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

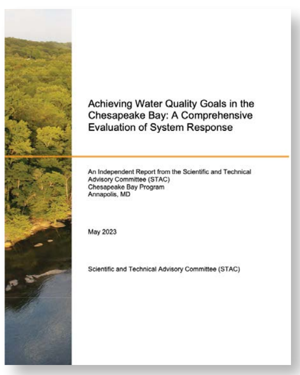
CESR

Report in Brief

Acknowledgments

The full report, "Achieving Water Quality Goals in the Chesapeake Bay: A Comprehensive Evaluation of System Response (CESR)" began as a Scientific and Technical Advisory Committee (STAC) independent initiative in 2019. Kurt Stephenson, Zach Easton, and Brian Benham of Virginia Tech proposed the idea of a report that would identify gaps and uncertainties in the Chesapeake Bay restoration effort that impact efforts designed to attain water quality standards. The report took over four years from conception to publication and was prepared by a writing team who utilized contributions from over 50 STAC members. The final report was reviewed by STAC membership and external US Geological Survey experts.

This Report in Brief was edited by Denice Wardrop and Kurt Stephenson, the editors of the full CESR report, and reviewed by the CESR Outreach Committee.



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)

To read the full report, visit

chesapeake.org/stac/cesr/

Cover photos by Carlin Stiehl/Chesapeake Bay Program (top), Will Parson/Chesapeake Bay Program (bottom left), Caitlin Finnerty/Chesapeake Bay Program (bottom right), and Ethan Weston/Chesapeake Bay Program (back cover).

Suggested citation for the full CESR Report: Scientific and Technical Advisory Committee (STAC). (2023). *Achieving water quality goals in the Chesapeake Bay: A comprehensive evaluation of system response* (K. Stephenson & D. Wardrop, Eds.). STAC Publication Number 23-006, Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC), Edgewater, MD. 129 pp.

The CESR Report: Who, What, and Why

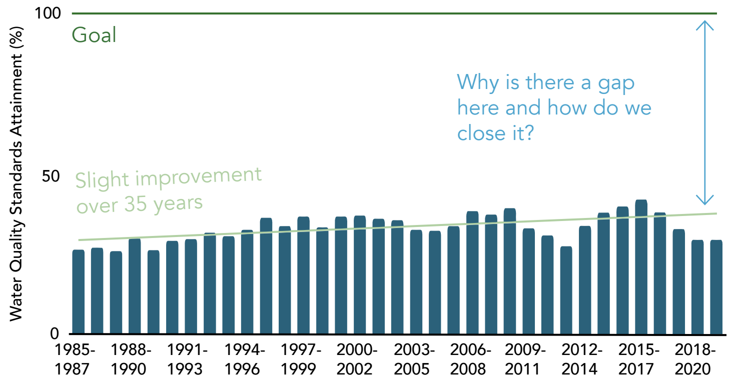
1

An independent group of scientists began "A Comprehensive Evaluation of System Response" (CESR) to look at what has worked and how we can continue to improve the water quality of the Chesapeake Bay.

The 40-year effort to restore Chesapeake Bay is one of the largest watershed restoration initiatives in the US and serves as a model for efforts across the globe. A healthy Chesapeake Bay supports abundant living resources, provides recreational opportunities, and contributes to community resilience, quality of life, and economic prospects of those living in this 64,000 mi^2 watershed.

For many decades, Bay scientists have known that excess nutrients and sediment cause algal blooms, which eventually die and reduce dissolved oxygen (DO) during decomposition. Aquatic animals need oxygen, and the underwater grasses that produce oxygen need light, which algal overgrowth also blocks.

Percent Attainment of Water Quality Goals in the Chesapeake Bay (measured for 3 year averages)



Concerted policy efforts have reduced nutrient and sediment pollution even with increasing human and animal populations, land development, and climate change. While holding the line against these headwinds is an exceptional achievement, we are still far from meeting the Chesapeake Bay Program's water quality and habitat goals (see graph above).

To investigate why the Chesapeake Bay partnership is not closer to the current water quality goals despite our collective efforts and funding to date, the Scientific and Technical Advisory Committee (STAC) undertook an independent, multi-year analysis of the system response to these efforts. This Report in Brief summarizes CESR's major findings and opportunities for a way forward.

