Comprehensive Assessment of the Impacts of Large Reductions in Point Source Nutrient Loading to the Patapsco River Estuary

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In partnership with the Maryland Department of the Environment

Motivating Questions

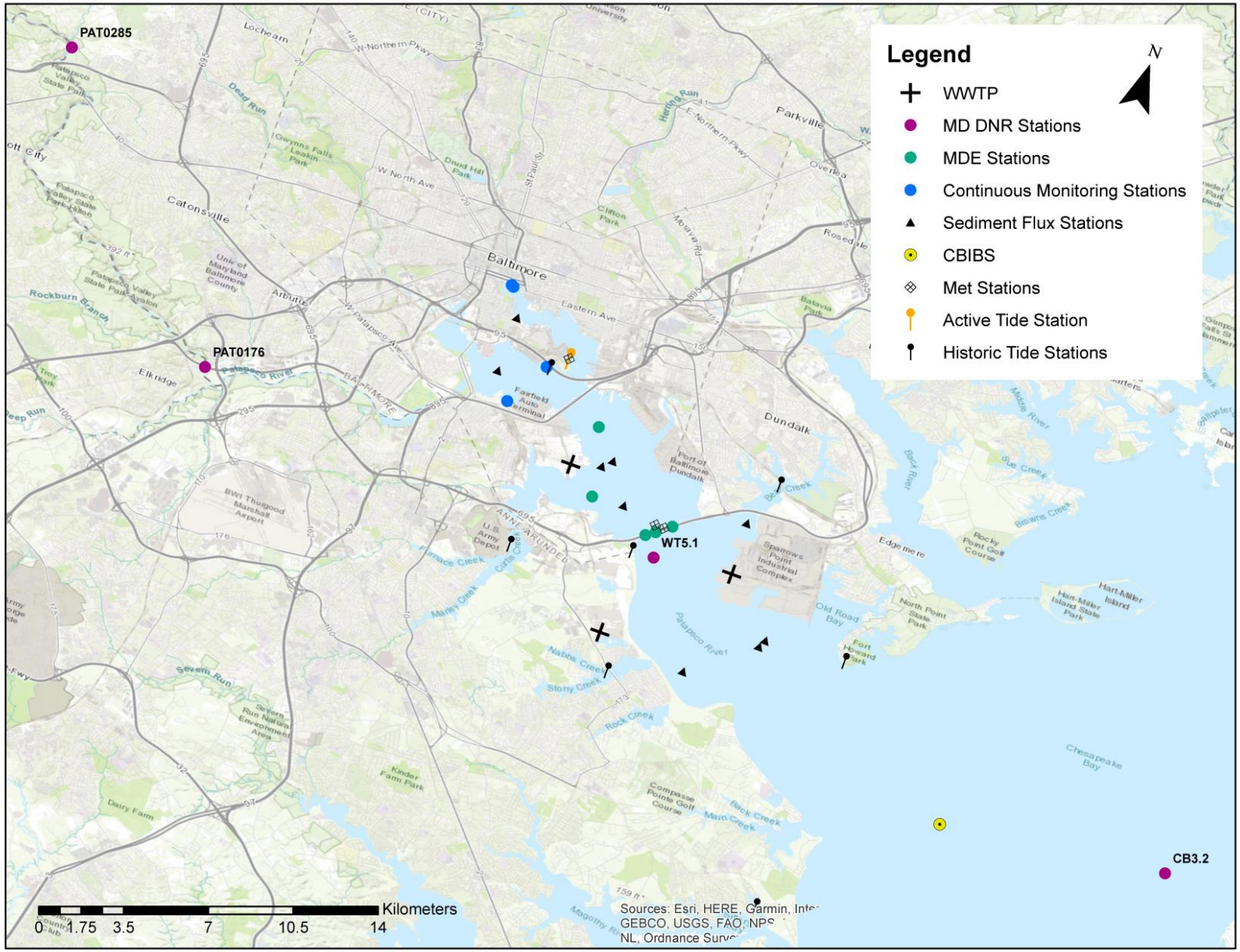
- How have wastewater nutrient load changes at municipal and industrial facilities affected water quality in the Patapsco estuary in the last 40 years?

- What can nutrient budgets tell us about the role of sediment recycling and Bay-tributary exchange in the dynamics of the Patapsco estuary?

Approaches

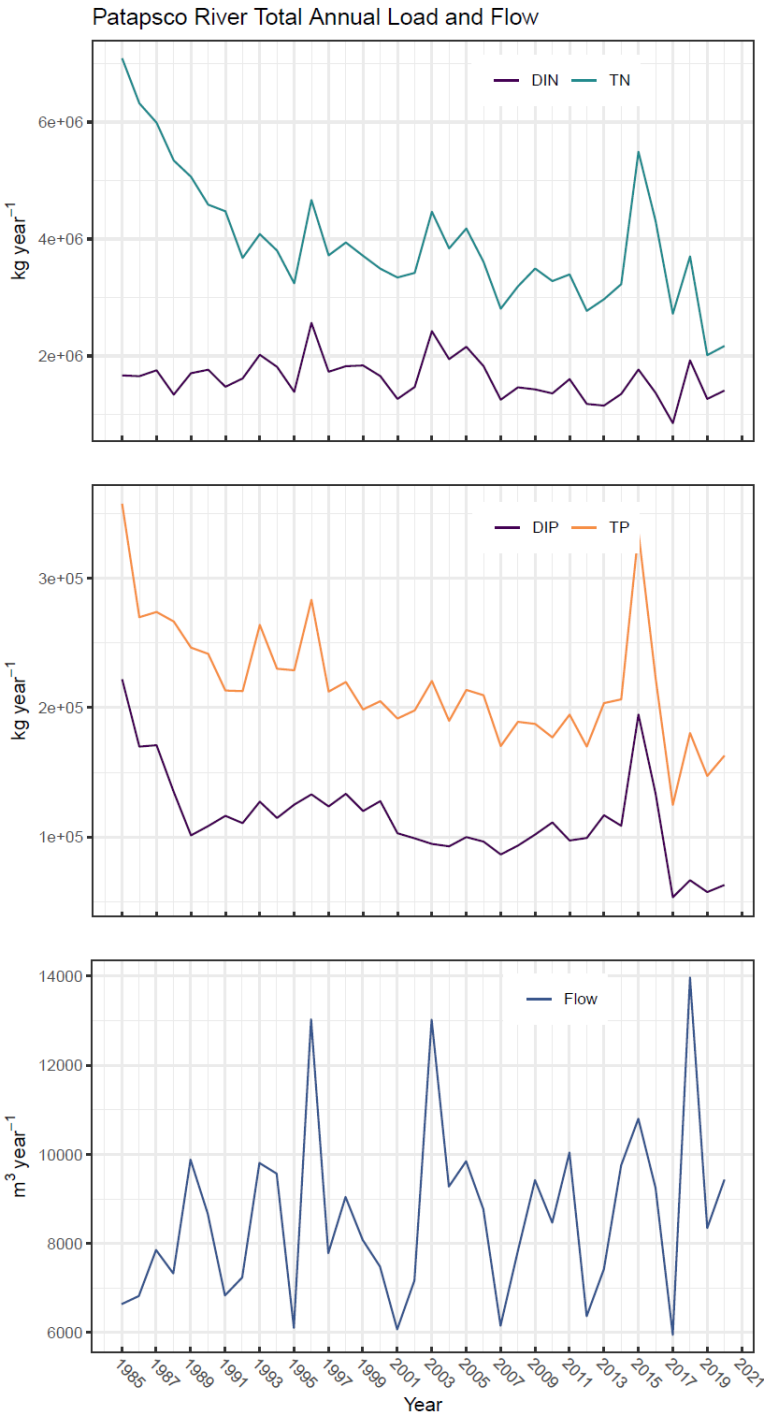
- Analyze time-series of loads and estuarine conditions
- Derive estimates of ecosystem metabolism at available locations
- Develop nitrogen and phosphorus budgets that draw from monitoring data, loading estimates, and numerical models of sediments and the water-column
  - sediment biogeochemical model, box model

