Tidal Water Quality Change

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 mainstem of the Chesapeake Bay 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 nutrients, dissolved oxygen (DO), Secchi depth (a measure of clarity), and chlorophyll-*a* using a Generalized Additive Modeling (GAM) approach. 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 left- and interval-censored data (Murphy et al, 2019, 2021).

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 2020 are summarized in Table 1.

Freshwater flow variability impacts the results, and the annual mean freshwater flow in 2019 entering the Chesapeake Bay was the highest since 1937 (Moyer and Blomquist, 2020). After several preceding wet years, 2020 was a more average flow year, likely mitigating the impact of the recent high flows on these results. Nutrient concentrations have improved at the majority of stations over the long-term. Secchi, chlorophyll-*a* and DO improved at fewer stations than nutrients, but the number of stations with degrading conditions have decreased in recent years.

Table 1. The percent of stations improving, degrading, and showing no change using data collected through 2020 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 (2011-12 to 2019-20)						
Dissolved Oxygen (summer, bottom layer)	13%	65%	22%	12%	50%	38%
Secchi Depth (annual)	18%	58%	23%	18%	57%	25%
Chlorophyll-a (spring, surface layer)	34%	58%	9%	32%	61%	7%
Total Nitrogen (annual, surface layer)	18%	62%	20%	49%	37%	14%
Total Phosphorus (annual, surface layer)	25%	55%	20%	26%	60%	14%
Long-term Trend (Period of Record)						
Dissolved Oxygen (summer, bottom layer)	21%	51%	27%	18%	44%	38%
Secchi Depth (annual)	10%	22%	68%	16%	25%	59%
Chlorophyll-a (spring, surface layer)	22%	34%	45%	24%	45%	31%
Total Nitrogen (annual, surface layer)	73%	21%	6%	85%	12%	2%
Total Phosphorus (annual, surface layer)	71%	15%	14%	71%	22%	7%

† Note that two or three months of data at each station were missing in 2020 due to sampling restrictions, but an analysis of the potential impact indicates that these results were not greatly impacted.

Dissolved Oxygen

The wide variety of trends in observed summer DO of the bottom layer is likely due to varying bottom conditions (i.e., varying depths and mixing) throughout the tidal waters. Overall, observed summer DO of the bottom layer over the long- (short-) term period show 21% (13%) of stations with improving conditions, 27% (22%) with degrading conditions, and 51% (65%) with no change.

Most degrading DO conditions occur in tributaries, most notably, in the deep waters of the Rappahannock over the long term.

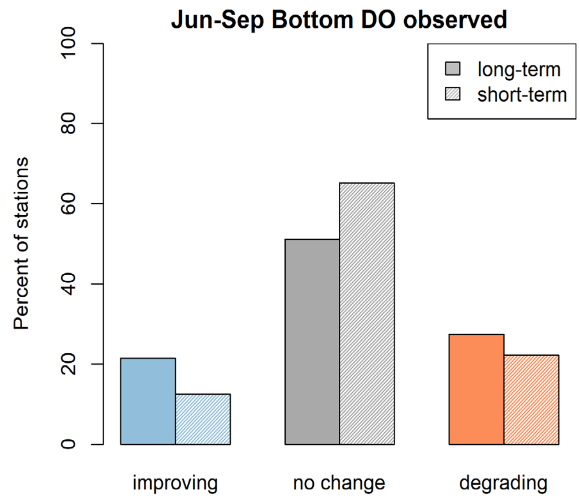


Figure 1. Percent of stations with improving, degrading, and no change for dissolved oxygen in the bottom layer during the summer season for long- and short-term periods.

