# Understanding the Pros and Cons of Tiered TMDL Implementation

## Stakeholder's Advisory Committee

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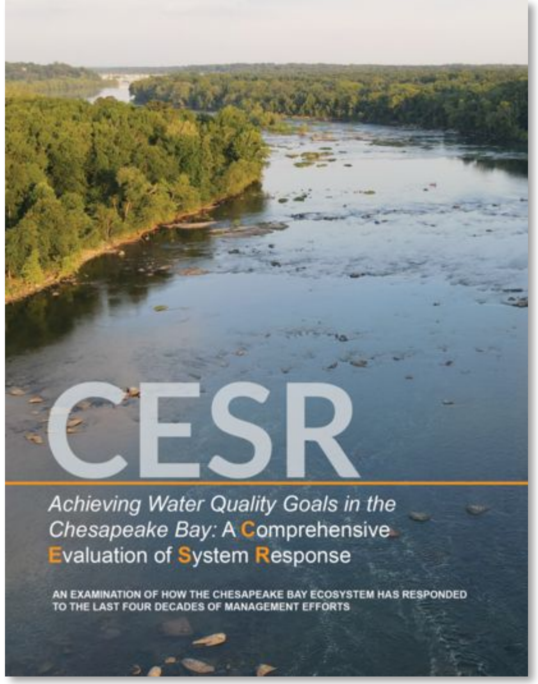
University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Chesapeake Bay Program
*Science. Restoration. Partnership.*

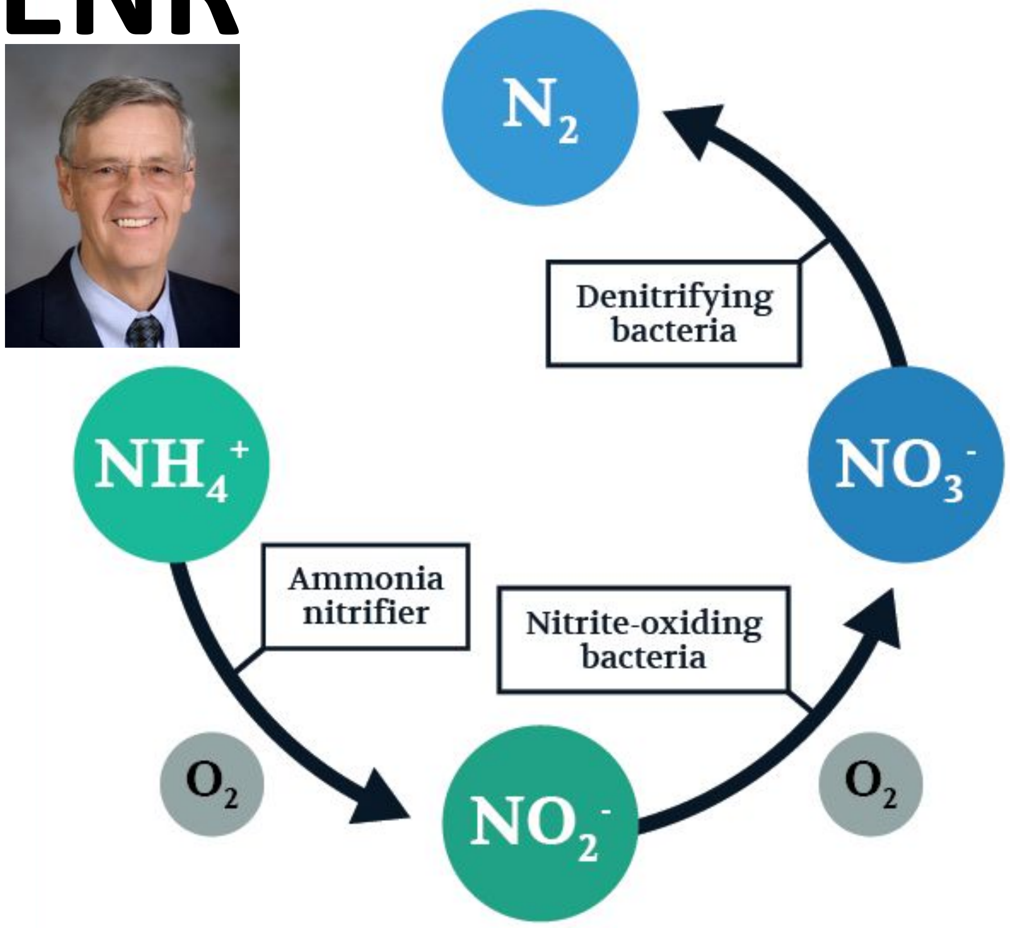
# “Hail CESR or CESR Salad?” *Kenny Rose*




- **Implementation** & **response** gaps in TMDL WIPs need **new** & **refined requirements** to control non-point sources based on **actual load reductions** & **targeting on high nutrient loss** areas and operations.
- Load reductions have not produced the expected increases in deep-water DO, water clarity & SAV, possibly due to **warming** & **non-linear thresholds**. Needs more research. Achievement of goals is uncertain and remains in distant future.
- Meanwhile, living resources can be improved by shallow-water structural enhancement & harvest management.
- Consider tiered TMDL implementation that prioritizes nutrient load reductions that impact living resources in shallow waters.
- Mo’ adaptive management.

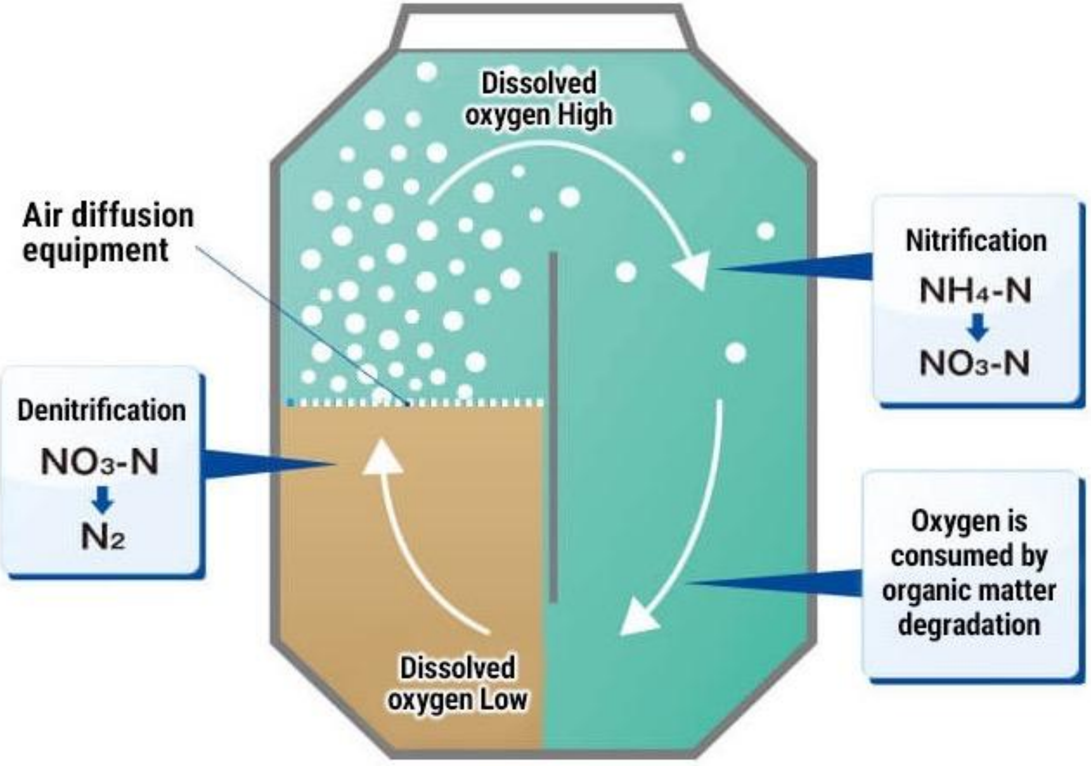
# A little chemistry . . . and microbiology

