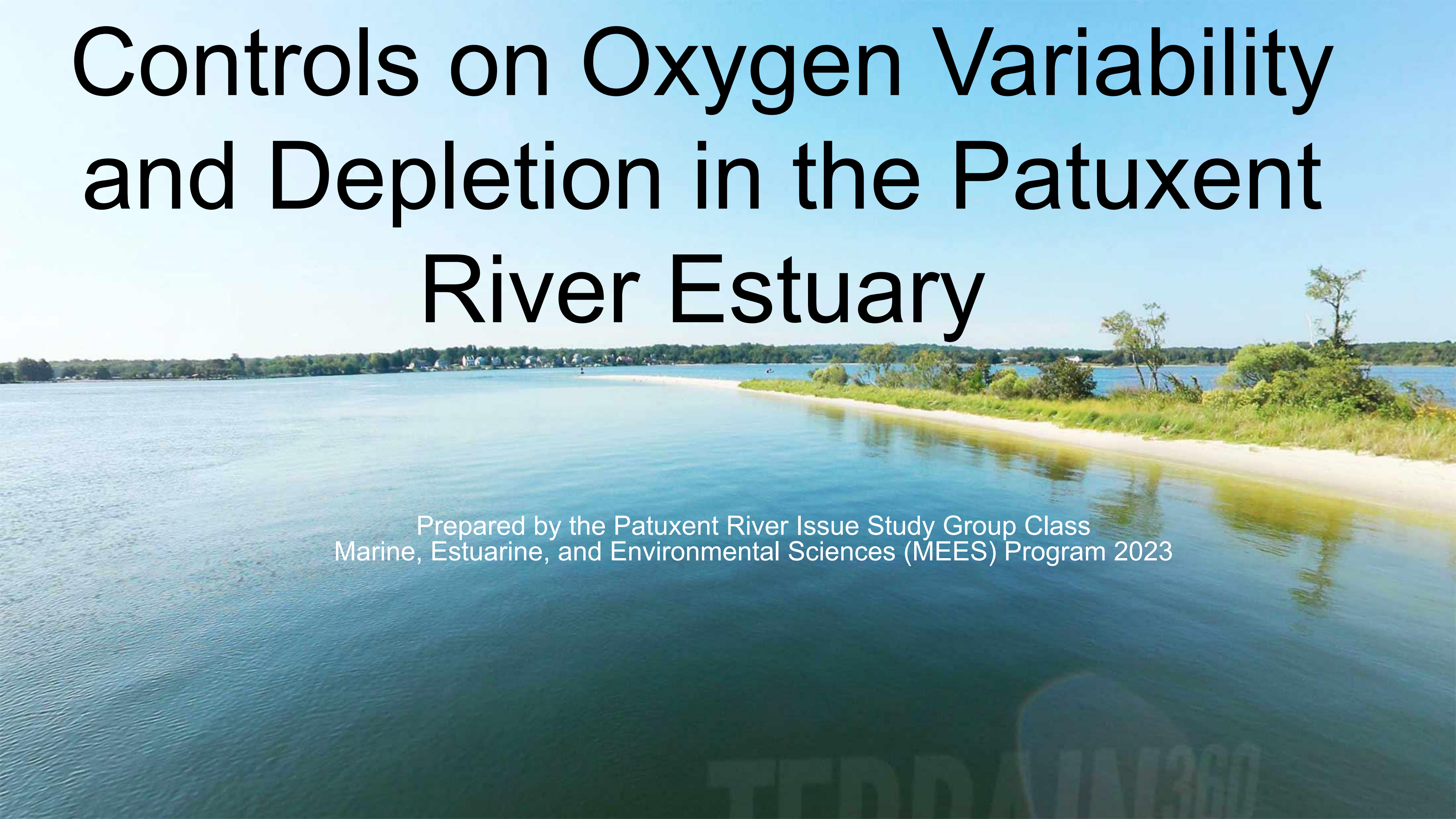
# Controls on Oxygen Variability and Depletion in the Patuxent River Estuary



