2024 Tidal Trends Summary

Rebecca Murphy (UMCES/CBP)

STAR meeting, Dec. 18, 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.

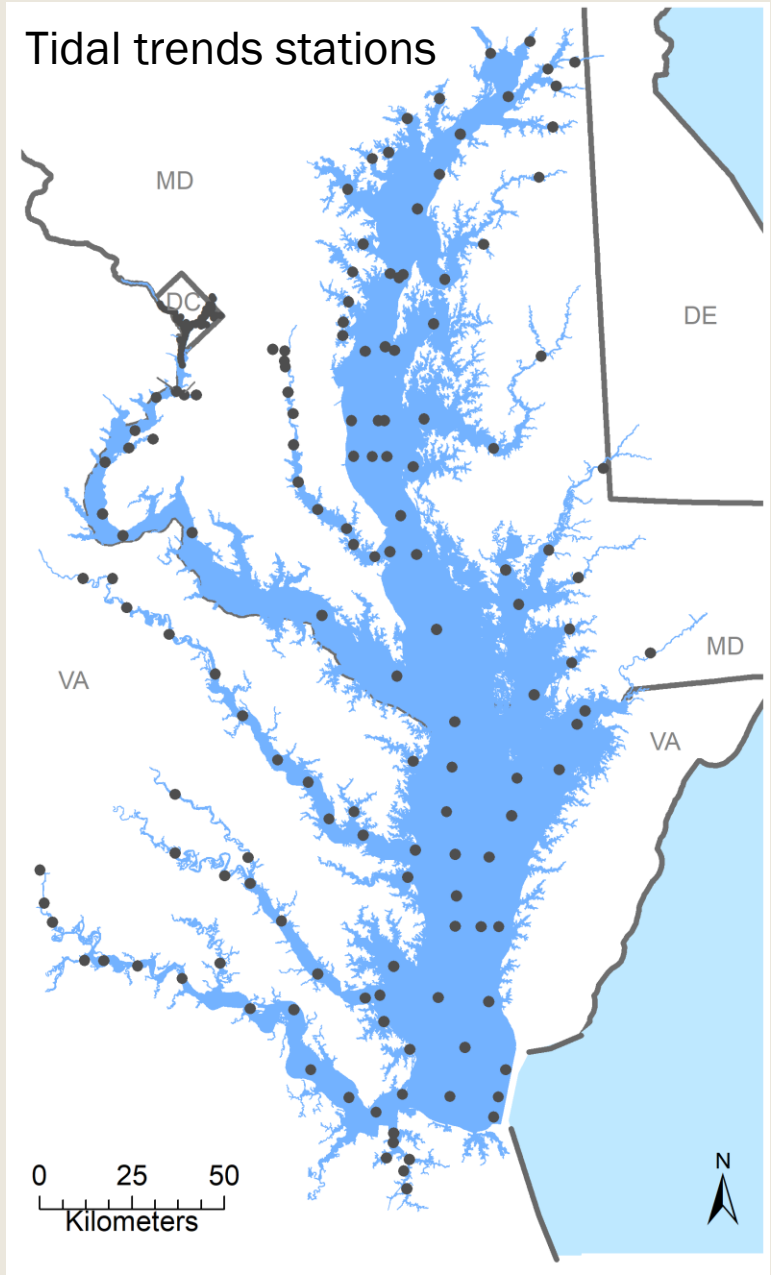
What are the tidal trends?

- 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 a nonlinear smoothing function* 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.

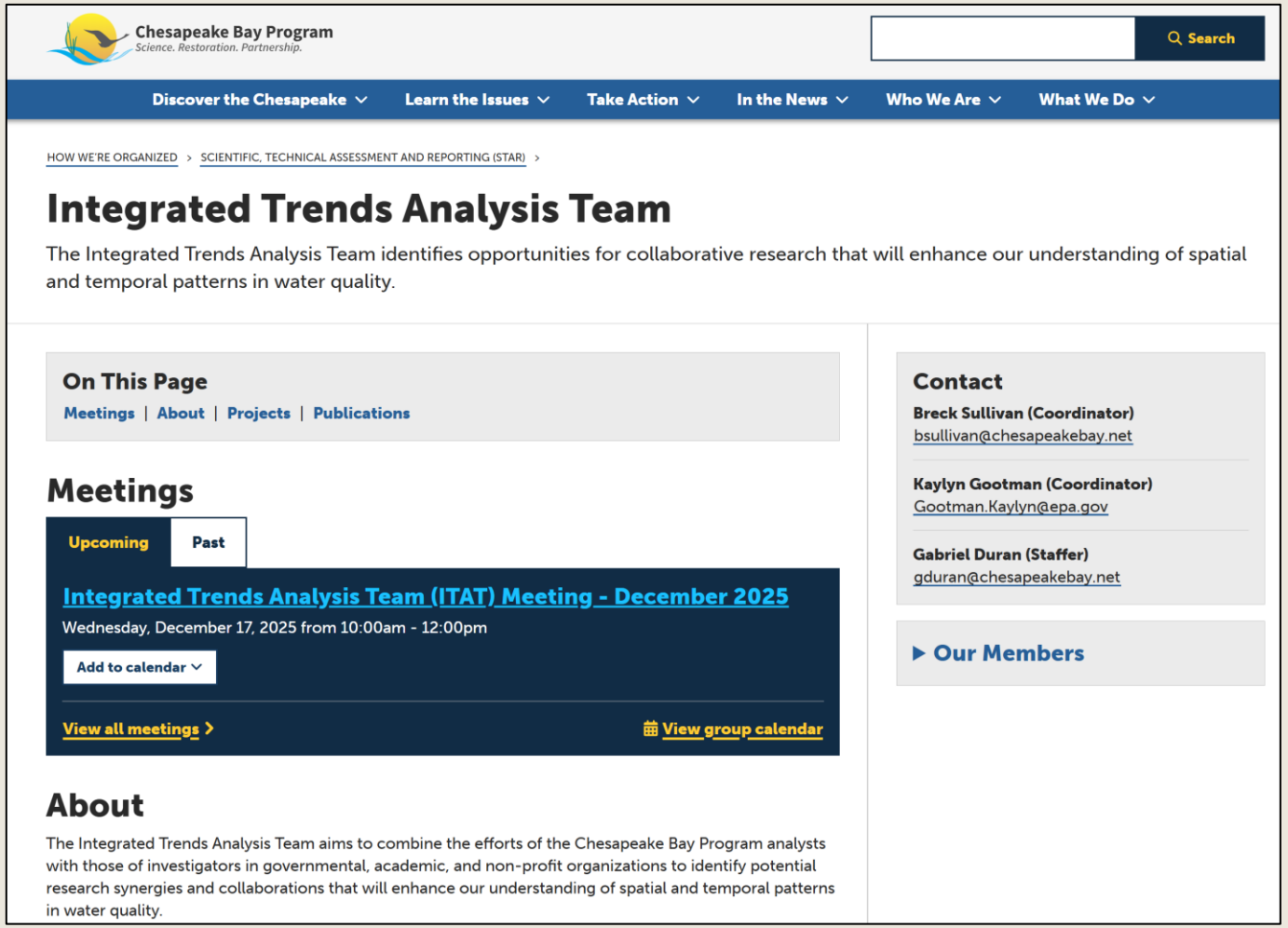
* Generalized Additive Models (GAMs)



Annual collaborative effort between partners

Integrated Trends Analysis Team

https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

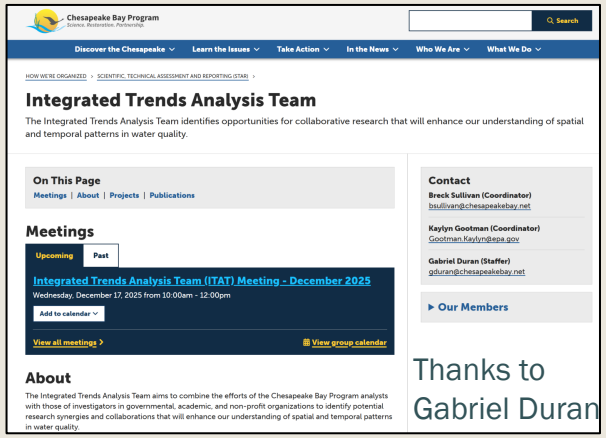


- Gather to identify the broad scope of on-going work related to **trends and patterns of water quality** in the Chesapeake watershed and estuary.
- Discover previously un-identified **linkages among the ongoing research activities** of participating individuals and organizations.
- Develop a standard set of **analysis tools** that can be applied in any relevant ecosystem within the Chesapeake watershed and estuary.
- Foster **increased collaboration** and awareness of ongoing research.
- Provide a forum for bringing findings to the broader Chesapeake Bay management community.

2024 Results

ITAT webpage:

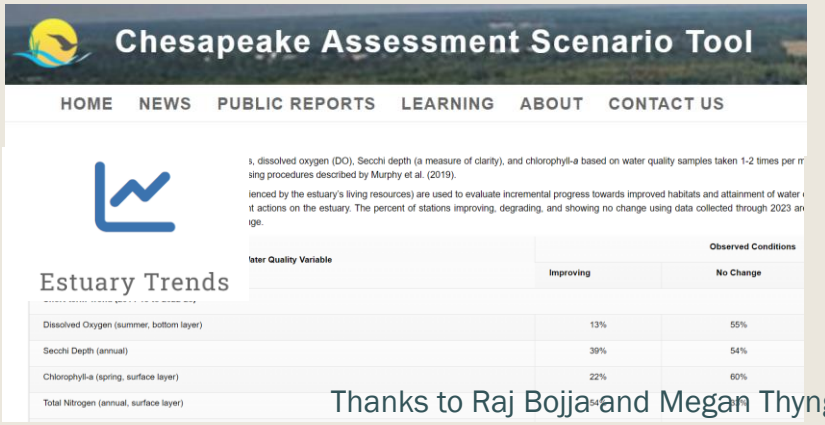
https://www.chesapeakebay.net/who/group/integrated-trends-analysis-team



Thanks to Gabriel Duran

CAST webpage/Trends over time:

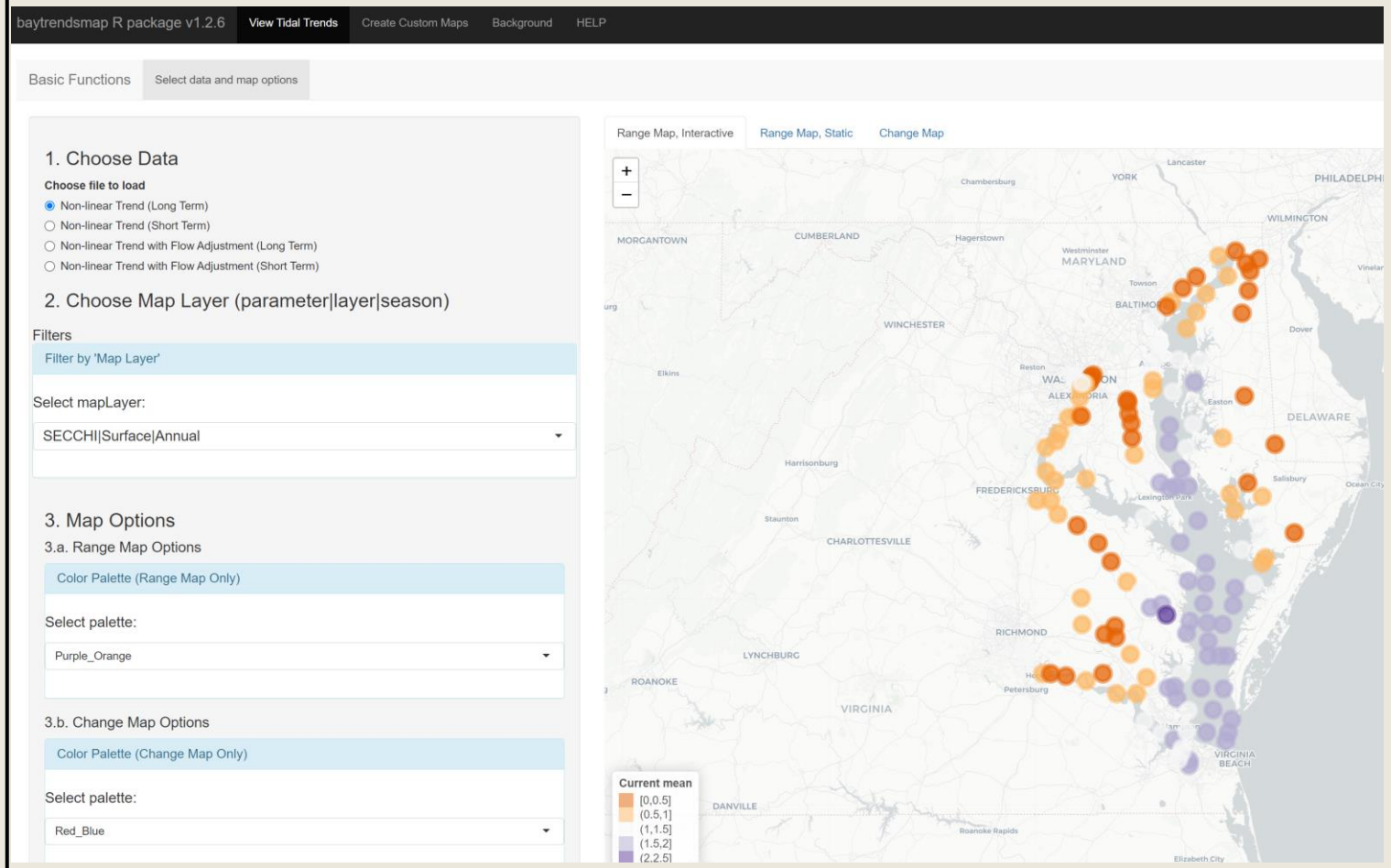
https://cast.chesapeakebay.net/EstuaryTrends