Water Quality Data in Patapsco

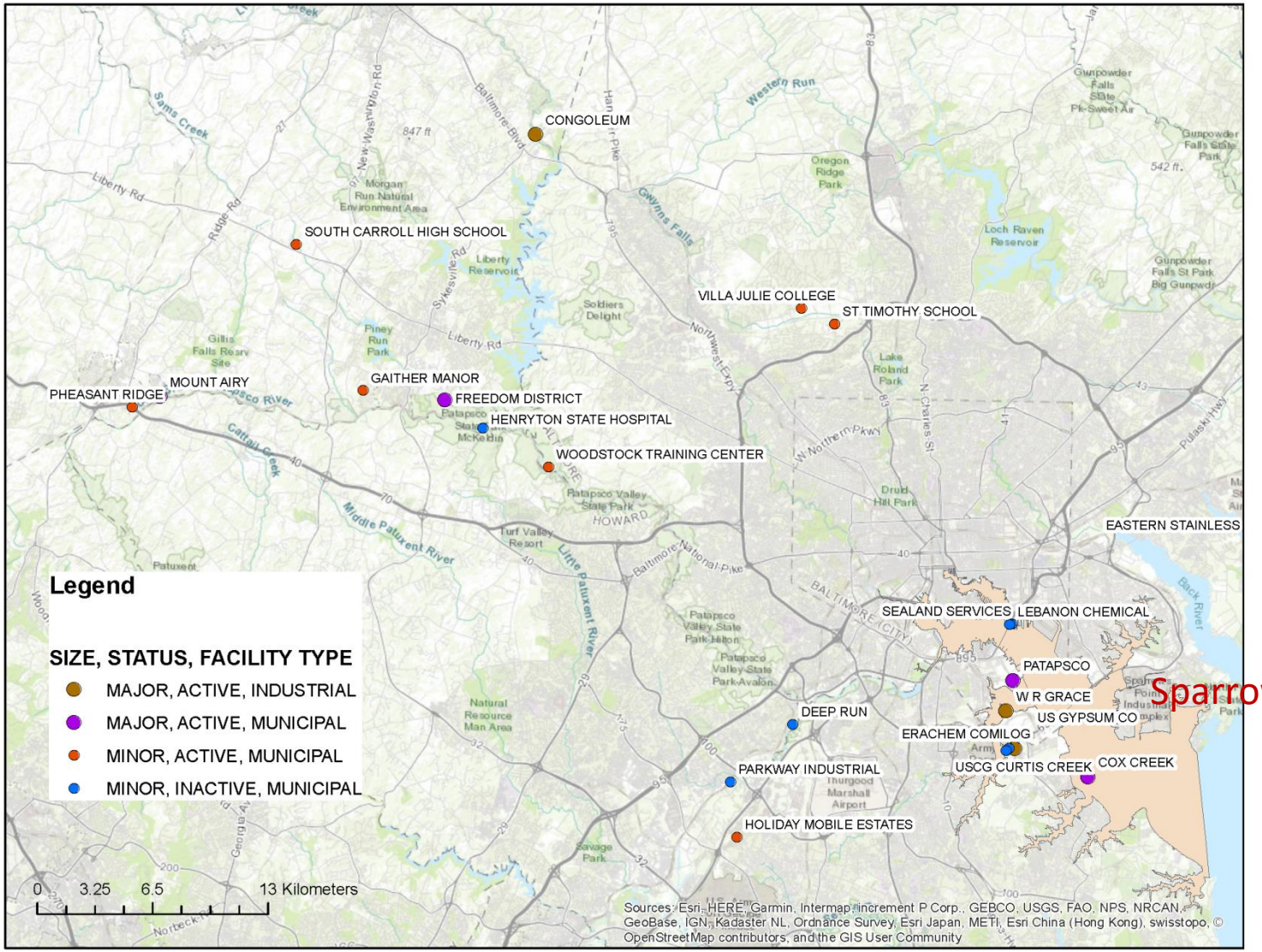


Total Watershed Loads Have Declined Since 1985

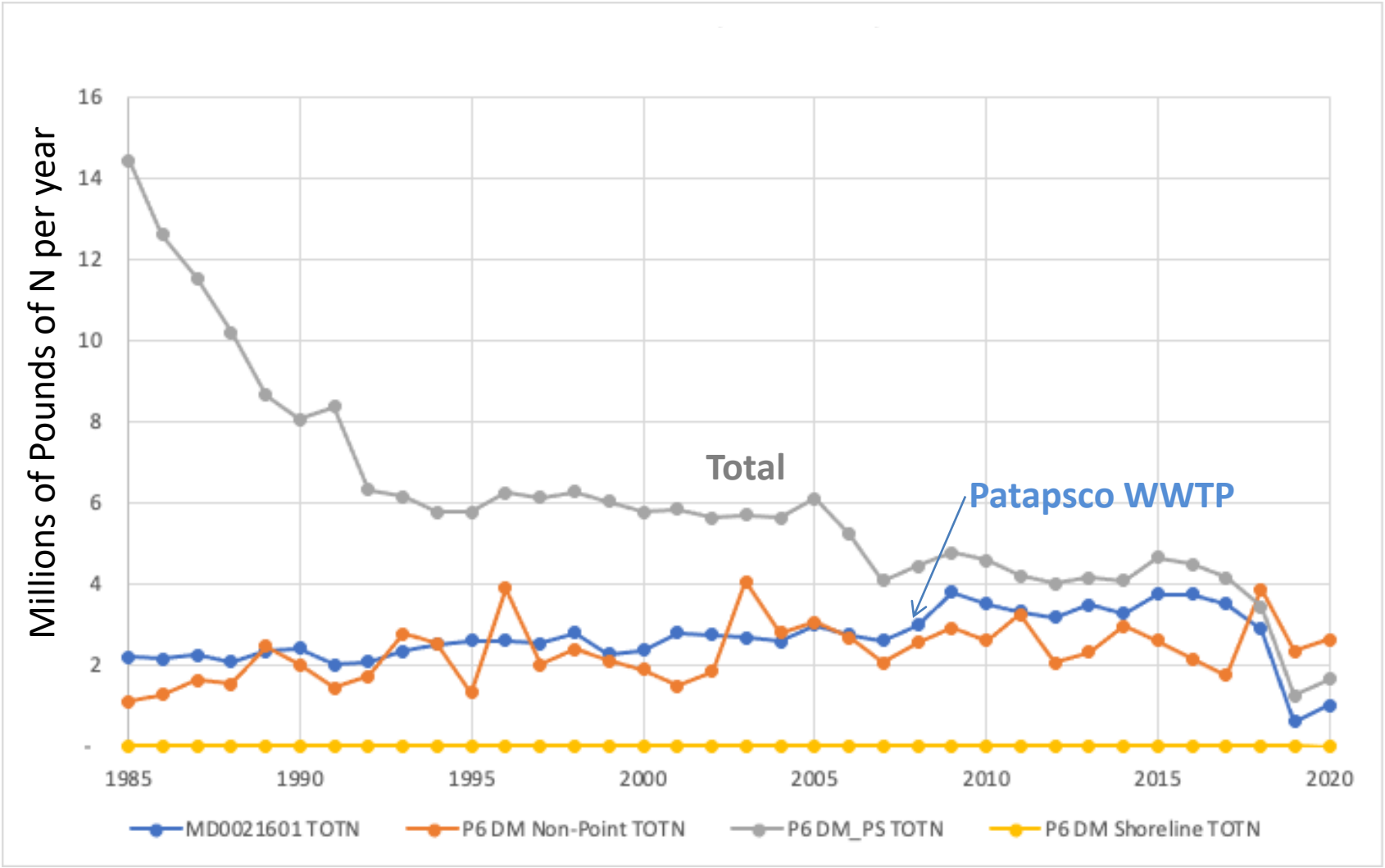
- TN declines since 1985 (less so for DIN)
- TP declines, abrupt decline after 2017
- Discharge increasing modestly, varies significantly from year to year



