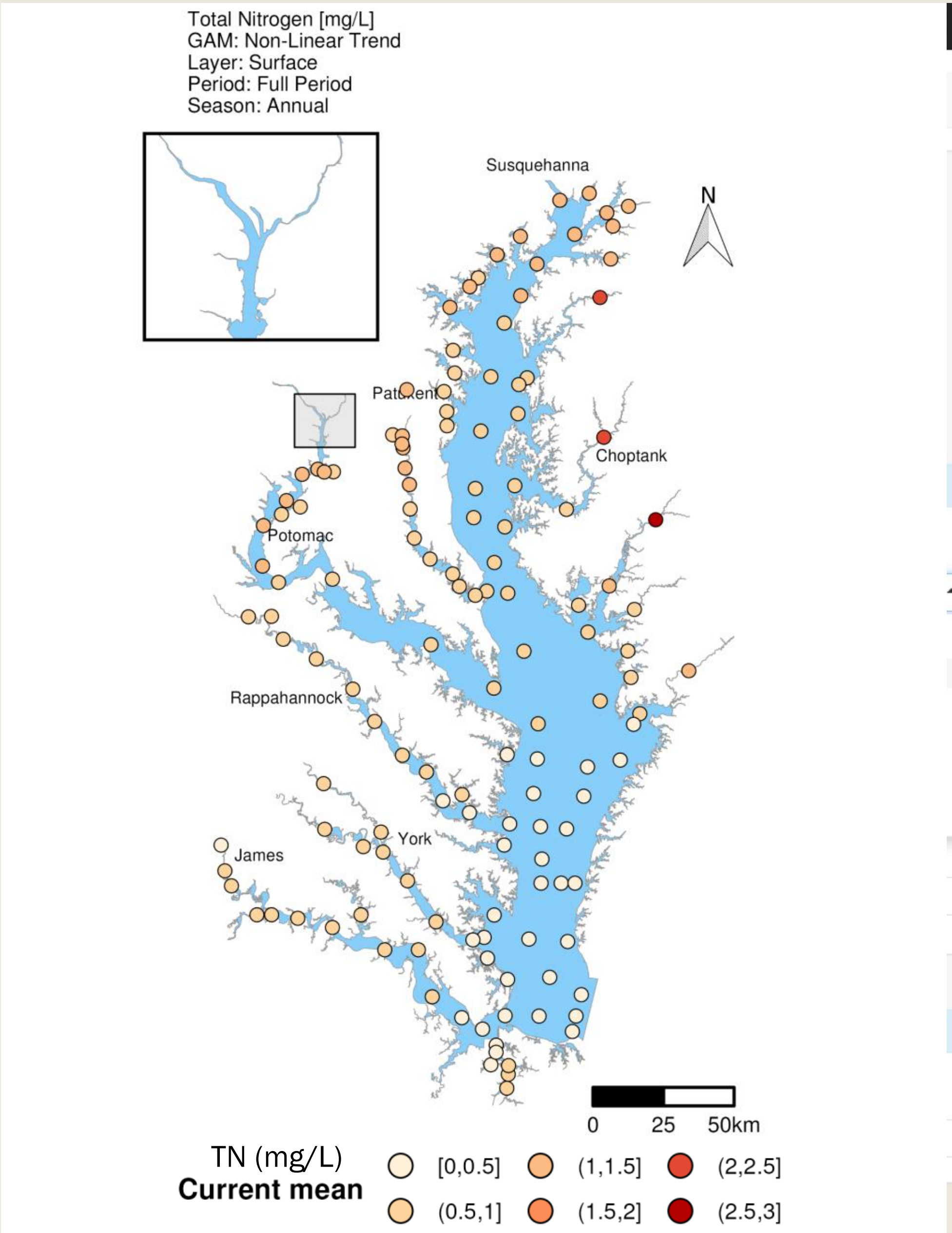

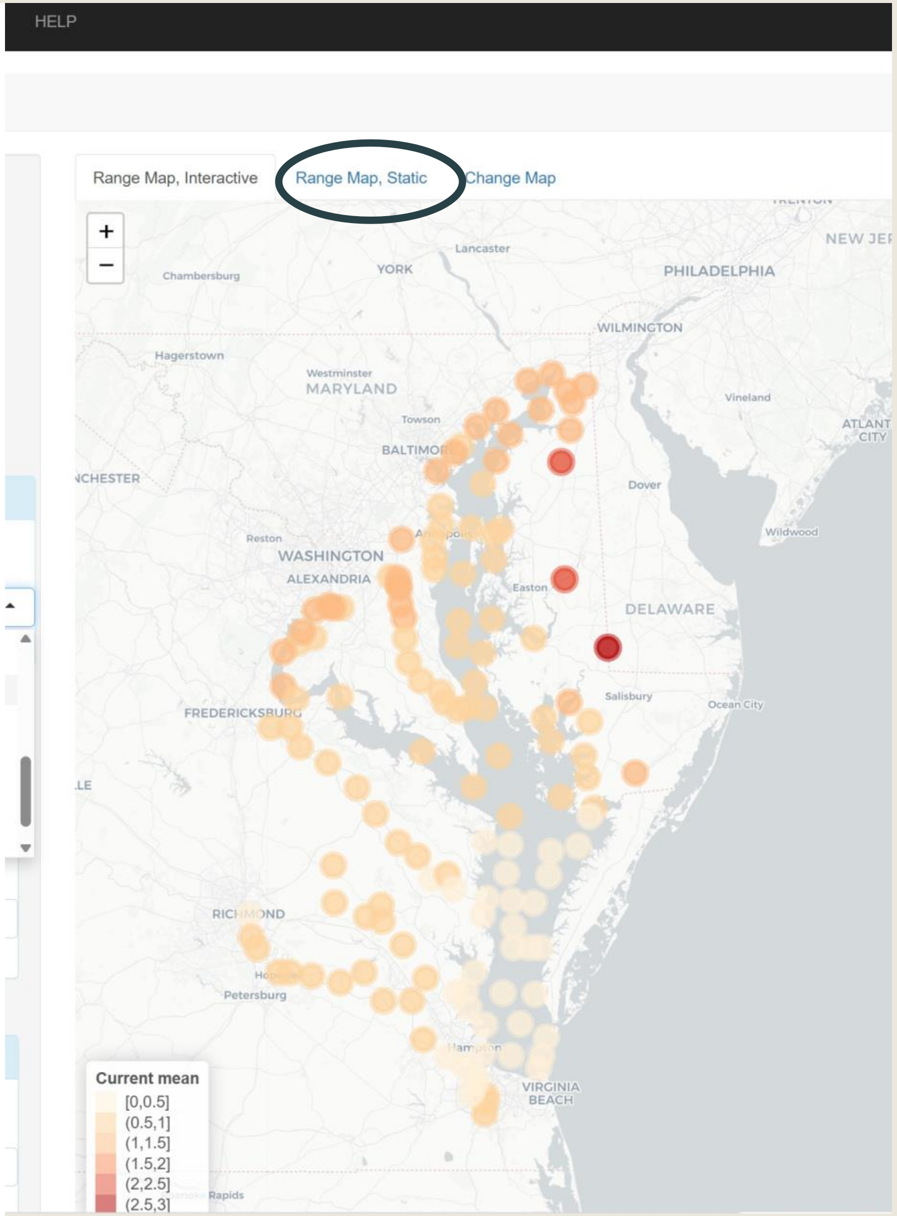

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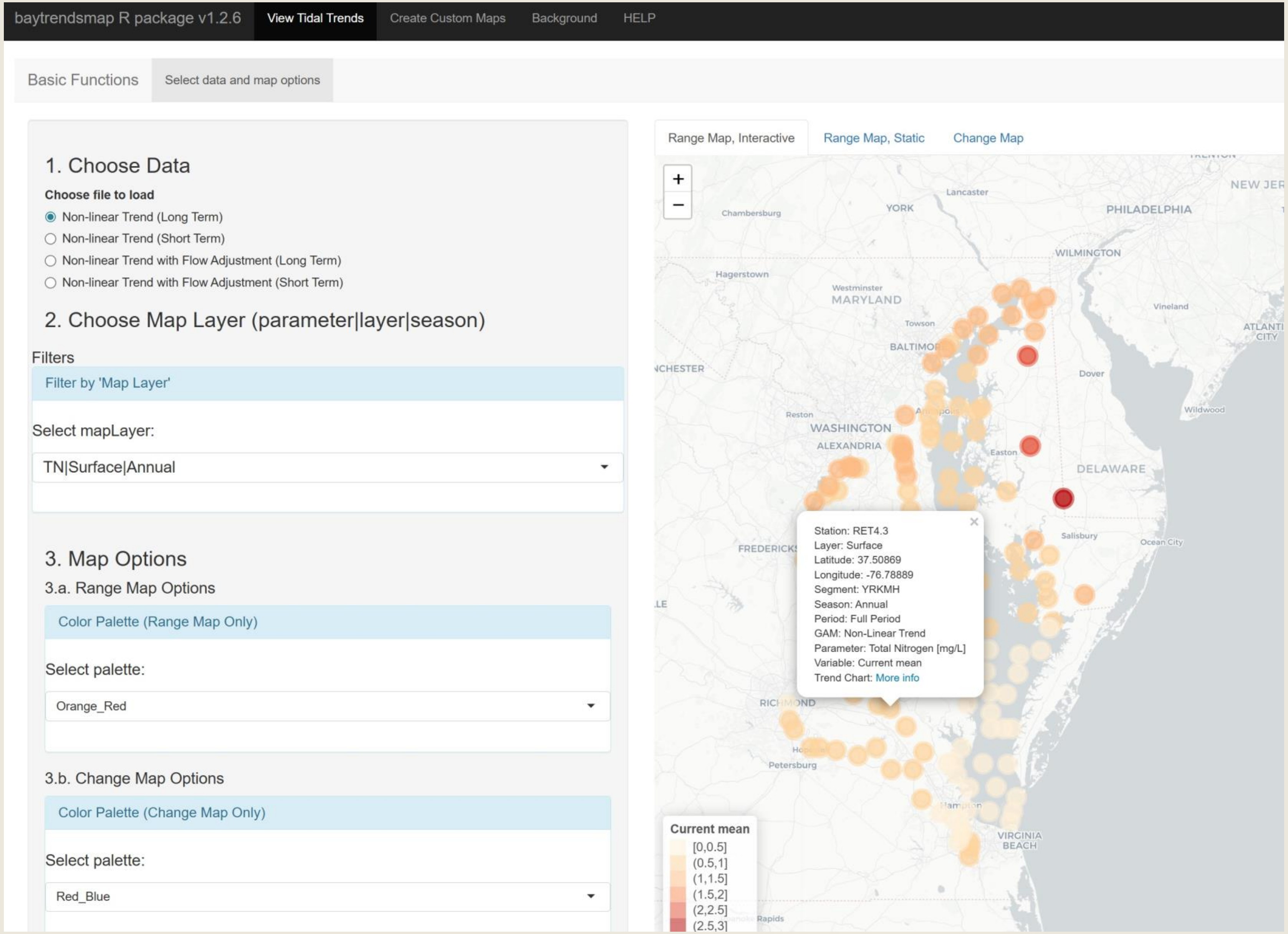
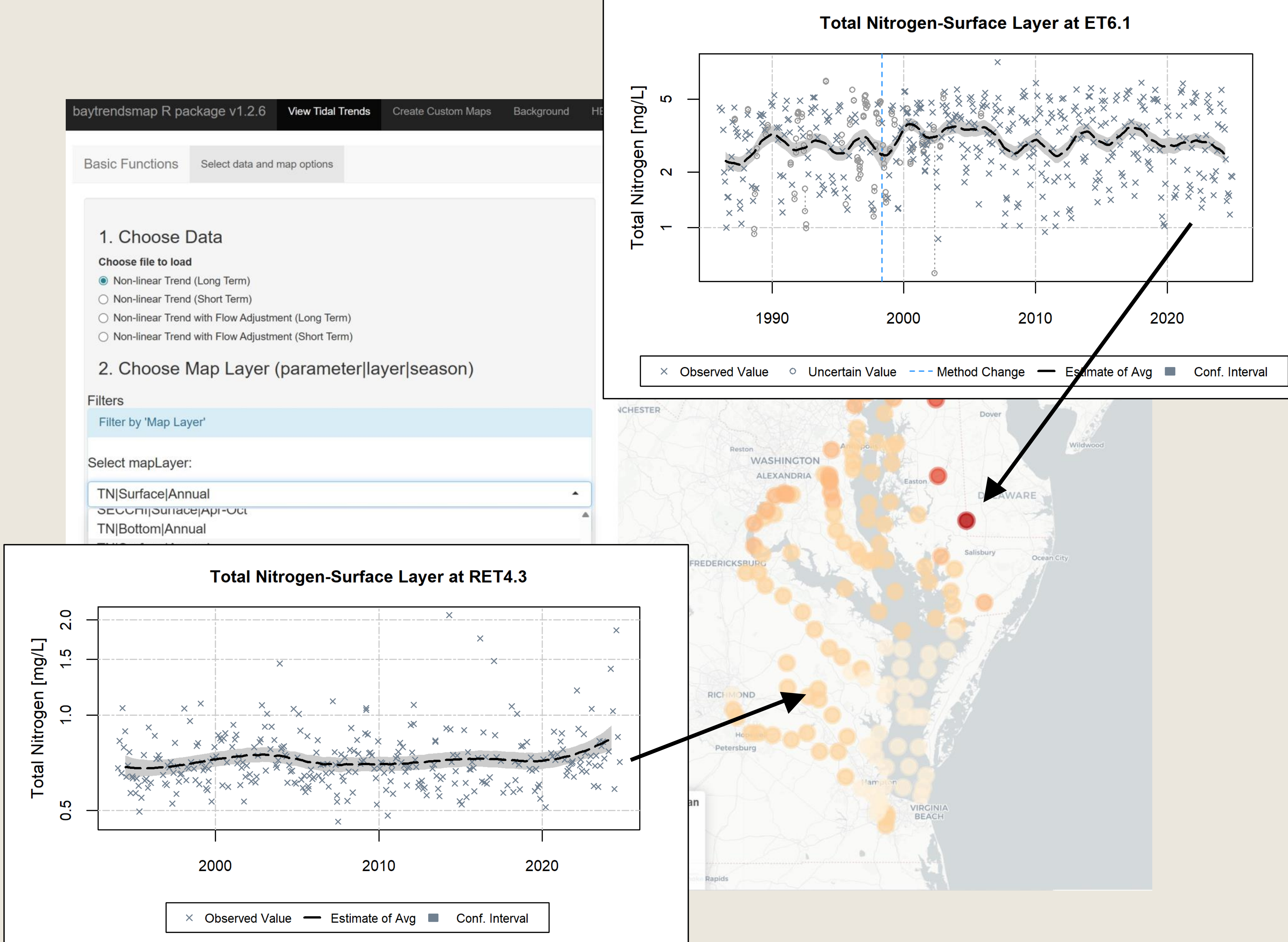


