Nutrient improvements in Chesapeake Bay: Direct effect of load reductions and implications for coastal management

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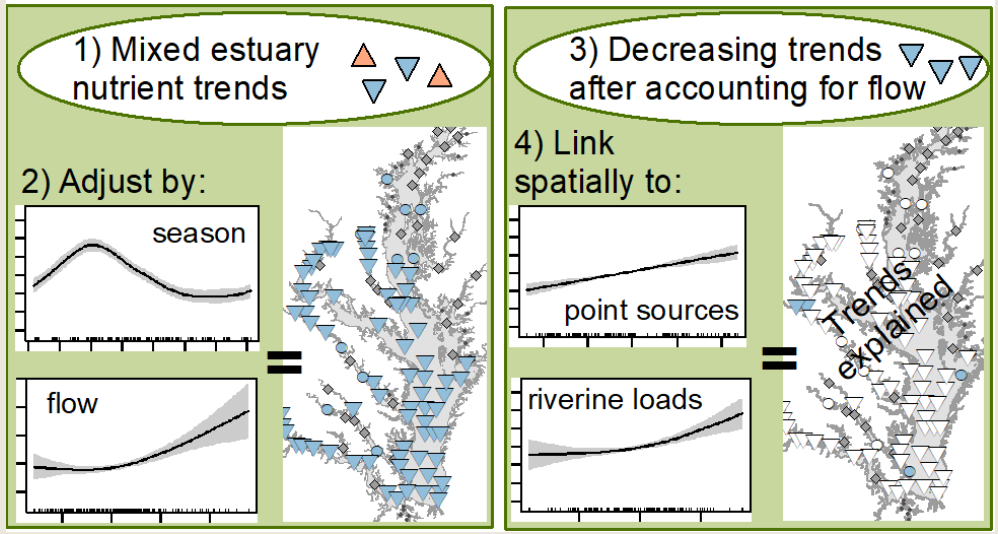

Presentation to WQGIT

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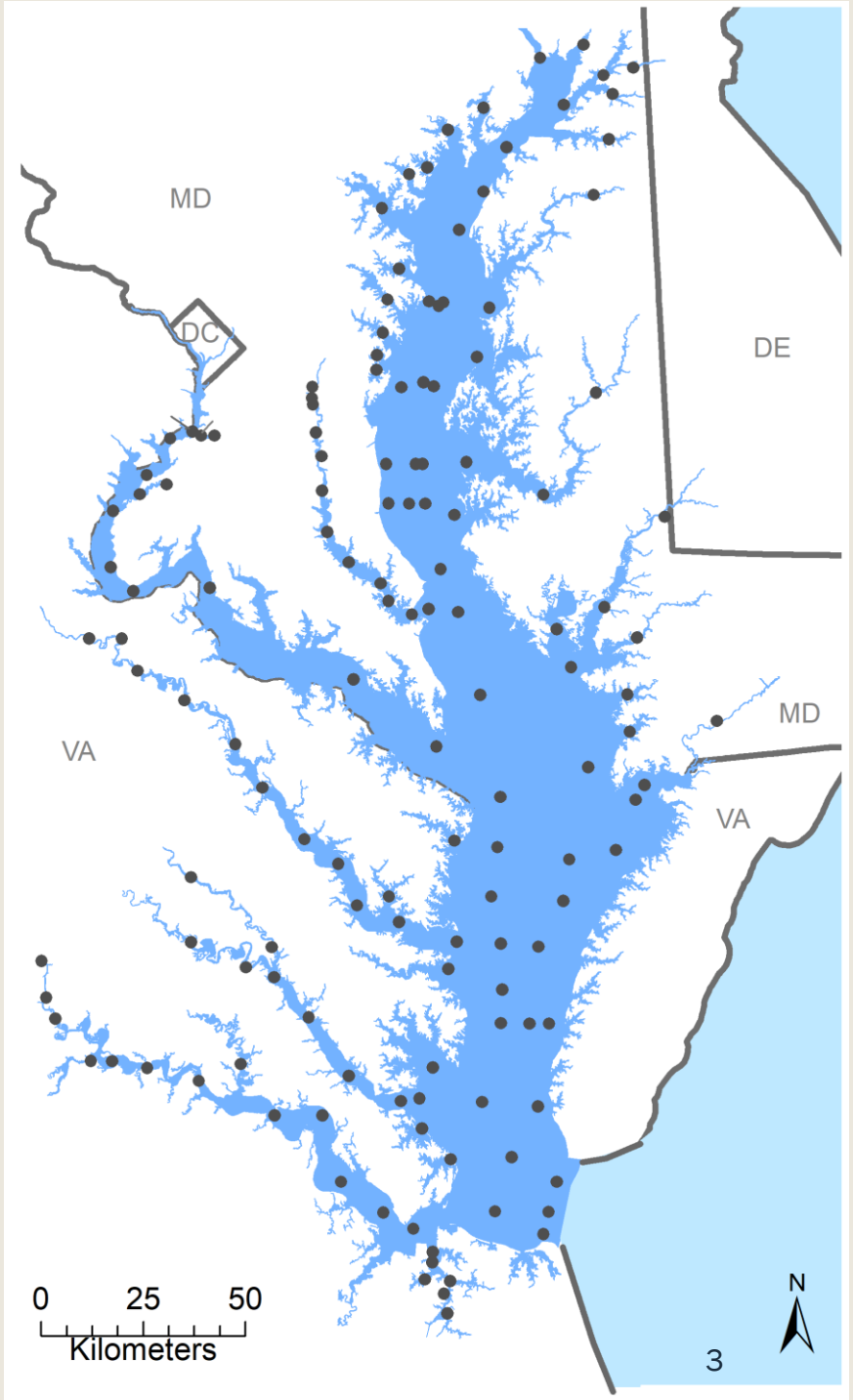
Goals of this study

- **Part 1:** Summarize the observed tidal nutrient changes over time for surface total nitrogen (TN) and total phosphorus (TP)

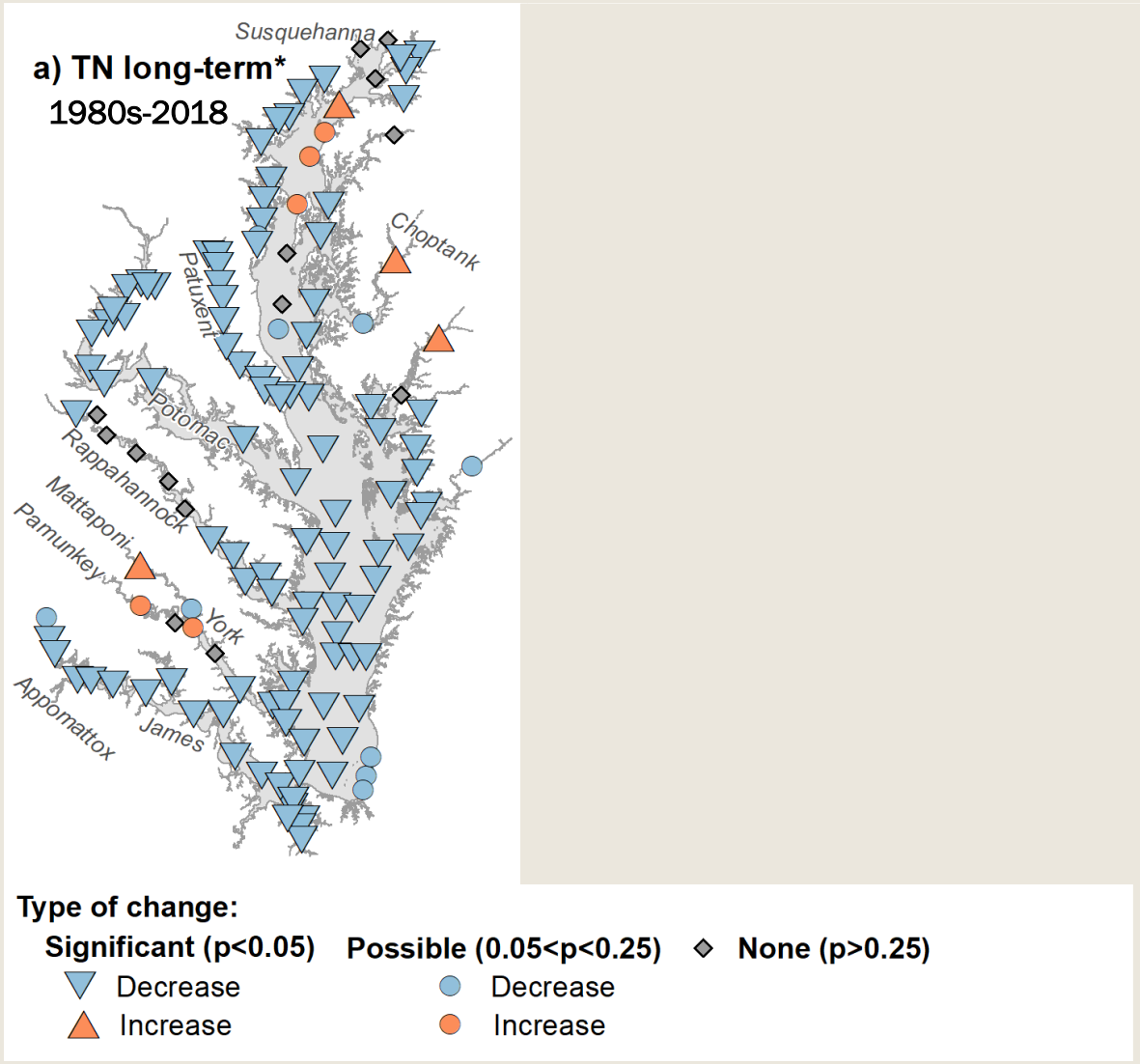
- **Part 2:** Evaluate and document the extent to which we can explain these estuary nutrient patterns with monitored nutrient loads
  - *RIM and some NTN loads of TN and TP ("river loads")*
  - *Below-gage point loads*

Methods: Part 1

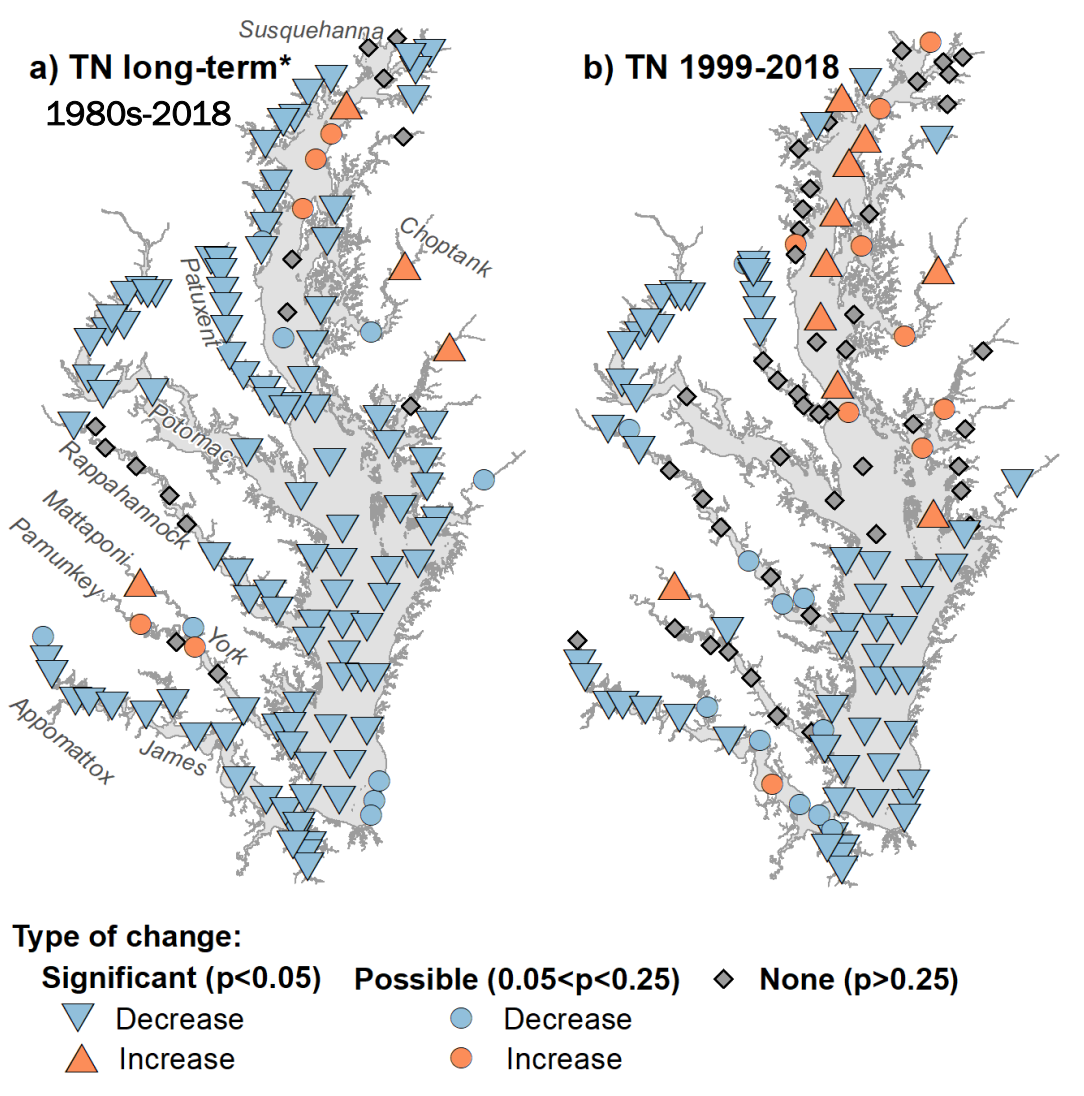
- Stations evaluated = 136 tidal monitoring stations with data from the mid-1980s to present
- Generalized Additive Model (GAM) approach:
  - *Statistical*
  - *Allows for nonlinear patterns over time and season*
  - *Allows for us to test additional factors to explain the changes over time*