Wastewater Sources to Patapsco

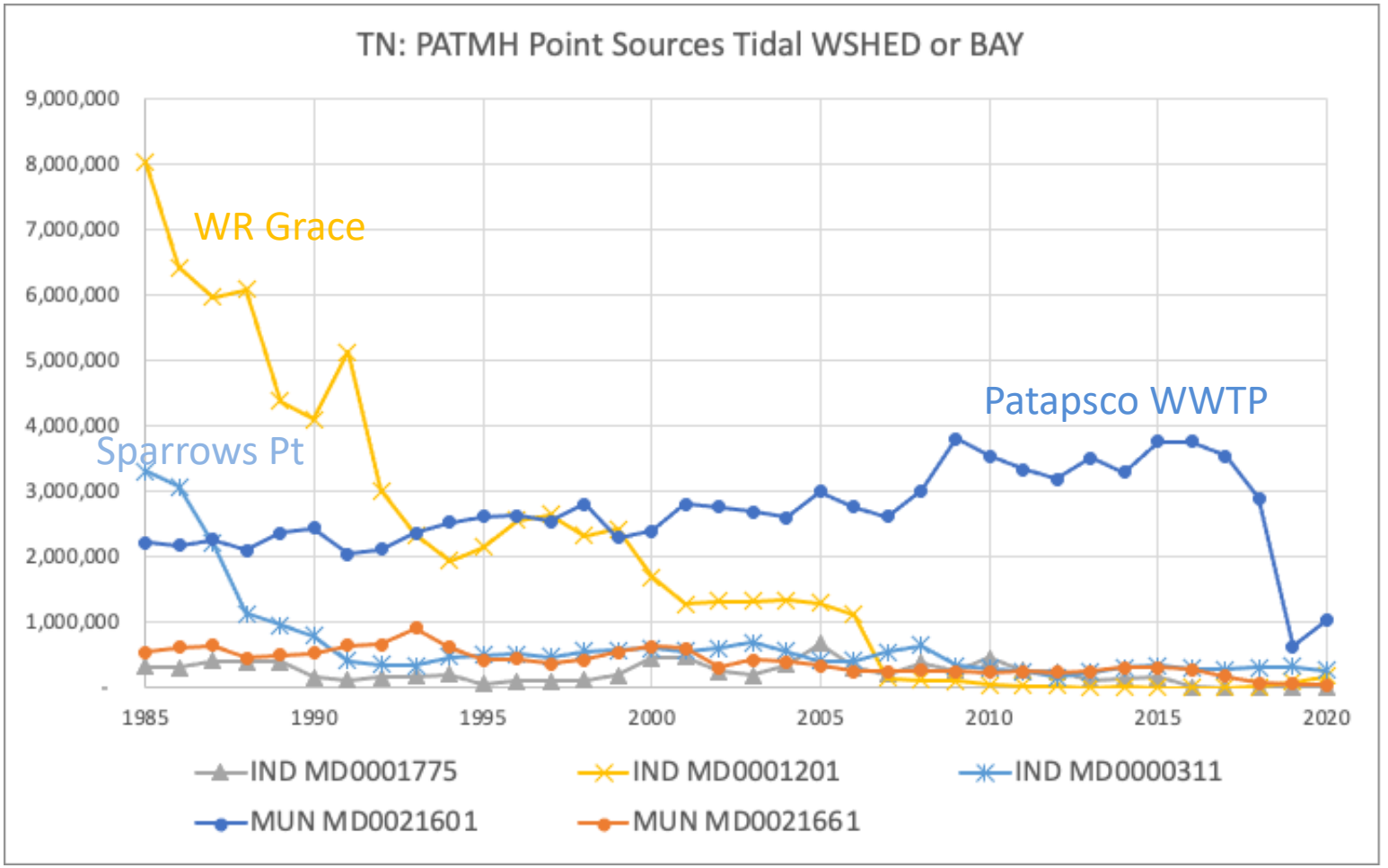


Wastewater Source to Patapsco: Municipal Sources Have Become Dominant



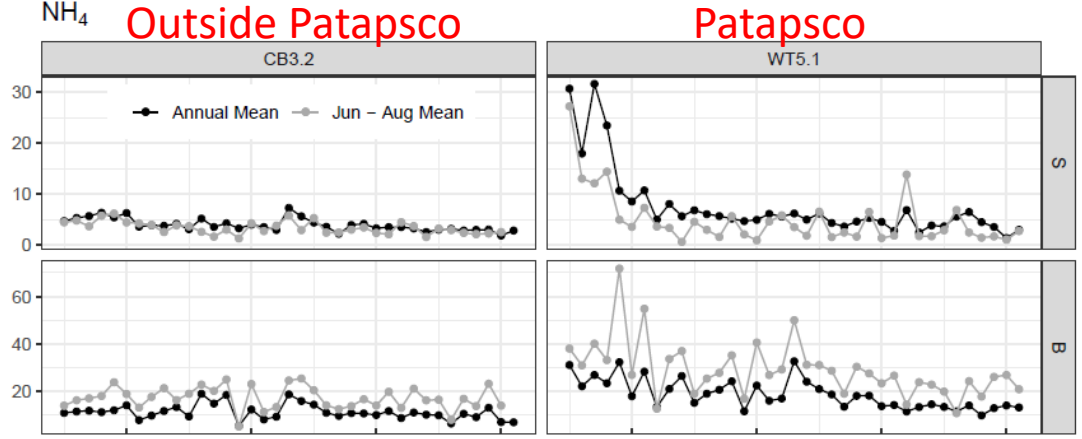
Phase 6 Model Output

Wastewater Sources to Patapsco: A Mix of Industrial and Municipal



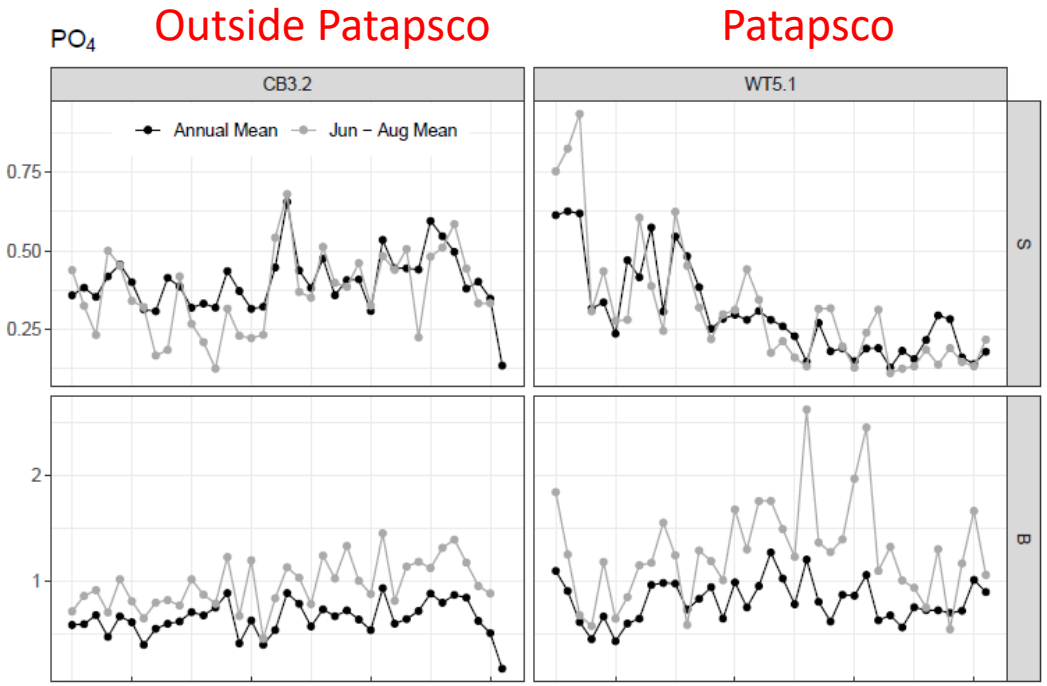
Data courtesy of Gopal Bhatt and Gary Shenk

Nitrogen Concentrations Have Declined



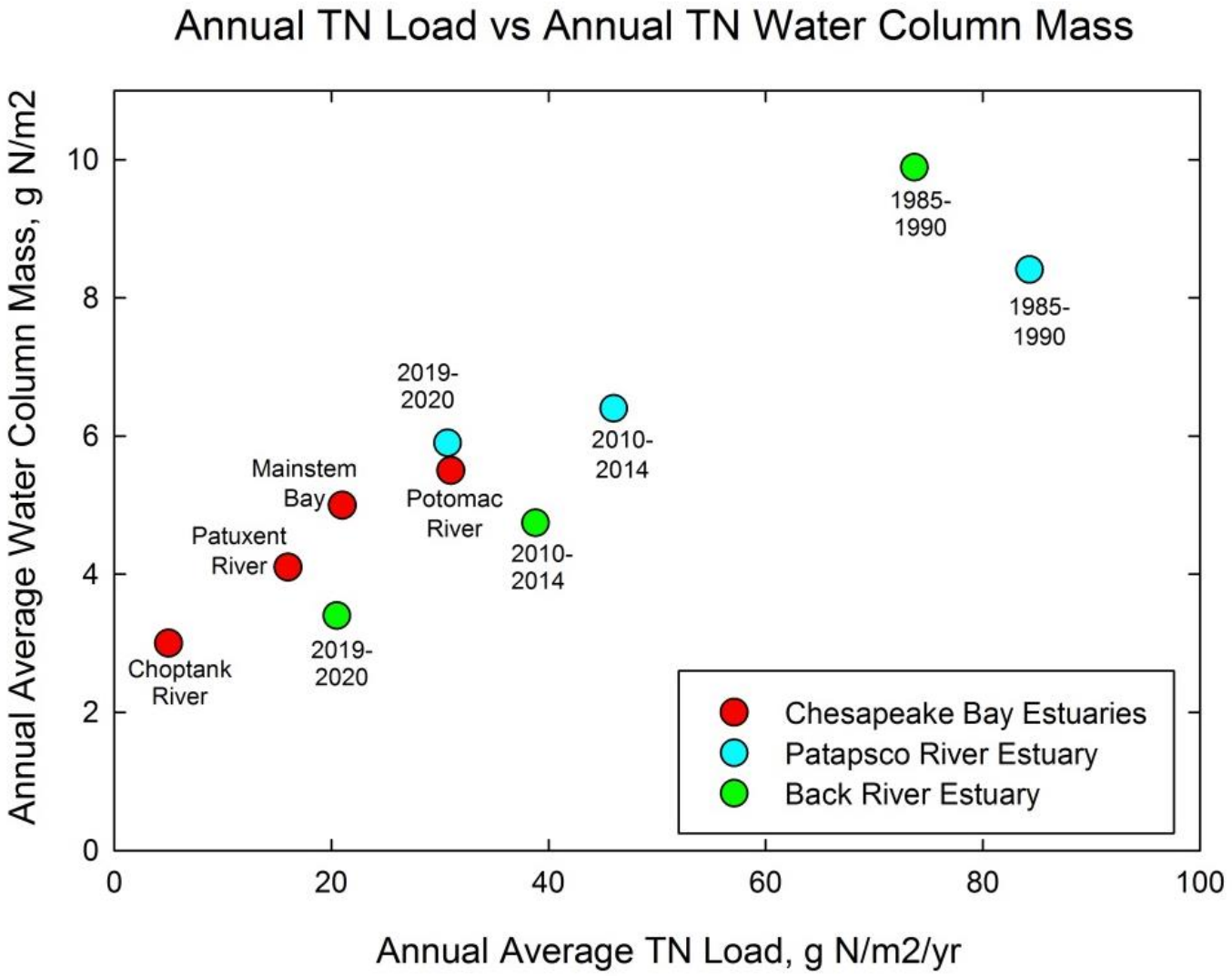
- Substantial NH_4 decline in Patapsco
- NO_{23} is variable over time
- TN declines modestly