TN

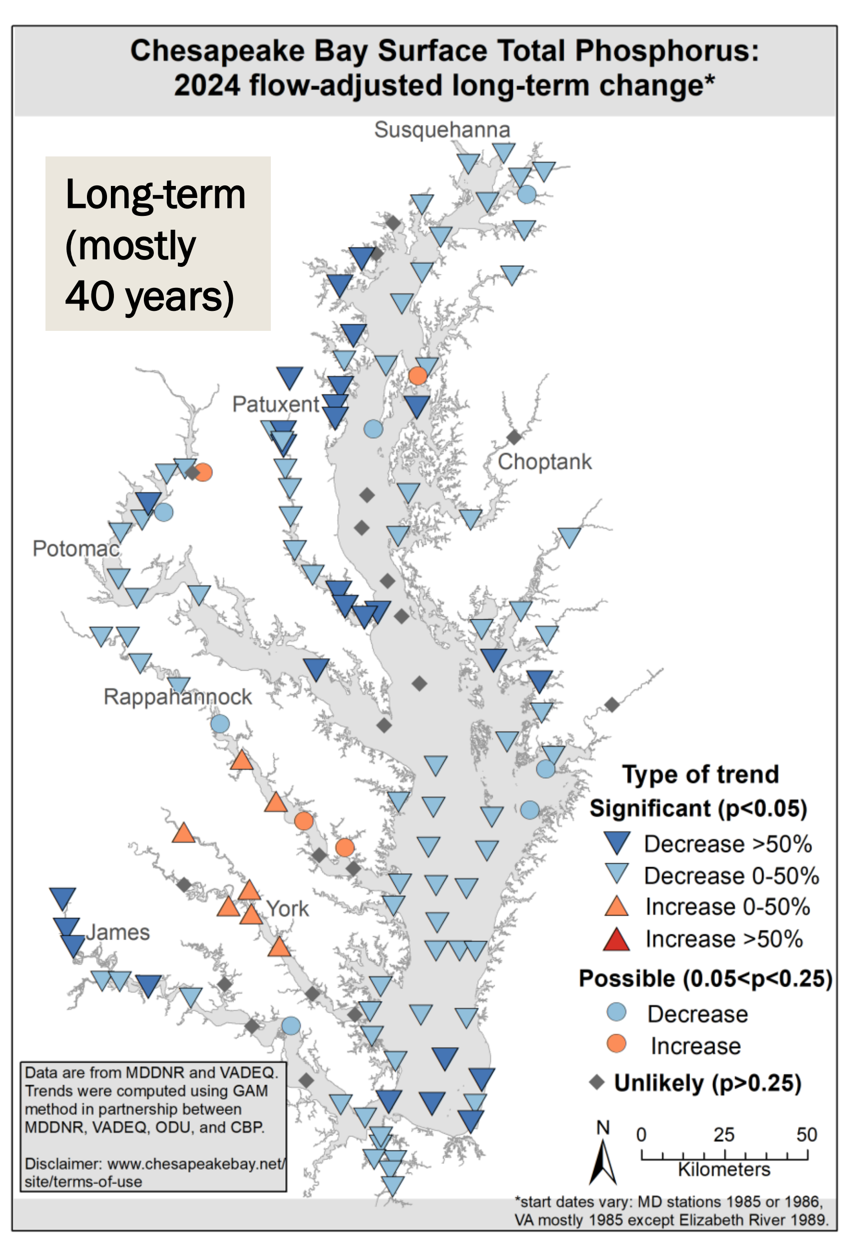
Surface



baytrendsmap R package v1.2.6
View Tidal Trends
Create Custom Maps
Background
Basic Functions
Select data and map options
1. Choose Data
Choose file to load
Non-linear Trend (Long Term)
Non-linear Trend (Short Term)
Non-linear Trend with Flow Adjustment (Long Term)
Non-linear Trend with Flow Adjustment (Short Term)
2. Choose Map Layer (parameter|layer|season)
Filters
Filter by 'Map Layer'
Select mapLayer:
TN|Surface|Annual
TN|Bottom|Annual
Total Nitrogen-Surface Layer at ET6.1
Total Nitrogen [mg/L]
1
2
5
1990
2000
2010
2020
Observed Value
Uncertain Value
Method Change
Estimate of Avg
Conf. Interval
WASHINGTON
ALEXANDRIA
Reston
Dover
Easton
Salisbury
Ocean City
Wildwood
FREDERICKSBURG
RICHMOND
Petersburg
VIRGINIA BEACH
Total Nitrogen-Surface Layer at RET4.3
Total Nitrogen [mg/L]
0.5
1.0
1.5
2.0
2000
2010
2020
Observed Value
Estimate of Avg
Conf. Interval

