Identifying Critical Uncertainties

The Comprehensive Evaluation of System Response (CESR) Report

Chesapeake Community Research Symposium, 7 June 2022

Who is STAC?

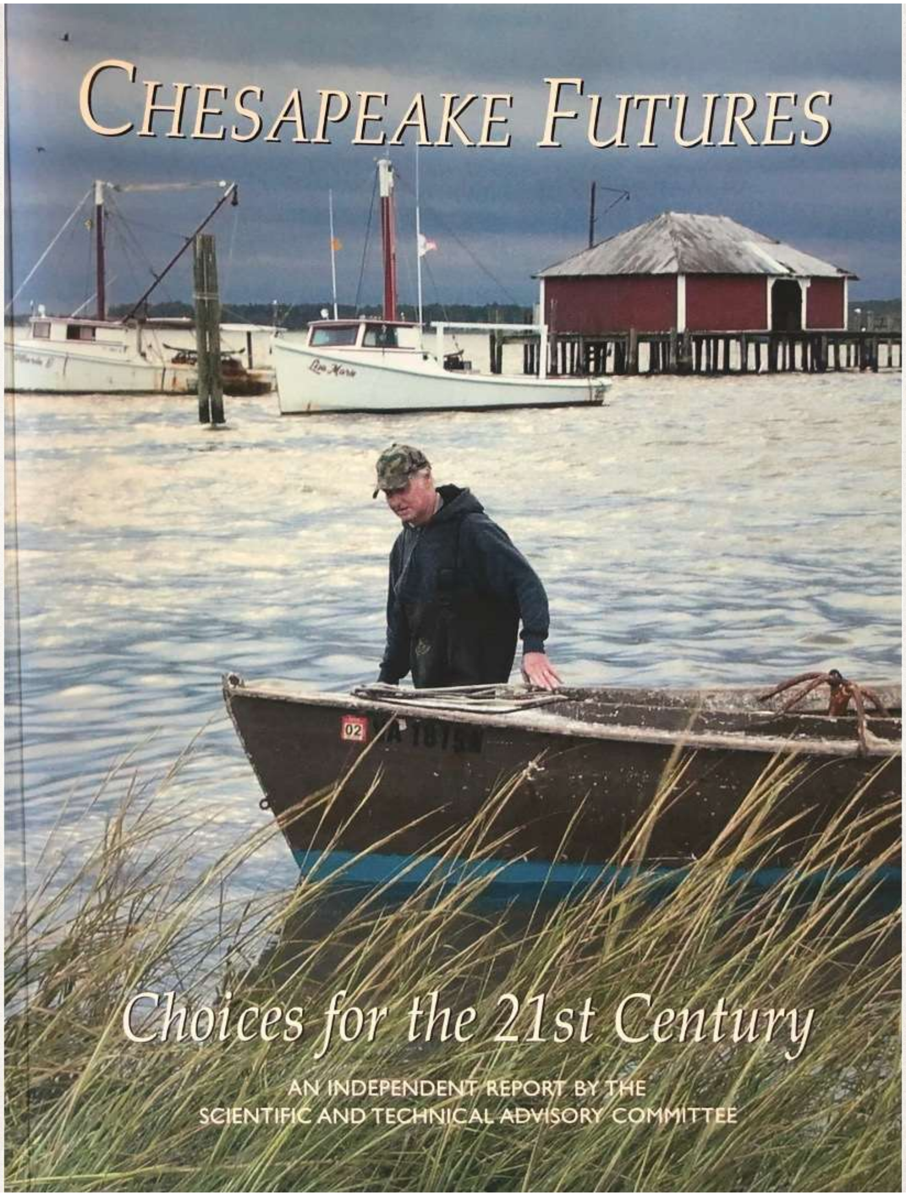
- Since its creation in December 1984, provides independent scientific and technical advice to the partnership via technical reports and position papers, organizing merit reviews of CBP programs and projects, technical workshops, and interaction between STAC members and the CBP.

Chesapeake Futures

Produced in January 2003

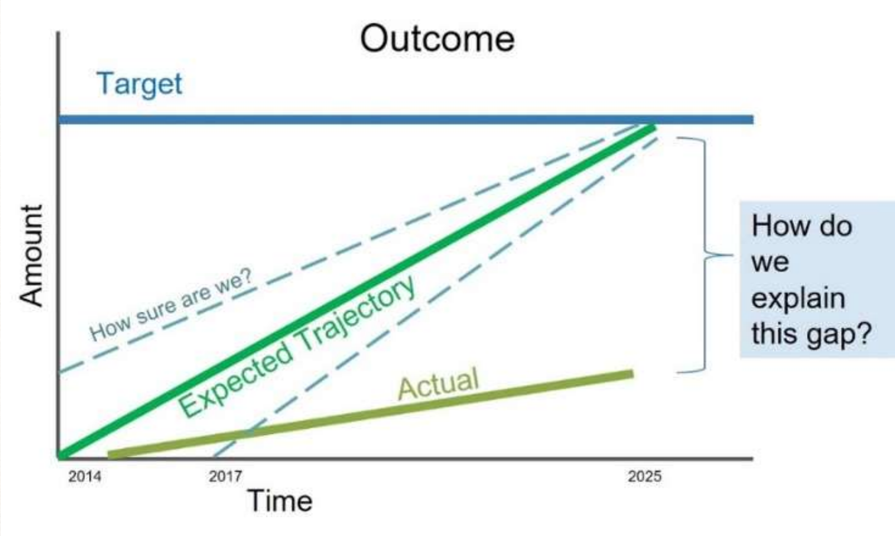
Captured the state of knowledge and presented a likely set of outcomes, or scenarios, based on that knowledge and projected trends

Scenarios of : 1) under recent trends, 2) if the objectives of agreements put in place at that time were met (e.g., Chesapeake 2000), and 3) if feasible alternatives were put in place



