Tidal Water Quality Change: 2023 results

Maryland Department of Natural Resources (MDDNR), Virginia Department of Environmental Quality (VADEQ), the District of Columbia, and others have coordinated to sample water quality on a bi-monthly or monthly basis at more than 130 stations located throughout the Chesapeake Bay mainstem and the tidal portions of numerous tributaries on the western and eastern shores since the mid-1980s. Scientists evaluate short- and long-term changes, or trends, in nitrogen, phosphorus, dissolved oxygen (DO), Secchi depth (a measure of clarity), chlorophyll *a*, and other constituents using a Generalized Additive Modeling (GAM) approach (Murphy et al, 2019, 2024).

The approach includes selecting a GAM structure to describe nonlinear seasonally-varying changes over time, incorporation of hydrologic variability via either river flow or salinity, the use of an intervention to accommodate method or laboratory changes suspected to impact data values, and representation of data reported less than or between method detection limit(s).

Changes in observed conditions (i.e., the conditions experienced by the estuary's living resources) are used to evaluate incremental progress towards improved habitats and attainment of water quality standards. Changes in flow-adjusted conditions account for year-to-year variations in streamflow or salinity and can be used for understanding the influence of watershed management actions on the estuary. The percent of stations improving, degrading, and showing no change using data collected through 2023 are summarized in Table 1. Short-term trends are for the last 10 years, and long-term trends are from the mid-1980s to 2023.

Overall, nutrient concentrations have improved at the majority of stations over the long-term. Secchi depth, chlorophyll *a,* and DO improved at fewer stations than nutrient concentrations over the long-term, however the number of stations with degrading conditions have decreased over the short-term. Freshwater flow variability does impact these trends, and annual mean freshwater flows in 2022 and 2023 were average to below average when compared to annual flows since 1937 (USGS, 2022).

Table 1. *The percent of stations improving, degrading, and showing no change using data collected through 2023 for nutrients, dissolved oxygen, chlorophyll a, and Secchi depth*

	Observed Conditions			**Flow-adjusted Conditions**		
Water Quality Variable	**Improving**	**No Change**	**Degrading**	**Improving**	**No Change**	**Degrading**
Short-term Trend (2014-15 to 2022-23)						
Dissolved Oxygen (summer, bottom layer)	13%	55%	33%	15%	63%	22%
Secchi depth (annual)	39%	54%	7%	34%	55%	11%
Chlorophyll *a* (spring, surface layer)	22%	60%	19%	24%	61%	15%
Total Nitrogen (annual, surface layer)	54%	33%	13%	48%	36%	16%
Total Phosphorus (annual, surface layer)	26%	50%	24%	28%	43%	29%
Long-term Trend (Period of Record)						
Dissolved Oxygen (summer, bottom layer)	30%	40%	30%	25%	44%	30%
Secchi depth (annual)	23%	33%	44%	23%	32%	45%
Chlorophyll *a* (spring, surface layer)	28%	32%	41%	30%	38%	32%
Total Nitrogen (annual, surface layer)	90%	7%	4%	86%	9%	4%
Total Phosphorus (annual, surface layer)	78%	14%	8%	78%	12%	10%

Dissolved Oxygen

For this summary, we describe both long- and short-term trend results, with short-term values in parentheses following long-term.

Summer bottom DO conditions and trends vary widely across the tidal waters due to differences in water depth impacting vertical mixing. Observed summer bottom DO over the long- (short-) term period show 30% (13%) of stations with improving conditions, 30% (33%) with degrading conditions, and 40% (55%) with no change.

More degrading DO conditions occur in the tributaries, while some notable long-term improvements are occurring along the deep mainstem channel.