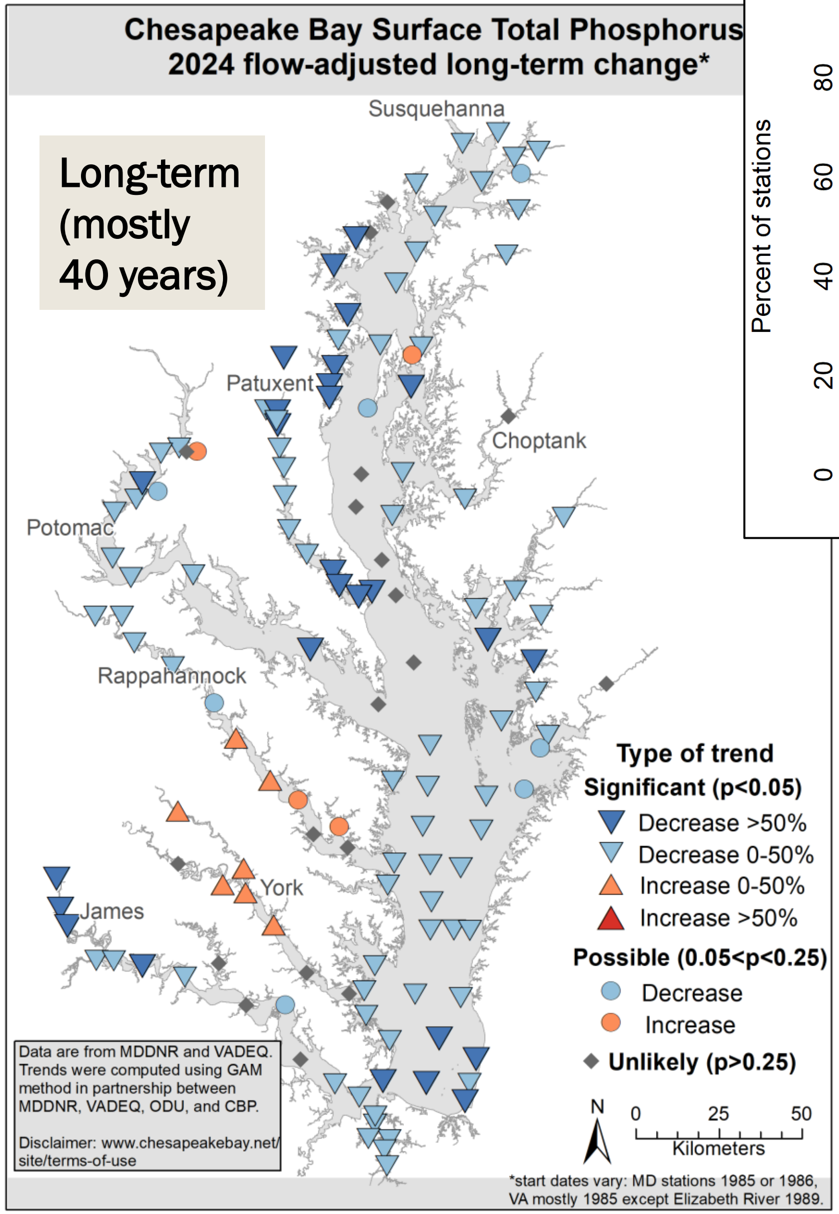
TP

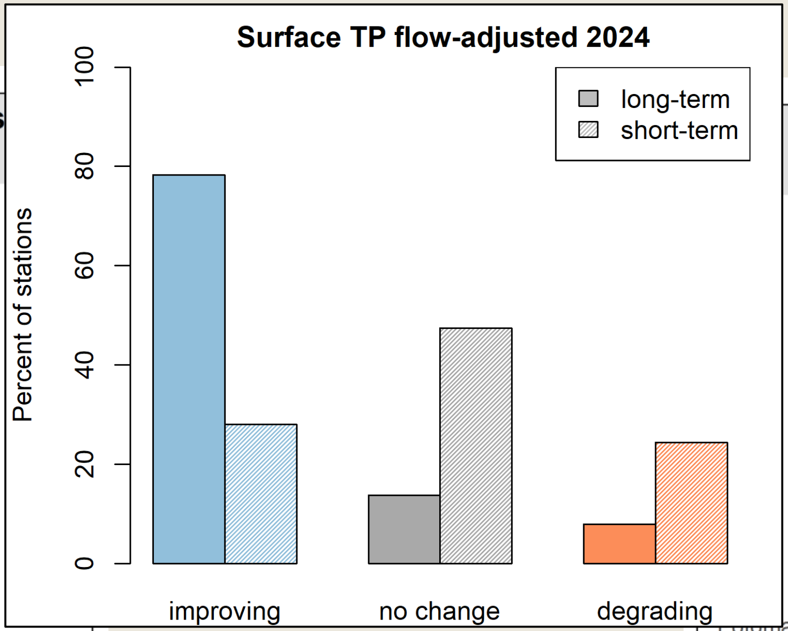
Surface Flow-adjusted

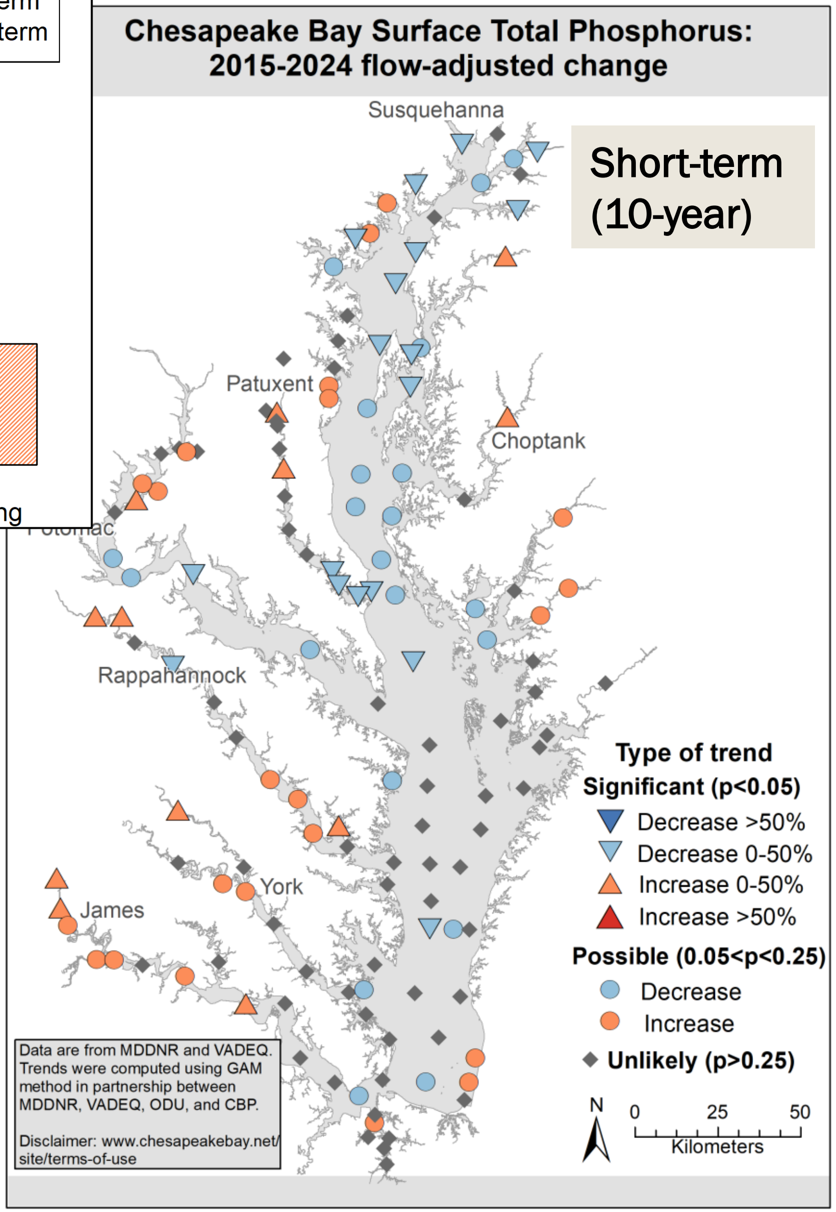


TP

Surface Flow-adjusted



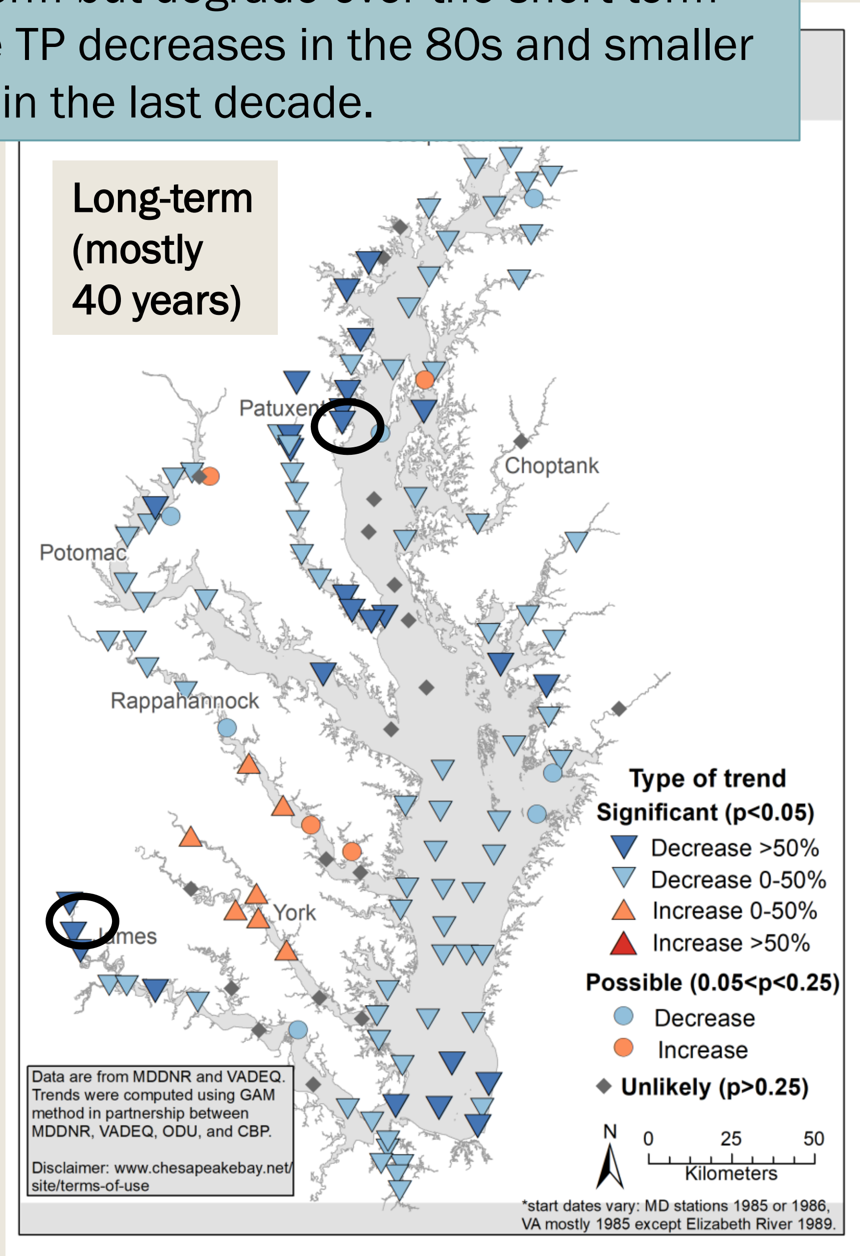


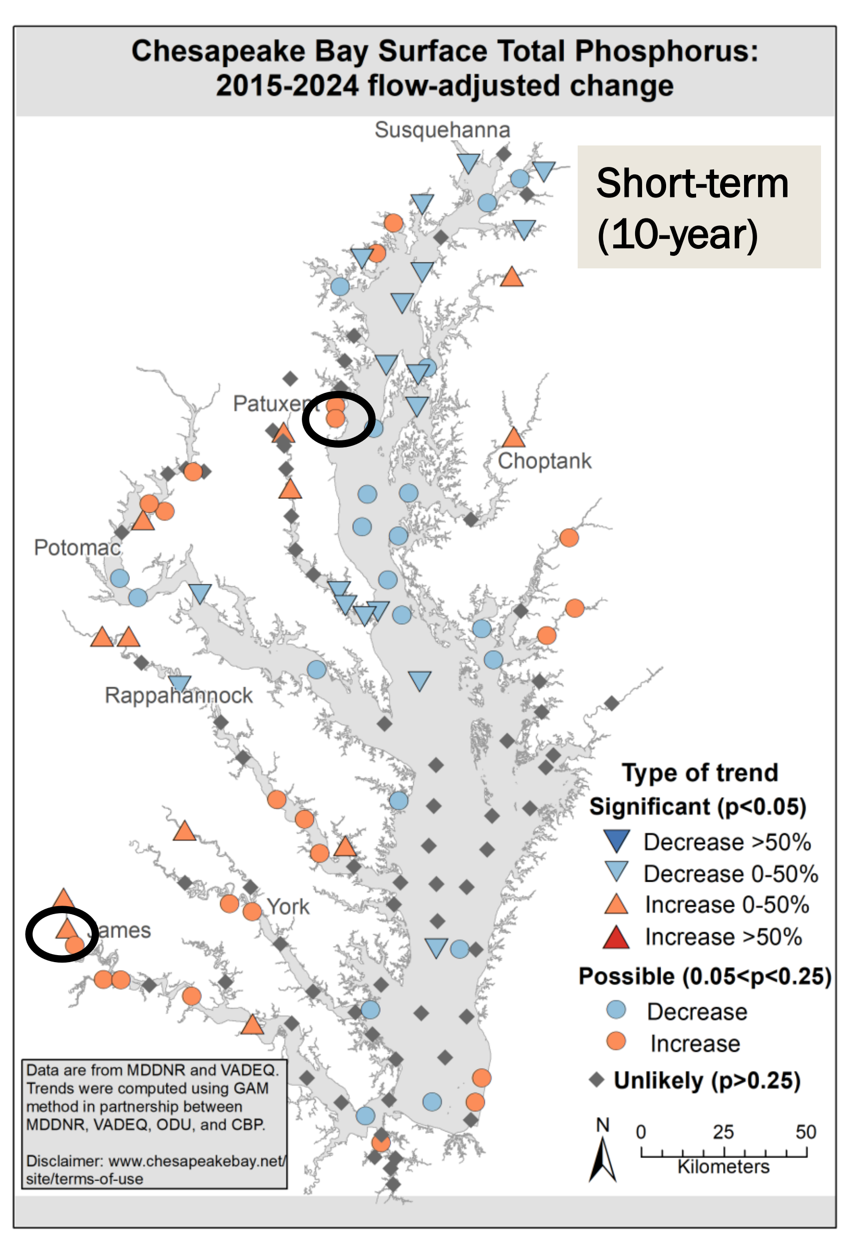


Summary for TP

- Long-term trends decreasing at majority of stations (bottom is similar).
- Short-term is more mixed, with the largest group with no trend.

Example: Several of the trends that improve over the long-term but degrade over the short-term have large TP decreases in the 80s and smaller increases in the last decade.





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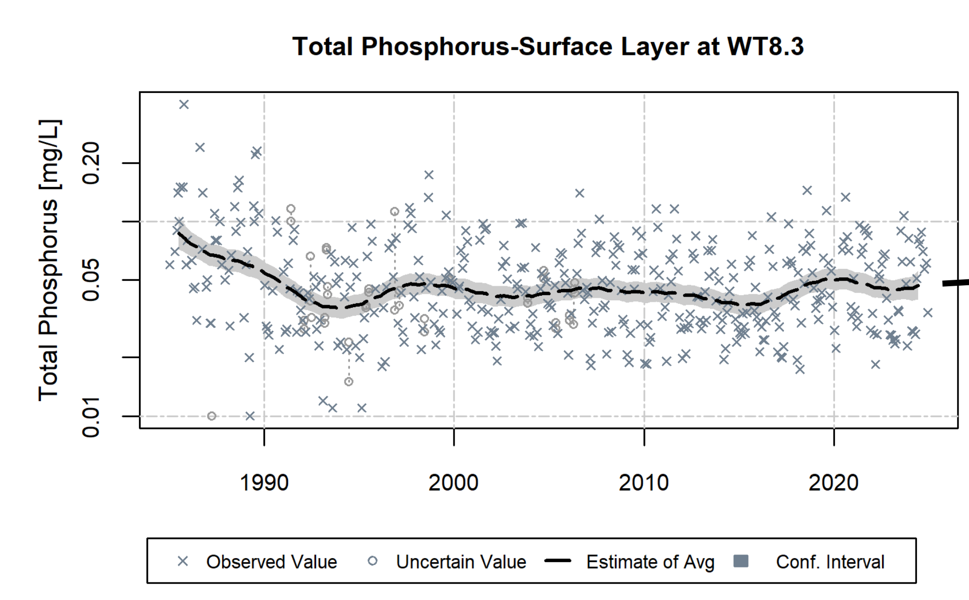
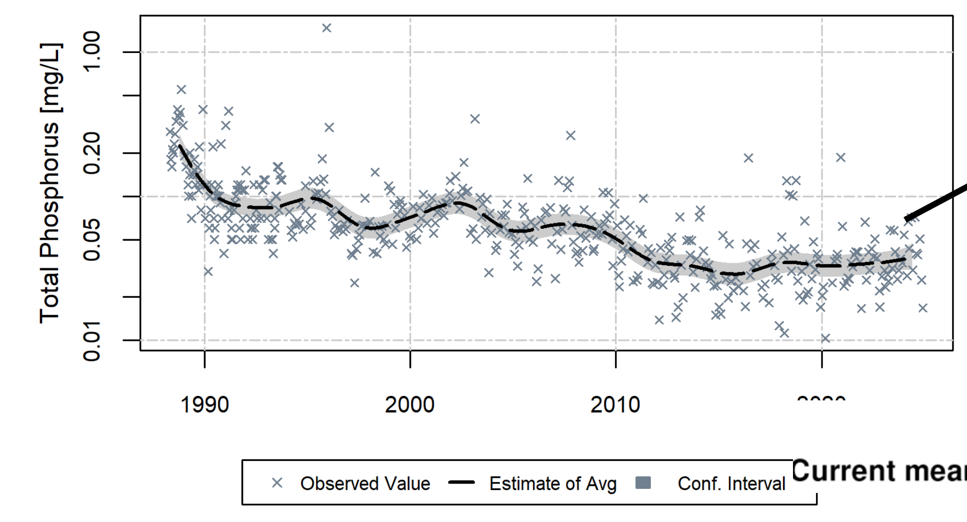
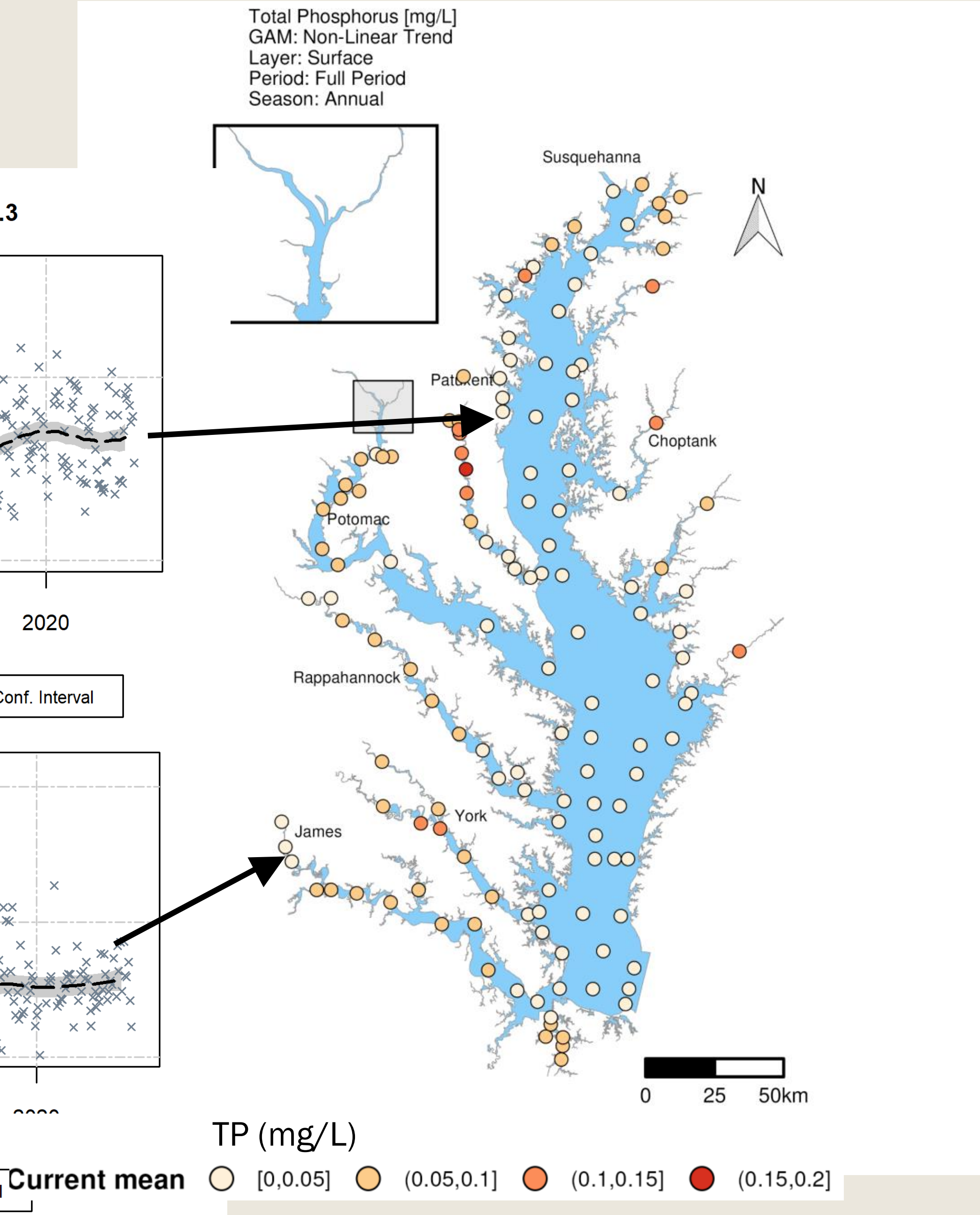






