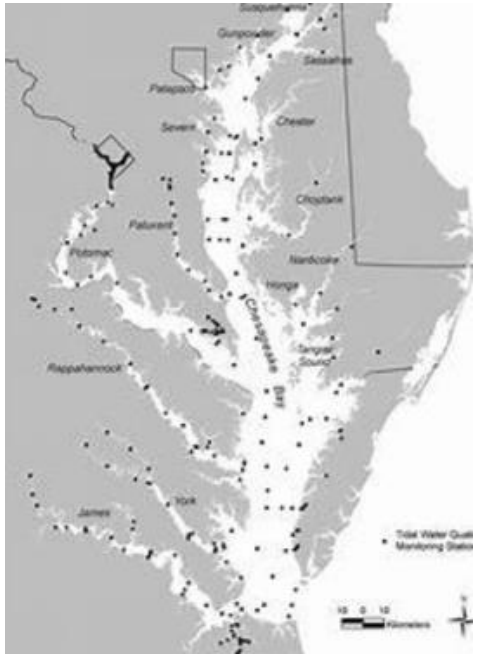
CAP WG Meeting
GIT funded project:
Sampling design workshop



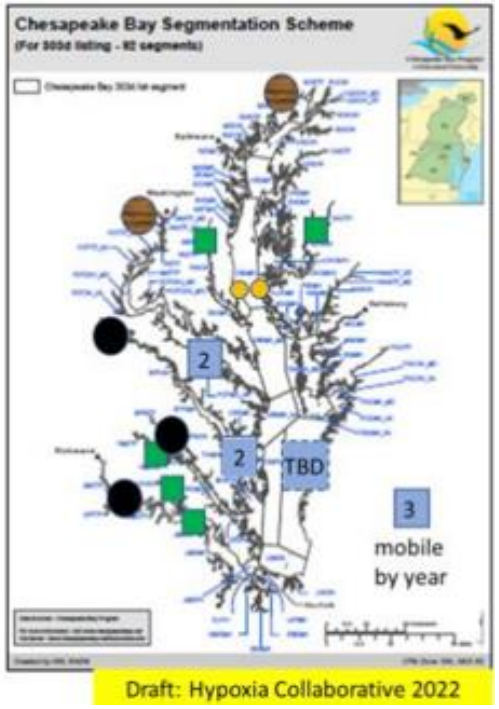
Segment selection considerations

Peter Tango

USGS@CBPO

Chesapeake Bay Monitoring Coordinator

8/11/2025

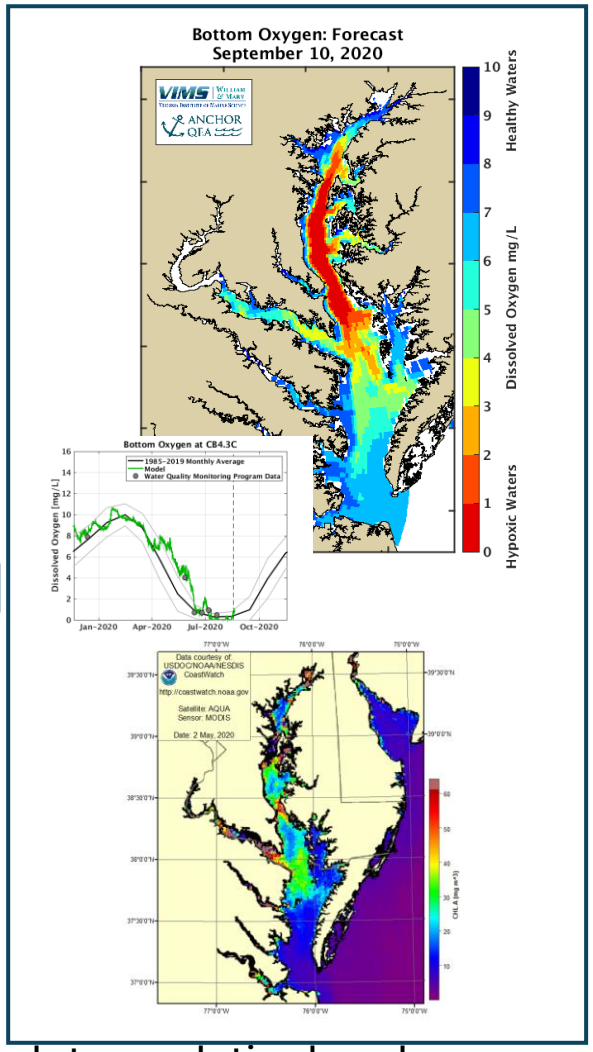


Thank you all!!! Without your passion, dedication, and amazing teams we wouldn't be here today ☺

