Tidal Water Quality Change: 2021 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. 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) (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 2021 are summarized in Table 1.

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 in recent years. Freshwater flow variability does impact these trends, but annual mean freshwater flows in 2020 and 2021 were close to average when compared to annual flows since 1937 (USGS, 2022).

	Observed Conditions			Flow-adjusted Conditions		
Water Quality Variable	**Improving**	**No Change**	**Degrading**	**Improving**	**No Change**	**Degrading**
Short-term Trend (2012-13 to 2020-21)						
Dissolved Oxygen (summer, bottom layer)	9%	69%	22%	5%	66%	29%
Secchi Depth (annual)	20%	65%	15%	25%	62%	13%
Chlorophyll *a* (spring, surface layer)	46%	48%	6%	44%	46%	10%
Total Nitrogen (annual, surface layer)	41%	48%	11%	51%	39%	10%
Total Phosphorus (annual, surface layer)	29%	54%	17%	29%	54%	17%
Long-term Trend (Period of Record)						
Dissolved Oxygen (summer, bottom layer)	24%	46%	30%	18%	50%	33%
Secchi Depth (annual)	16%	26%	58%	20%	27%	53%
Chlorophyll *a* (spring, surface layer)	27%	39%	34%	36%	43%	22%
Total Nitrogen (annual, surface layer)	82%	14%	4%	87%	10%	3%
Total Phosphorus (annual, surface layer)	79%	9%	12%	78%	14%	8%

Table 1. *The percent of stations improving, degrading, and showing no change using data collected through 2021 for nutrients, dissolved oxygen, chlorophyll-a, and Secchi depth †*

† 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 bottom DO is likely due to varying bottom conditions (i.e., varying depths and mixing) throughout the tidal waters. Overall, observed summer bottom DO over the long- (short-) term period show 24% (9%) of stations with improving conditions, 30% (22%) with degrading conditions, and 46% (69%) with no change.

More degrading DO conditions occur in the tributaries, while some notable long-term improvements are occurring in the deeper lower mainstem waters.

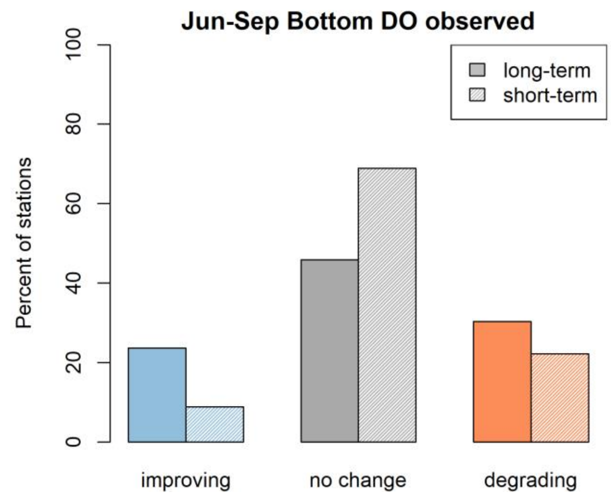

***Figure 1**. Percent of stations with improving, degrading, and no change for dissolved oxygen in the bottom layer during the summer season for long- and short-term periods.*