Thanks to Raj Bojja and Megan Thynge

Baytrendsmap :

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



Thanks to Erik Leppo and John Massey

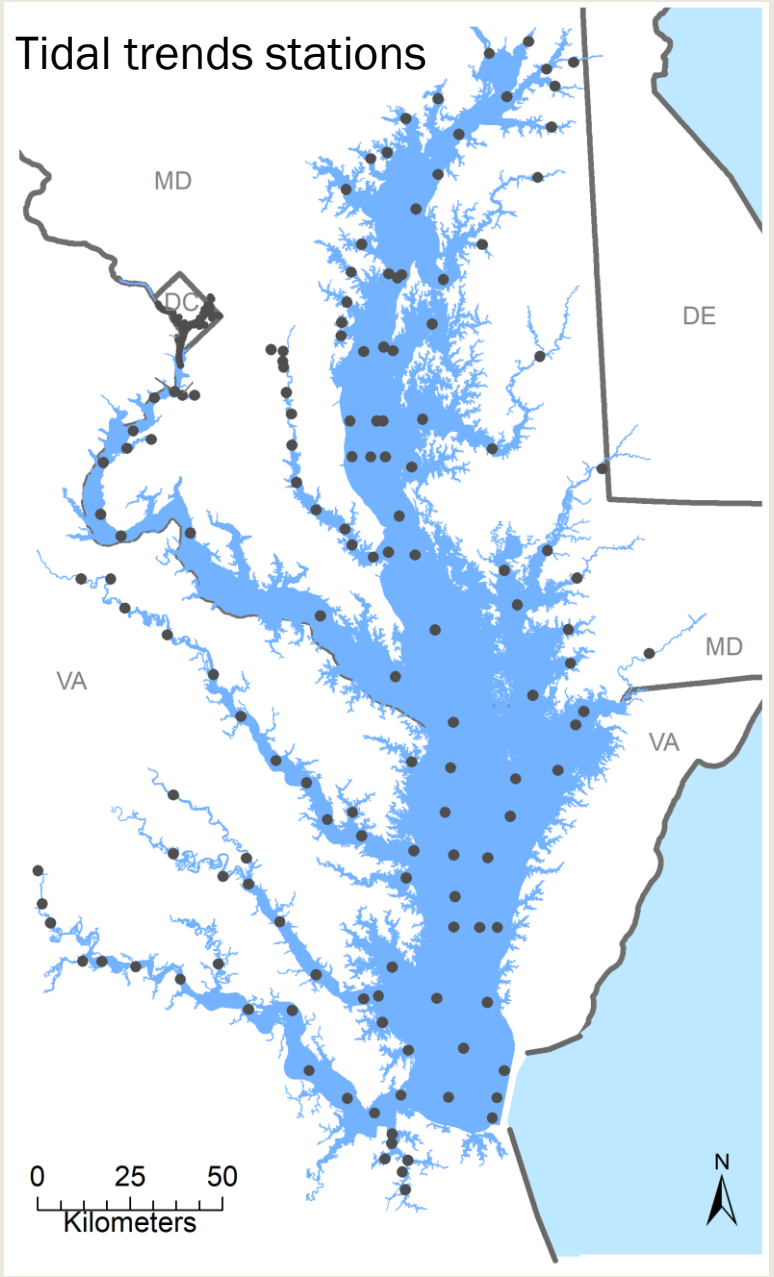
2024 Results

- 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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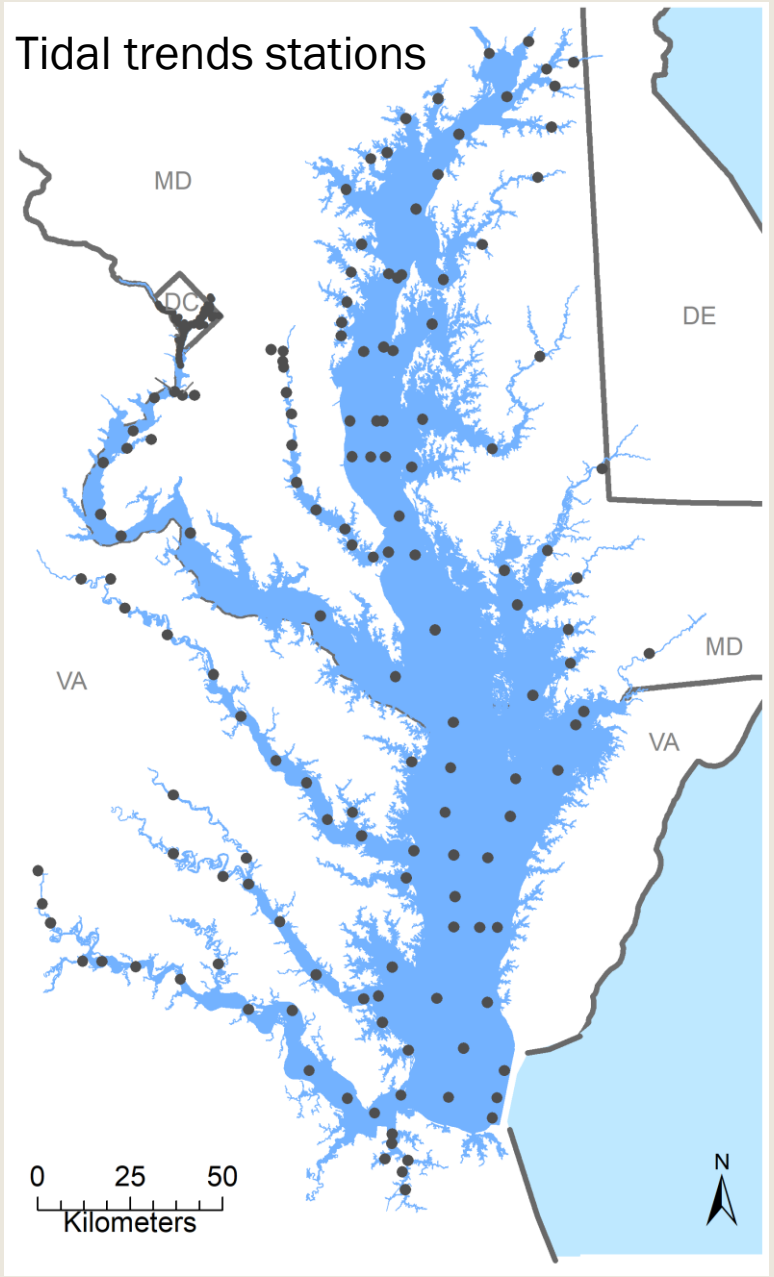
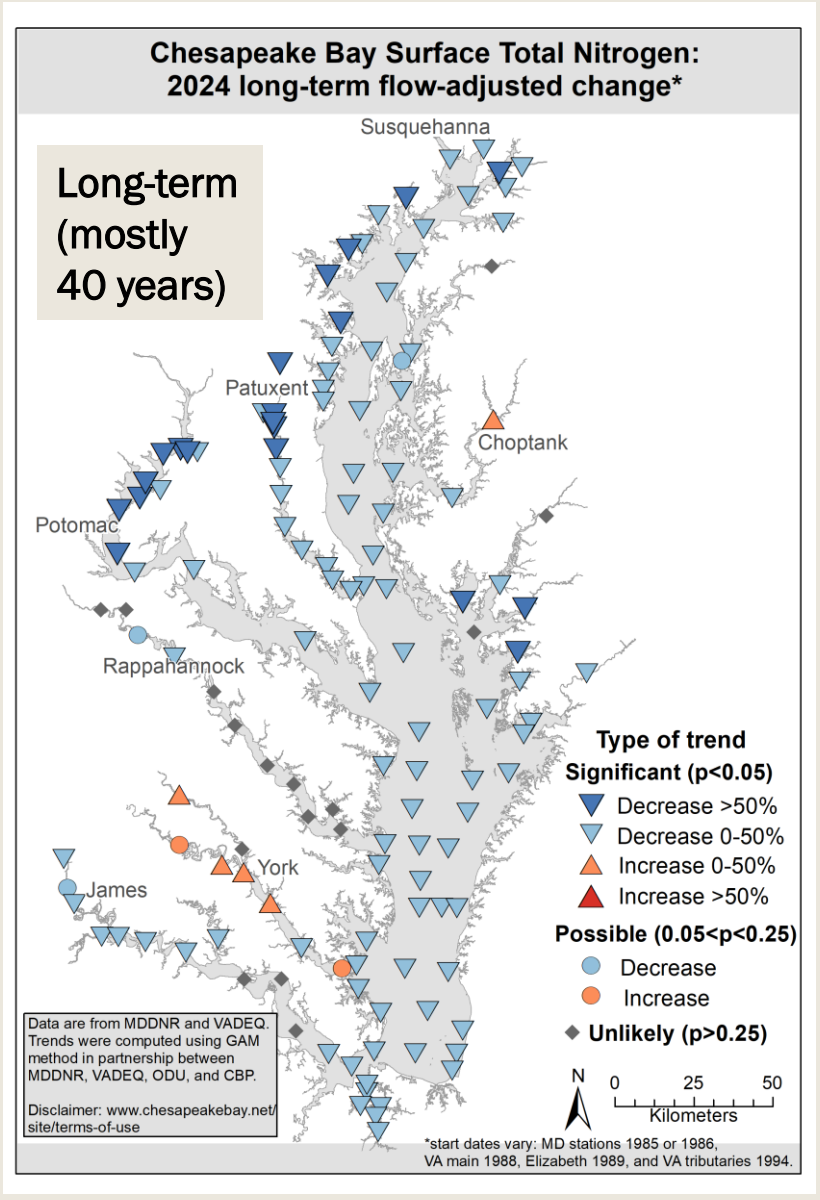