- Chesapeake Bay Monitoring, Modeling, Research and Management

Today: Expanded capacities coincident with need for deployment plans and commitments to a schedule

Update integrated monitoring approach



Update analytical and assessment approaches

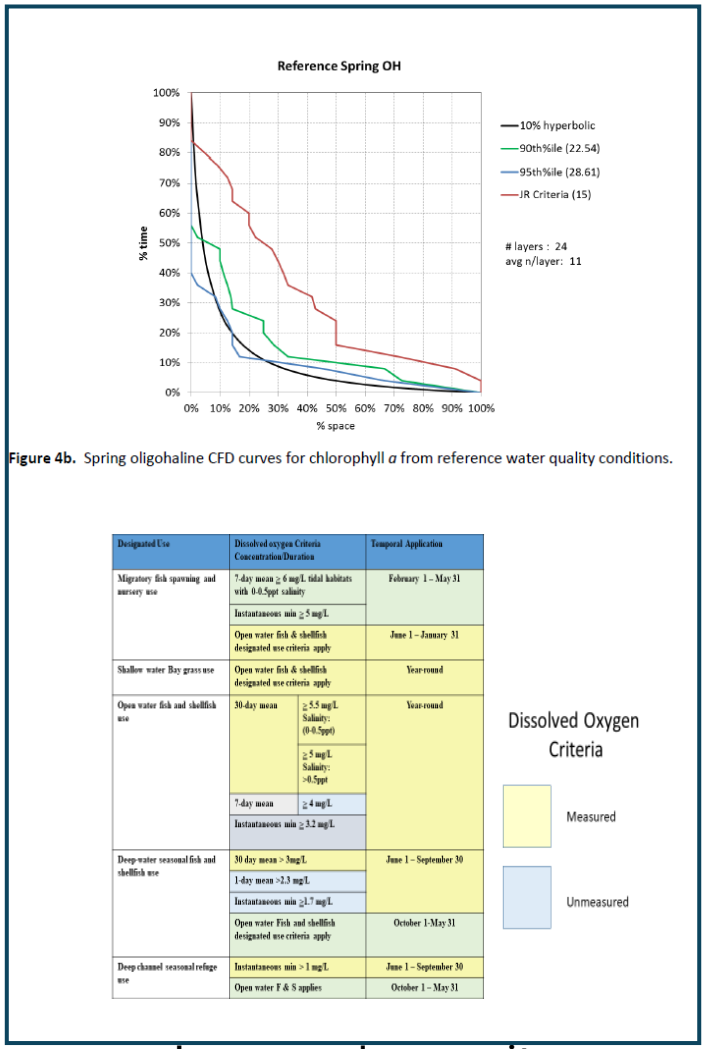


Figure 4b. Spring oligohaline CFD curves for chlorophyll *a* from reference water quality conditions.

Designated Use	Dissolved oxygen Criteria Concentration/Duration		Temporal Application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg/L tidal habitats with 0-0.5ppt salinity		February 1 – May 31
	Instantaneous min ≥ 5 mg/L		
	Open water fish & shellfish designated use criteria apply		June 1 – January 31
Shallow water Bay grass use	Open water fish & shellfish designated use criteria apply		Year-round
Open water fish and shellfish use	30-day mean	≥ 5.5 mg/L Salinity: (0-0.5ppt)	Year-round
		≥ 5 mg/L Salinity: >0.5ppt	
	7-day mean	≥ 4 mg/L	
	Instantaneous min ≥ 3.2 mg/L		
Deep-water seasonal fish and shellfish use	30 day mean > 3mg/L		June 1 – September 30
	1-day mean >2.3 mg/L		
	Instantaneous min ≥1.7 mg/L		
	Open water Fish and shellfish designated use criteria apply		October 1-May 31
Deep channel seasonal refuge use	Instantaneous min > 1 mg/L		June 1 – September 30
	Open water F & S applies		October 1 – May 31