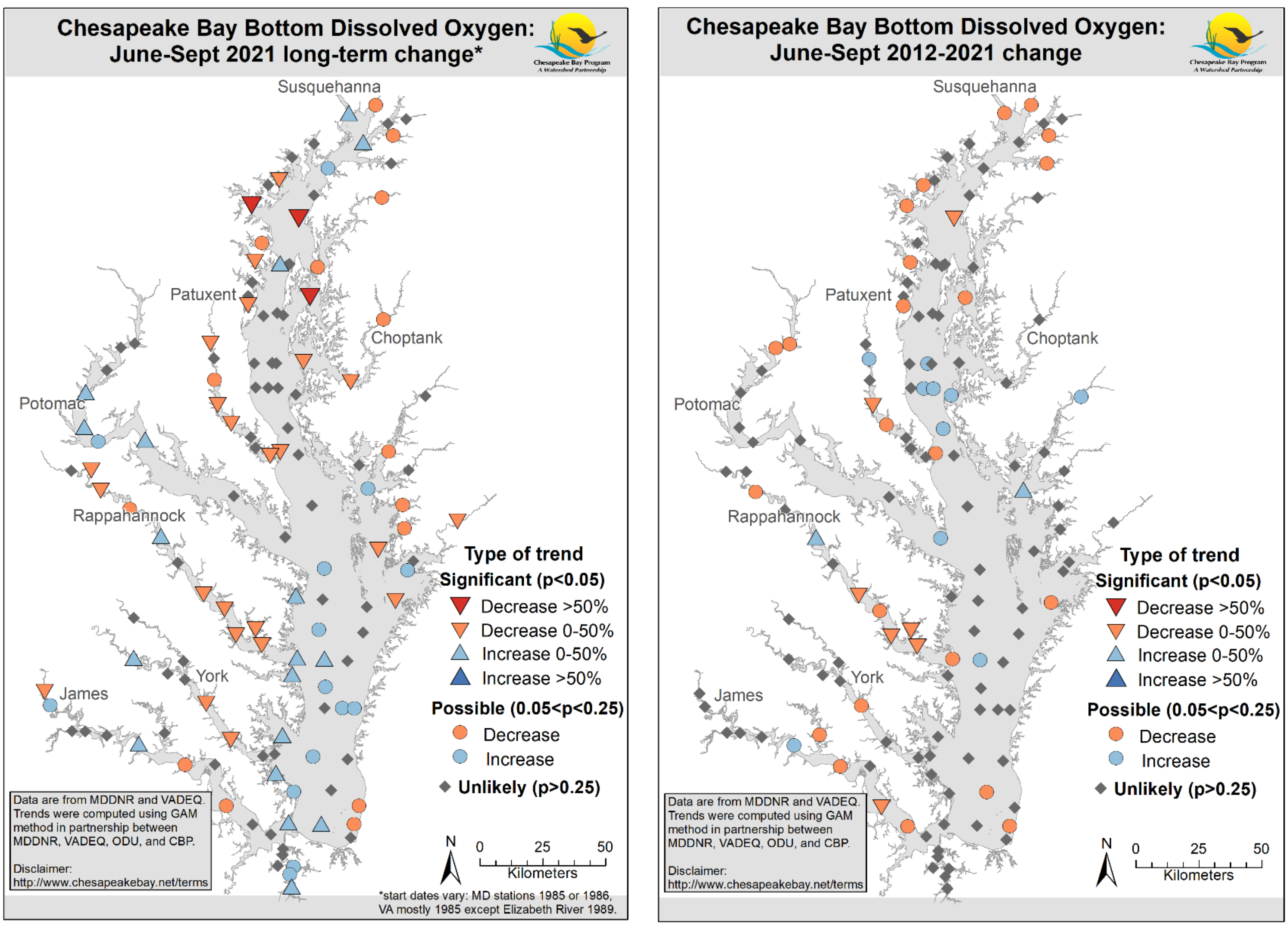

***Figure 2**. Changes in observed dissolved oxygen in the bottom layer during the summer season for long- (left panel) and short-term (right panel) periods.*

Secchi Depth

Trends in flow-adjusted annual Secchi depth have changed over time. Overall, 20% (25%) of stations show improving conditions, 53% (13%) show degrading conditions, and 27% (62%) have no change in flow-adjusted Secchi depth over the long- (short-) term period.

Secchi trends at tidal Washington D.C. stations are included for the first time 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 at the majority of stations. Fewer degrading trends persist over the short-term period.

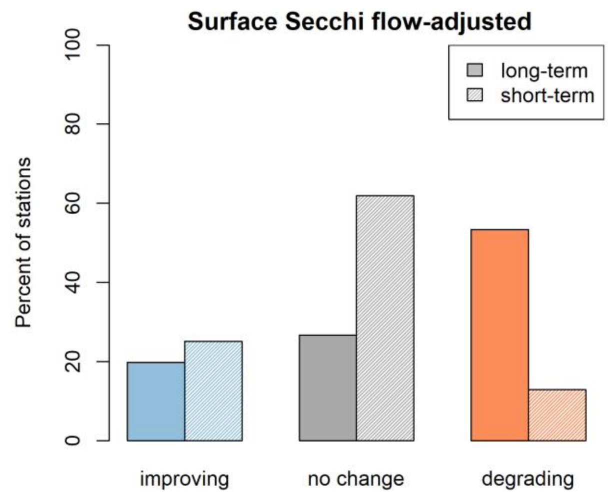

Figure 3. *Percent of stations with improving, degrading, and no change for flow-adjusted annual Secchi depth for long- and short-term periods.*