## ENR

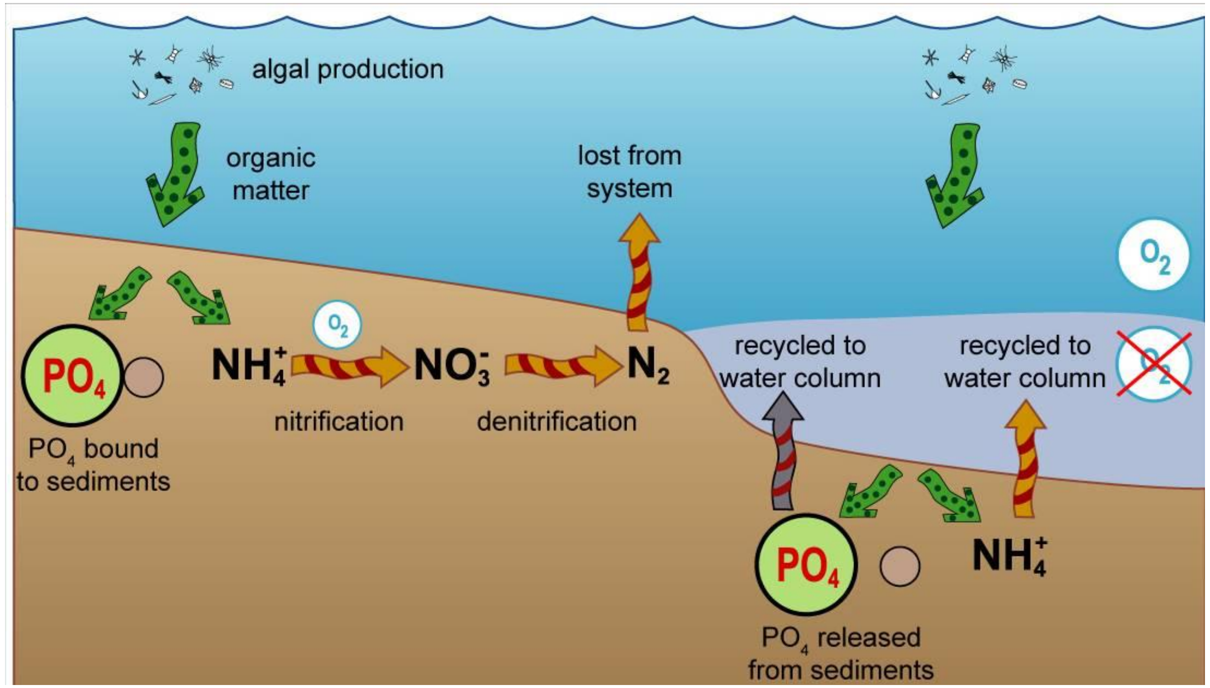



Reaction route of conventional nitrification and denitrification

Anaerobic single-tank nitrification/denitrification process

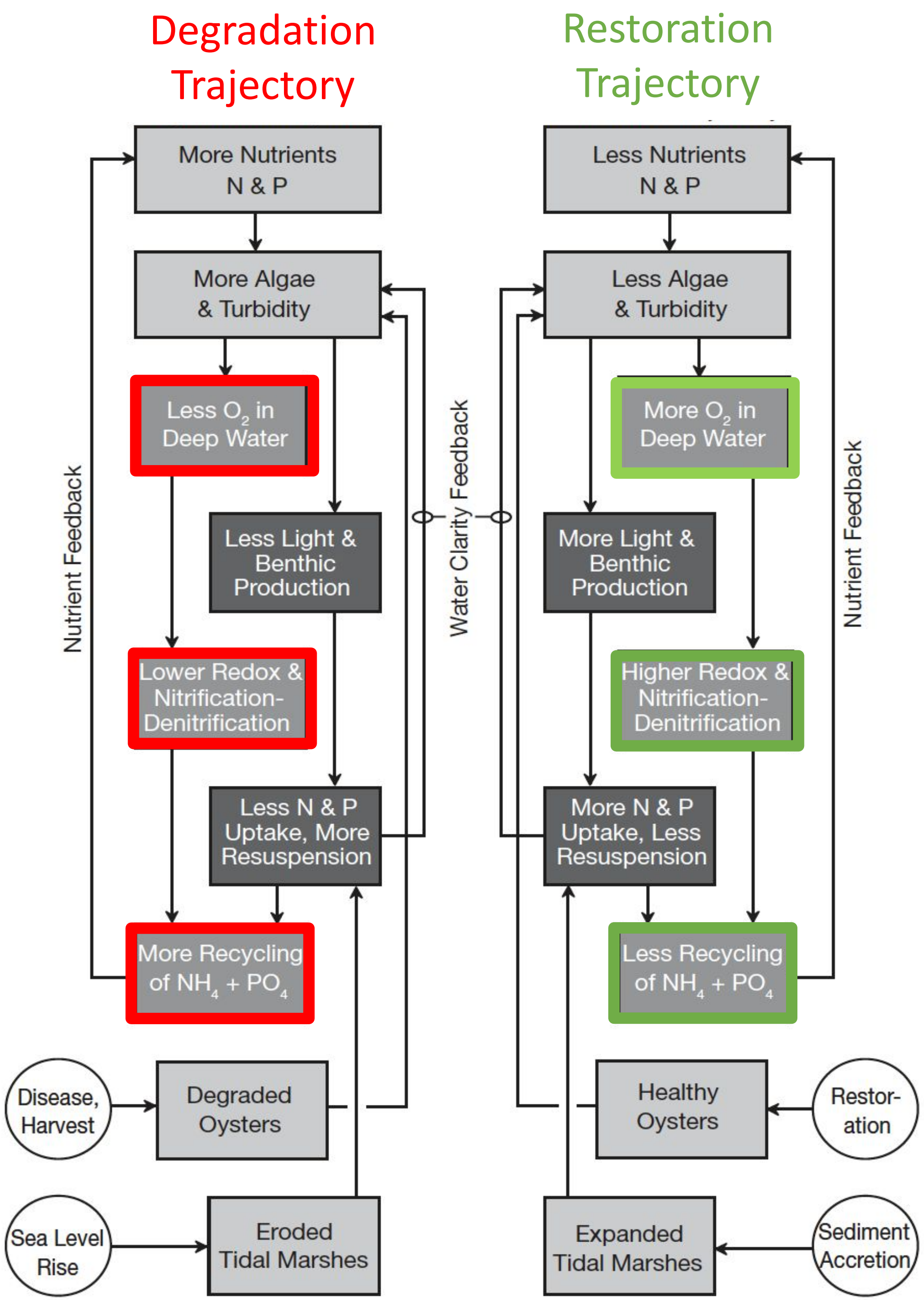


# It happens in the Bay as well




Boesch, Brinsfield & Magnien 2001
*J. Environmental Quality*

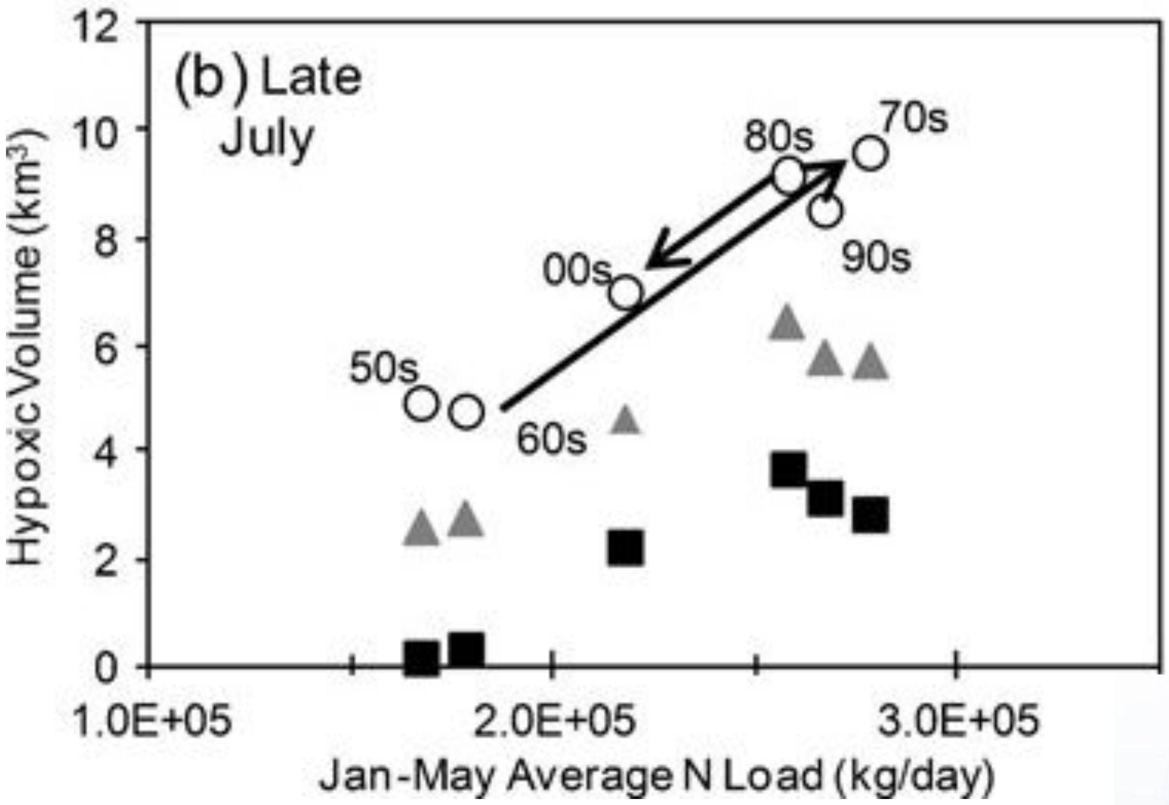
Kemp et al. 2005 *MEPS*



# Indicators of recovery

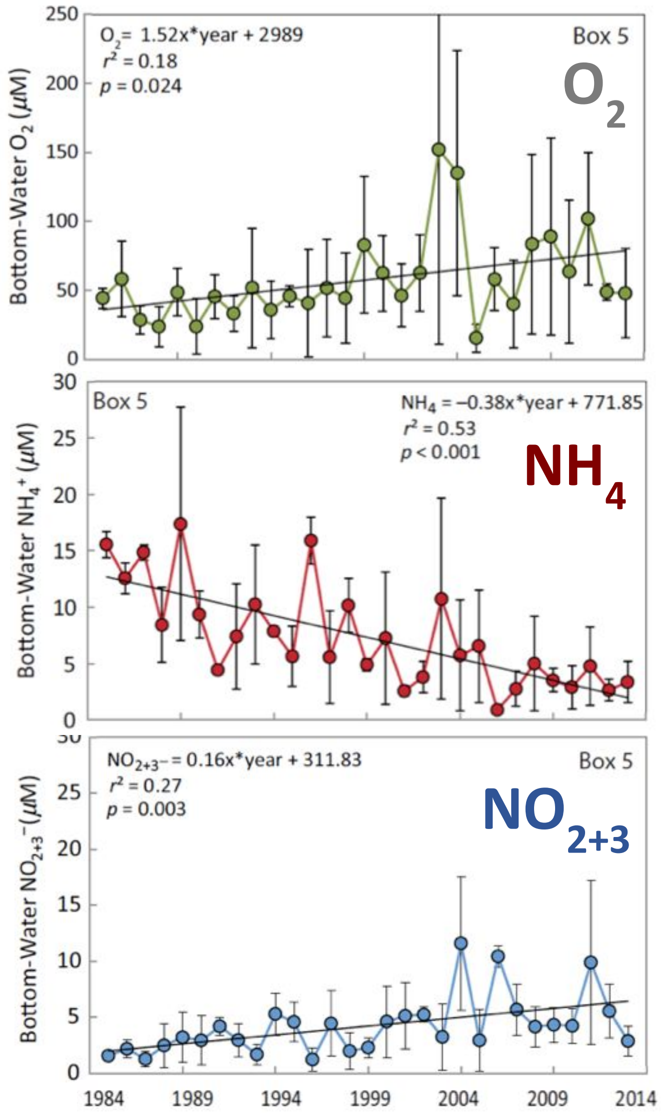
## Hypoxia

○ <2 mg/L ▲ <1 mg/L ■ <0.2 mg/L



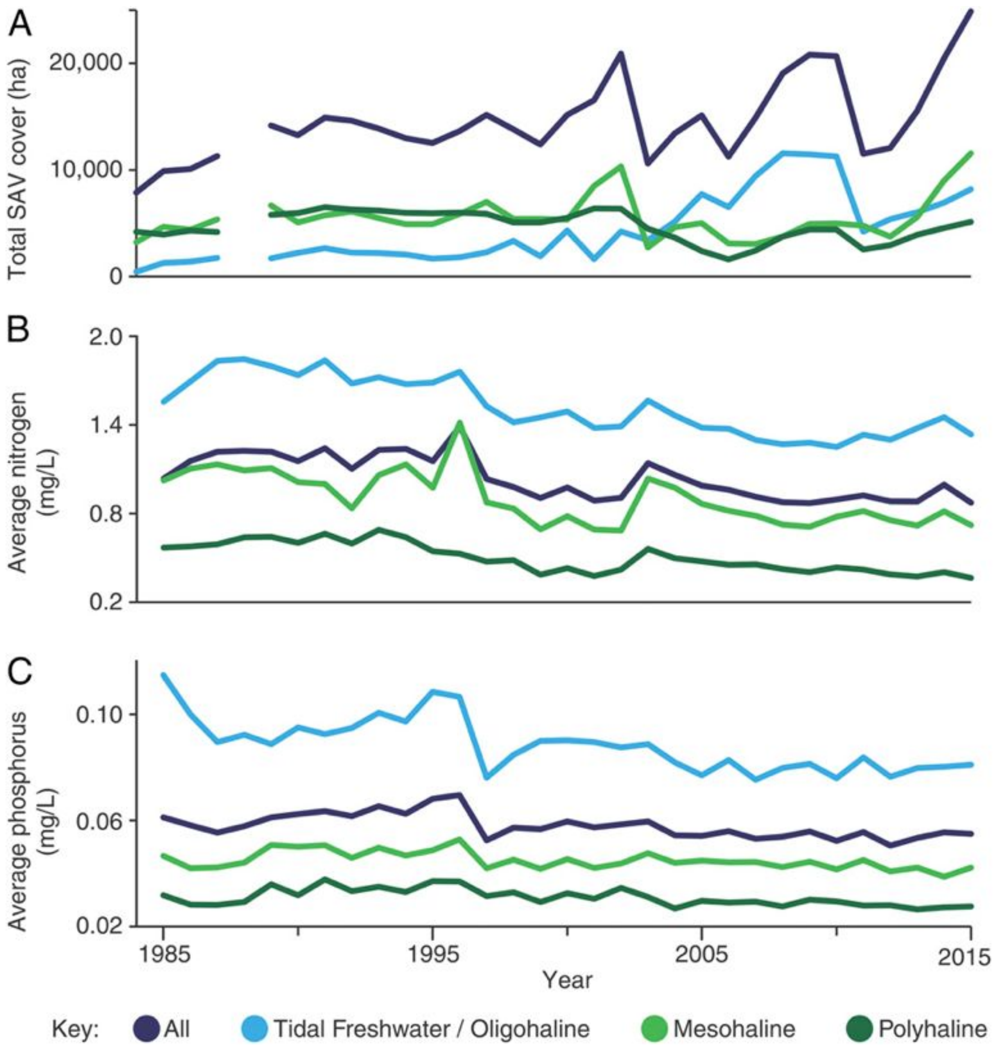

Murphy et al. 2011 *Estuaries & Coasts*

## Nutrient cycling




Testa et al. 2018 *L&O*

# More encouraging signs



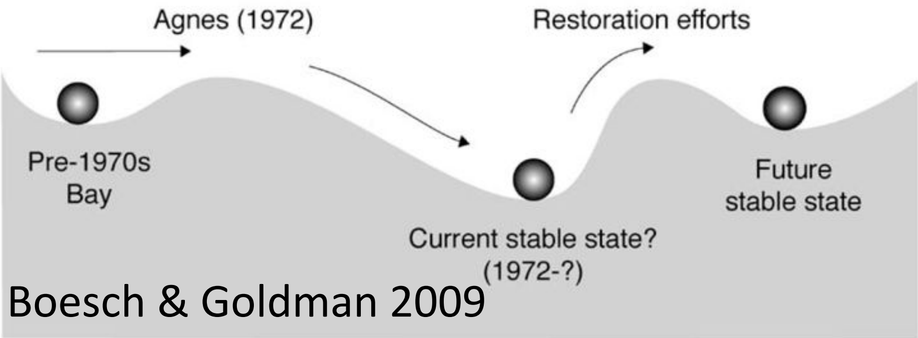

Lefcheck et al. 2018 *PNAS*