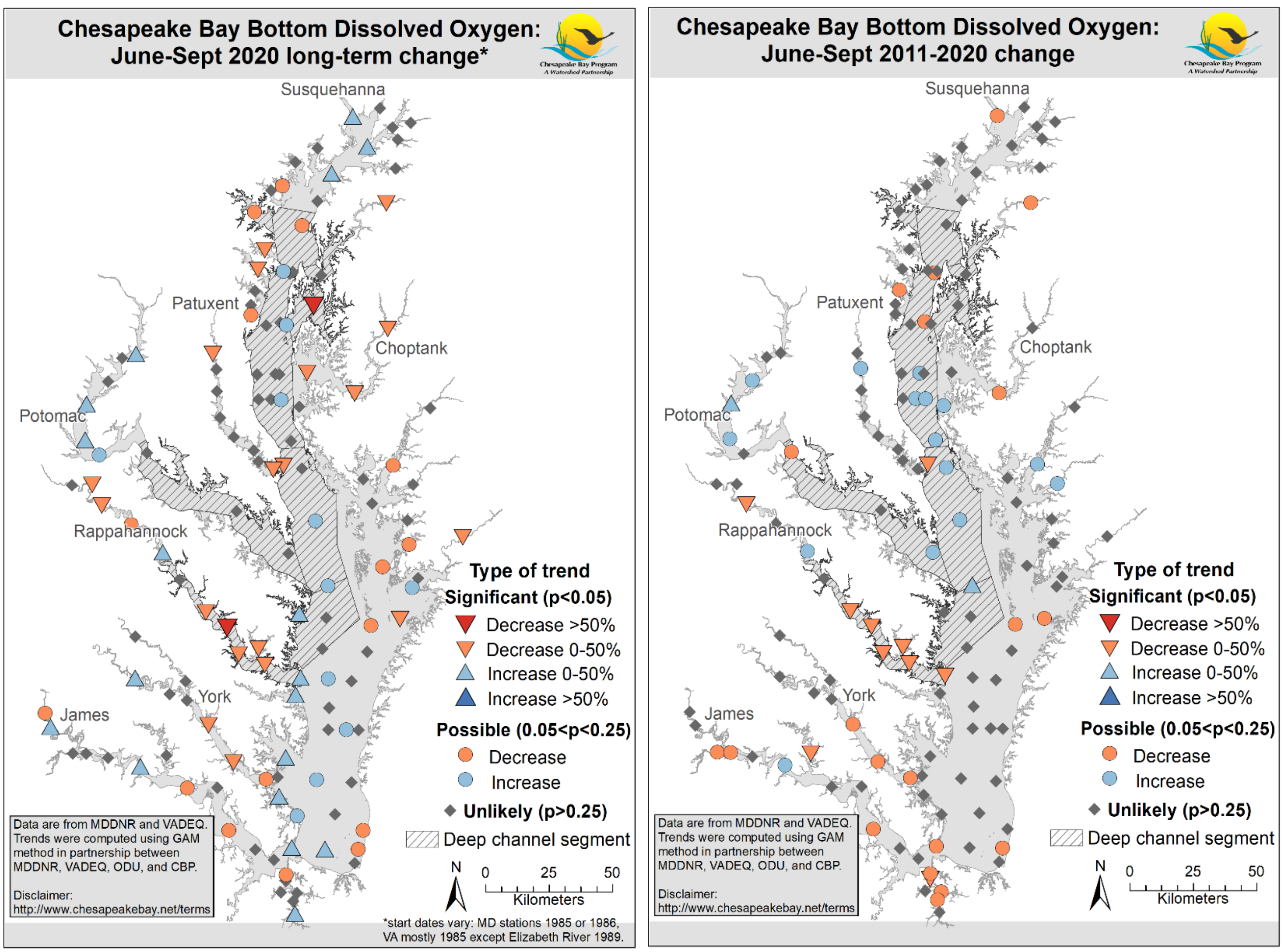


Figure 2. Changes in observed dissolved oxygen in the bottom layer during the summer season for long- (left panel) and short-term (right panel) periods. Deep channel segments with summer criteria of 1 mg/L are indicated with hatching.

Secchi Depth

Trends in flow-adjusted annual Secchi depth vary across the tidal waters. Overall, 16% (18%) of stations show improving conditions, 59% (25%) with degrading conditions, and 25% (57%) with no change in flow-adjusted Secchi depth over the long- (short-) term period.

Long-term degradation in flow adjusted Secchi depth is notable at most of the mainstem stations and a smaller portion of tributary stations. Fewer degrading trends persist over the short-term period.