Critical Uncertainties

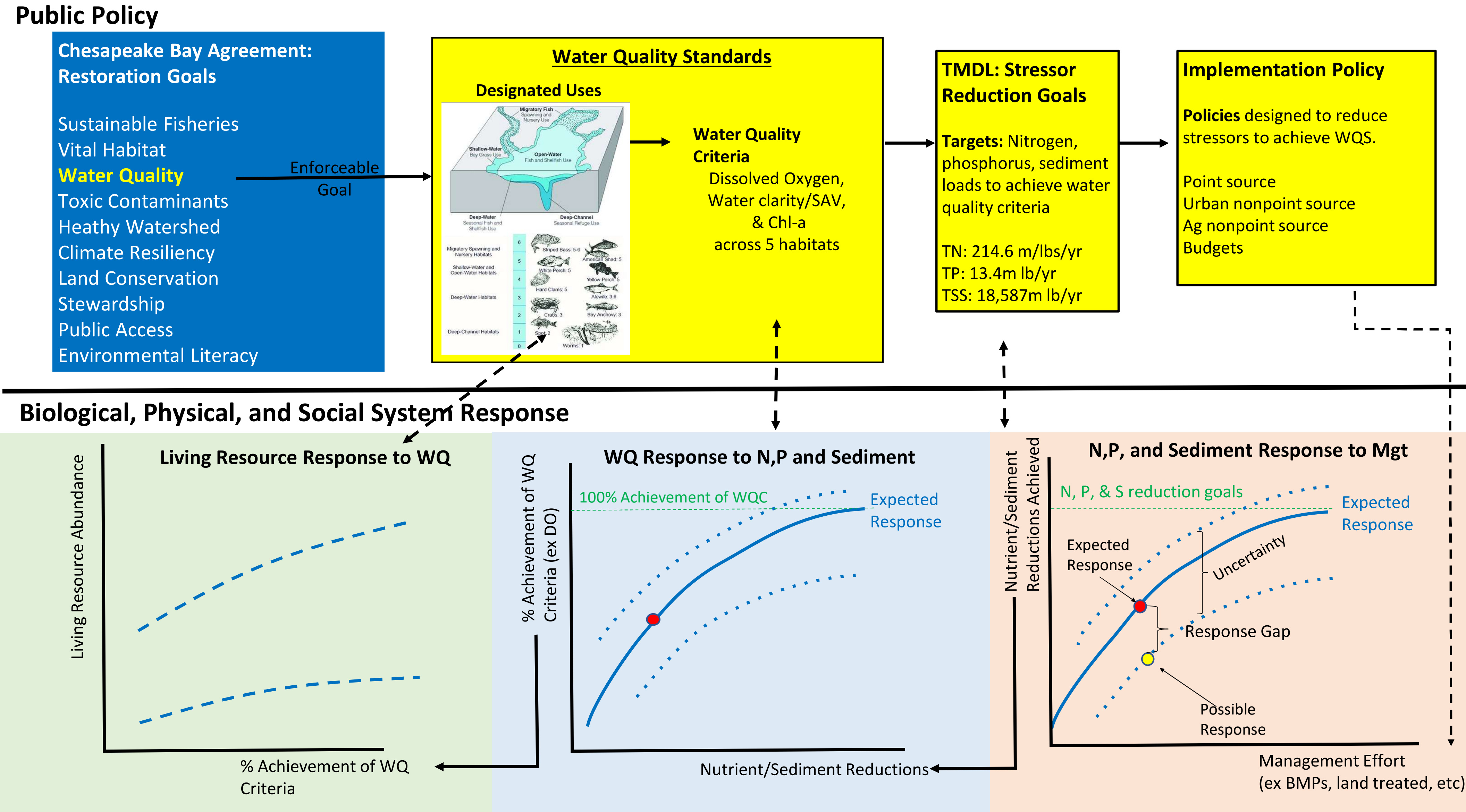
- Critical uncertainty: if addressed or resolved, would change the course of action



The restoration effort will always require us to make decisions with incomplete information and assess the results in order to learn, meaning that we knowingly recognize that one kind of risk (that our selected management and policy actions may need to be improved or revised) is being accepted to avoid another (continuing to make choices with incorrect information). Assessing and managing this balance requires that we formally assess the efficacy of our actions and/or their unintended consequences.

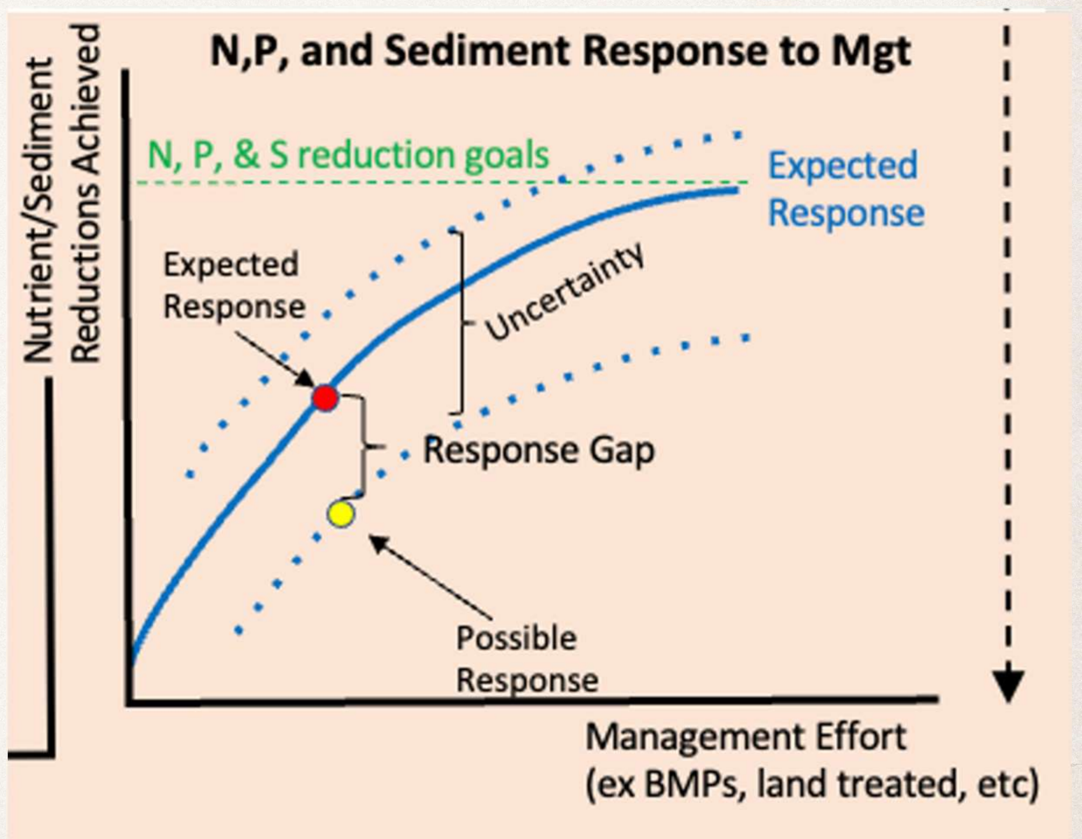
Achieving Water Quality Goals in the Chesapeake Bay: An Evaluation of System Response

- Identify gaps and uncertainties in system response —physical, chemical, biological, and socioeconomic— that impact efforts designed to attain WQS.
- Identify recent scientific developments that can shed light on the gaps and uncertainties in system response to advance efforts to attain WQS.
- Recommend research strategies that improve understanding of system response to support informed decision making to attain WQS.
- Recommend strategies for integrating scientific and technical analysis with active adaptive management in order to aid decision-making under uncertainty (to achieve WQS).


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
Enforceable Goal
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 loads to achieve water quality criteria
TN: 214.6 m/lbs/yr
TP: 13.4m lb/yr
TSS: 18,587m lb/yr
Implementation Policy
Policies designed to reduce stressors to achieve WQS.
Point source
Urban nonpoint source
Ag nonpoint source
Budgets
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
Nutrient/Sediment Reductions
N,P, and Sediment Response to Mgt
Nutrient/Sediment Reductions Achieved
N, P, & S reduction goals
Expected Response
Expected Response
Uncertainty
Response Gap
Possible Response
Management Effort (ex BMPs, land treated, etc)