Comparison to watershed loads (USGS RIM Trends)

	RIM Monitoring Station	Long term: 1985 - 2024			Short term: 2015 - 2024		
		TN	TP	SS	TN	TP	SS
Maryland RIM stations	SUSQ	-31.2%	-4.6%	+21.5%	-12.4%	-22.8%	-24.8%
	CHOP	-2.5%	+77.4%	-34.3%	-4.5%	+20.2%	-7.5%
	PATX	-69.5%	-66.8%	-44.0%	-21.0%	-5.5%	-4.5%
	POTO	-18.4%	-24.3%	-41.7%	-7.6%	-1.0%	+13.1%
Virginia RIM stations	RAPP	-15.6%	+31.2%	+50.0%	+7.3%	+7.6%	+1.7%
	MATT	-6.4%	+6.4%	+8.6%	+1.7%	+8.9%	+26.9%
	PAM	-1.3%	+59.2%	+36.3%	-3.9%	+1.0%	-9.9%
	JAMC	-8.0%	-22.1%	+40.3%	+11.2%	+25.8%	+20.9%
	APPO	+6.4%	+99.5%	+44.2%	+5.4%	+23.4%	+38.9%

Trend Direction Improving (green) Degrading (orange) No trend (grey)

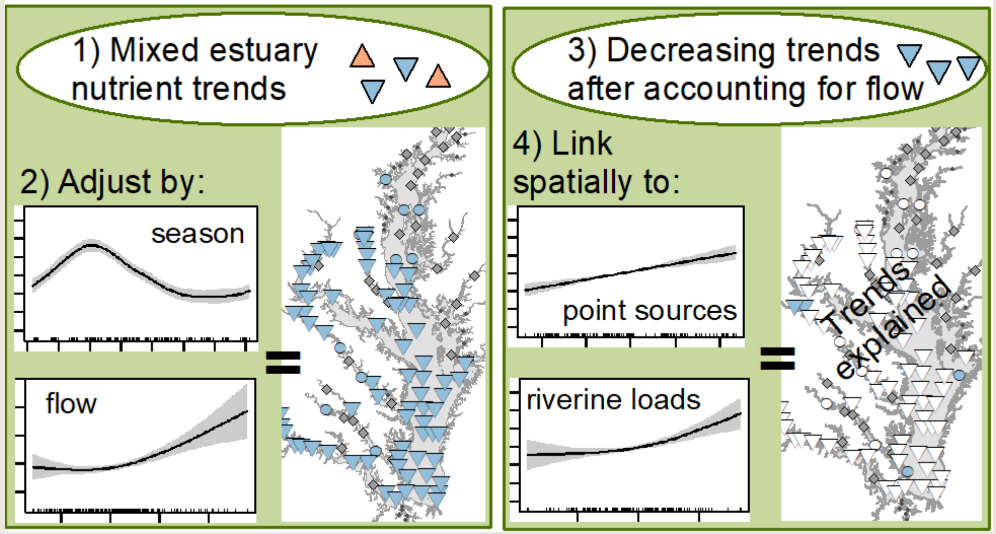
- Similar long and short-term patterns in nontidal and tidal tributaries.
- TN: more improving long-term than short-term.
- TP: More mixed conditions than TN, with the same tributaries showing increasing trends.

From Jimmy Webber, USGS

Comparison to watershed loads (previous work)

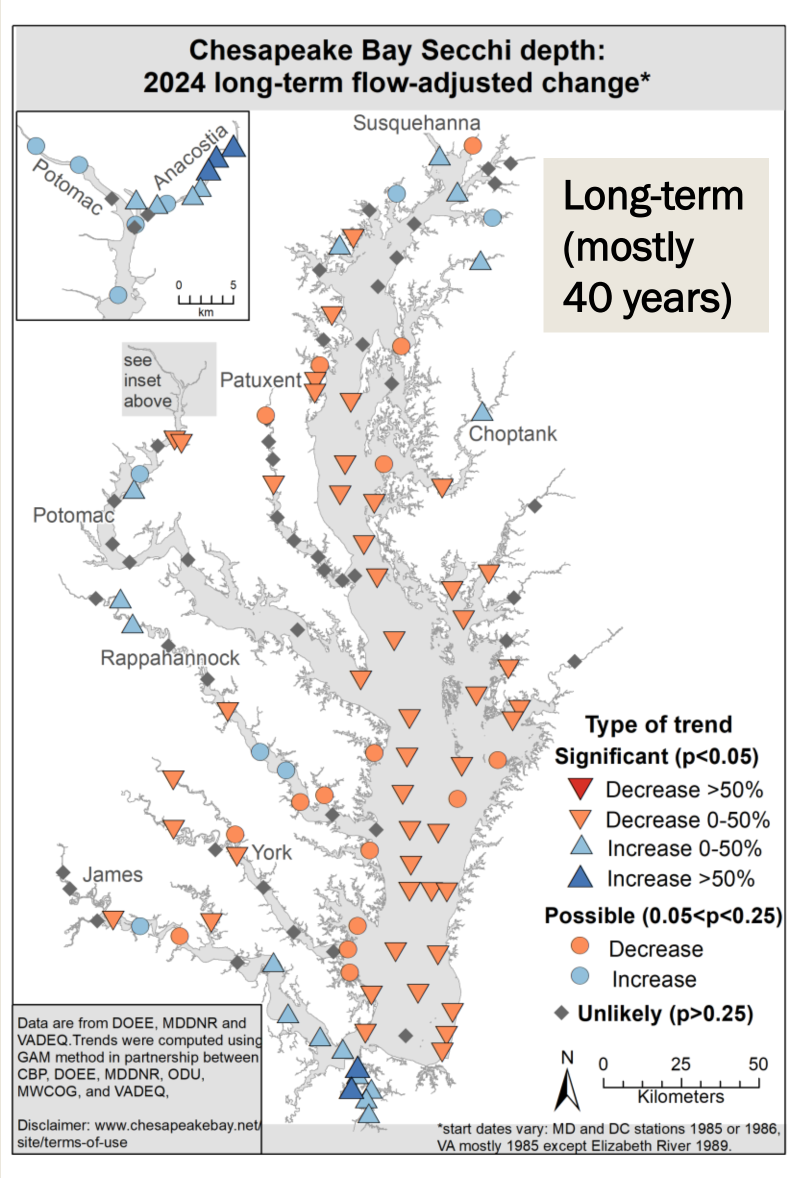
Our 2022 study using 1999-2018 trends showed:

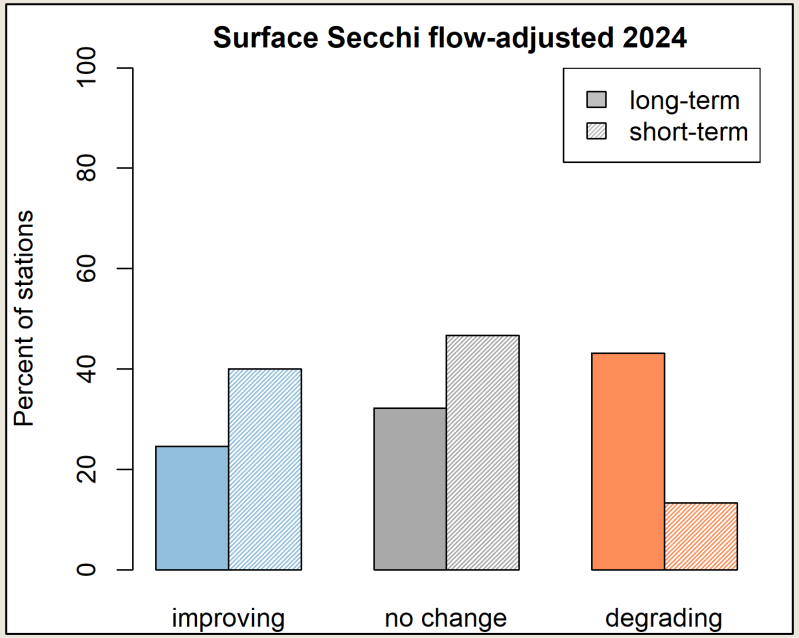
- Flow impacts on trends are substantial
- Both riverine and point sources together are responsible for nutrient trends in the estuary.
- There is large spatial influence of loads from many parts of the watershed, indicating that reductions from only one source type or subbasin will not be sufficient to reduce nutrient concentrations bay-wide.



Murphy et al. 2021 "Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management" https://doi.org/10.1021/acs.est.1c05388