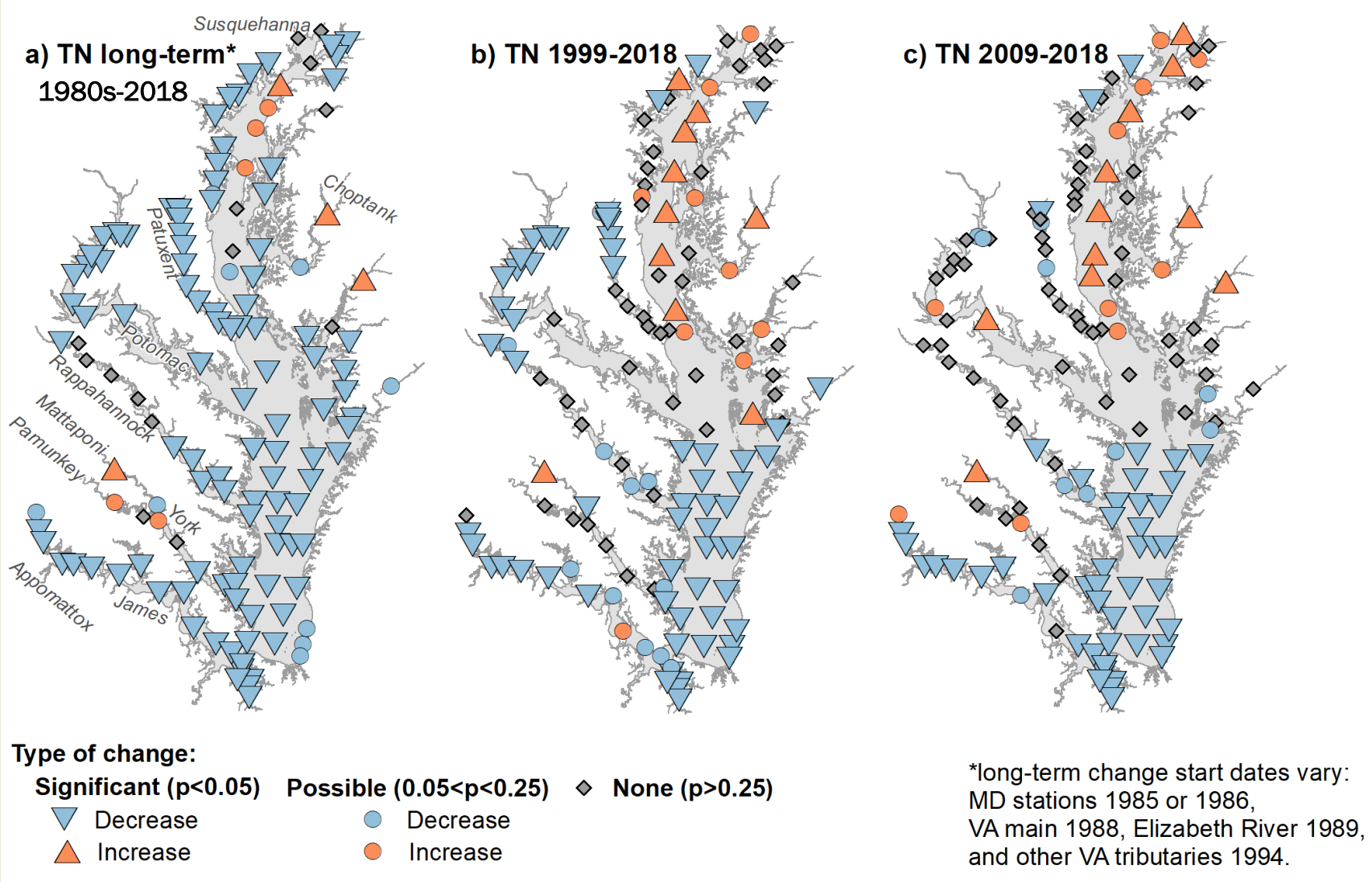
Results Part 1: Observed surface TN change



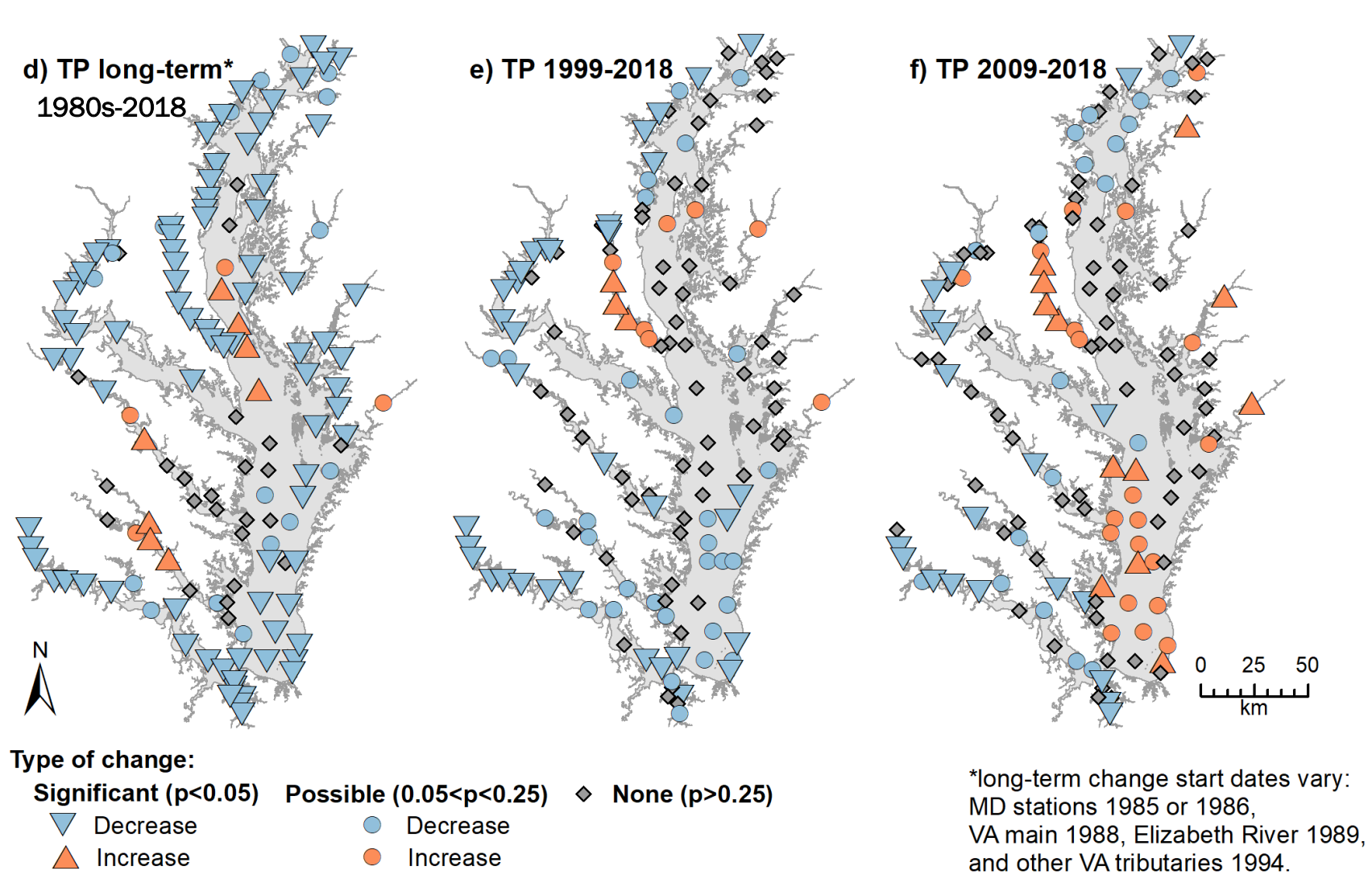
Results Part 1: Observed surface TN change



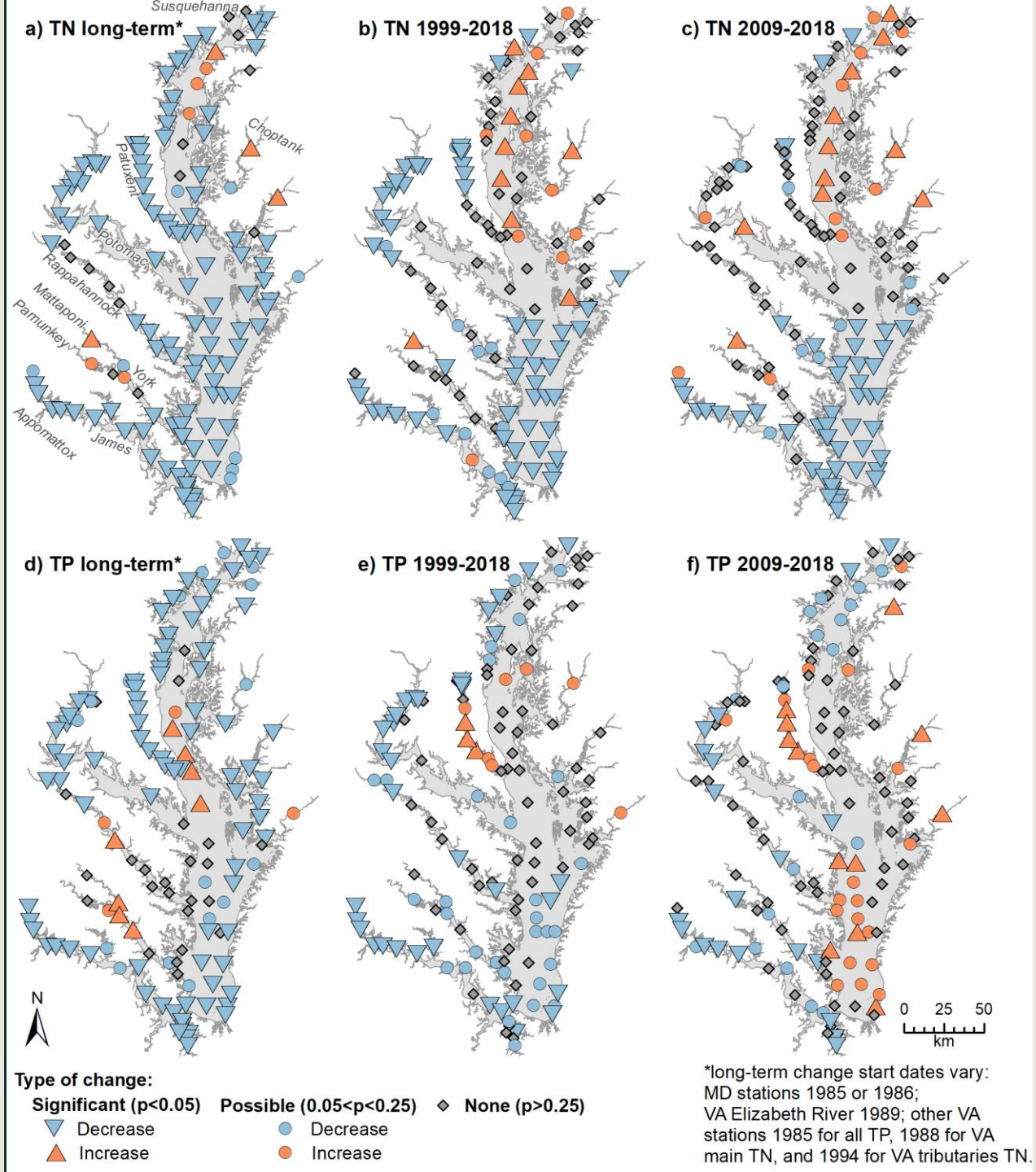
Results Part 1: Observed surface TN change