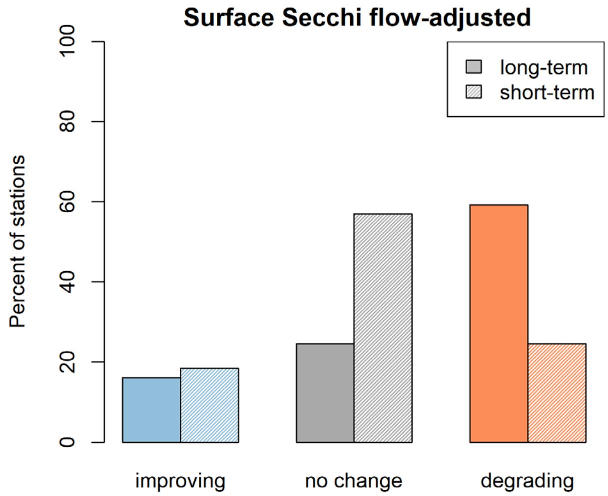
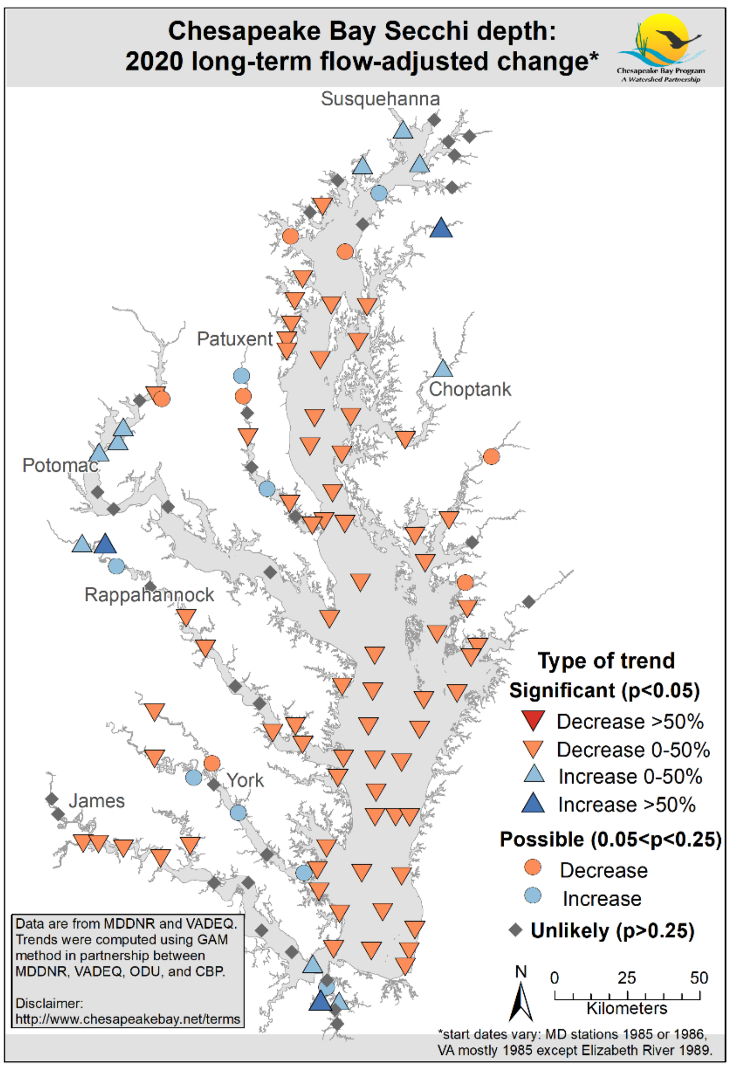


Figure 3 Percent of stations with improving, degrading, and no change for flow-adjusted annual Secchi depth for long- and short-term periods.