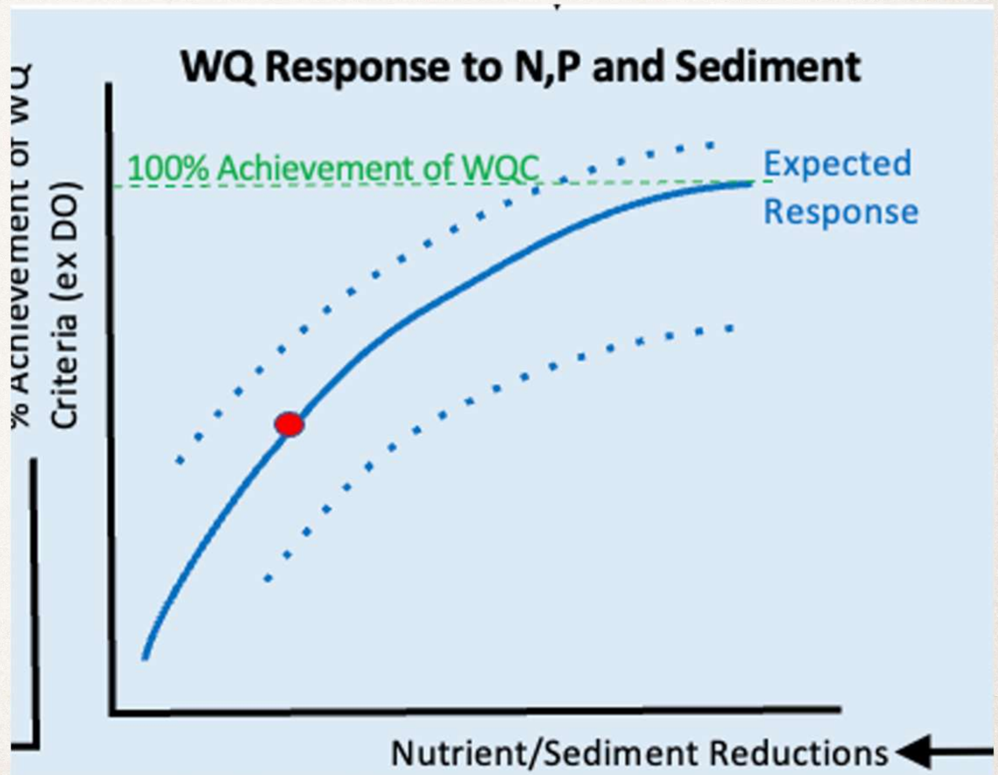
Evaluation of Watershed System Response to Nutrient and Sediment Policy and Management

Easton, Z., K. Stephenson, B. Benham, J.K. Bohlke, C. Brosch, A. Buda, A. Collick, L. Fowler, E. Gilinsky, C. Hershner, A. Miller, G. Noe, L. Palm-Forster, T. Thompson.



Knowledge Gaps, Uncertainties, and Opportunities Regarding the Response of the Chesapeake Bay Estuary to proposed TMDLs

Dennison, W., L. Sanford, J. Testa, B. Benham, C. Hershner, W. Ball, D. Gibson, M. Runge, and K. Boomer.



Proposed Framework for Analyzing Water Quality and Habitat Effects on the Living Resources of Chesapeake Bay

Rose, K., M. Monaco, K. Havens, H. Karimi, J. Hubbart, E. Smith, J. Stauffer, T. Ihde, L. Shabman.

Any fool can know. The point is to understand.

Albert Einstein

Final Report

- Initiated in March 2019; publishing date August 2022
- First STAC "consensus" report (not everything we want, but we can all live with what is in there) in 20 years
- Committed to communicating all of the work; decision to publish foundational work as "Resource Documents"

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

Table of Contents

Supplemental Reports (listed, but not included, in the report and published by CRC separately):

Easton, Z., K. Stephenson, B. Benham, J.K. Bohlke, C. Brosch, A. Buda, A. Collick, L. Fowler, E. Gilinsky, C. Hershner, A. Miller, G. Noe, L. Palm-Forster, T. Thompson. 2022. *Evaluation of Watershed System Response to Nutrient and Sediment Policy and Management*, STAC Publication Number 22-XXX. Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD. XX pp.

Dennison, W., L. Sanford, J. Testa, B. Benham, C. Hershner, W. Ball, D. Gibson, M. Runge, and K. Boomer. 2022. *Knowledge Gaps, Uncertainties, and Opportunities Regarding the Response of the Chesapeake Bay Estuary to proposed TMDLs,* STAC Publication Number 22-XXX. Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD. XX pp.

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Screenshot

- Easton, Z., K. Stephenson, B. Benham, J.K. Bohlke, C. Brosch, A. Buda, A. Collick, L. Fowler, E. Gilinsky, C. Hershner, A. Miller, G. Noe, L. Palm-Forster, T. Thompson. 2022. **Evaluation of Watershed System Response to Nutrient and Sediment Policy and Management**

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- Rose, K., M. Monaco, K. Havens, H. Karimi, J. Hubbart, E. Smith, J. Stauffer, T. Ihde, L. Shabman. 2022. **Proposed Framework for Analyzing Water Quality and Habitat Effects on the Living Resources of Chesapeake Bay**.

Expectations

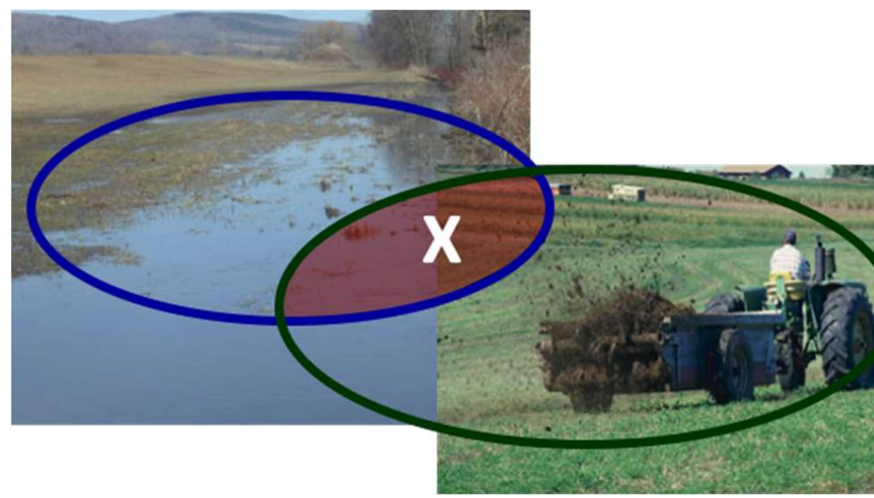
- Initiated in March 2019; publishing date August 2022
- First STAC "consensus" report (not everything we want, but we can all live with what is in there) in 20 years?

Watershed

Is the Watershed Responding to Management as Expected

- **The Nonpoint Source Challenge**
  - *Legacy Nutrients*
  - *Nutrient Mass Balance*
  - *BMP Nutrient/ Sediment Removal Effectiveness*
- **Storage Transport & Delivery**
- **Climate Change**
- **Adaptative Management in the Face of Uncertainty**

Nonpoint Sources



Effectiveness of Nonpoint Source Management Efforts

Achievement of remaining nutrient/ sediment reduction goals rests primarily with agricultural/NPS sources

