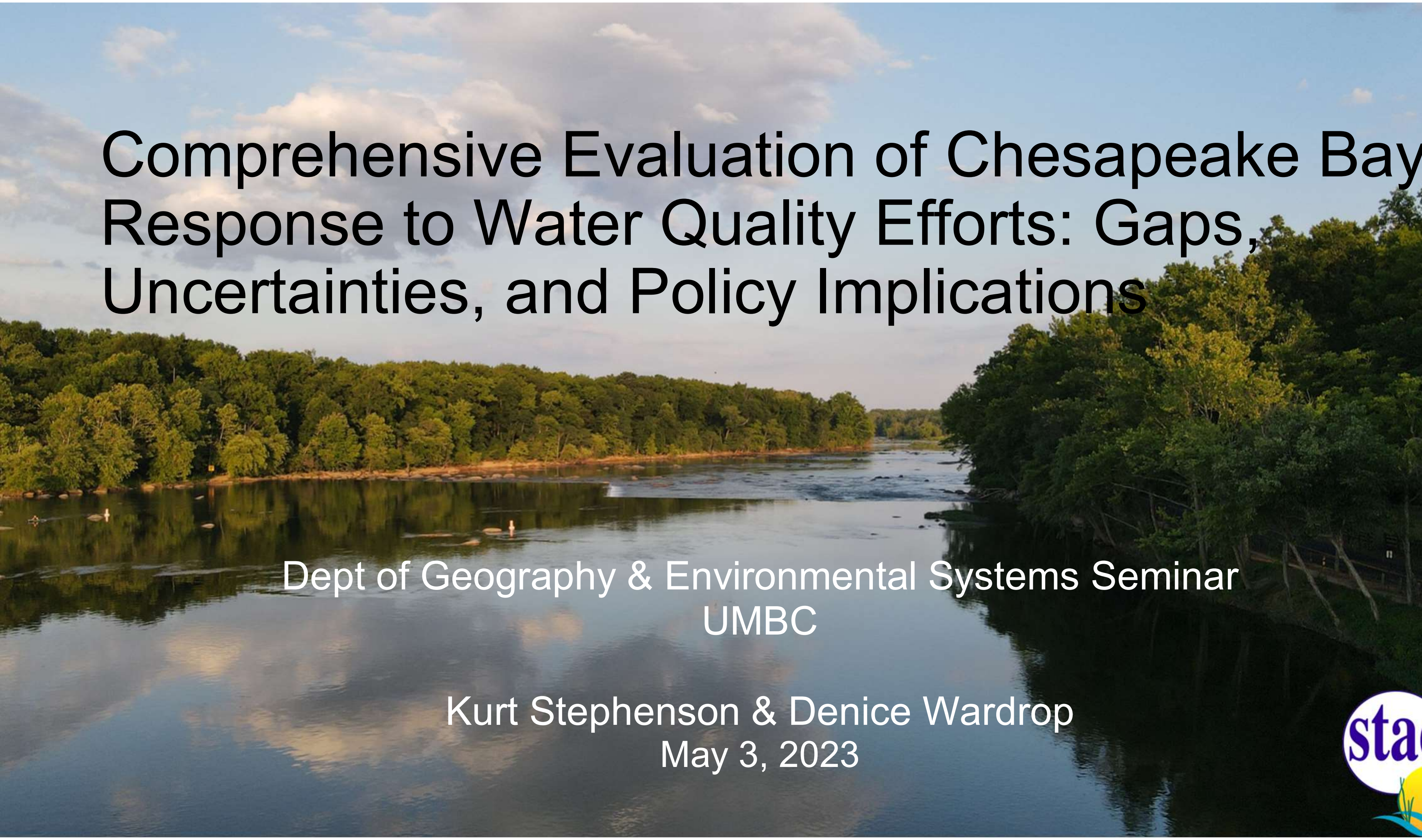
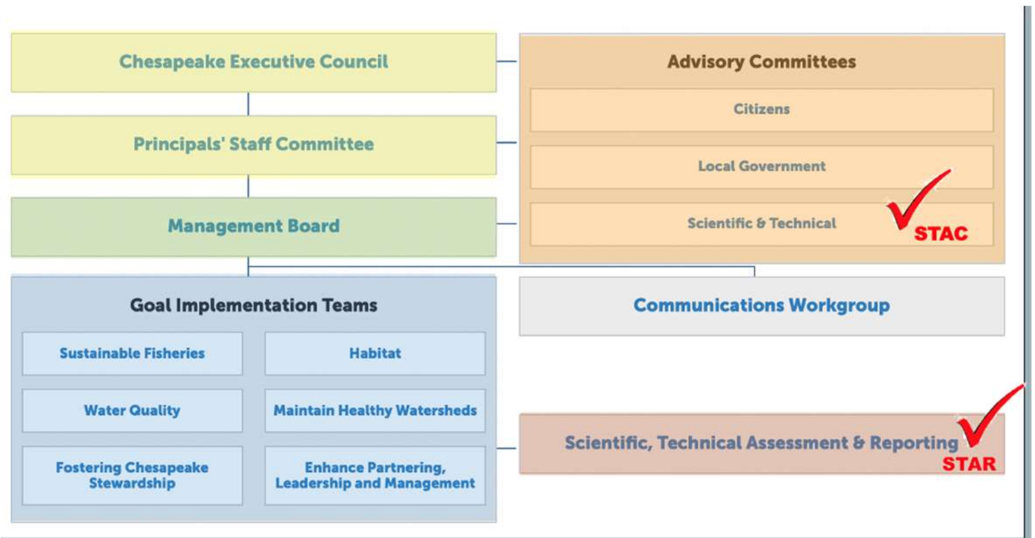
# Comprehensive Evaluation of Chesapeake Bay Response to Water Quality Efforts: Gaps, Uncertainties, and Policy Implications



Dept of Geography & Environmental Systems Seminar
UMBC

Kurt Stephenson & Denice Wardrop

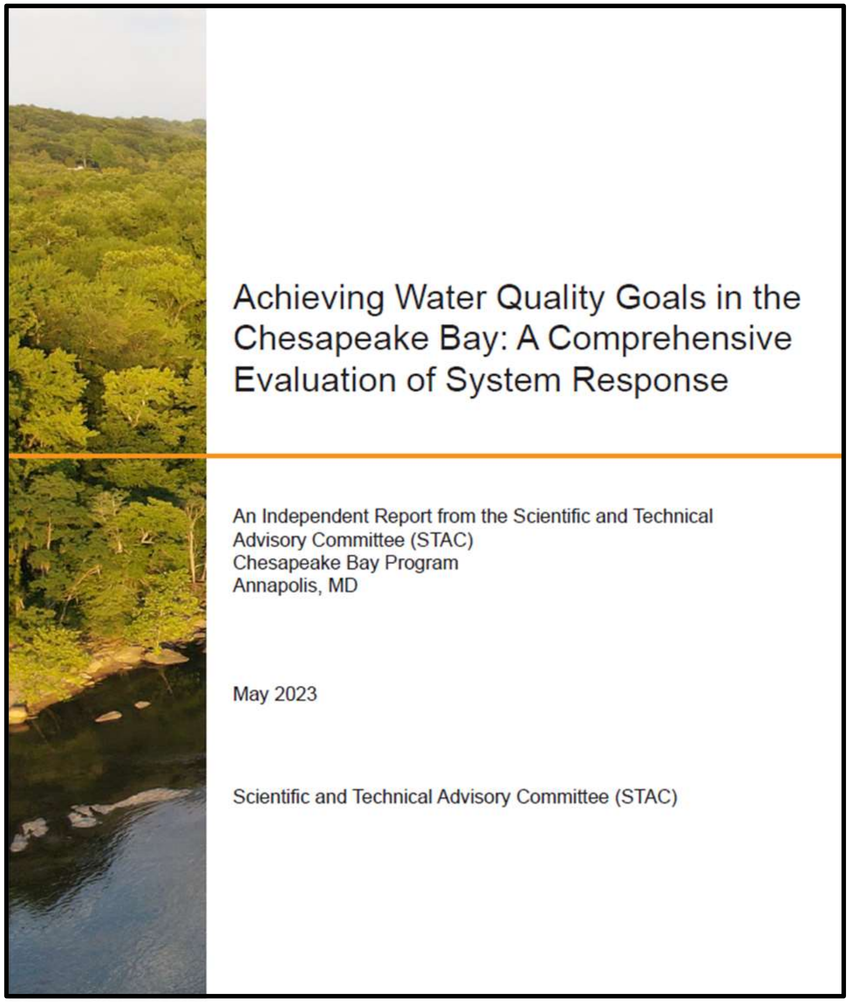
May 3, 2023




## What is the job of an advisory committee?

- 38 experts from various research, academic, federal, and private institutions in the watershed
- Provides <u>advice</u>
- Transdisciplinary, able to synthesize, independent, consensus

ad·vice *noun* guidance or recommendations offered with regard to prudent future action.



Achieving Water Quality Goals in the Chesapeake Bay: A Comprehensive Evaluation of System Response

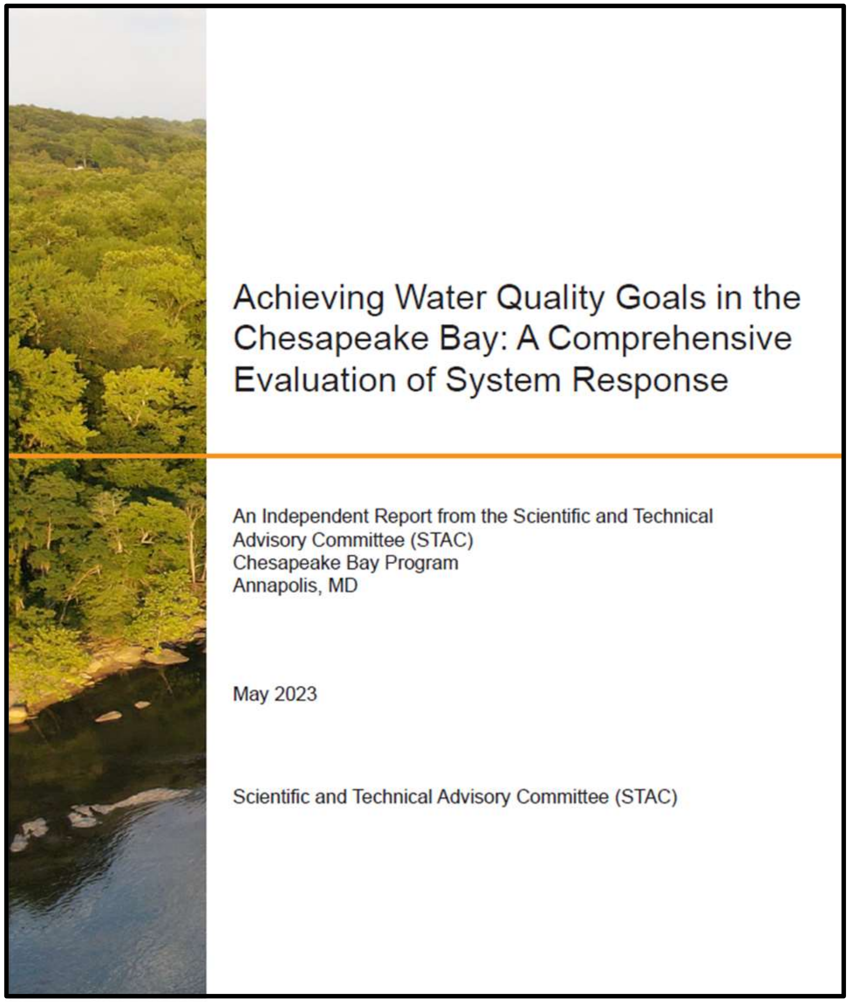
An Independent Report from the Scientific and Technical Advisory Committee (STAC)
Chesapeake Bay Program
Annapolis, MD

May 2023

Scientific and Technical Advisory Committee (STAC)

# “CESR” Report

- Joint STAC effort (2019-2023)
- Inclusive of STAC Membership
- Census-based process
- Synthesis
- Multiple levels of review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## Report Editors


**Kurt Stephenson**, Virginia Tech
**Denice Wardrop**, CRC & Penn State


## Steering Committee


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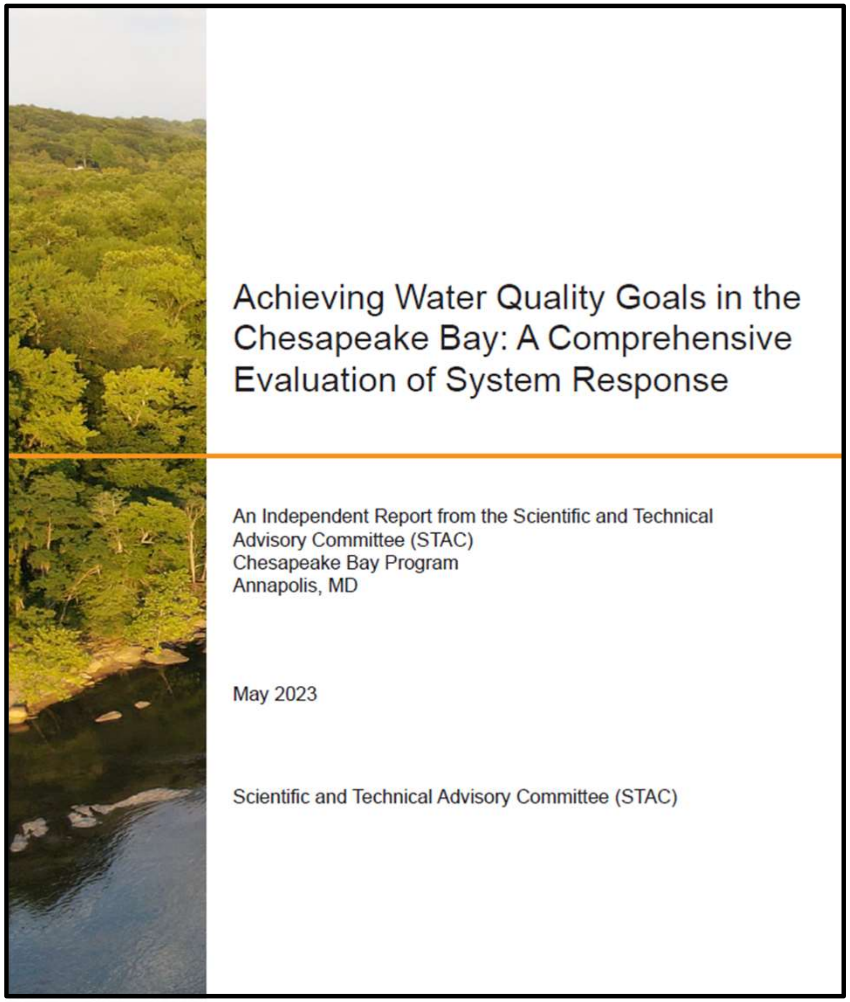
**Kurt Stephenson**, Virginia Tech
**Jeremy Testa**, UMCES



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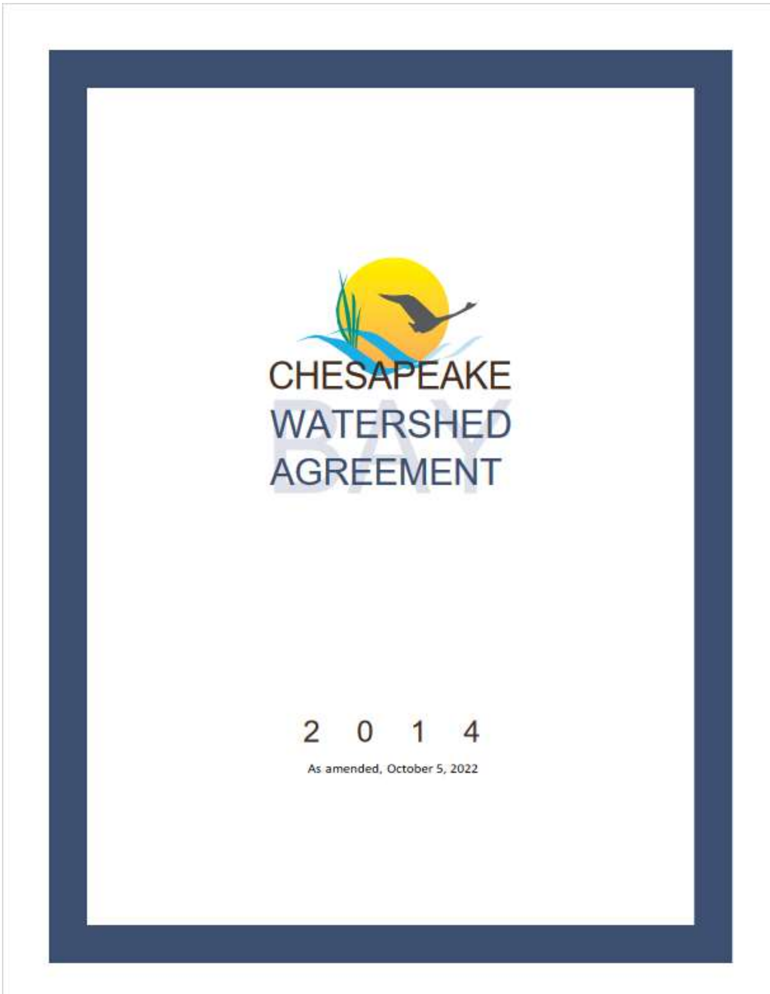
# CESR Related Documents


Easton, Z., Stephenson, K., Benham, B., Böhlke, J. K., Brosch, C., Buda, A., Collick, A., Fowler, L., Gilinsky, E., Hershner, C., Miller, A., Noe, G., Palm-Forster, L., & Thompson, T. (2023). *Evaluation of watershed system response to nutrient and sediment policy and management*. STAC Publication Number 23-003, Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD

Testa, J. M., Dennison, W. C., Ball, W. P., Boomer, K., Gibson, D. M., Linker, L., Runge, M. C., & Sanford, L. (2023). *Knowledge gaps, uncertainties, and opportunities regarding the response of the Chesapeake Bay estuary to proposed TMDLs*. STAC Publication Number 23-004, Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD.