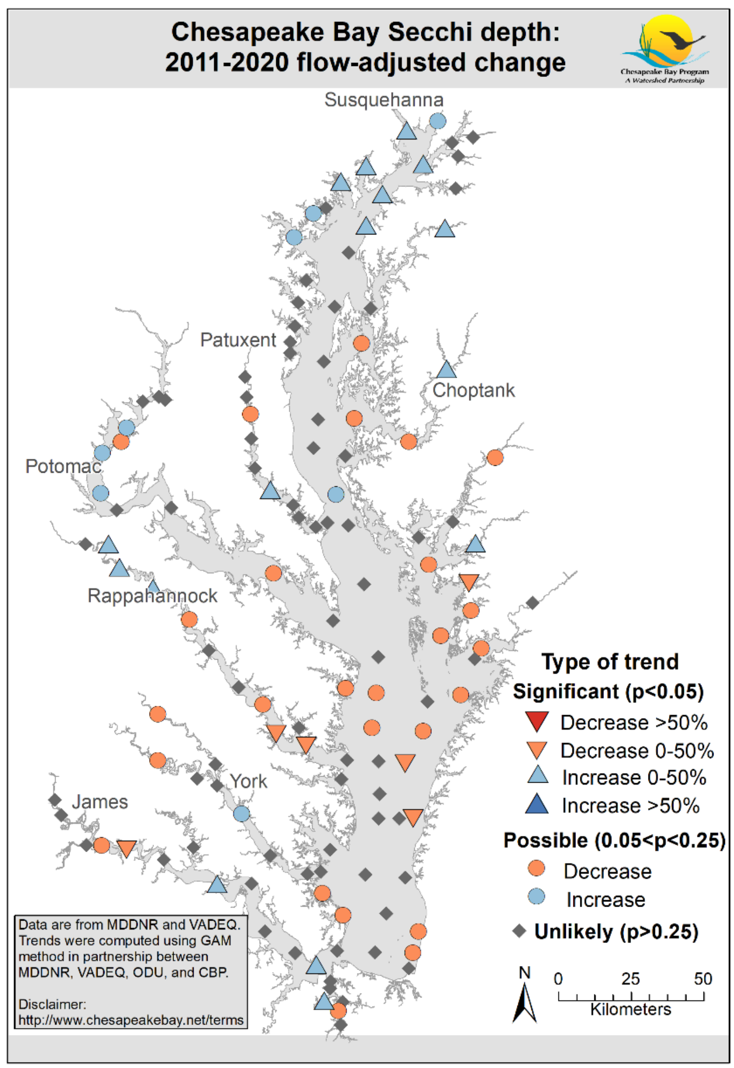


Figure 4 Changes in flow-adjusted annual Secchi depth in the surface layer for long- (left panel) and short-term (right panel) periods.

Chlorophyll-*a*

Changes in spring surface chlorophyll-*a* also vary by region. Overall, 24% (32%) of stations show improving conditions, 31% (7%) with degrading conditions, and 45% (61%) with no change in flow-adjusted spring chlorophyll-*a* of the surface layer over the long- (short-) term period.

Over the long term, most degrading chlorophyll patterns occur in the mid and upper portions of the bay and associated tributaries. Short-term trends are predominately stable or improving.

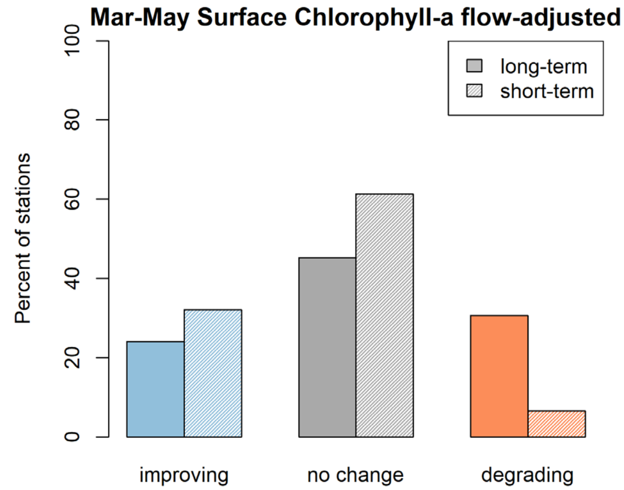


Figure 5 Percent of stations with improving, degrading, and no change in flow-adjusted spring chlorophyll-a in the surface layer for long- and short-term periods.