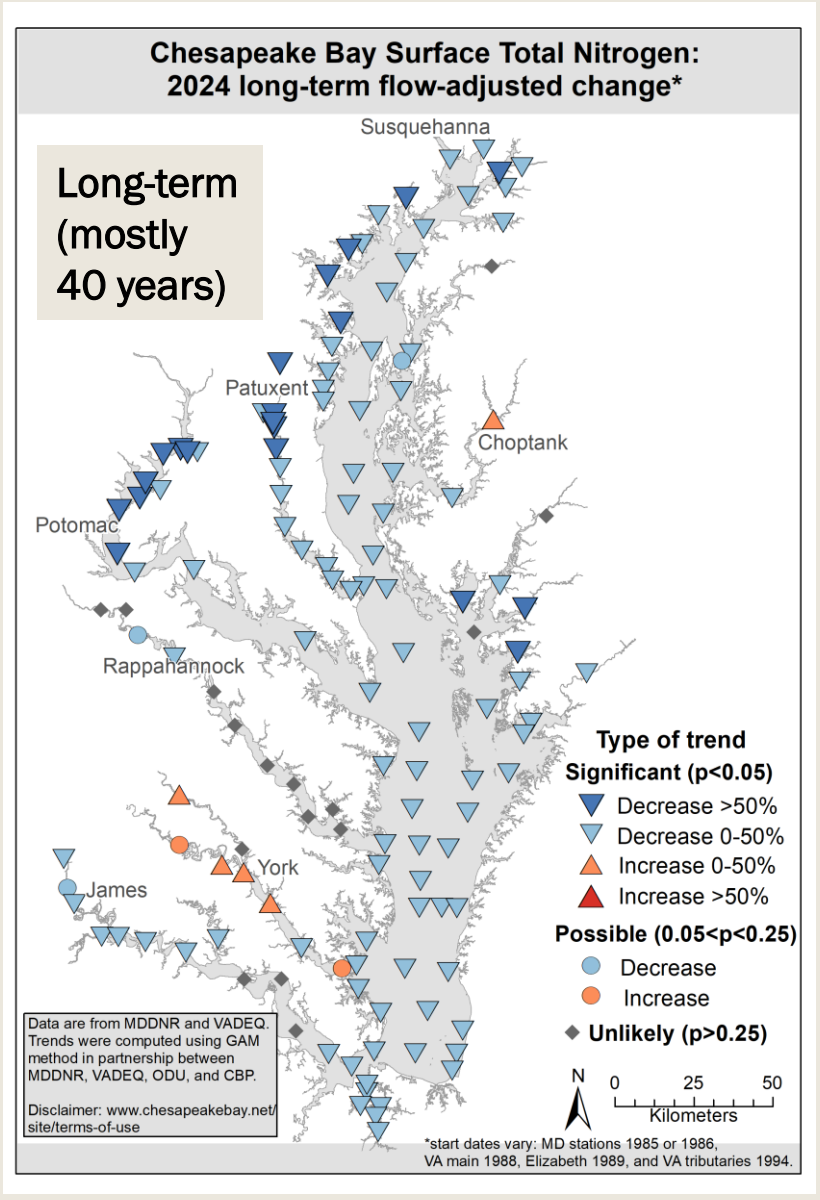
TN

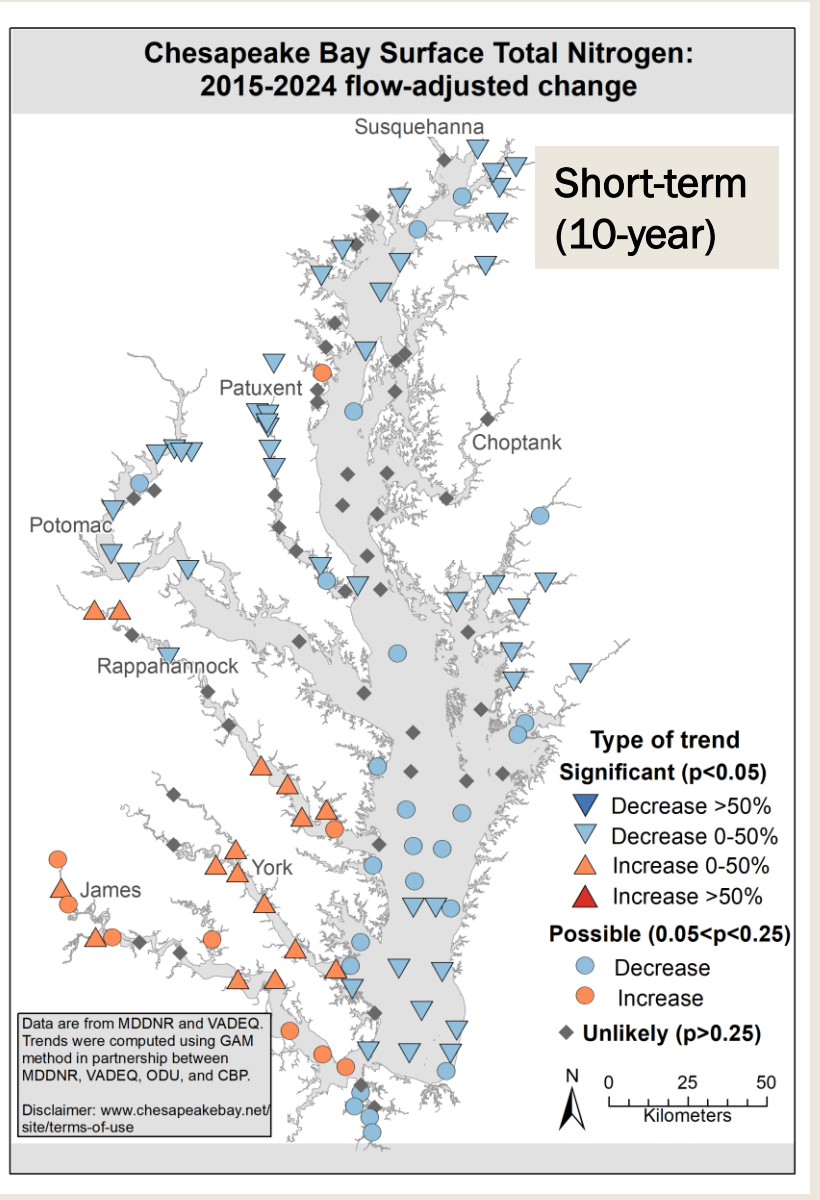
Surface Flow-adjusted



TN

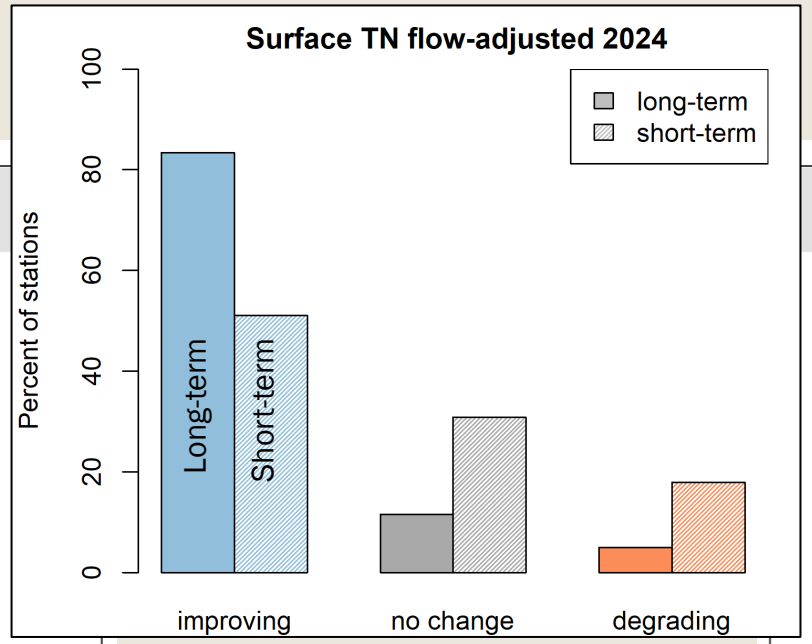
Surface Flow-adjusted

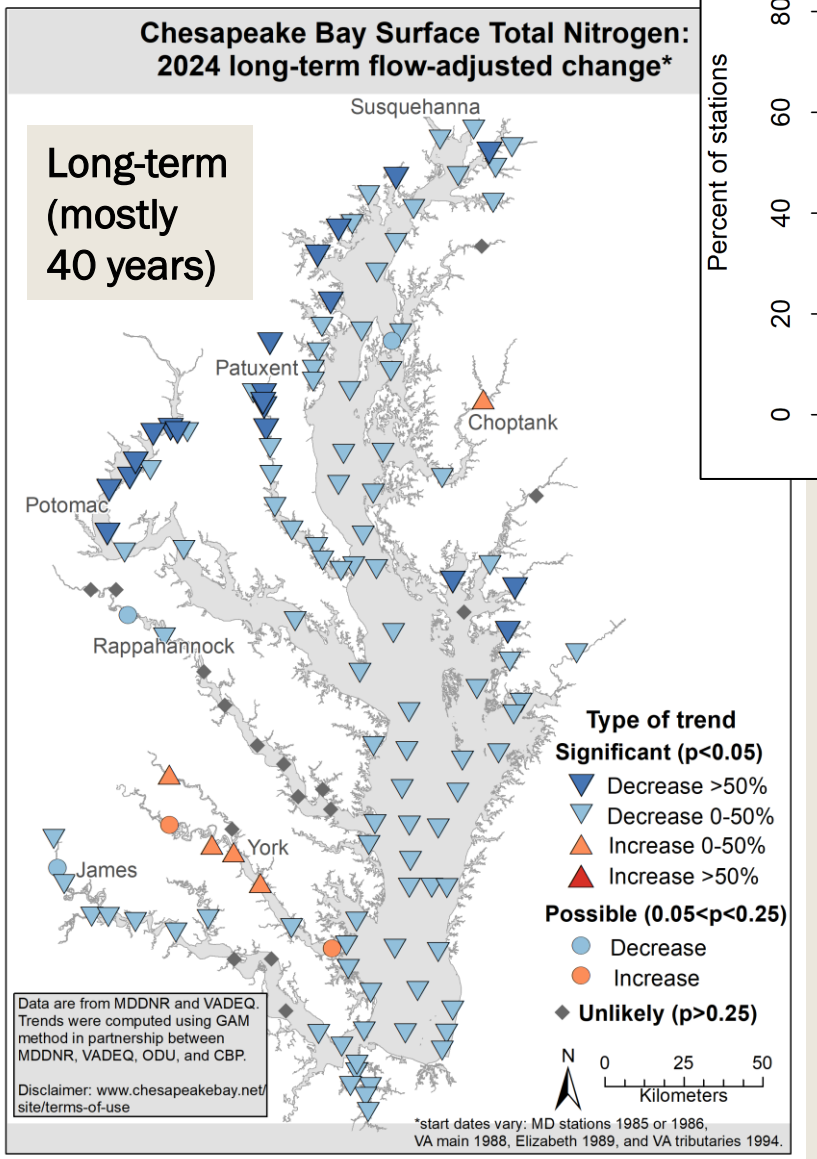


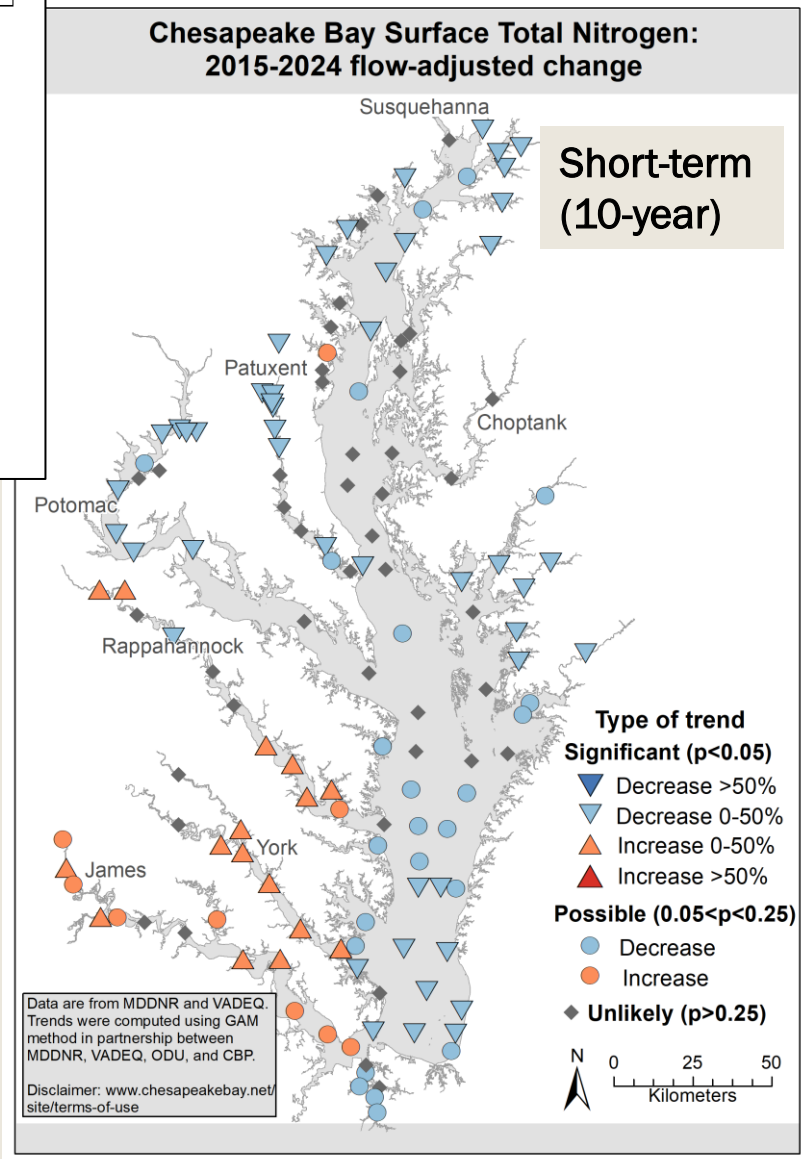


TN

Surface Flow-adjusted





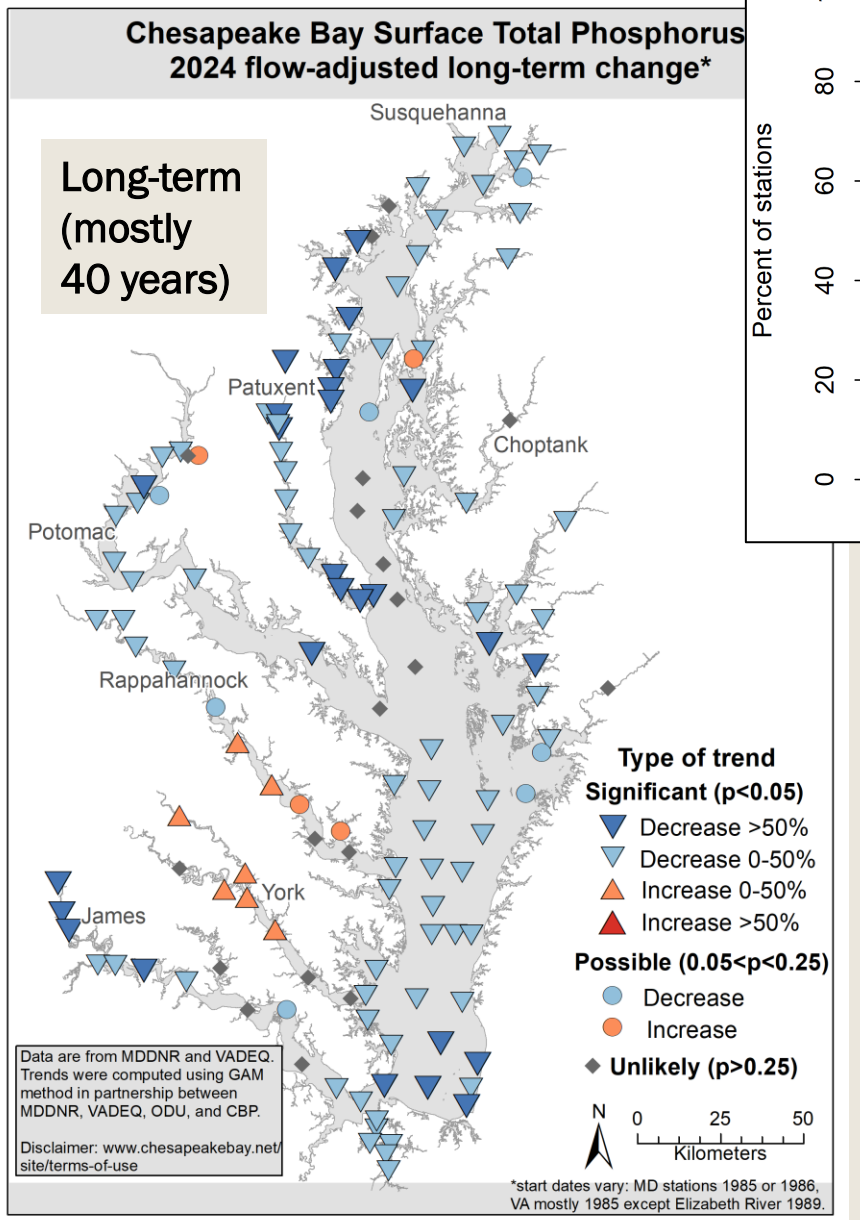


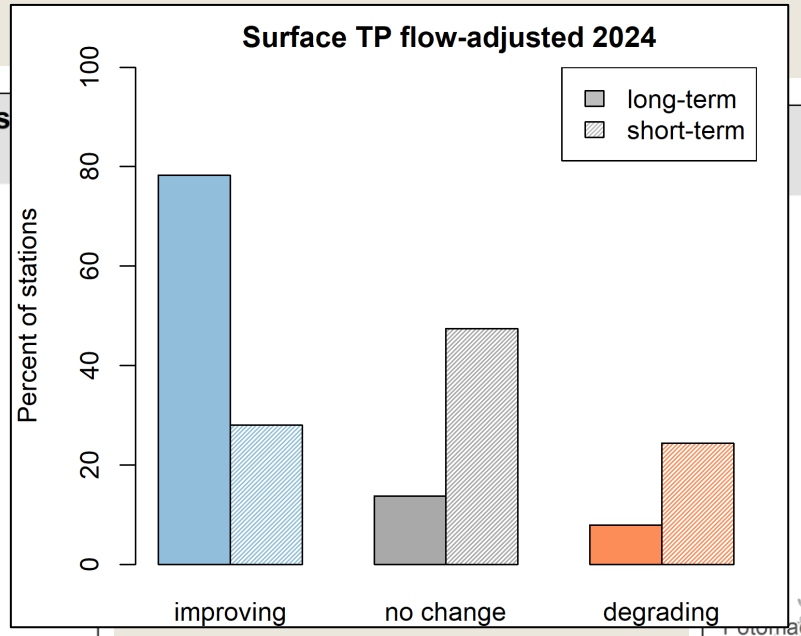
Summary for TN