Rose, K., Monaco, M. E., Ihde, T., Hubbart, J., Smith, E., Stauffer, J., & Havens, K. J. (2023). *Proposed framework for analyzing water quality and habitat effects on the living resources of Chesapeake Bay*. STAC Publication Number 23-005, Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD.

# Focus of CESR




## 10 Goals

1. Sustainable Fisheries
2. Vital Habitats
3. **Water Quality**
4. Toxic Contaminants
5. Healthy Watersheds
6. Land Conservation
7. Stewardship
8. Public Access
9. Environmental Literacy
10. Climate Resiliency

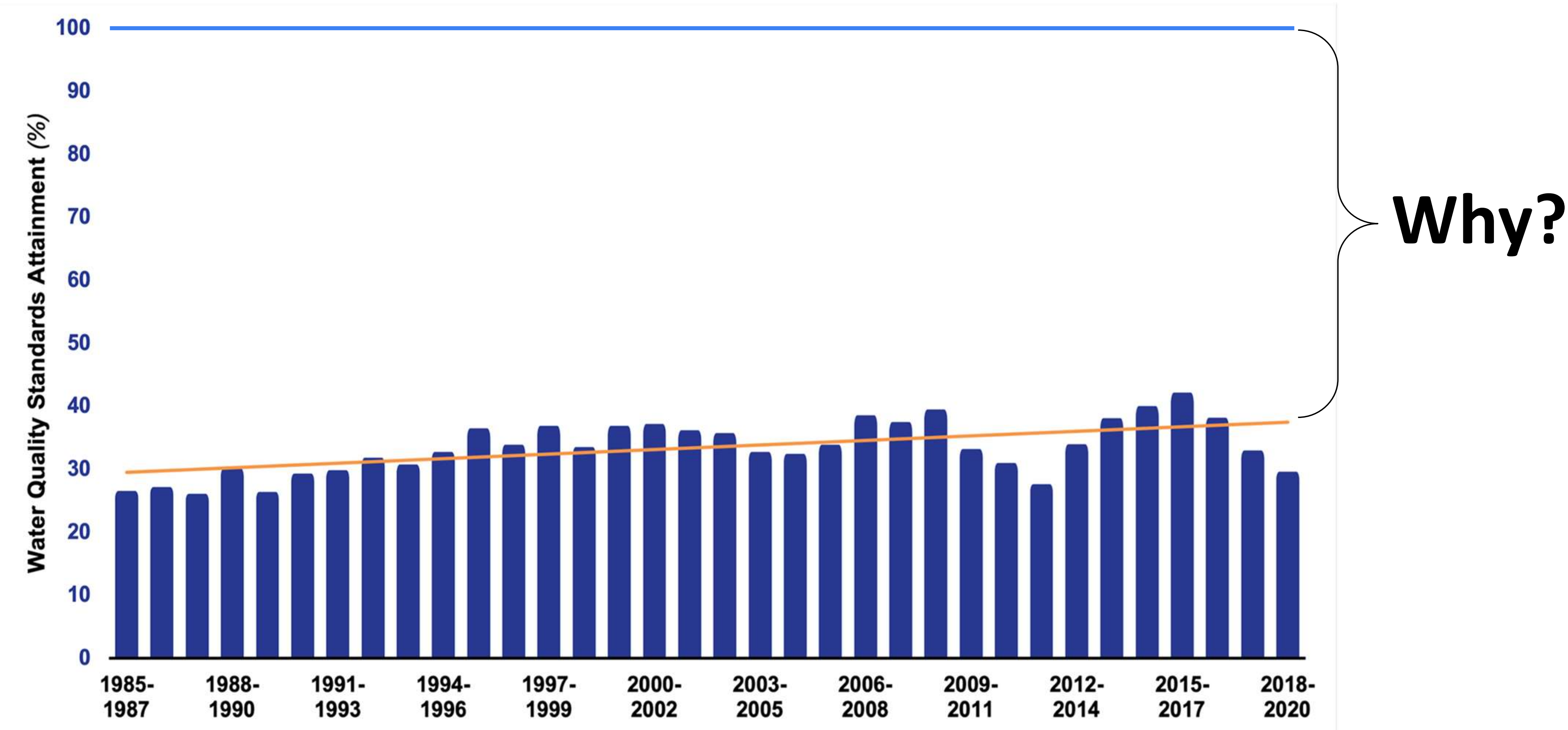
# First Chesapeake Bay Agreement, 1983

The one--page agreement acknowledged the "historical decline in the living resources of the Chesapeake Bay" and committed to addressing a major cause of the decline by pledging "to fully address the extent, complexity, and sources of pollutants entering the Bay." Nitrogen and phosphorus were identified as the two key pollutants.

# CESR: Why now?

- **1983** – 1st CBay Agreement
- **1987** – 2nd CBay Agreement
- **2000** – 3rd CBay Agreement
- **2003-4** – Revision of water quality standards
- **2009** – CBay TMDL
- **2014** – 4th CBay Agreement
- **2025** – All pollution control measures needed to fully restore the Bay & its tidal rivers are in place

# Objective of CESR



# Approach of CESR

## Public Policy

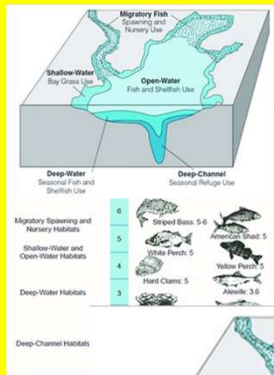
**Chesapeake Bay Agreement: Restoration Goals**

- Sustainable Fisheries
- Vital Habitat
- **Water Quality**
- Toxic Contaminants
- Heathy Watershed
- Climate Resiliency
- Land Conservation
- Stewardship
- Public Access
- Environmental Literacy

→

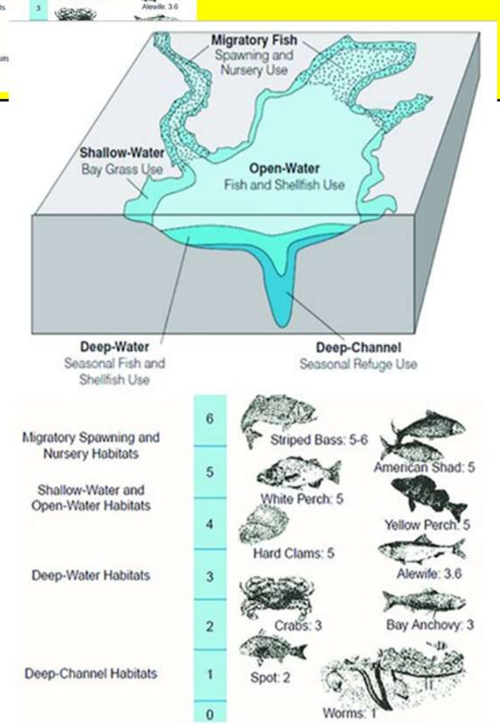
**Water Quality Standards**

**Designated Uses**



→ **Water Quality Criteria**

Dissolved Oxygen, Water clarity/SAV, & Chl-a across 5 habitats




→

**TMDL: Stressor Reduction Goals**

Targets: Nitrogen, phosphorus, sediment

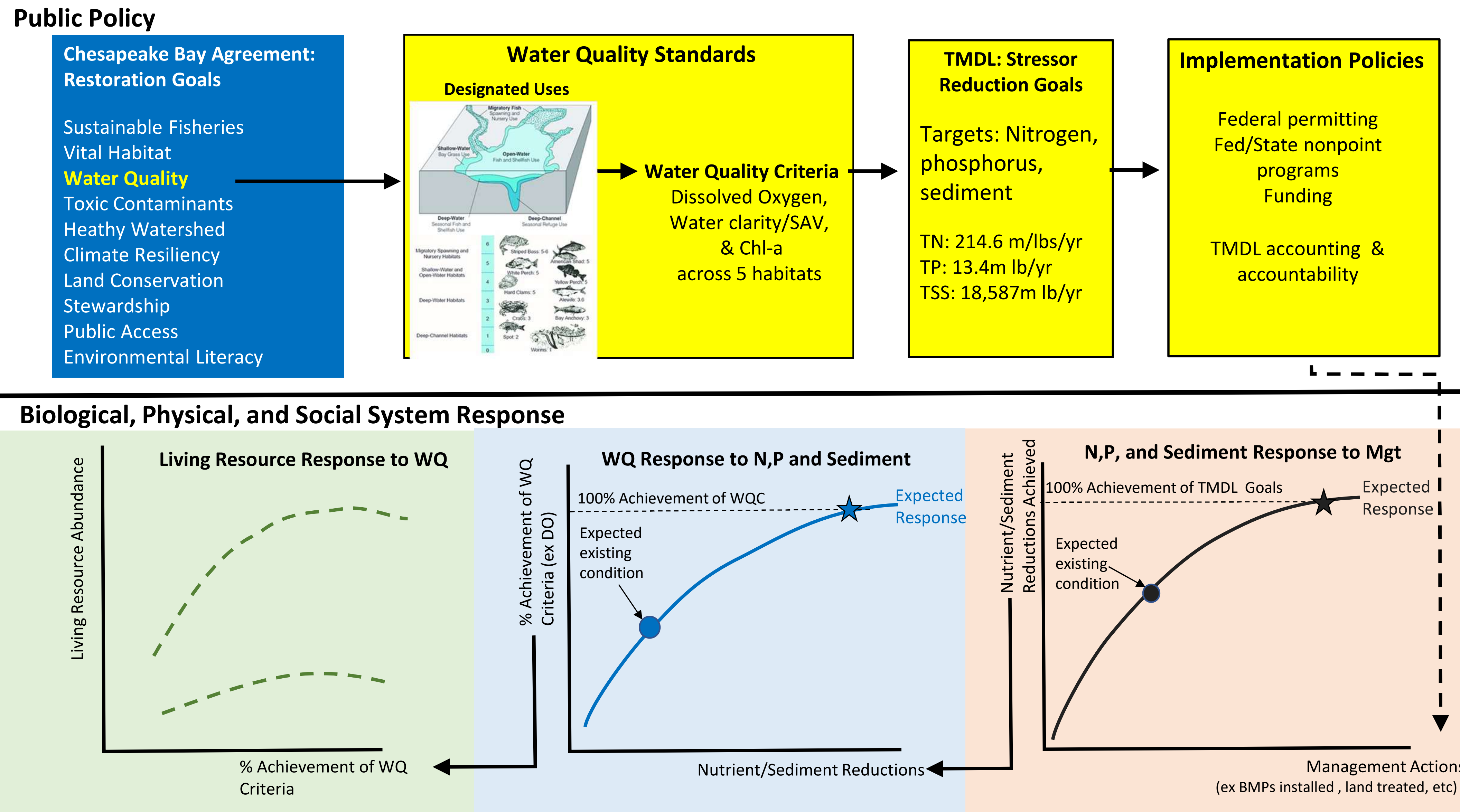
TN: 214.6 m/lbs/yr
TP: 13.3m lb/yr
TSS: 18,587m lb/yr

→

**Implementation Policies**

Federal permitting
Fed/State nonpoint programs
Funding

TMDL accounting & accountability


Public Policy
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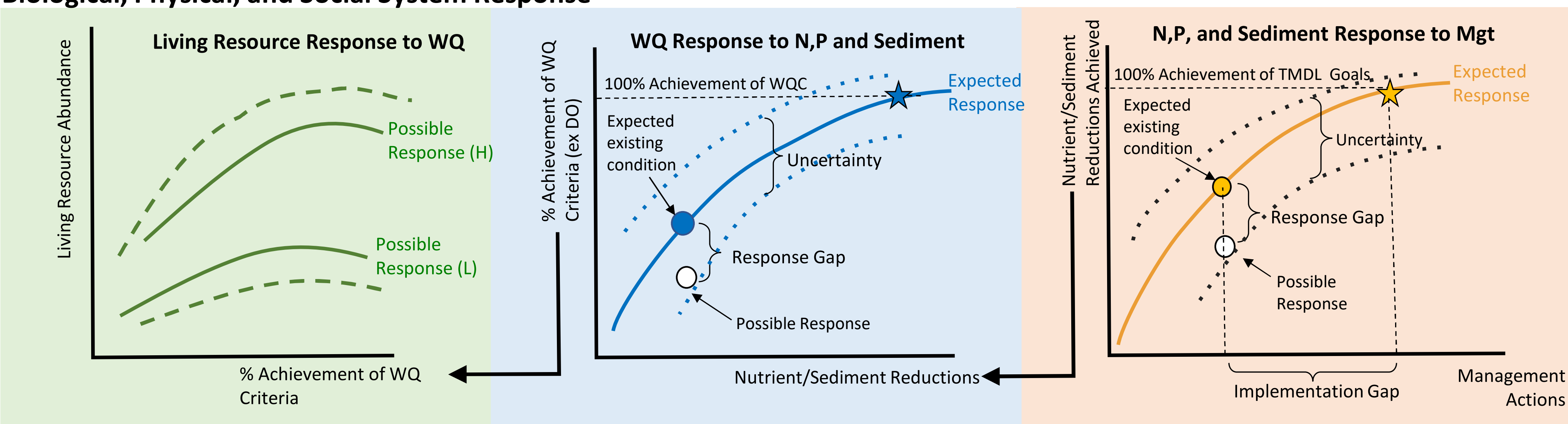
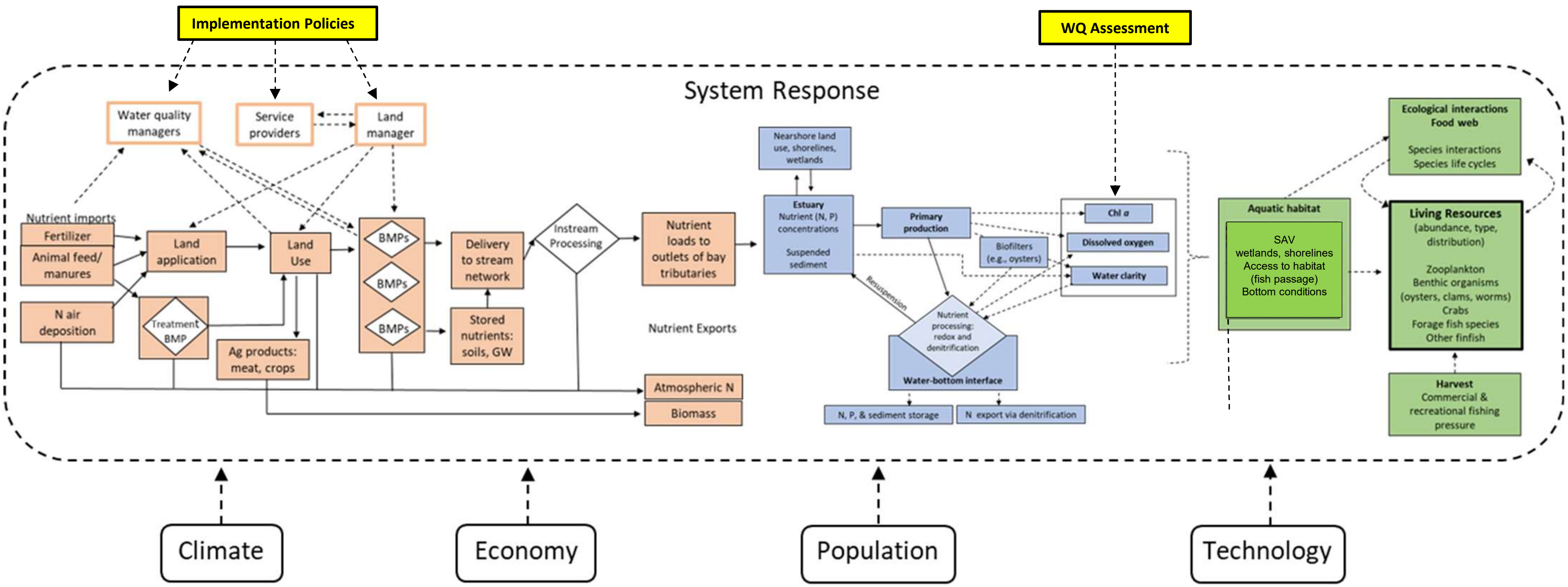
Implementation Policies
Federal permitting
Fed/State nonpoint programs
Funding
TMDL accounting & accountability
Biological, Physical, and Social System Response
Living Resource Response to WQ
Living Resource Abundance
% Achievement of WQ Criteria
WQ Response to N,P and Sediment
% Achievement of WQ Criteria (ex DO)
100% Achievement of WQC
Expected Response
Expected existing condition
Nutrient/Sediment Reductions
N,P, and Sediment Response to Mgt
Nutrient/Sediment Reductions Achieved
100% Achievement of TMDL Goals
Expected Response
Expected existing condition
Management Actions
(ex BMPs installed , land treated, etc)