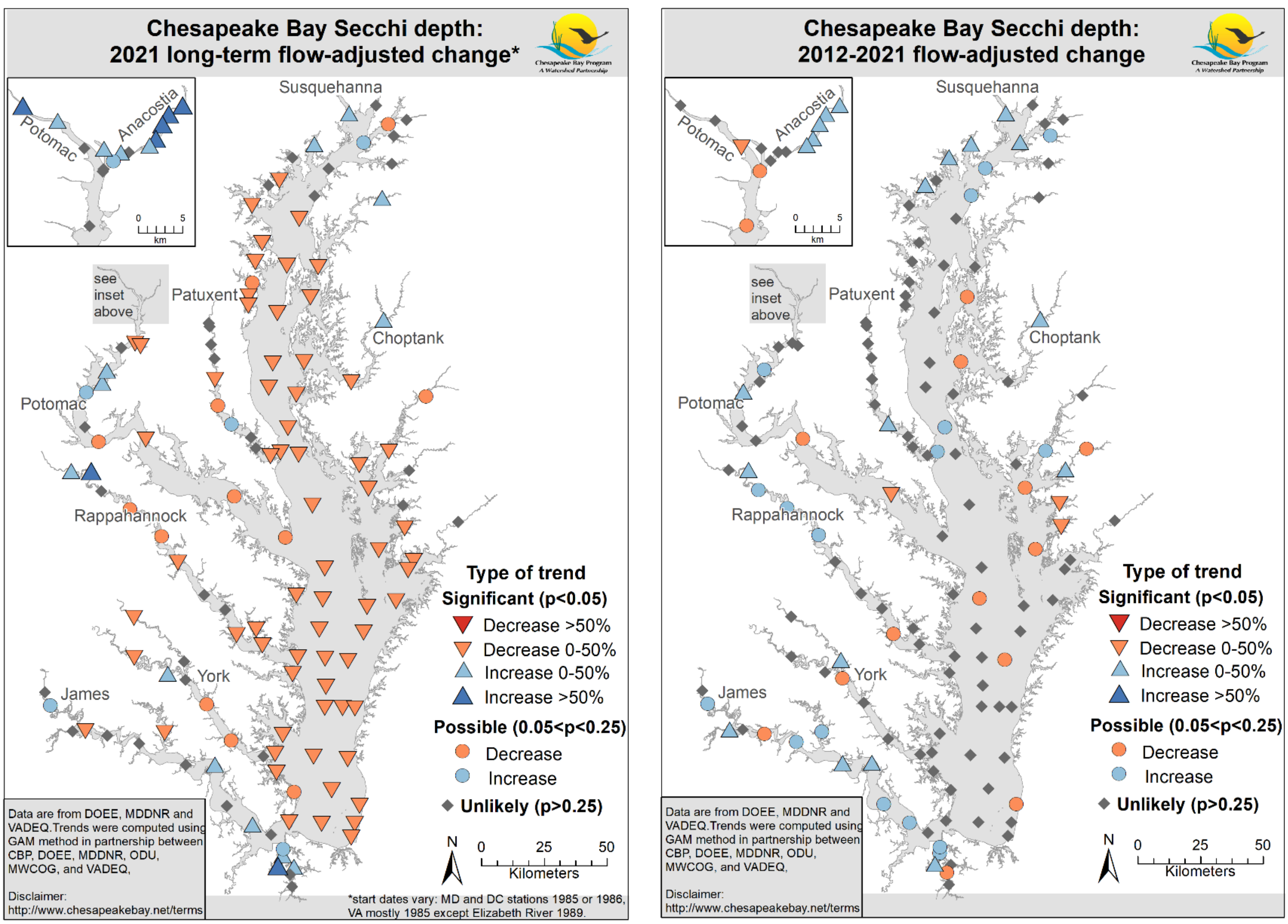

Figure 4. Changes in flow-adjusted annual Secchi depth for long- (left panel) and short-term (right panel) periods.