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

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

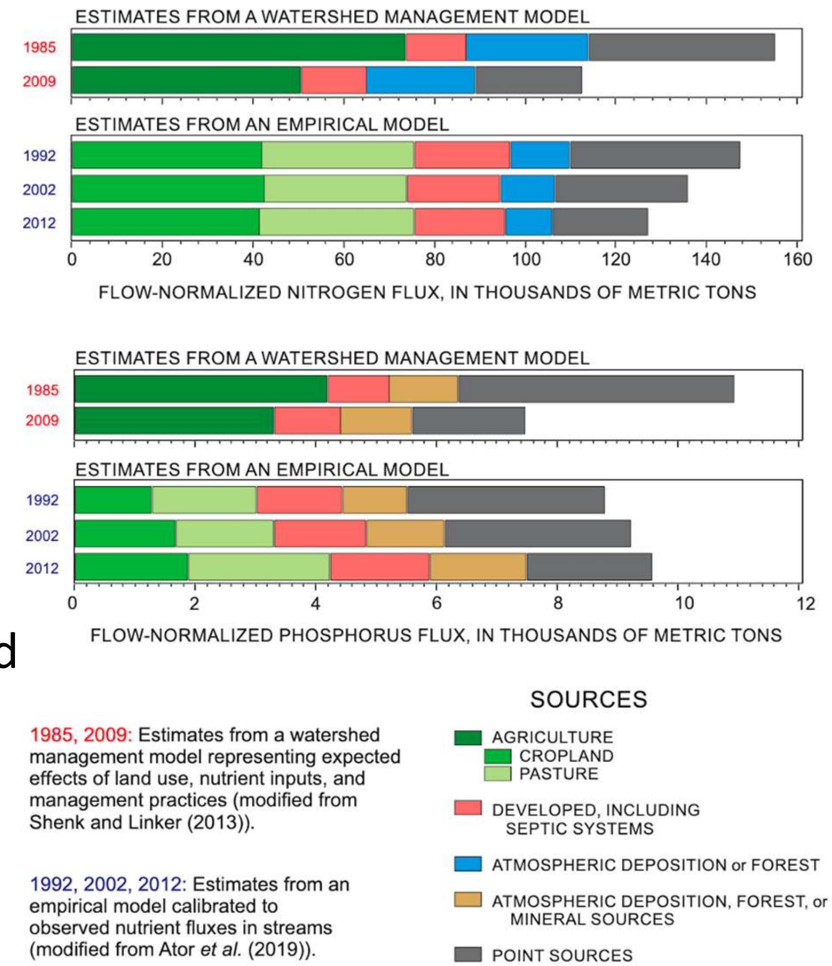
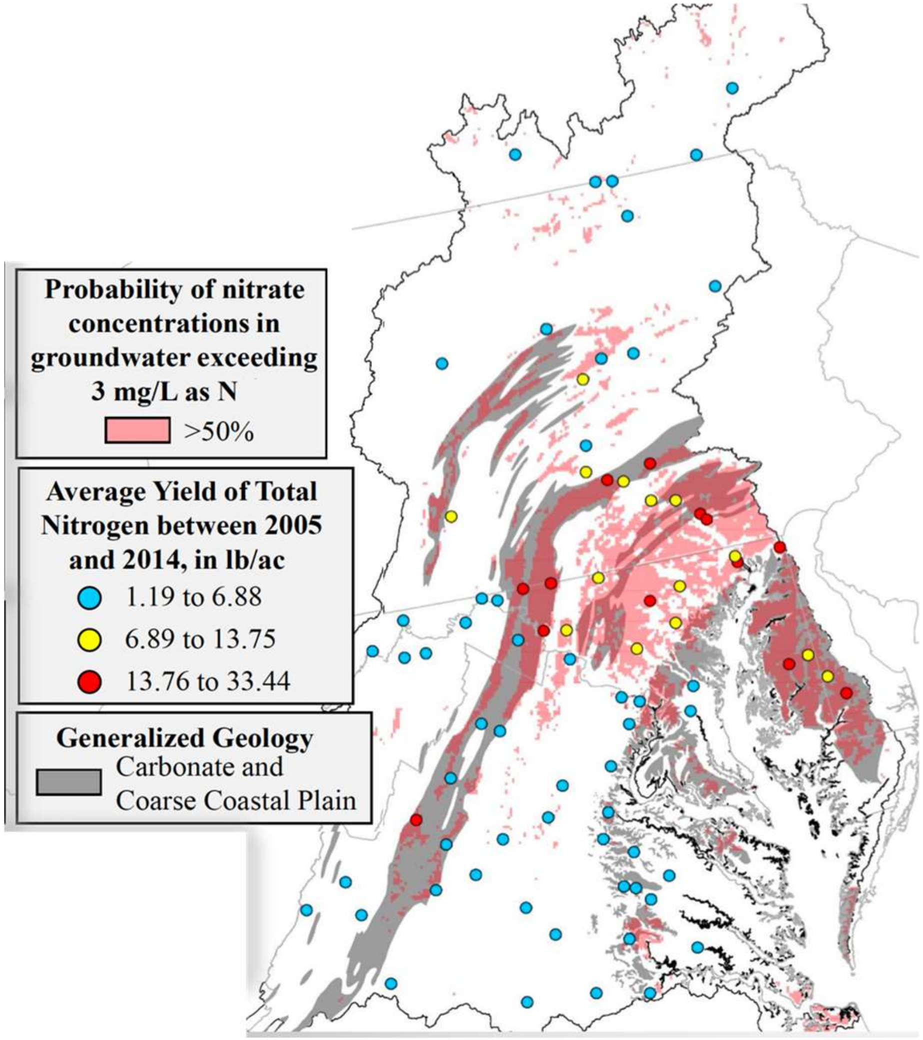


FIGURE 3 Estimated flow-normalized total and source specific annual fluxes of nitrogen and phosphorus to Chesapeake Bay for selected years from different models (Ator et al., 2019; Shenk & Linker, 2013)

Legacy Nutrients

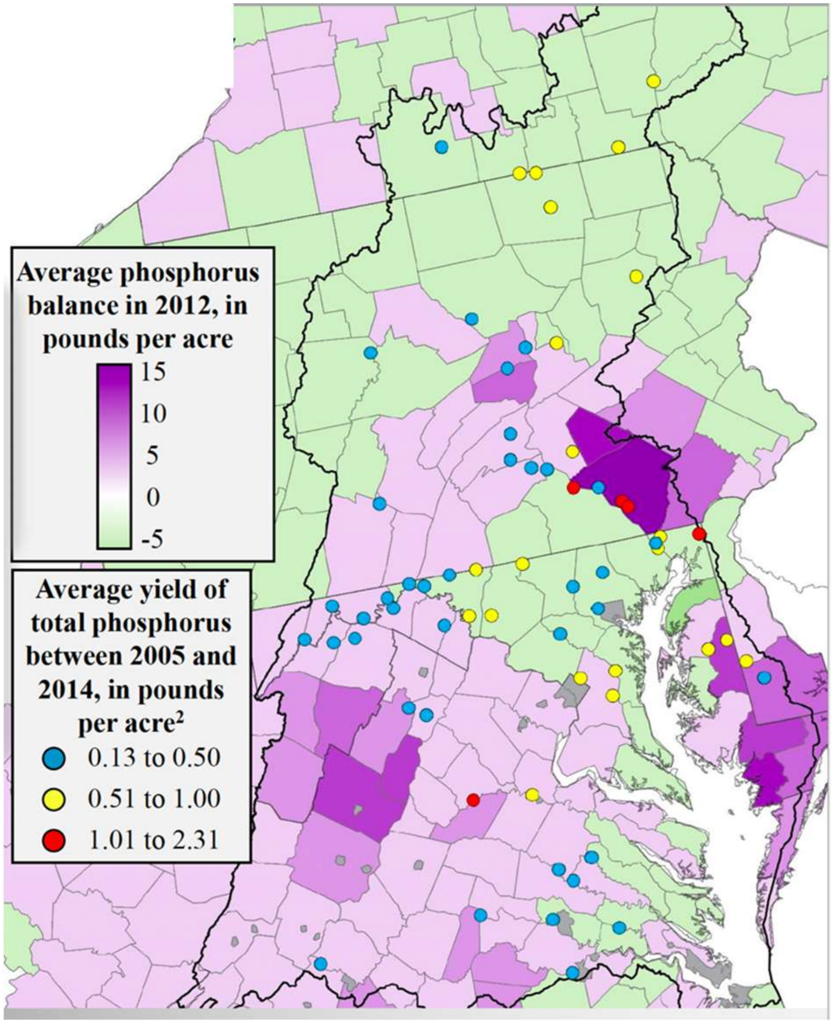
- Large stores of N and P in soils and groundwater exist throughout the watershed
- Under the most optimistic assumptions, the drawdown in P and N levels from soils and groundwater could take decades



Source: Jimmy Webber USGS, STAC workshop presentation Dec 2017.