# Gaps & Uncertainties

## Biological, Physical, and Social System Response



# Approach to Evaluating System Response



# CESR Conclusions

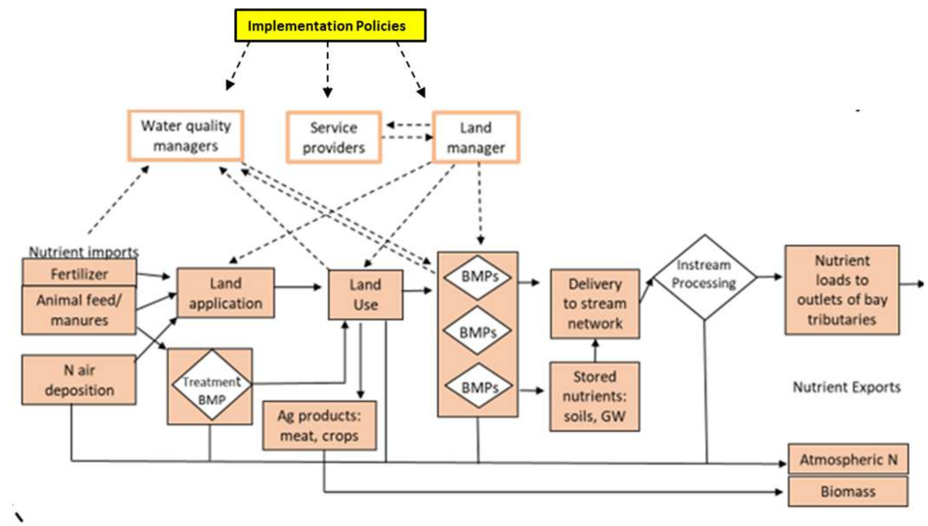
Gaps & uncertainties present major challenges to achieving water quality goals & improving living resource response.

There are opportunities to improve program effectiveness but will require change in thinking & approach.

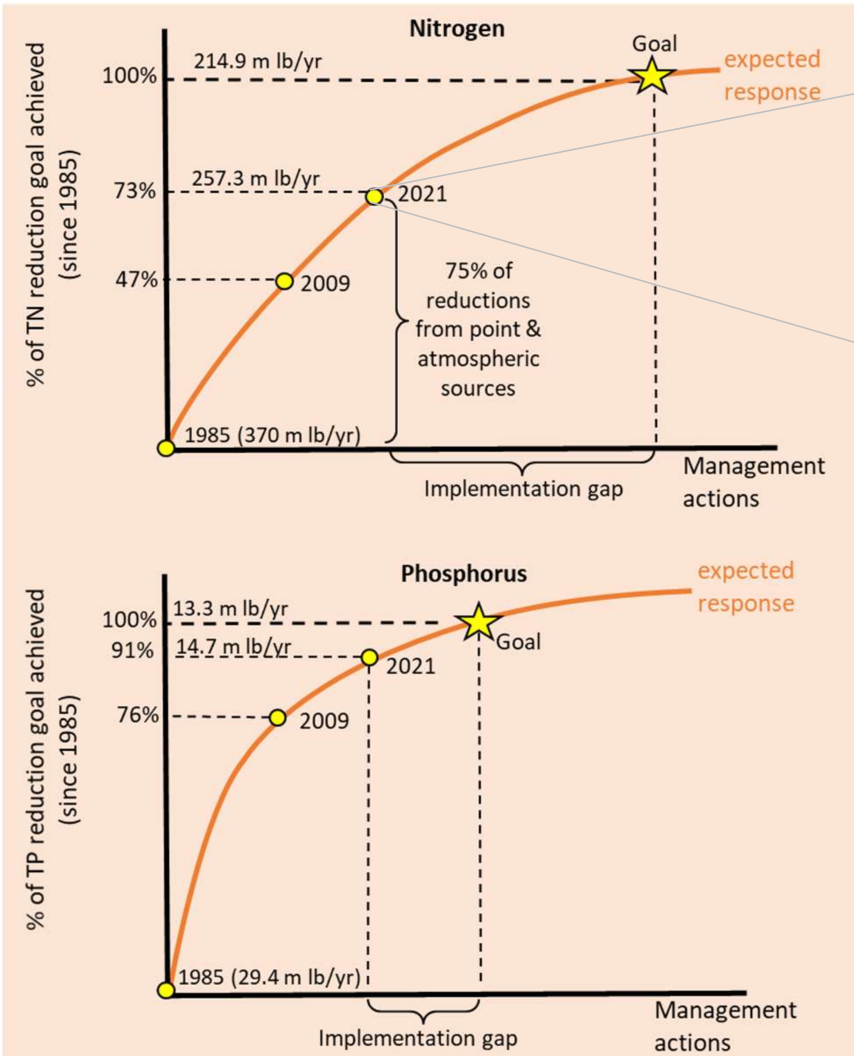
Photo by Will Parson/Chesapeake Bay Program

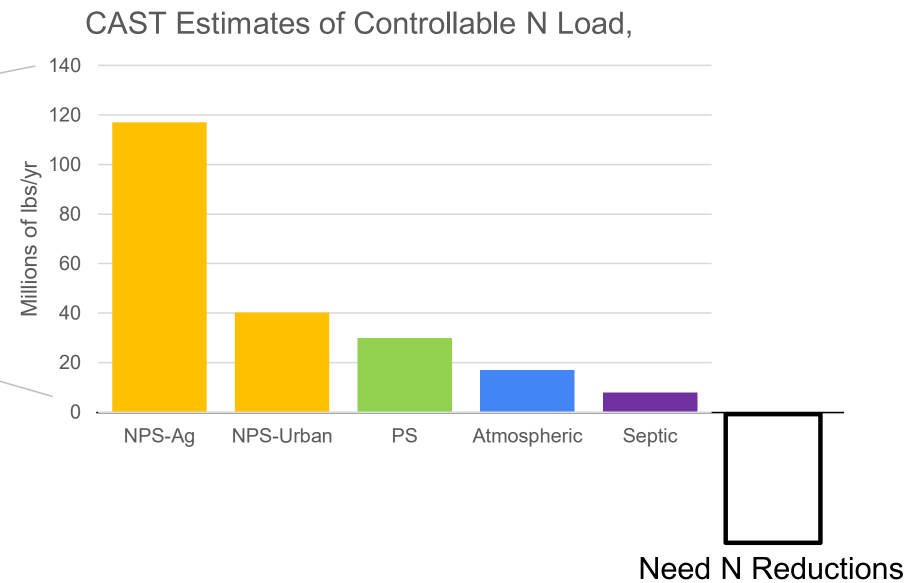
# Findings and Implications:

Pollutant Response to Management



# Implementation Gap




Annual rate of NPS N reductions achieved as estimated by CAST model since the TMDL (2009-2021)

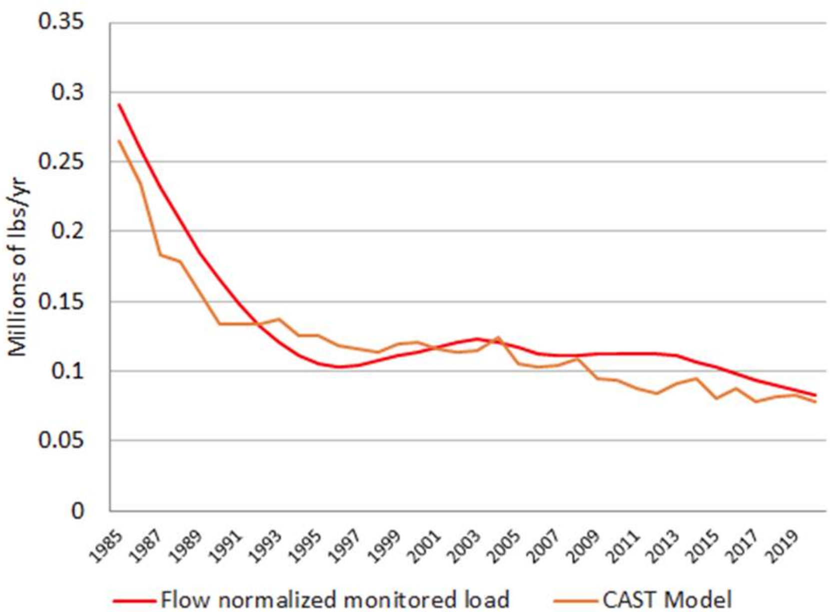
**0.3 mil lbs/yr**

# NPS Response Gap:

## Effectiveness of Nonpoint Source Management Efforts

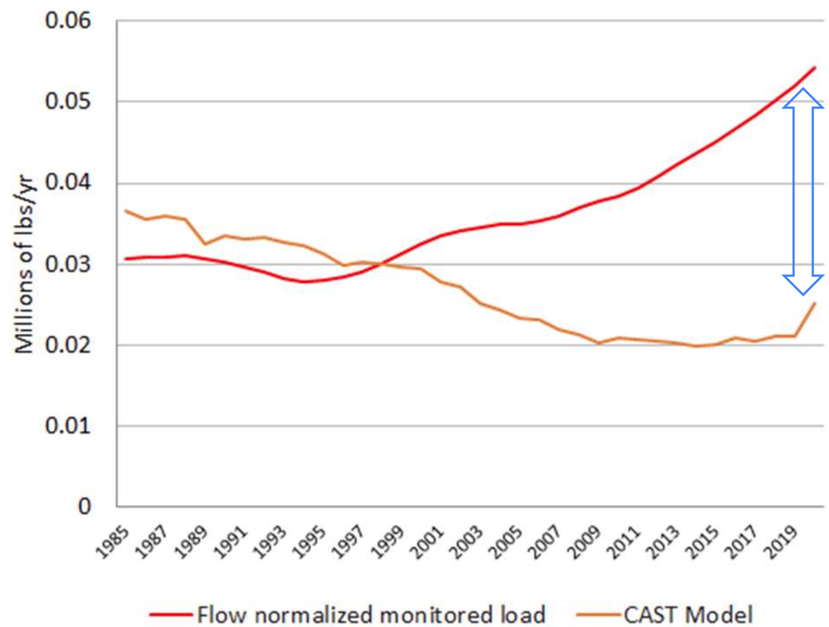
Point Source Dominated Watershed

Total P, Patuxent



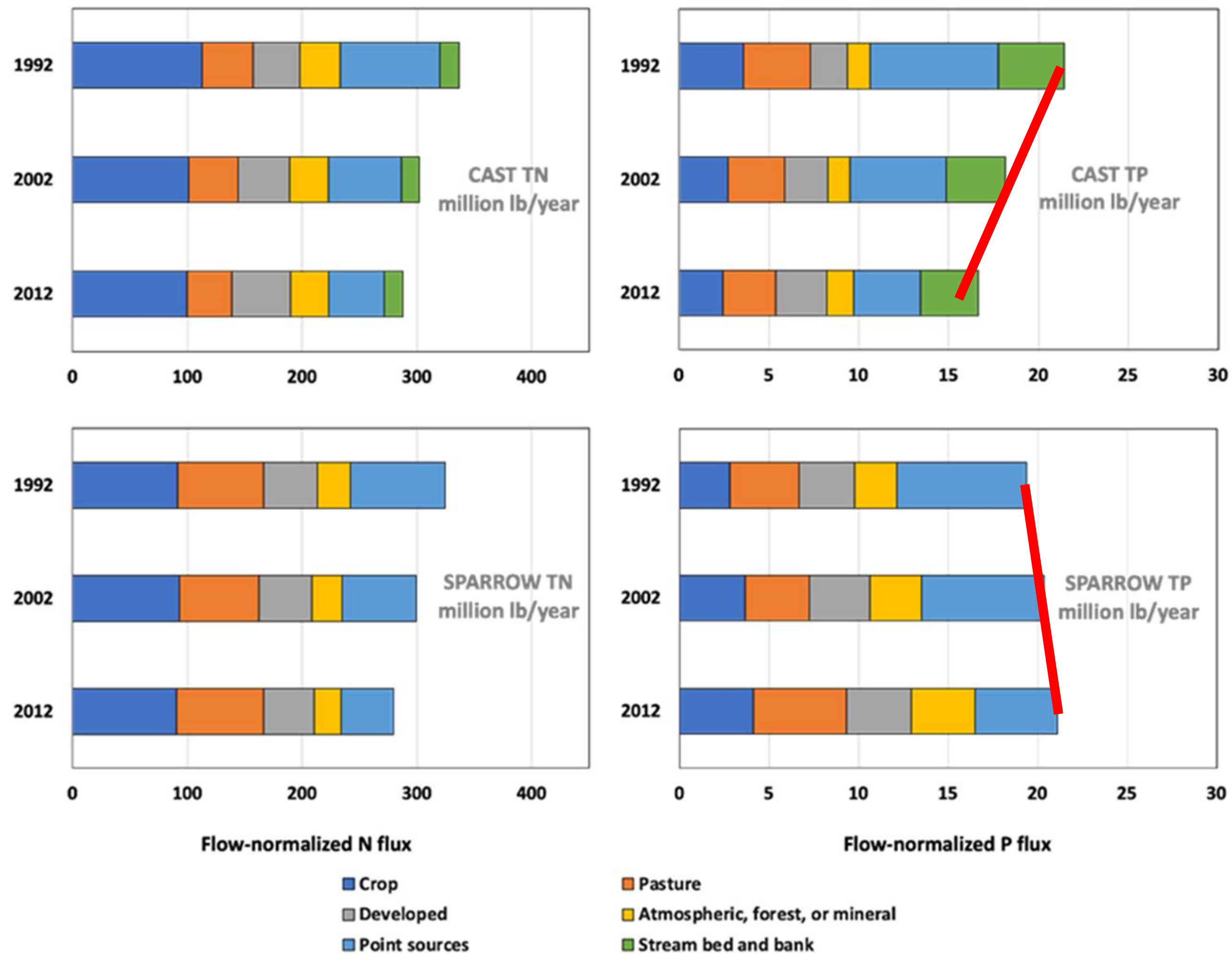

Nonpoint Source Dominated Watershed

Total P, Choptank



# Response Gap

Monitoring data shows mixed signals of NPS management effectiveness. Several studies have found relatively little change in NPS loads between 1990 and today. Keisman et al 2018; Ator et al. 2019; 2020




Ator et al 2020

## Why Implementation Gaps

Limits to Adoption (under existing programs)