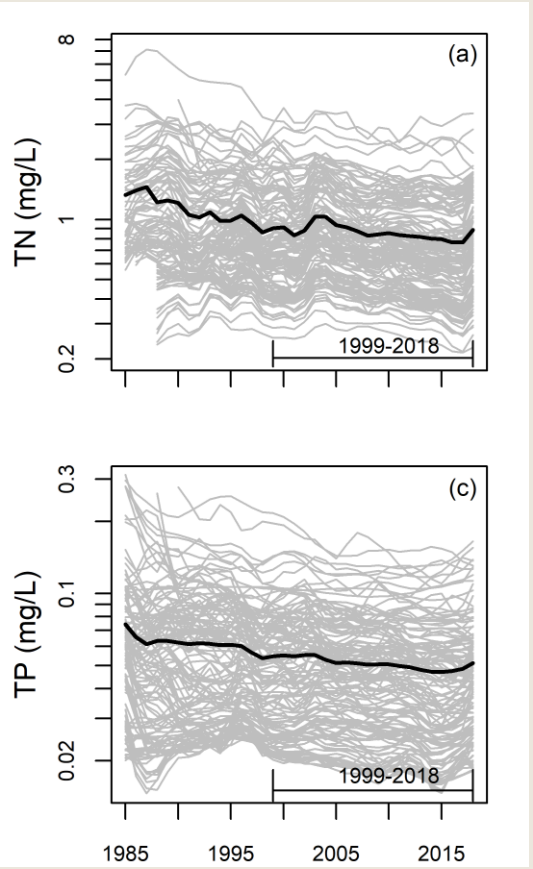


Results Part 1: Observed surface TP change



Results Part 1: Surface TN and TP changes

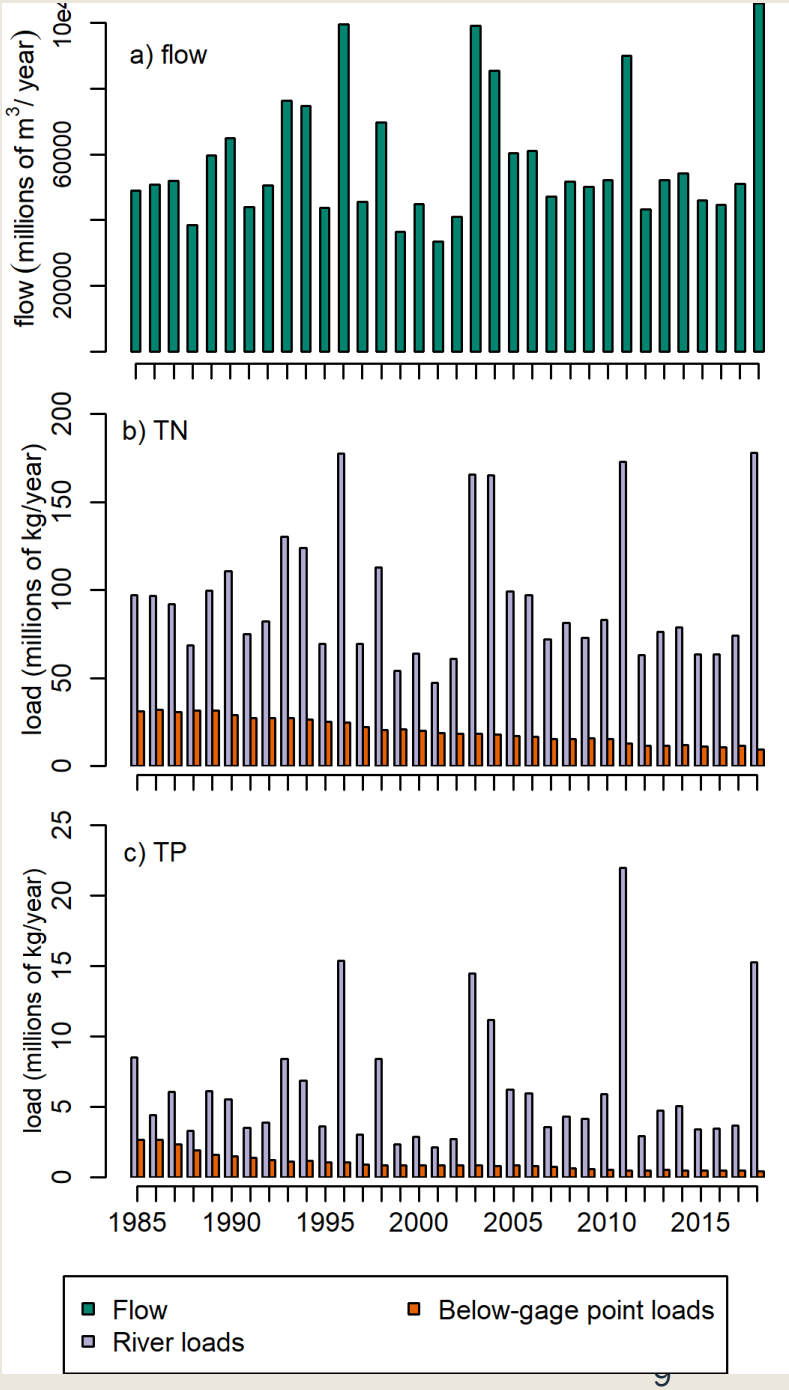




All annual average GAM fits (grey lines) and average bay-wide pattern (black lines)

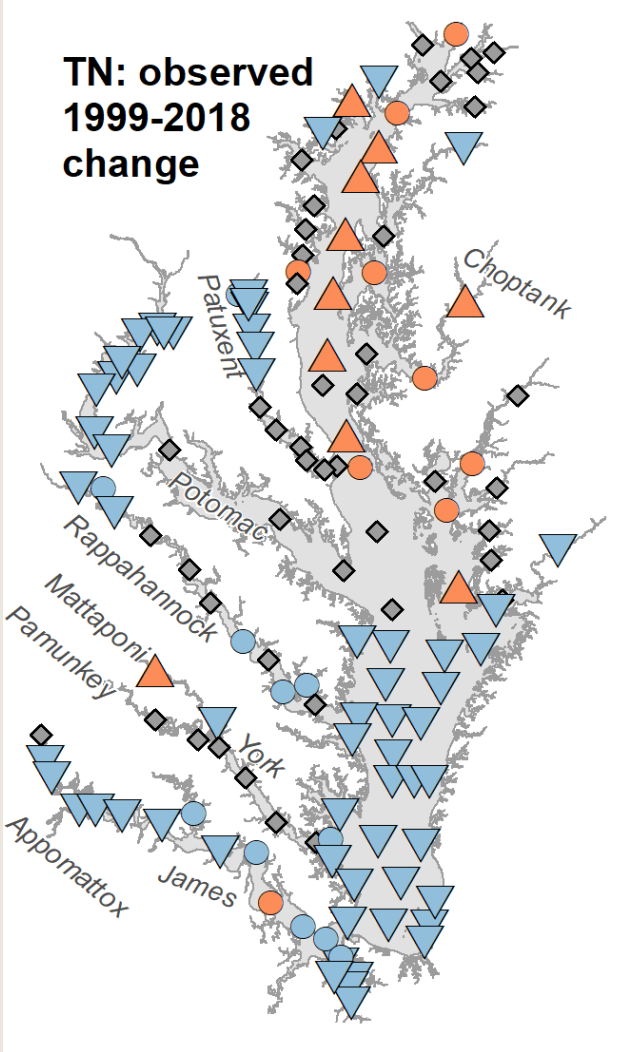
Part 2. Using GAMs to test factors influencing trends

Are variations in freshwater flow and nutrient loads causing the trends over time?

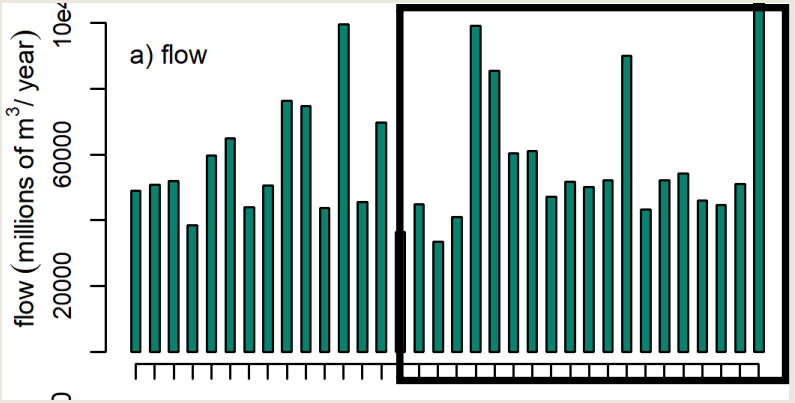


Step 1

Test if freshwater flow explains trends



a. Put flow in the equations



b. Use the results to answer the question:

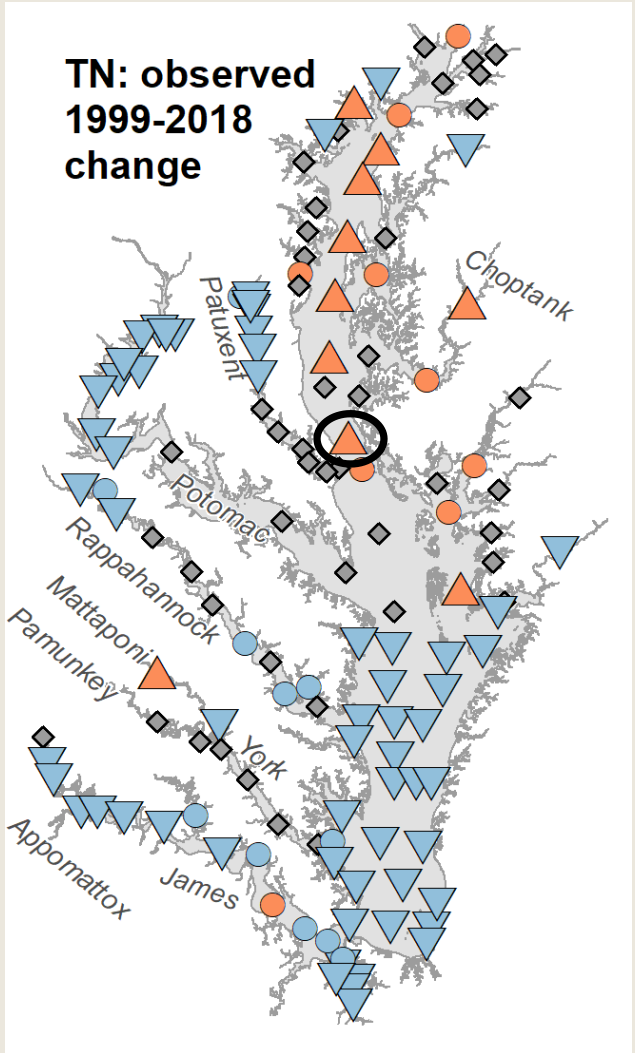
What is the trend after removing the effect of flow?