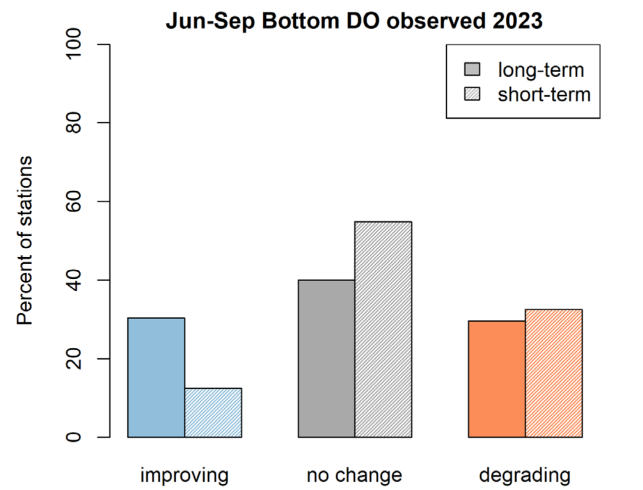


Figure 1. Percent of stations with improving, degrading, and no change for dissolved oxygen in the bottom layer during the summer season for long- and short-term periods.

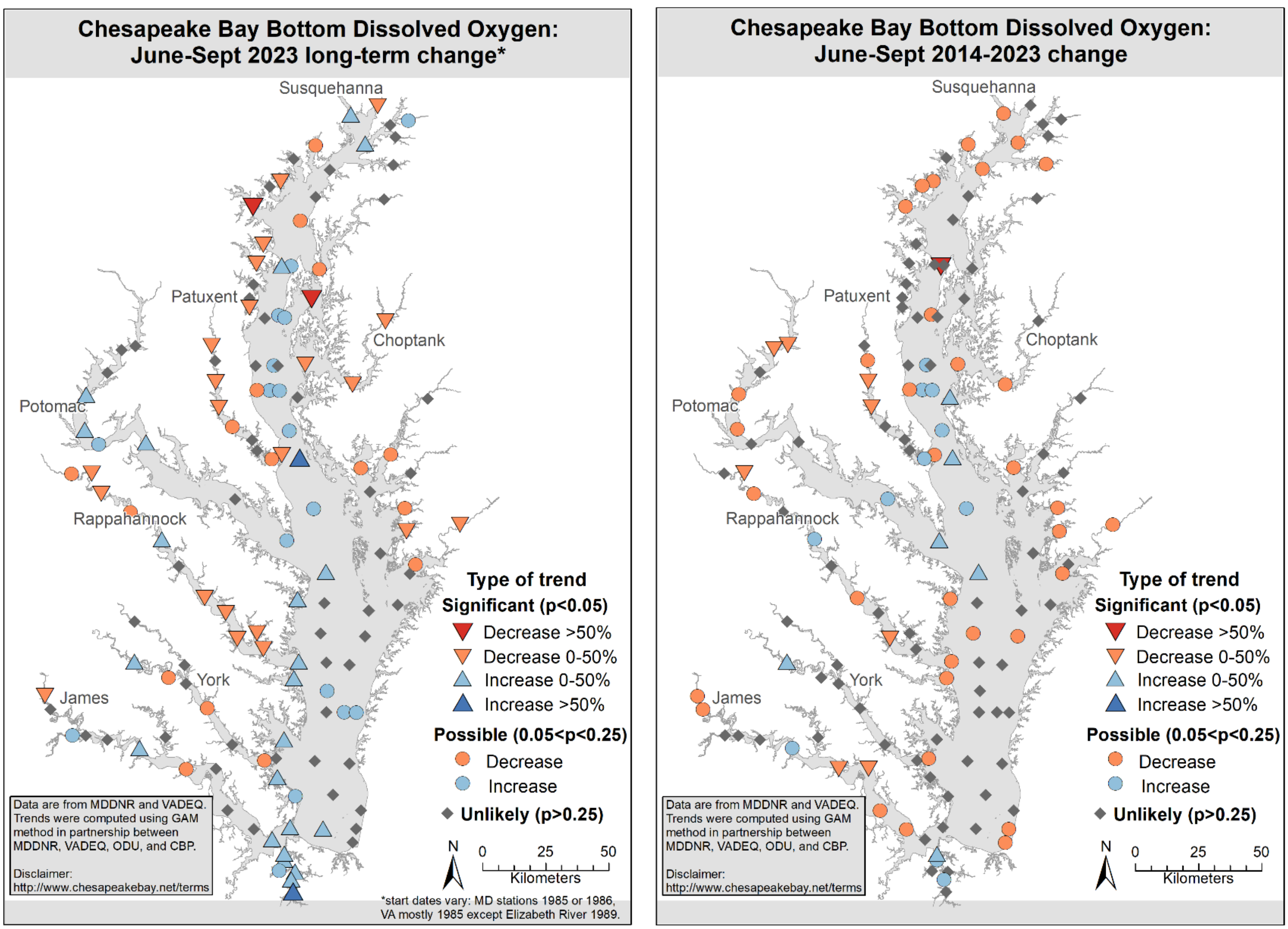


Figure 2. Changes in observed dissolved oxygen in the bottom layer during the summer season for long- (left panel) and short-term (right panel) periods.