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

TP

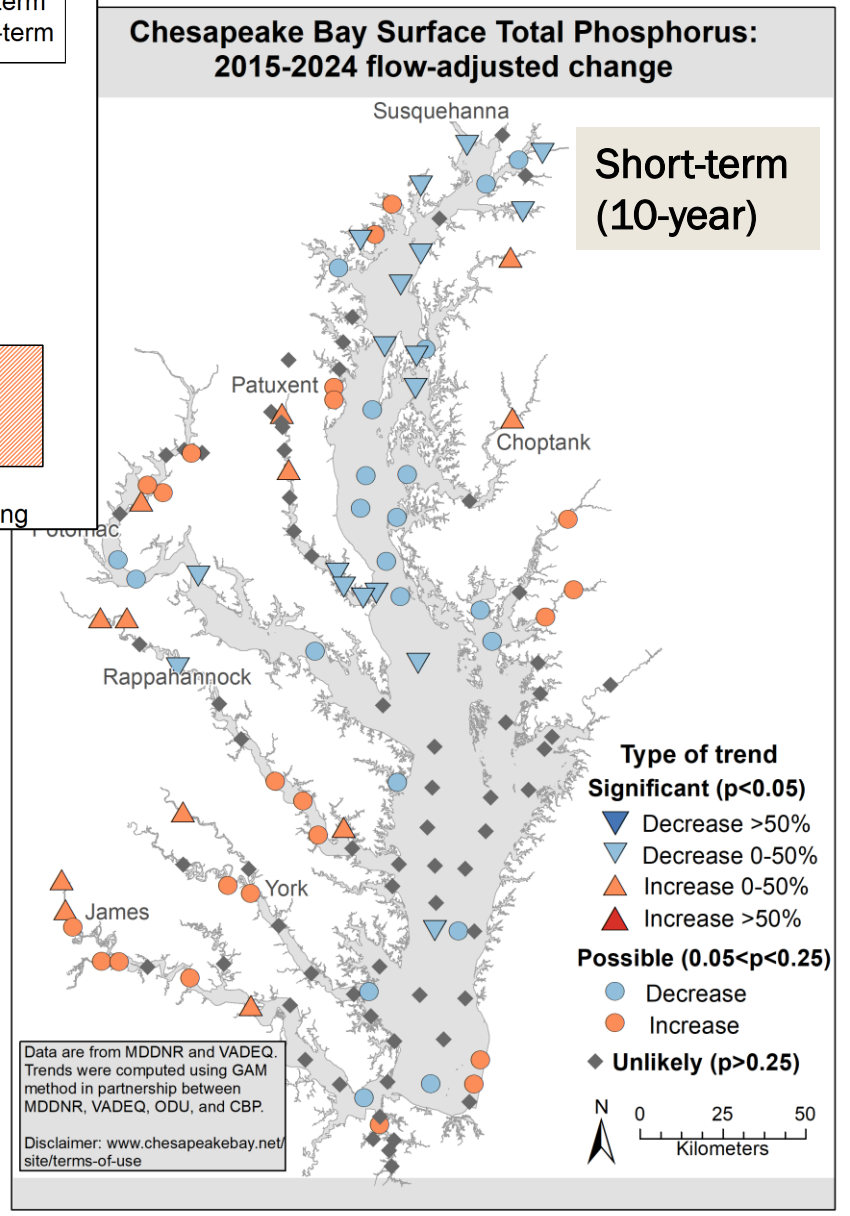
Surface Flow-adjusted





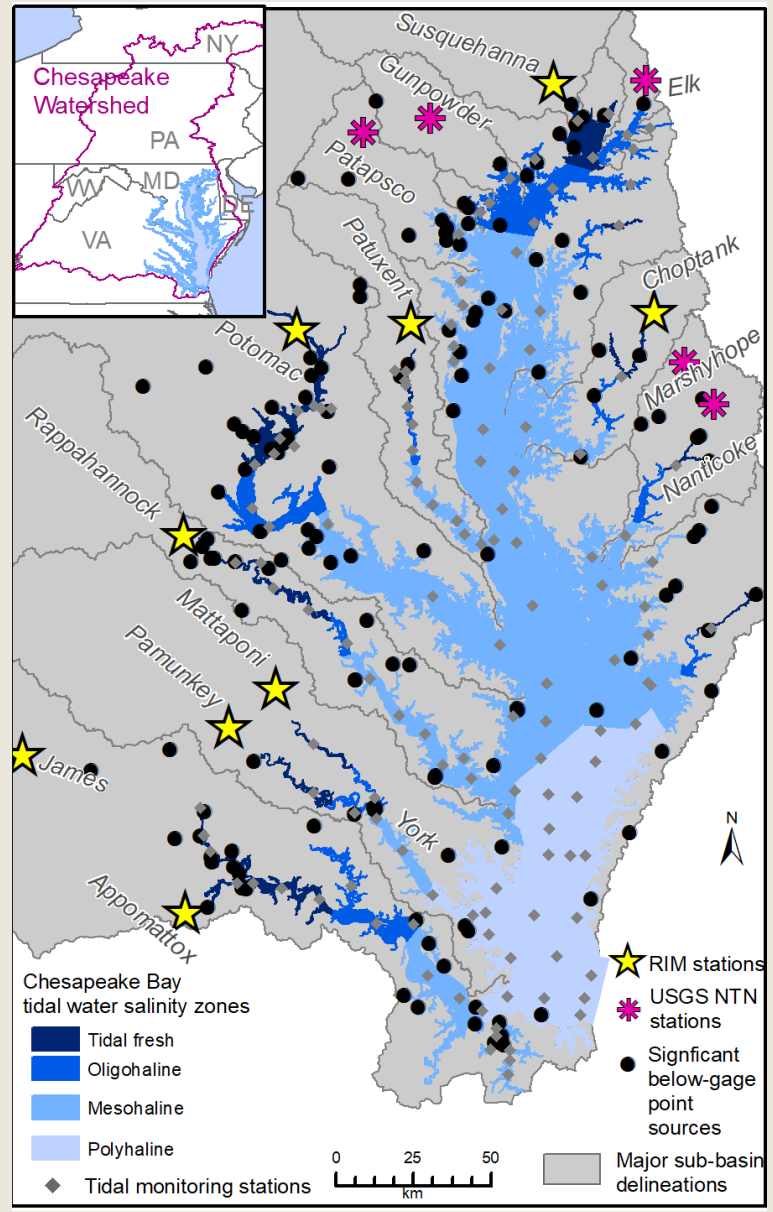
Summary for TP

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



Comparison to watershed loads

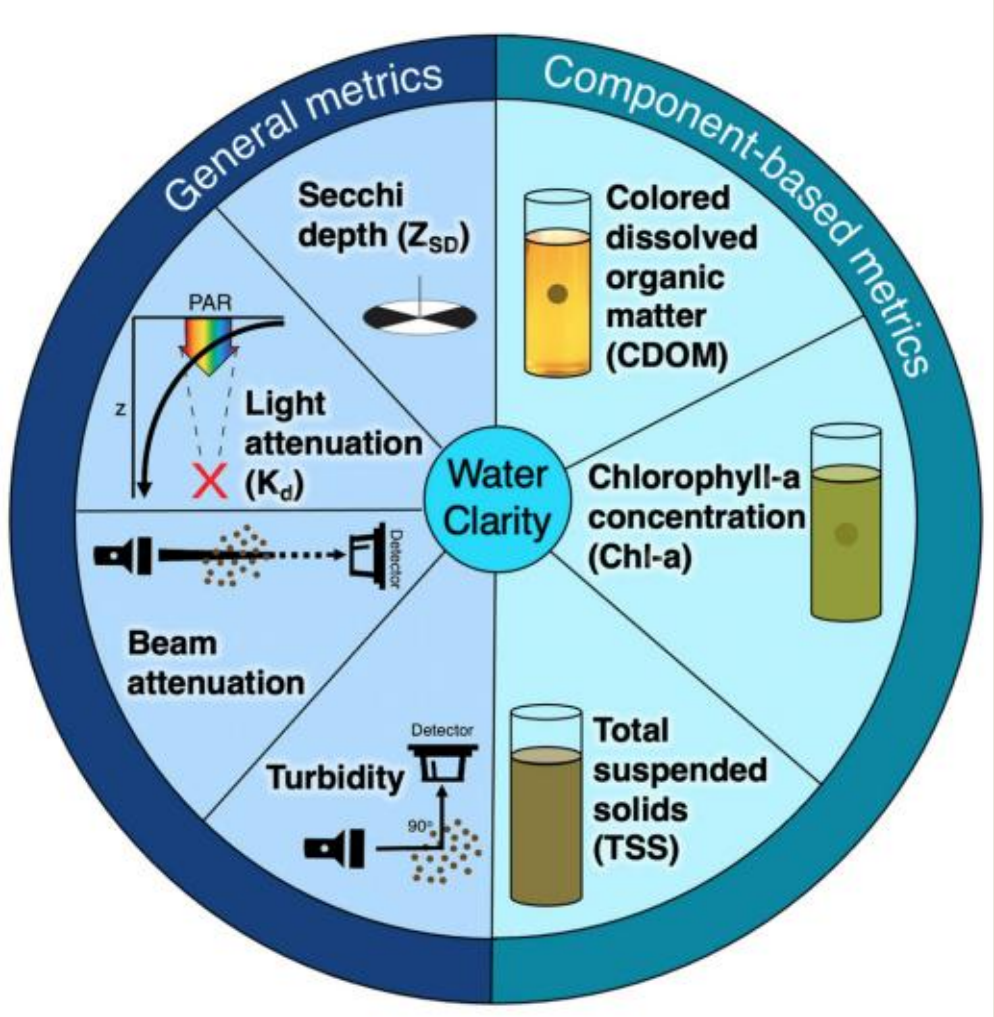
- Jimmy Webber will show some comparison next.
- ITAT & NTN conversations yesterday.
- Previous analysis provided insights as well.