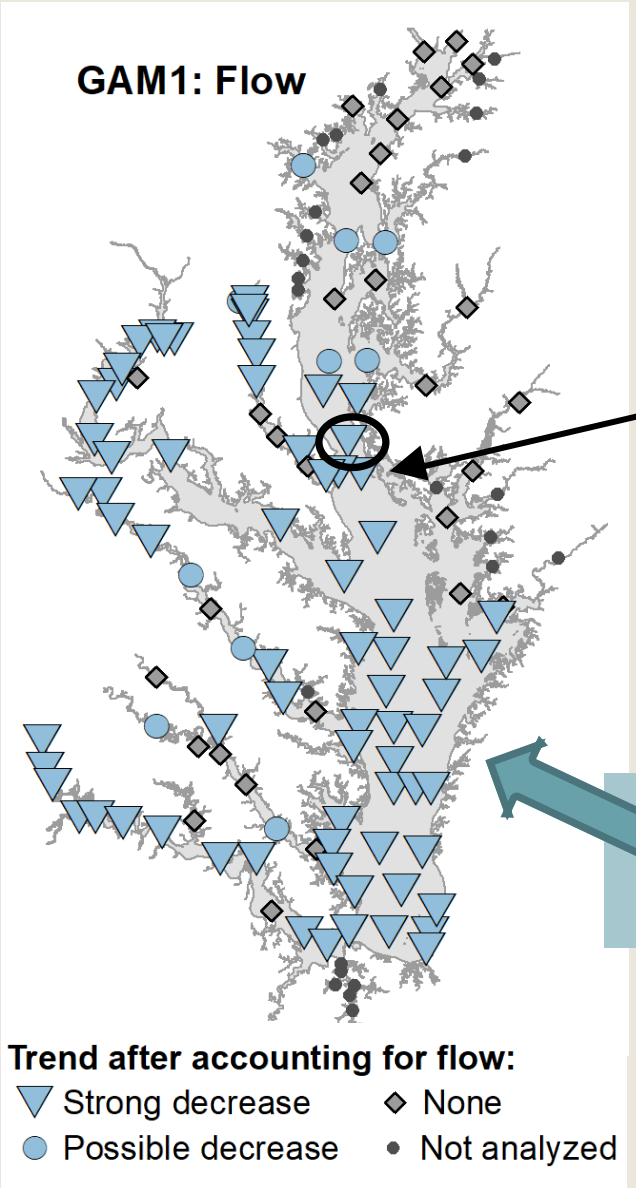
Type of change: **Significant (p<0.05)** **Possible (0.05<p<0.25)**

None (p>0.25) Decrease Increase Decrease Increase

Step 1

TN: Examine flow-adjusted trends



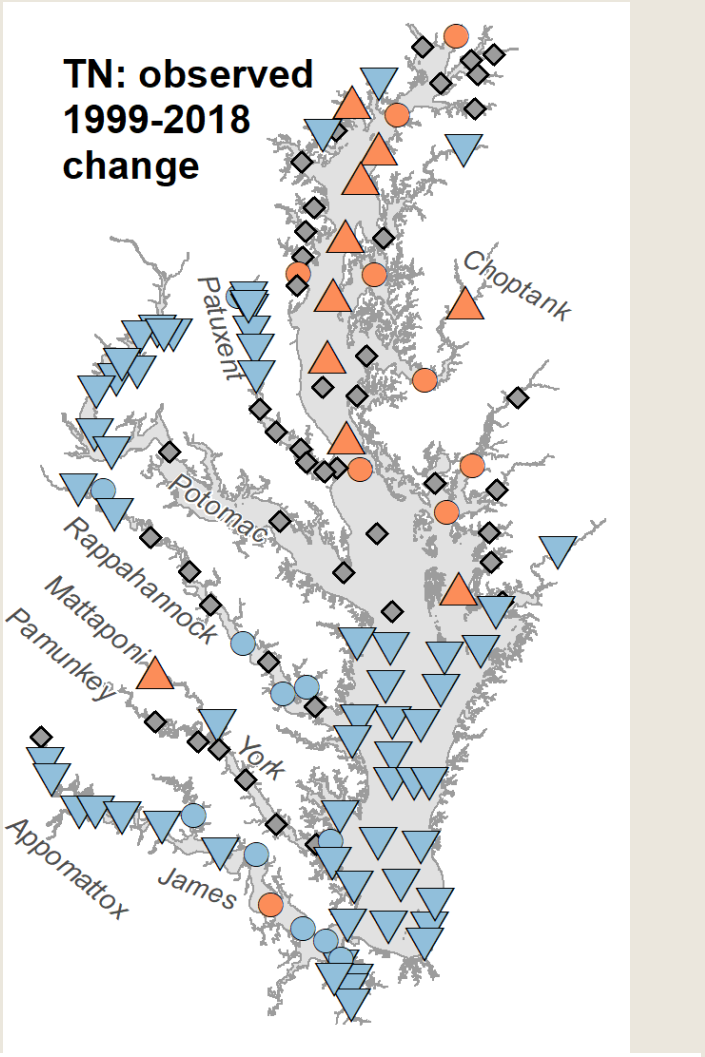


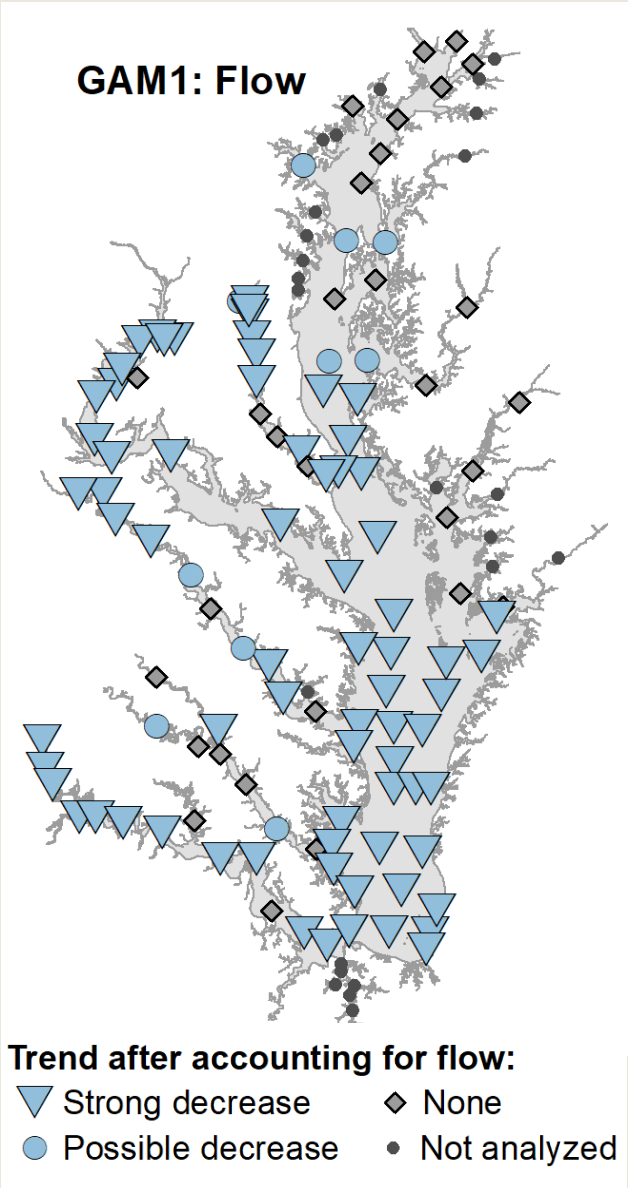
Example mid-bay: *The observed TN was increasing at this station, after accounting for freshwater flow, TN is strongly decreasing.*

What is the trend after removing the effect of flow?

Step 1

TN: Examine flow-adjusted trends

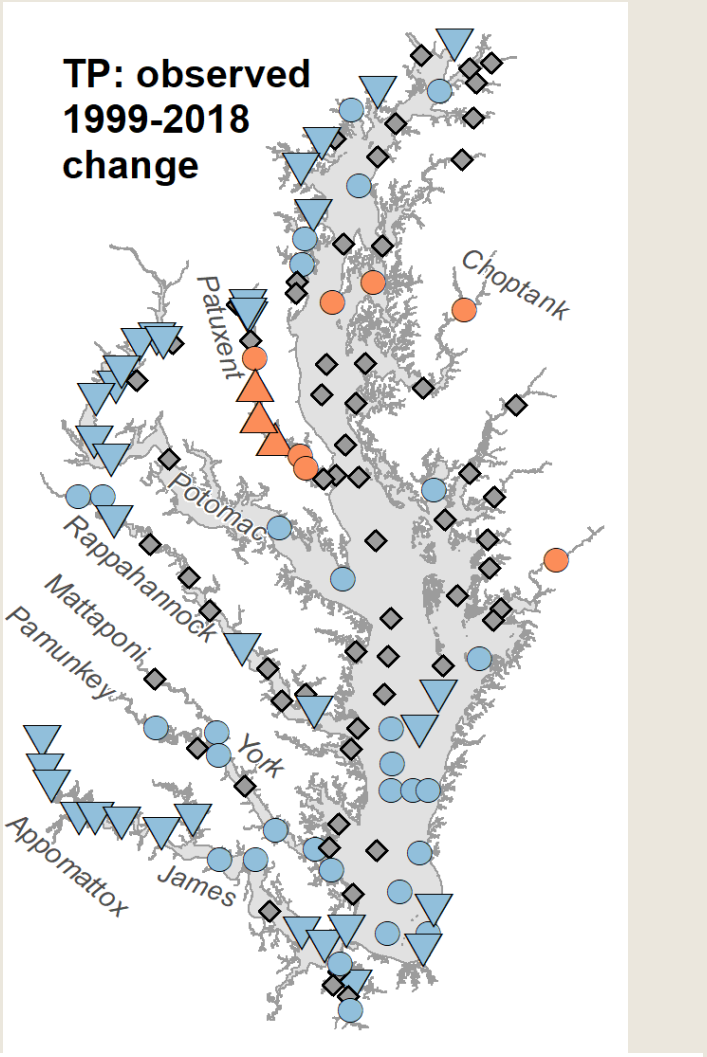


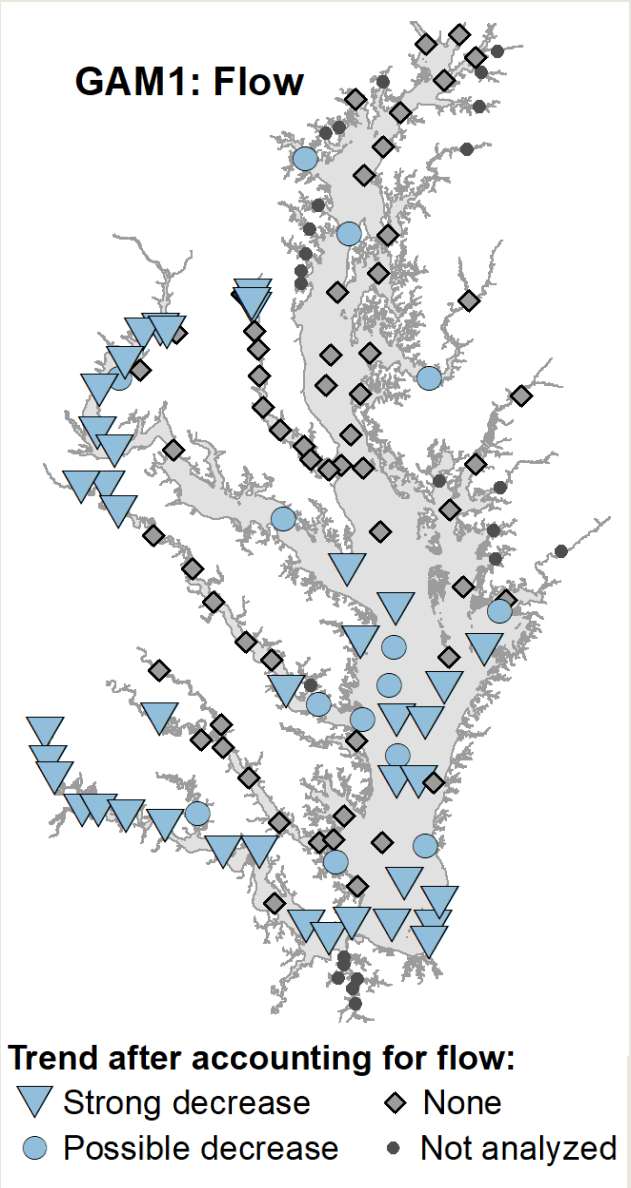


- For TN, the increasing observed trends appear to be mostly explained by freshwater flow fluctuations
- After flow adjustment:
  - *27% of stations have no trend*
  - *73% of stations have improving flow-adjusted TN*