Phosphorus Concentrations Have Declined



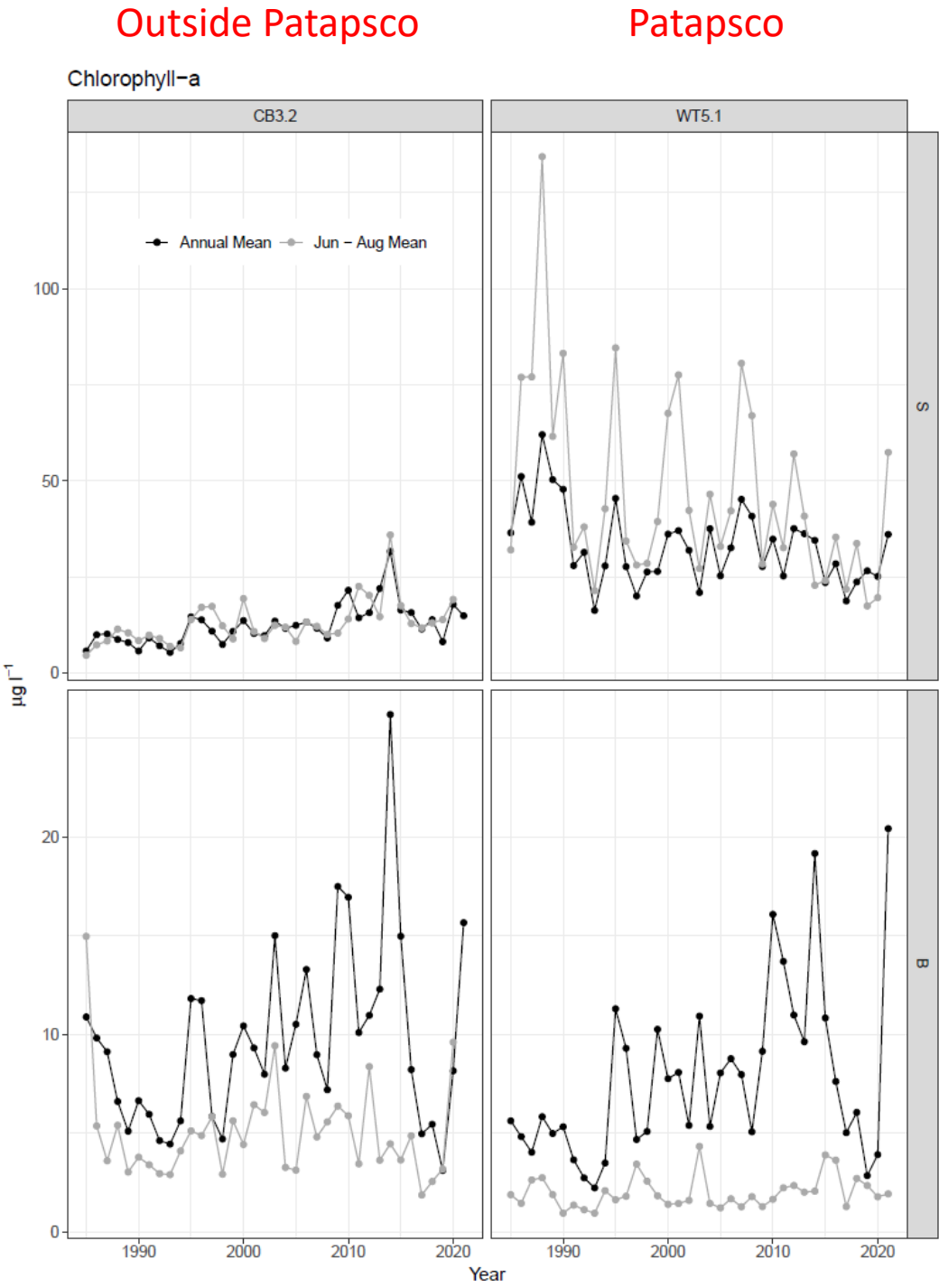
- Substantial TP and PO4 decline in surface water of Patapsco
- Bottom water is variable over time
- If anything, increase outside Patapsco
- Recent (2019-2021) declines in mainstem are not well understood

Patapsco 'Recovery' Consistent with Other Larger Bay Environments

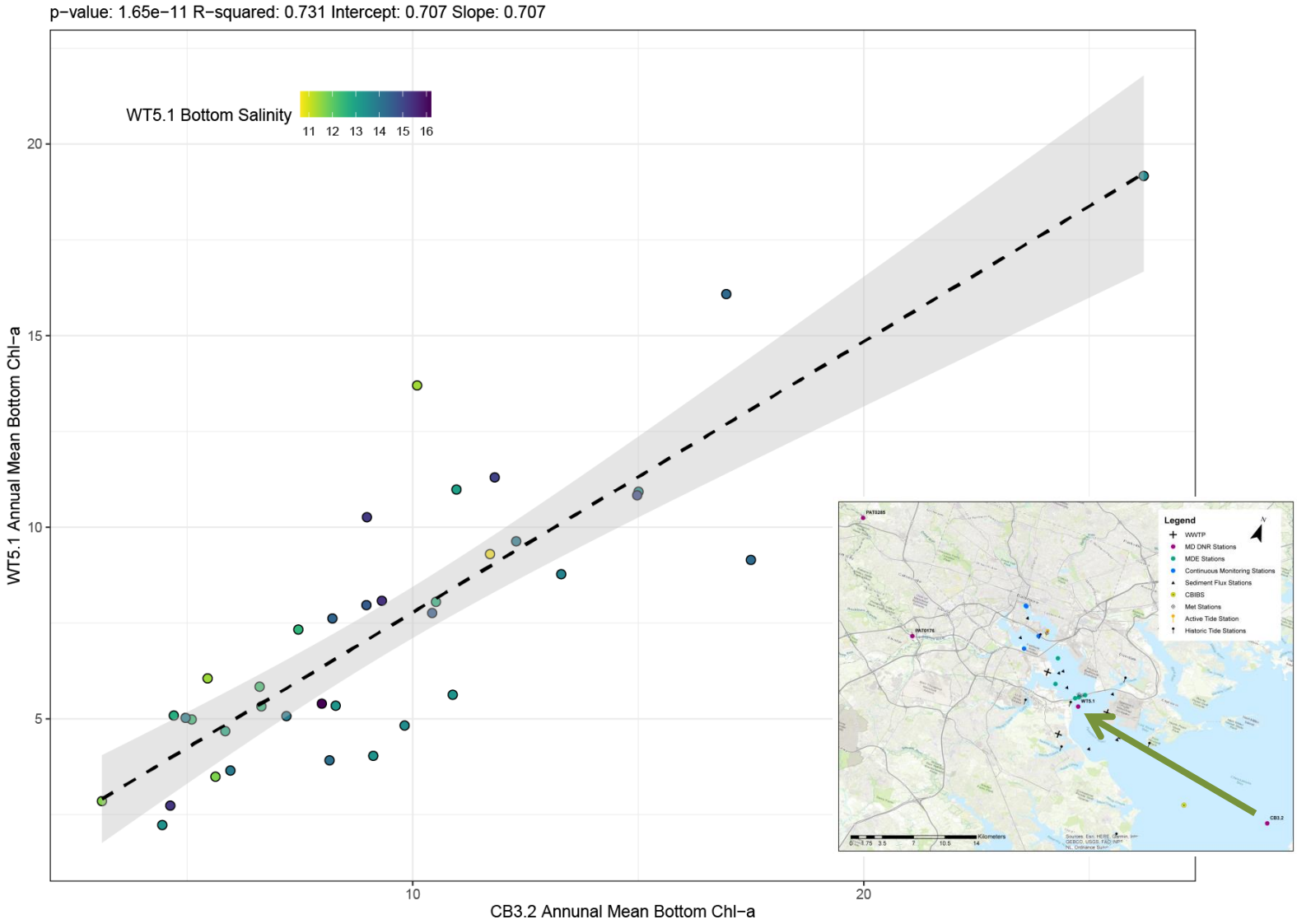


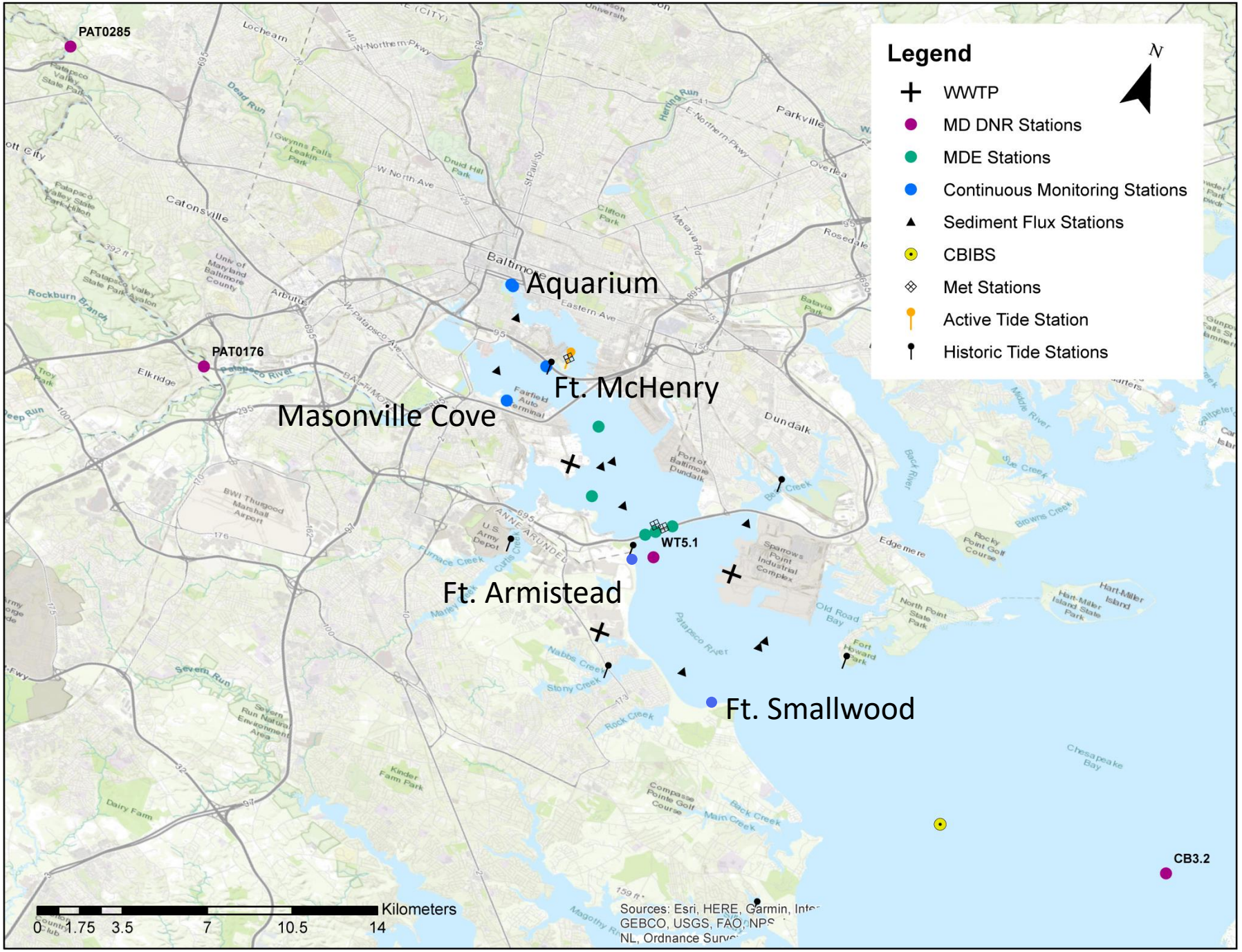
Chlorophyll-a Concentrations

- Substantial surface water decline in Patapsco
- Substantial year to year variations
- Increase in chl-a Bay outside
- Bottom chl-a rising in both locations
- Chl-a rose in 2021