- ✔ Decline in late summer hypoxia attributed to reduced Susquehanna N loads (Murphy et al. 2011)
- ✔ Better DO criteria attainment in 2014–2016 than 1985-87 (Zhang et al. 2018)
- ✔ Modest DO increases despite warming effect (Ni et al. 2016)
- ✔ WQ indicators (DO, clarity, chlorophyll) improved 1985–2016 (Murphy et al. 2018)
- ✔ Decline in nutrient concentrations in Bay (Murphy et al. 2022)
- ✔ Increased nutrient limitation of phytoplankton (Zhang et al. 2021)
- ✔ Increase in SAV cover owing to N reductions (Lefcheck et al. 2018)

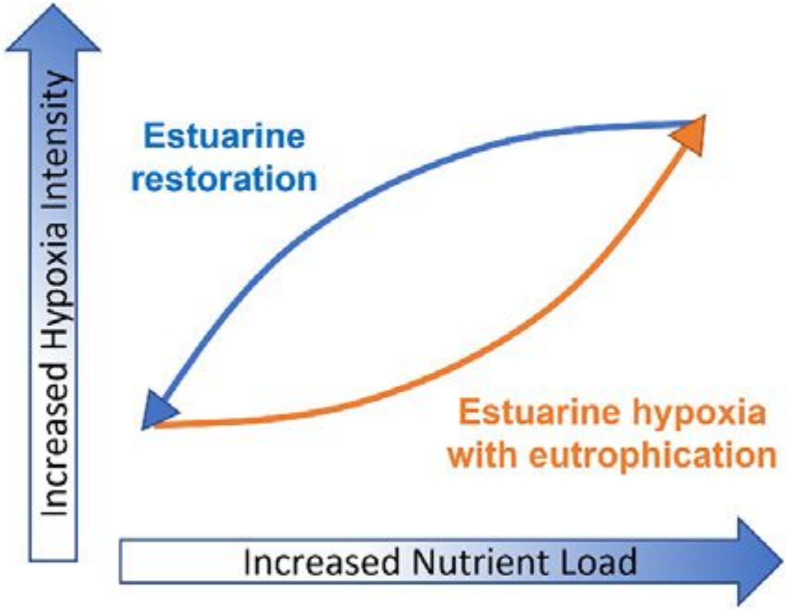
# Hysteresis between eutrophication & restoration

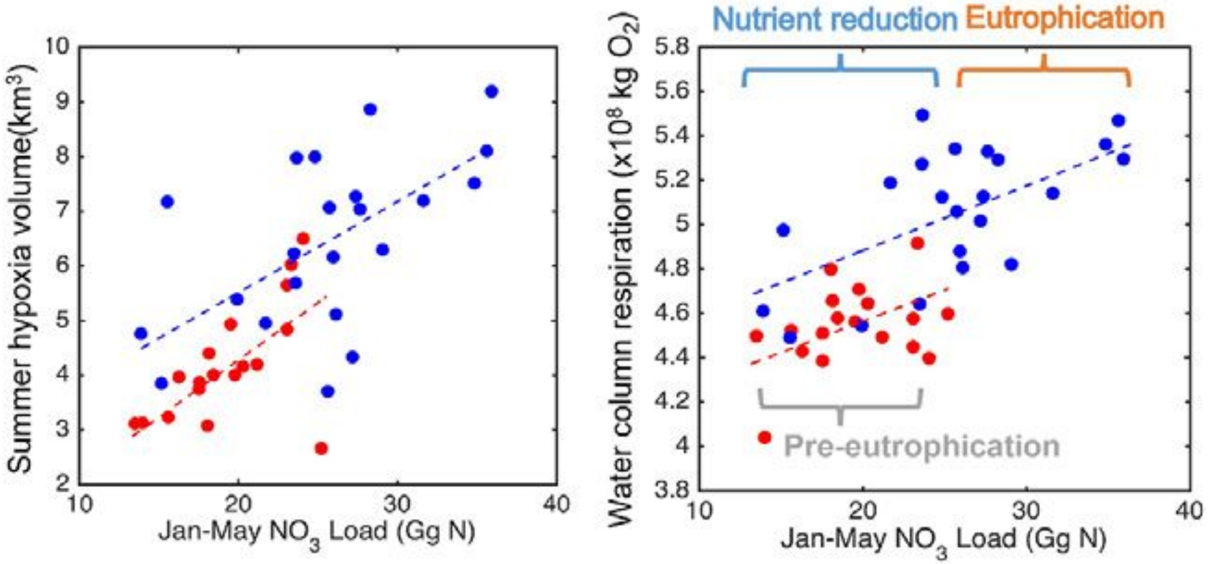
Nutrient load threshold along restoration trajectory is lower than along the degradation trajectory.