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

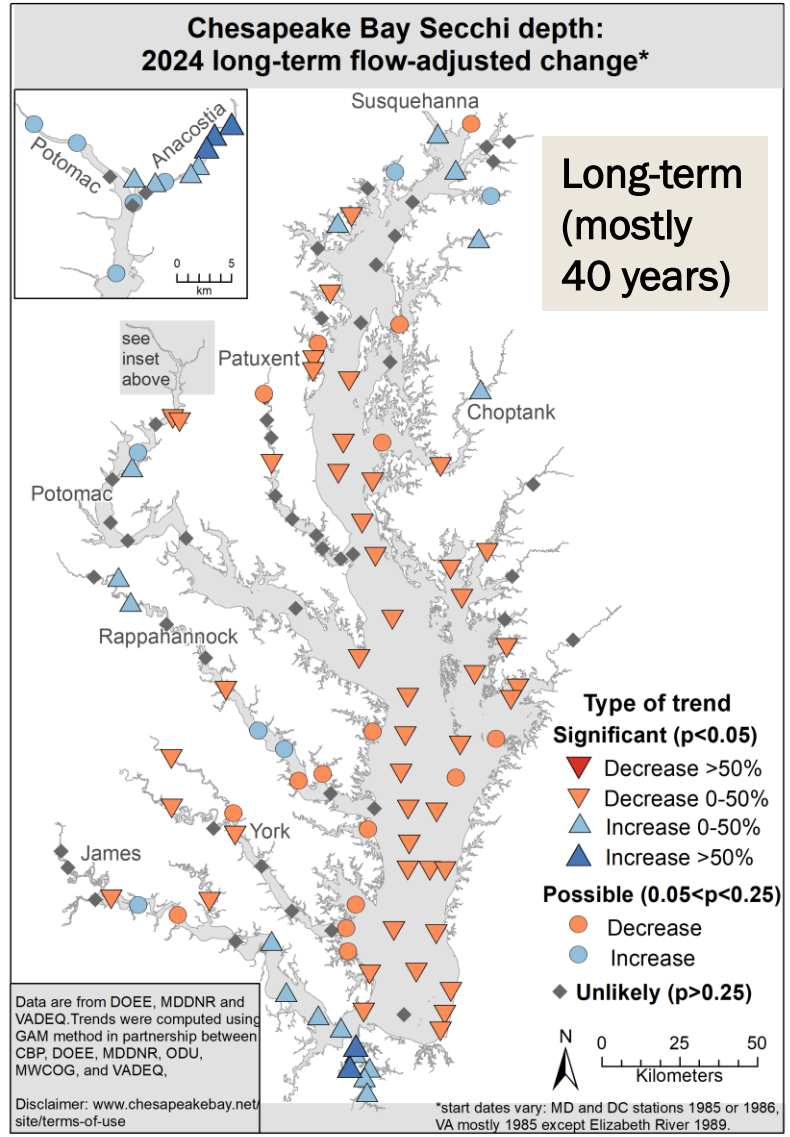
Multiple ways to consider water clarity

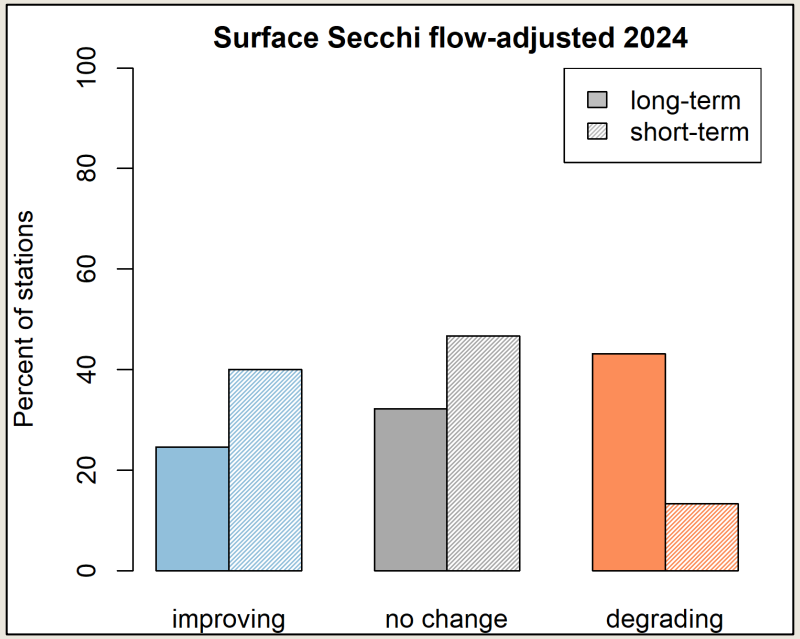
- Next trends = Secchi Depth
  - *Transparency and visibility*
  - *Long term data available for historical comparison*
  - *Community science and engagement opportunities*



Sources: Turner et al., 2022; IAN UMCES media library

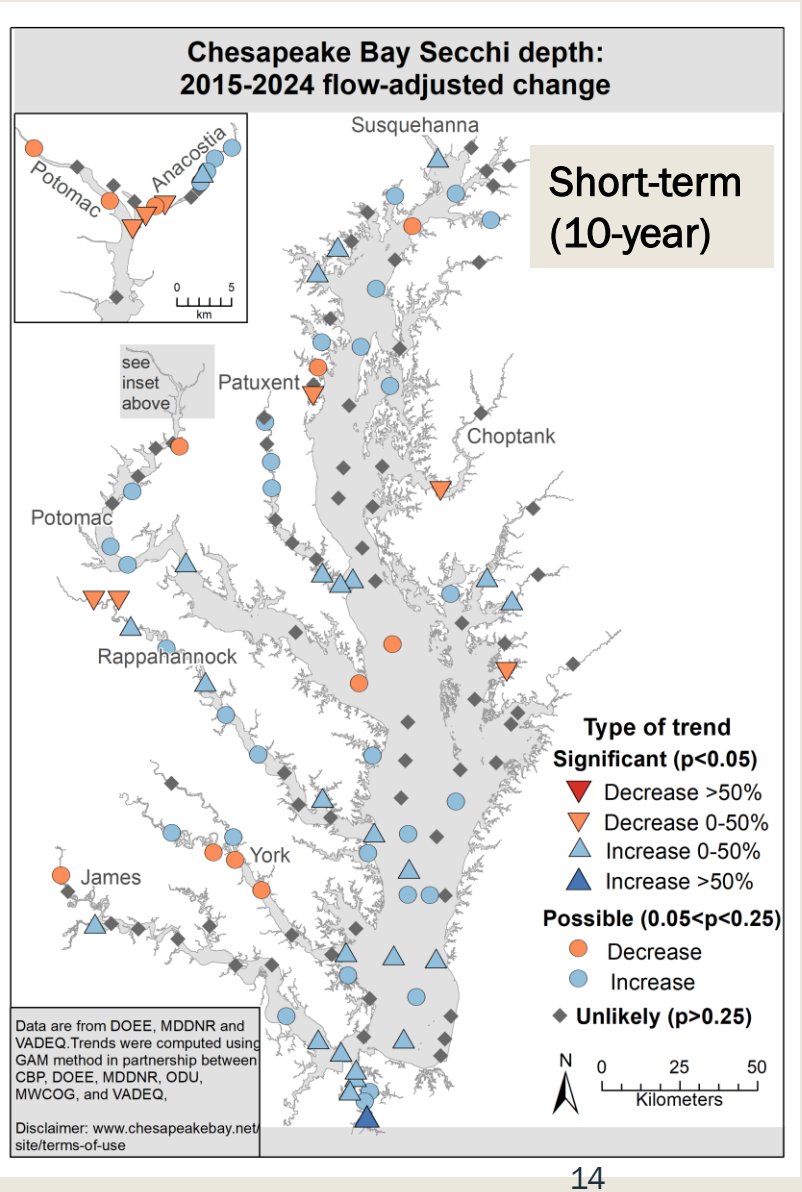
Secchi depth





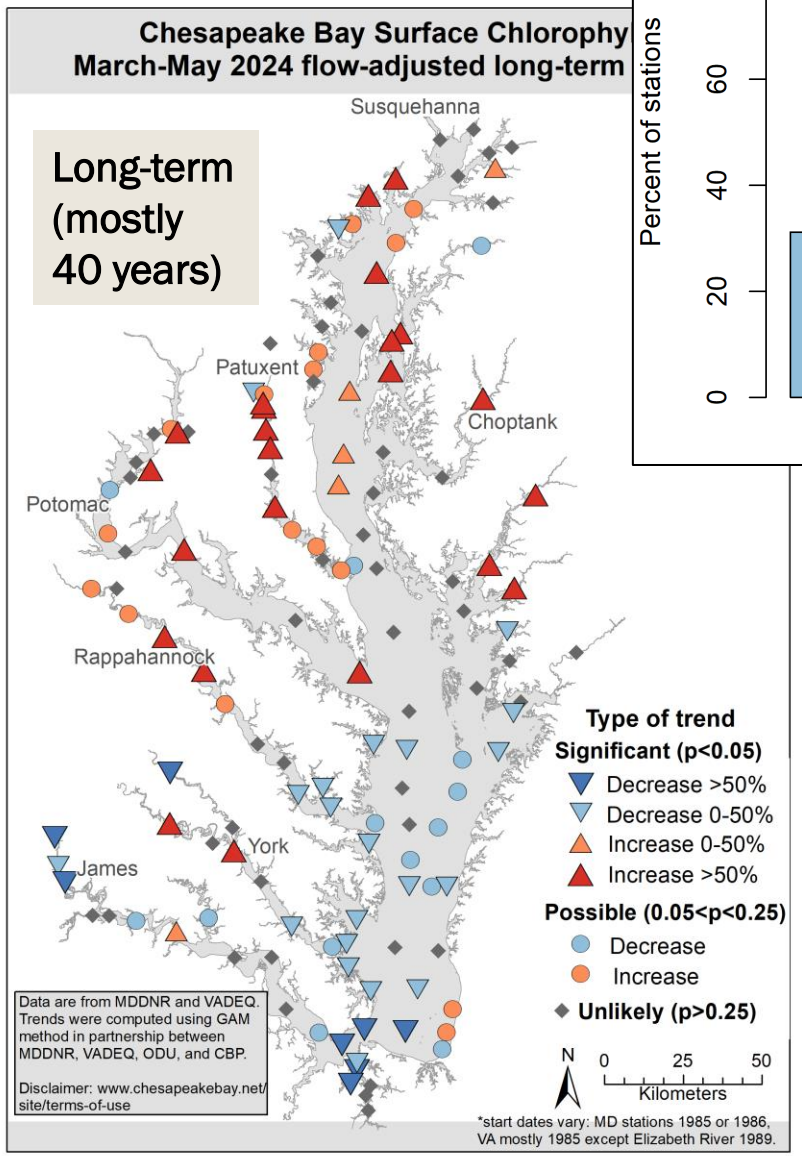
Summary for Secchi

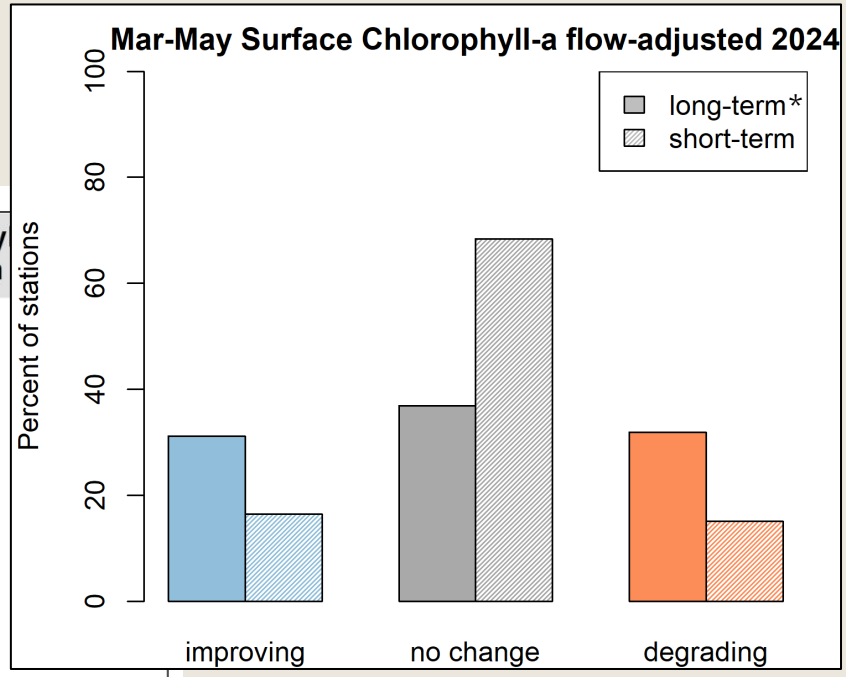
- Long-term degradation in Secchi depth is notable across many regions of the bay.
- But in last 10 years, there are more improvements than degradations.
- These patterns were analyzed recently by Turner et al. 2025: https://doi.org/10.1146/annurev-marine-040224-120528