Secchi Depth

Trends in flow-adjusted annual Secchi depth have notably changed from the long-term period to short-term. Flow-adjusted Secchi depth over the long- (short-) term show 23% (34%) of stations have improving conditions, 45% (11%) have degrading conditions, and 32% (55%) have no change.

Secchi trends at tidal Washington D.C. stations are included this year (see inset in Figure 4) and include mostly long-term improvements with mixed trends in the short-term. Bay-wide, long-term degradation in flow-adjusted Secchi depth is notable across a large portion of the tidal waters. Fewer degrading trends persist over the short-term period.

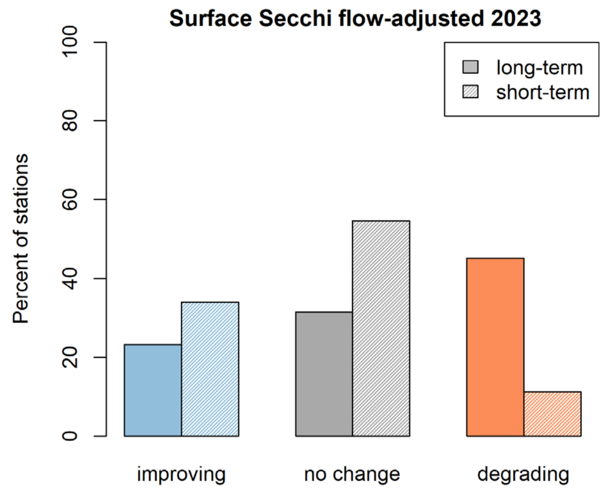


***Figure 3**. Percent of stations with improving, degrading, and no change for flow-adjusted annual Secchi depth for long- and short-term periods.*