Ni & Li 2023 *Science of the Total Environment*

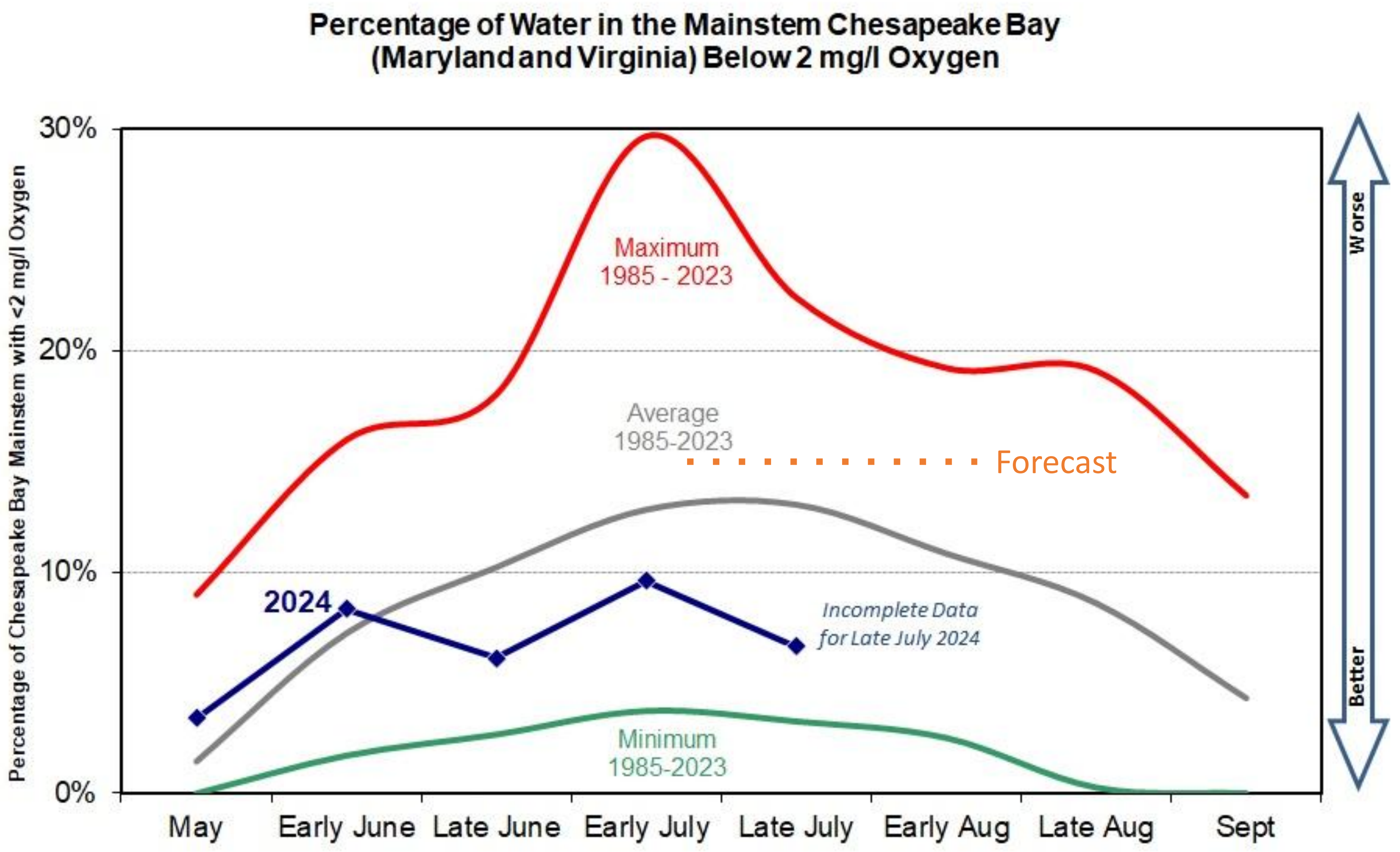



Boesch & Goldman 2009



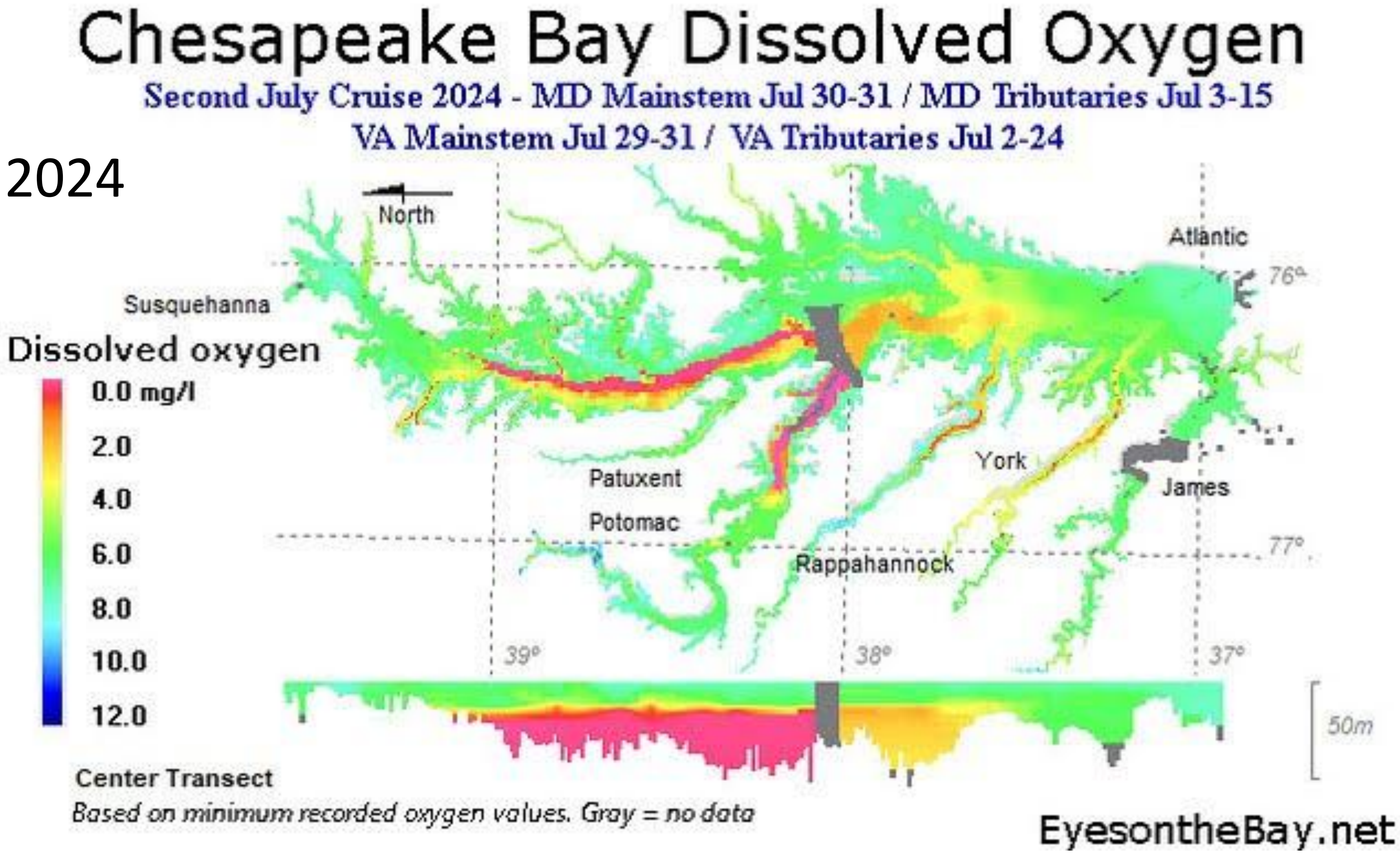



# Summer of 2024, a hopeful sign 🤞



# Hypoxia is not just a deep trough issue

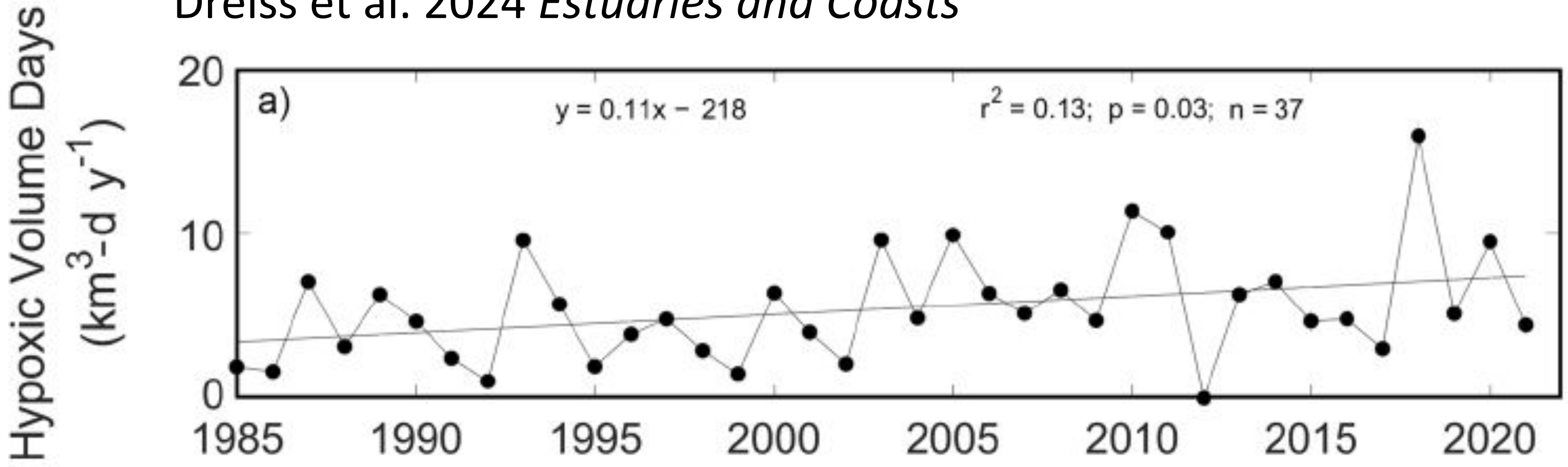
July 2024

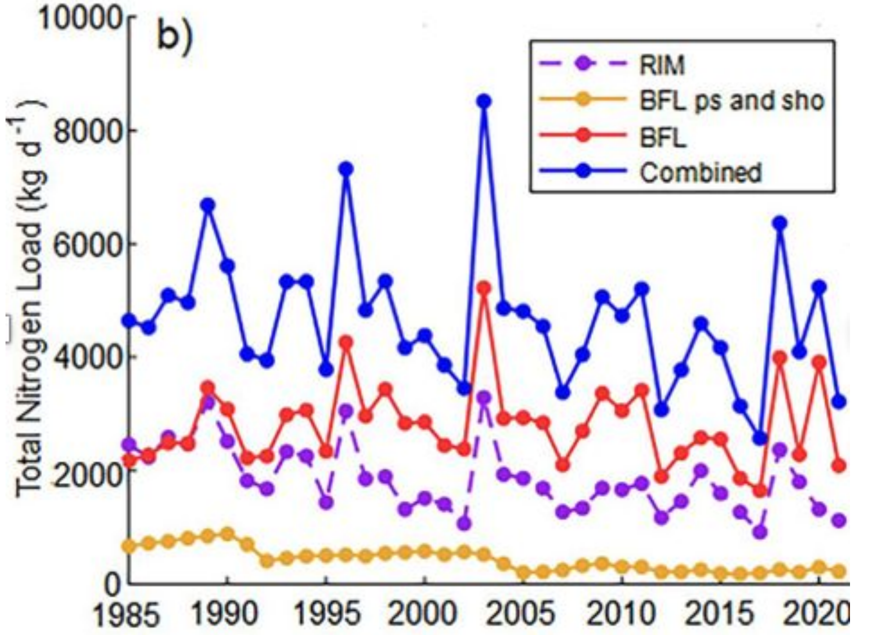


# Hypoxia also occurs in tidal tributaries

Lower Patuxent estuary: hypoxia increased while N loads declined & P loads remained steady

Dreiss et al. 2024 *Estuaries and Coasts*





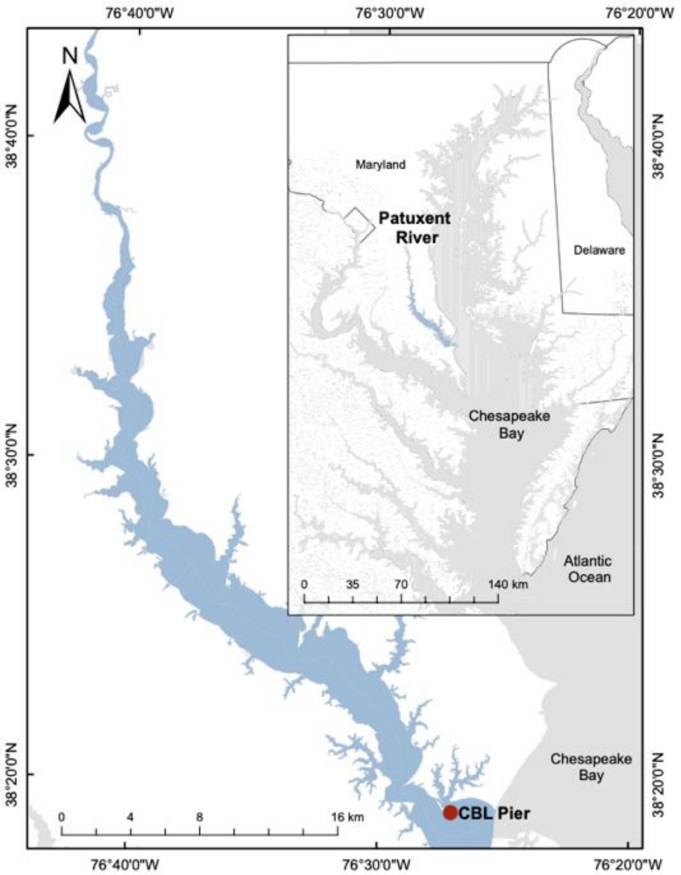




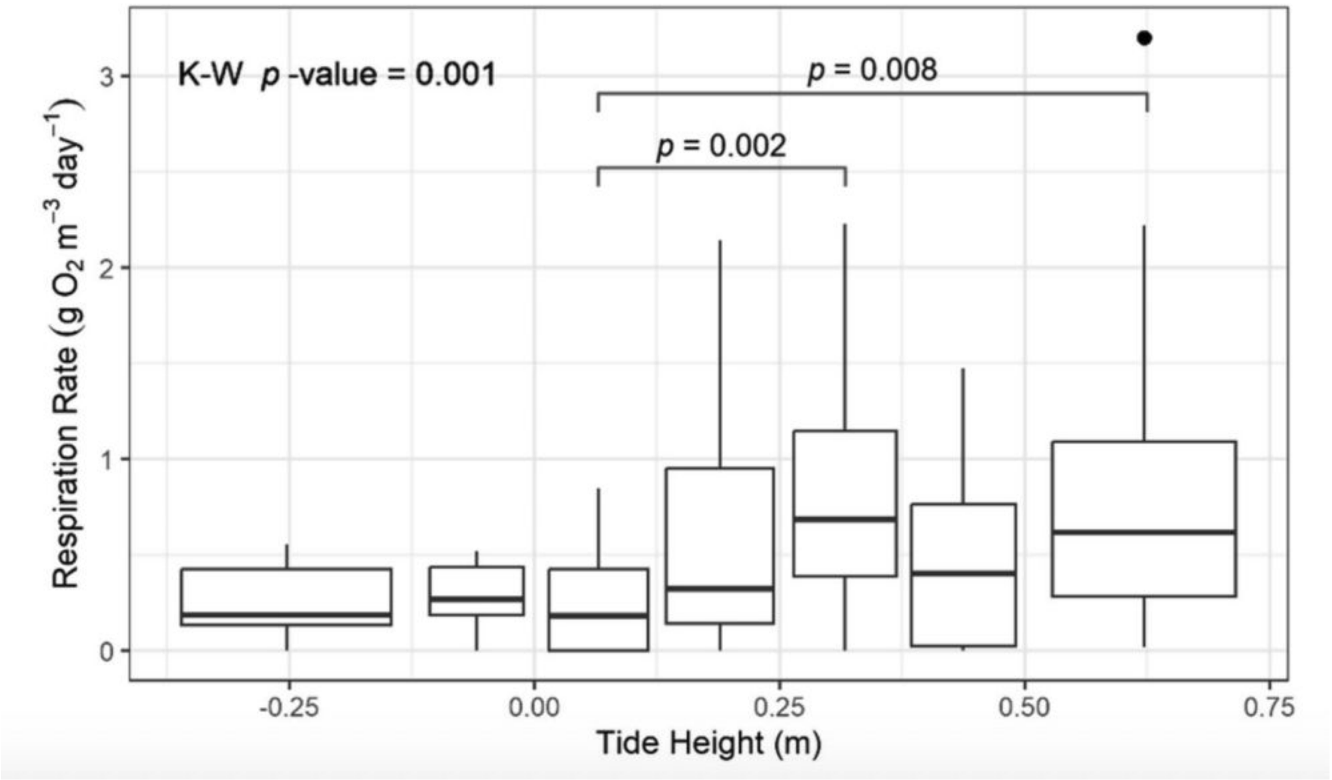
RIM monitoring
Below fall line
BFL point sources
Combined

# Nutrients imported from Bay

Oxygen consumption in lower Patuxent was higher during high tide due to import of particulate nutrients from the Bay