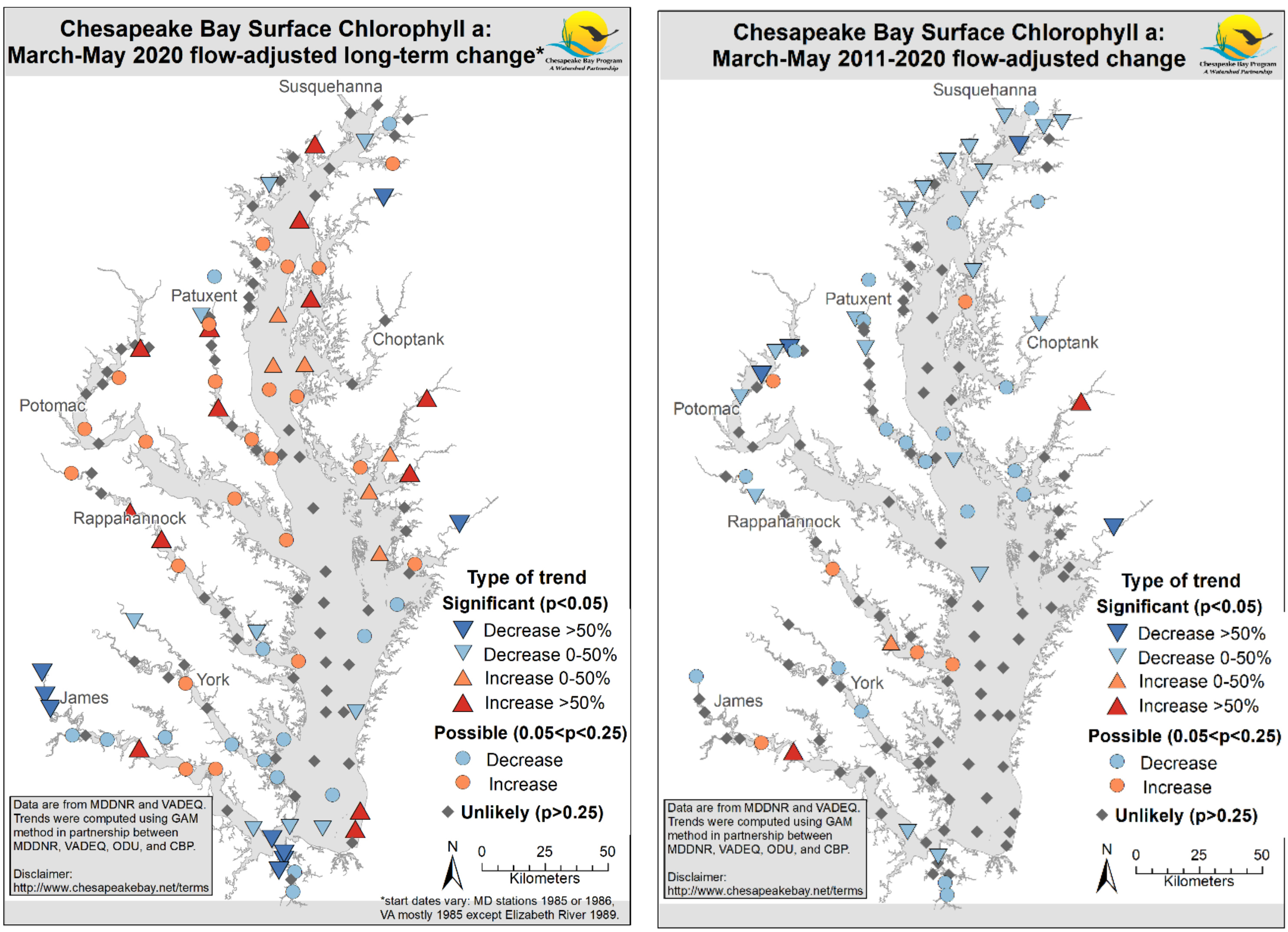


Figure 6 Changes in flow-adjusted spring chlorophyll-a in the surface layer for long- (left panel) and short-term (right panel) periods.

Total Nitrogen

Overall, 85% (49%) of stations show improving conditions, 2% (14%) with degrading conditions, and 12% (37%) with no change in flow-adjusted annual total nitrogen of the surface layer over the long- (short-) term period.

There is a long-term decrease in flow-adjusted total nitrogen of the surface layer throughout the tidal waters of the Chesapeake Bay. Many of these trends persist over the short term as well, although there is an increase in stations with stable conditions and some short-term degrading conditions in the mainstem and Rappahannock.