Major findings:

- Nonpoint source programs are not generating enough pollutant reductions to meet Bay water quality goals *(CESR Chapter 3: Nutrient and Sediment Response to Management Efforts).*
- The slow rate of water quality change in the Bay suggests that achievement of water quality goals is uncertain and remains in the distant future (*CESR Chapter 4: Estuary Water Quality Responses to Nutrient and Sediment Load Reductions).*
- A new approach to water quality management, combined with nearshore habitat management, can open new opportunities for living resource abundance *(CESR Chapter 5: Living Resource Response to Water Quality Conditions*).
- Making "learning while doing" central to Bay management can make pollutant reduction more effective and accelerate improvements in living resource outcomes (*CESR Chapter 6.6: Expanding Adaptive Decision-Making and Improving Program Learning*).

From Policy to Bay Water Quality: Evaluating the Causal Chain

2

The CESR report reviews how management has translated to water quality improvements and follows the path from policy to living resources.

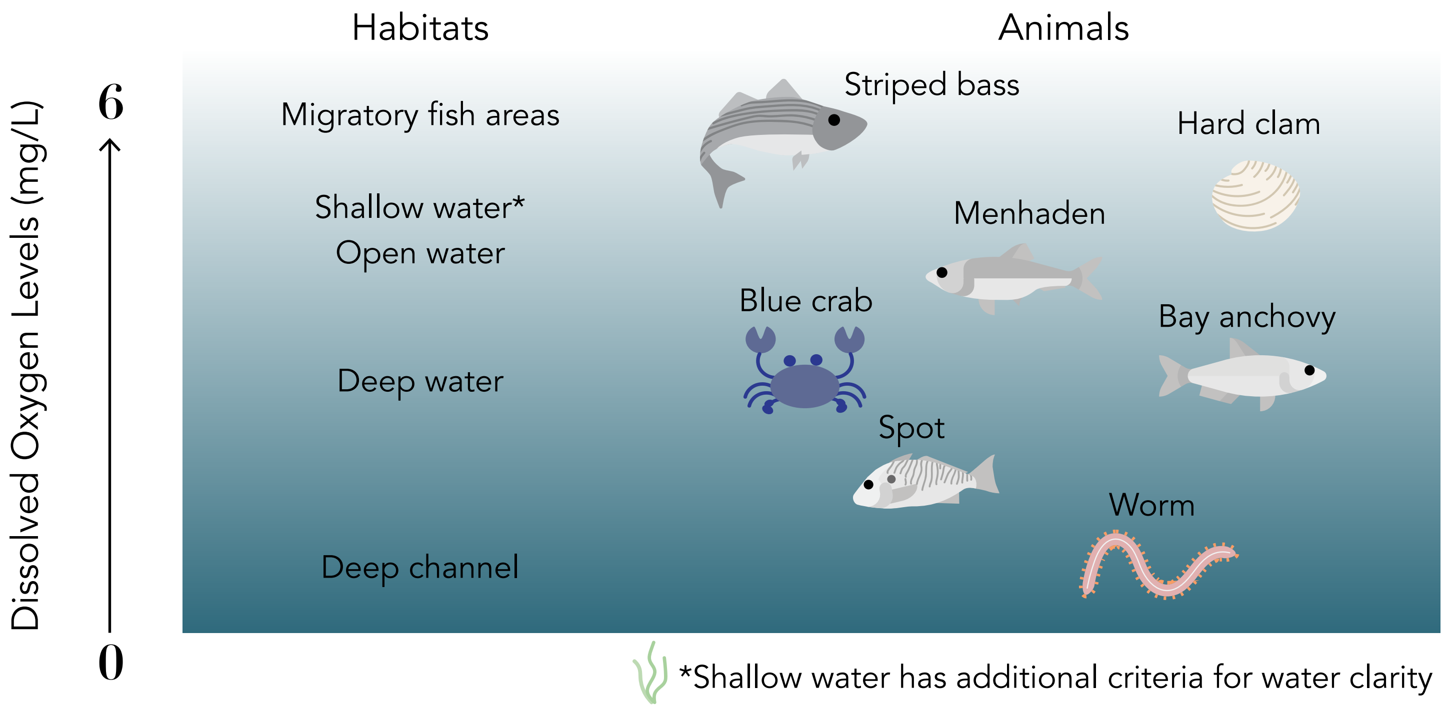
1 *Policies & Programs* — Policies and programs aim to reduce nutrient and sediment pollution to the Bay from point sources (e.g., a wastewater pipe) and nonpoint sources (runoff from agricultural, suburban and urban land).