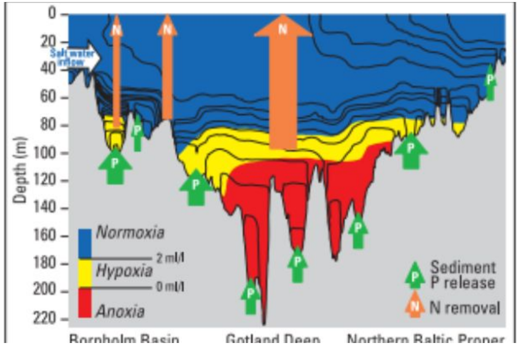
Prepared by the Patuxent River Issue Study Group Class
Marine, Estuarine, and Environmental Sciences (MEES) Program 2023

# Students Introduction

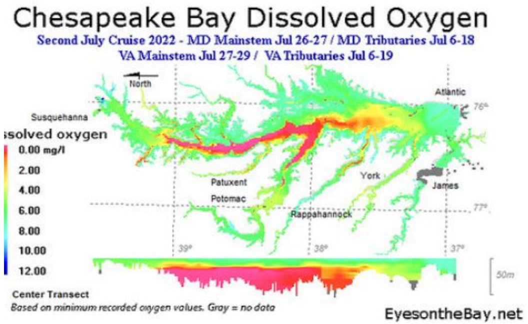
| Name | Research Interests |
|---|---|
| ALLISON | WATER QUALITY AND HYPOXIA MODELING |
| AMIR | BIOGEOCHEMICAL AND HYDRODYNAMIC MODELING |
| ANNA | METHANE CYCLING; SEDIMENT BIOGEOCHEMISTRY |
| FARDIS | HURRICANE MODELING |
| NANI (VERONICA) | SOCIAL NETWORK ANALYSIS OF PATUXENT RIVER STAKEHOLDERS |
| SADIA | STABLE ISOTOPIC MEASUREMENT AND CLIMATE CHANGE EFFECTS |

# Coastal Hypoxia and Eutrophication

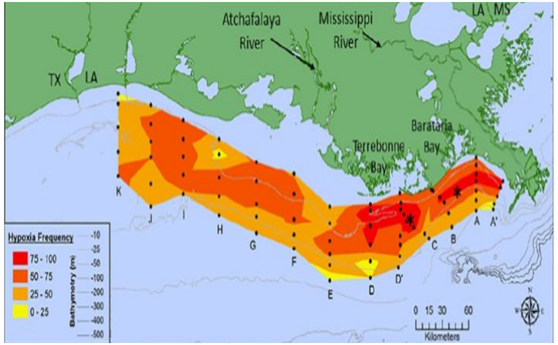

**BALTIC SEA**




**CHESAPEAKE BAY**




**GULF OF MEXICO**




https://www.epa.gov/system/files/images/2022-06/rabalais-turner-2019.png

# Why Patuxent Estuary


https://planning.maryland.gov/Pages/OurWork/PaxRiverComm/PatuxentRiverCommInfo.aspx