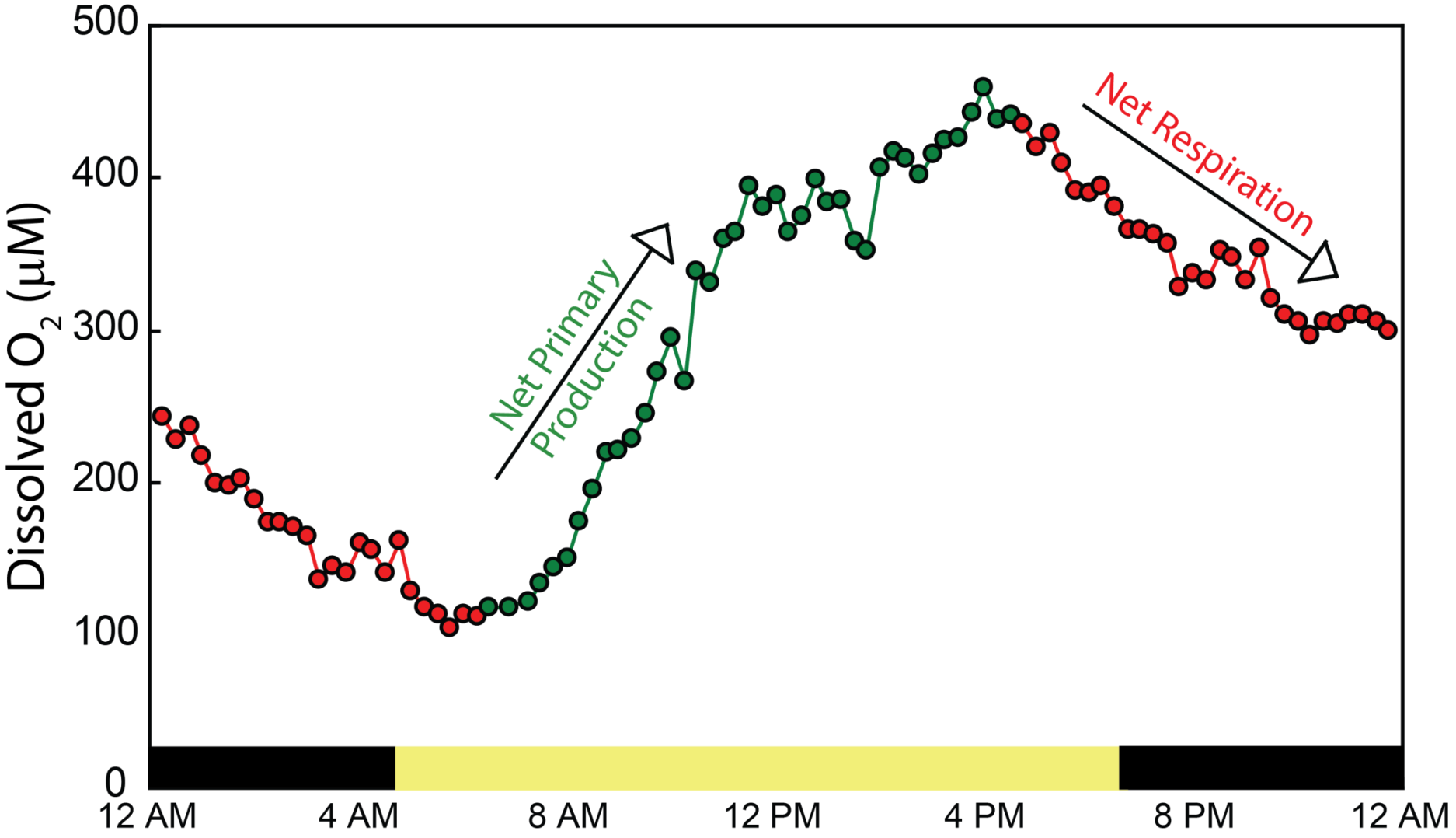


Bottom Water Chlorophyll-a In Patapsco Sourced from the Mainstem?

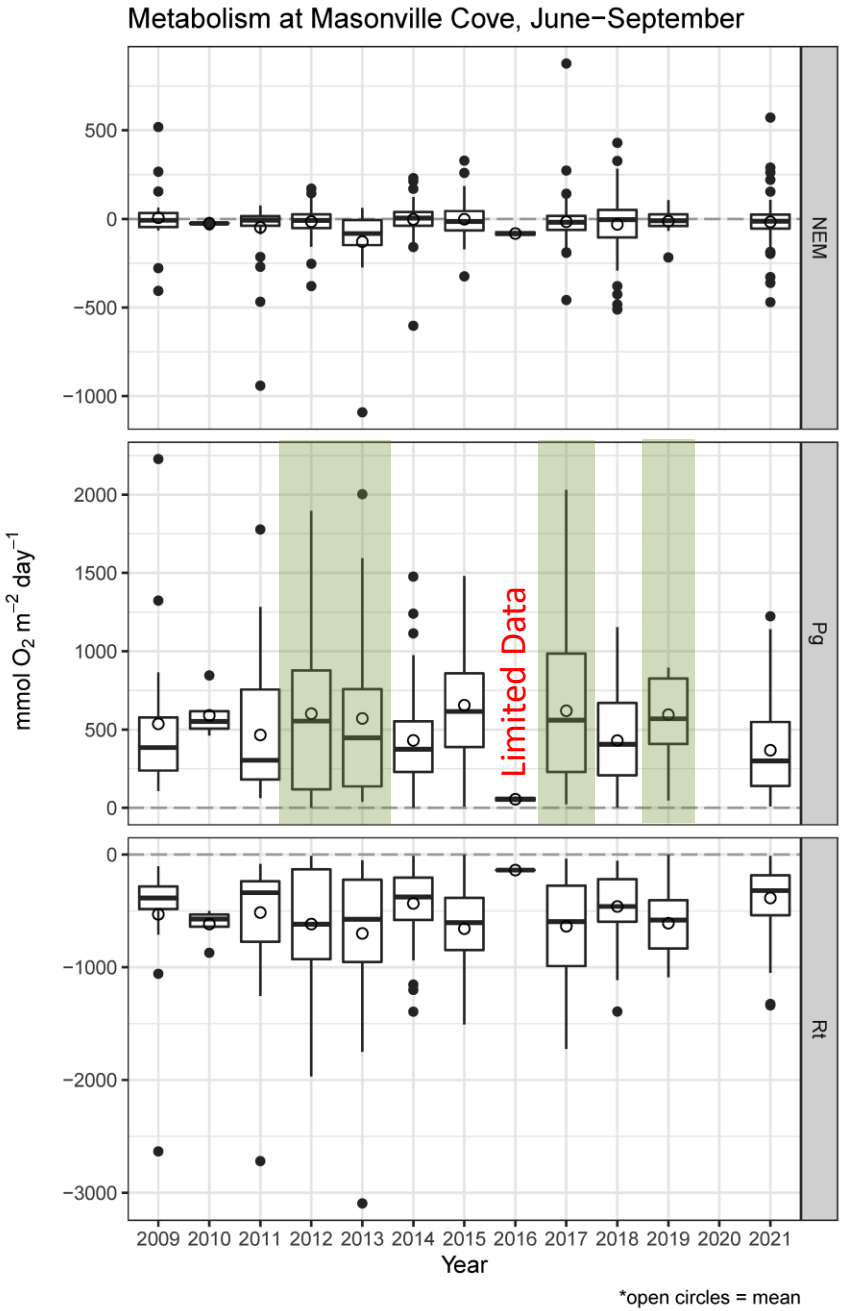


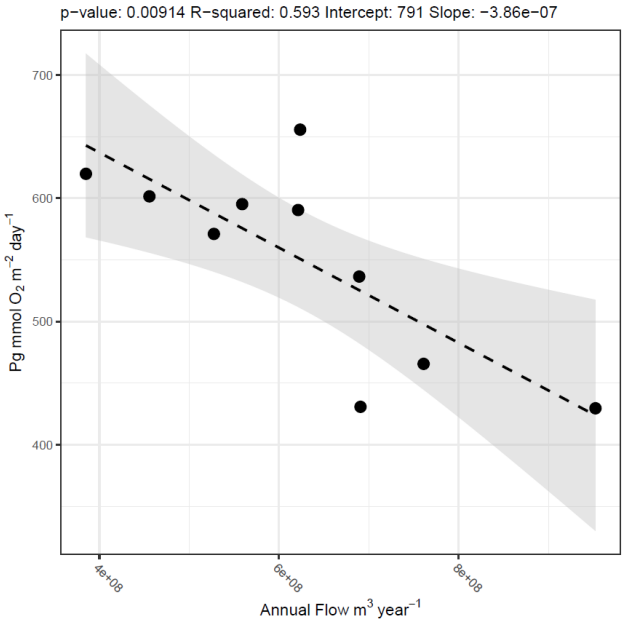

Legend
N
WWTP
MD DNR Stations
MDE Stations
Continuous Monitoring Stations
Sediment Flux Stations
CBIBS
Met Stations
Active Tide Station
Historic Tide Stations
PAT0285
PAT0176
Aquarium
Ft. McHenry
Masonville Cove
Ft. Armistead
Ft. Smallwood
WT5.1
CB3.2
Kilometers
0 1.75 3.5 7 10.5 14
Sources: Esri, HERE, Garmin, Inte
GEBCO, USGS, FAO, NPS
NL, Ordnance Surve