Step 1

TP: Examine flow-adjusted trends





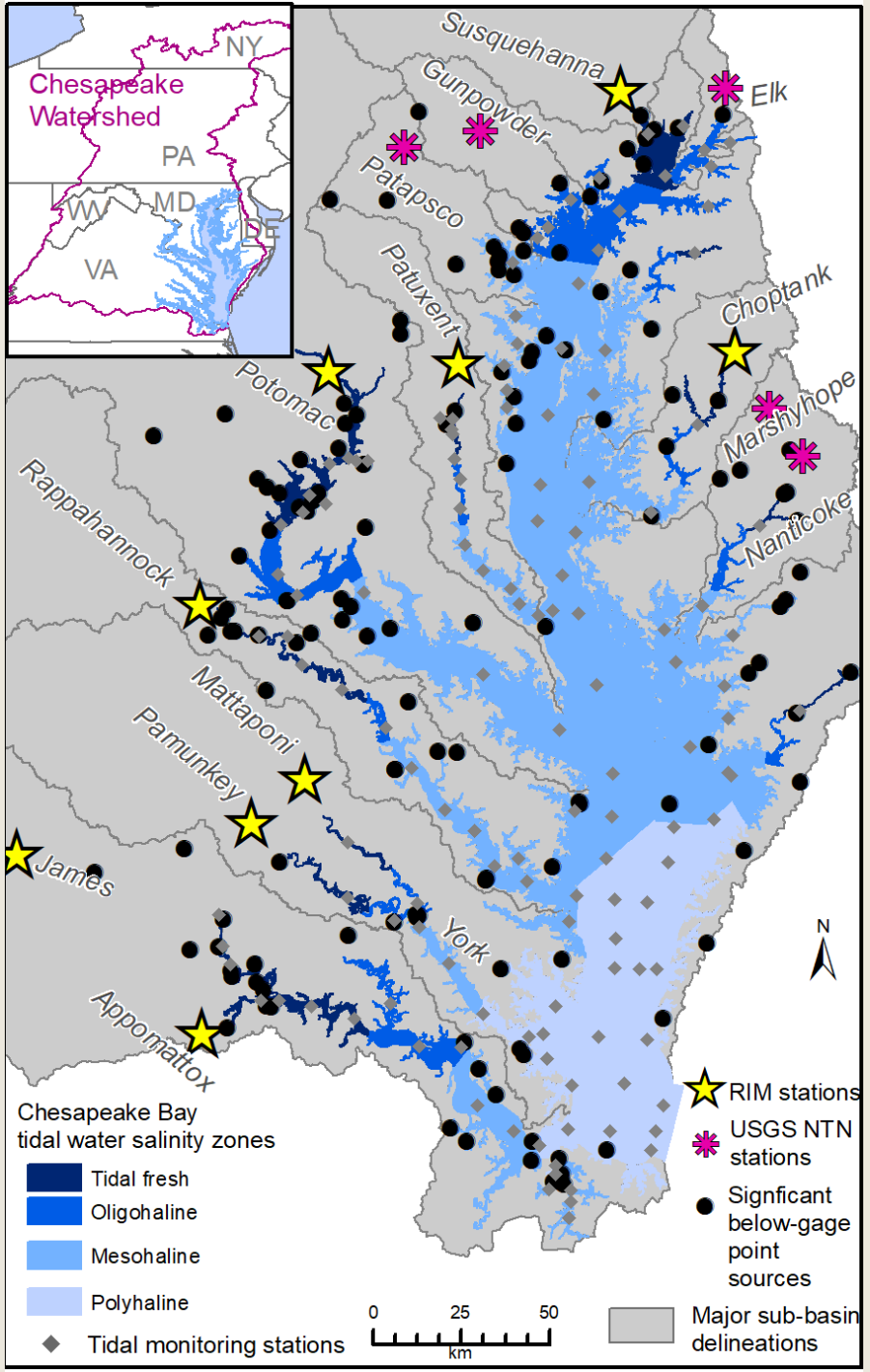
- For TP, similarly, the increasing trends are explained by flow
- After flow adjustment:
  - *51% of stations have no trend*
  - *49% of stations have improving flow-adjusted TP*

Step 2 – Test if nutrient loads from the watershed explain change

Approach:

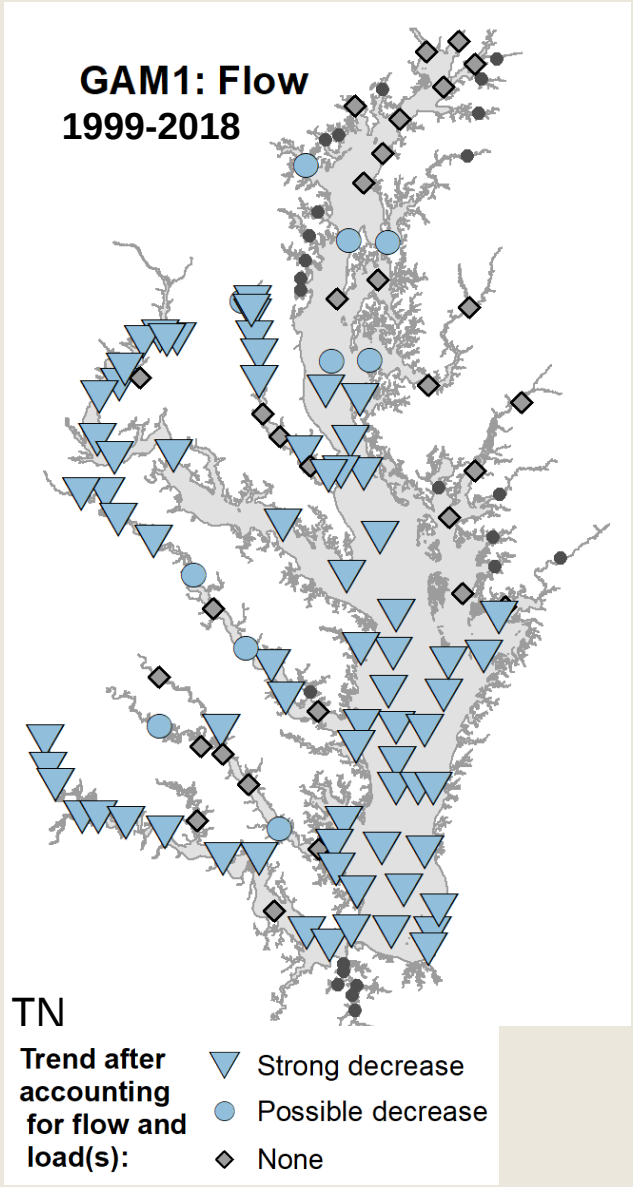
Tidal stations were matched to loads from parts of the watershed that best explained the trends at the stations.

The matching results are documented in the paper.

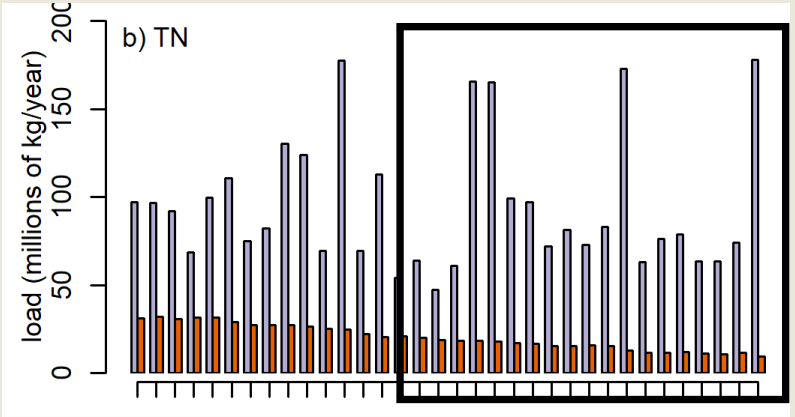


Step 2

TN: Test if loads explain change



a. Put nutrient loads in the equations

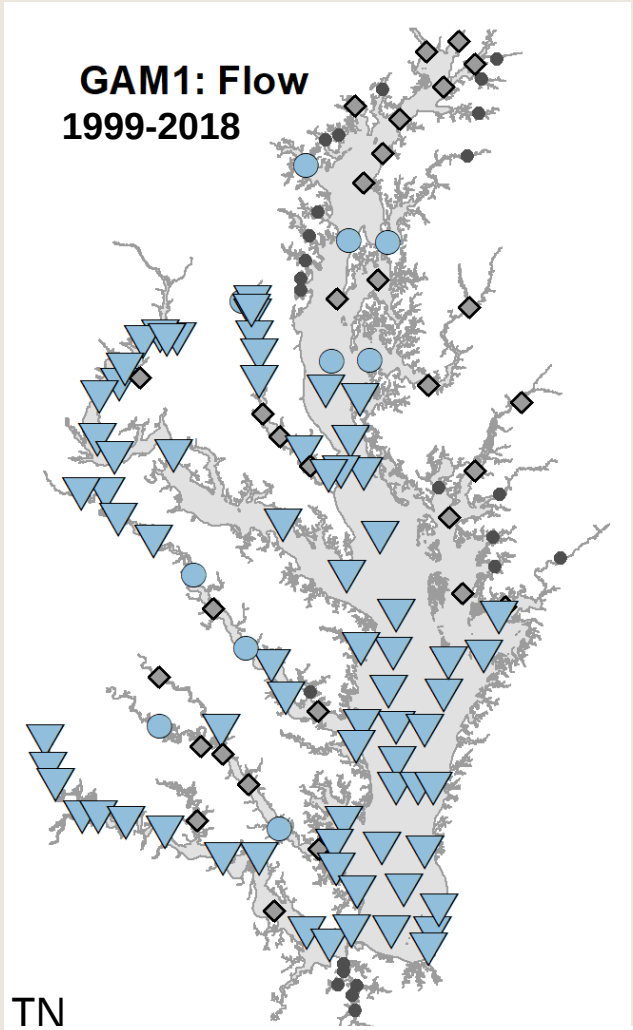


b. Use the results to answer the question:

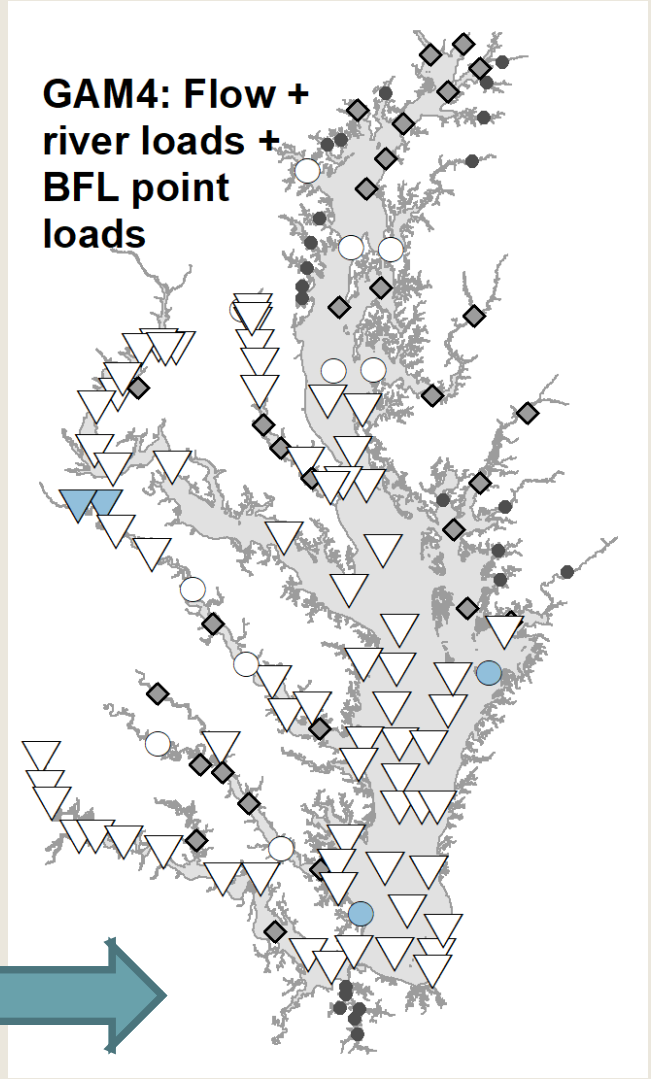
Do the loads and flow together explain the trends?