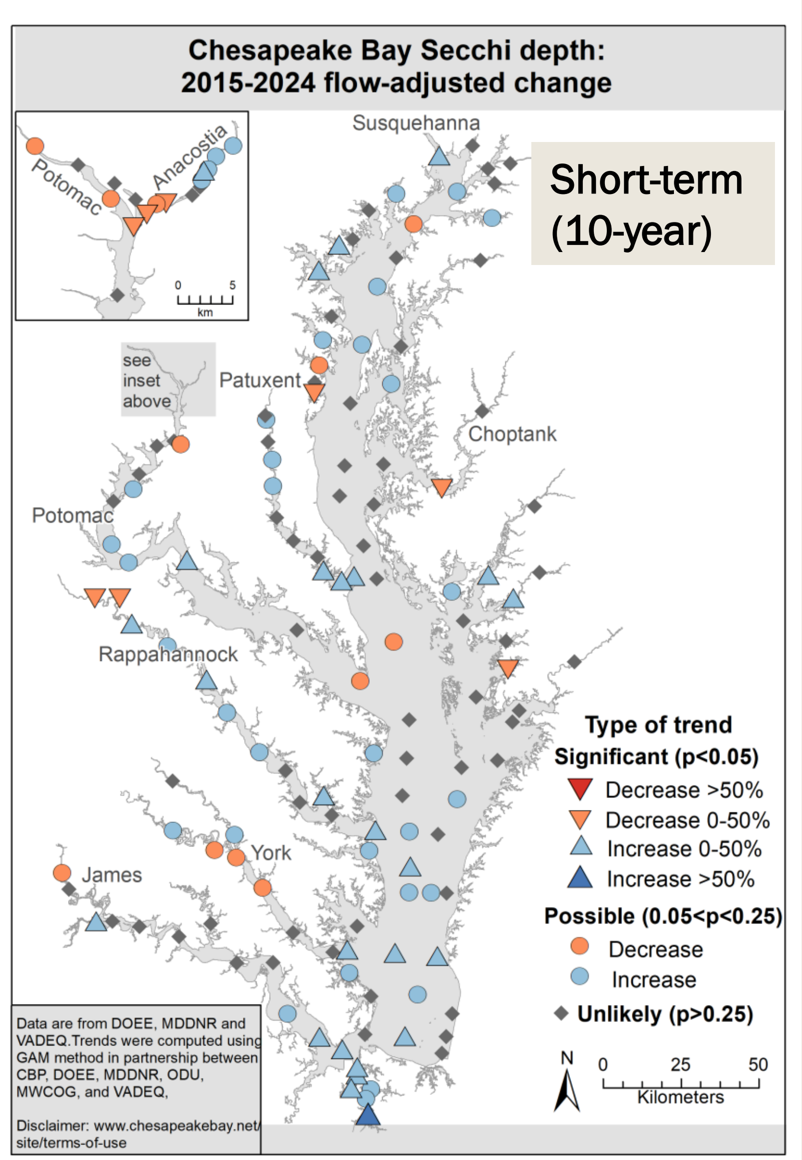
Secchi depth



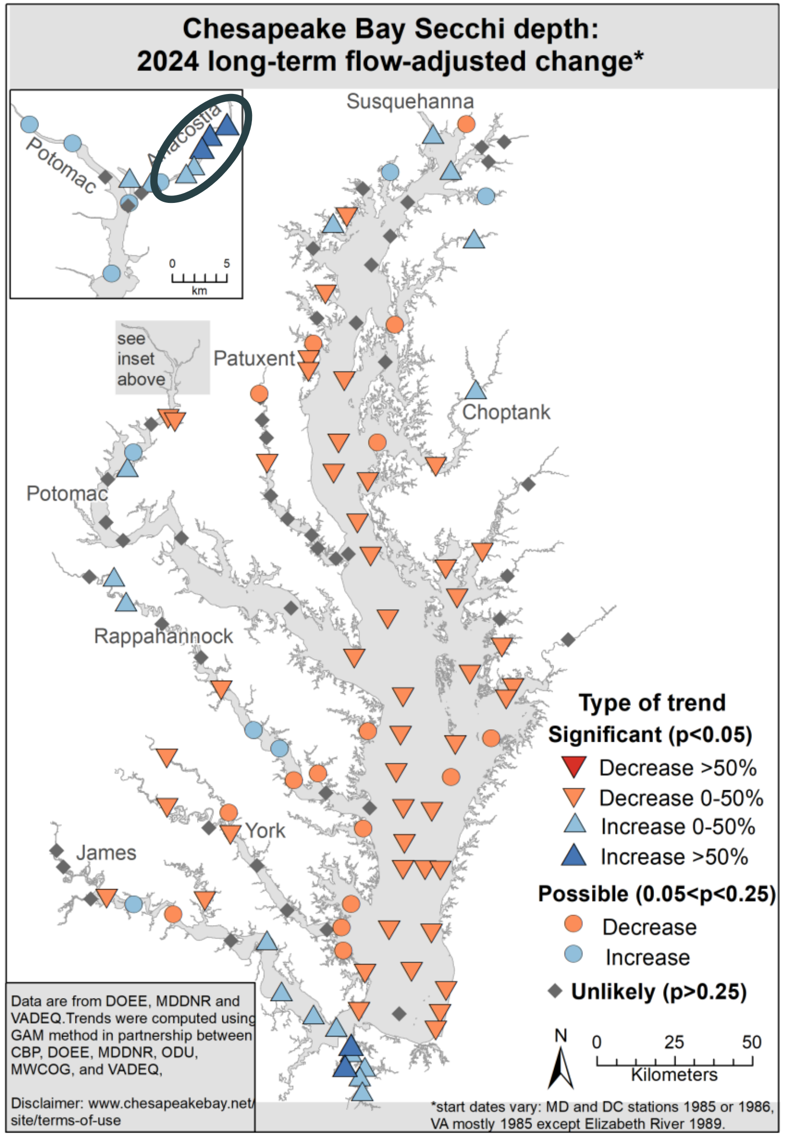


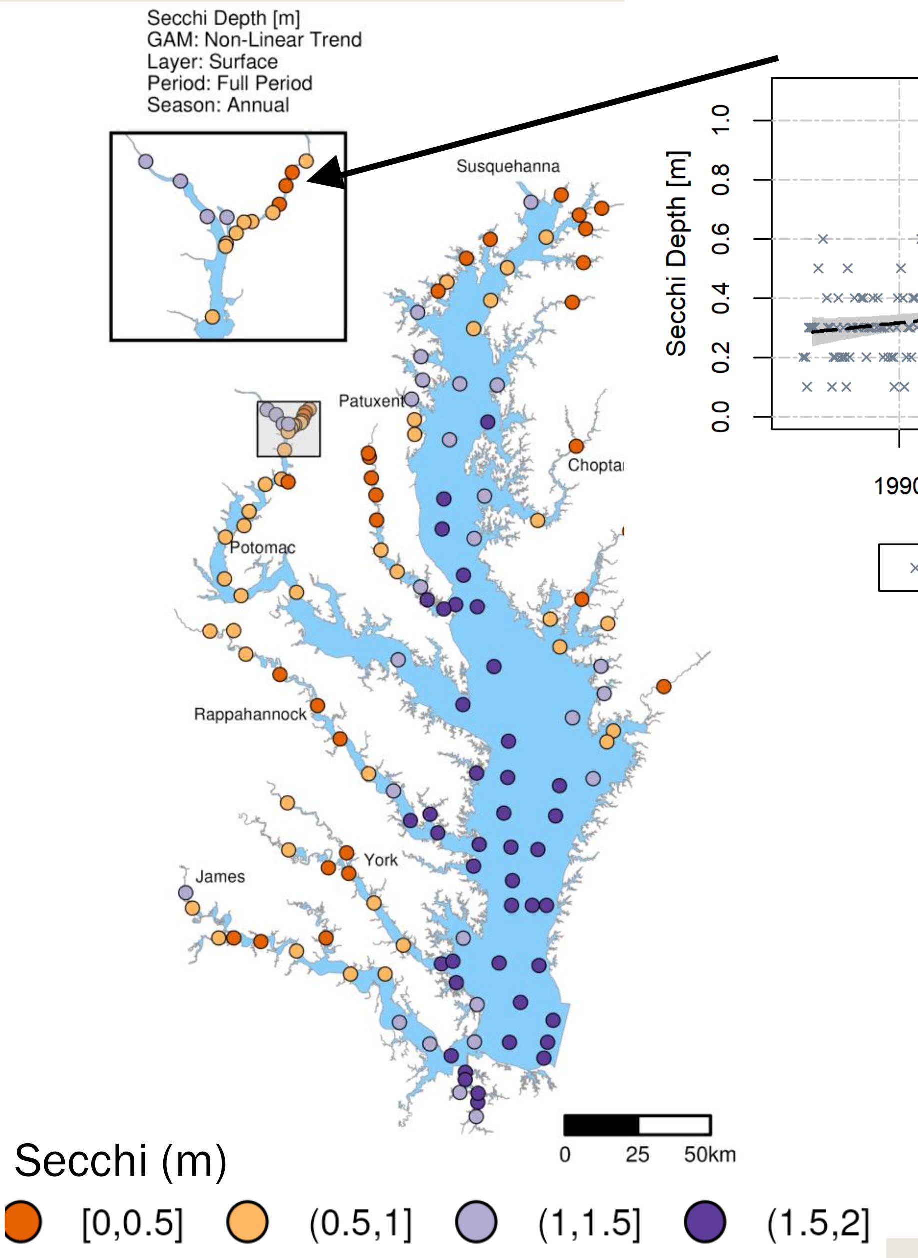
Summary for Secchi

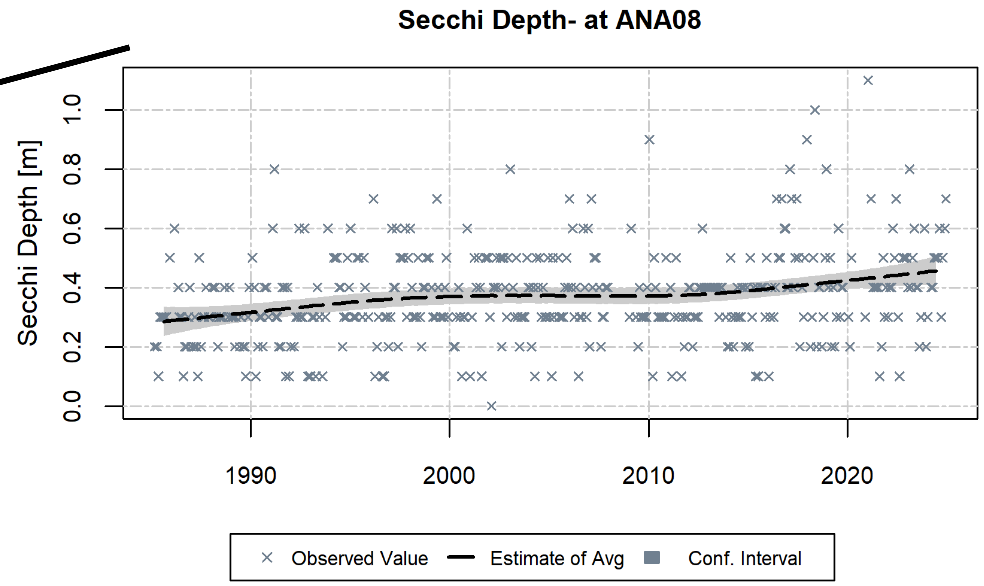
- Long-term degradation in Secchi depth is notable across many regions of the bay.
- But in last 10 years, there are more improvements than degradations.
- These patterns were analyzed recently by Turner et al. 2025: https://doi.org/10.1146/annurev-marine-040224-120528