Mass Nutrient Imbalances

# Implementation Gap
# Limits to Adoption (practice-based cost share)

Cover crops

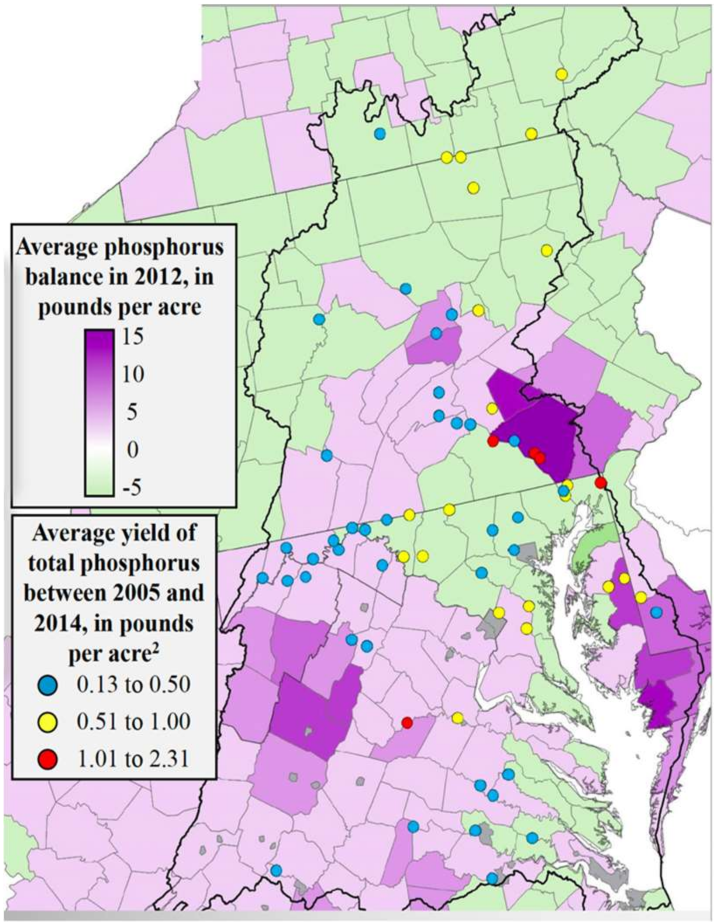
Livestock Exclusion Fencing

Denitrifying Bioreactor

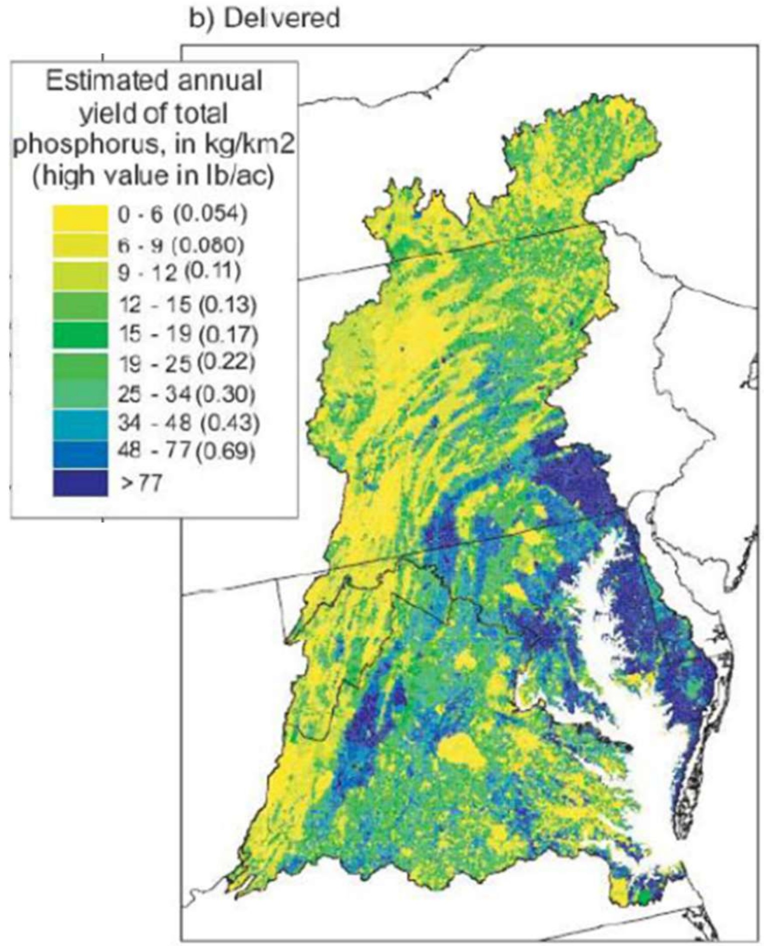
Low upfront installation costs
Private benefits

High up front installation costs
No private benefits

# Nutrient Mass Balance




Moyer et al. 2107, Webber, 2017




Source: USGS Sparrow Model Output

# Nonpoint Source Response Gap

***What is responsible for divergence between expected and observed NPS loads?***

Lag Time/Legacy Pollutants

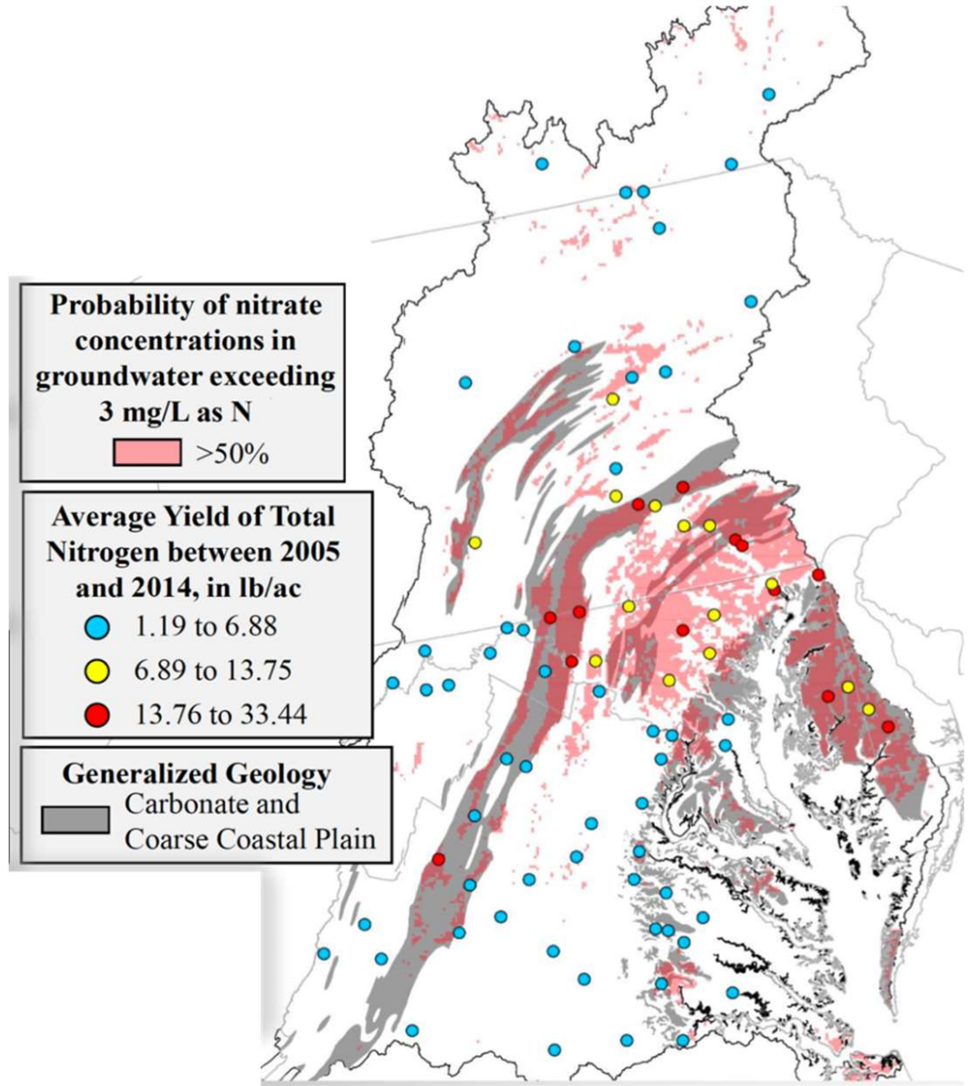
BMP Effectiveness

Behavior/Implementation

Data/Monitoring Limitations

**Legacy Nutrients**

Large stores of legacy N and P in soils and groundwater may mask signal from NPS BMPs




Jimmy Webber USGS, STAC workshop presentation Dec 2017

**Response Gap & BMP Effectiveness**

BMPs may not be as effective as expected
(as assigned in CAST model)

- Uncertainty surrounds estimates of BMP effectiveness
- Generalized over diverse situations
- Long-term effectiveness over BMP lifepsan
- Maintenance

## Additional Explanations for Response Gaps

**Behavior and Implementation**

- Nutrient use: actual vs assumed behavior
- Complex systems/behavior
- Differential/selective adoption (“who, does what, where” may not match the “average” condition)

**Data Issues**

- Model inputs may not adequately reflect nutrient inputs, BMPs, etc.

**Monitoring may be insufficient to detect response**

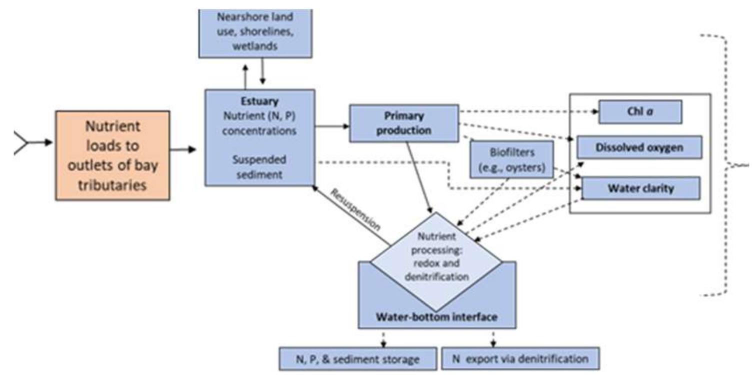
**FINDING:** Existing nonpoint source water quality programs are insufficient to achieve the nonpoint source reductions required by the TMDL

# Implications for Nonpoint Source:

- Shift the focus to **achieving outcomes** and away from counting practices.
  - Improved targeting of investments (identification of high loss areas)
  - Shift incentives toward outcomes rather than practices
- Additional attention on mass imbalances
- Willingness to reform and experiment with incentives and TMDL accounting: Consider “Sandboxing”
- Great attention to uncertainty

# Findings and Implications:

## Water Quality Response



# Water Quality Response

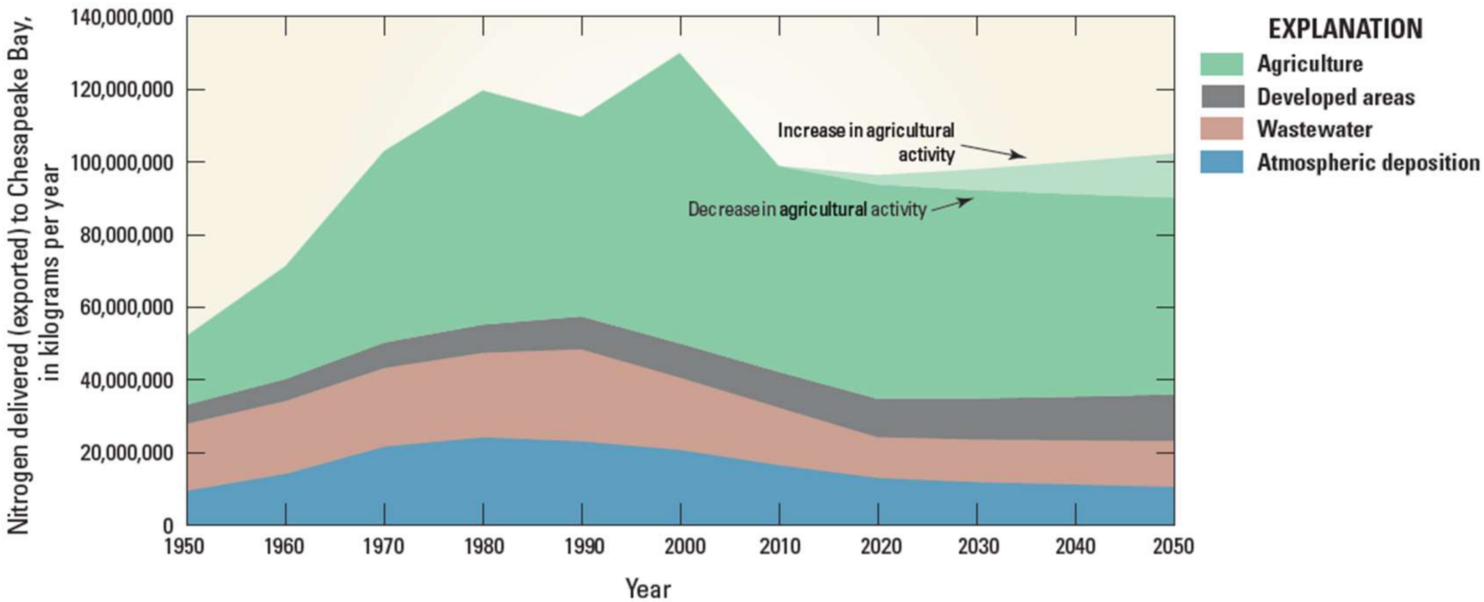
As we approach 2025, we aimed to reflect on the following questions:

a) Has the recovery trajectory of Bay water quality criteria in response to reduced loads matched our expectations in both direction and magnitude?