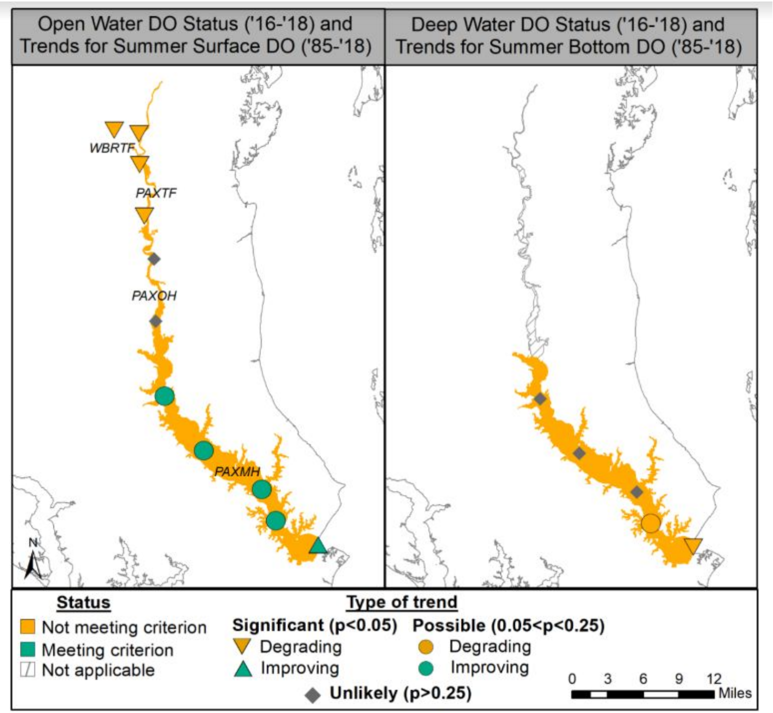
- It has oxygen depletion at multiple scales
- It has had a lot of wastewater reductions, but there is still poor water quality in the lower part of the estuary

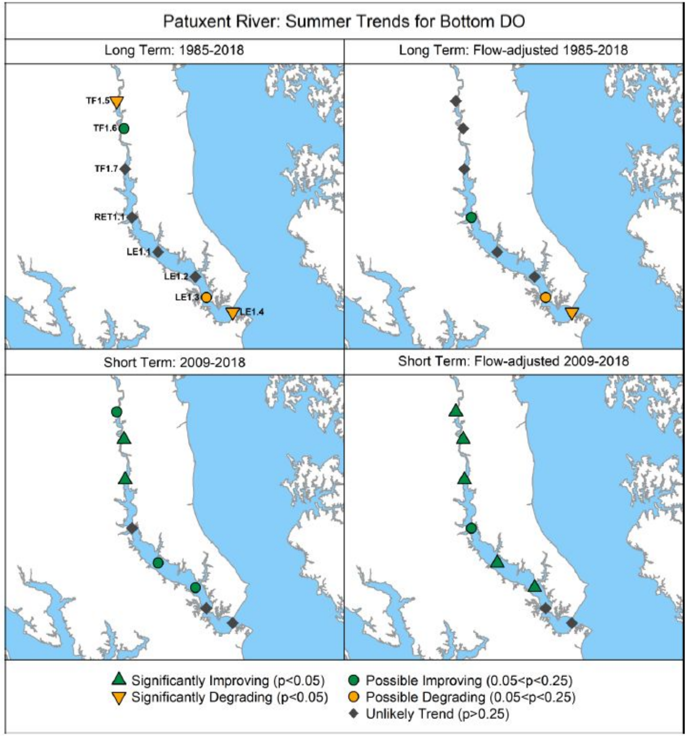
# Research Question

- What are the major factors that control oxygen depletion in the Patuxent River?
- Is there a relationship between these factors and benthic biomass?

# Goal 1: Dissolved Oxygen in the Patuxent (1930-Present)

- Sparse Dissolved Oxygen (DO) Data Pre-1985
  - Present and future assessments will rely heavily
    - Data from 1985 to Present
    - Comparable waterbodies with data rich history




ITAT report, 2021

# Dissolved Oxygen in the Patuxent (1930-Present)

- Modern Water Quality Standards → Contributing factor to short term DO improvement
  - Protect aquatic living resources
  - Specific criteria for dissolved oxygen (DO)
  - Water clarity/underwater bay grasses