Dissolved Oxygen Criteria
Measured
Unmeasured

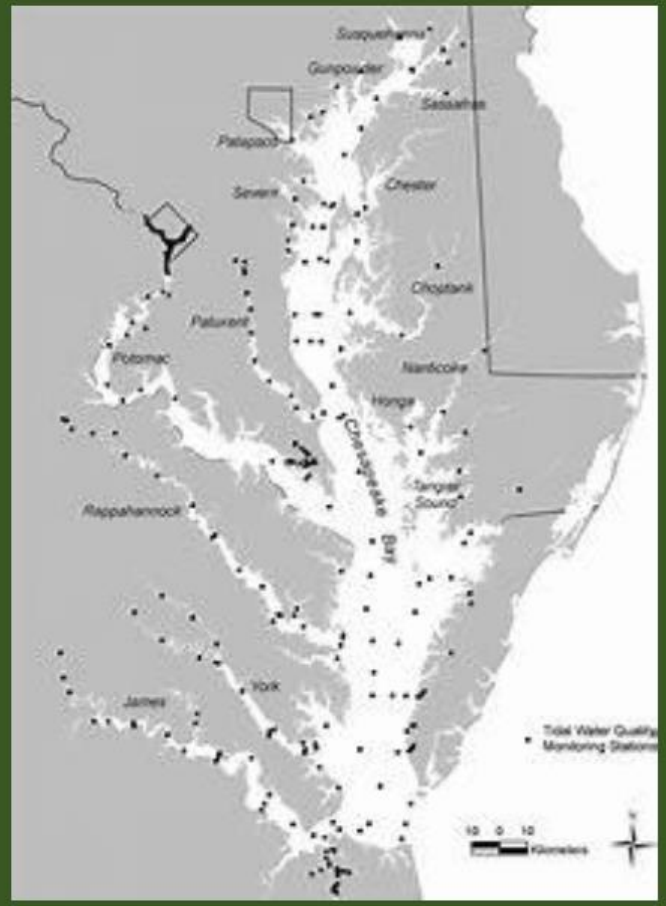
Improved capacity
Fill Habitat Assessment Gaps

And here we are today… ☺

- Create the short list of areas of interest/priority segments to inform deployment sampling designs
- Familiarize ourselves with the process, outputs when creating design options
- Understand our resources and limitations on design options
- Co-produce geographic filtering of locations we can’t deploy sampling equipment

Traditional Chesapeake Bay Long-term Water Quality Monitoring Program sampling design

- 156 stations
- Monthly cruise schedule
- 14-20 cruises per year
- Physical, chemical, biological sampling in vertical profile
- Designed for annual and seasonal insights