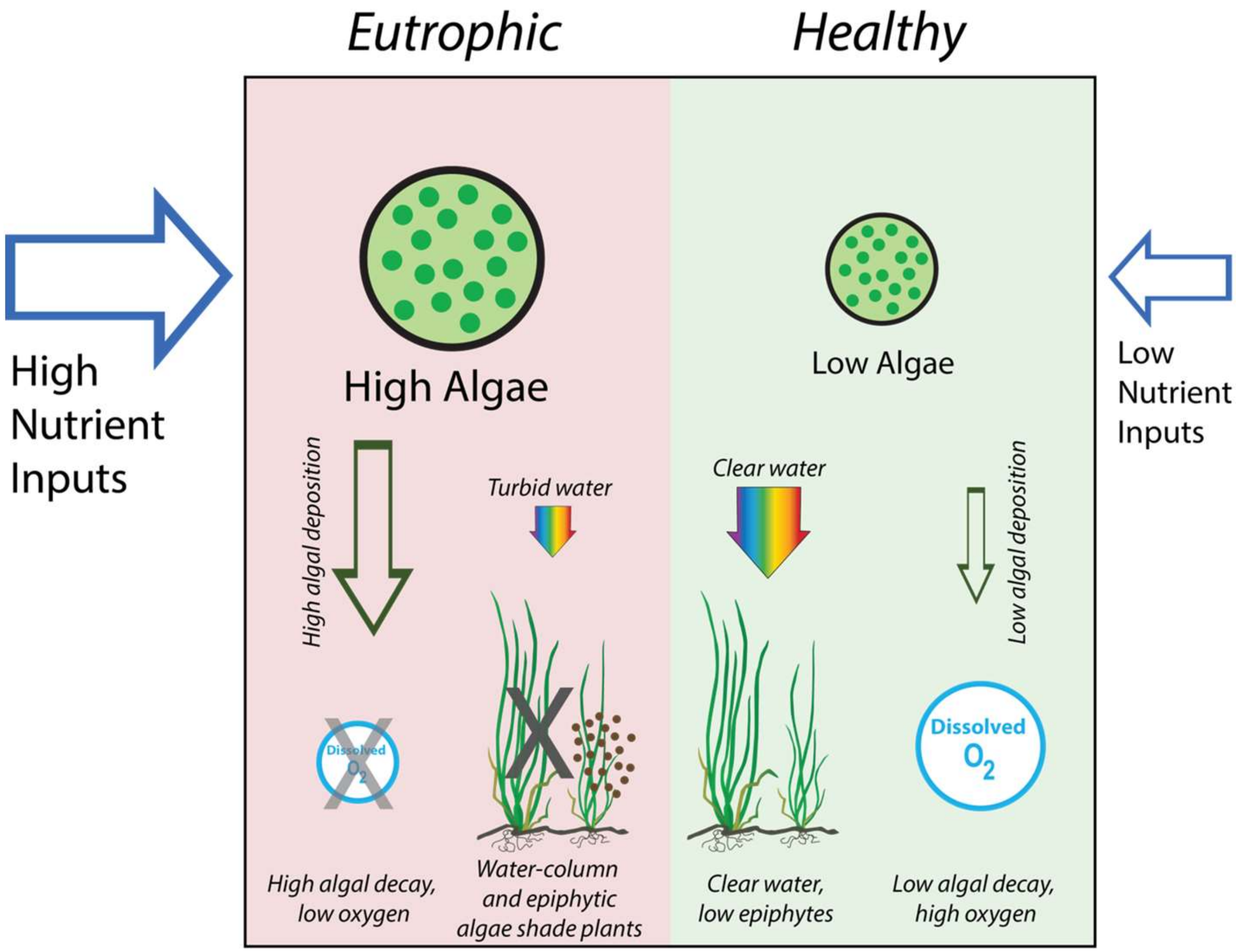
***and if not***

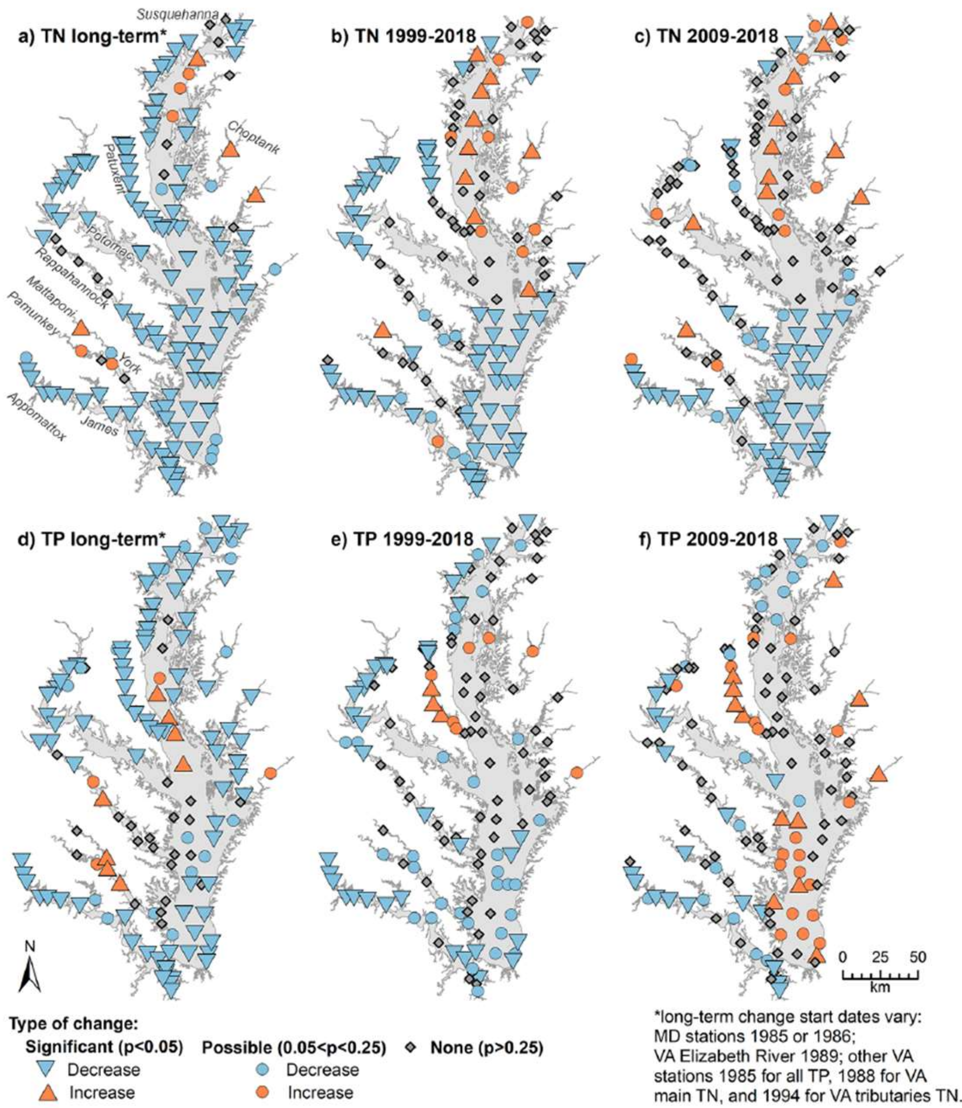
b) Why is there a gap in the response between what we have measured and that which we expected?

# How Has Nutrient Load Changed Over Time?



# Our Most Basic Model of Bay Water Quality






# Water Quality Response at Bay Scale; TN and TP Responding

Chesapeake Bay tidal station categorical results for mean change in surface TN (a−c) and TP (d−f) over three time periods computed using temporal GAM fits. From Murphy et al., 2022.

**Slide 33**

5 Has the red text been resolved?
Lauren Huey, 11/16/2022

# Loads and Nutrient Concentrations

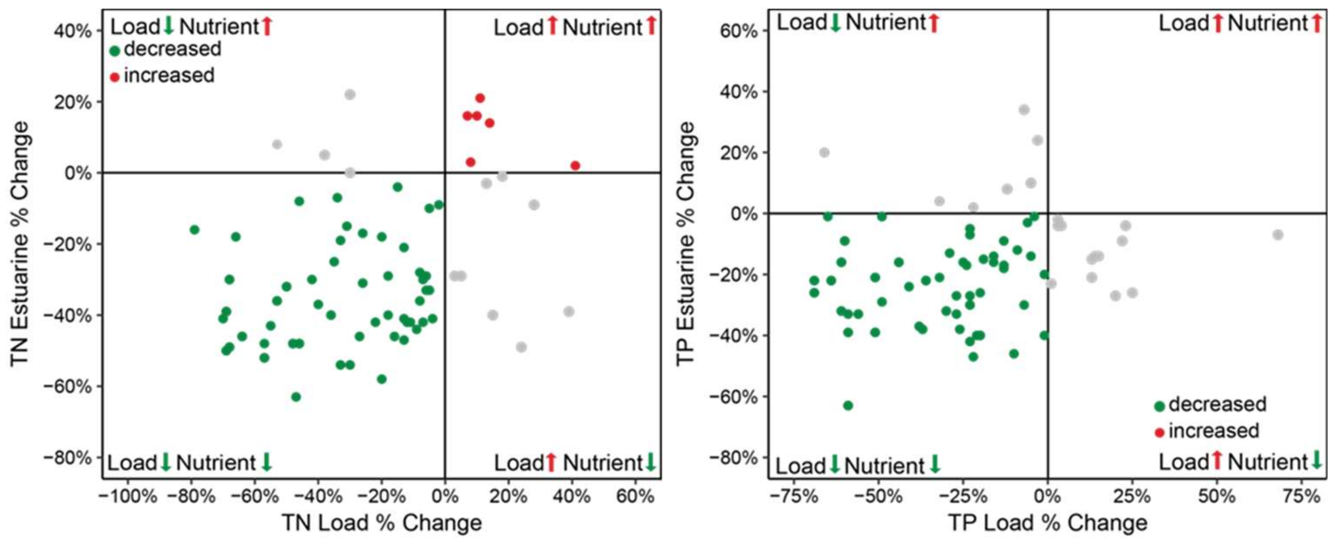
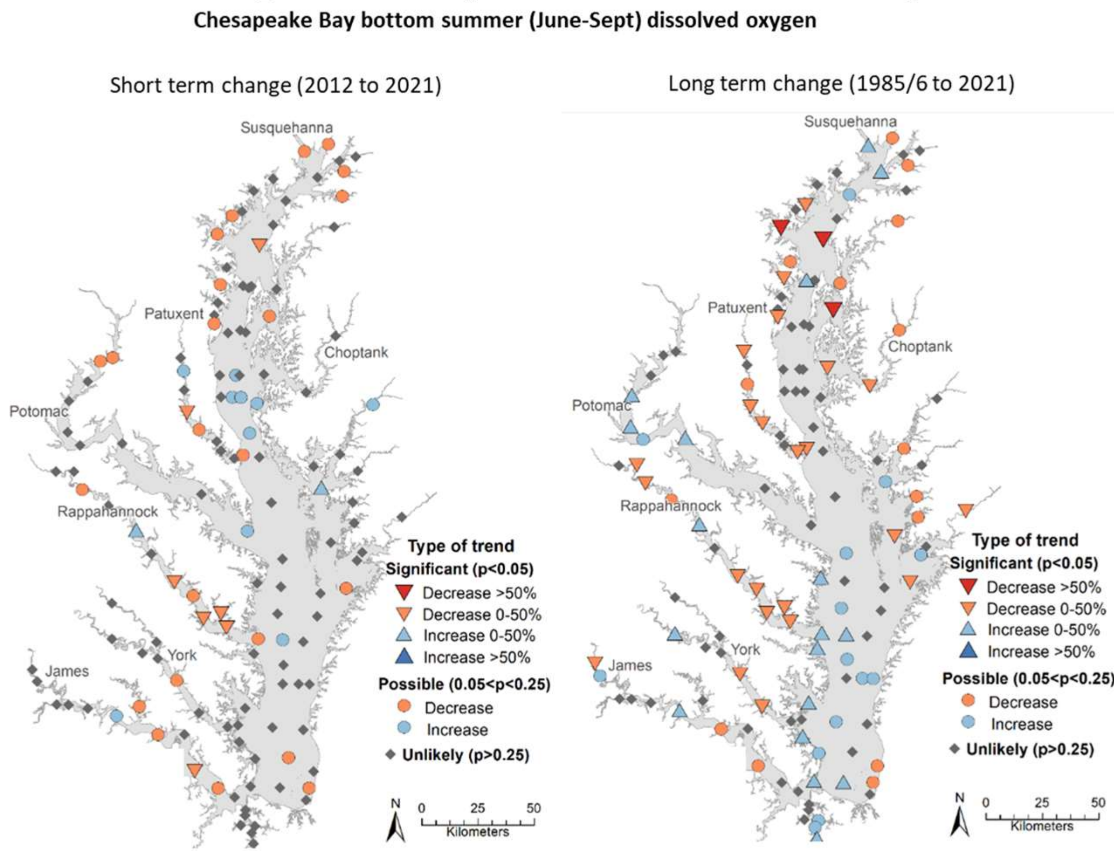



**FIGURE 4.6.—Percent change in estuarine TN and TP loads and concentrations, late 1980s to mid-2010s, where each dot represents a Bay segment (Source: Testa et al., 2018).**

# Water Quality Response at Bay Scale; DO

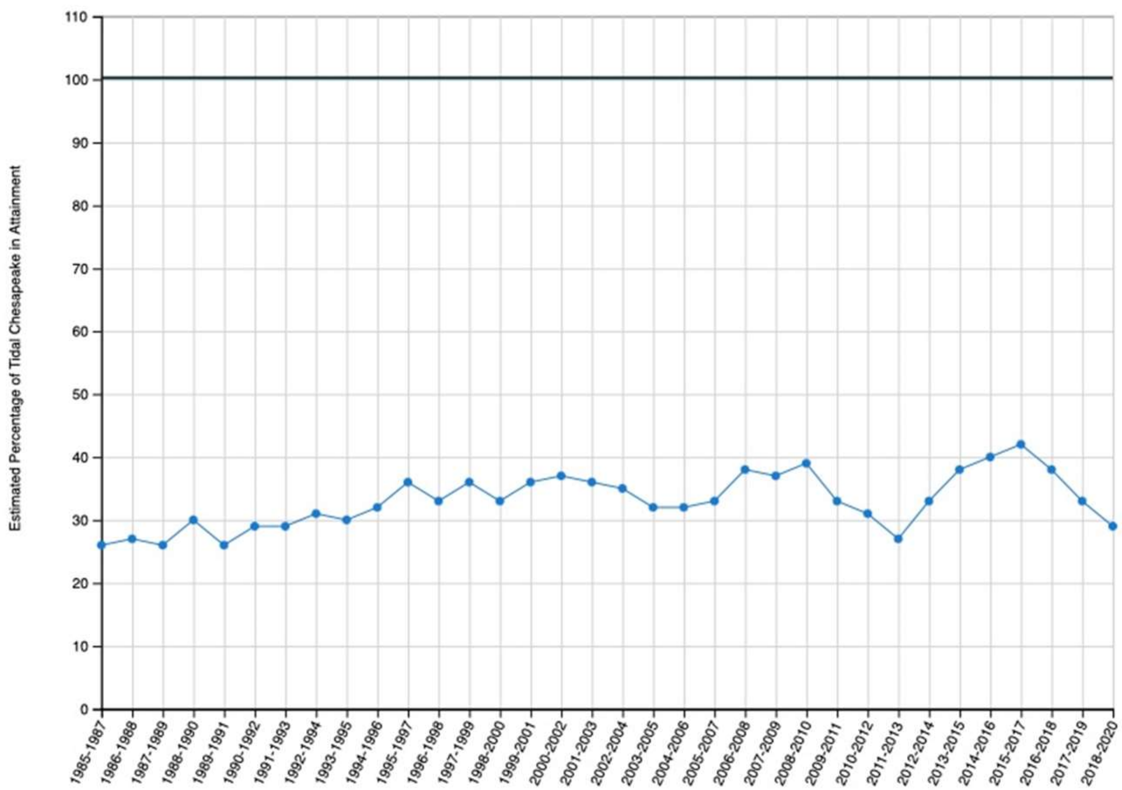



**Changes in DO in bottom water layer measured during June–September, short-term (left panel) and long-term (right panel); starting dates for long-term measurements vary (Source: CBP, n.d.-b).**

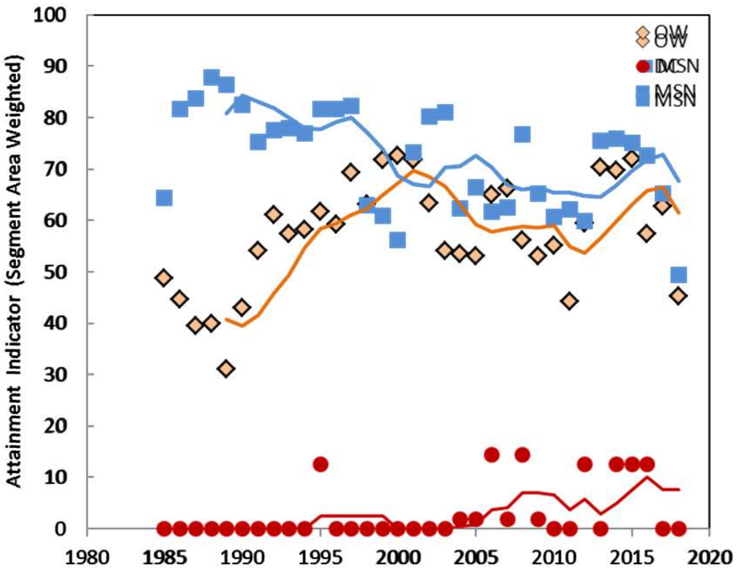
# Water Quality Standards Attainment (1985-2020)

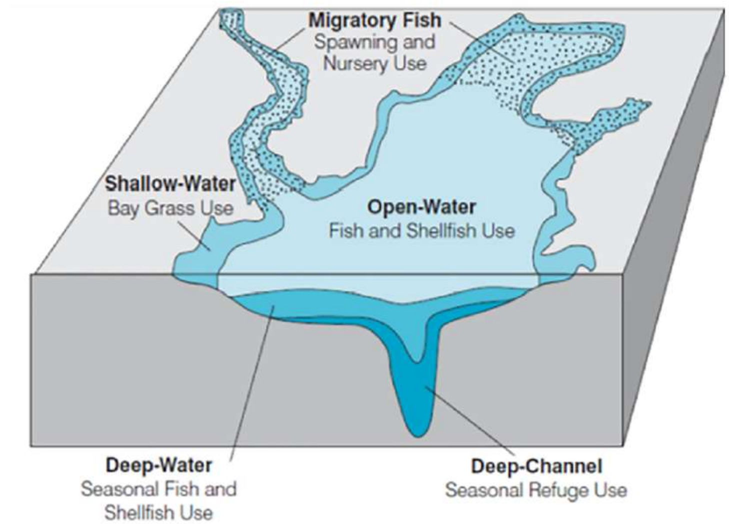
Water quality is evaluated using three parameters: dissolved oxygen, water clarity or underwater grass abundance, and chlorophyll a (a measure of algae growth).