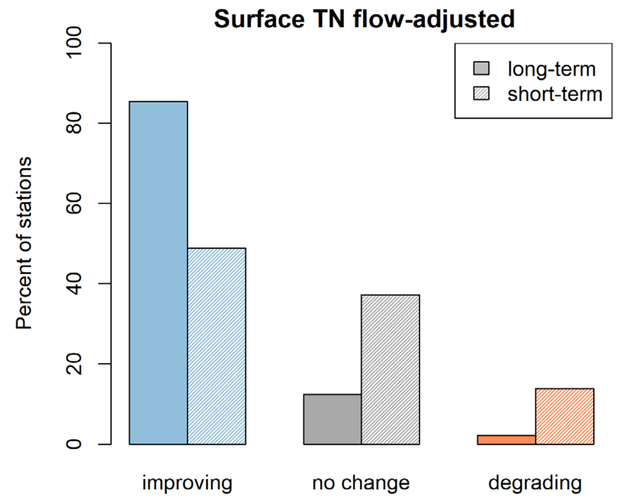
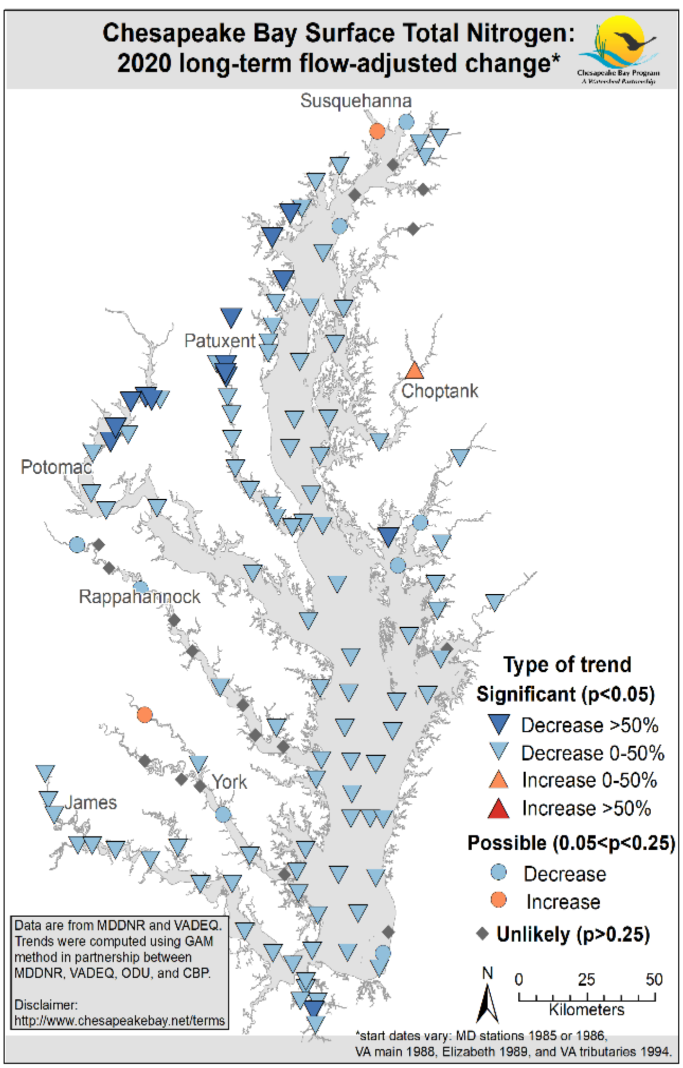


Figure 7 Percent of stations with improving, degrading, and no change in flow-adjusted annual total nitrogen in the surface layer for long- and short-term periods.