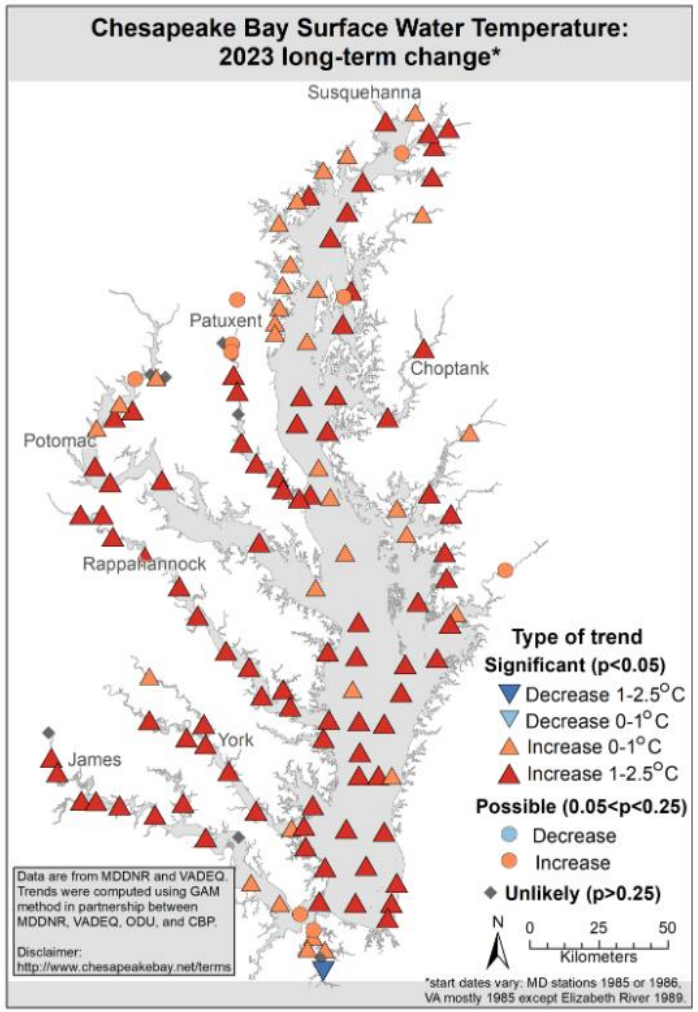
Sampling Design

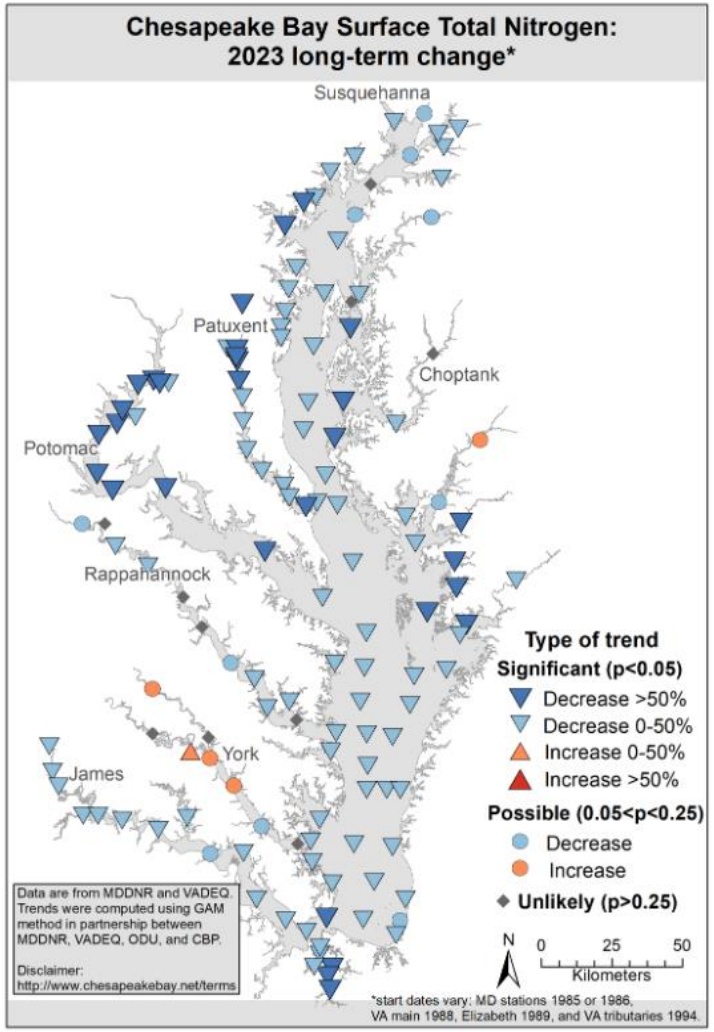
1980s

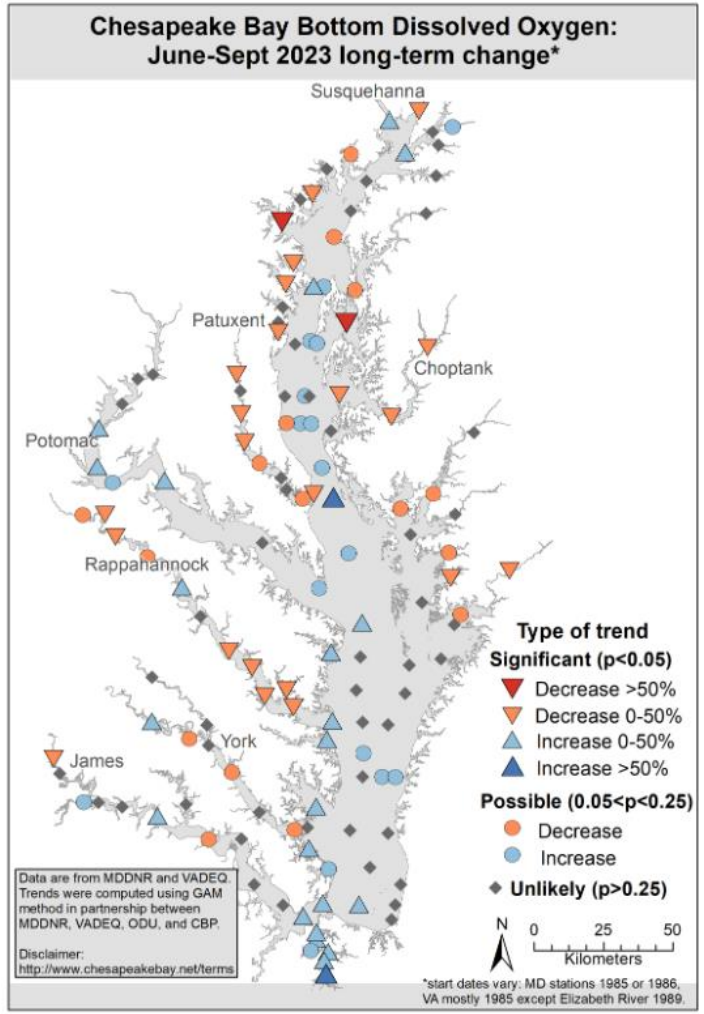
USGS science for a changing world

Chesapeake Bay Program
A Watershed Partnership

Fruits of thy labors: 4 decades of insights







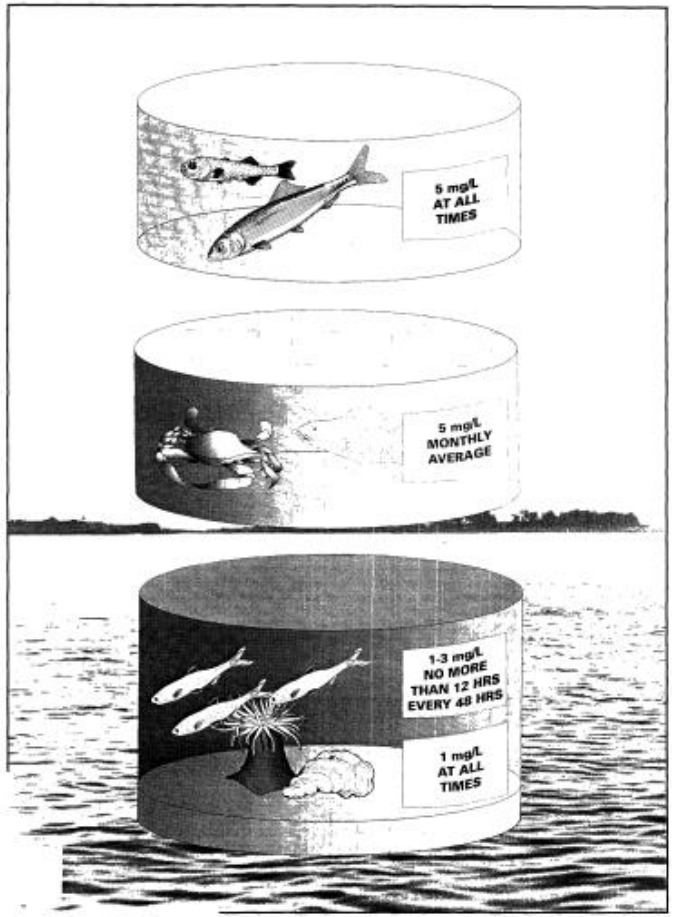
Water Quality Criteria development was brewing in the 1980s and 1990s

The Chesapeake Bay Dissolved Oxygen Goal for Restoration of Living Resource Habitats is:

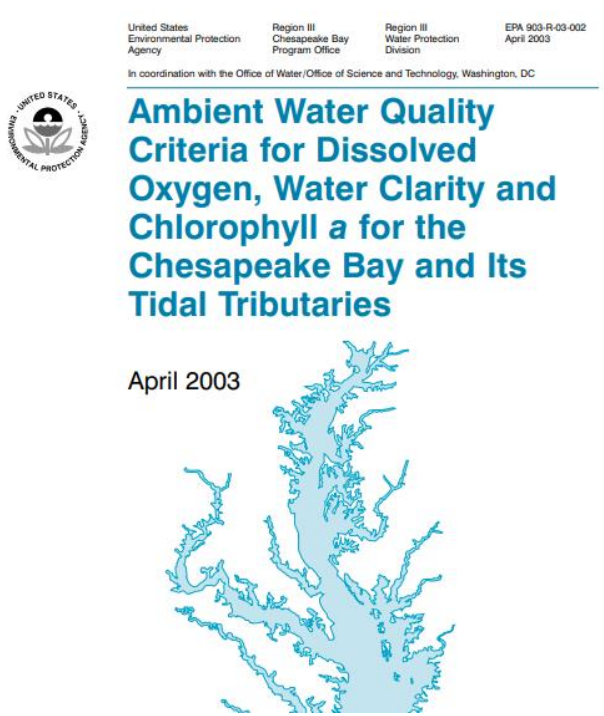
to provide for sufficient dissolved oxygen to support survival, growth and reproduction of anadromous, estuarine and marine fish and invertebrates in Chesapeake Bay and its tidal tributaries by achieving, to the greatest spatial and temporal extent possible, the following four target concentrations of dissolved oxygen, and by maintaining the existing minimum concentration of dissolved oxygen in areas of Chesapeake Bay and its tidal tributaries where dissolved oxygen concentrations are above the recommended targets.