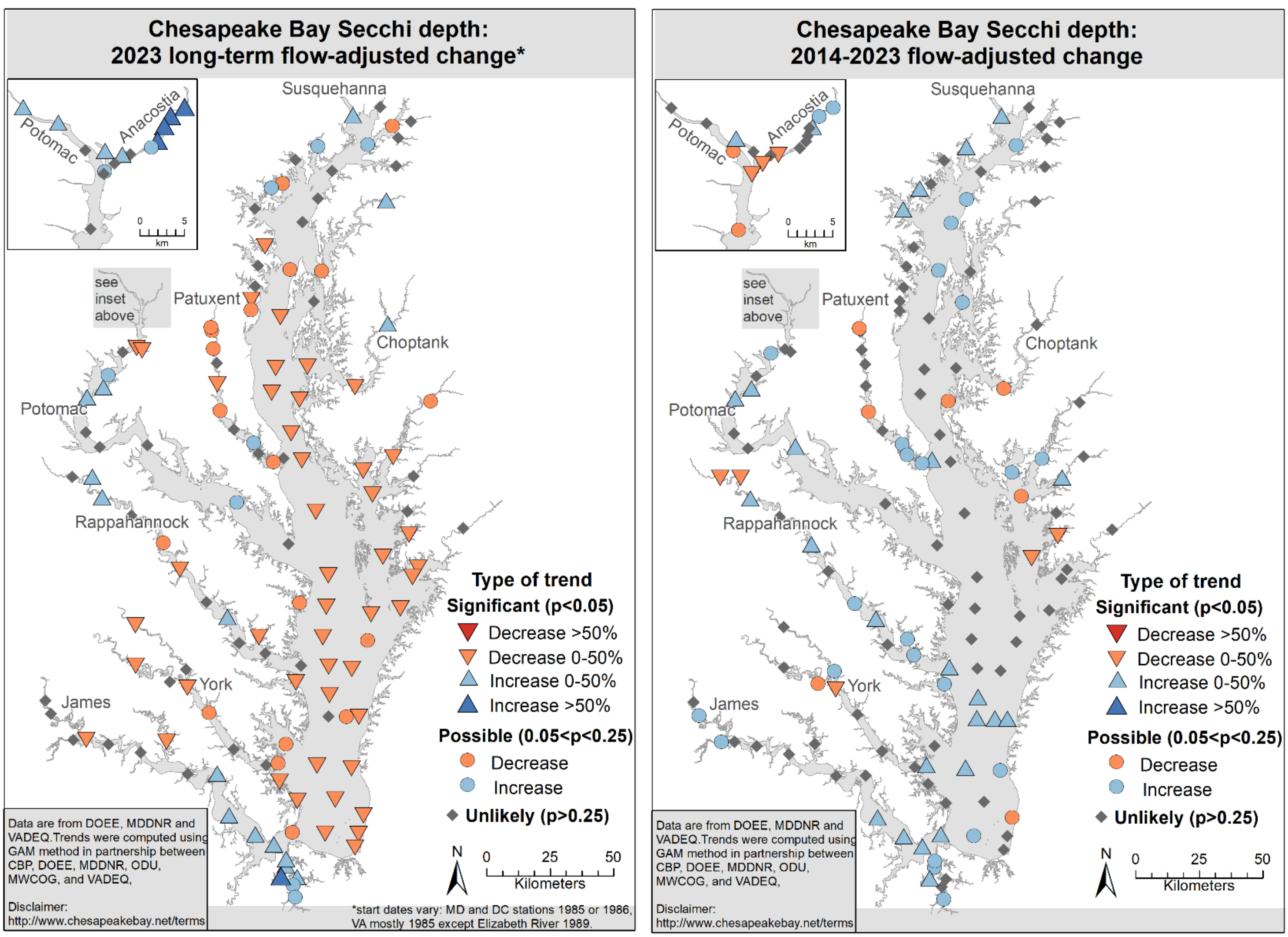


Figure 4. Changes in flow-adjusted annual Secchi depth for long- (left panel) and short-term (right panel) periods.

Chlorophyll *a*

Changes in spring surface chlorophyll *a* vary by region. Overall, flow-adjusted spring chlorophyll *a* in the surface layer over the long- (short-) term show 30% (24%) of stations have improving conditions, 32% (15%) have degrading conditions, and 38% (61%) have no change.

Long-term trends are mixed spatially for spring chlorophyll *a* with approximately the same percent of stations improving and degrading. Over the short-term, fewer stations have degrading chlorophyll *a*. Short-term trends were computed for the Washington DC stations and show improving spring chlorophyll *a*.

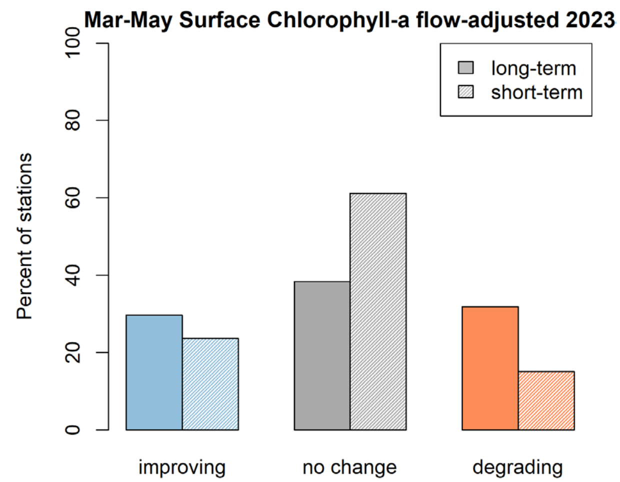


Figure 5. *Percent of stations with improving, degrading, and no change in flow-adjusted spring chlorophyll a in the surface layer for long- and short-term periods.*