Nutrient Mass Balance

- Large mass balance issues exist in many agricultural dominated regions (inputs of feed and fertilizer exceeding assimilative capacity)
- Continued growth in intensive animal agriculture has compounded this issue and represent large potential source of nutrients in the system
- Significant heterogeneity in nutrient use efficiency (nutrient mass imbalances) across livestock operations Pearce and Maguire 2020

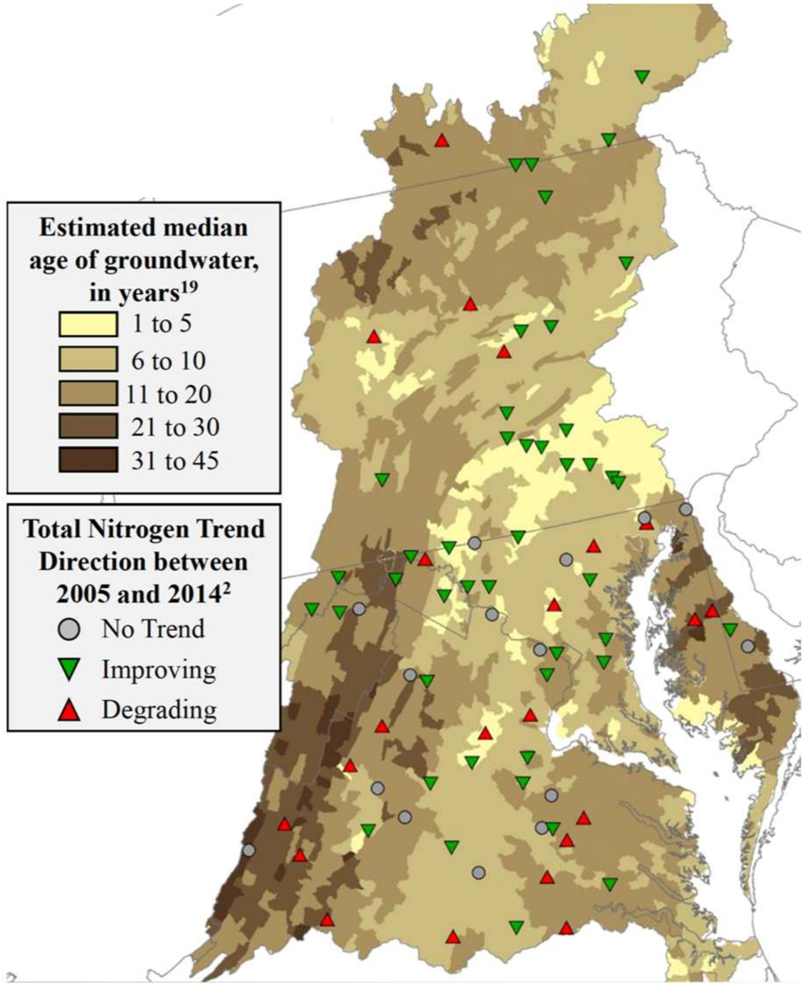


Moyer et al. 2107, Webber, 2017

5

BMP Effectiveness

- Uncertainty regarding BMP efficiencies
  - Constant assumed effectiveness over BMP lifetime
  - Constant removal efficiencies across storms
- Lag times
- Monitoring and modeling is insufficient to detect a signal
  - BMPs may be effective but we cannot detect or isolate the signal



Baseflow nitrogen from decades old groundwater may be masking BMP effects

Moyer et al. 2017; Bhatt et al. 2017

5 I would like to get something about assumed behavior ... For example CBP assumes behavior about maintenance.. assumed behavior regarding nutrient management plans, etc... See comment in the note section for slide 8

Kurt Stephenson, 6/5/2022

Storage Transport & Delivery

- TMDL framework focuses on TN and TP, yet we know it is the bioavailable constituents that pose the most significant impact to achieving water quality criteria.
- Uncertainties related instream processing, storage, and transport
  - Conowingo

Behavioral Responses

A substantial portion of planned reductions come from voluntary technical and financial assistance programs

- What are the limits to participation (type and level) under existing technical assistance and financial assistance programs
- How can adoption/participation/cost effectiveness change under alternative voluntary or regulatory programs
- How effective are stakeholder engagement and communication processes at encouraging adoption of effective practices
- Assumptions about behavior pertaining to BMP maintenance, behavior regarding nutrient management plans, many others

Adapting to an Uncertain Future

- **Climate Change**
  - Load and management effectiveness given changing annual & extreme precipitation, temperature, sea level rise.
- **Land Use/Population**
  - Forms of urbanization, types of agriculture (including changing preferences for ag products)
- **Atmospheric deposition**
  - Changing electric power, transportation sectors

Watershed Group

- Zach Easton – Virginia Tech
- John Karl Bohlke – USGS
- Anthony Buda – USDA
- Brian Benham – Virginia Tech
- Ellen Gilinsky – Gilinsky Consulting
- Tom Johnson – EPA
- Elliott Kellner – WVU
- Andy Miller – UMBC
- Gregory Noe – USGS
- Leah Palm-Forster – Univ Delaware
- Michael Runge – USGS
- Kurt Stephenson – Virginia Tech
- Tess Thompson – Virginia Tech

Estuary

Knowledge Gaps, Uncertainties, and Opportunities Regarding the Response of the Chesapeake Bay Estuary to TMDLs

William C. Dennison, Jeremy M. Testa, Lawrence Sanford, William P. Ball, Deidre M. Gibson, Michael C. Runge, Lewis Linker and Kathleen Boomer

How did we approach this document?

We could have approached our report simply with answers to the question:

Is the Bay's tidal water quality response to efforts to meet the TMDL consistent with expectations?

In many ways, we looked past this Y/N question, perhaps because:

(1) we would have needed a long-term research program to answer that question ***in detail*** on our own,

(2) a wealth of literature had recently emerged to show ecosystem responses in line with nutrient load reductions where they were substantial, and

(3) we decided that a broader view of the tidal Bay restoration was needed

Do we think the Bay is responding to the TMDL as expected?