**VIEW CHART**  VIEW TABLE



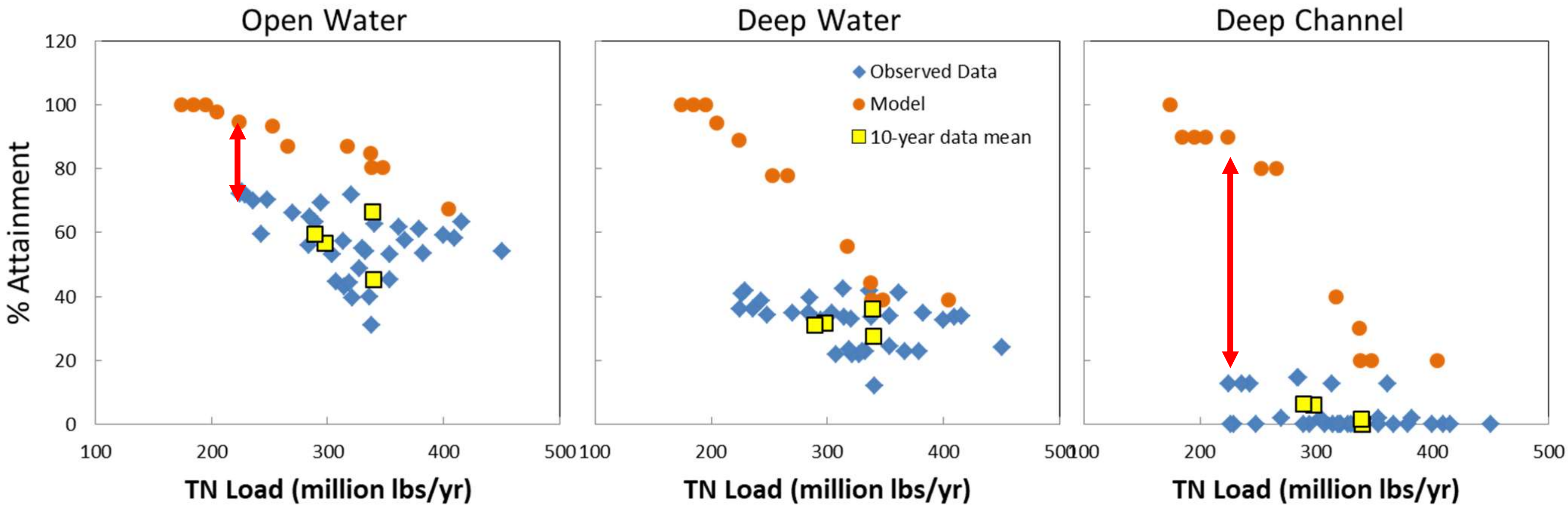
# Breaking Down WQC Attainment



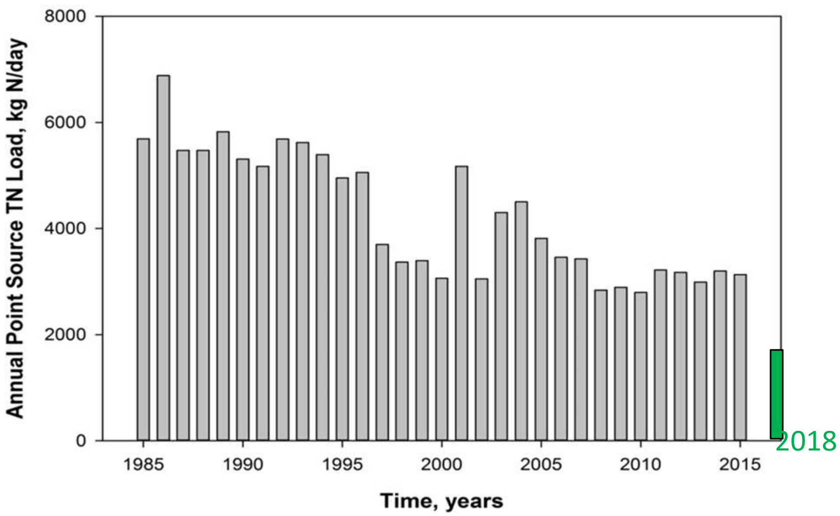

We have estimates of Baywide water quality criteria over the period in which nutrient load reductions have been made; these estimates show high attainment in some habitats, but negative trend AND low attainment in other habitats, but positive trend

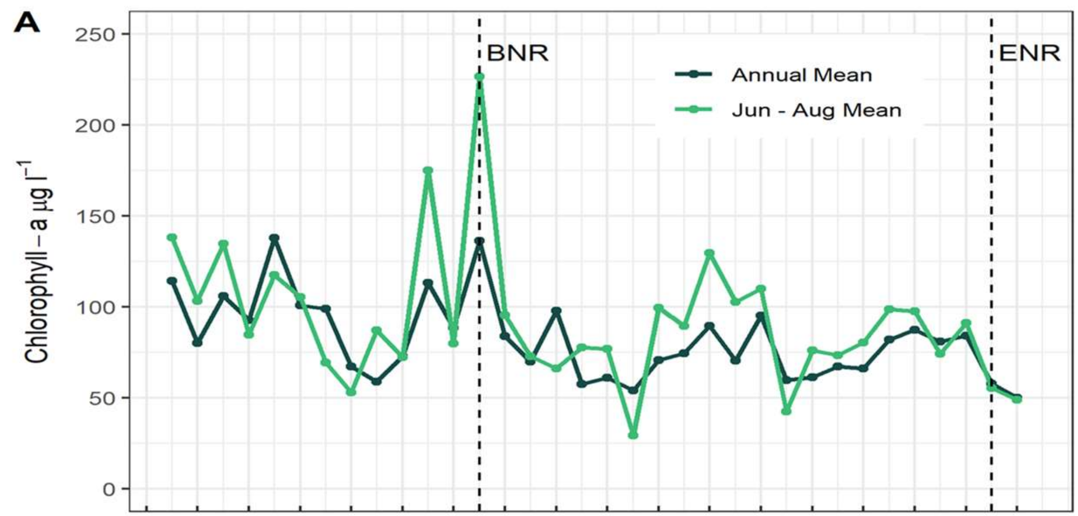
# Response Gap for DO across Habitats




**Expected and realized relationships between TN loads and DO criteria attainment for open water, deep water, and deep channel habitat, calculated as 3-year running mean observed values (blue diamonds) and expected responses from estuary model (orange dots) for the same time periods. Yellow squares are 10-year means of the observed data.**

# Water Quality Response at Local Scales: Back River

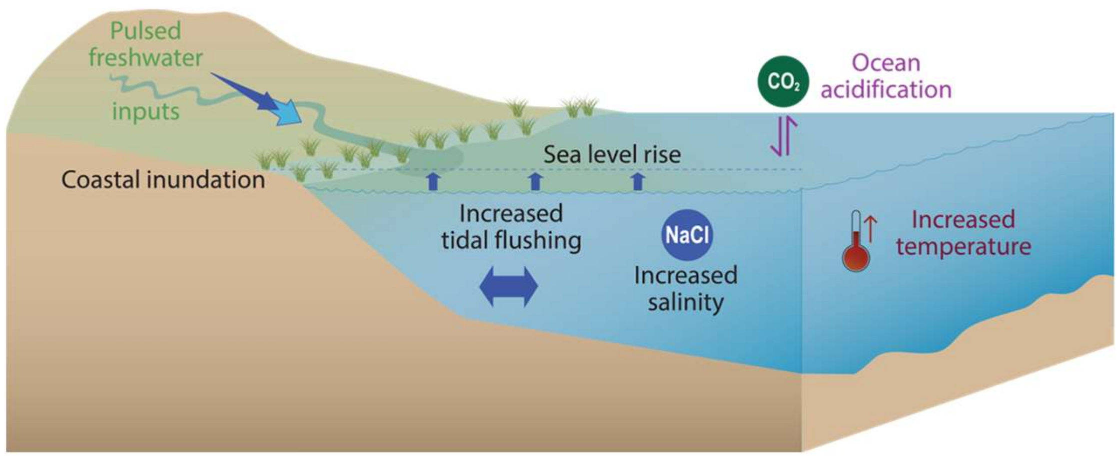


# Why Do We have Response Gaps?

Some Answers (all have uncertainties):

(a) **Climate change**: warming, sea level rise, precipitation




(b) **Tipping points, feedbacks, and trajectories of response**: Features that make Bay changes not always immediately available

# Climate Change

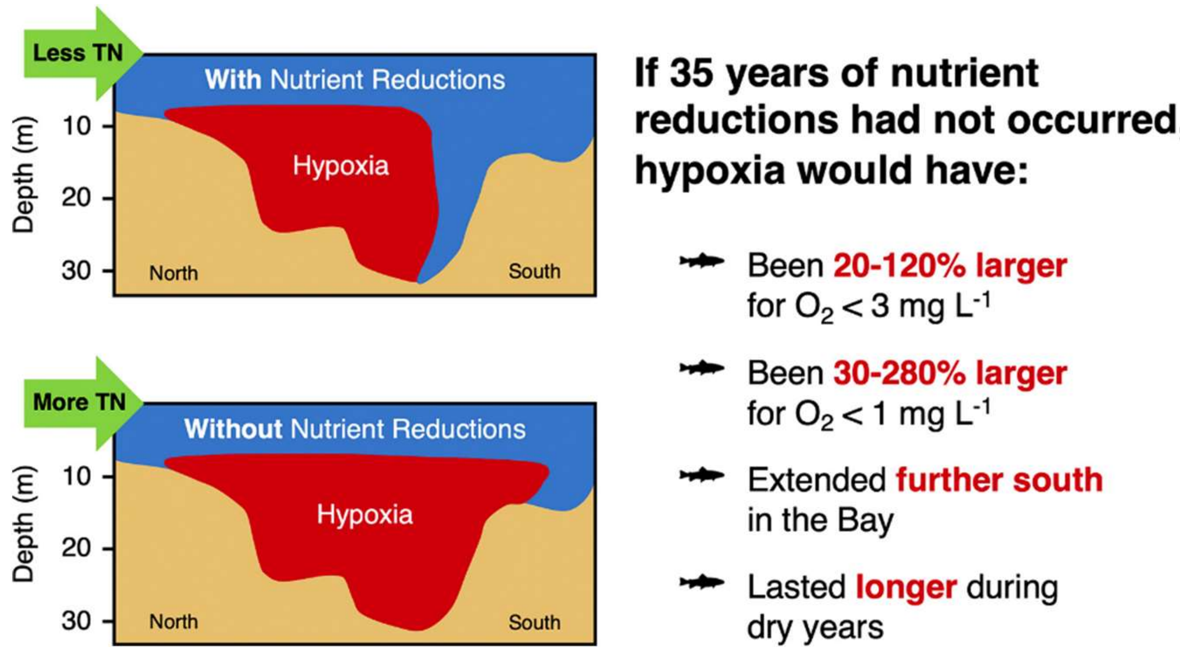
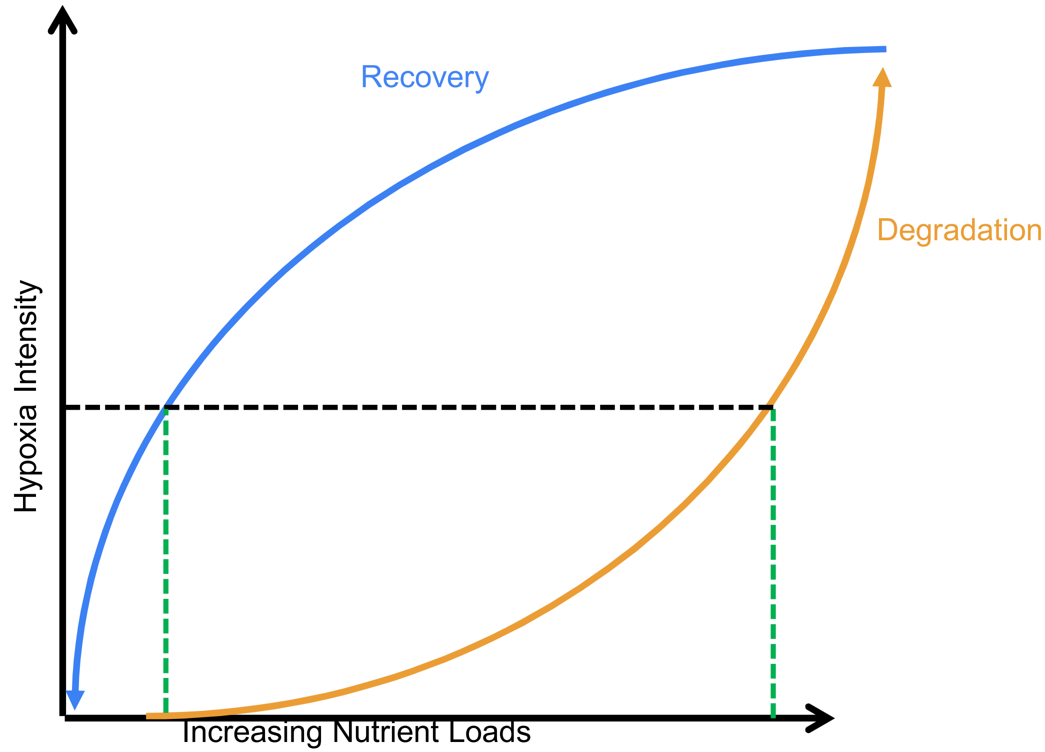



FIGURE 4.13.—Estimated extent of Chesapeake Bay hypoxia with and without 35 years of nutrient reductions (Source: Frankel et al., 2022).