Secchi depth

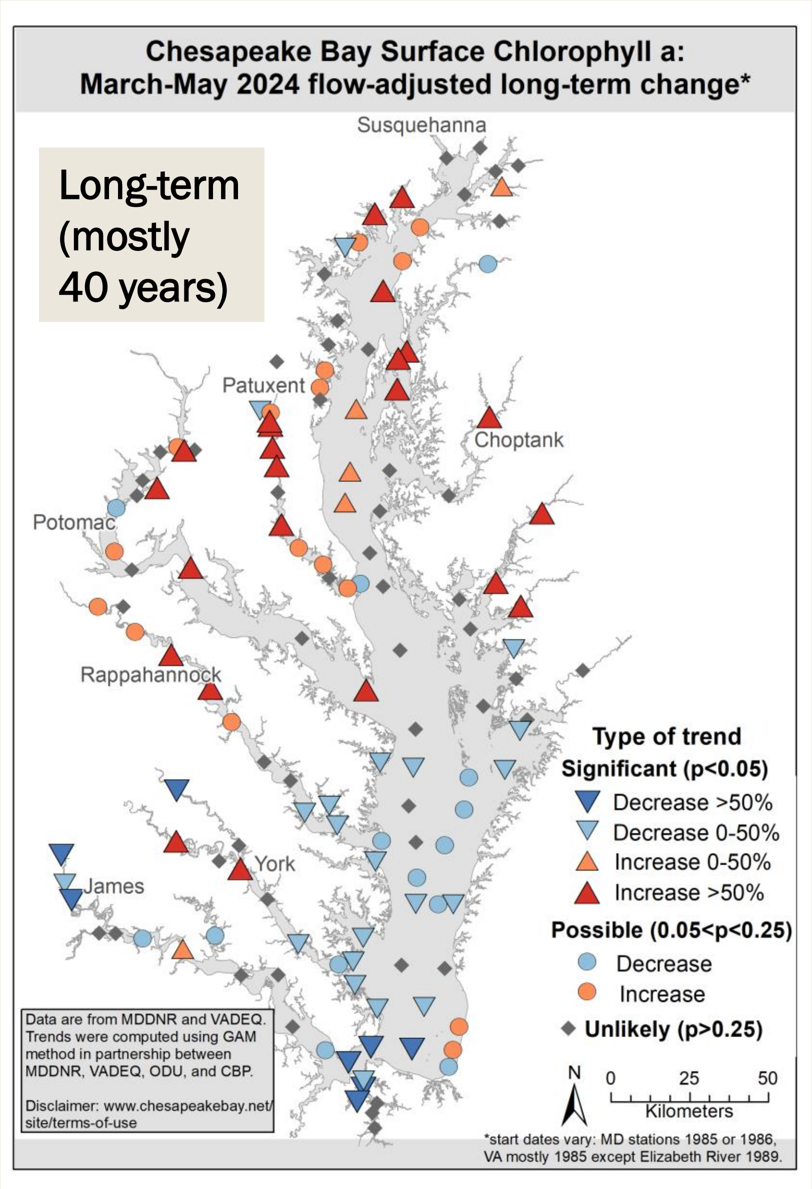


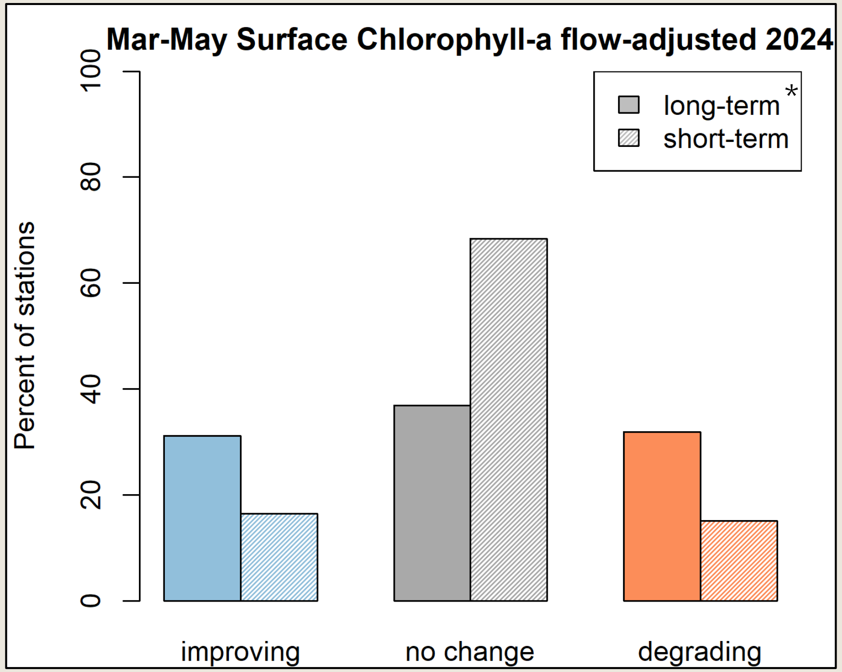


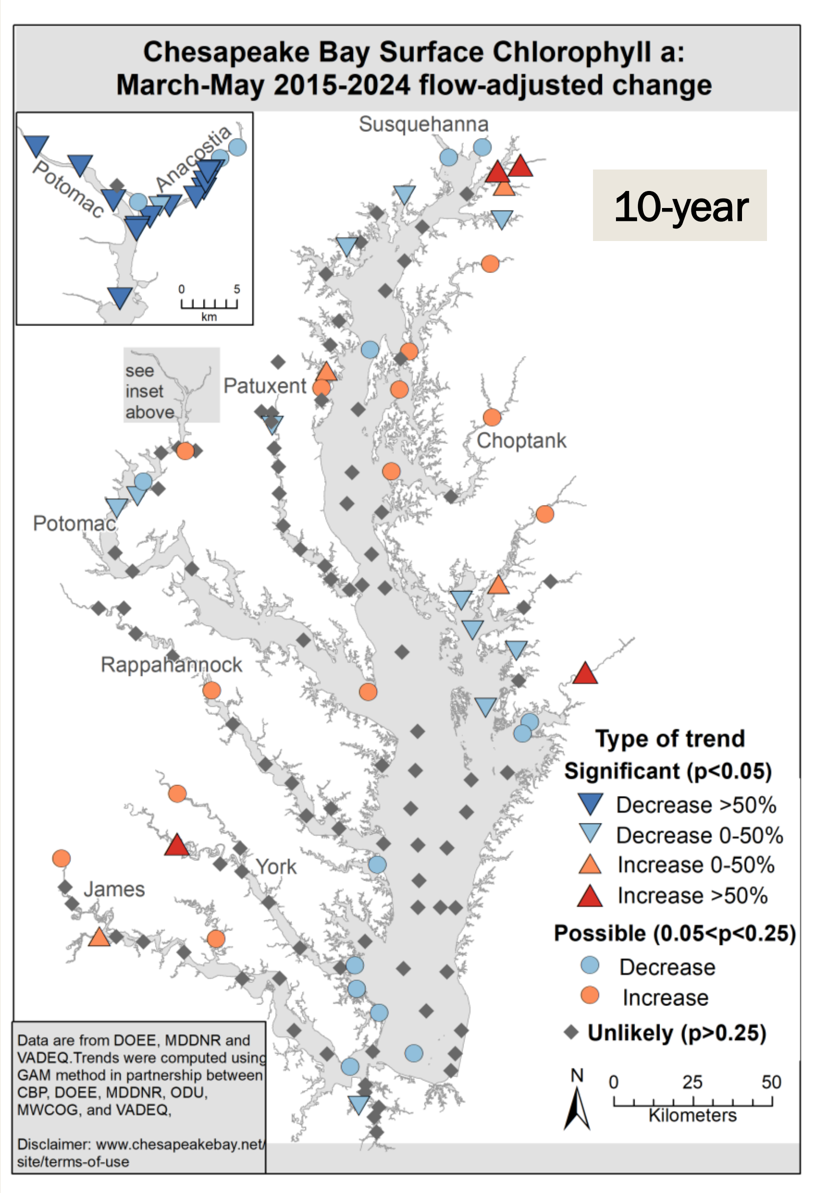


Spring Chlorophyll *a*

Surface Flow-adjusted





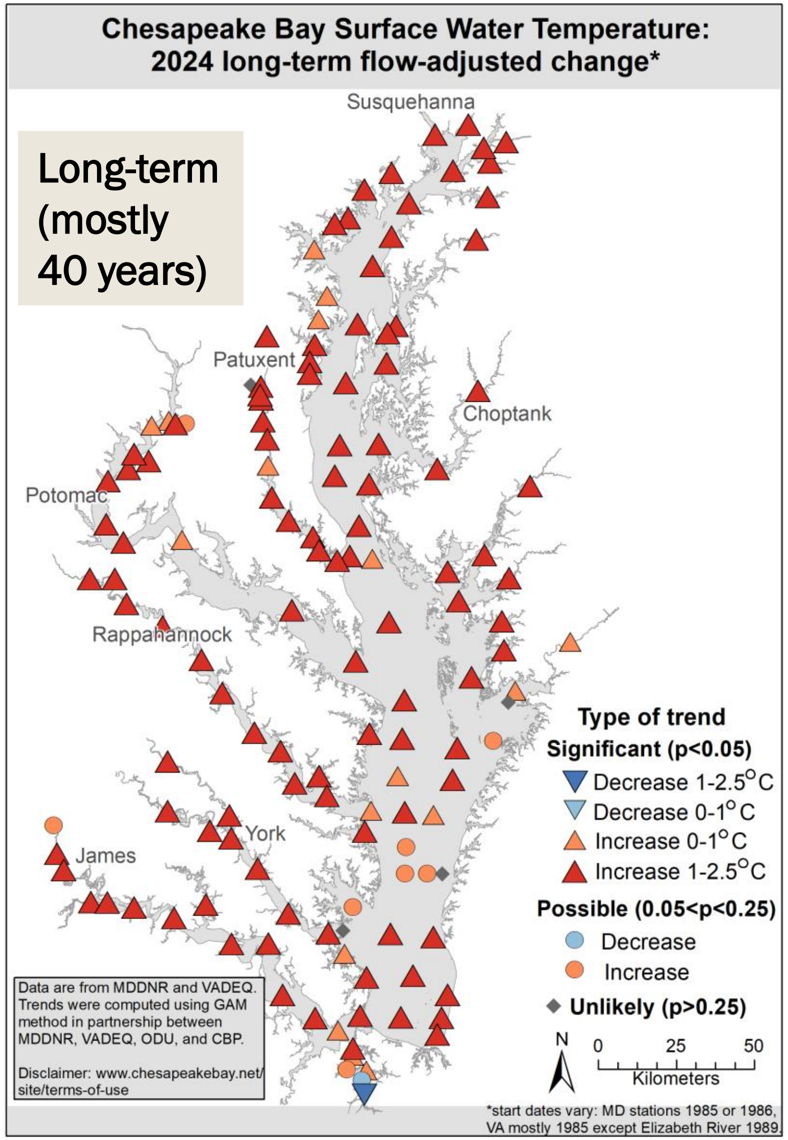


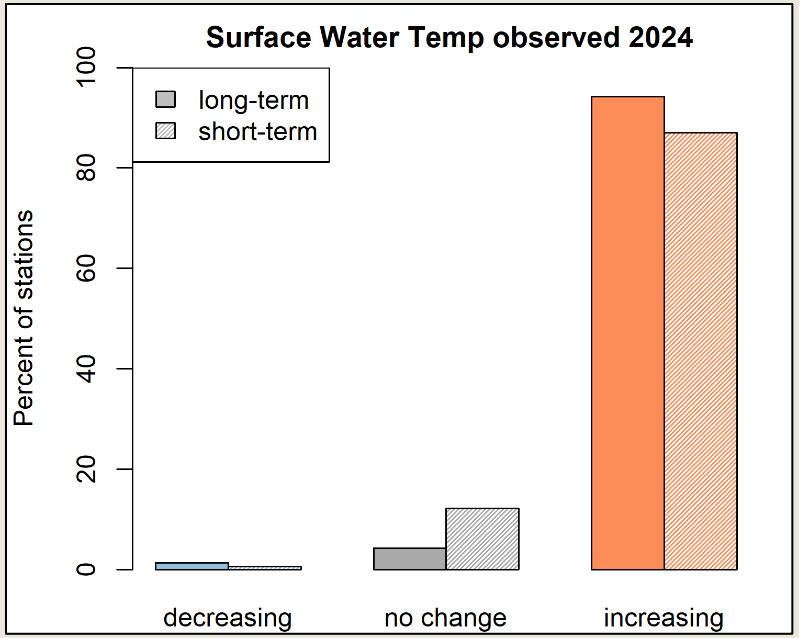
Summary for Chlorophyll

- A large mixture of trend types for chlorophyll *a*.
- The summer trends are similar.

*Bar chart does not include DC trends since we don't have them for both long and short-term.

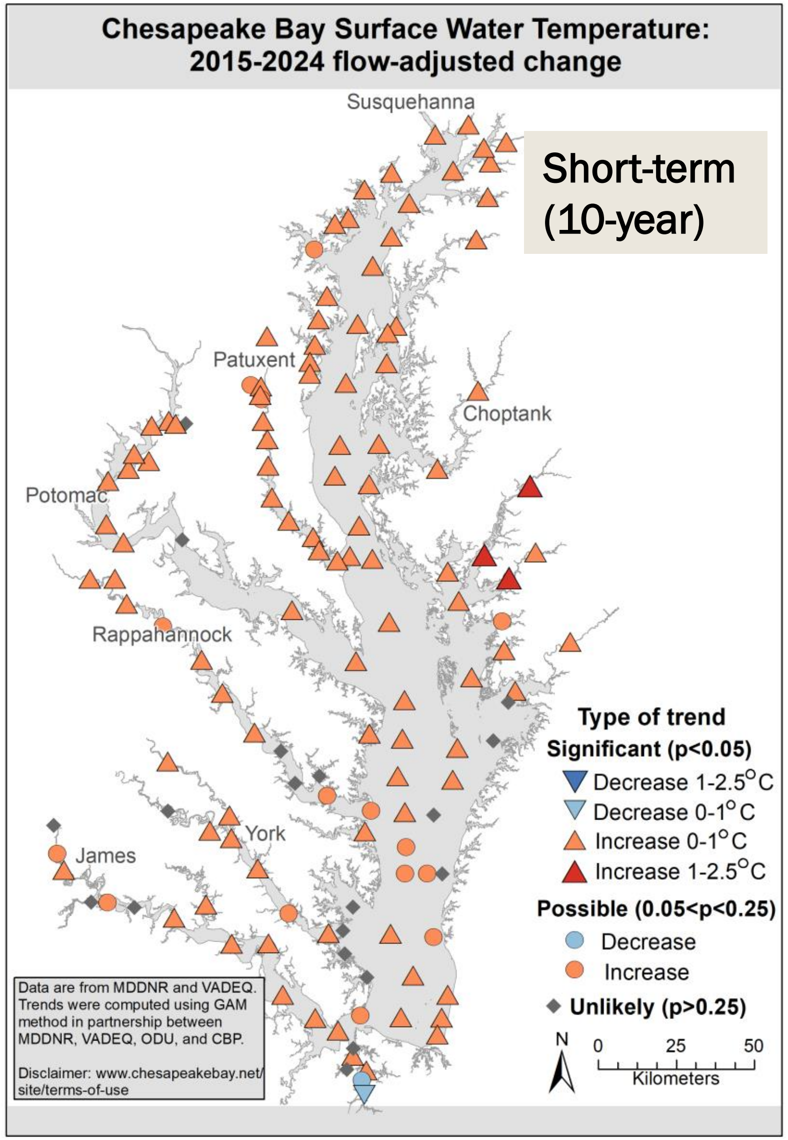
Water Temperature



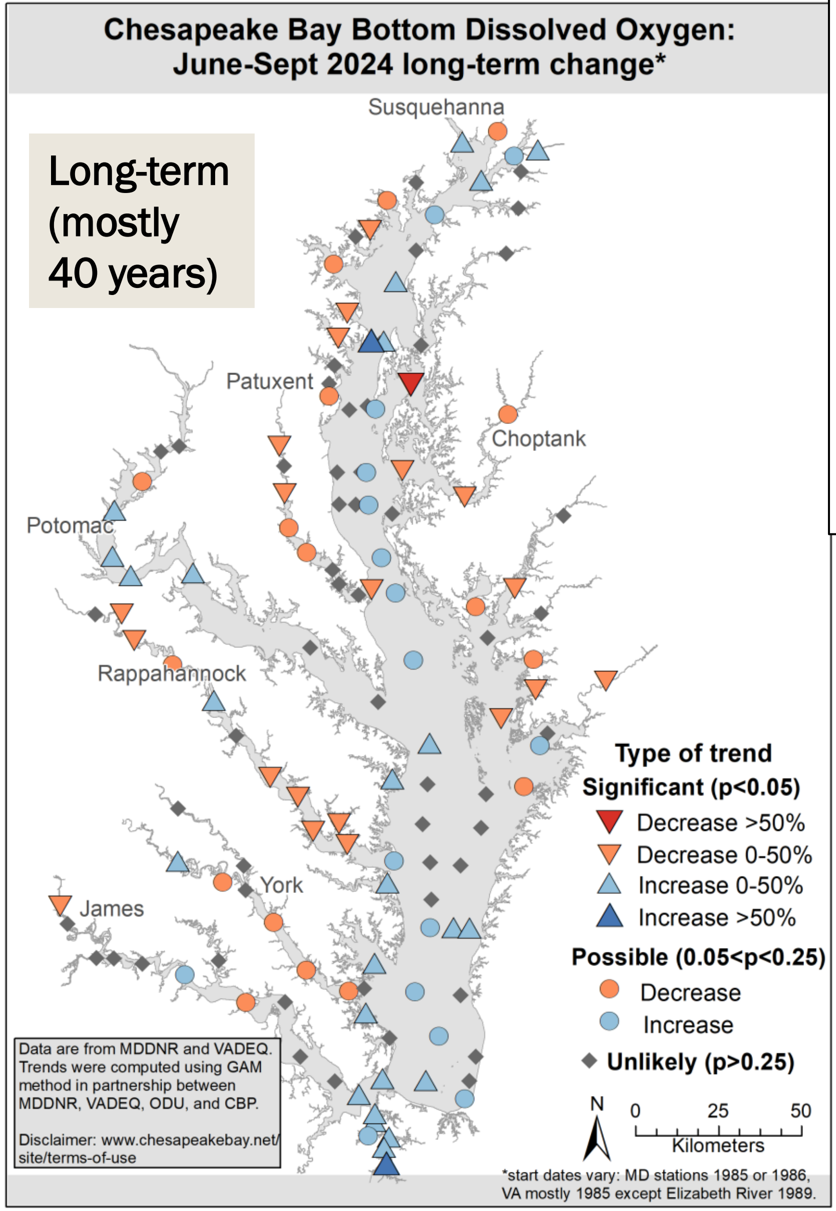


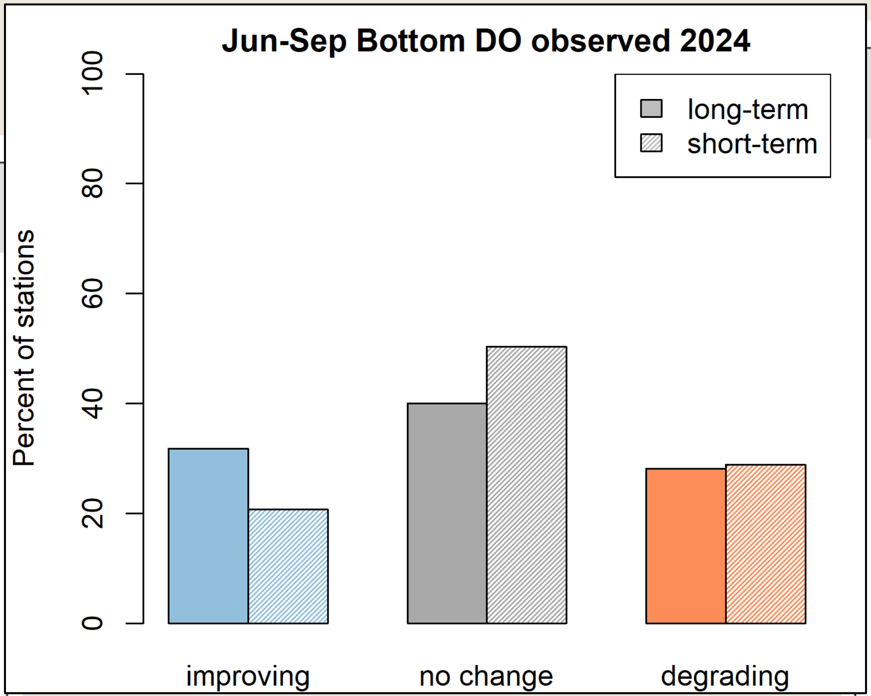
Summary for water temperature

- Water temperature is increasing across the entire tidal waters, both in the long- and short-term
- Water temperature can impact water quality and habitat in many ways.