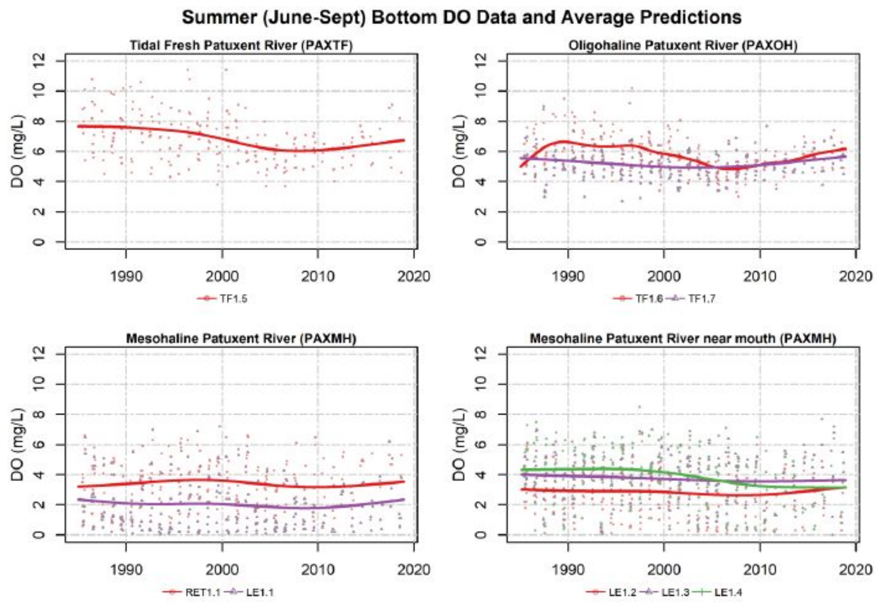


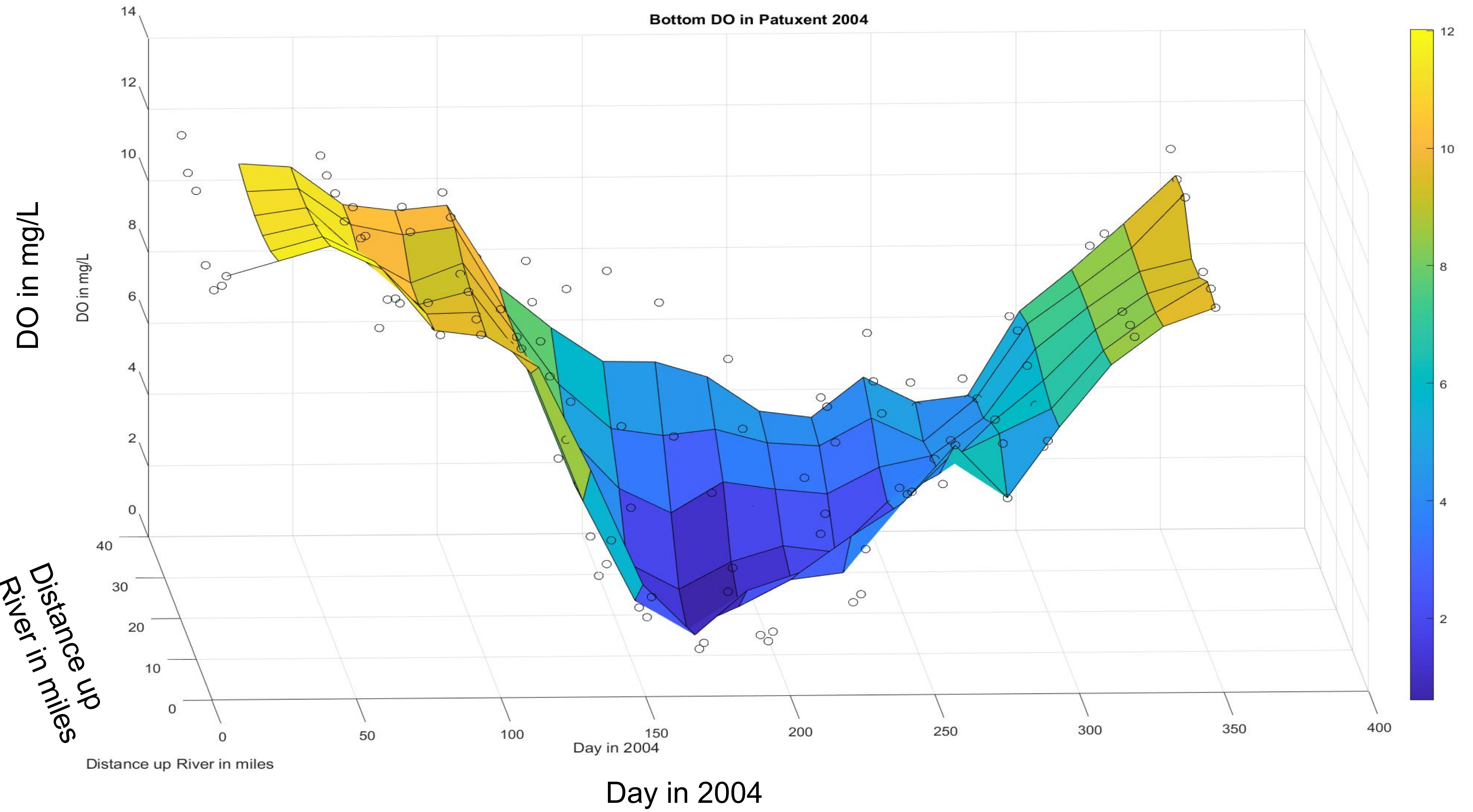

Figure 17. Summer (June-September) bottom DO data (dots) and mean seasonal long-term pattern generated from non-flow adjusted GAMs. Colored dots represent June-September data corresponding to the monitoring station indicated in the legend; colored lines represent mean summer GAM estimates for the noted monitoring stations.

ITAT report, 2021