Answer: Yes…., and No (not as much as expected)

YES

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

Rebecca R. Murphy,* Jennifer Keisman, Jon Harcum, Renee R. Karrh, Mike Lane, Elgin S. Perry, and Qian Zhang

Increasing Severity of Phytoplankton Nutrient Limitation Following Reductions in Point Source Inputs to the Tidal Freshwater Segment of the James River Estuary

Joseph D. Wood · Paul A. Bukaveckas

Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region

Jonathan S. Lefcheck[a,b,1], Robert J. Orth[b], William C. Dennison[c], David J. Wilcox[b], Rebecca R. Murphy[d], Jennifer Keisman[e], Cassie Gurbisz[f,g], Michael Hannam[h], J. Brooke Landry[i], Kenneth A. Moore[b], Christopher J. Patrick[j], Jeremy Testa[k], Donald E. Weller[h], and Richard A. Batiuk[l]

Biogeochemical states, rates, and exchanges exhibit linear responses to large nutrient load reductions in a shallow, eutrophic urban estuary

Jeremy M. Testa,* Walter R. Boynton, Casey L. S. Hodgkins, Amanda L. Moore, Eva M. Bailey, Johanna Rambo

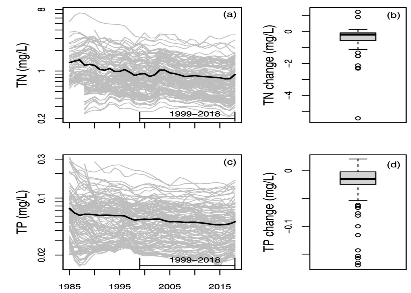
Localized Water Quality Improvement in the Choptank Estuary, a Tributary of Chesapeake Bay

Thomas R. Fisher[1] · Rebecca J. Fox[2] · Anne B. Gustafson[1] · Erika Koontz[1] · Michelle Lepori-Bui[1,3] · James Lewis[4]

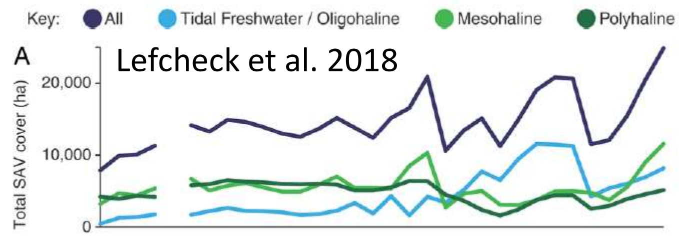
Multi-decade Responses of a Tidal Creek System to Nutrient Load Reductions: Mattawoman Creek, Maryland USA

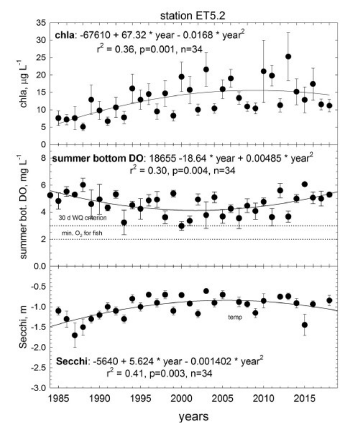
W. R. Boynton · C. L. S. Hodgkins · C. A. O'Leary · E. M. Bailey · A. R. Bayard · L. A. Wainger

Murphy et al. 2022



Lefcheck et al. 2018





Fisher et al. 2021

But why not as much as expected?

Potential Key Uncertainties:

- ***Natural variation and inherent randomness:***
  - The climate is already changing, and the Bay (and watershed) is responding
  - Species distributions are changing

- ***Parameter uncertainty***
  - Even with substantial nutrient load reductions in some regions, mostly driven by wastewater and atmospheric deposition (pipes), loading is increasing or stable in many locations, and nutrient legacies still unknown → **tipping points?**
  - Parameters in numerical models

- ***Structural uncertainty***
  - Unaccounted systems processes or drivers limit capacity to predict system behavior → **terrestrial-estuarine transition zone (T-zone)** regulates interactions between the watershed and the mainstem

---

- ***Observational uncertainty***

What steps should we take to reduce uncertainties?

(1) Targeted new monitoring, modeling and research in the T-zone

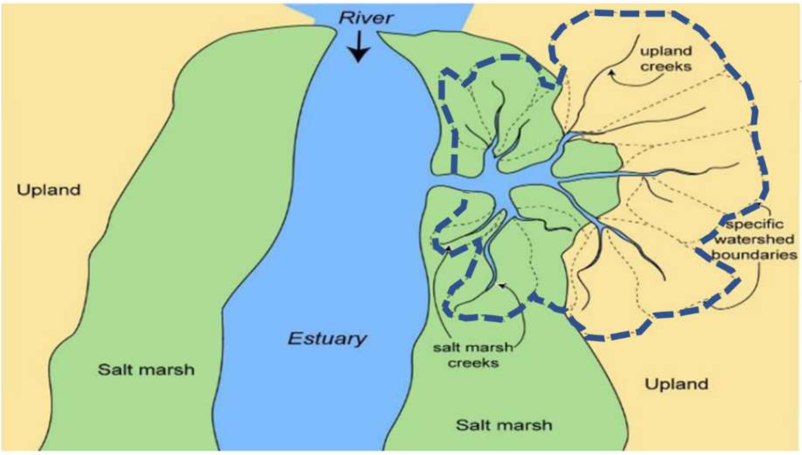
(2) Greater emphasis on nearshore, shallow systems (triblets) as harbingers of change

(3) Come to terms with the fact that we are chasing a moving target, rethink what we want through restoration (i.e., *increase certainty in shared goals, consensus)*

(4) Ensure that next generation model frameworks include the capacity for different recovery trajectories – tipping points, new species, disappearance of old species, changing habitats.

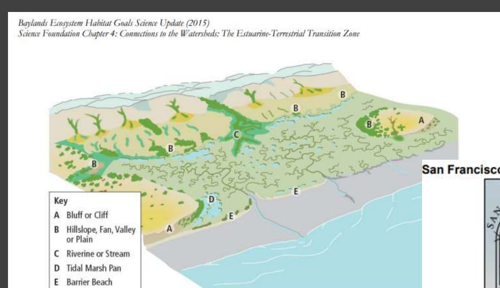
Triblet:

A waterway and its adjacent floodplain corridor that flows through T-zone and connects uplands to coastal waters.



Terrestrial-Estuarine Transition Zone (T-zone):

"the area of *existing and predicted future* interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems."



San Francisco Bay Joint Venture

Ensign and Noe 2018
CBP 2018

Resource Document Key Quotes

"As we look forward, we envision that the pressure of climate change combined with an expectation of tipping points in the estuarine response to both TMDL-related activities and climate change will demand a new suite of monitoring, data analysis, and modeling tools to better quantify uncertainties in restoration outcomes."

"To accelerate restoration, we need to better understand and predict:

(a) how restoration proceeds under alternative management and climate change scenarios;

(b) how can we meaningfully identify and evaluate new potential restoration means/strategies;

(c) accordingly, where and how to best spend our restoration dollars"

Living Resources

A Proposed Framework for Analyzing Water Quality and Habitat Effects on Aquatic Living Resources of Chesapeake Bay

Kenneth Rose
University of Maryland Center for Environmental Science
Horn Point Laboratory

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

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University Park, PA

Tom Ihde
Morgan State University
St. Leonard, MD

Kirk J. Havens
Virginia Institute of Marine Science
Gloucester Point, VA

Why?