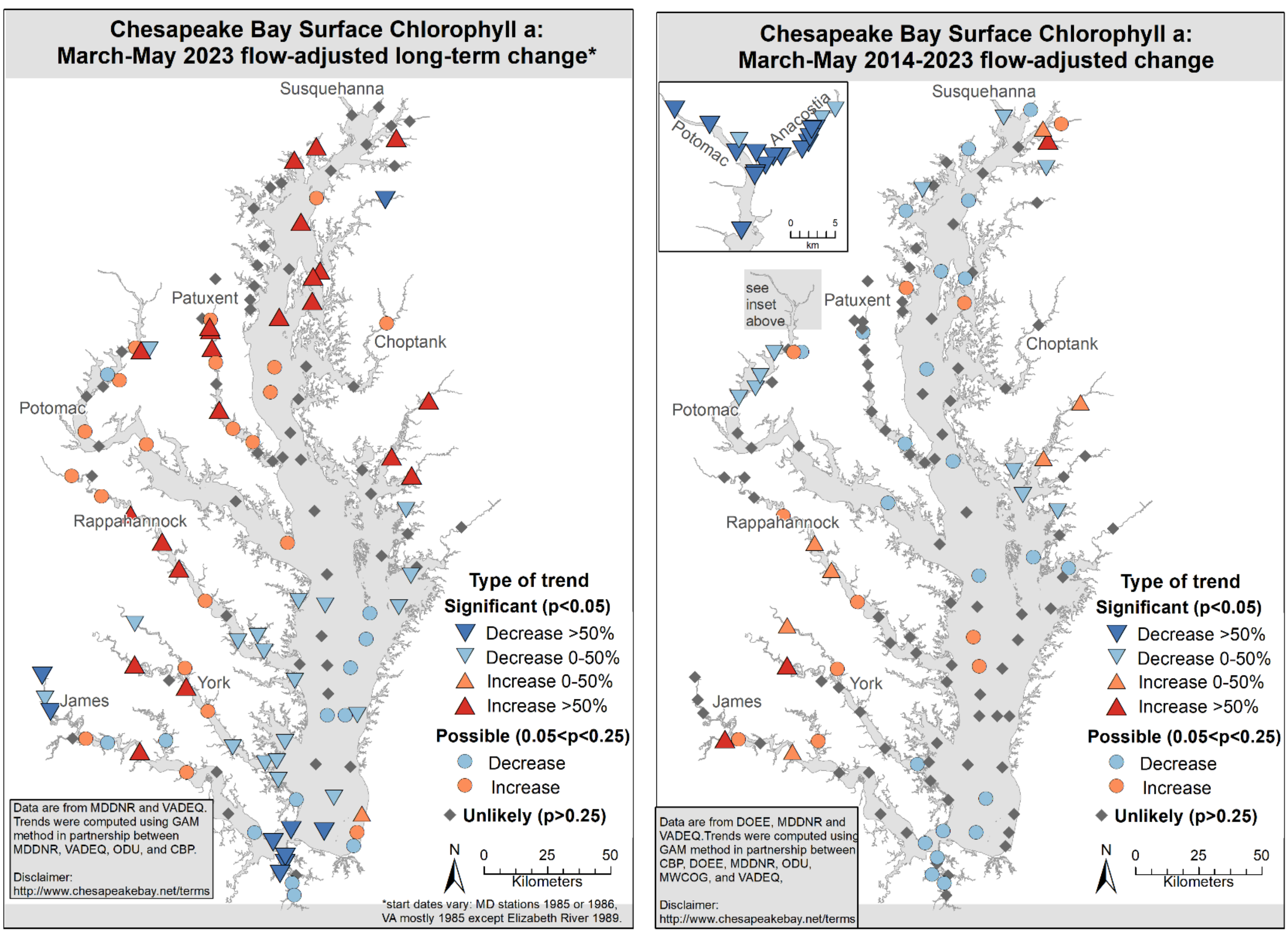


Figure 6. *Changes in flow-adjusted spring chlorophyll a in the surface layer for long- (left panel) and short-term (right panel) periods.*

Total Nitrogen

Both total nutrients have improved bay-wide over the long-term. Flow-adjusted surface total nitrogen over the long- (short-) term show 86% (48%) of stations have improving conditions, 4% (16%) have degrading conditions, and 9% (36%) have no change.

Long-term surface total nitrogen concentrations are clearly decreasing throughout most of the Chesapeake Bay tidal waters. Many of these trends persist over the short term as well, although more stations show stable or degrading conditions over the short-term, especially in several tributaries.