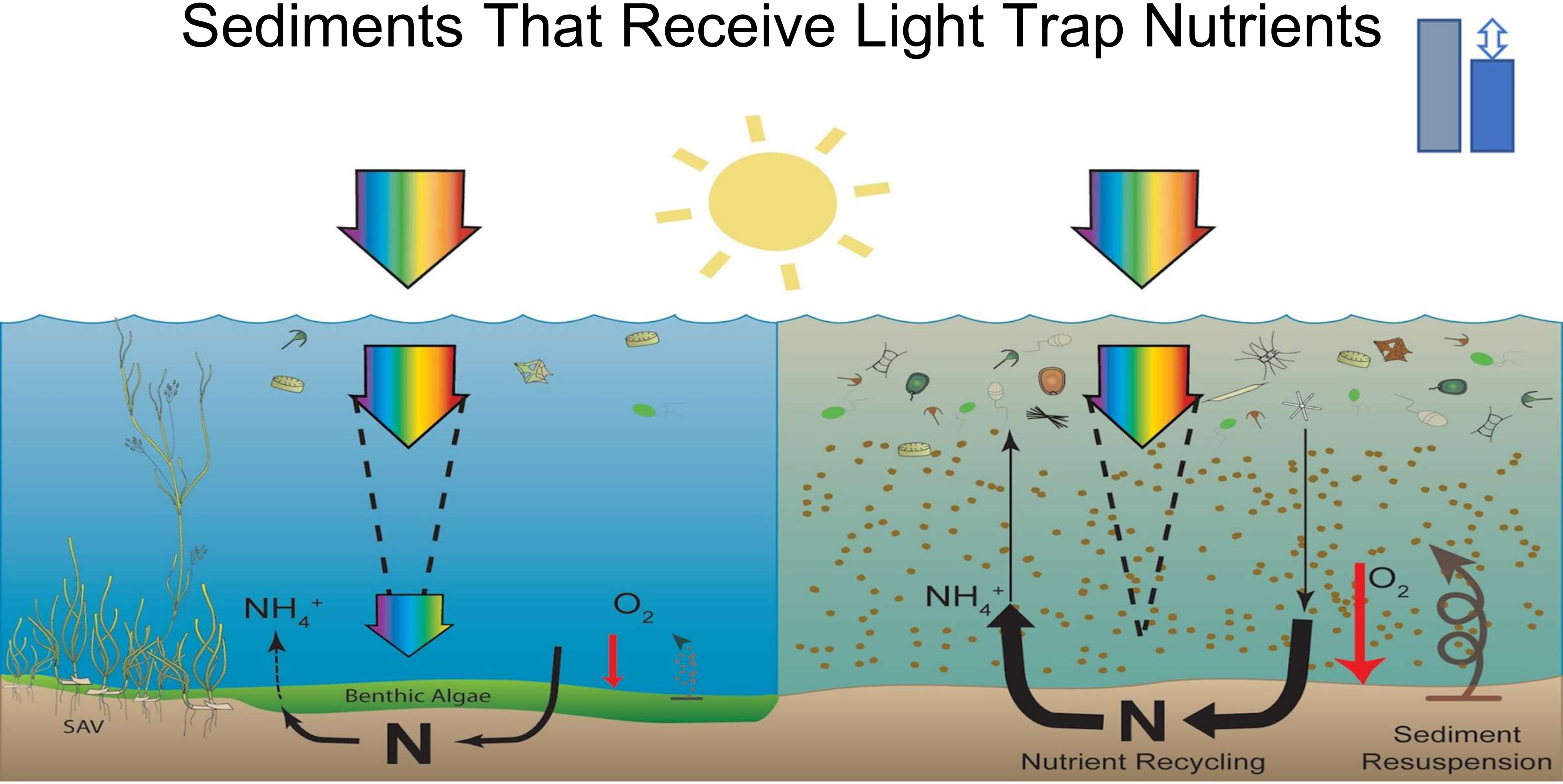
# Trajectories of Response



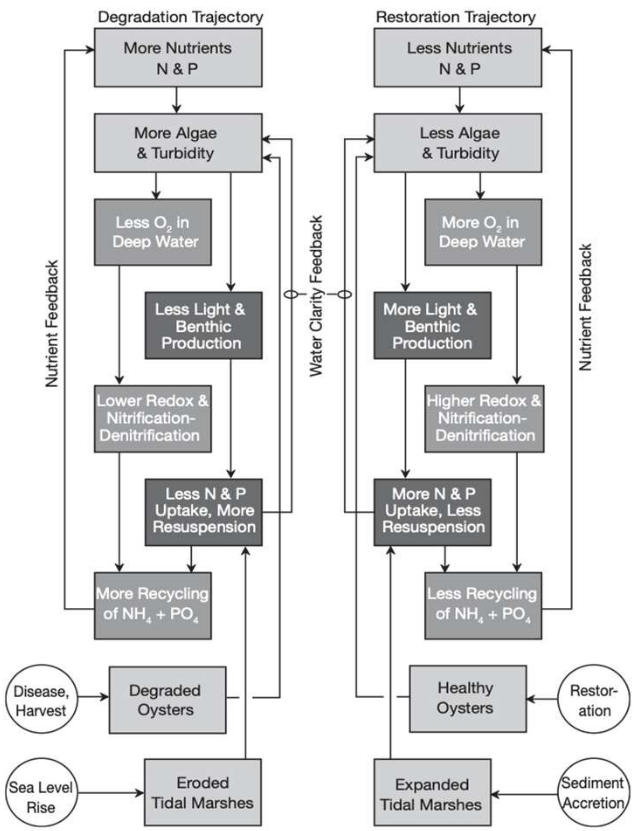

*Nutrient loading at which system will reach attainment*

*Nutrient loading at which system fell short of attainment*

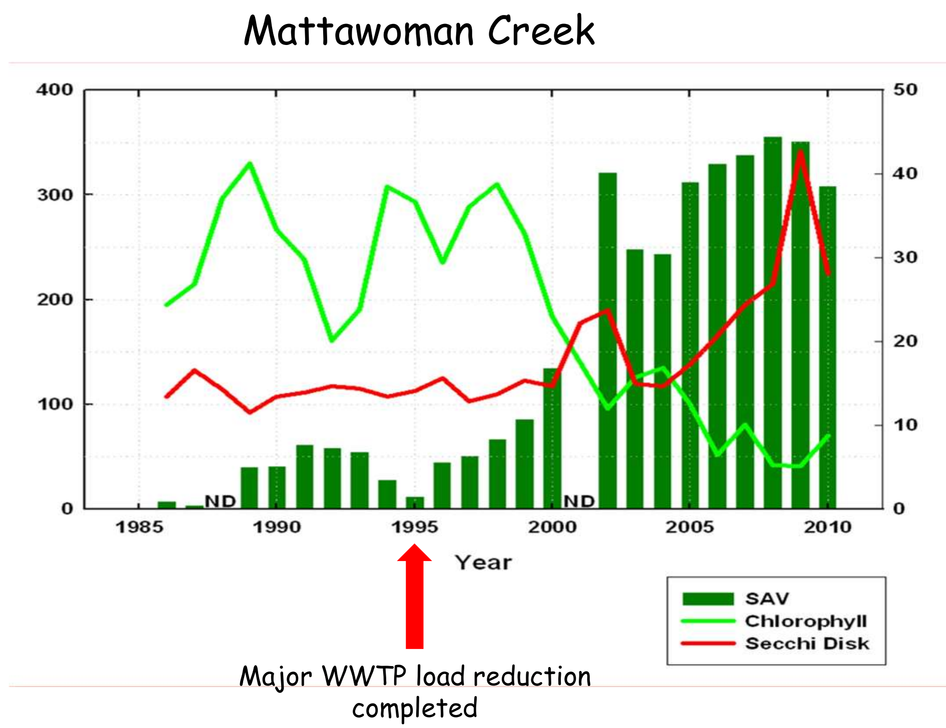
# Sediments That Receive Light Trap Nutrients



# Tipping Points and Feedbacks:
# *Where Restoration Stalls, or Takes off*



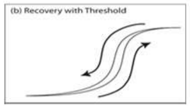

Effects of N and P additions on physical, chemical, and biological elements of the estuarine system, including algal biomass, bottom water oxygen, and nutrient recycling. (Source: Kemp et al., 2005).



SAV off Poplar Island in late summer 2015

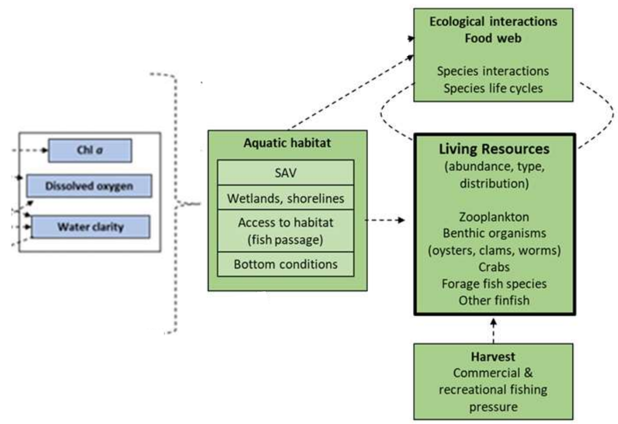
**FINDING:** Uncertain if it is possible to achieve water quality criteria (DO, SAV), **but** efforts have stemmed further declines in water quality.

- The modest reductions in nutrient loads we have achieved Baywide, which are substantial in some locales, have initiated a recovery.
- Water quality response to nutrient reductions is less than expected.
- In the deeper waters of the Bay, progress towards attainment has been slow.
- There are tipping points in the Bay ecosystem that can slow recovery in early stages but potentially accelerate recovery down the road.
- Some Bay conditions are changing, permanently altered, and irreversible.



# Findings and Implications:

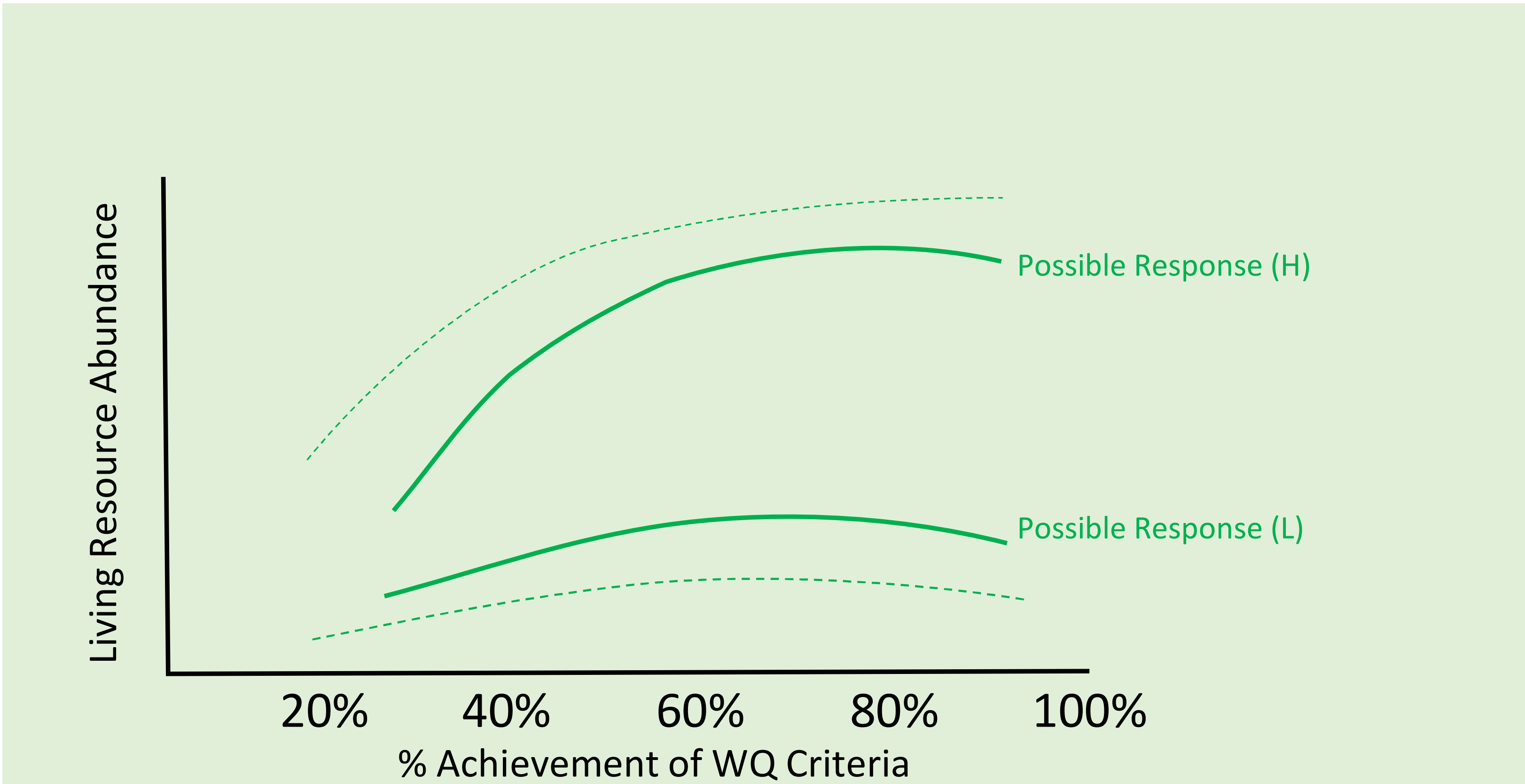
## Living Resource Response



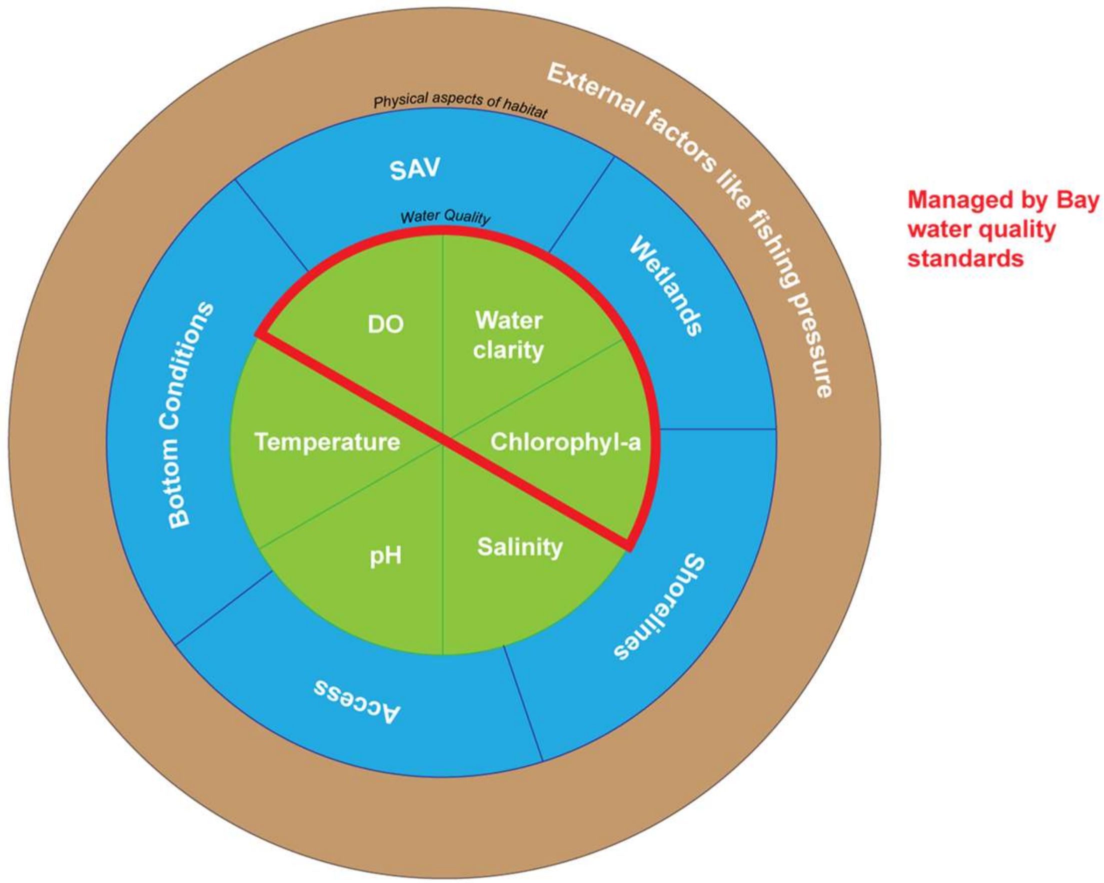
# Living Resources Response

As we approach 2025, we aimed to reflect on the following question:

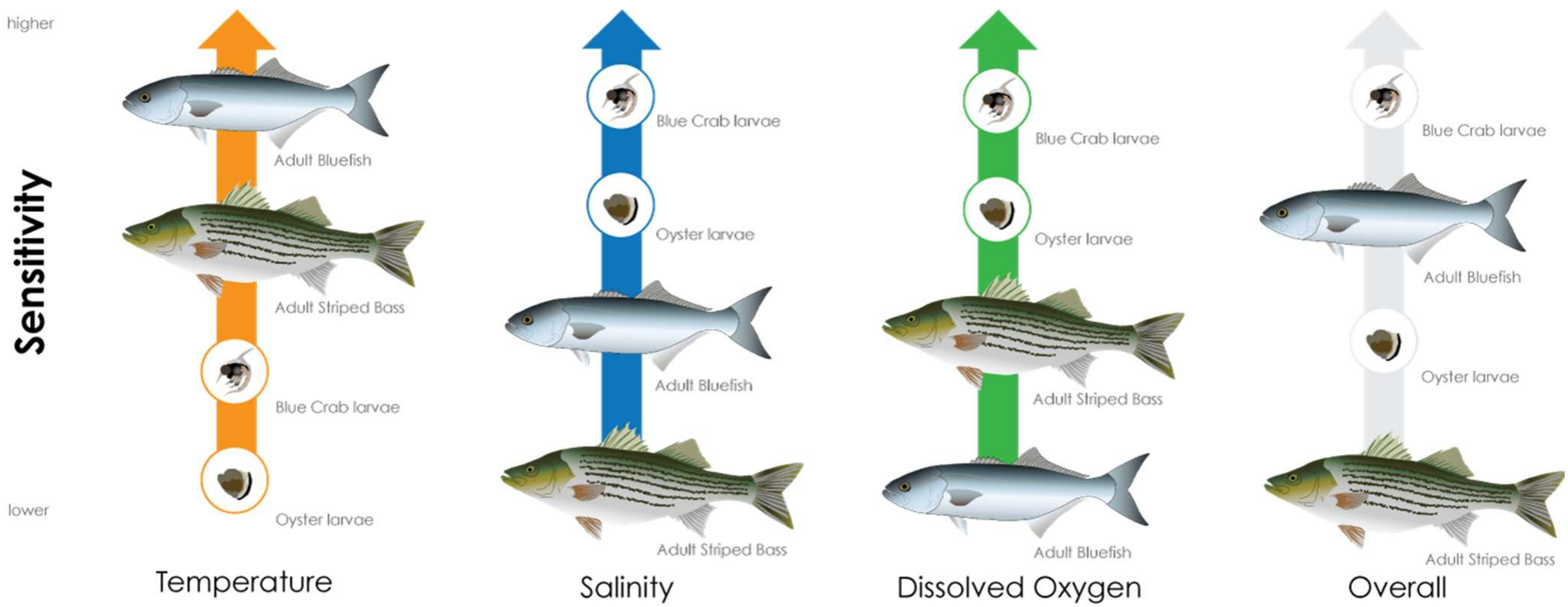
To what extent are Bay living resources improving as a result of efforts to improve water quality conditions (particularly the identified water quality criteria DO, water clarity, and Chl-a)?


Possible Response (H)
Possible Response (L)
Living Resource Abundance
20%
40%
60%
80%
100%
% Achievement of WQ Criteria

# Many Knobs of Living Resource Response



# Many Knobs of Living Resource Response




*Reinterpreted from Schelnger et al., 2022*

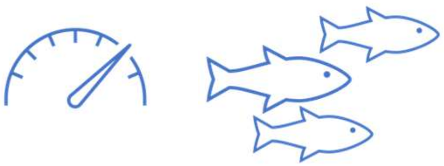
**FINDING:** It might not be possible to meet the all TMDL and WQ goals **but** this may not be necessary to meet and support living resource goals.