2 *Behavior Change* — These policies and programs can only be effective if enough people (especially landowners, leaders of public and private institutions, policy makers, etc.) make the necessary changes.

3 *Load Reduction* — Adoption of pollutant control technologies and approaches are expected to reduce inputs of the primary stressors to the Bay ecosystem: nitrogen (N), phosphorus (P), and sediment.

4 *Water Quality* — Reduced nutrients in the Bay should decrease algae in the water. Less algae and sediment should lead to increased oxygen levels and water clarity which will improve the five main habitat types in the Bay (see figure below).

GOAL: Living Resources — Water quality goals will provide the necessary conditions for fish, shellfish, and other aquatic animals that are valued by the public to thrive. However, water quality alone is not sufficient to meet this goal.



*Shallow water has additional criteria for water clarity

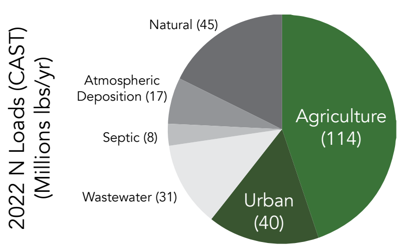
On Achieving Nutrient and Sediment Reductions

3

Finding: Nonpoint source programs are not generating enough pollutant reductions to meet Bay water quality goals.

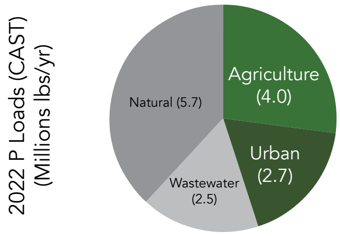
Nonpoint source reductions are essential to meeting pollutant reduction goals.

Nitrogen

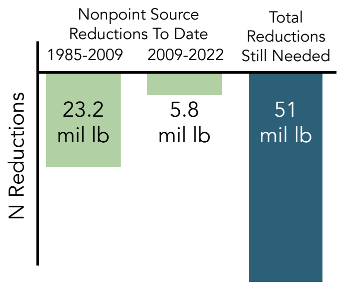


Point source nutrient loads, primarily wastewater loads, have been dramatically reduced already, leaving little opportunity for more reductions. The CESR report focuses on the largest, manageable sources of nutrients to the Bay – agricultural (green) and urban (dark green) nonpoint source pollution.

Phosphorus



Current nonpoint source programs are not producing enough adoption.



To reduce nutrient pollution, new approaches must accelerate adoption of nutrient reduction practices in the locations with the greatest load reduction potential. Over 50 million pounds of nonpoint nitrogen reduction is still needed to meet the current target, but it has taken over a decade to generate less than six million pounds of nonpoint nitrogen reductions.

Bay water quality model predictions have overestimated program effectiveness.

Observed versus modeled P trend in the major tributaries of the Chesapeake Bay from 1985-2021. The dashes are no trend, while arrows represent decreasing or increasing P loads.

**Chesapeake Assessment Scenario Tool (CAST) is a load estimator tool used by the partnership to assess the impacts of various management practices on pollutant loads. CAST builds scenarios based on practices applied to estimate N, P, and sediment load reductions.*

Rivers	Monitoring Observations	CAST Predictions
Susquehanna	—	↓
Potomac	↓	↓
Choptank	↑	↓
Patuxent	↓	↓
Rappahannock	↑	↓
Mattaponi	—	↑
Pamunkey	↑	↓
James	↓	↓
Appomattox	↑	↓

Monitoring data suggests that the CAST model* may overestimate nonpoint source load reduction, particularly for phosphorus. The table to the left shows that long-term phosphorus declines have been observed in three of the nine major tributaries to the Bay, while declines were estimated by CAST in eight of nine rivers.

Water quality response does lag behind load reduction actions, but that is not the only factor causing the discrepancy. In a large watershed with millions of people, it is difficult to understand perfectly how nutrients are applied and move through the watershed. STAC and others are pursuing improved knowledge.