Chlorophyll *a*

Changes in spring surface chlorophyll *a* vary by region. Overall, 36% (44%) of stations show improving conditions, 22% (10%) have degrading conditions, and 43% (46%) have 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-to upper-portions of the bay and associated tributaries. Short-term trends are predominately stable or improving, except for several tributaries.

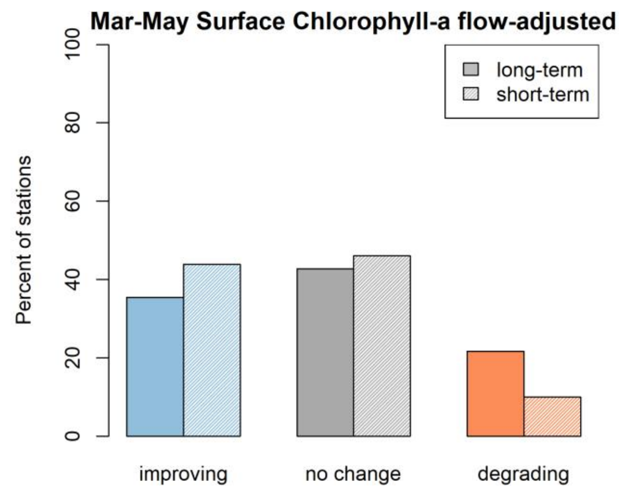

Figure 5. *Percent of stations with improving, degrading, and no change in flow-adjusted spring chlorophyll a in the surface layer for long- and short-term periods.*