TARGET DO CONCENTRATIONS	TIME AND LOCATION
DO ≥1.0 mg/L	ALL TIMES, EVERYWHERE;
1.0 mg/L ≤DO ≤3.0 mg/L	FOR NO LONGER THAN 12 HOURS, INTERVAL BETWEEN EXCURSIONS AT LEAST 48 HOURS, EVERYWHERE;
MONTHLY MEAN DO ≥5.0 MG/L	ALL TIMES, THROUGHOUT ABOVE-PYCNOCLINE WATERS;
DO ≥5.0 mg/L	ALL TIMES, THROUGHOUT ABOVE-PYCNOCLINE WATERS, IN SPAWNING REACHES, SPAWNING RIVERS AND NURSERY AREAS.

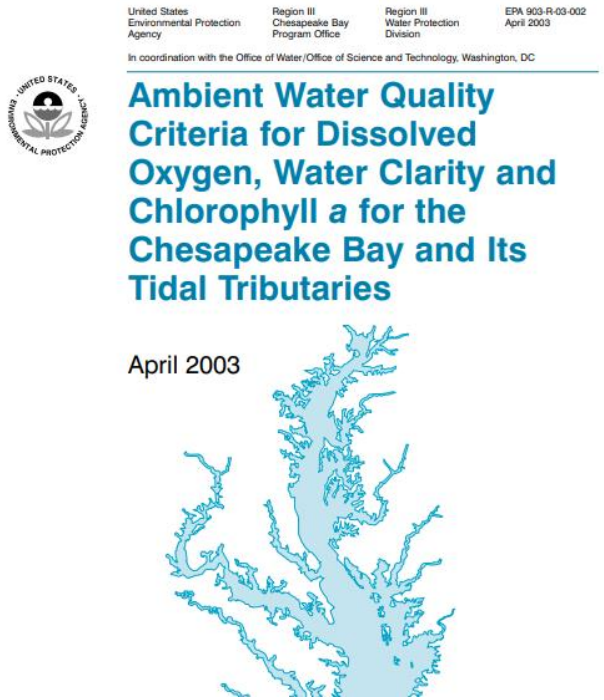
The pycnocline is the portion of the water column where density changes rapidly because of salinity and temperature



Jordan, S. J., C. Stenger, M. Olson, R. Batiuk and K. Mountford. 1992. Chesapeake Bay dissolved oxygen goal for restoration of living resource habitats: A Synthesis of Living Resource Requirements with Guidelines for Their Use in Evaluating Model Results and Monitoring Information. CBP/TRS 88/93. Chesapeake Bay Program Office, Annapolis, Maryland.



Thy WQ Criteria Good Book



Thy WQ Criteria Good Book

	Dissolved oxygen Criteria Concentration/Duration		Temporal Application
pawning and	7-day mean ≥ 6 mg/L tidal habitats with 0-0.5ppt salinity		February 1 – May 31
	Instantaneous min ≥ 5 mg/L		
	Open water fish & shellfish designated use criteria apply		June 1 – January 31
ay grass use	Open water fish & shellfish designated use criteria apply		Year-round
and shellfish	30-day mean	≥ 5.5 mg/L Salinity: (0-0.5ppt)	Year-round
		≥ 5 mg/L Salinity: >0.5ppt	
	7-day mean	≥ 4 mg/L	
	Instantaneous min ≥ 3.2 mg/L		
onal fish and	30 day mean > 3mg/L		June 1 – September 30
	1-day mean >2.3 mg/L		
	Instantaneous min ≥1.7 mg/L		
	Open water Fish and shellfish designated use criteria apply		October 1-May 31
asonal refuge	Instantaneous min > 1 mg/L		June 1 – September 30
	Open water F & S applies		October 1 – May 31