- Valued by stakeholders and society
- Ecological/economic efficiency (“reckoning”)
- Realistic/feasible targets and goals
- Restoration is costly
- Expectations
- Adaptive management
- Winner and losers

Chesapeake Bay

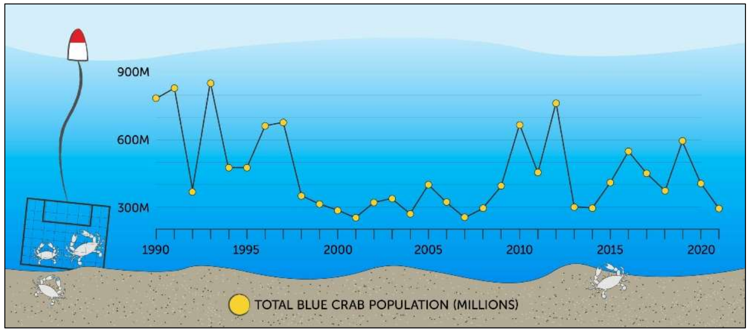
Good news	Bad News
• CB is not alone	• Challenging (Everglades)
• We know how to do this	• Answers may not satisfying; false negatives
• Chesapeake is well studied	• Major effort
• Long history of monitoring, modeling, and process studies	• Other management occurring to promote stability

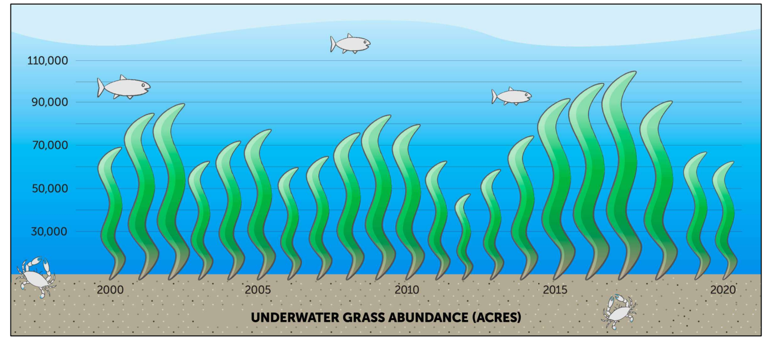
Very Different Situation to “WQ”

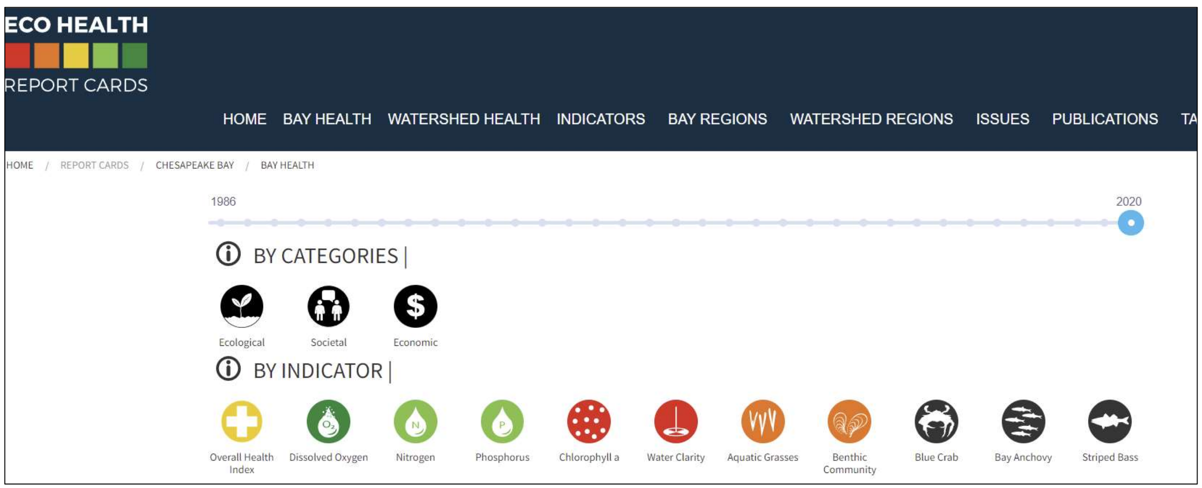
- Questions change
- Not specific targets for many living resources
- Not an established set of data or models
- Greater uncertainties

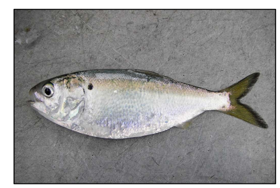
Very Different Situation to “WQ”

- Many critters move
- Affected by many factors in a complex life cycle
- Responses are on longer time scales
- Ability to isolate responses to actions decreases


900M
600M
300M
1990
1995
2000
2005
2010
2015
2020
TOTAL BLUE CRAB POPULATION (MILLIONS)

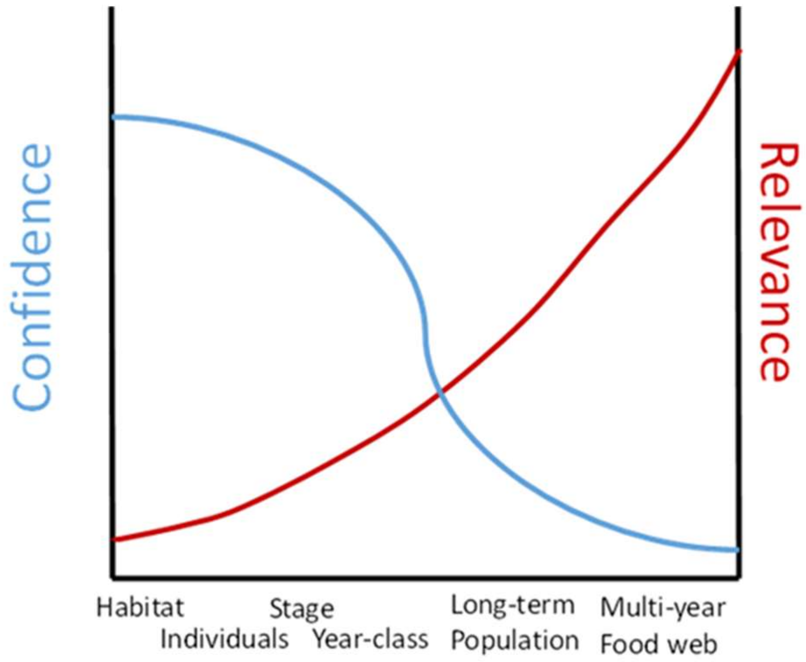

110,000
90,000
70,000
50,000
30,000
2000
2005
2010
2015
2020
UNDERWATER GRASS ABUNDANCE (ACRES)


ECO HEALTH
REPORT CARDS
HOME
BAY HEALTH
WATERSHED HEALTH
INDICATORS
BAY REGIONS
WATERSHED REGIONS
ISSUES
PUBLICATIONS
HOME / REPORT CARDS / CHESAPEAKE BAY / BAY HEALTH
1986
2020
BY CATEGORIES |
Ecological
Societal
Economic
BY INDICATOR |
Overall Health Index
Dissolved Oxygen
Nitrogen
Phosphorus
Chlorophyll a
Water Clarity
Aquatic Grasses
Benthic Community
Blue Crab
Bay Anchovy
Striped Bass