Policy Implications for Reducing Nonpoint Sources

4

In addition to funding, new programs and policies will be needed to make significant progress in reducing nonpoint source pollution.

Nutrient mass balance

Some areas of the watershed import more nutrients for crop and animal production than are exported in products or lost to the atmosphere. The larger the imbalance, the higher the storage and/or risk of excess nutrient runoff into the Bay. Actions that do not alter the total nutrients imported or exported in a watershed have limited potential to reduce nutrient pollution. Solutions must reduce imports, increase products, or move excess nutrients to areas that are lacking.

Targeting

Nonpoint source loads are unevenly distributed across most watersheds. Identifying high load areas (hotspots) where attention and funding can be directed will improve effectiveness. If modeling and monitoring are at too coarse of a scale, hotspots can be missed. Modeling and monitoring at finer resolution could pinpoint problems and lead to more effective treatment options.

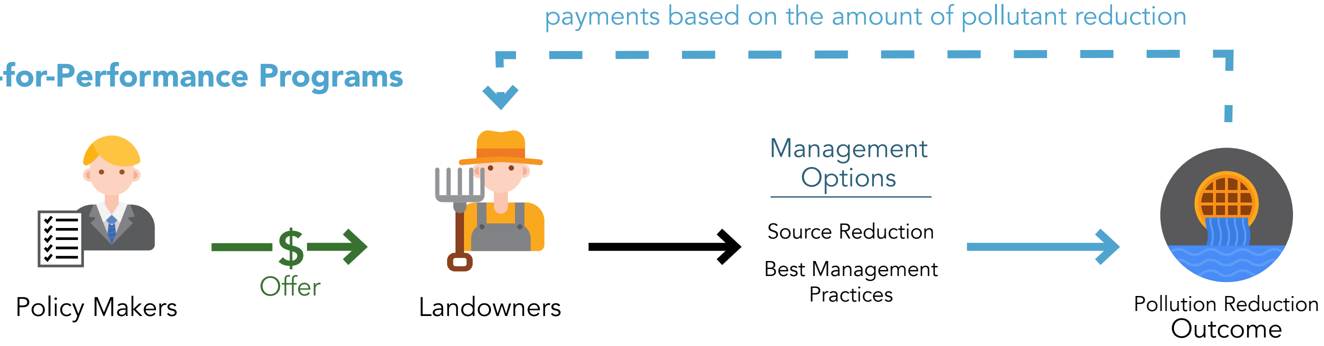
The resolution of the model is too coarse to pinpoint the problem.

A finer resolution identifies the red problem area.

Incentives for outcomes

Typical nonpoint source programs encourage specific best management practices by paying for a portion of the installation cost. Under existing policies, land managers cannot be directly rewarded based on the amount of pollutants reduced, though that is the overall goal. Pay-for-performance (or pay-for-outcomes) programs reward the successful treatment of hotspots, even with non-standard practices. Creating opportunities to experiment are also needed (see sandboxing on page 9).