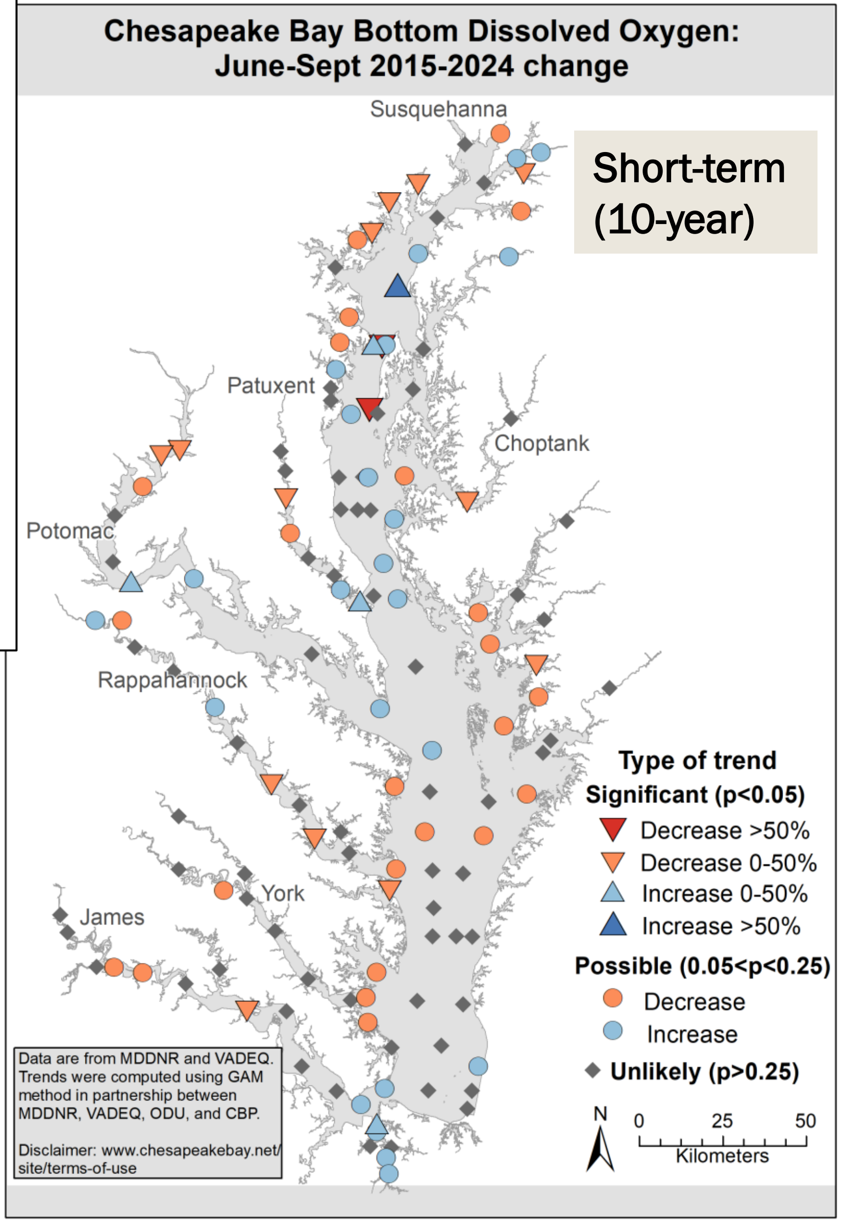
Bottom Summer DO





Summary for DO

- Bottom DO conditions vary widely across these stations due to depth and mixing.
- Improving conditions are observed in some of the deepest waters, while mixed trends exist elsewhere.
- Consistent with criteria-based analysis, Zhang et al. 2024, presented in March https://doi.org/10.1016/j.scitotenv.2024.177617



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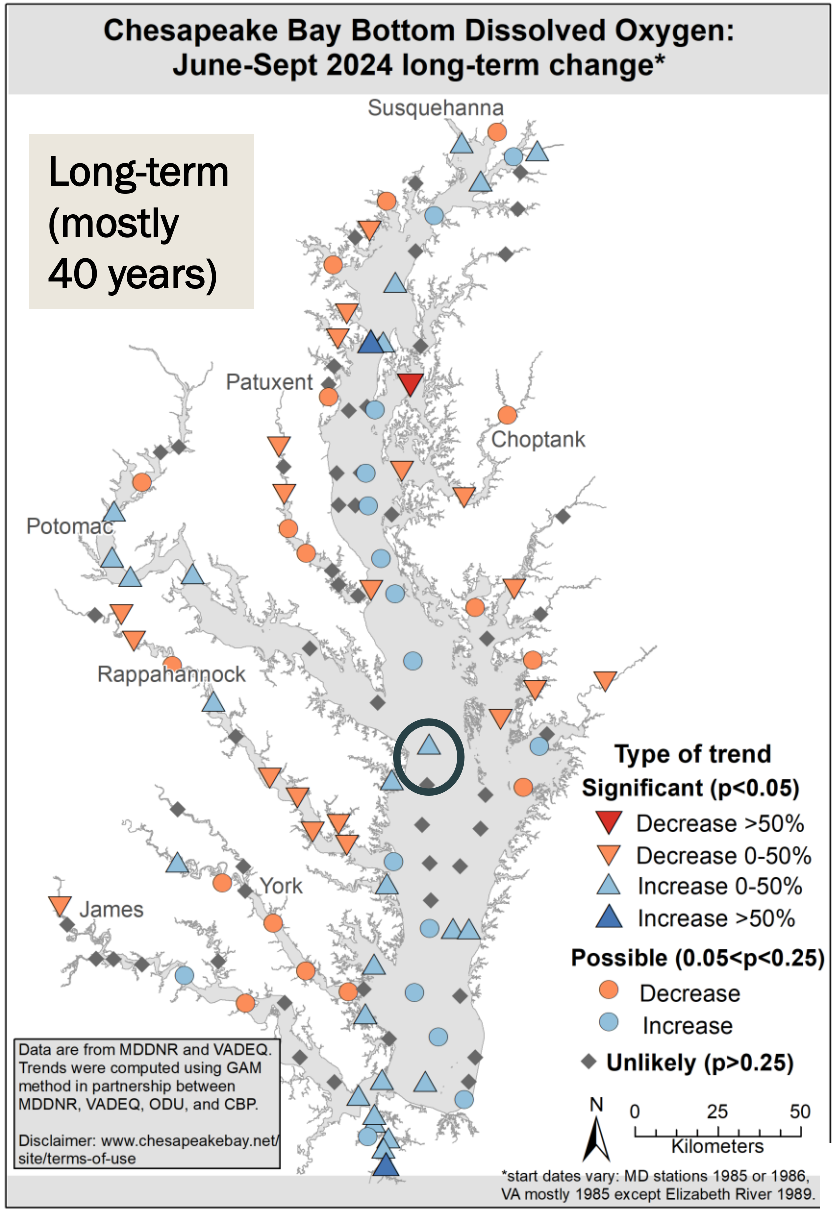
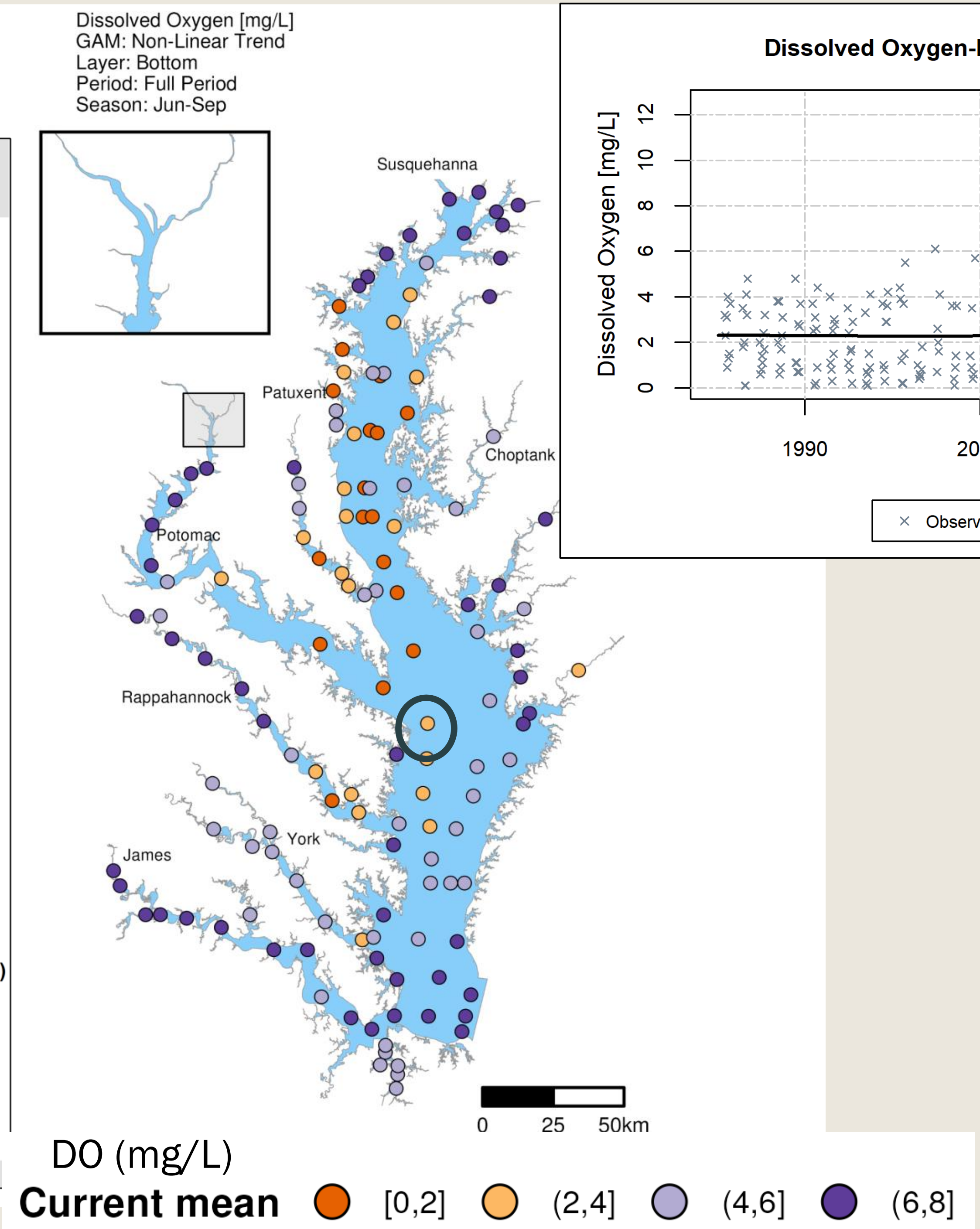
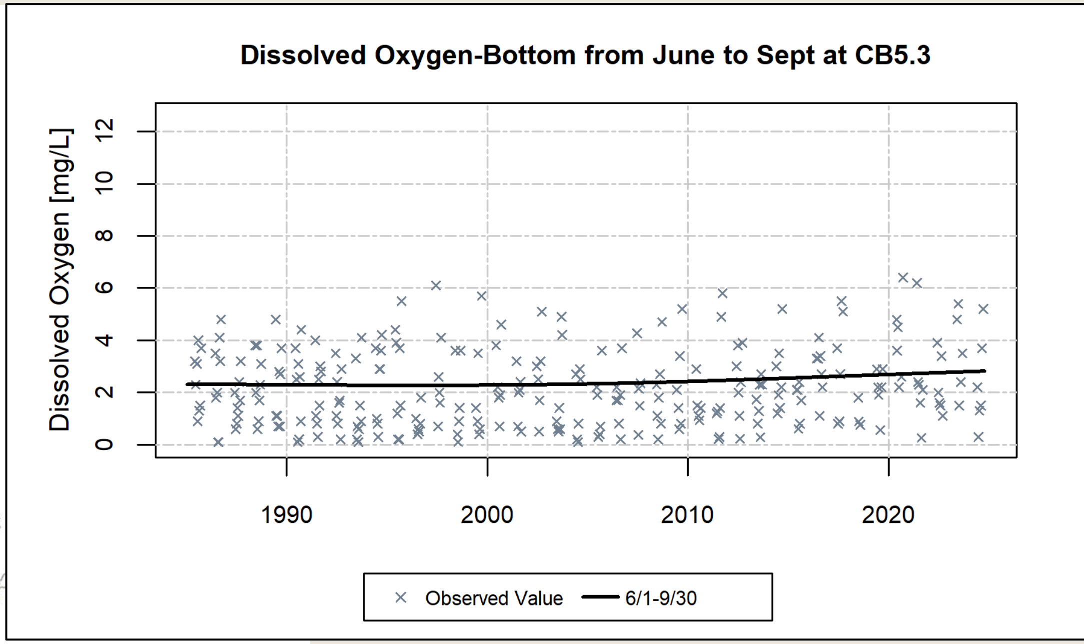
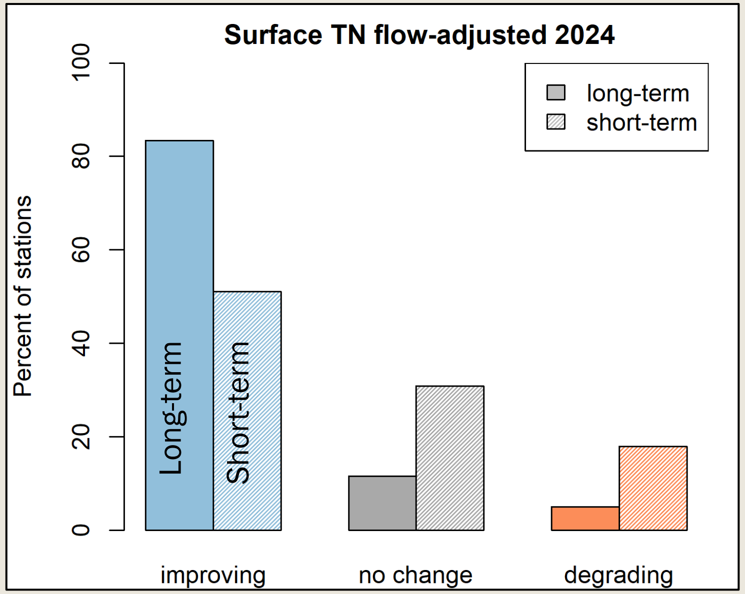