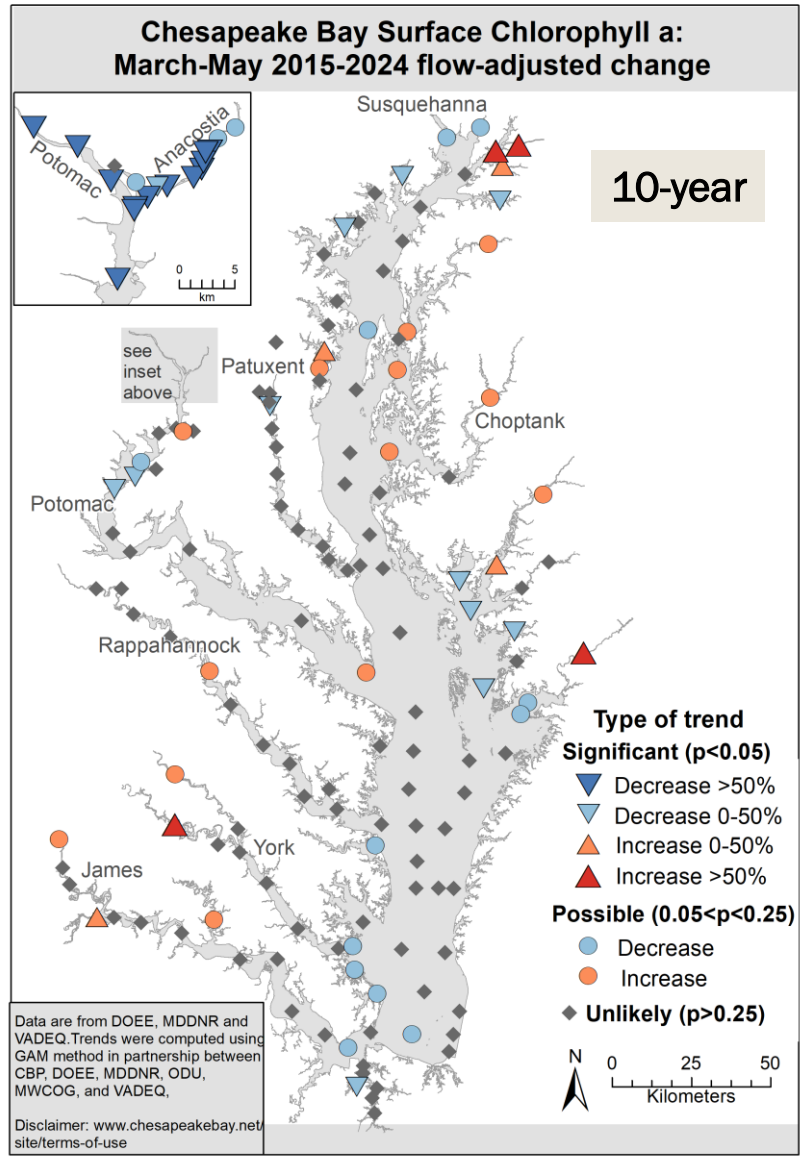


Spring Chlorophyll *a*

Surface Flow-adjusted





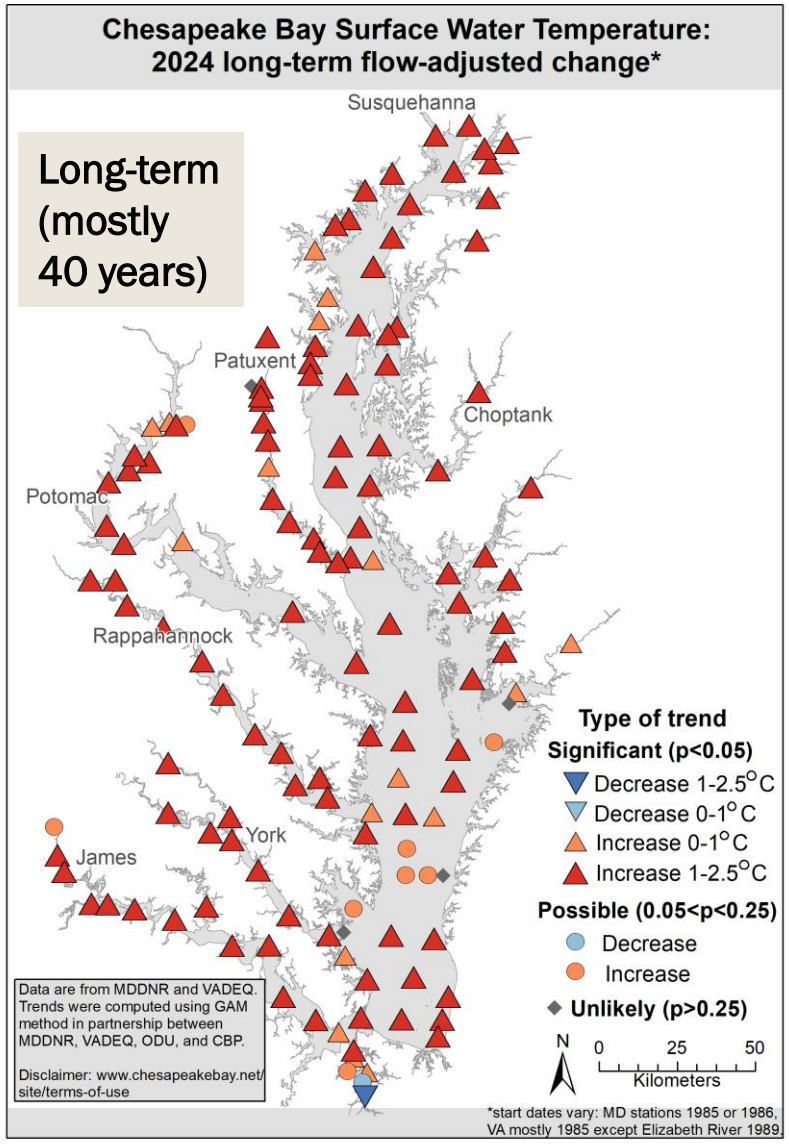


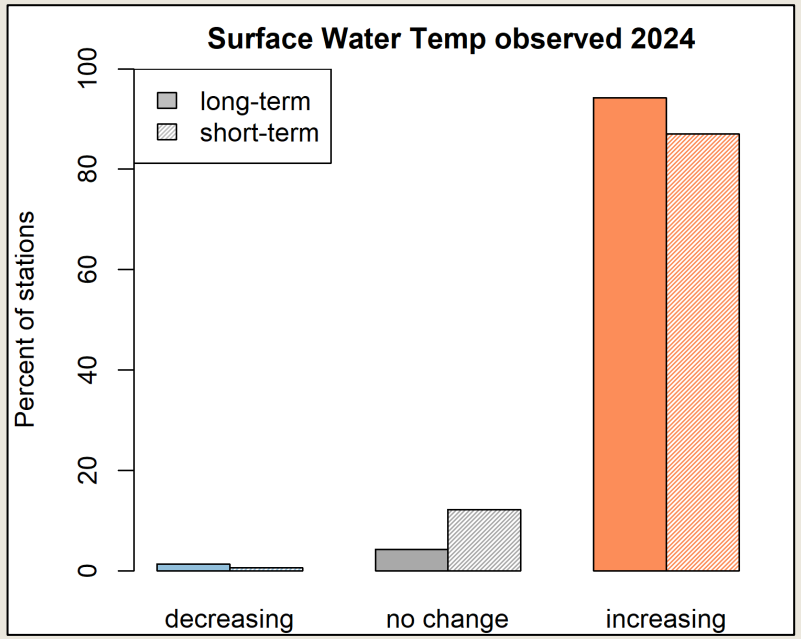
Summary for Chlorophyll

- 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.