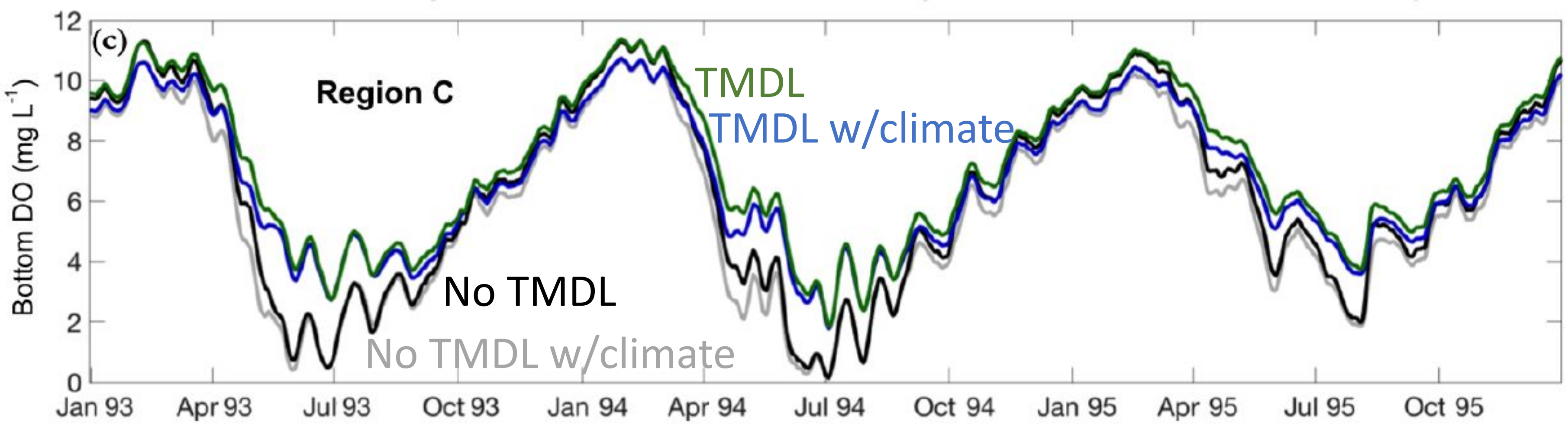


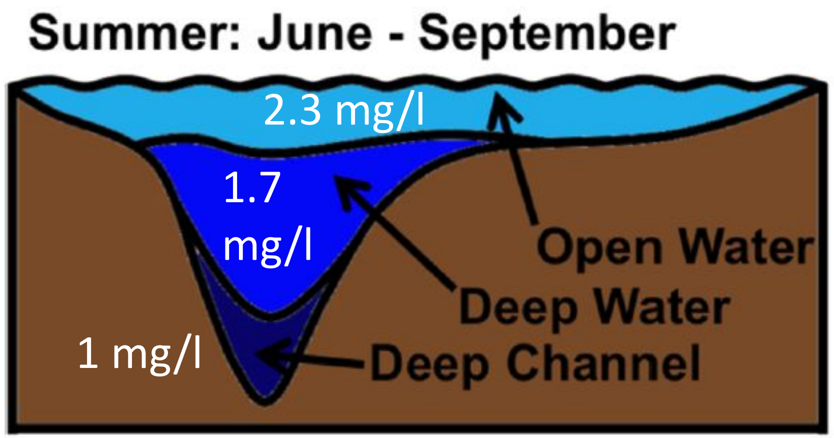

Lower Patuxent River based on eight year, biweekly time series




Prichett, Bonilla Pagan, Hodgkins and Testa 2024 *Estuaries and Coasts*

# Multiple effects of climate change on hypoxia

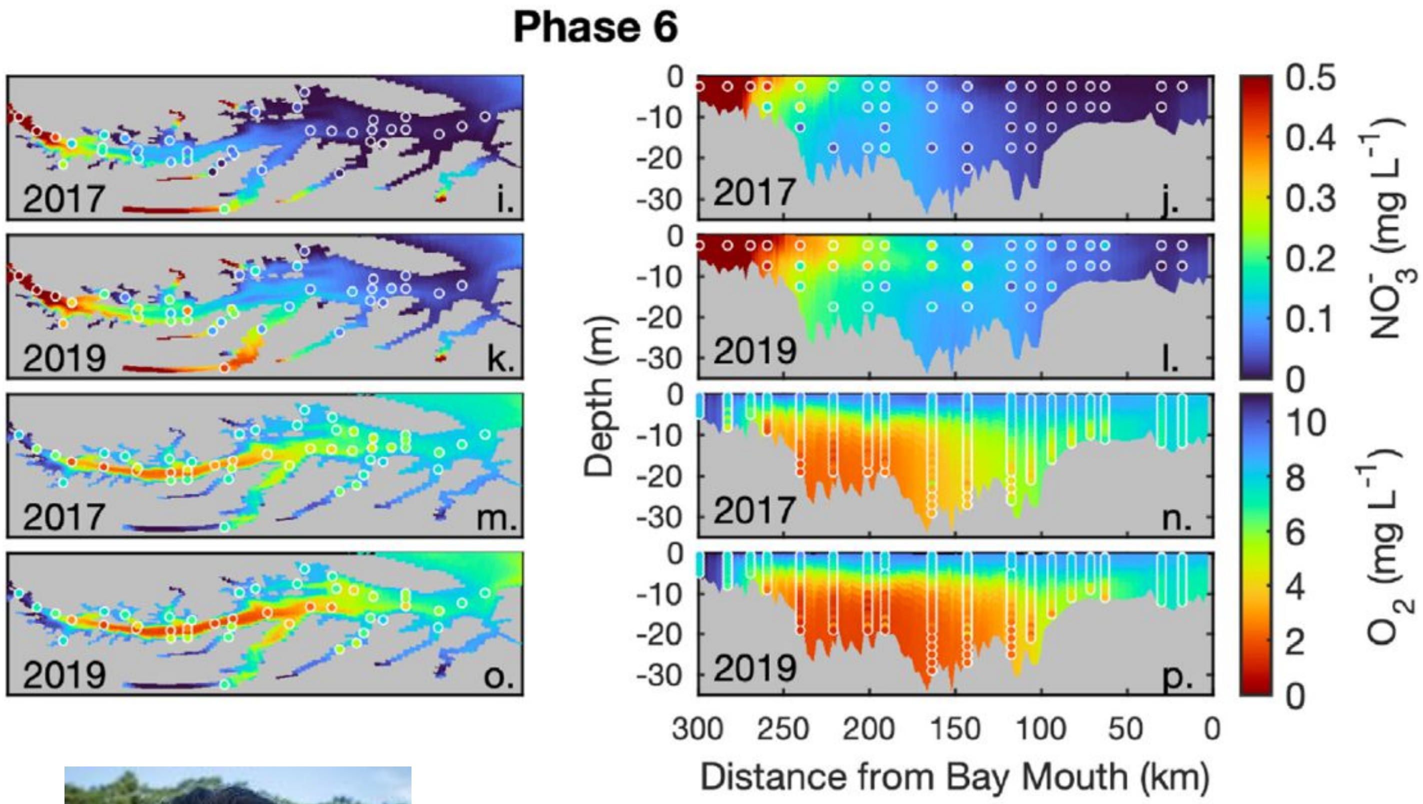



Through mid-century, climate change, mostly as a result of warmer water temperature, increased volume of hypoxia.

Nonetheless, achieving the TMDL would result in substantially less hypoxia.

# Nitrogen load reductions have decreased hypoxia




**Without the nitrogen load reductions achieved hypoxia** would:

- Be of substantially **greater volume**

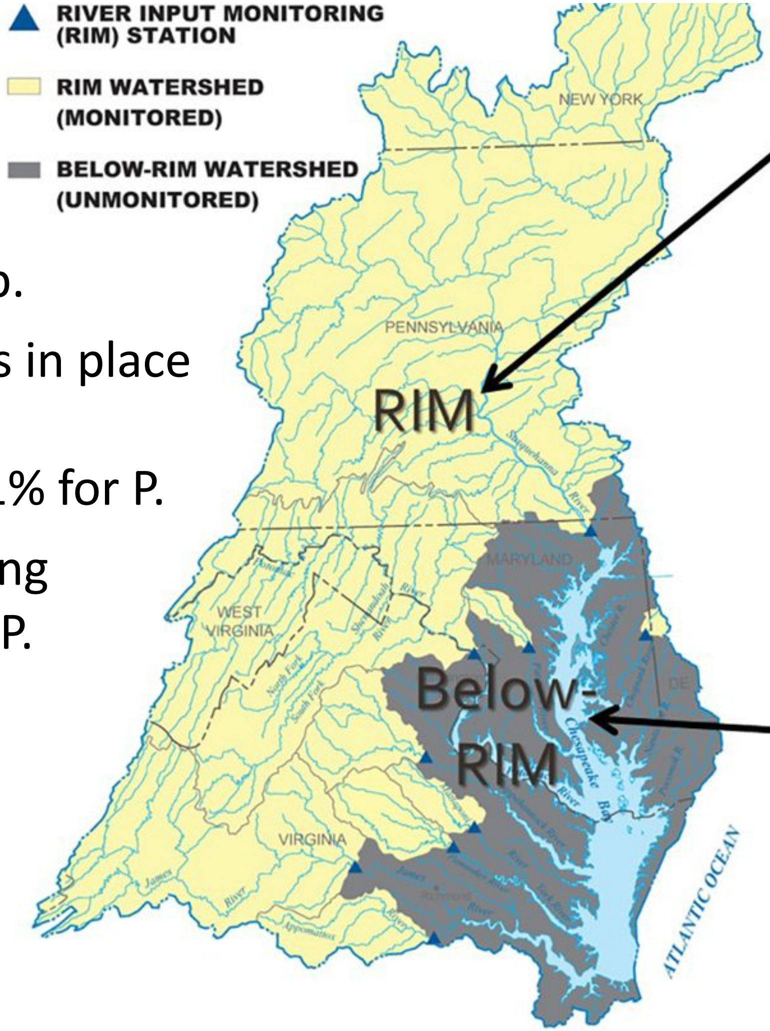
| | Avg. year | Dry year |
|---|---|---|
| $O_2$ <3 mg/L | 50–120% | 20–50% |
| $O_2$ <1 mg/L | 80–280% | 30–100% |