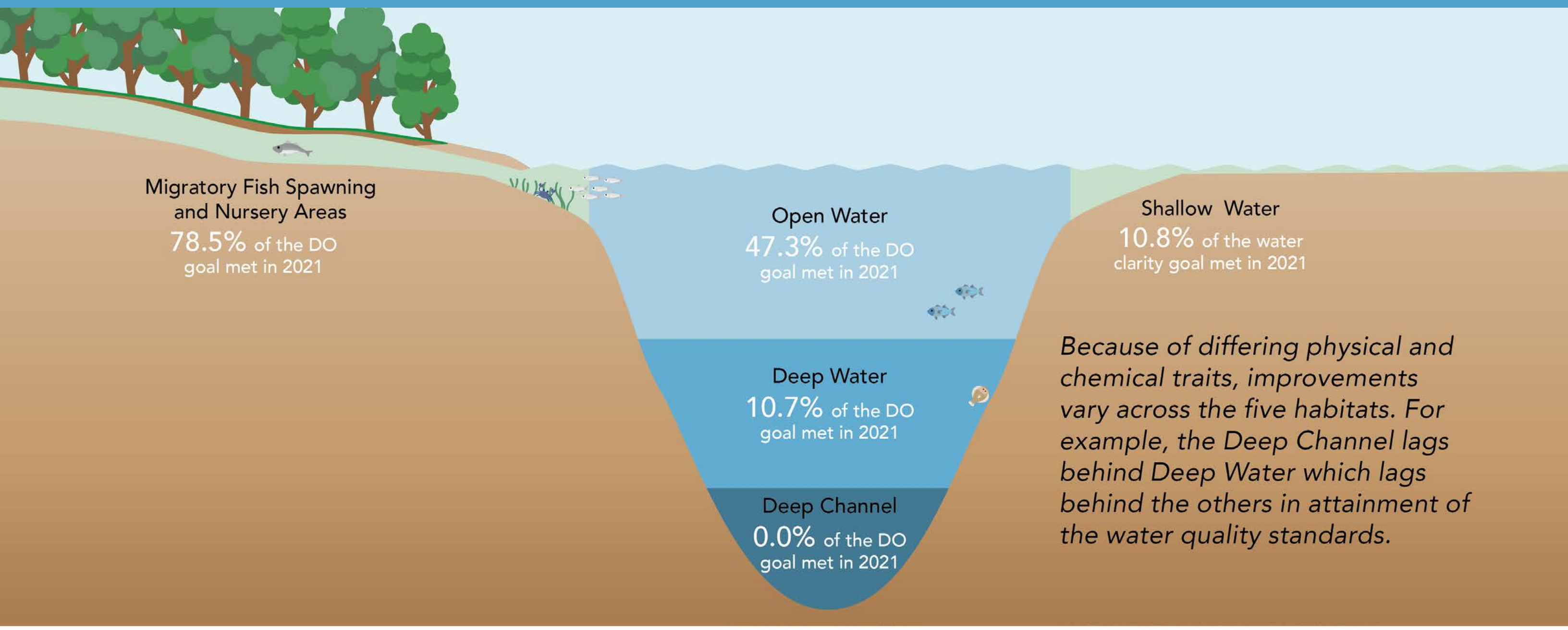
Pay-for-Performance Programs



On Achieving Water Quality Standards

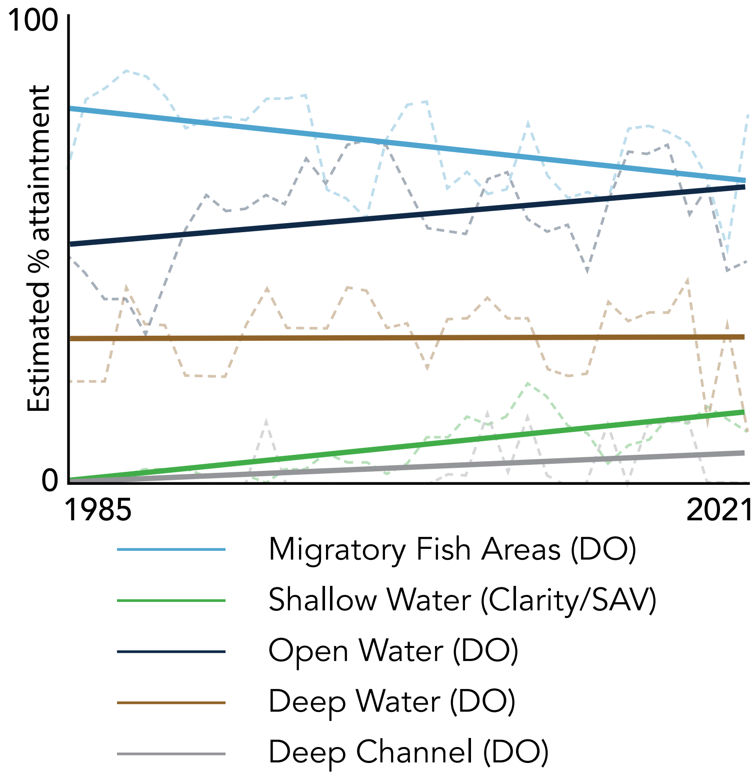
5

Finding: The slow rate of water quality change in the Bay suggests that achievement of water quality goals is uncertain and remains in the distant future.



Nutrient reductions are leading to improved DO levels over the entire Bay. However, complete attainment of water quality standards has proved challenging and differs by Bay habitat (above).