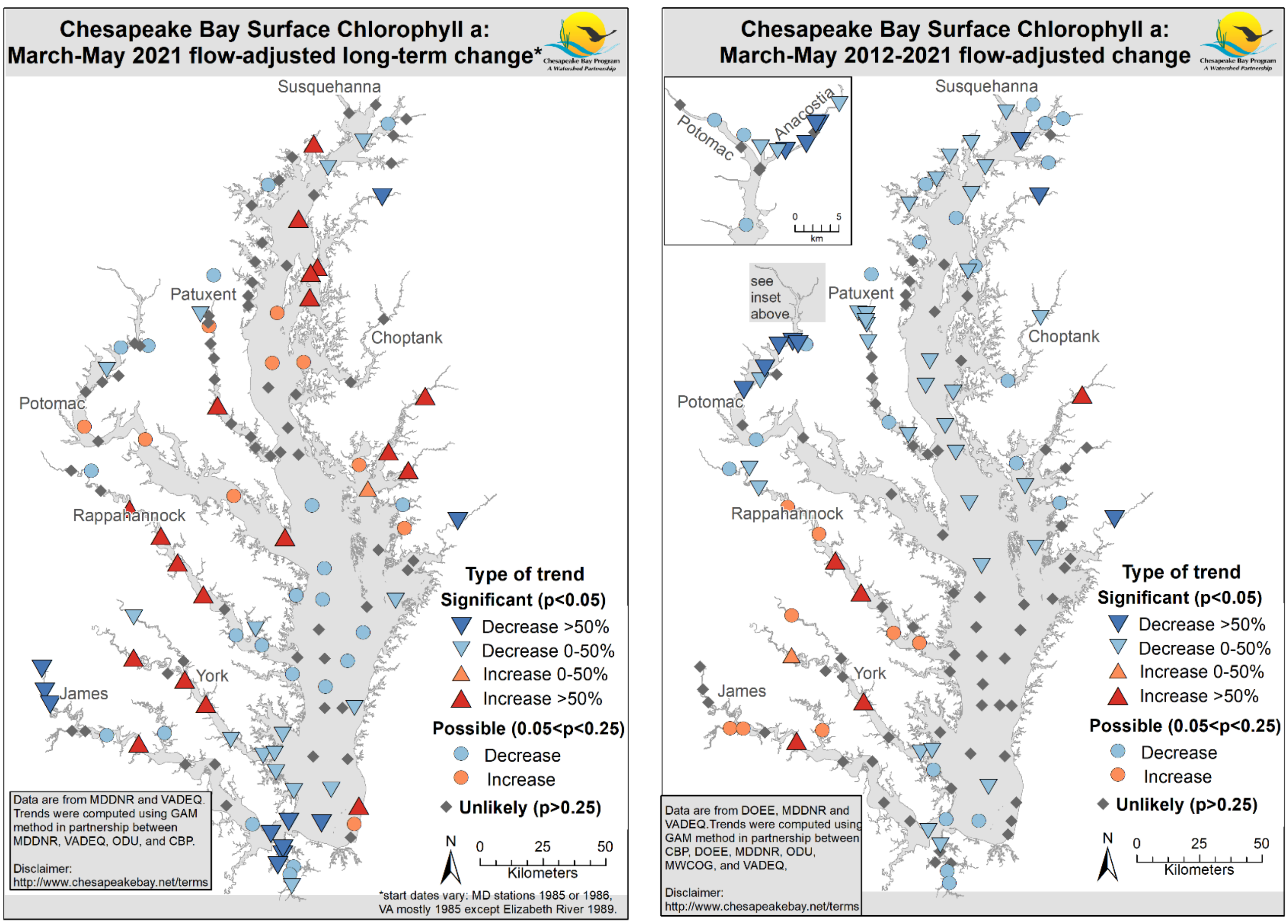

Figure 6. *Changes in flow-adjusted spring chlorophyll a in the surface layer for long- (left panel) and short-term (right panel) periods.*

Total Nitrogen

Both total nutrients have improved bay-wide over the long-term. For surface total nitrogen, 87% (51%) of stations show improving conditions, 3% (10%) have degrading conditions, and 10% (39%) have no change in flow-adjusted concentrations over the long- (short-) term period.

There is a clear pattern of long-term decreasing flow-adjusted total nitrogen throughout 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.

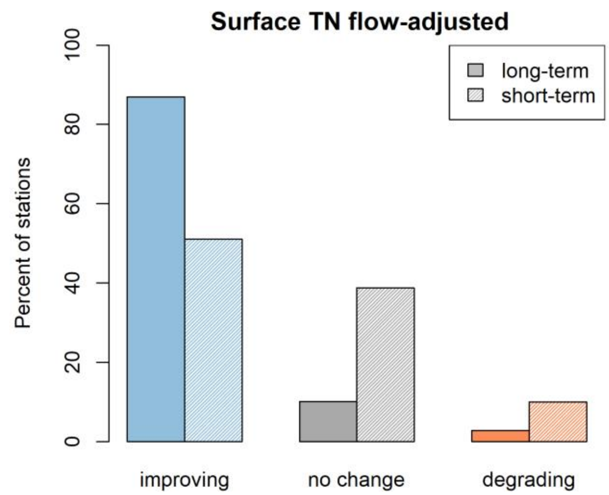

Figure 7. *Percent of stations with improving, degrading, and no change in flow-adjusted annual total nitrogen in the surface layer for long- and short-term periods.*