Step 2

TN: Test if loads explain change

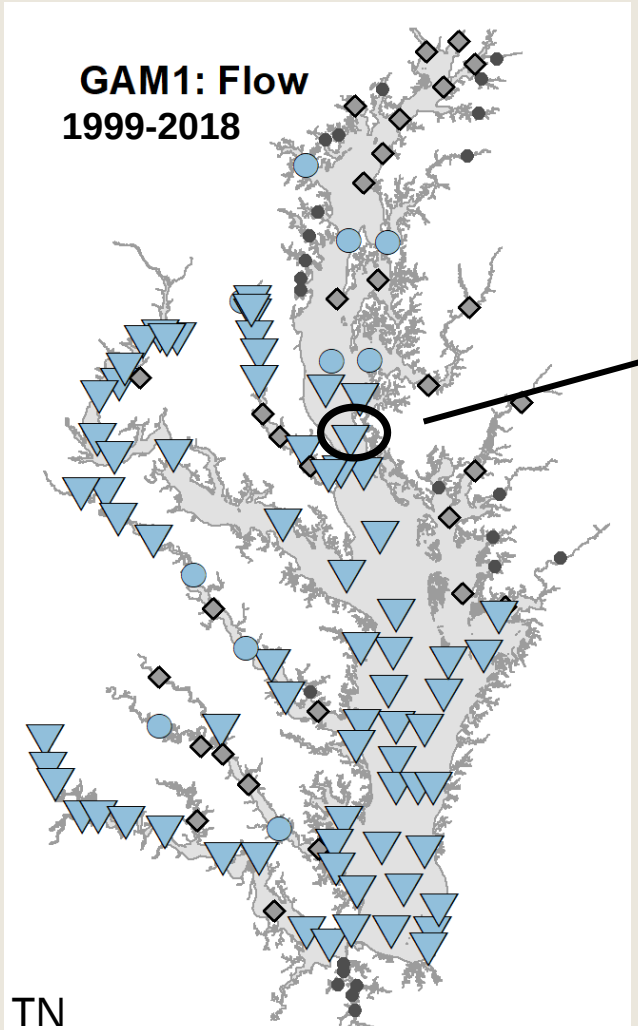


Do the loads and flow together explain the trends?

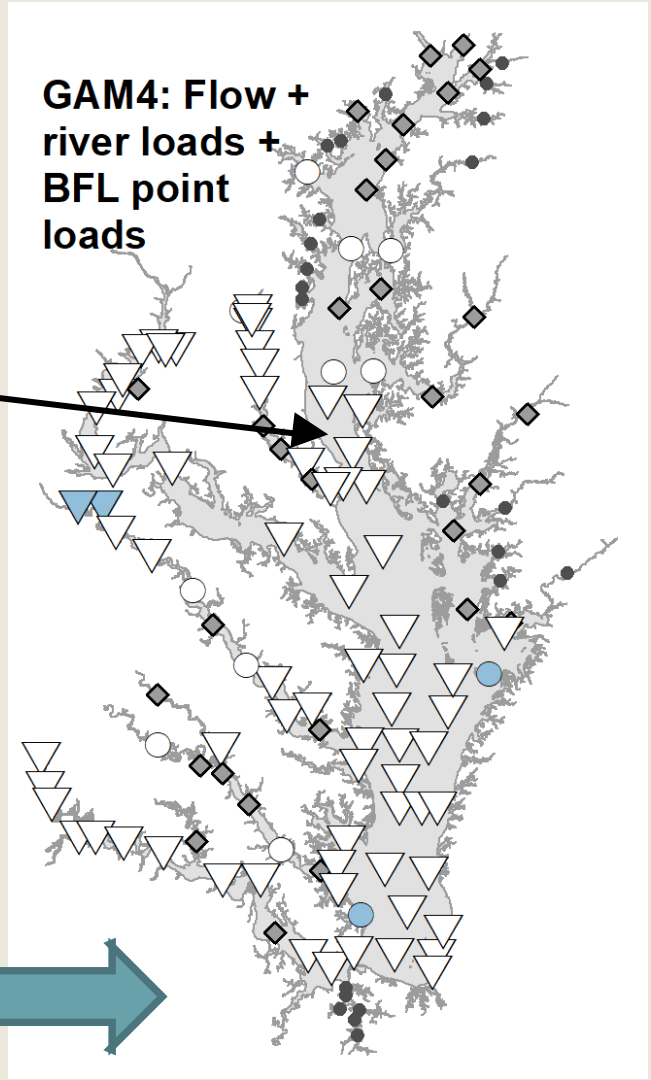


Step 2

TN: Test if loads explain change



Example mid-bay: *After accounting for flow + watershed loads, there is* ***no unexplained trend*** *at this station*



Do the loads and flow together explain the trends?

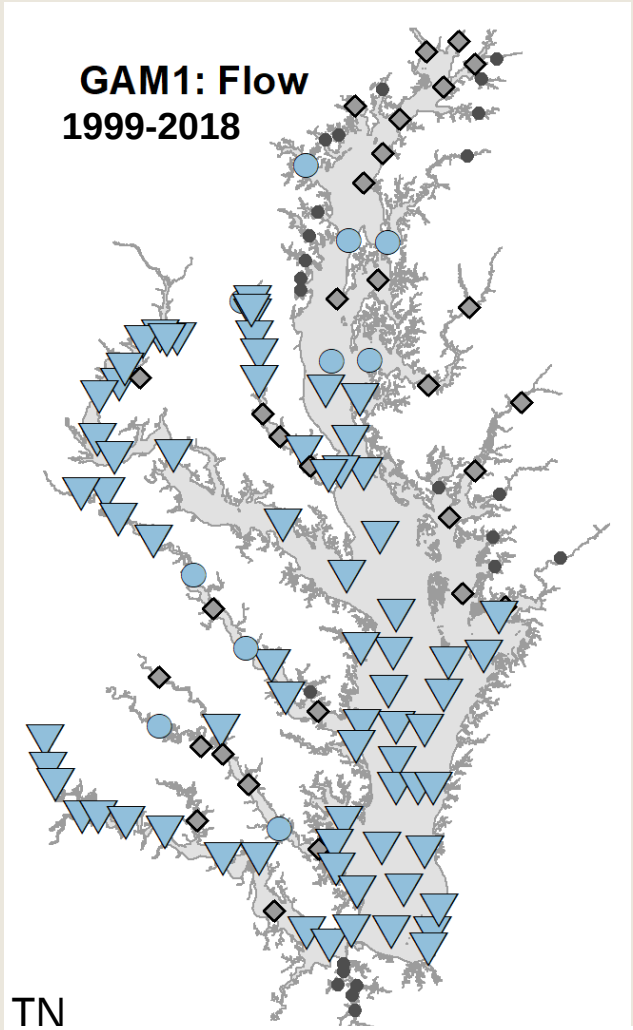
TN

Trend after accounting for flow and load(s):

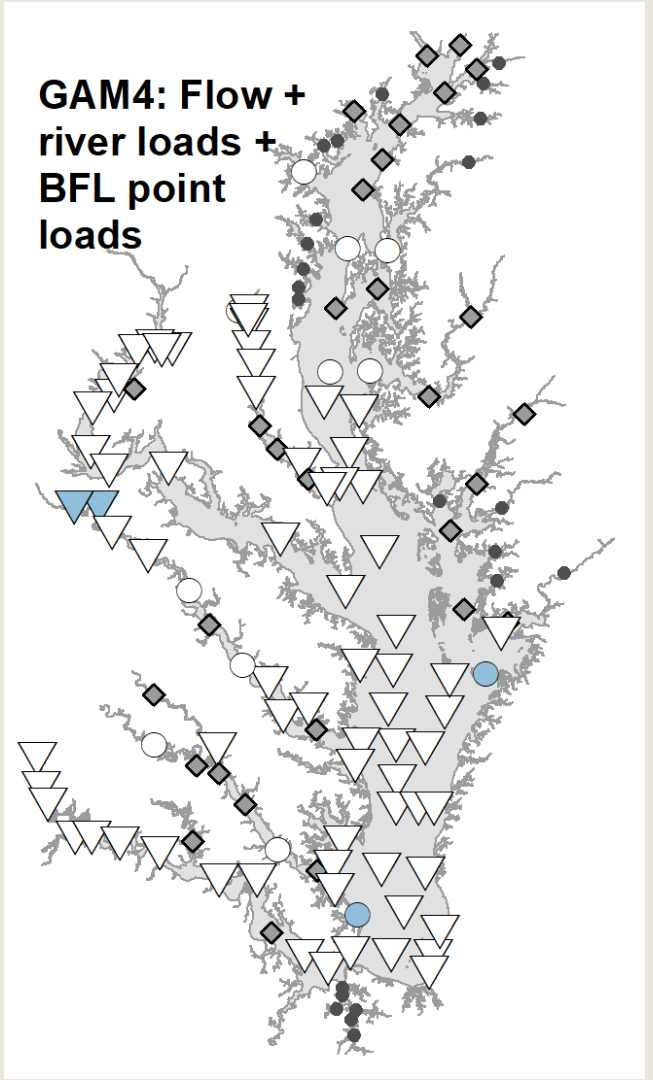
- Strong decrease
- Possible decrease
- None
- None, at station with strong decrease after accounting for flow only
- None, at station with possible decrease after accounting for flow only
- Station not analyzed