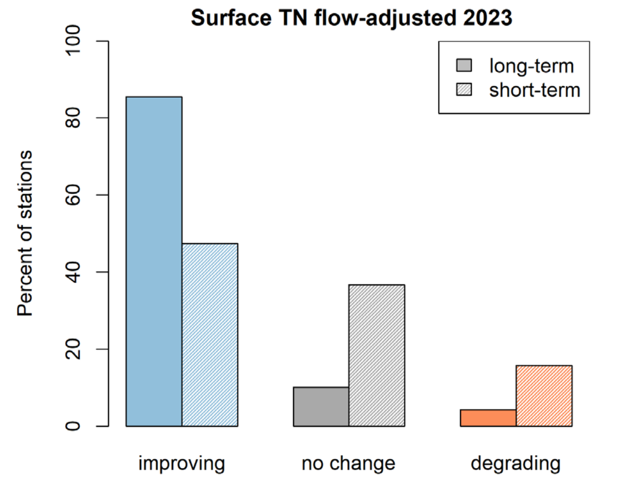


Figure 7. *Percent of stations with improving, degrading, and no change in flow-adjusted annual total nitrogen in the surface layer for long- and short-term periods.*

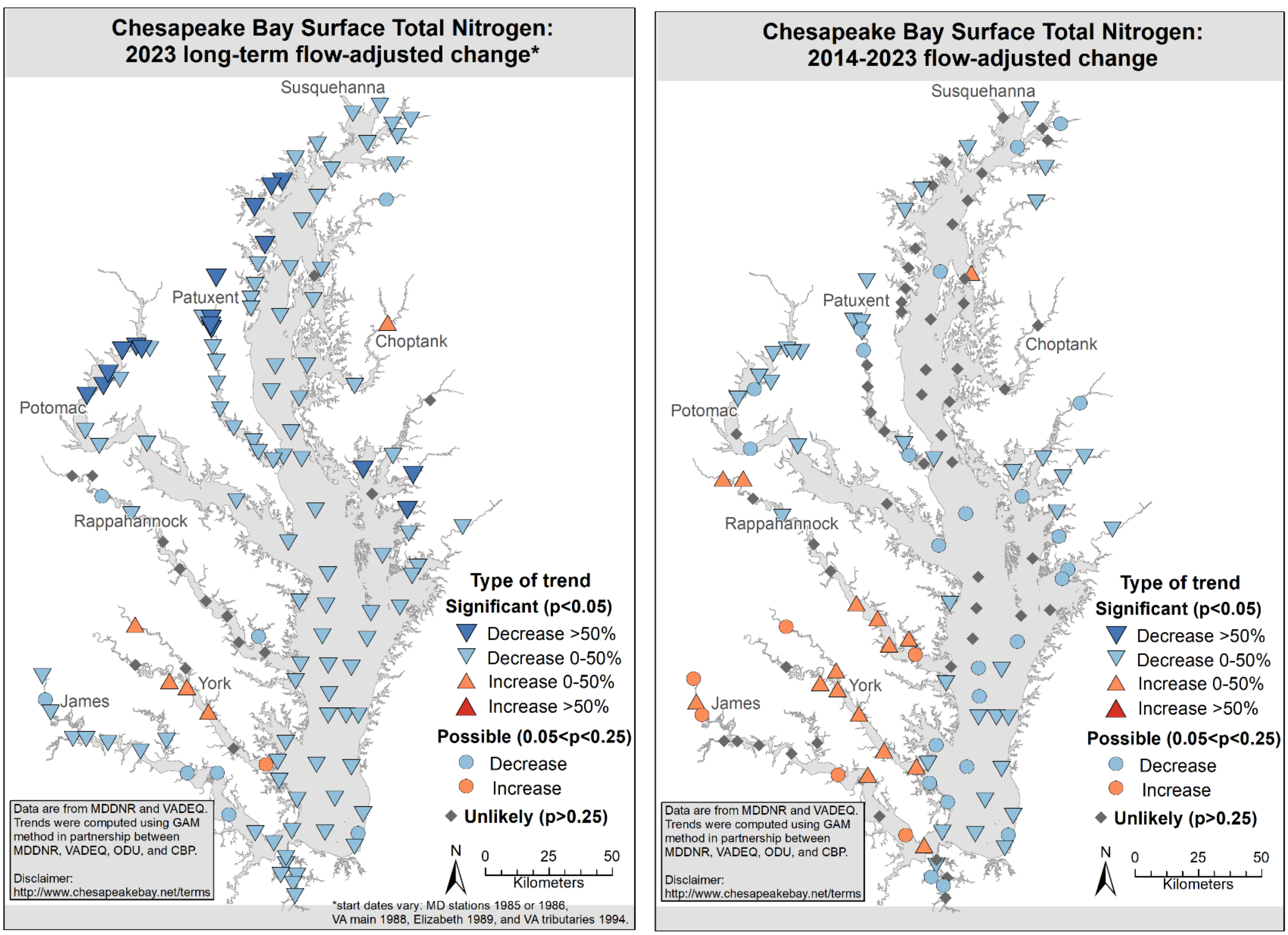


Figure 8. *Changes in flow-adjusted annual total nitrogen in the surface layer for long- (left panel) and short-term (right panel) periods.*

Total Phosphorus