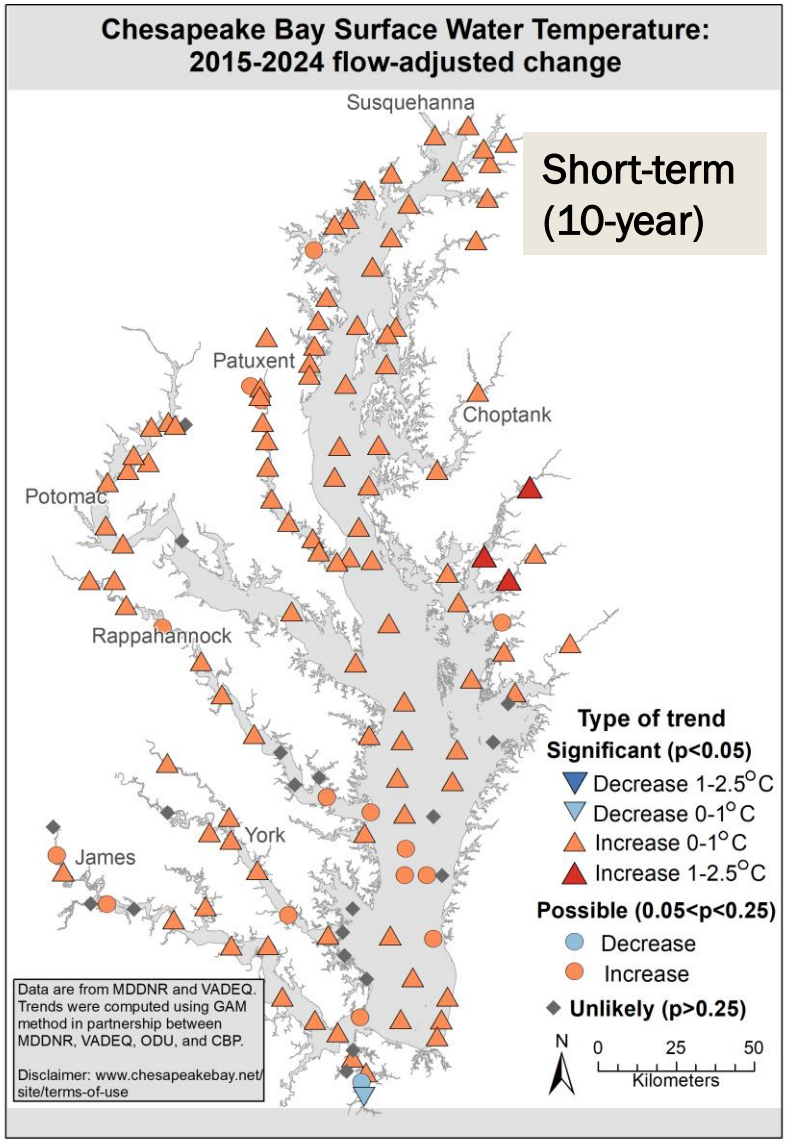
Water Temperature



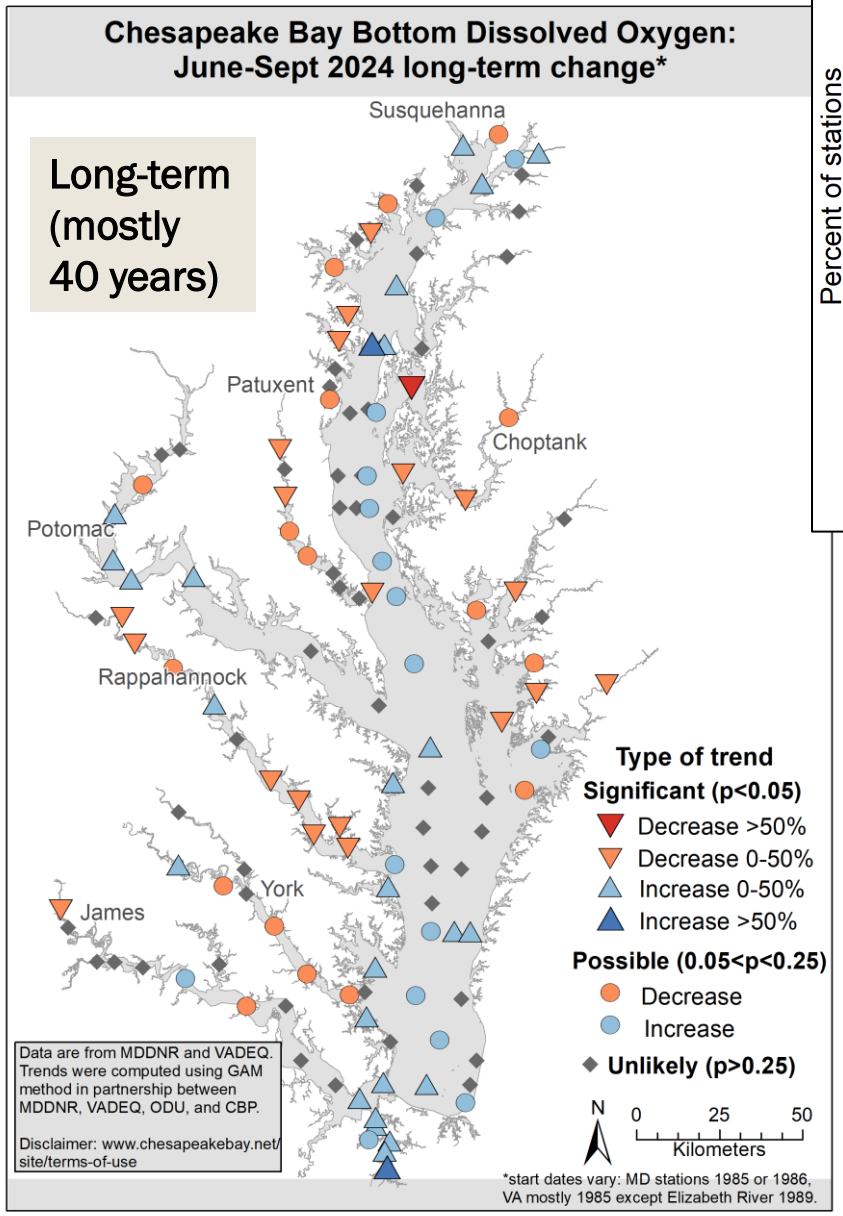


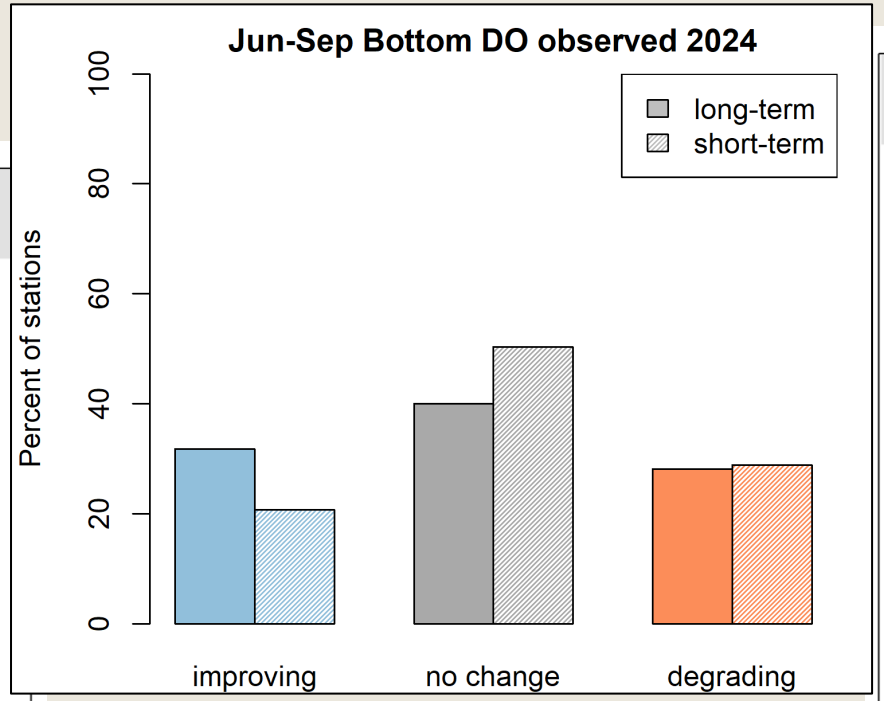
Summary for water temperature

- 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.



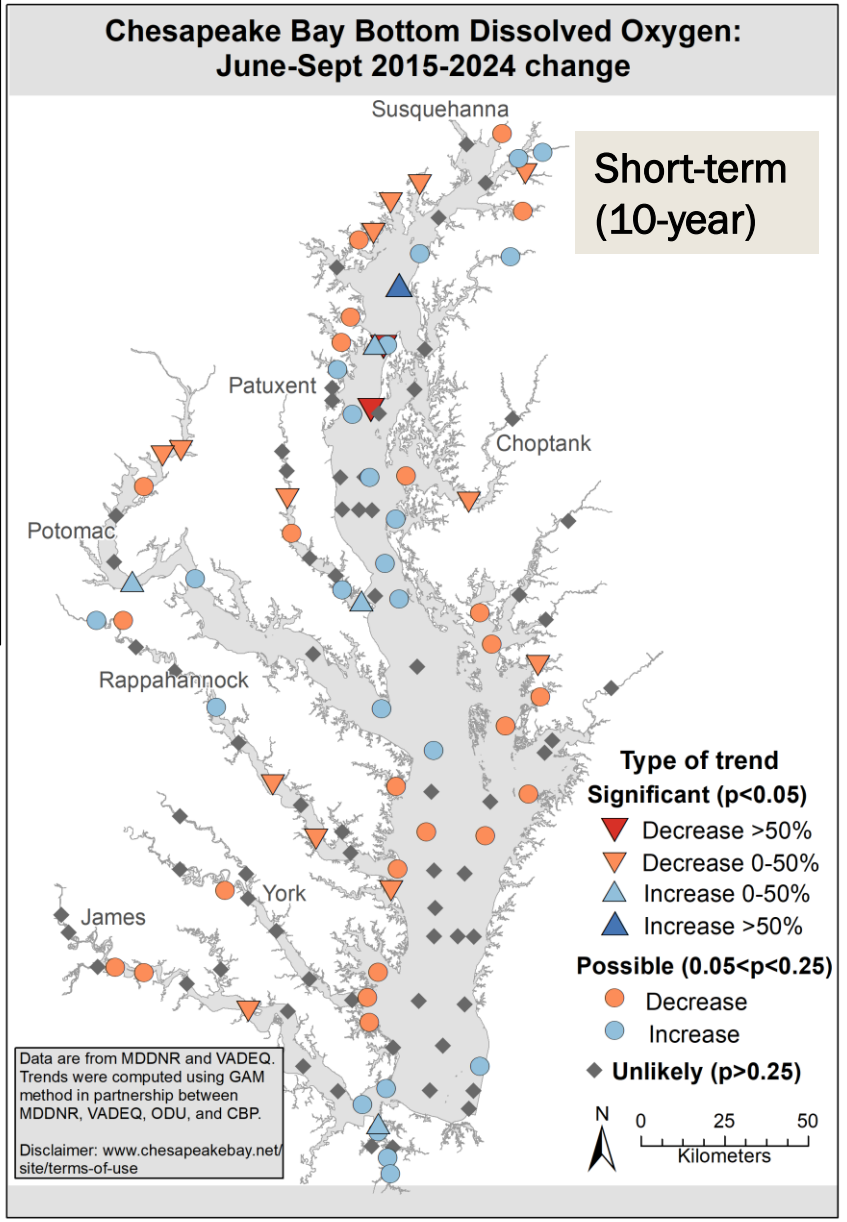
Bottom Summer DO





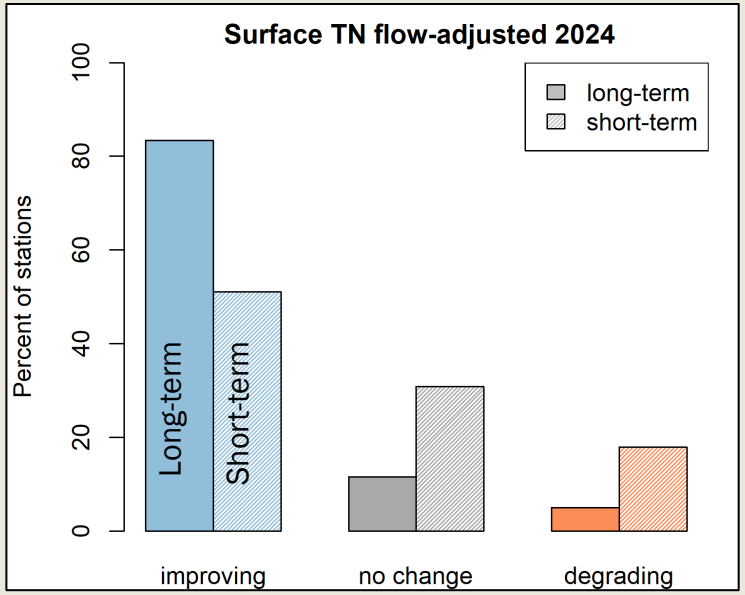
Summary for DO

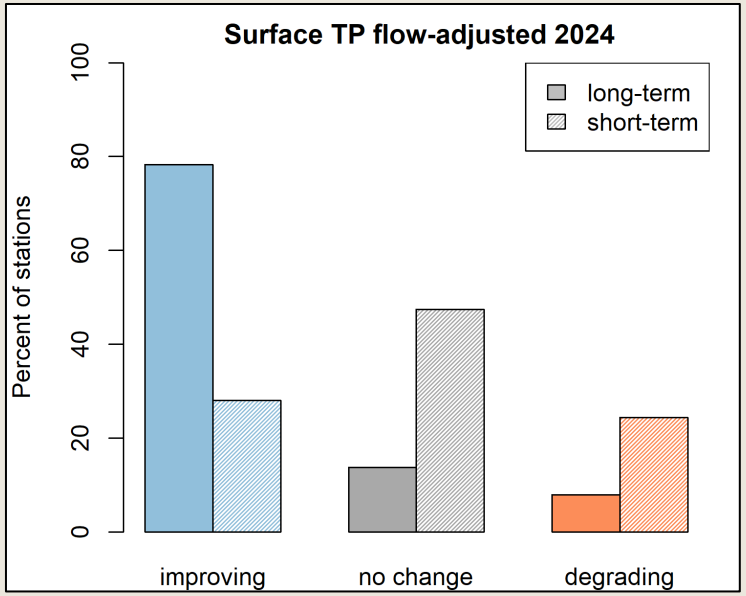
- Bottom DO conditions vary widely across these stations due to depth and mixing.
- Improving conditions are observed in some of the deepest waters, while mixed trends exist elsewhere.
- Consistent with criteria-based analysis, Zhang et al. 2024 https://doi.org/10.1016/j.scitotenv.2024.177617



2024 Summary

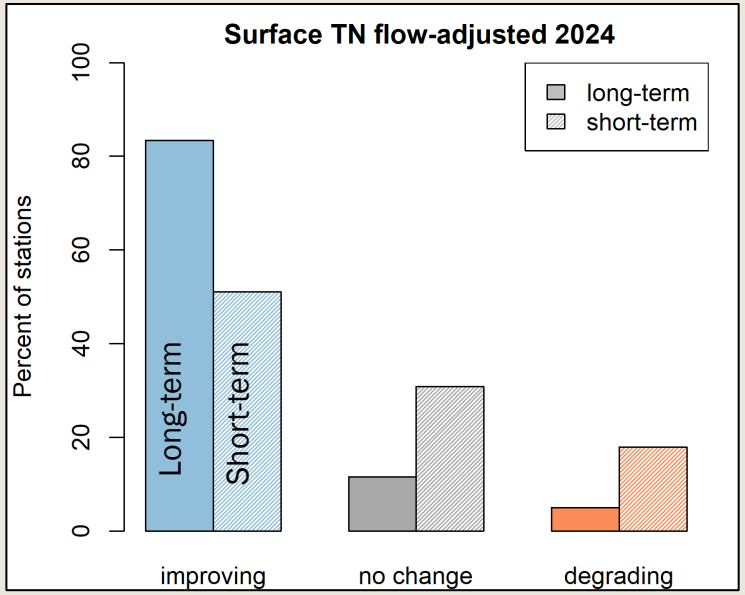
- Nutrient trends mostly improving over the long-term with some leveling-out over the short-term.