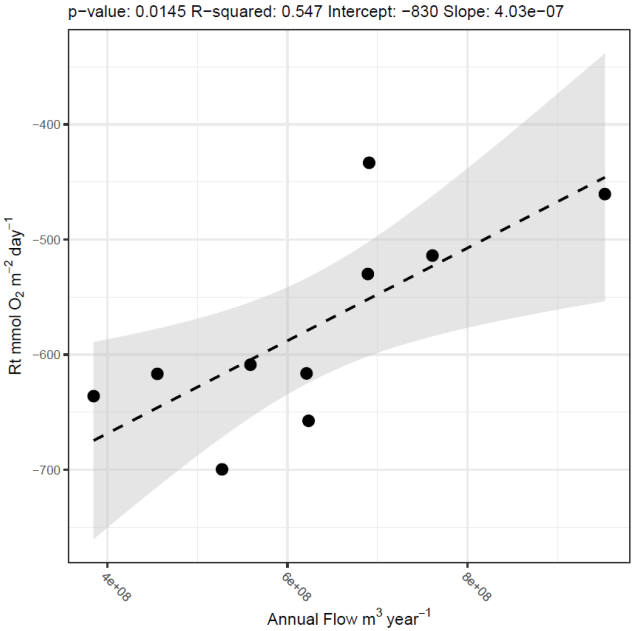
Computed Metabolic Rates from DO Time-Series



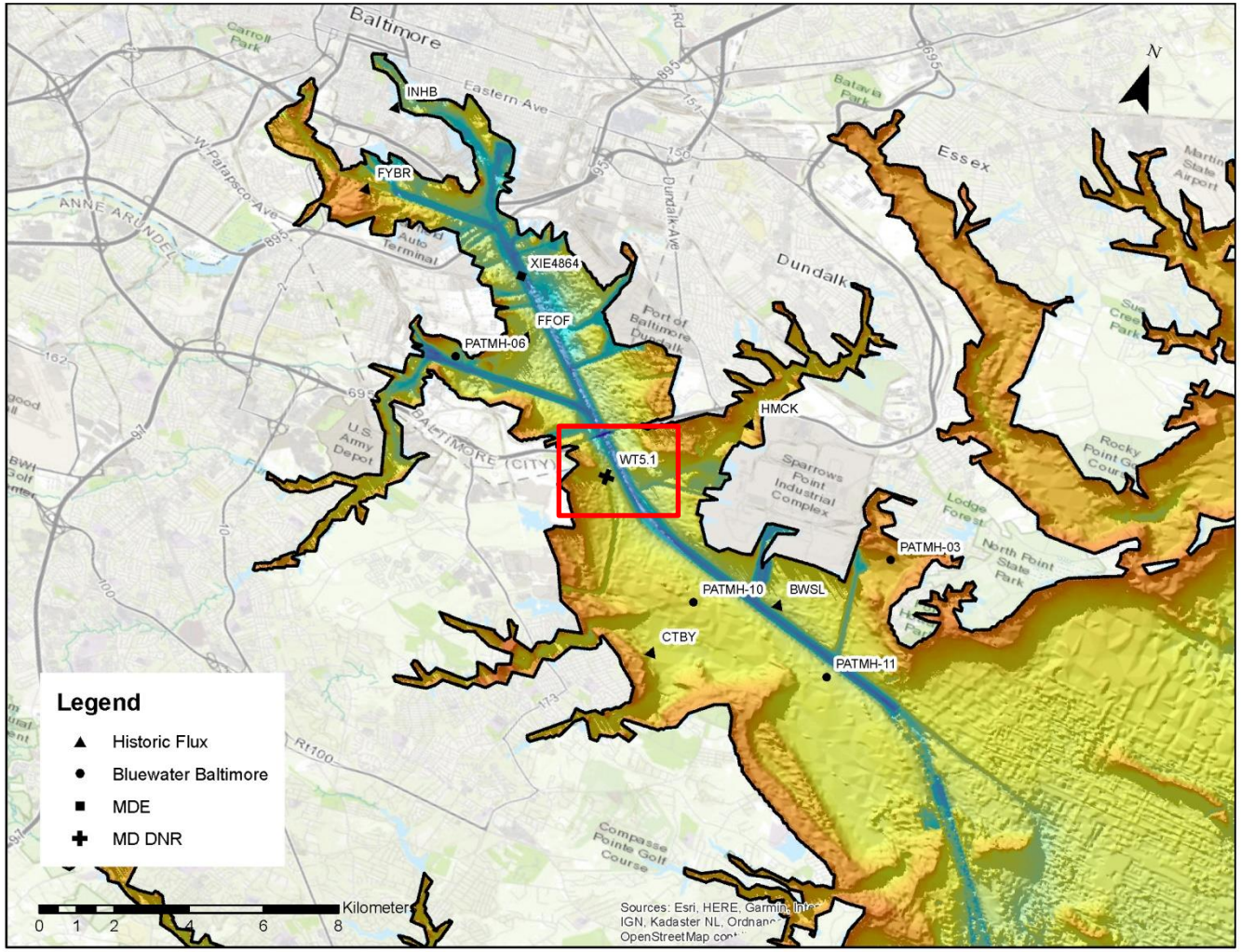
Metabolic Rates: No Clear Response to WWTP Load, Flow is Dominant







Another Metabolic Index: Oxygen Depletion



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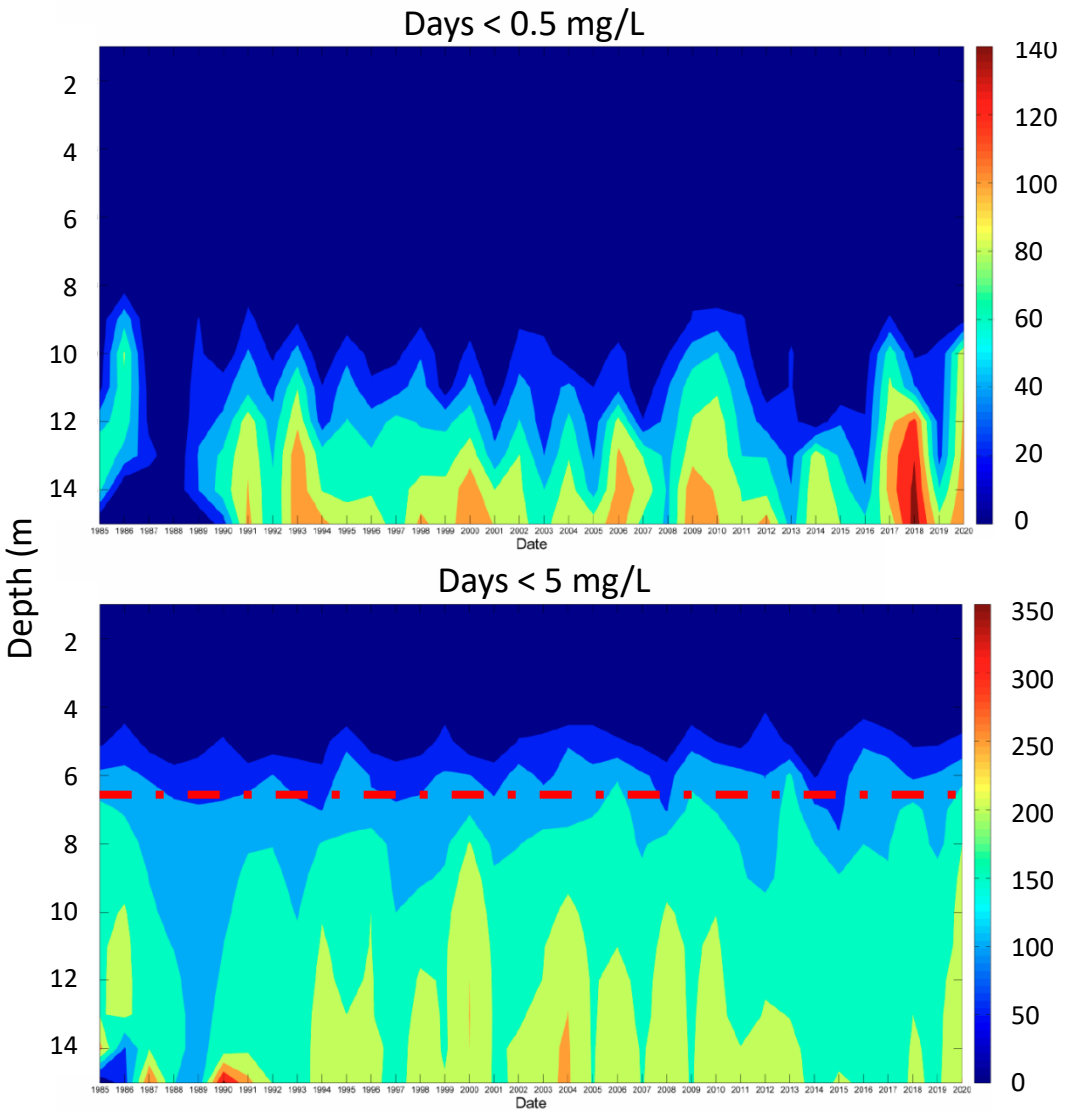
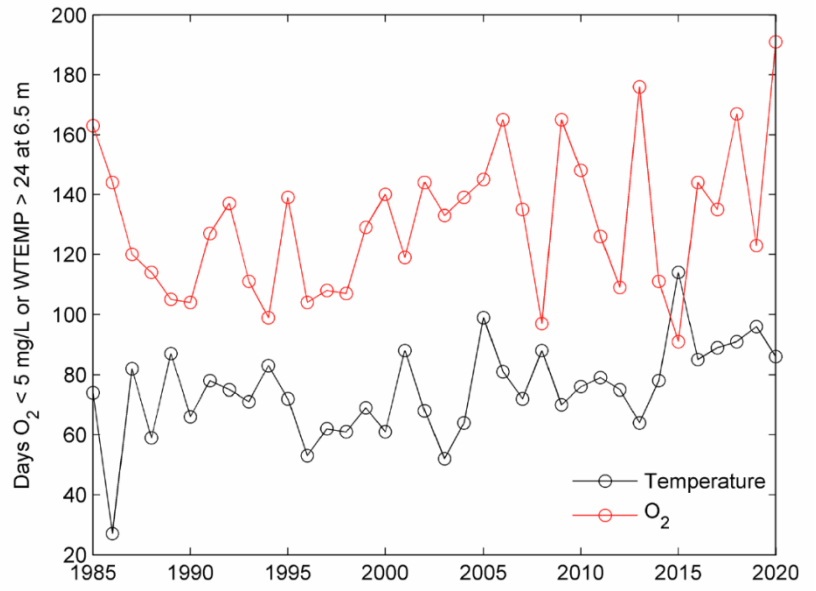
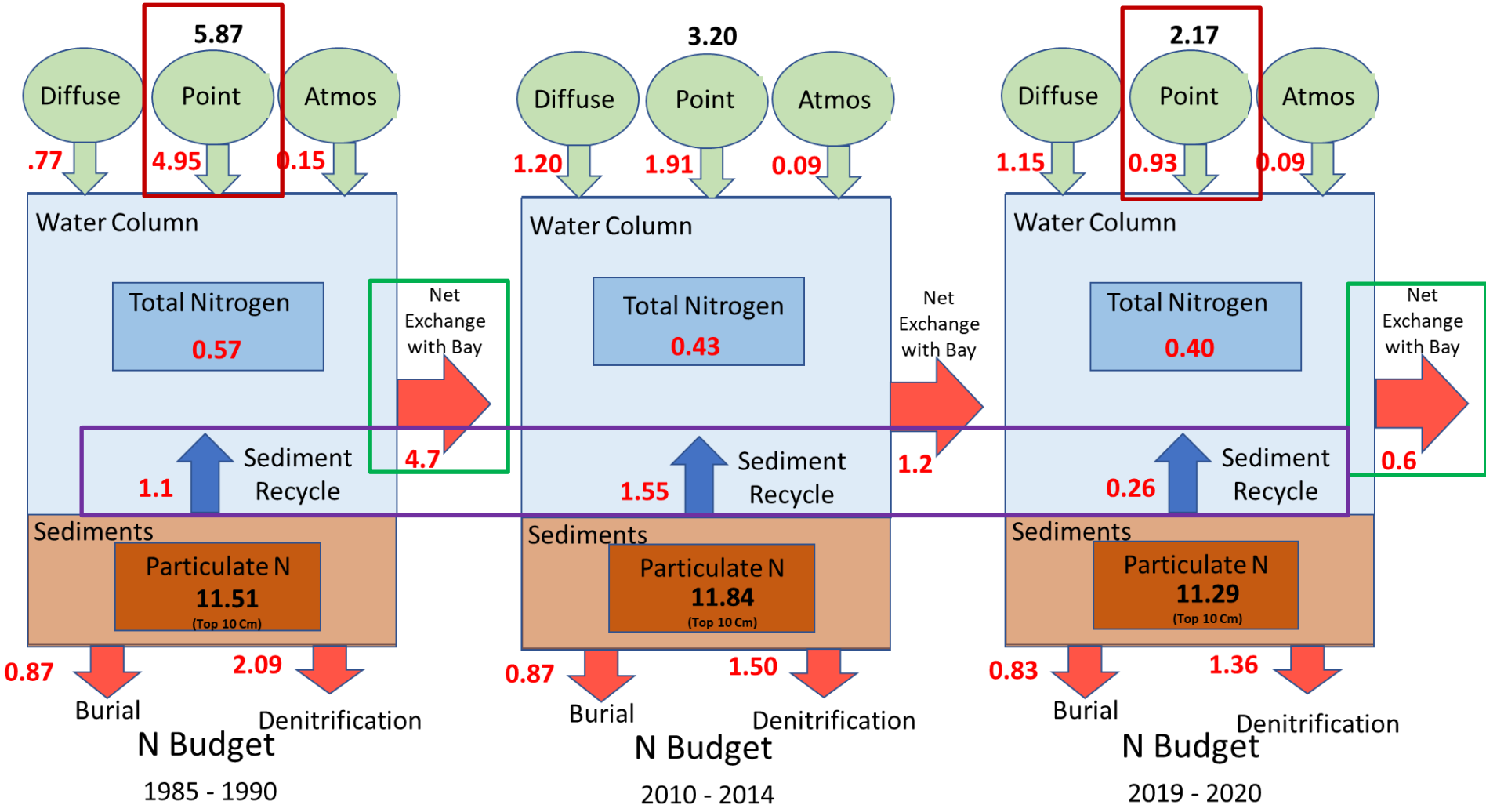