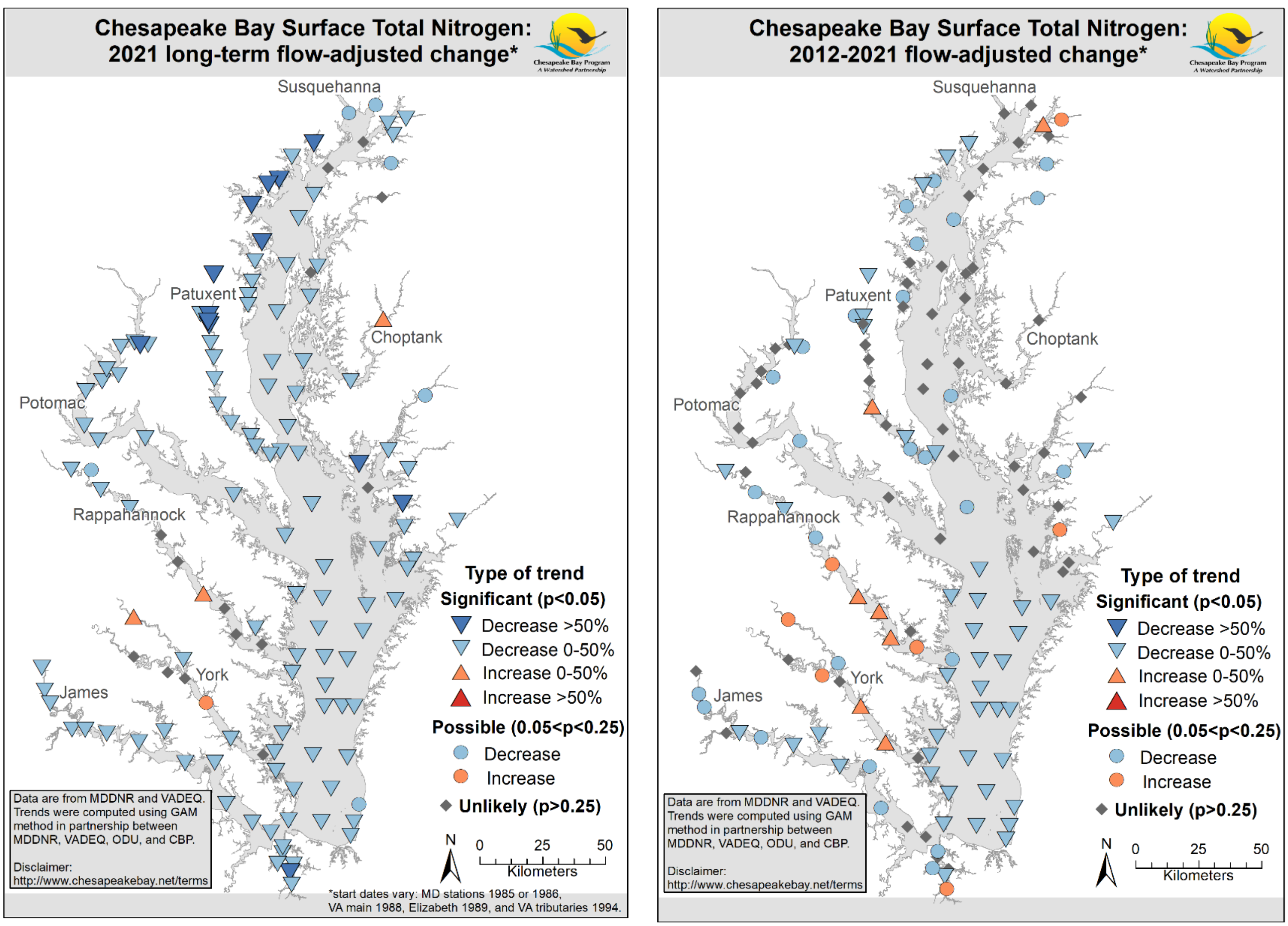

Figure 8. *Changes in flow-adjusted annual total nitrogen in the surface layer for long- (left panel) and short-term (right panel) periods.*

Total Phosphorus

For surface total phosphorus, 78% (29%) of stations show improving conditions, 8% (17%) have degrading conditions, and 14% (54%) have no change in flow-adjusted concentrations over the long- (short-) term period.

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.

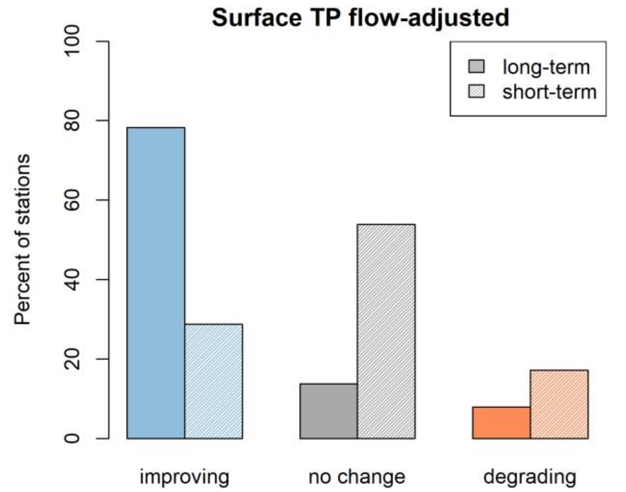

Figure 9. *Percent of stations with improving, degrading, and no change in flow-adjusted annual total phosphorus in the surface layer for long- and short-term periods.*