# Goal 2: Quantify long-term changes in hypoxic volume and area (1985-2022) and quantify controls

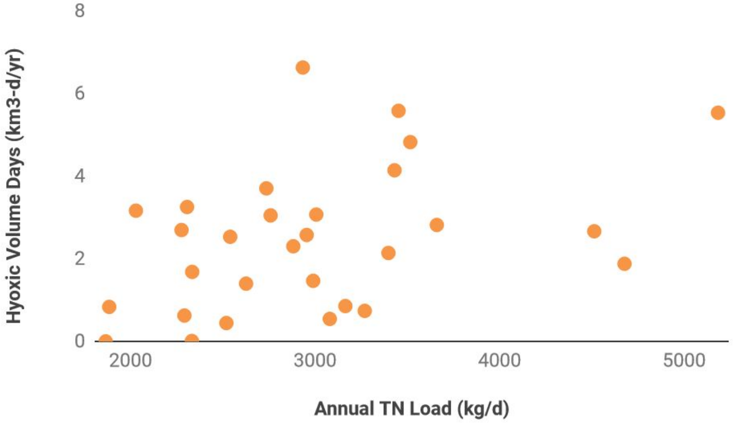
(a) Use interpolation and monitoring data to compute volumes, lengths, and areas
   (i) Explore kriging versus IDW, methods
   (ii) Compute hypoxia at various thresholds (<1, 2, 3, 5 mg/l)
   (iii) Compute stratification strength from T/S profiles

(b) Statistical models to explain size of hypoxic regions (nutrient load, flow, temperature, wind)