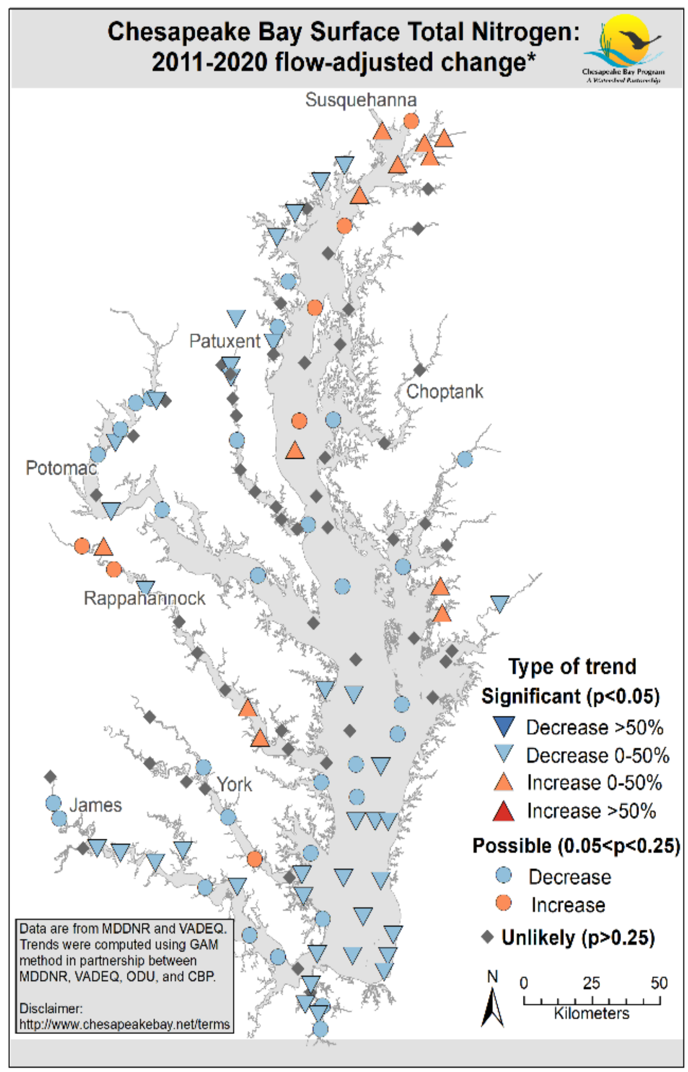


Figure 8 Changes in flow-adjusted annual total nitrogen in the surface layer for long- (left panel) and short-term (right panel) periods.

Total Phosphorus

Overall, 71% (26%) of stations show improving conditions, 7% (14%) with degrading conditions, and 22% (60%) with no change in flow-adjusted annual total phosphorus in the surface layer over the long- (short-) term period.

Long-term flow adjusted annual total phosphorus in the surface layer is improving at most stations with exceptions of several stations in the York and Rappahannock. Short-term degradations occurred in several new areas including several lower eastern shore stations and Patuxent stations

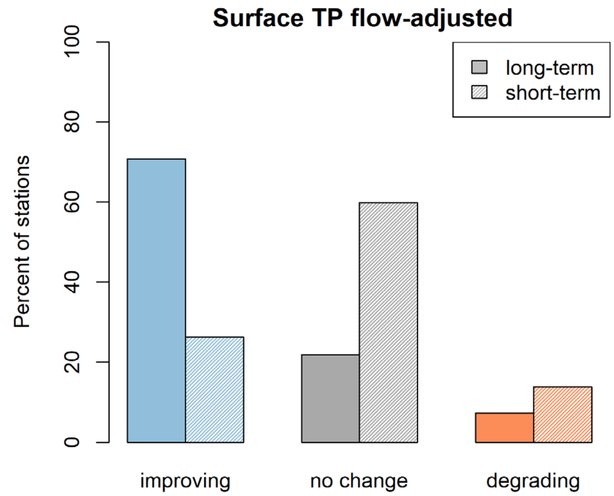
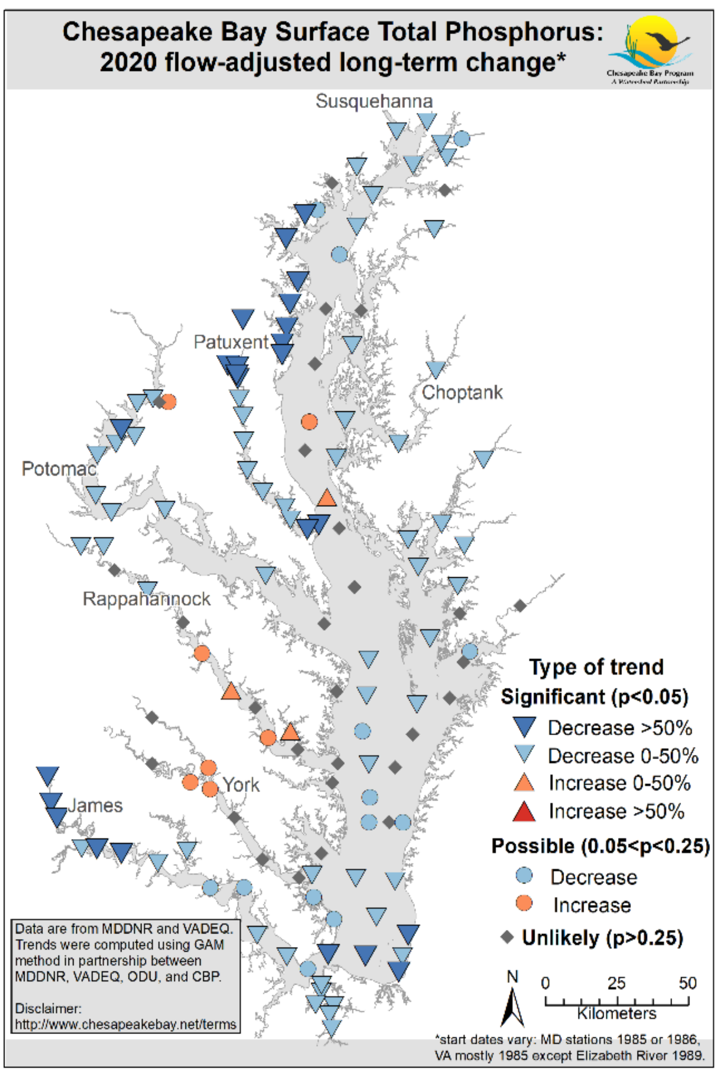