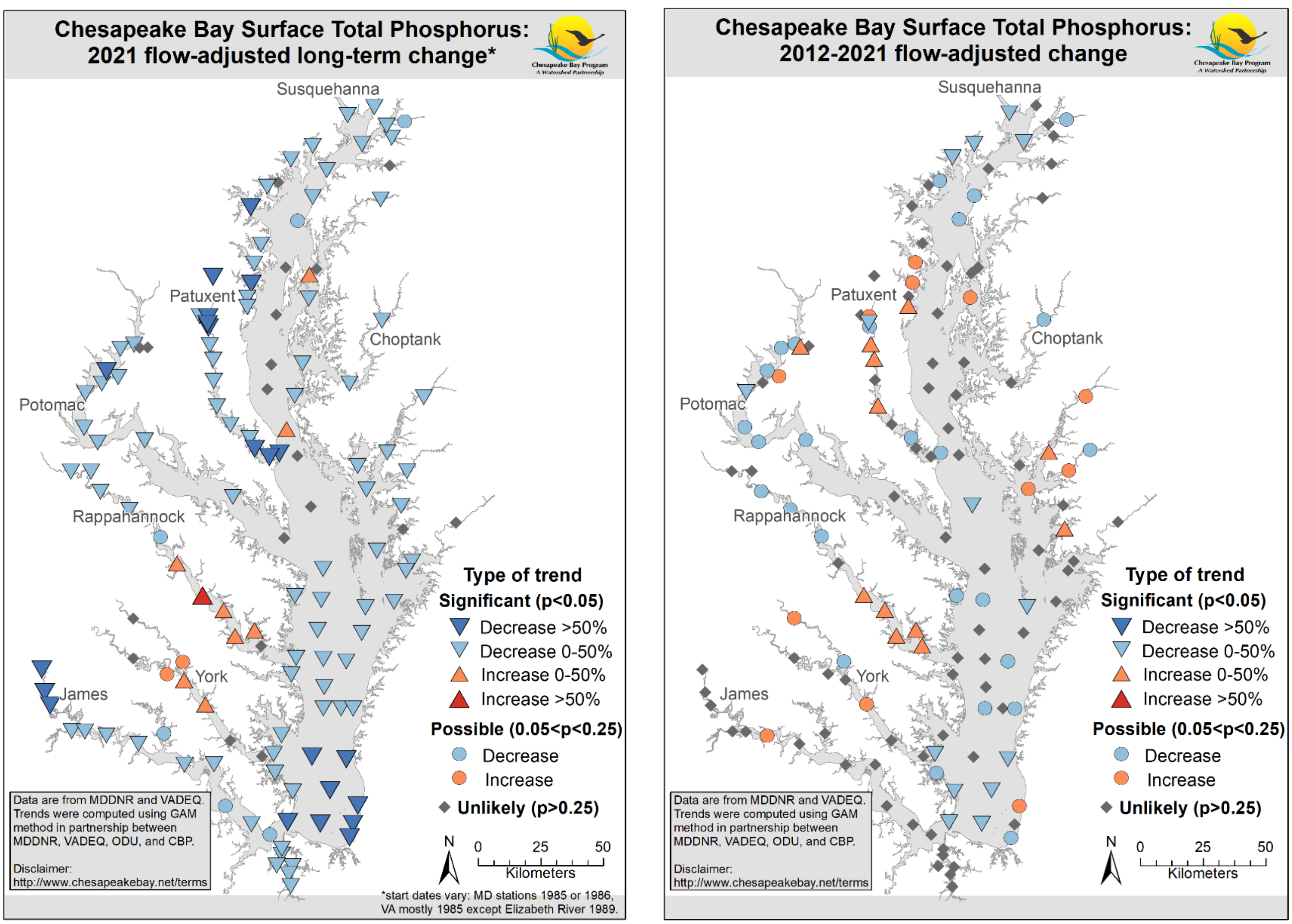

Figure 10. *Changes in flow-adjusted annual total phosphorus in the surface layer for long- (left panel) and short-term (right panel) periods.*

References

USGS. 2022. https://www.usgs.gov/centers/chesapeake-bay-activities/science/freshwater-flow-chesapeake-bay

Murphy, R, E. Perry, J. Keisman, J. Harcum, and E. Leppo. 2021. baytrends: Long Term Water Quality Trend Analysis. R package version 2.0.5. 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.