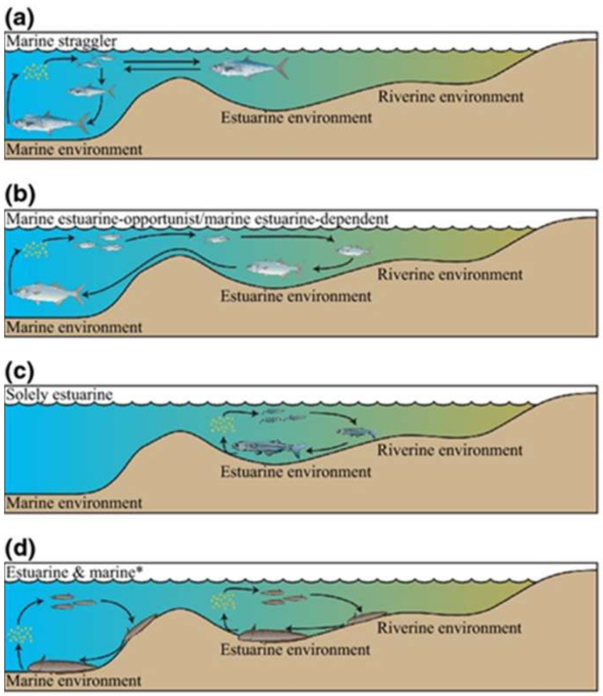


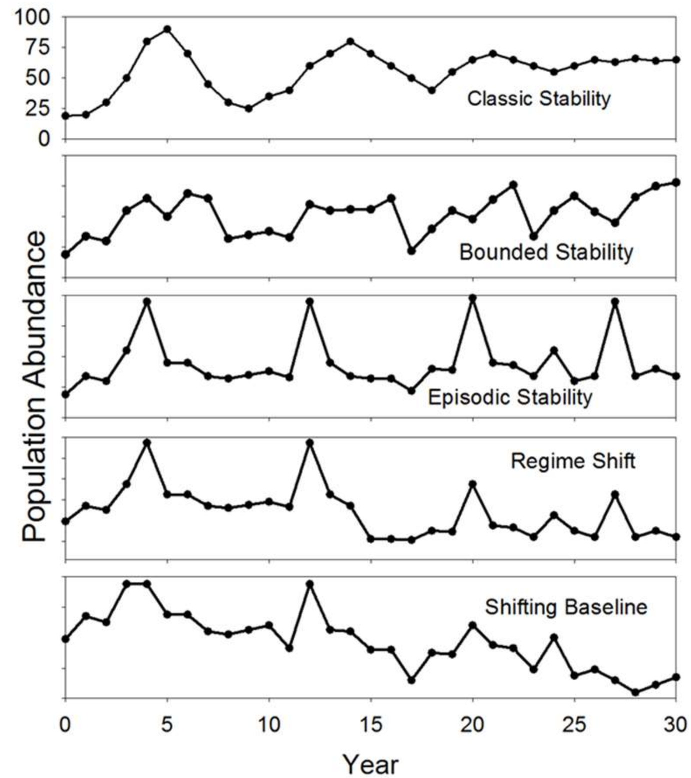
Framework

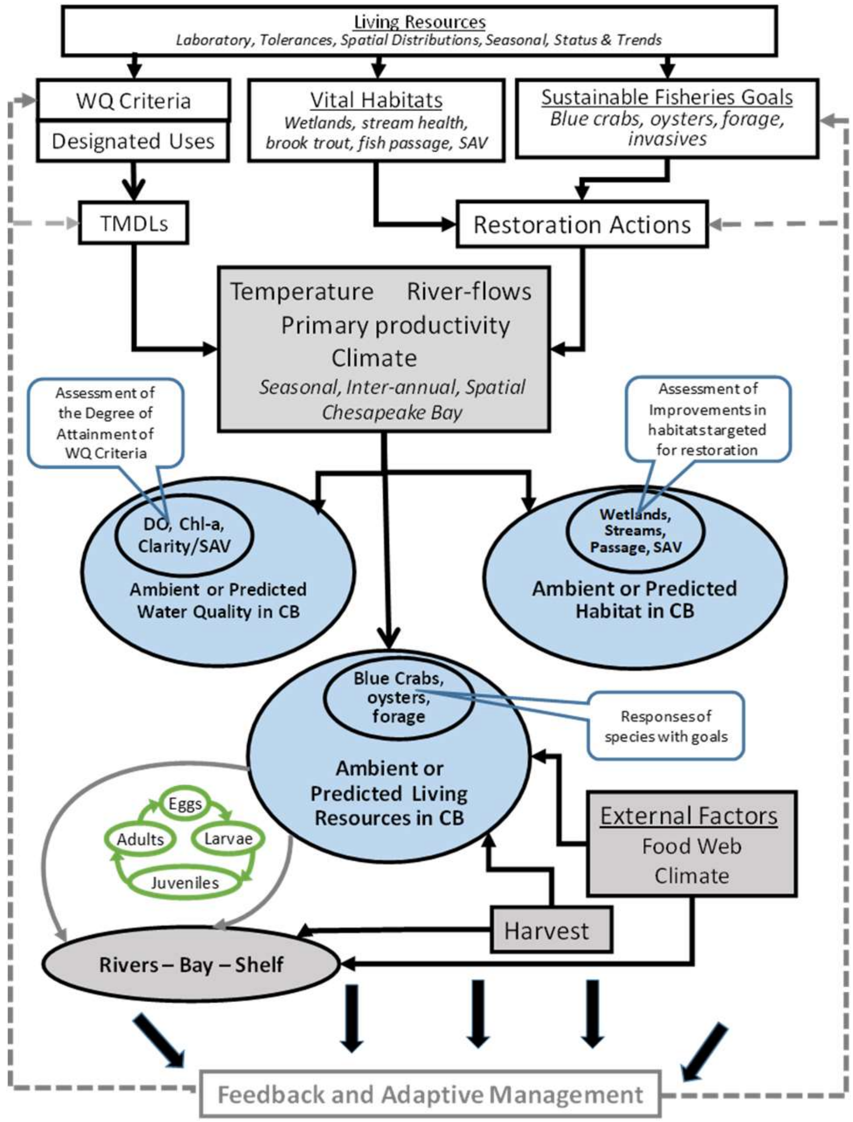
- Uses the results of the Watershed and Estuary
  - Types, timing, locations, magnitude
  - WQ and habitat
- Describes translation of these changes into responses of living resources



Foundational Concepts - Examples






Living Resources
Laboratory, Tolerances, Spatial Distributions, Seasonal, Status & Trends
WQ Criteria
Designated Uses
Vital Habitats
Wetlands, stream health, brook trout, fish passage, SAV
Sustainable Fisheries Goals
Blue crabs, oysters, forage, invasives
TMDLs
Restoration Actions
Temperature River-flows
Primary productivity
Climate
Seasonal, Inter-annual, Spatial
Chesapeake Bay
Assessment of the Degree of Attainment of WQ Criteria
Assessment of Improvements in habitats targeted for restoration
DO, Chl-a, Clarity/SAV
Ambient or Predicted Water Quality in CB
Wetlands, Streams, Passage, SAV
Ambient or Predicted Habitat in CB
Blue Crabs, oysters, forage
Responses of species with goals
Ambient or Predicted Living Resources in CB
Eggs
Adults
Larvae
Juveniles
External Factors
Food Web
Climate
Harvest
Rivers – Bay – Shelf
Feedback and Adaptive Management

Going Forward

- We know the question(s) pretty well
- Incentive (demand?) and ingredients are available
- Leverage existing analyses; identify new analyses
  - CA Delta, Everglades, Coastal LA, NCEAS, NAS, Columbia River
- Follow the framework, we can add analyses:
  - “meta-methods”
  - “meta-results”
- Rigorous and robust assessment
- We present this in early stage and welcome comments, criticisms, and suggestions (krose@umces.edu)

Key Messages

- Doable and messy
- Strategic
- Explained