Step 2

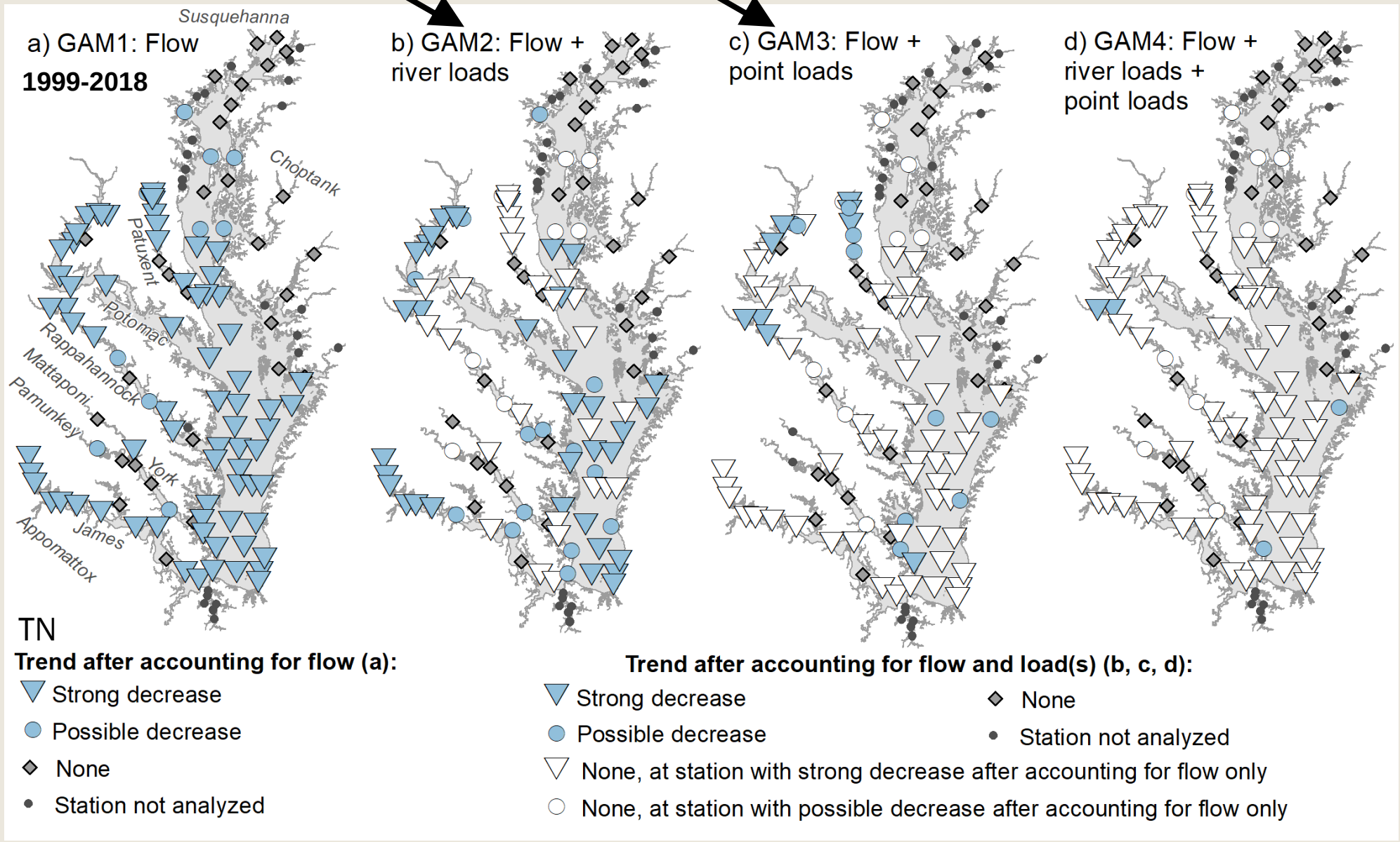
TN: Test if loads explain change



- TN loads are highly explanatory at most stations.
- 95% of the flow-adjusted trends are explained by monitored TN loads in the rivers and point sources together.



TN: Are River or Point loads more influential?

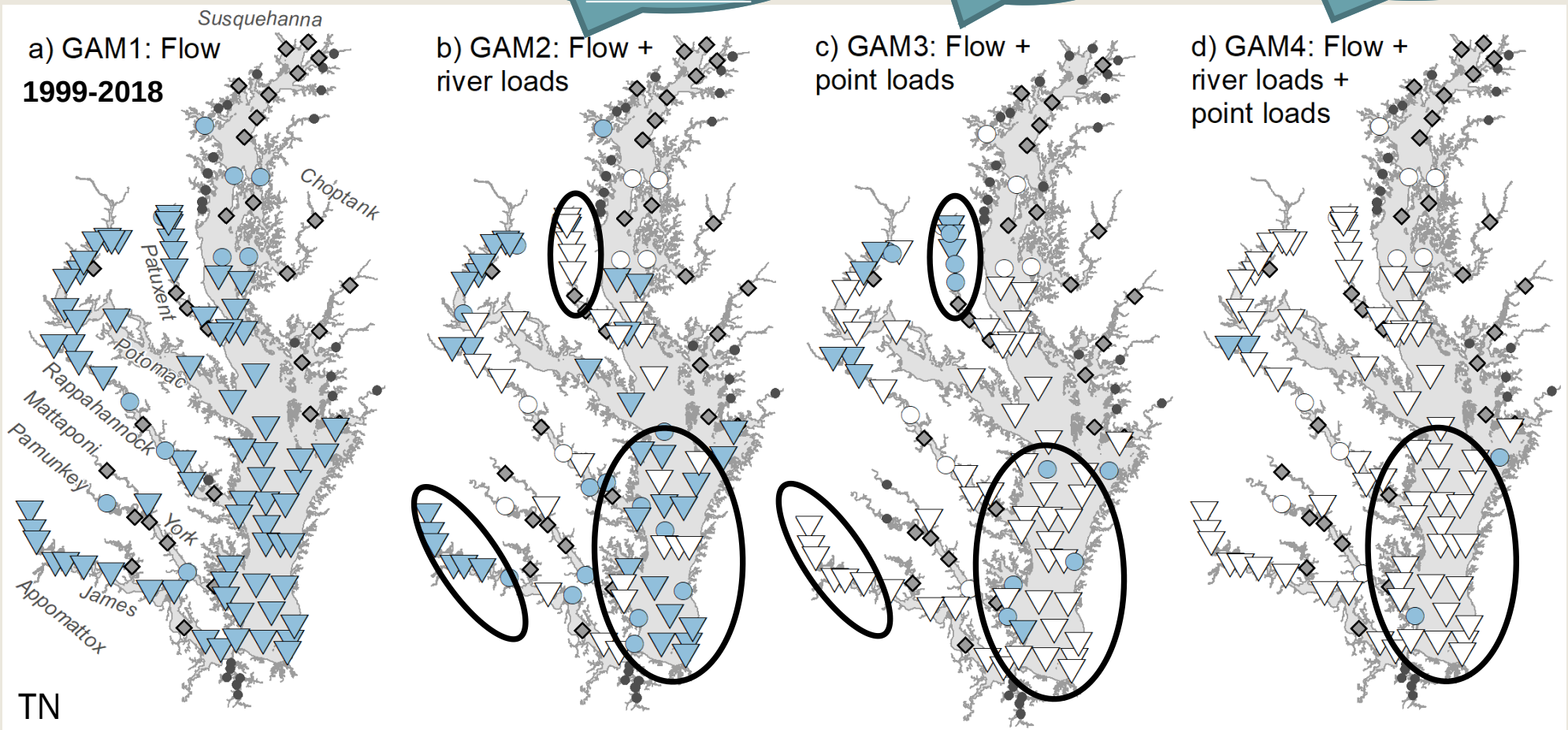


TN

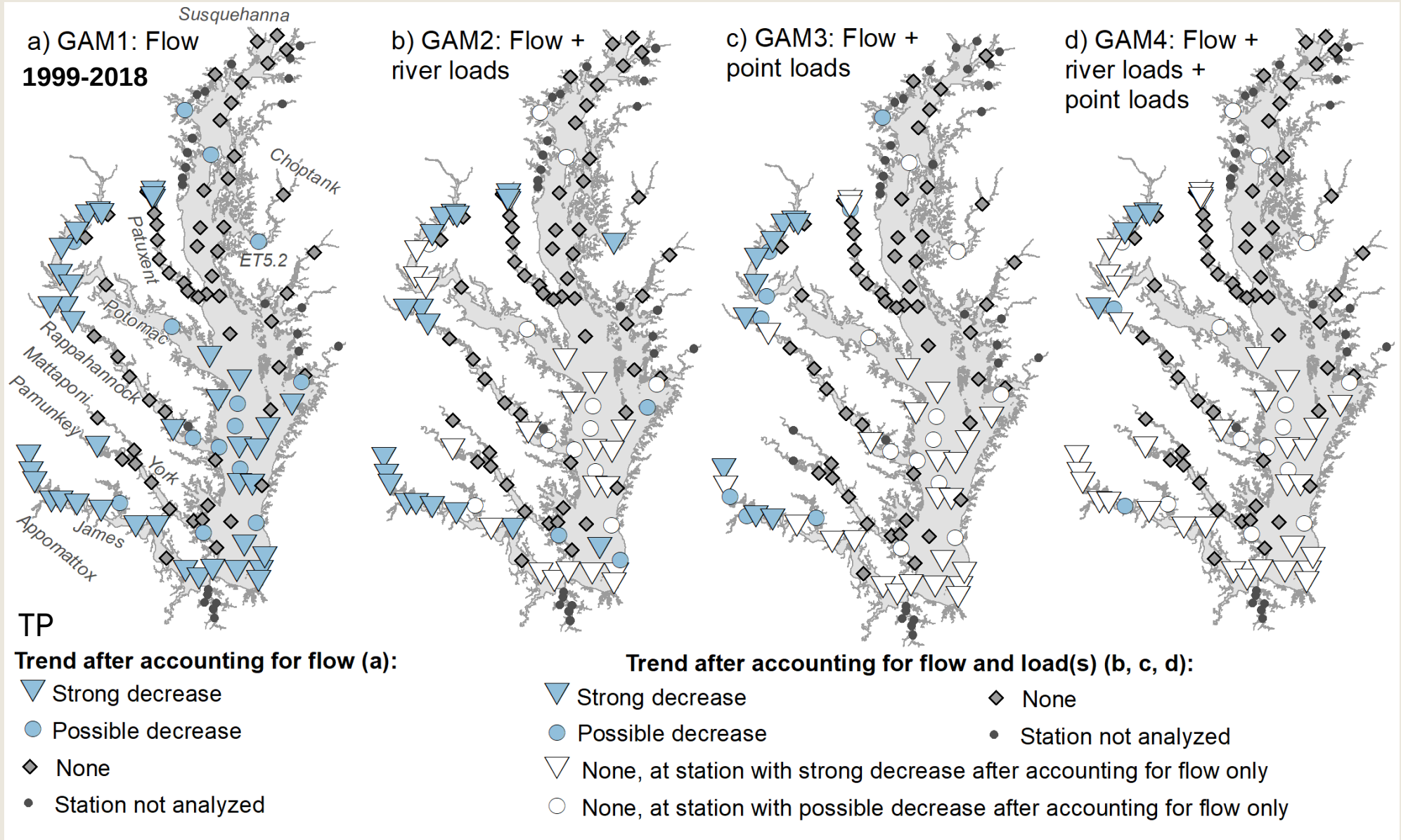
41% of flow-adjusted trends explained by river loads