Figure 9 Percent of stations with improving, degrading, and no change in flow-adjusted annual total phosphorus in the surface layer for long- and short-term periods.



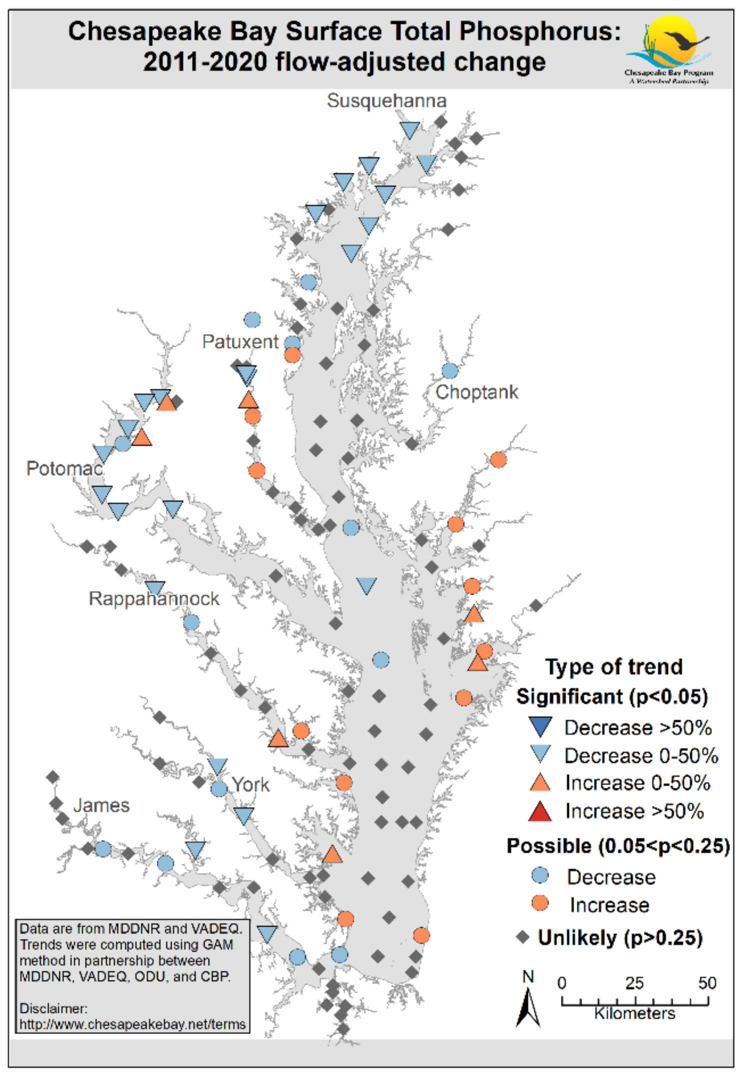


Figure 10 Changes in flow-adjusted annual total phosphorus in the surface layer for long- (left panel) and short-term (right panel) periods.

References

Moyer, D. and J. Blomquist. 2020. https://doi.org/10.5066/P9VG459V.

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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.