For flow-adjusted surface total phosphorus, long- (short-) term trends show that 78% (28%) of stations have improving conditions, 10% (29%) have degrading conditions, and 12% (43%) have no change.

Long-term flow adjusted annual total phosphorus in the surface layer is improving at most stations with exceptions in several tributaries. Like for total nitrogen, more stations show stable or degrading conditions over the short-term.

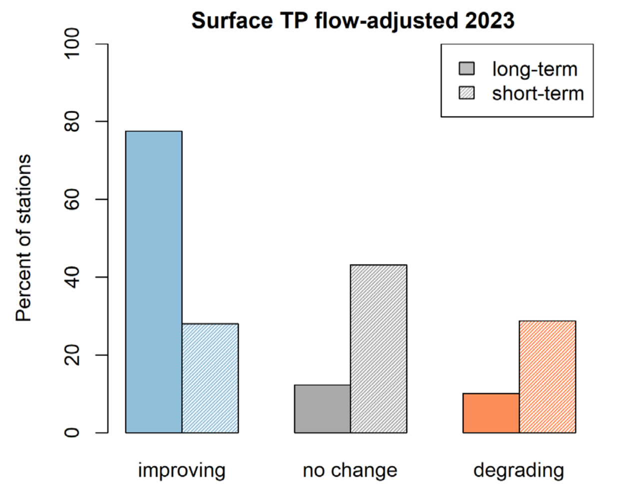
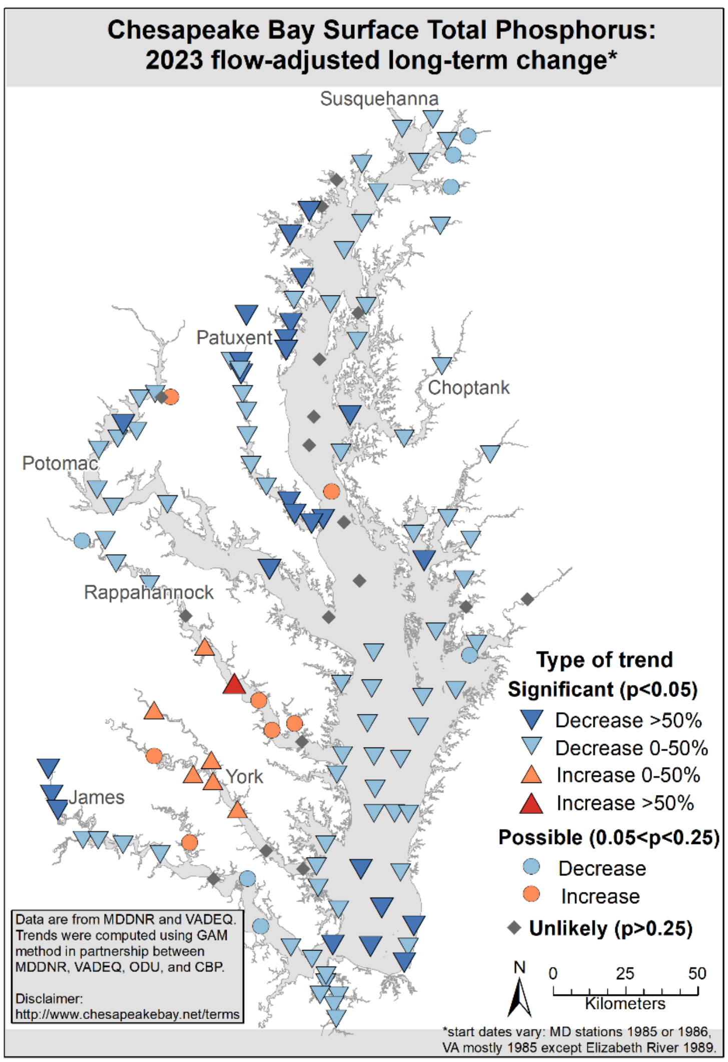