No Bay habitat has yet achieved sustained attainment of its water quality goals. Levels of DO criteria attainment are lowest in the deeper water habitats, with an average of less than 3% of the deep channel habitat meeting the DO criteria. Over time, a higher portion of open water habitats are achieving Bay DO criteria (see graph to the right), but DO attainment trends in other habitats have been relatively flat or declining. The magnitude of these improvements may not be enough to achieve the Bay water quality goals (primarily DO and water clarity) in the near future.



Dashed lines show the data while the solid lines show the trend over time

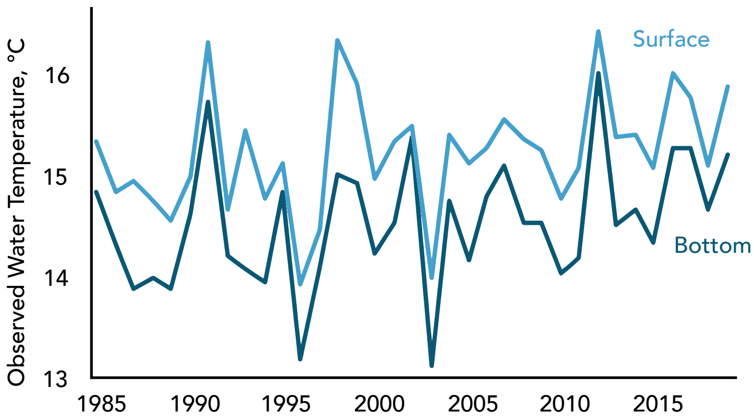
Why have we not seen water quality improve more across habitats?

6

1 Nutrient loads need to be low enough for a biological response to occur.
Many shallow tidal waters throughout the Bay show limited DO and water clarity response despite substantial reductions in loads. This can occur because loads have not been reduced enough to slow the growth of algae, which continue to cloud the water and do not allow light to reach the bottom, where underwater grasses and bottom-dwelling organisms can further remove nutrients from the system. When these nutrients stay in the system they continue to fuel more algae, which leads to further decreases in DO. However, if nutrient inputs are low enough to reduce algae and improve water clarity, a "tipping point" will be reached where grasses and organisms can remove nutrients to improve DO.

Underwater grasses, like this wild celery, can remove nutrients from the system. In order to do so, they need light to reach the Bay bottom where they grow. Photo by Will Parson/Chesapeake Bay Program.

2 Nutrient loads need to be low enough to offset the impacts of climate change.
The waters of the Bay are warming (see graph to the right), which has limited the water quality response to phosphorus and nitrogen reductions. For example, recent studies show that higher water temperatures offset roughly 6–34% of the water quality improvement from our nitrogen reduction achievements to date. Sea level rise can increase stratification, limiting the mixing of oxygen-rich surface waters with deeper waters and leading to a further decline in DO in the bottom water. Additional studies have indicated that warming was the dominant driver of long-term changes in DO and hypoxia in the Chesapeake Bay over the past 30 years.



Adapted from the STAC Rising Water Temperatures Report Summary: ian.umces.edu/publications/stac-rising-water-temperatures-report-summary/

Shad are a migratory fish that utilize the migratory and spawning habitat of the Chesapeake Bay. Photo by Will Parson/Chesapeake Bay Program.

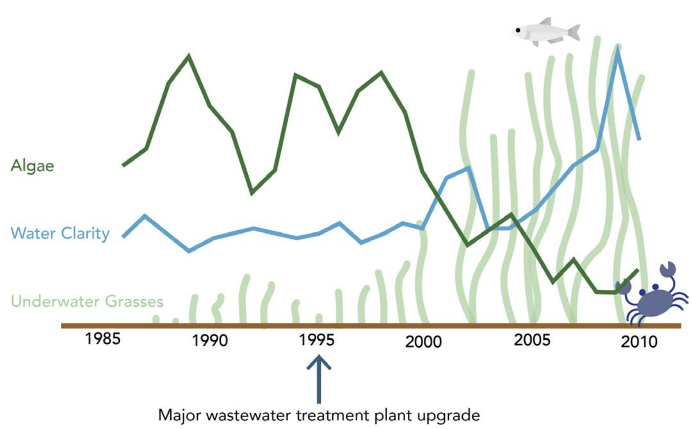
On Living Resource Response

7

Finding: A new approach to water quality management, combined with nearshore habitat management, can open new opportunities for living resource abundance.