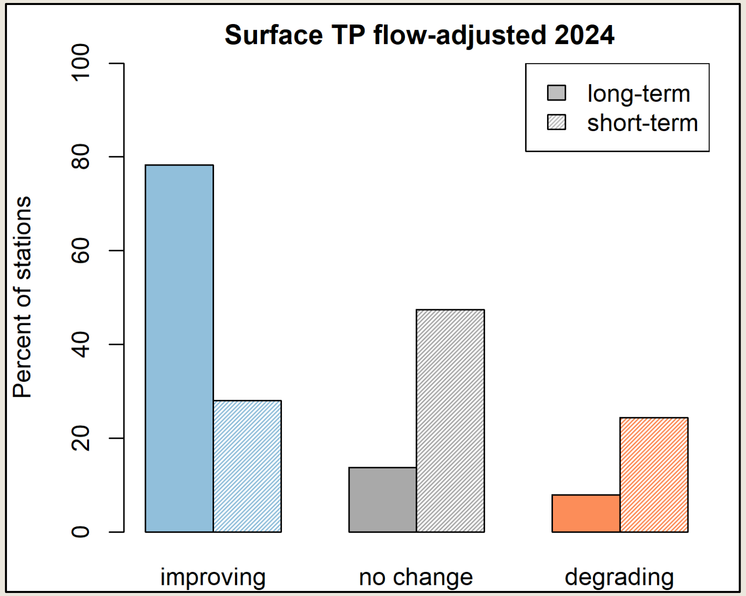




2024 Summary

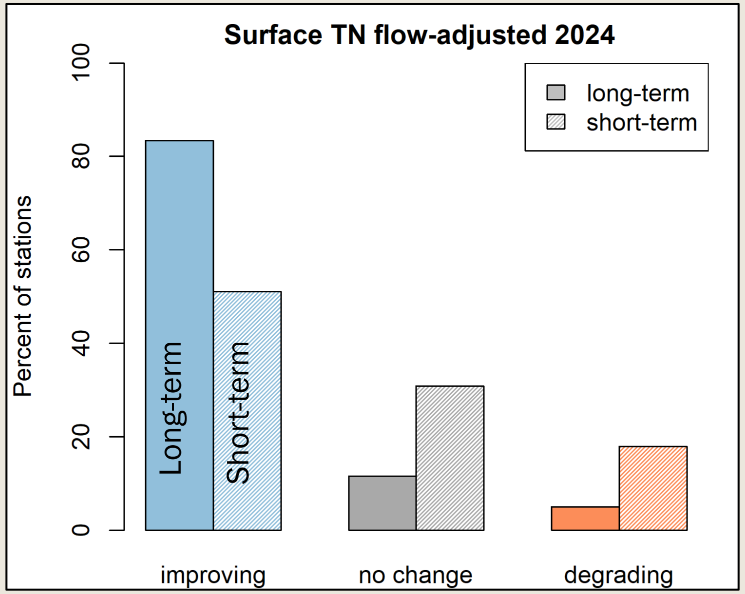
- Nutrient trends mostly improving over the long-term with some leveling-out over the short-term.

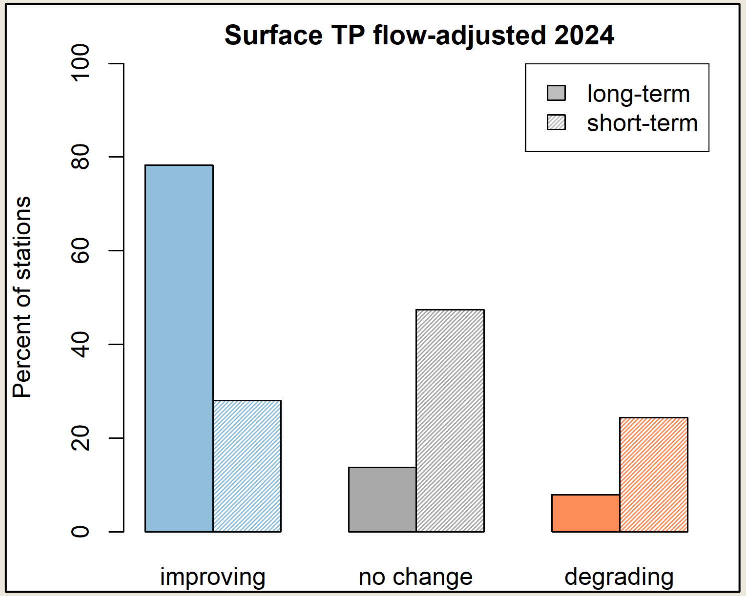


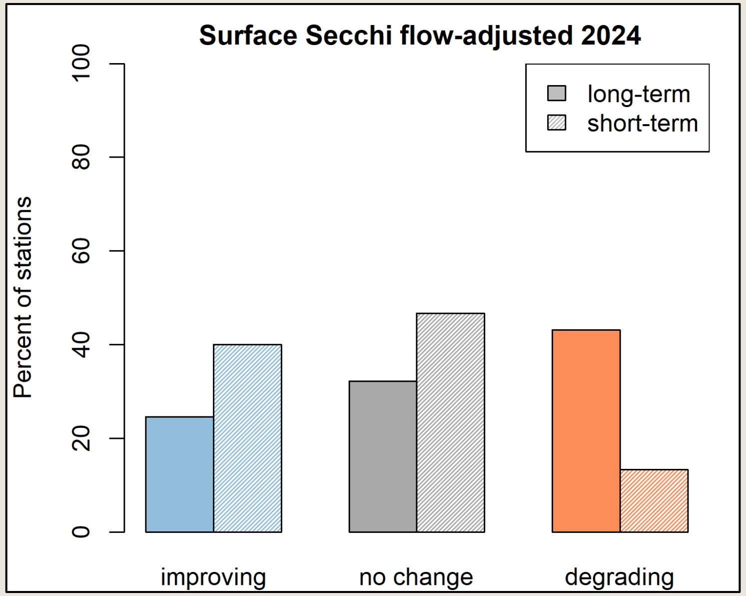


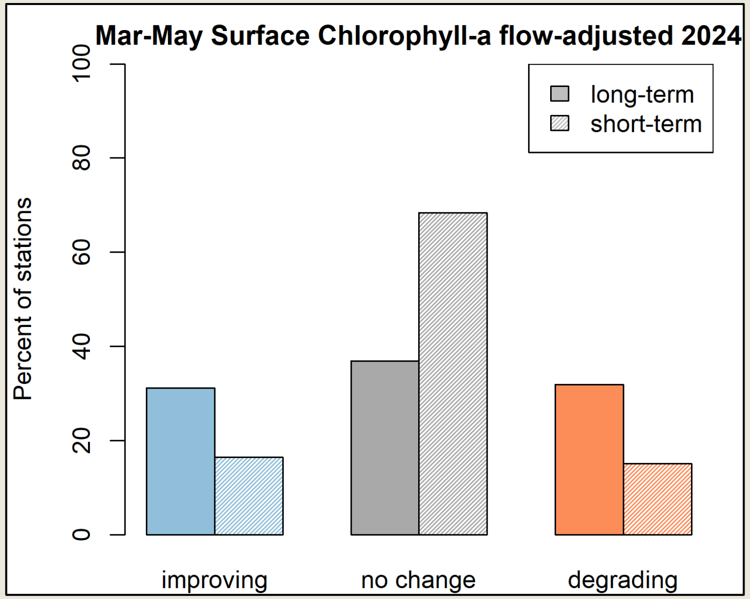
2024 Summary

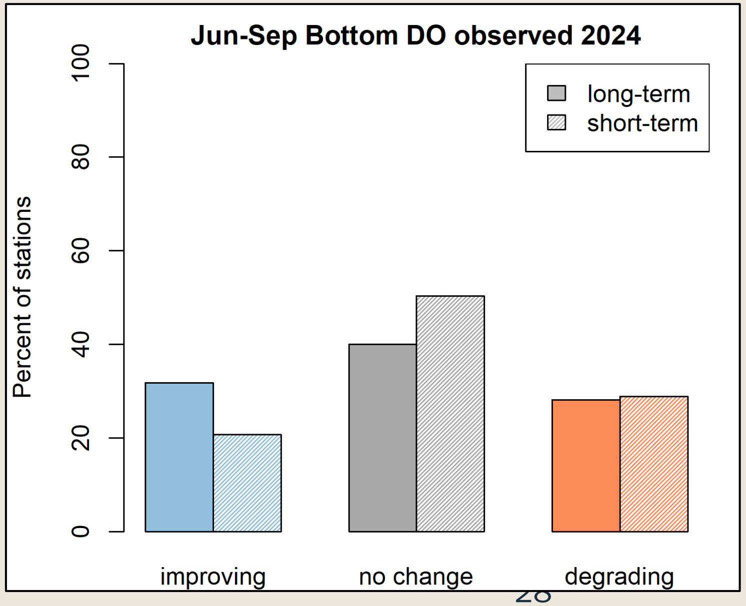
- Nutrient trends mostly improving over the long-term with some leveling-out over the short-term.
- The number of stations with degrading conditions have decreased over the short-term for Secchi and chlorophyll *a,* while DO has different patterns in deeper vs. tributary waters.
- Overall patterns consistent with last few years.





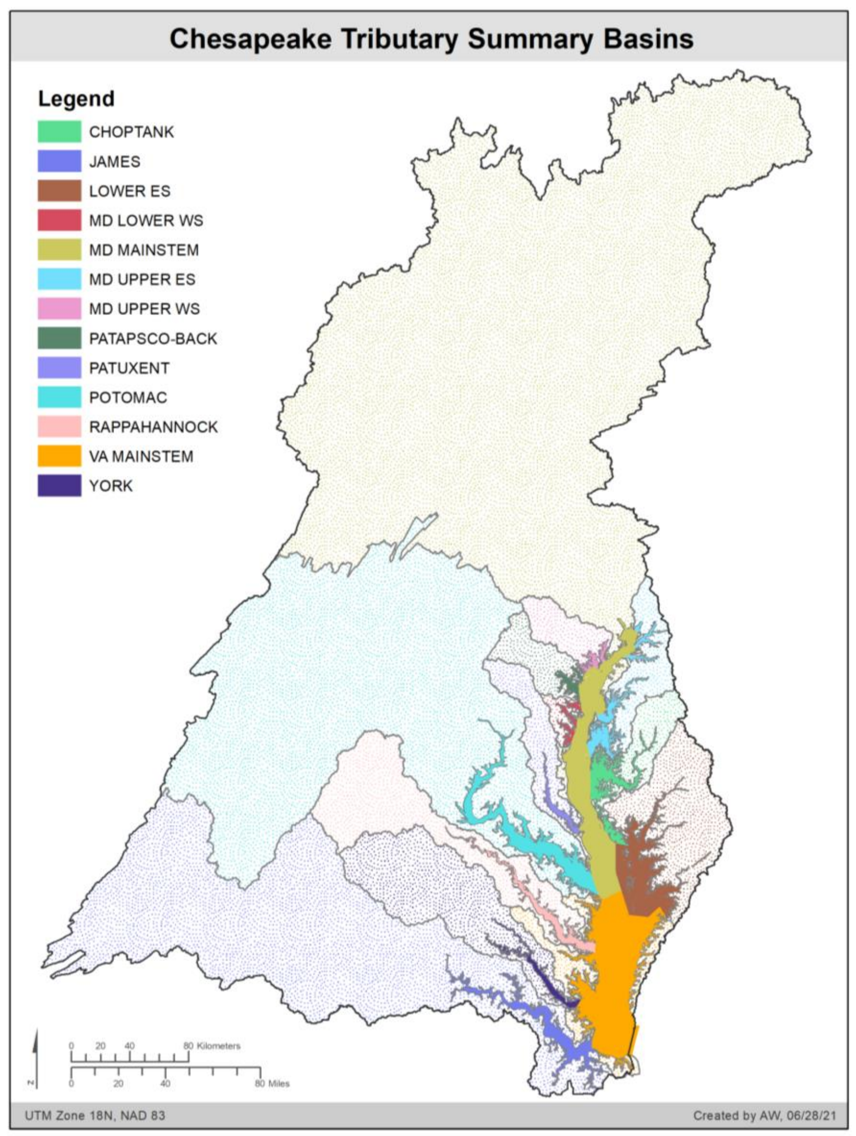




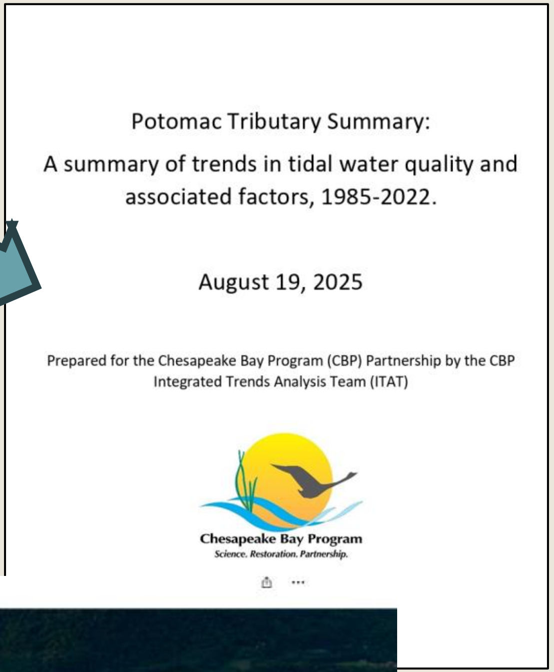


For region-specific information: Tributary Summaries

https://www.chesapeakebay.net/projects/tributary-summaries1



PDF documents


Potomac Tributary Summary:

A summary of trends in tidal water quality and associated factors, 1985-2022.

August 19, 2025

Prepared for the Chesapeake Bay Program (CBP) Partnership by the CBP Integrated Trends Analysis Team (ITAT)

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Online Story Maps

Acknowledgements and links

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- ITAT Projects Page: https://www.chesapeakebay.net/who/projects-archive/integrated-trends-analysis-team
- Baytrendsmap: https://baytrends.chesapeakebay.net/baytrendsmap/
- CAST link with trends: https://cast.chesapeakebay.net/Home/TMDLTracking#tributaryRptsSection

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Trend-related references cited here:

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- Zhang et al. 2024. "Dissolved oxygen criteria attainment in Chesapeake Bay: where has it improved since 1985?" Science of the Total Environment 957 https://doi.org/10.1016/j.scitotenv.2024.177617