Figure 9. *Percent of stations with improving, degrading, and no change in flow-adjusted annual total phosphorus in the surface layer for long- and short-term periods.*



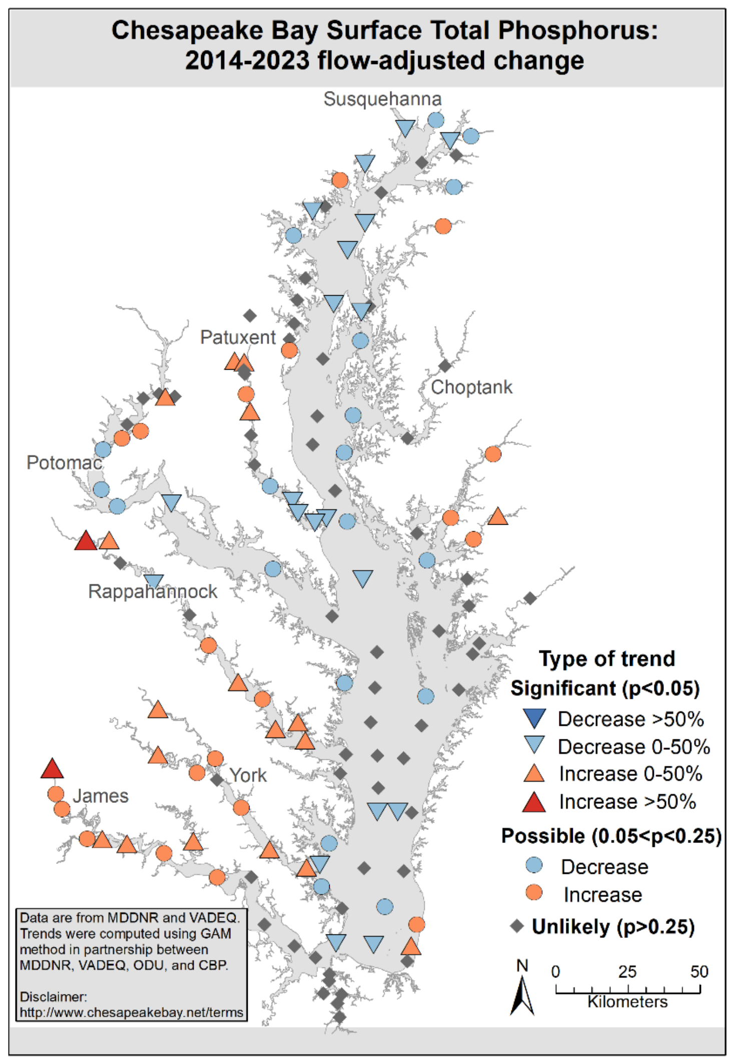


Figure 10. *Changes in flow-adjusted annual total phosphorus in the surface layer for long- (left panel) and short-term (right panel) periods.*

References

USGS. 2024. https://www.usgs.gov/centers/chesapeake-bay-activities/science/freshwater-flow-chesapeake-bay

Murphy, R, E. Perry, J. Keisman, J. Harcum, and E. Leppo. 2024. 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. A generalized additive model approach to evaluating water quality: Chesapeake Bay case study. Environmental Modeling and Software 118 (August 2019): 1-13.