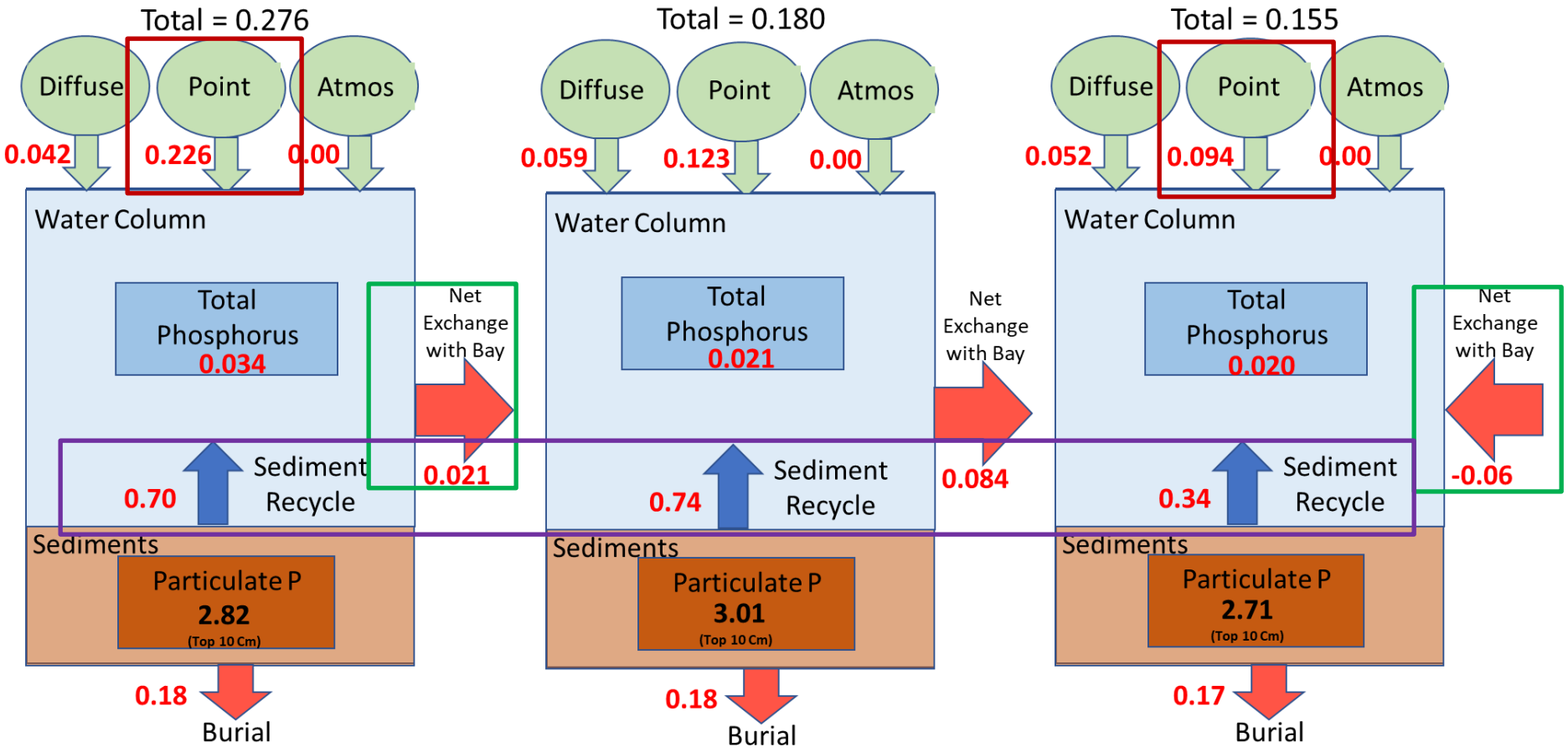
- Anoxia persists over time, but is more restricted to deeper depths
- Fewer days below 5 mg/L in recent years, but 'shallowing' of water below this threshold

Nitrogen Budget: Export to Bay has Declined, Sediment Recycling Important



Units for all flows = Kg N year $^{-1}$ x 10^6 Units for storages = Kg N x 10^6

Phosphorus Budget: Export to Bay has Declined, Sediment Recycling Important



Units for all flows = Kg P year $^{-1}$ x 10^6 Units for storages = Kg P x 10^6

Conclusions

(1) There is a signal of decreasing N and P concentrations in estuary consistent with WWTP load declines (WWTP previously dominated by Industrial load)