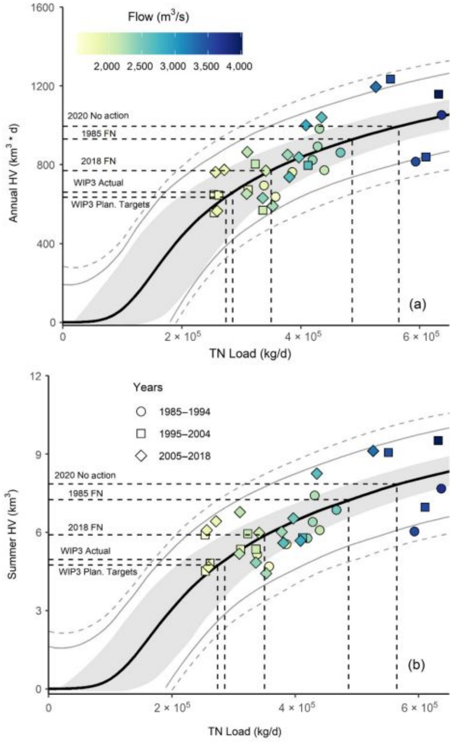


Bottom DO in Patuxent 2004
DO in mg/L
DO in mg/L
0
2
4
6
8
10
12
14
Distance up River in miles
Distance up River in miles
0
10
20
30
40
Day in 2004
Day in 2004
0
50
100
150
200
250
300
350
400
2
4
6
8
10
12

# Past ISG class did not find any correlation between hypoxic volume and total nitrogen loads




From previous Patuxent ISG class




SCAVIA, et. al 2021

# Goal 3: Derive estimates of hypoxia onset, breakup, and rates of DO depletion

- Overarching questions:
  - How does the onset of hypoxia vary over time? → <u>temporal variation</u>
  - How does the onset of hypoxia vary along the Patuxent River? → <u>spatial variation</u>
  - How quickly does DO decrease during the onset of hypoxia?
  - What factors are controlling seasonal variability in hypoxia onset?
- Approach
  - Compute at each monitoring station for each year
  - Validate with high-frequency data where possible (Benedict Bridge, St. Leonard Creek, etc.)

# Goal 3: Derive estimates of hypoxia onset, breakup, and rates of DO depletion

**Table 1** Monitoring station characteristics and hypoxia metrics in the modern (1985–2009) Chesapeake Bay Program-MD Department of Natural Resources dataset

| Station | Latitude | Longitude | Depth (m) | Surface salinity | Hypoxia onset | % years hypoxic | $O_2$ depletion rate (mmol $O_2$ $m^{-3}$ $day^{-1}$) |
|---|---|---|---|---|---|---|---|
| CB3.3C | 38.996 | −76.359 | 26 | 9.13 | May 4 (±13) | 100 | 3.19 (±0.78) |
| CB4.1C | 38.826 | −76.399 | 33 | 10.77 | May 8 (±15) | 100 | 3.16 (±0.63) |
| CB4.2C | 38.646 | −76.421 | 28 | 11.82 | May 17 (±16) | 100 | 3.34 (±0.69) |
| CB4.3C | 38.555 | −76.428 | 28 | 12.15 | May 19 (±17) | 100 | 3.31 (±0.63) |
| CB4.4 | 38.415 | −76.346 | 32 | 12.90 | May 23 (±18) | 100 | 3.16 (±0.75) |
| CB5.1 | 38.319 | −76.292 | 36 | 13.55 | May 24 (±18) | 100 | 3.09 (±0.91) |

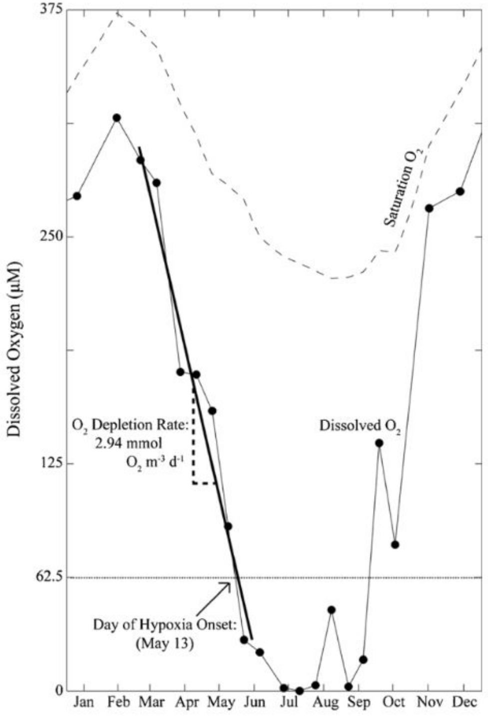



**Fig. 2** Seasonal cycle of bottom water $O_2$ saturation and concentration a CB5.1 (Fig. 1) in 2004 and illustration of how rate water column O depletion and date of hypoxia onset were derived from the time series dat (see text)