77% explained by point loads

95% explained by the loads together



Same analysis for TP

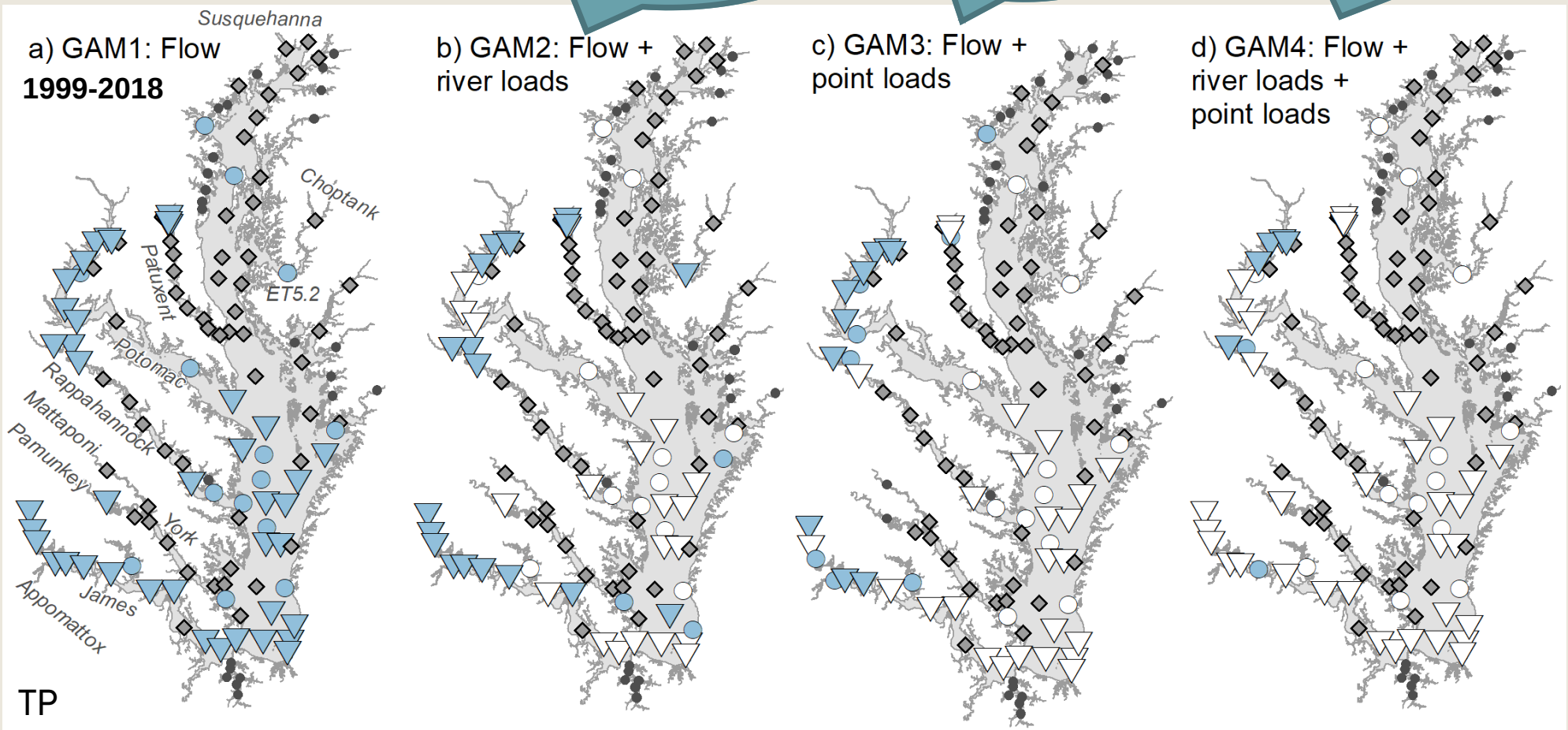


TP

60% of flow-adjusted trends explained by river loads

67% explained by point loads

87% explained by the loads together



Conclusions

- Both upstream loads to the rivers and nearby 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.

- Flow impacts on trends are substantial
  - The good news: After accounting for flow, TN and TP are improving at most stations.
  - However, reductions from nutrient sources may be masked in the estuary by impacts of large flows if flow variability increases in the future.

Thank you!

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ITAT webpage for link to the manuscript and tidal trends:

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

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Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management

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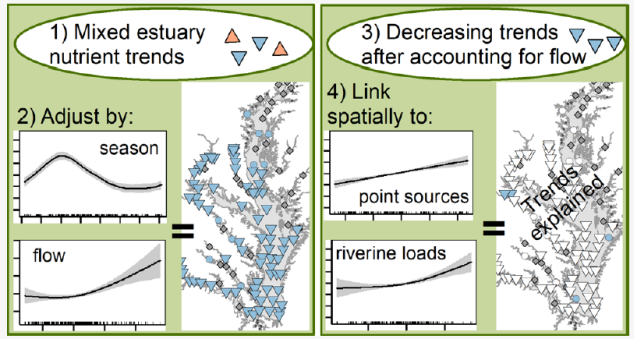
ABSTRACT: In Chesapeake Bay in the United States, decades of management efforts have resulted in modest reductions of nutrient loads from the watershed, but the corresponding improvements in estuarine water quality have not consistently followed. Generalized additive models were used to directly link river flows and nutrient loads from the watershed to nutrient trends in the estuary on a station-by-station basis, which allowed for identification of exactly when and where responses are happening. Results show that Chesapeake Bay's total nitrogen and total phosphorus conditions are mostly improving after accounting for variation in freshwater flow. Almost all of these improving nutrient concentrations in the estuary can be explained by reductions in watershed loads entering through 16 rivers and 145 nearby point sources, with the nearby point source reductions being slightly more effective at explaining estuarine nutrient trends. Overall, these two major types of loads from multiple locations across the watershed are together necessary and responsible for the improving estuarine nutrient conditions, a finding that is highly relevant to managing valuable estuarine resources worldwide.

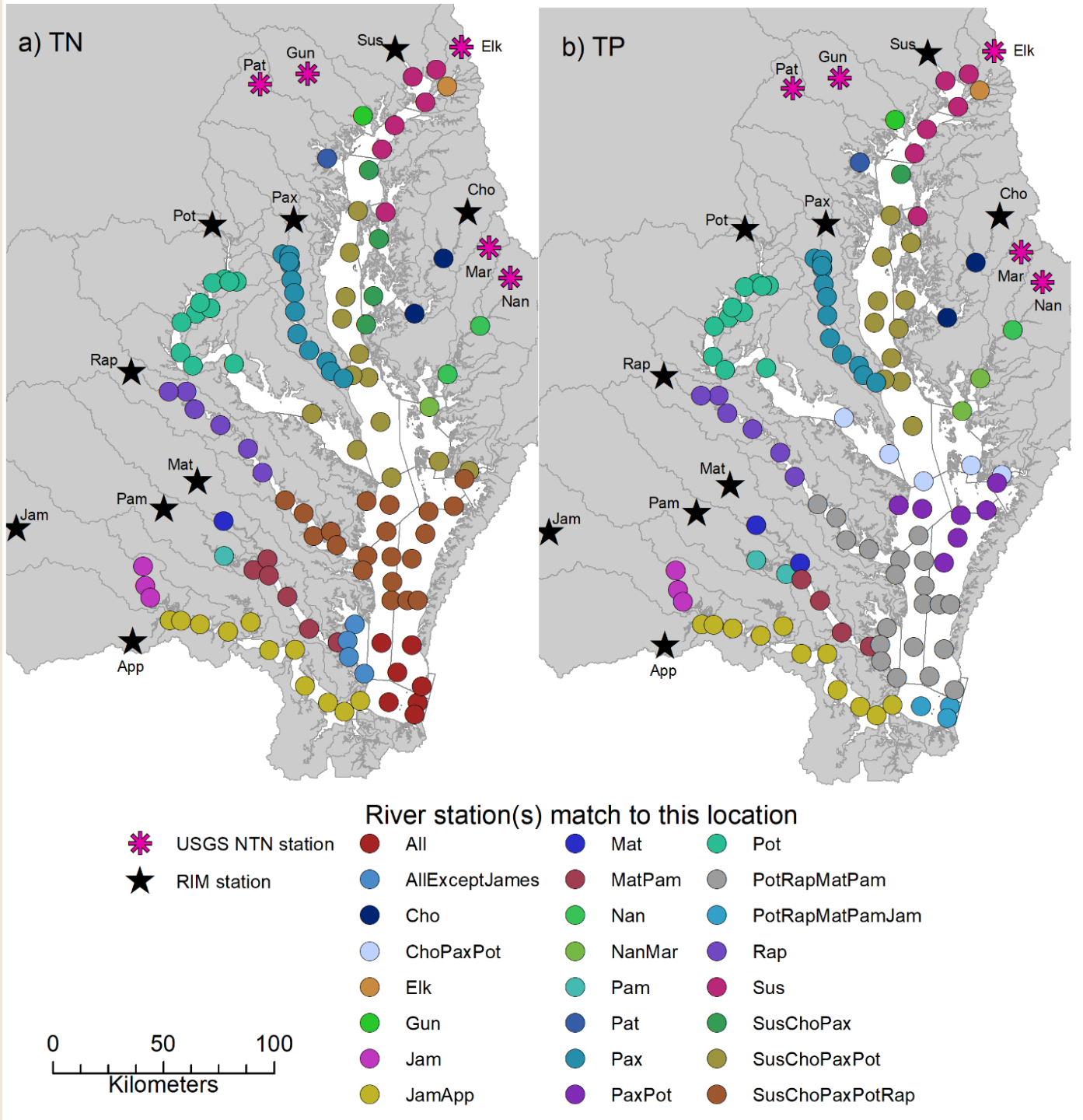


KEYWORDS: *water quality, estuary, eutrophication, generalized additive models, trends*

extras

Spatial influence of loads

- Key step: Identify which nutrient loads are most explanatory at each estuarine station.



Places with unexplained trends

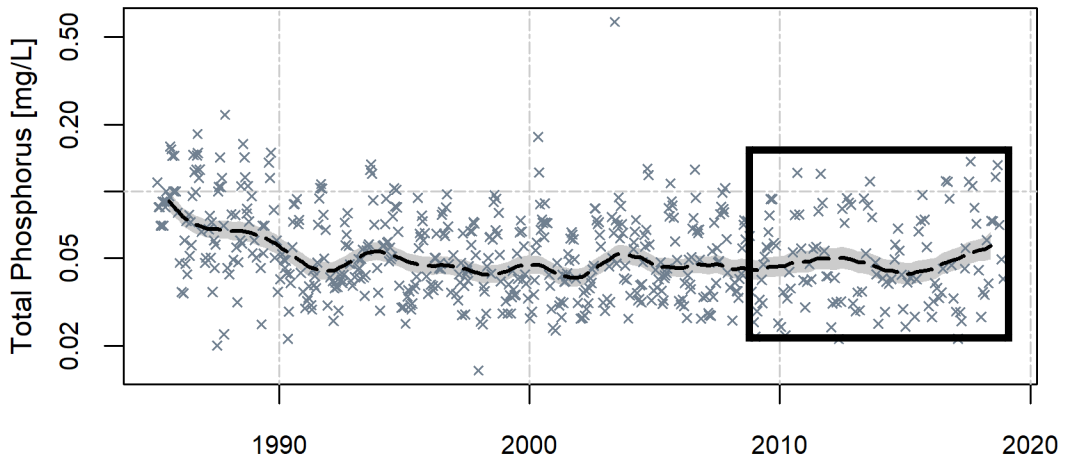
- TN in tidal fresh Rappahannock
- TP in tidal fresh Rappahannock and Potomac

Some notes and hypotheses:

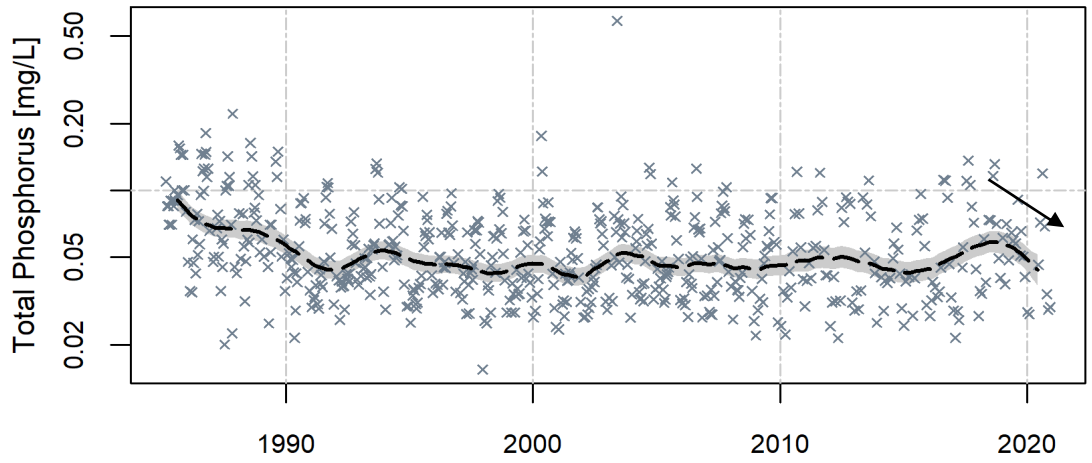
- The nutrient loads are highly explanatory at these stations (low p-values in the GAMs), there is just still residual trend even after they are included.
- SAV resurgence in the tidal fresh could play a role, if it causes a decrease in tidal nutrients at times that don't link up to the nutrient loads.
- This could be method-related – that the monthly aggregated loads are not fine enough resolution in this region for capturing the load-to-estuary relationships.

Observed short-term TP increases

This study period



With data to 2020



The Patuxent and lower mainstem TP short-term increases through 2018 appear to mostly due to increases in wet years, during otherwise plateaued recent decades. Trends ending in 2020 show no short-term change in these places.

10-year change map with data to '20