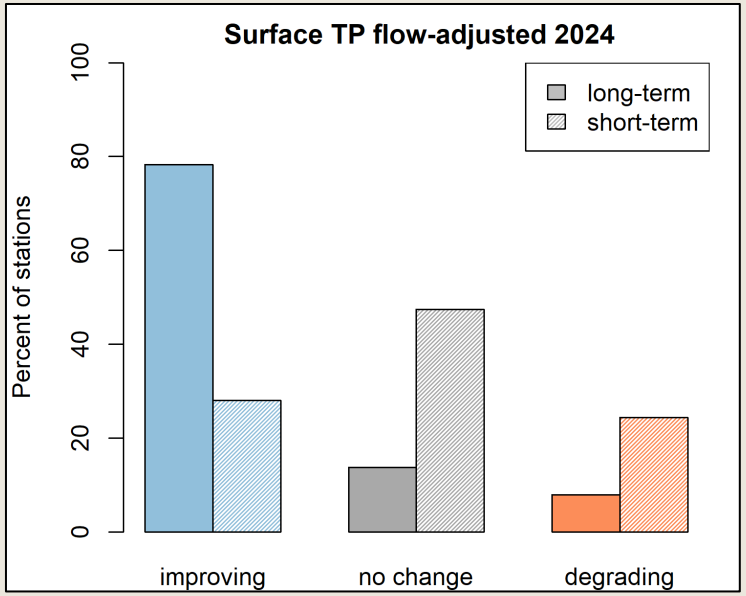


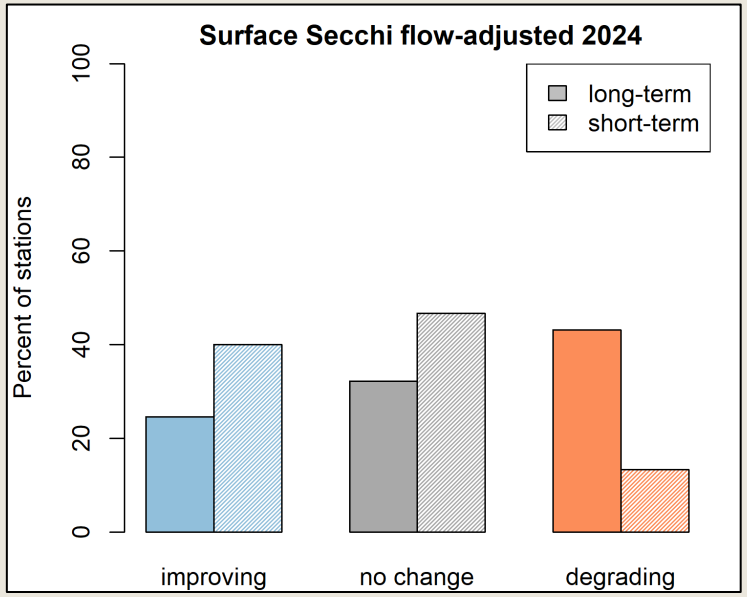


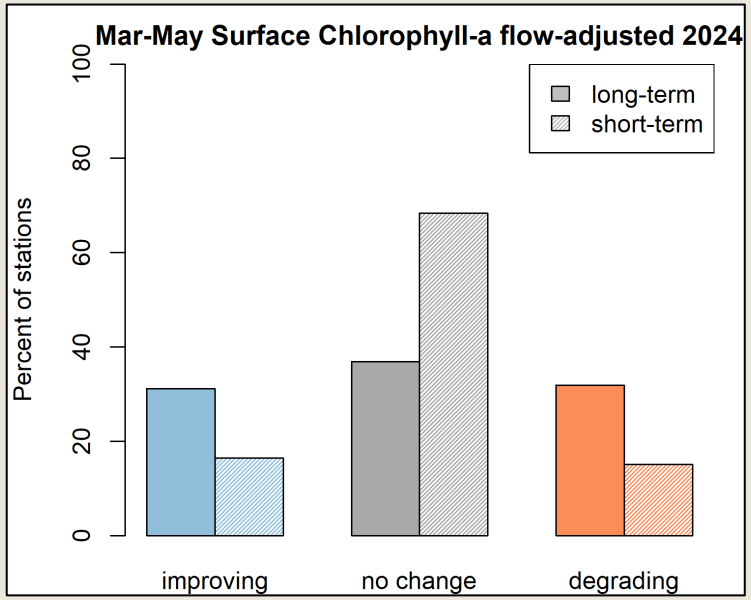
2024 Summary

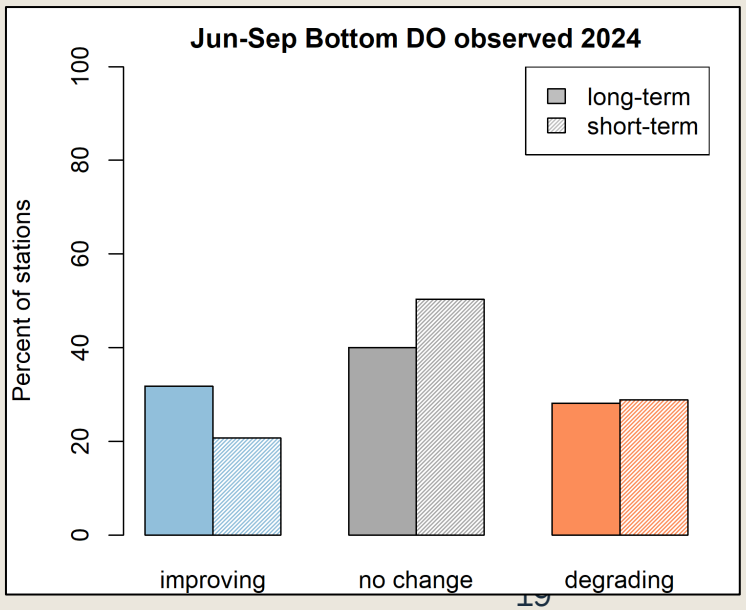
- Nutrient trends mostly improving over the long-term with some leveling-out over the short-term.
- The number of stations with degrading conditions have decreased over the short-term for Secchi and chlorophyll *a,* while DO has different patterns in deeper vs. tributary waters.
- Overall patterns consistent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





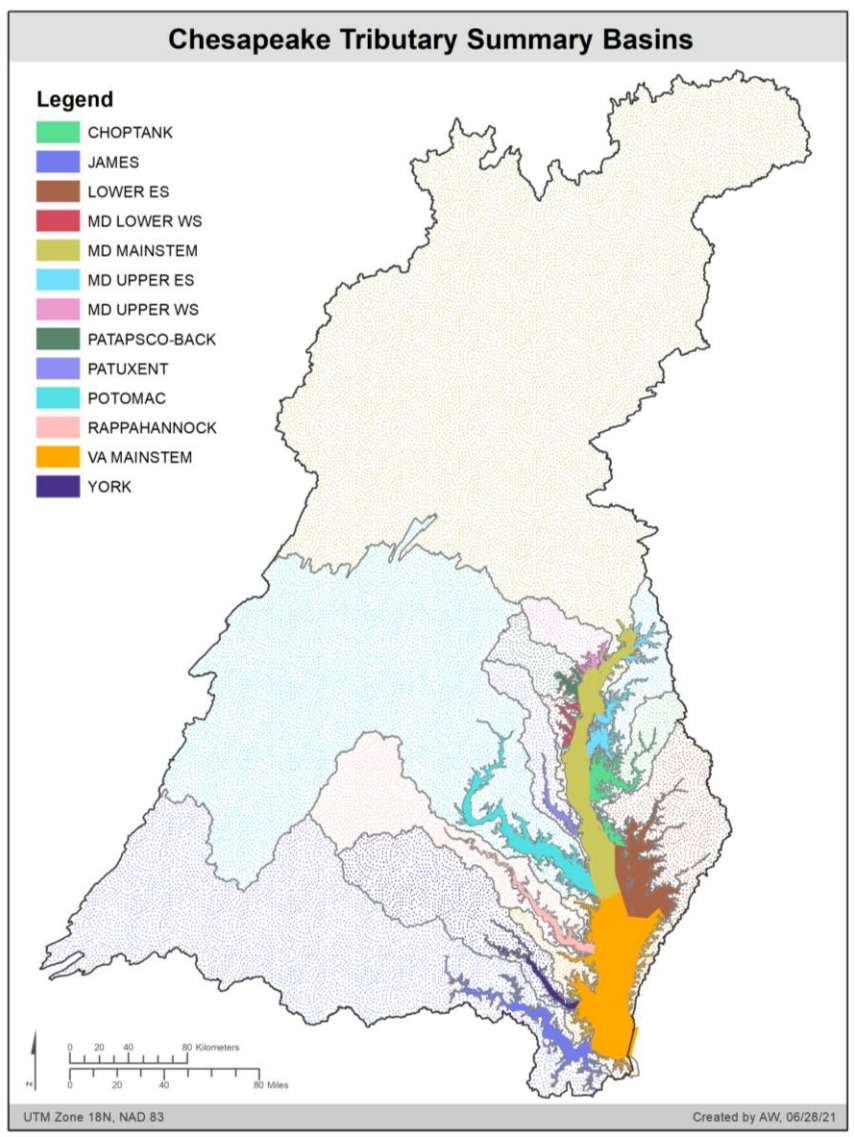




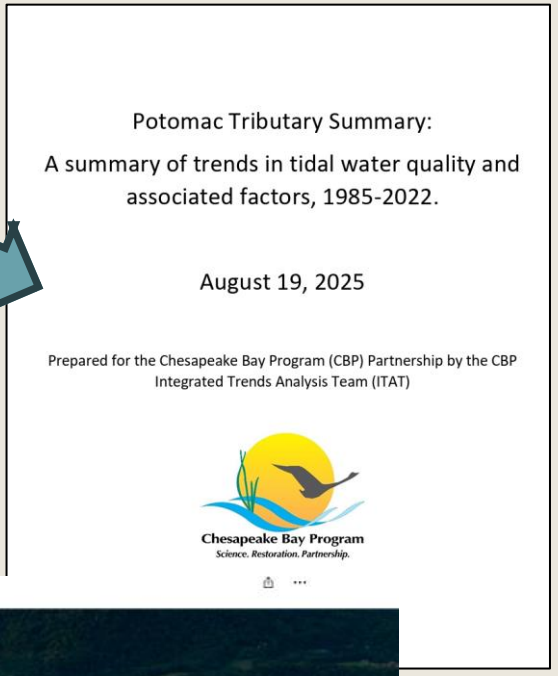


For region-specific information: Tributary Summaries

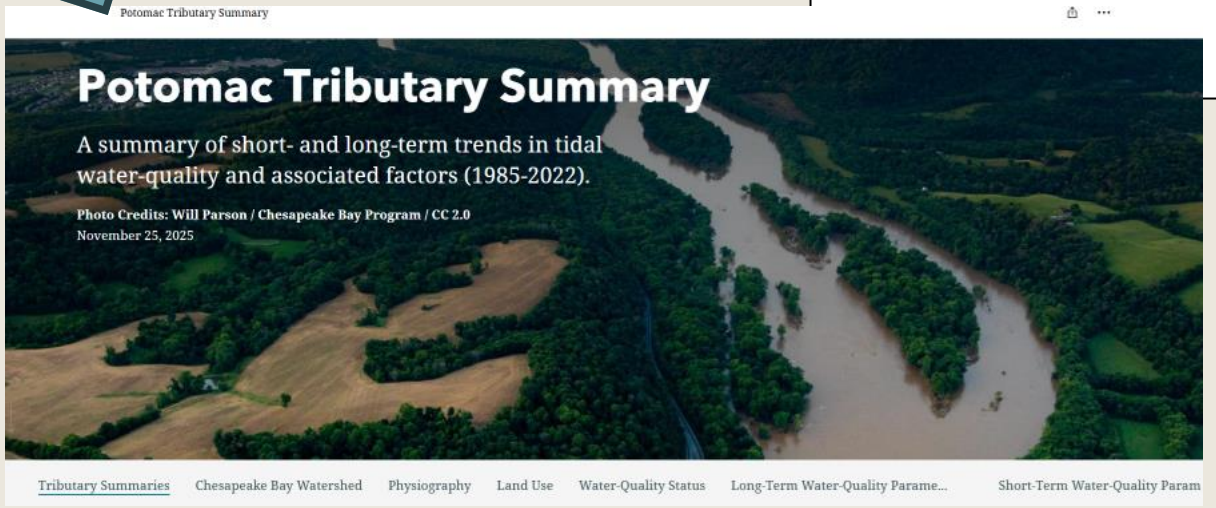
https://www.chesapeakebay.net/projects/tributary-summaries1



PDF documents



Online Story Maps



Acknowledgements and links

- 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

- 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)*
- Baytrends and baytrendsmap maintenance: Jon Harcum and Erik Leppo (Tetra Tech)
- And no trends are possible without data collection from DOEE, MDDNR, and VADEQ teams!

More info on trends approach:

- 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

Contact Information and References

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- **ITAT Co-coordinator:** Breck Sullivan, USGS: bsullivan@chesapeakebay.net
- **ITAT Staffer:** Gabriel Duran, Chesapeake Research Consortium: gduran@chesapeakebay.net
- **ITAT Co-coordinator:** Kaylyn Gootman, EPA: gootman.kaylyn@epa.gov

Trend-related references cited here:

- Murphy et al. 2019. "A Generalized Additive Model approach to evaluating water quality: Chesapeake Bay case study." Environmental Modelling & Software 118. https://doi.org/10.1016/j.envsoft.2019.03.027
- Murphy et al. 2021. "Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management." Environmental Science and Technology 56(1). https://doi.org/10.1021/acs.est.1c05388
- Turner et al. 2025. "Chesapeake Bay Water Clarity: Challenges and Successes." Annual Review of Marine Science 18. https://doi.org/10.1146/annurev-marine-040224-120528
- 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

extras

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 Degrading No trend

From Jimmy Webber, USGS

- 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.