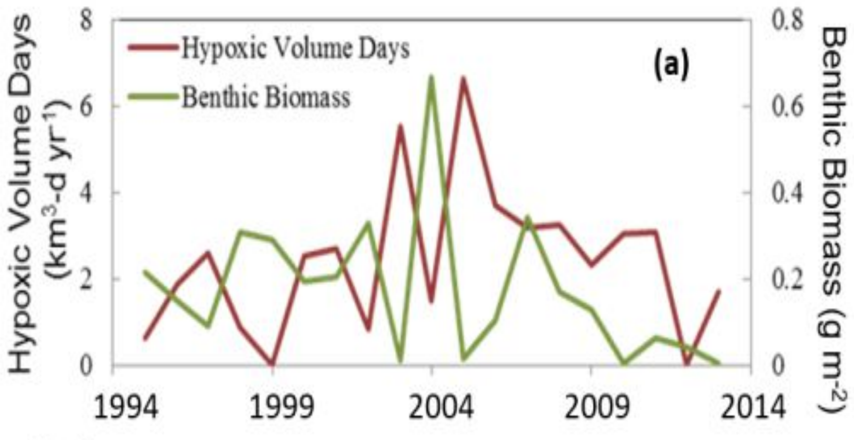
Testa and Kemp, 2014

# Goal 4: Relate changes in oxygen depletion to metrics of living resources

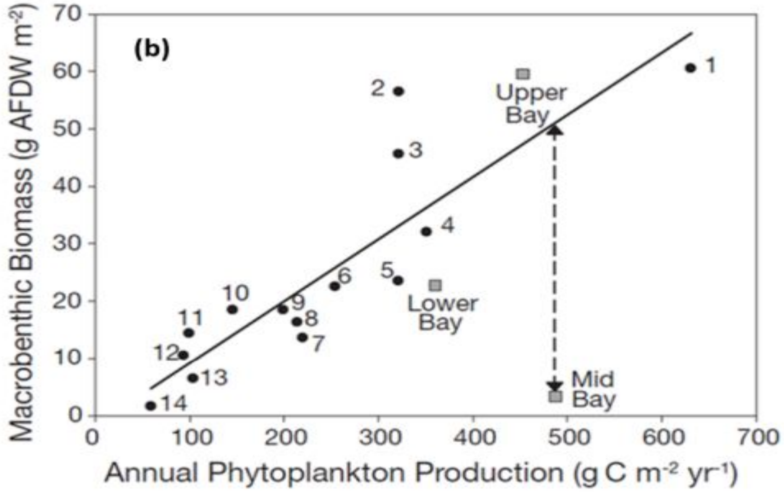
- Statistical models (GAMs, regression) to relate oxygen depletion metrics (area, volume, duration) to benthic invertebrate biomass and abundance

- Consider non-hypoxia variables that also control benthic biomass (temperature, salinity, productivity)