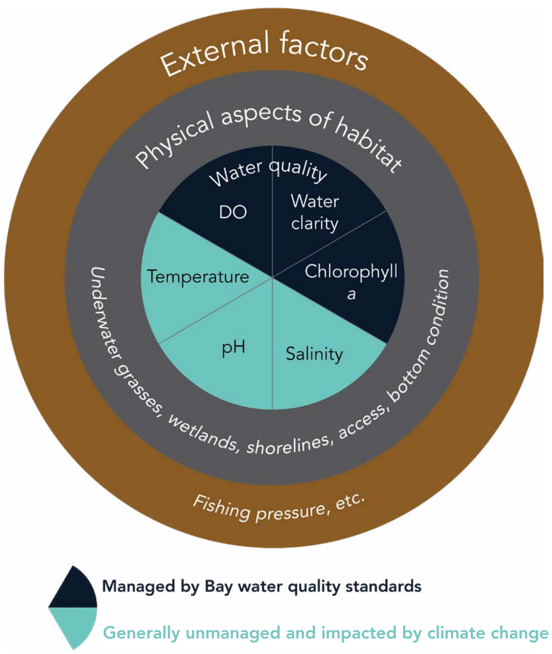
Where water quality improvements occur matters for living resource response.

Mattawoman Creek



When water quality is the primary stressor, load reduction in some areas can have a larger impact on living resources than others. For example, in Mattawoman Creek (a shallow tidal system), water quality response to a load reduction significantly increased underwater grass habitat—although it was not immediately apparent. In the graph to the right, less pollution resulted in less algae in the water over several years (green line). Once algae declined, improved water clarity and increased light reaching the Bay bottom (blue line) helped the underwater grass grow, providing critical habitat as well as further reducing nitrogen and phosphorus. Efforts in these types of shallow water habitats may be particularly important for sustaining the living resources the Bay restoration effort aims to protect. Mattawoman Creek is also a lesson in staying the course until a biological response can occur.

Water quality changes occur within other stressors and management actions.



Structural aquatic habitat, nearshore habitat (e.g., wetlands, shoreline), commercial and recreational harvest, disease, and other water conditions are also significant drivers of the composition and abundance of living resources. Some of these other conditions are actually more important for certain animals, like fish, than water quality.

The graphic to the left shows factors that influence living resources. DO, water clarity, and chlorophyll *a* (dark blue) are identified in the water quality standards. Temperature, pH, and salinity (light blue) are all factors that are generally not managed and are actively changing with the changing climate. Other factors that influence living resources are physical traits of habitat (gray) and other external factors such as fishing pressure (brown).

Policy Implications for Living Resource Response

8

Opportunities exist to adjust approaches to prioritize management actions that improve living resource response.

A tiered implementation of the Bay's Total Maximum Daily Load (TMDL) system would prioritize attainment of water quality goals where living resources can benefit the most. Living resources respond to water quality improvements differently across habitats and locations. Improvements in certain habitats (e.g., shallow waters and migratory, spawning habitat, local open water) in certain locations can provide earlier and more substantial living resource benefits than other habitats (deep water and deep channel). In addition, these same habitats are often particularly important to stakeholders. Under tiered implementation, the overall pollutant reduction target and water quality goal remains the same, but the path to attainment is modified to prioritize living resource impact.

Increase understanding of the role of water quality in living resource response. The Chesapeake Bay Program has devoted substantial resources to the development of analytical and statistical modeling of pollutant loads and water quality outcomes. By comparison, quantitative assessment of living resource responses is limited to reporting of annual indicators of population health and little attention has been paid to assessing the impact of water quality relative to other factors on living resource response. The report outlines concrete steps that we can make to attain this understanding (*CESR Chapter 6: Findings and Implications).*

Recognize opportunities for investments that produce greater living resource response. The 2025 deadline creates an opportunity to learn and adjust goals to attain better living resource outcomes. The Bay Program has been legally obligated to make pursuit of water quality standards a top priority, resulting in most available staff resources and funding being directed towards load reductions. Consideration of other investments, and where they are made, could secure greater living resources response.