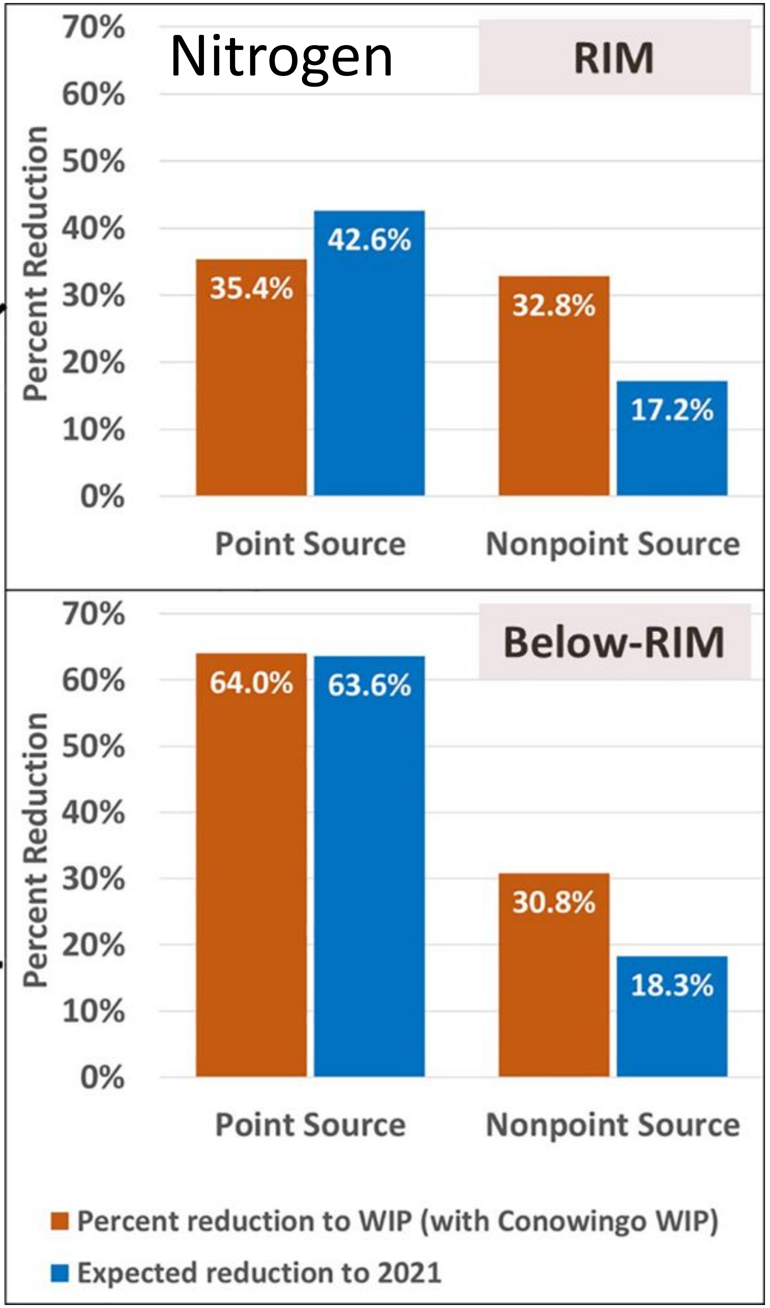
- Extend **farther down the Bay**
- **Last longer**

Frankel et al. 2022 *Science of the Total Environment*

# Matching models & monitoring

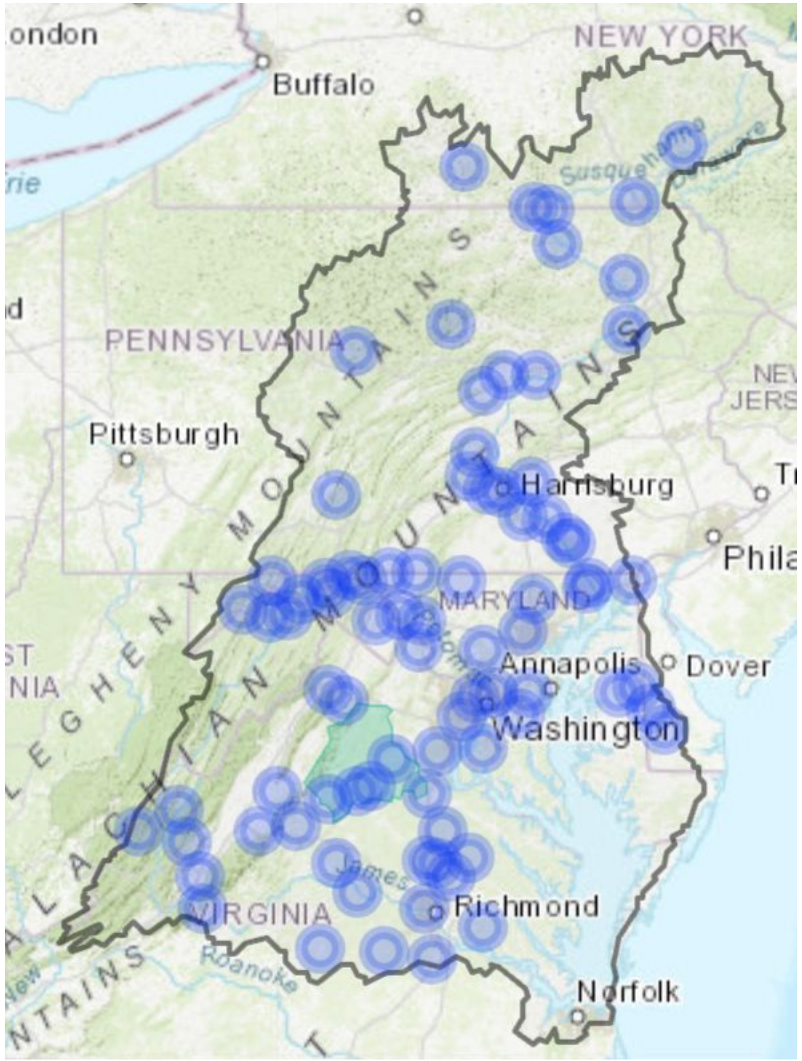
- Estimated lagged response gap.
- Management implementations in place in 2021 represent 60% of total reduction needed for N and 51% for P.
- Compared to WRTDS monitoring trends; large response gap for P.