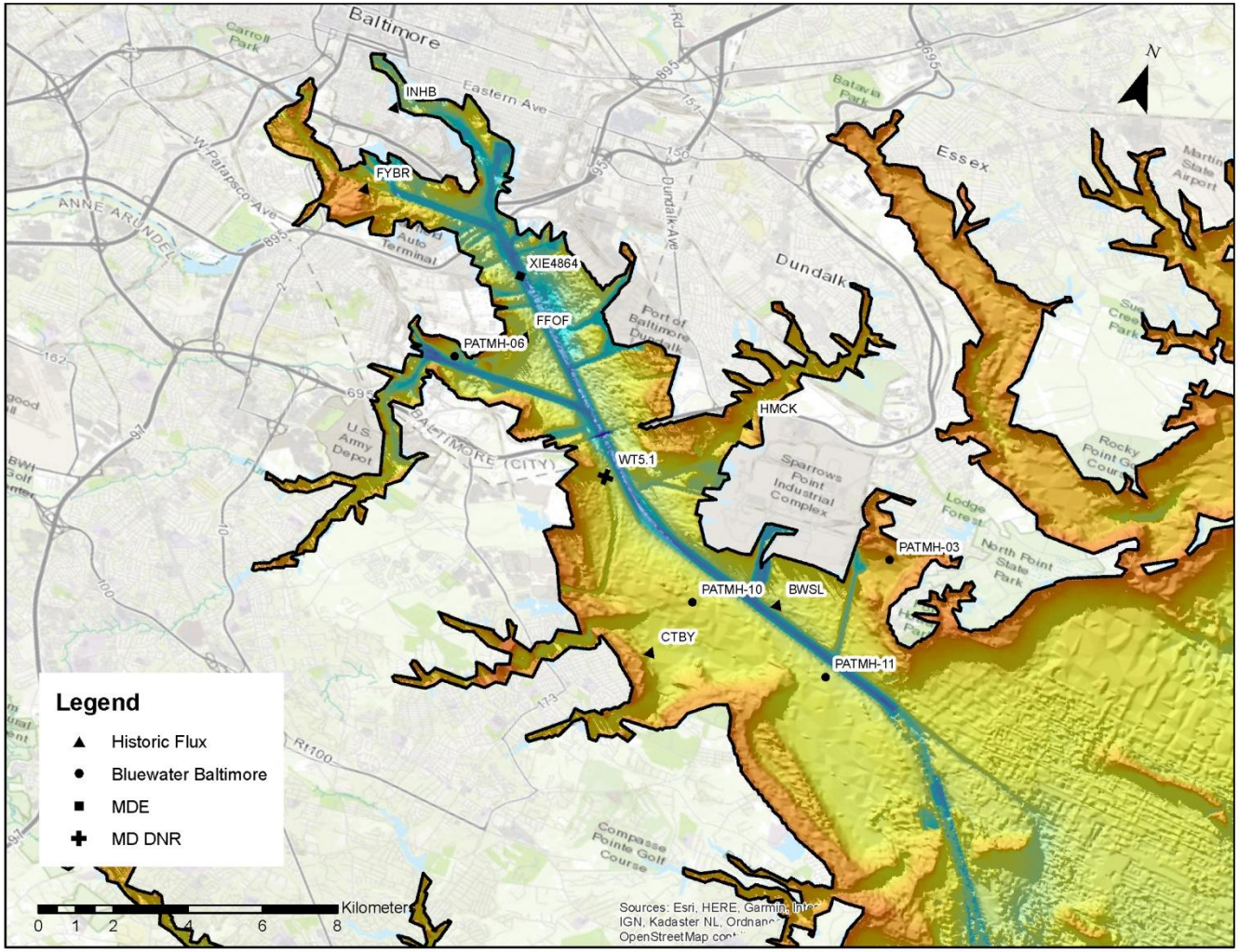
(2) N and P further declined with upgrade to Patapsco WWTP

(3)Exchange with the mainstem Bay is important:

- evidence for chlorophyll-a import from mainstem
- reduced N loads to Patapsco led to reduced Patapsco loads to Bay
- P exchanges with Bay may now be comparable to external loads

(5) Sediment-water recycling of N has declined as load declined, but P fluxes from sediments remain an central part of the budget

Sediment-Water Flux Survey in 2023

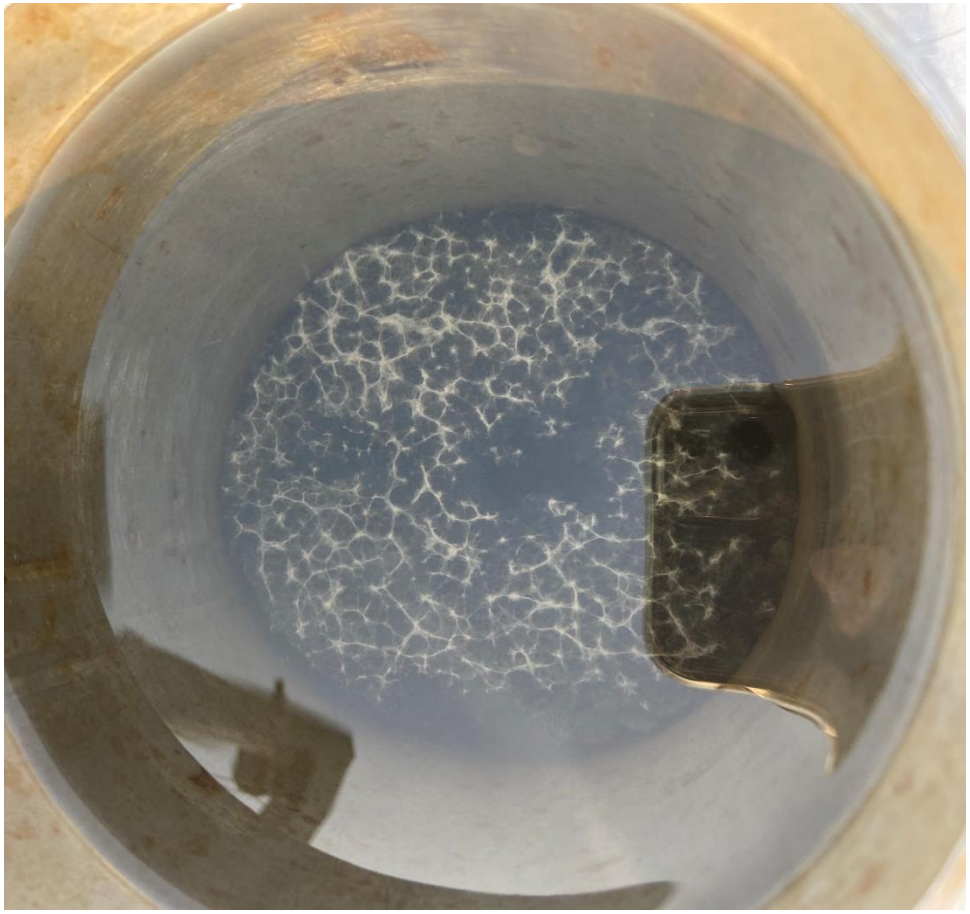


Sediment-Water fluxes of N, P, and O_2 at 12 stations in May and August 2023

Goals: Examine long-term changes, validate models, and balance nutrient budgets

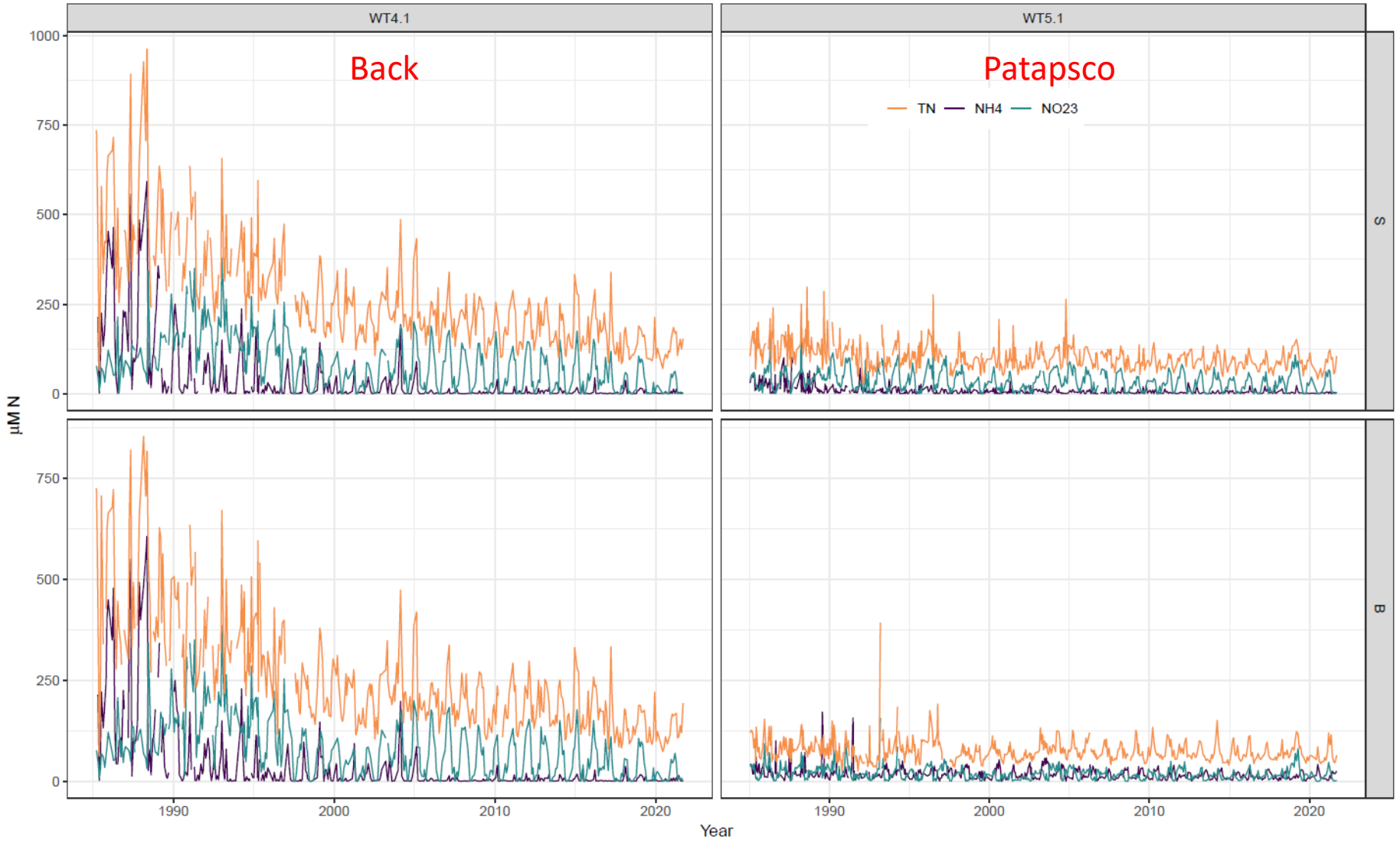
Sediment-Water Flux Survey in 2023

Likely *Beggiatoa* at ~0.7 mg/L in Inner Harbor



Thanks to MDE for their support: Dinorah Dalmasy, Guido Yactayo, Jeff White

Nitrogen Concentrations: Back versus Patapsco through 2021



Phosphorus Concentrations: Back versus Patapsco through 2021