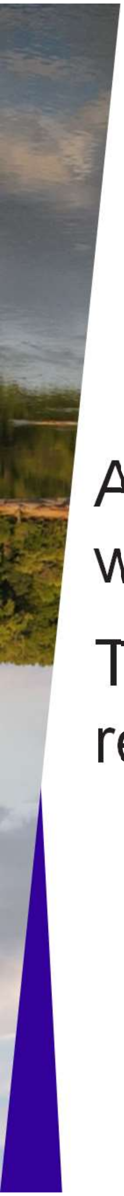
- Water quality improvements in shallow water may have more of a benefit to living resources than elsewhere.
- Water quality alone does not guarantee improvements in Living Resources. There are other factors!

# Improving Living Resource Response to Water Quality management Efforts

Implication: Opportunities exist to adjust water quality goals to prioritize management actions to improve living resource response.

- Prioritize nutrient reduction where you will get a living resource response sooner.
- Bay Program should be willing to shift investments to efforts that increase Living Resources for the water quality gains that are achieved.

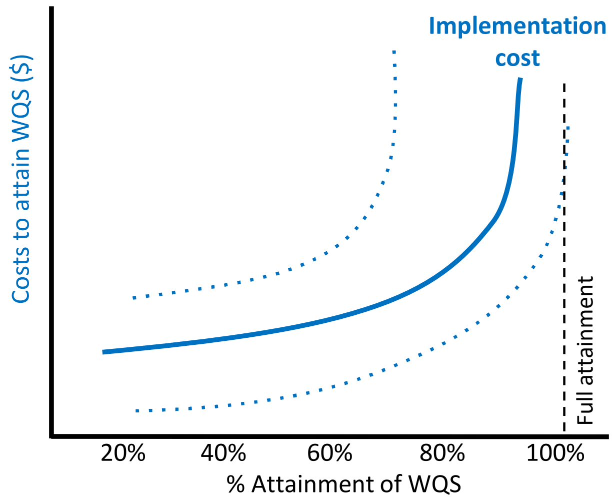




Achieving our desired outcomes is proving more challenging than we expected.

There are opportunities to improve our effectiveness, but they will require a significant change in our thinking and our programs.

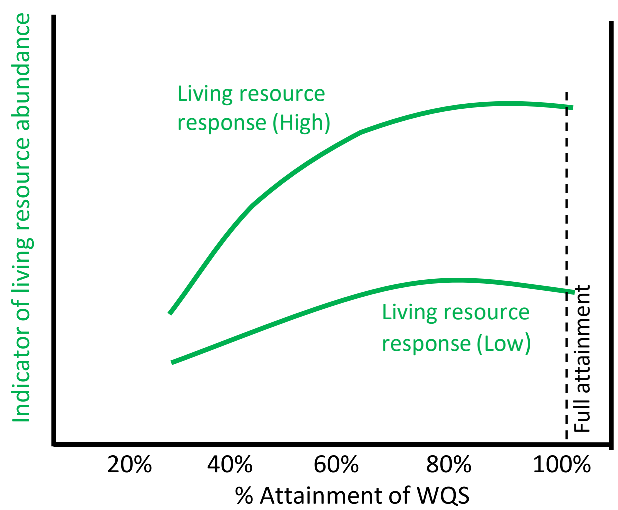
**Panel A: Costs of attaining WQS**




Costs increase rapidly as nutrient reductions approach TMDL goals.

May not be able to achieve all water quality criteria even at high cost (particularly deep waters)

**Panel B: Possible living resource response**



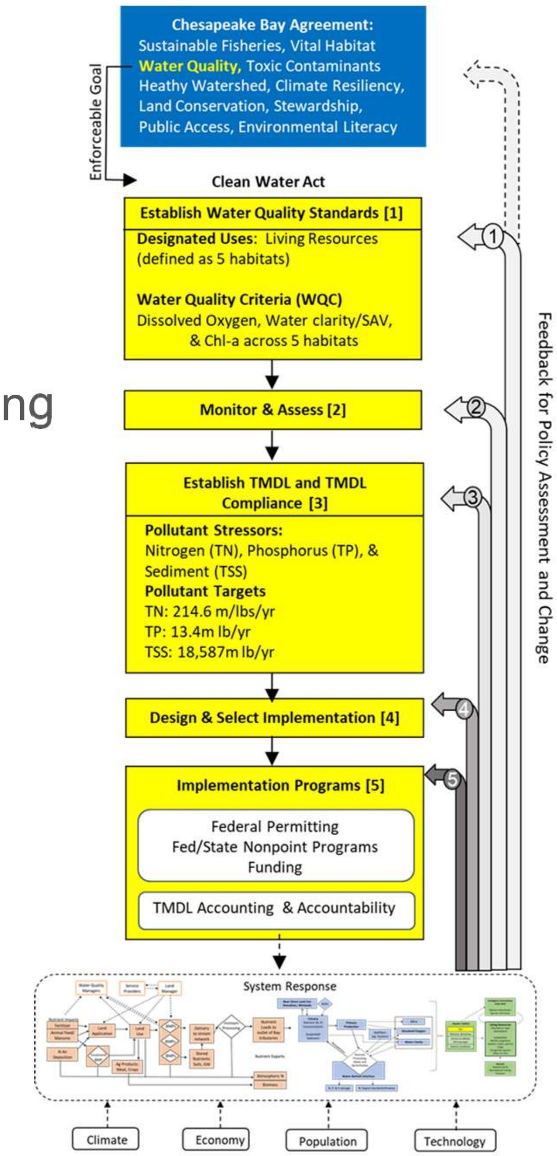

The improvements in living resources from improvements in targeted water quality conditions (DO, SAV) depends on:

1) location, timing, magnitude of Bay water quality improvements;

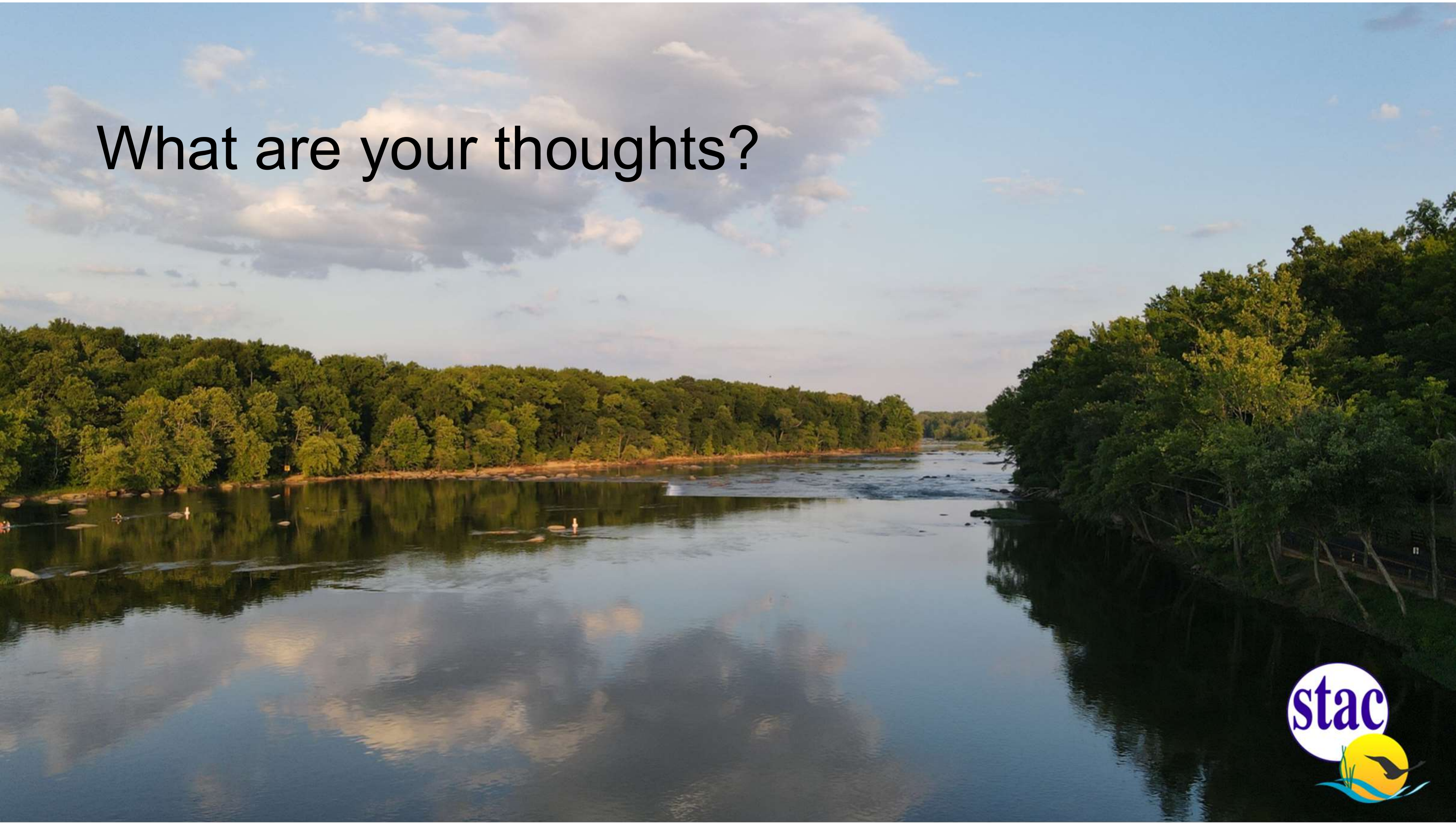
2) the status of all other factors that influence living resource abundance (habitat, harvest, etc)

# How to translate this into decision-making?

- Will need to include all levels of policy feedback and learning in the existing CWA approach (arrows 1 through 4).
  - Who?
  - How?
- Now is an opportunity to developed expanded adaptive management processes



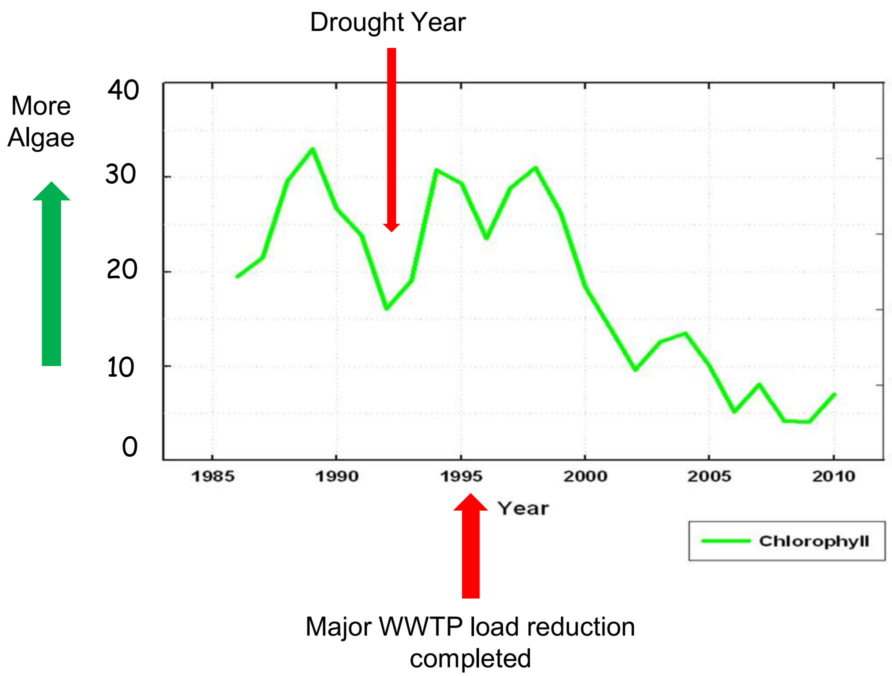
# What are your thoughts?



# Water Quality Response at Local Scales: Mattawoman Creek

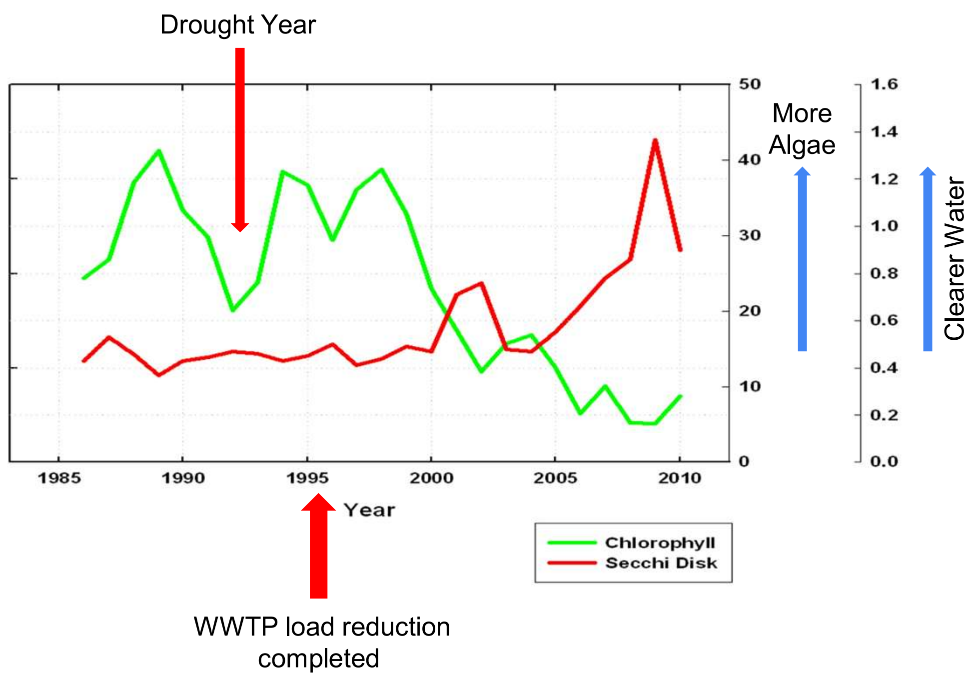

Photo from Elena Gilroy

# Algal Biomass Decreased …with Substantial Lag Time



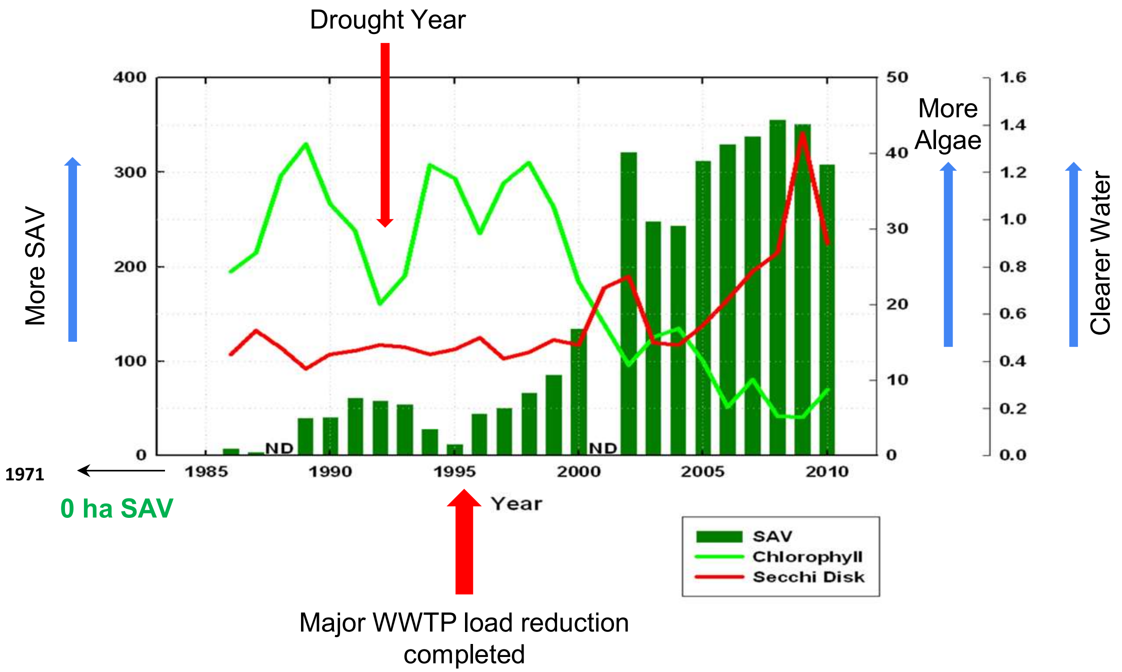

- No clear response for about 4 years followed by sharp decline in algae
- After 2005 low levels of algae became normal

# Water Clarity Increased …Also with a Lag Time




- No clear increase for about 8 years followed by sharp increase in clarity
- Water clarity and algae highly correlated in shallow Chesapeake Bay systems

# SAV Increased
# …Shorter Lag with Threshold Response




- Very low levels of SAV were present prior to nutrient load reductions
- Major expansion of SAV in 2002, a severe drought year
- SAV relatively stable after 2002; lag in SAV relatively short