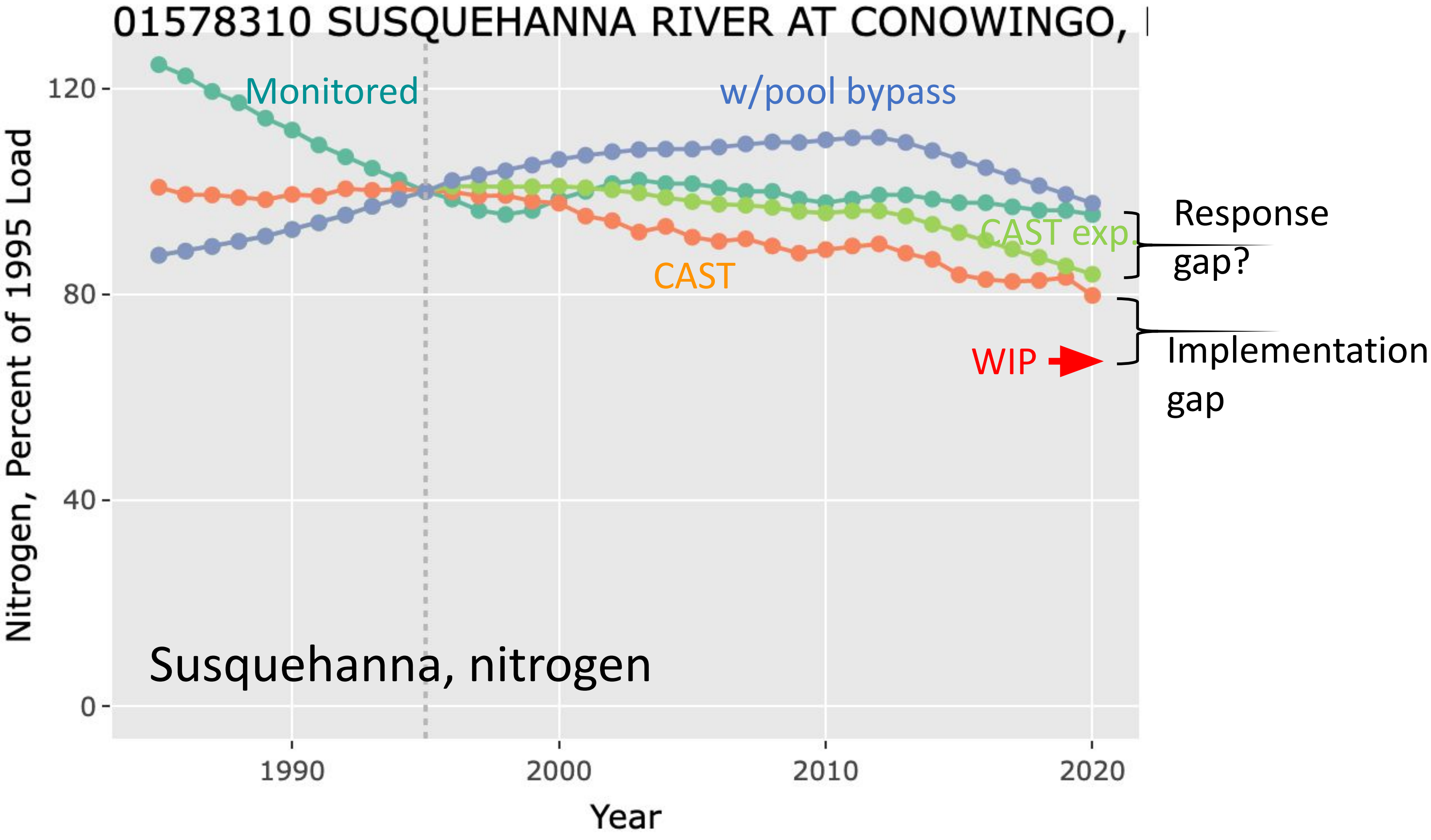


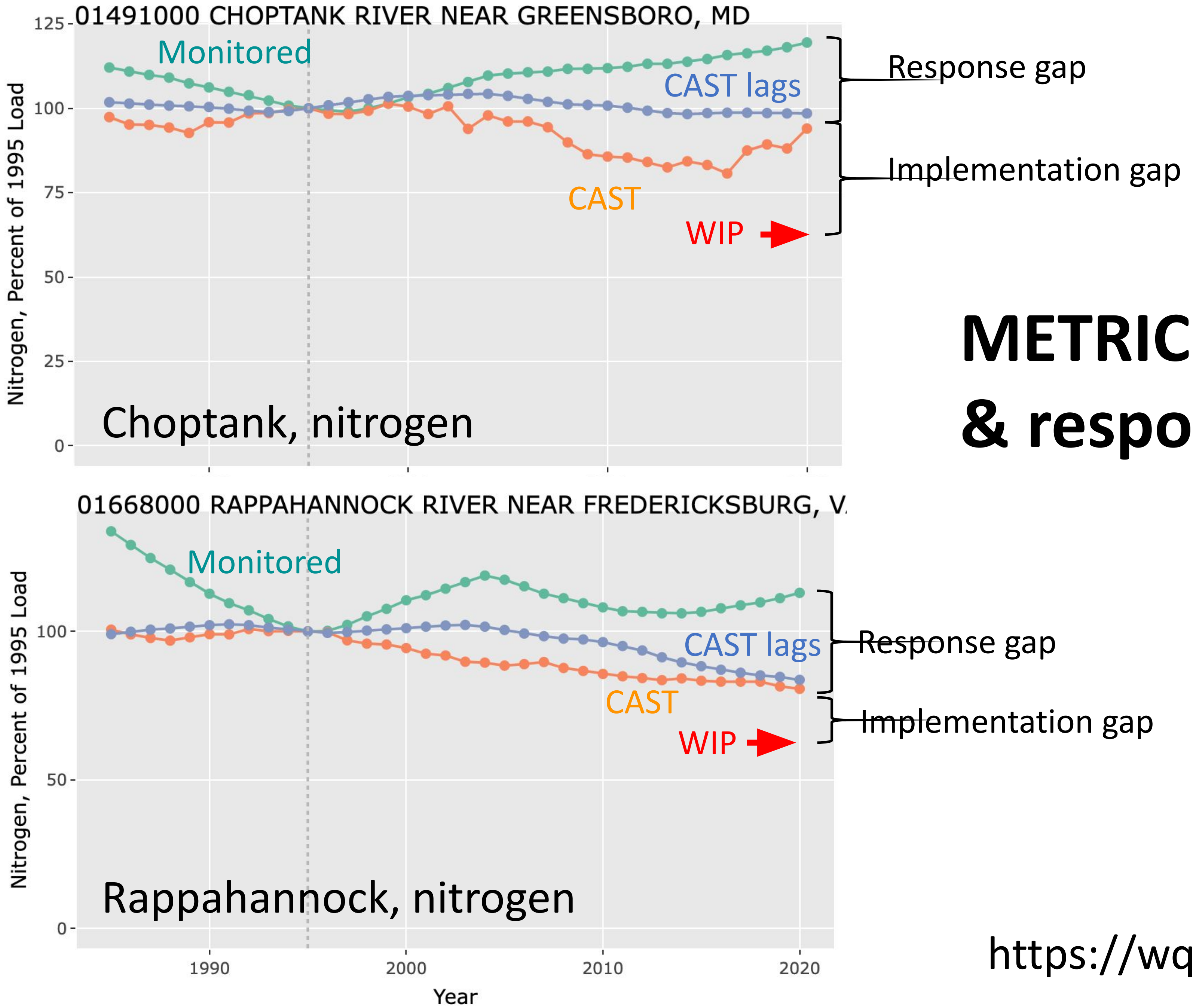

Zhang et al. 2024 *Ecological Indicators*

# METRIC: CAST expected vs. monitored




https://wqs.chesapeakebay.net/metric/

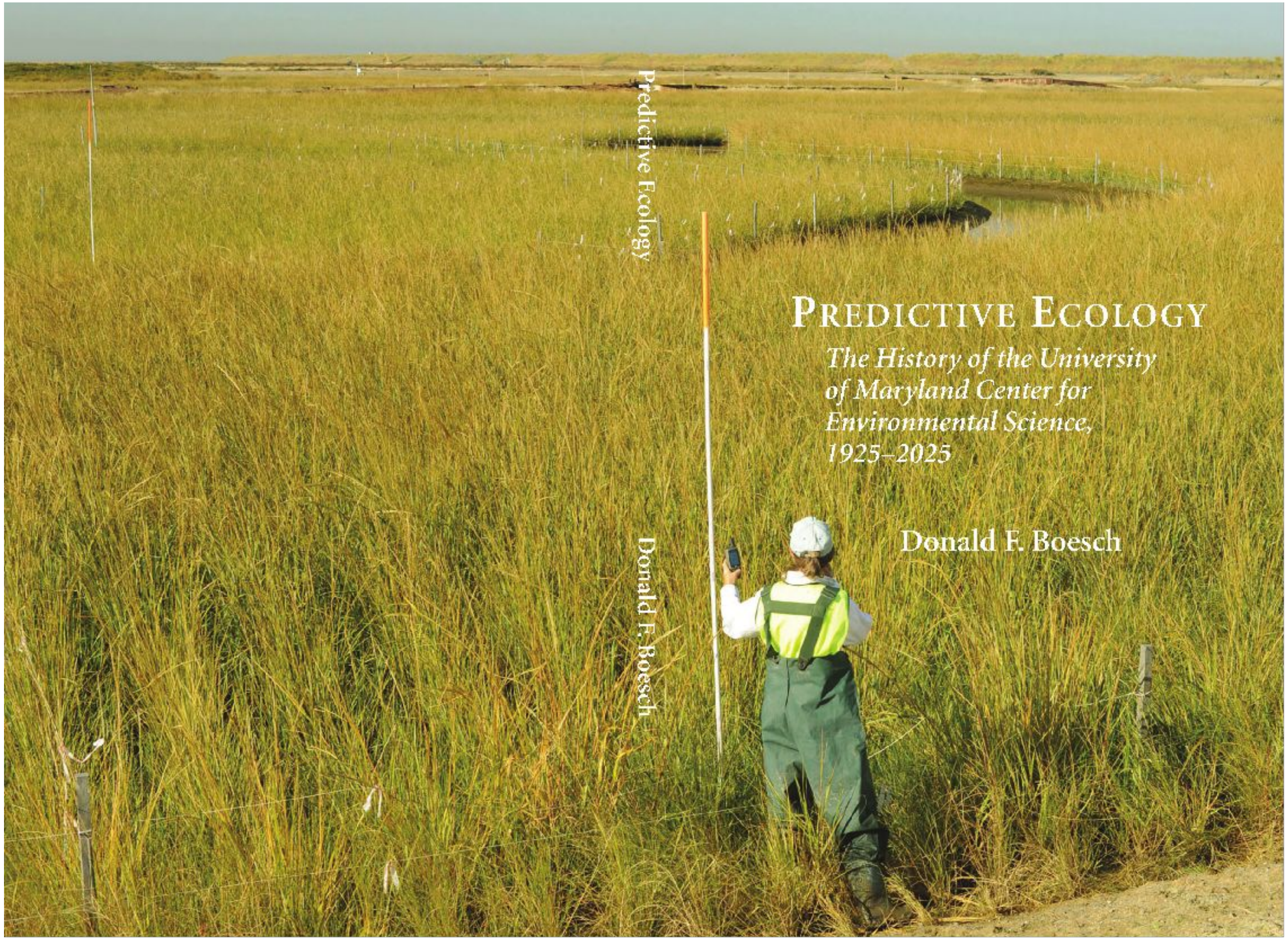



# METRIC: Implementation & response gaps *a la* CESR

https://wqs.chesapeakebay.net/metric/

# So what do we do about the TMDL?

- WIPs have been and will be adjusted for climate and other changes; they are unlikely to lower load reductions required.
- Shifting priorities to shallows is unlikely to be practical or effective, diverts attention from reducing extent and duration of hypoxia and excessive nutrient regeneration on the ecosystem scale.
- Don’t just keep foot on the TMDL pedal, but press it down to achieve the WIPs well within a decade though performance-based innovation, targeting and accountability.
- Invest in knowledge needed to manage ecosystem resilience into the future.




**Coming Soon!**

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