Shoreline type influences living resources. Below, a living shoreline is pictured on the left in Chesapeake, Virginia and a bulkhead on the right along the Nanticoke River. The shorelines have differing suitability for different animal and plant species. Photos by Will Parson/Chesapeake Bay Program.

Adaptive Management

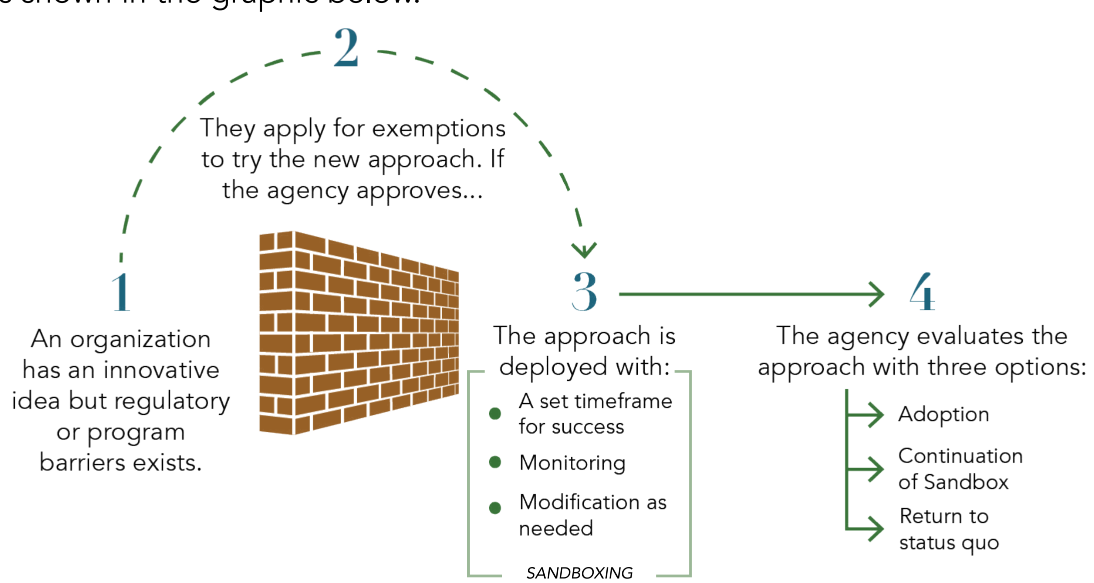
9

Finding: Making "learning while doing" central to Bay management can make pollutant reduction more effective and accelerate improvements in living resource outcomes.

The Chesapeake Bay program must make decisions and explicitly acknowledge that the pollutant, water quality, or living resource response may not be fully understood in advance. Unlike the past, "learning while doing" has to be supported with funding, modeling, and monitoring that improves understanding about what works, what doesn't, and why. Meanwhile, the Bay and its watershed are changing in ways that make the future difficult to predict because historical precedent cannot guide us. Bay temperatures are increasing, precipitation patterns are changing, and land use is shifting, all presenting challenges to attaining the original water quality goals. The ability to learn and adapt will be critical to our success as we make decisions in an uncertain world.

Accountability for outcomes, not just effort.
State and local governments are accountable for meeting nonpoint source goals by using the Chesapeake Bay Program model to decide the type and amount of best management practices (BMPs) to implement. However, the models are never a perfect mirror of reality and are too often treated as such. Greater accountability for observed outcomes such as measured pollutant loads and watershed indicators, rather than just BMPs installed, can increase attention to whether pollutant reduction programs are working as intended.

More experimentation and innovation.
Improving program outcomes will require a commitment to experimentation and innovation with new pollutant control technologies, programs, and behavior change approaches. Program innovation may require permission and encouragement to operate under a new or modified set of administrative rules. Sandboxing is a way to test and evaluate new rules without disrupting existing programs, as shown in the graphic below.



Visit chesapeake.org/stac/cesr/
to read the full report and view more resources, including a video and FAQs

Have Questions? Visit
chesapeake.org/stac/cesr-questions/

"Not meeting the goal isn't the failure.
The failure would be if we didn't learn how to do it better."

-Denice Wardrop, Co-Editor of CESR