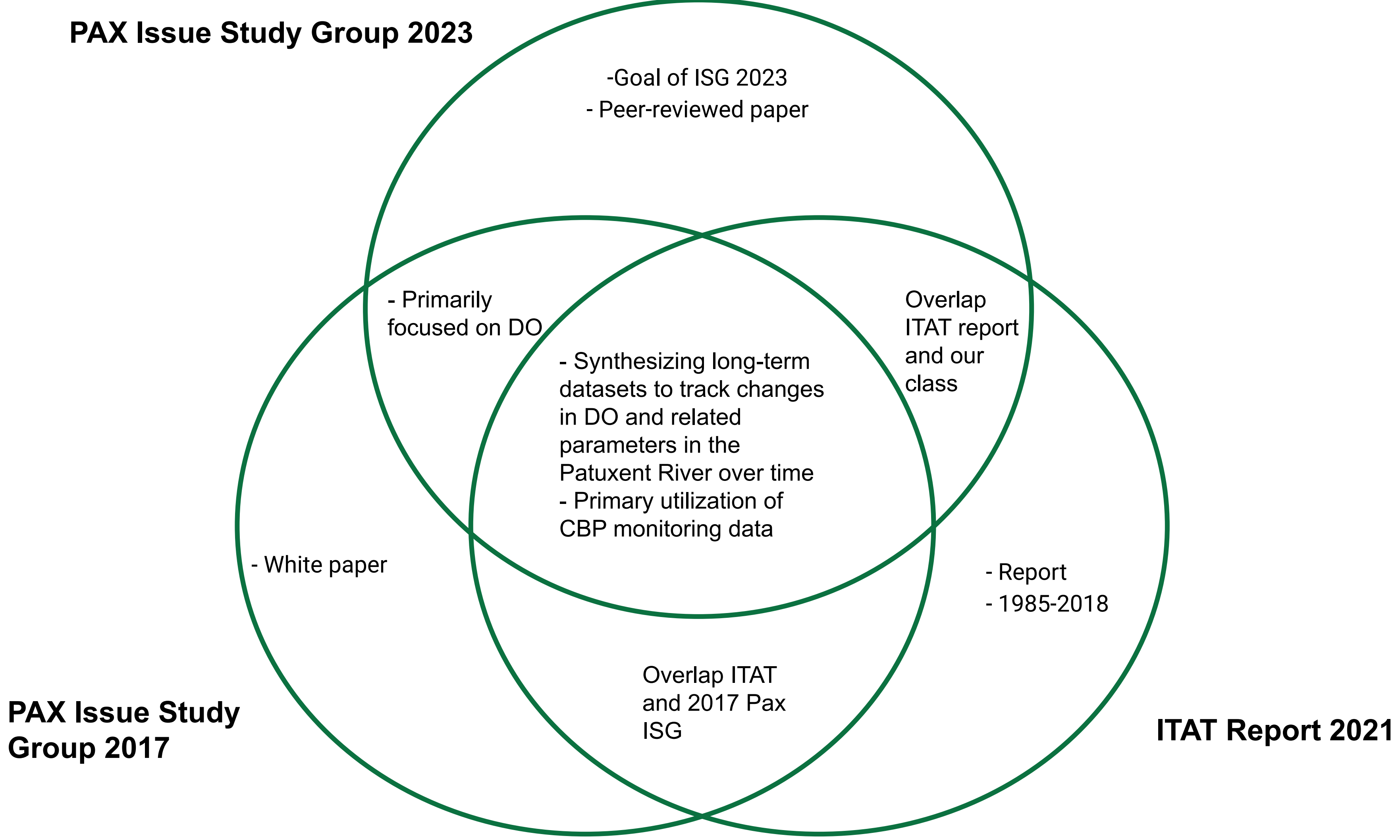
# Goal 4: Relate changes in oxygen depletion to metrics of living resources




From previous Patuxent ISG class (2017)




Cross river comparison from Kemp et al. 2005


PAX Issue Study Group 2023
-Goal of ISG 2023
- Peer-reviewed paper
- Primarily focused on DO
Overlap ITAT report and our class
- Synthesizing long-term datasets to track changes in DO and related parameters in the Patuxent River over time
- Primary utilization of CBP monitoring data
- White paper
- Report
- 1985-2018
Overlap ITAT and 2017 Pax ISG
PAX Issue Study Group 2017
ITAT Report 2021