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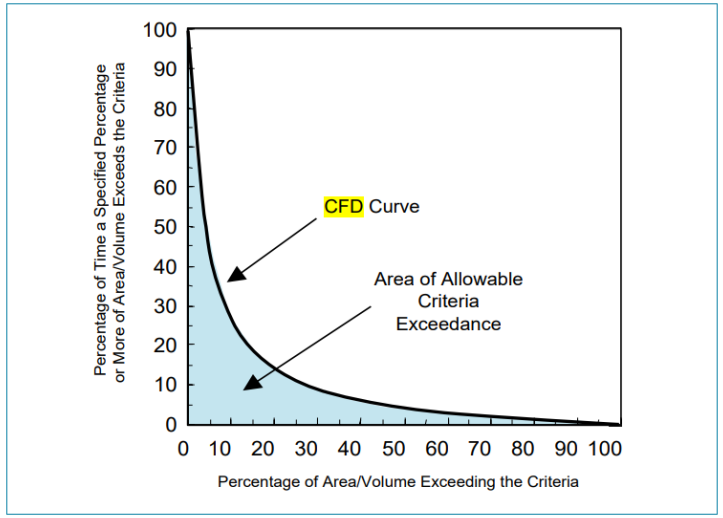


Figure VI-18. Cumulative frequency distribution curve in the shape of a hyperbolic curve that represents approximately 10 percent allowable exceedances equally distributed between time and space.

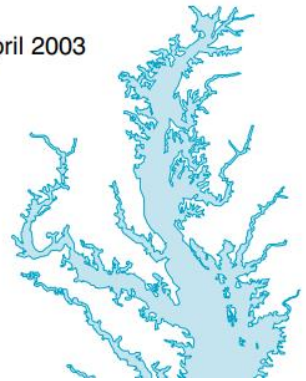
Thy Criteria and Thy Assessment Rules therein

United States Environmental Protection Agency | Region III Chesapeake Bay Program Office | Region III Water Protection Division | EPA 903-R-03-002 April 2003

In coordination with the Office of Water/Office of Science and Technology, Washington, DC

Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and Its Tidal Tributaries

April 2003



MONITORING TO SUPPORT THE ASSESSMENT OF CRITERIA ATTAINMENT

To support the development of cumulative frequency distributions for criteria attainment assessment purposes, additional monitoring will be required. The current fixed-station Chesapeake Bay Water Quality Monitoring Program will support many aspects of the effort to assess criteria attainment. However, some aspects will require new monitoring in areas of Chesapeake Bay tidal waters from which data have not yet been collected. Other aspects will require new types of monitoring based on new technologies that will better address the technical requirements of the criteria as they are currently defined. The Chesapeake Bay Program has developed a tidal monitoring network design that identifies the needs and proposes options for addressing those needs. Many of those options can feasibly be implemented, but additional monitoring will be expensive, and it is expected that available funds will limit what can be done.

In 2003 – to be effective, *we need more monitoring*.

"To support the development of cumulative frequency distributions for criteriaattainment assessment purposes, additional monitoring will be required."

p. 176, USEPA (2003)

Dissolved Oxygen Criteria Assessment

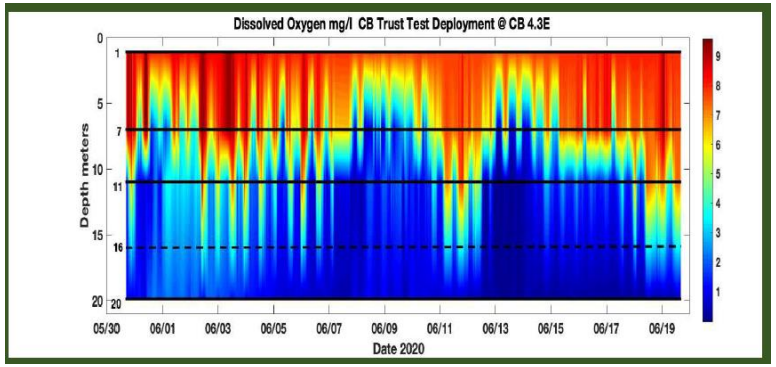
More insights from USEPA 2003 on future design considerations

* "The current monitoring is best suited for assessing the 30-day mean dissolved oxygen criteria component and poorly suited for assessing the 7-day, 1-day mean and instantaneous minimum criteria components."

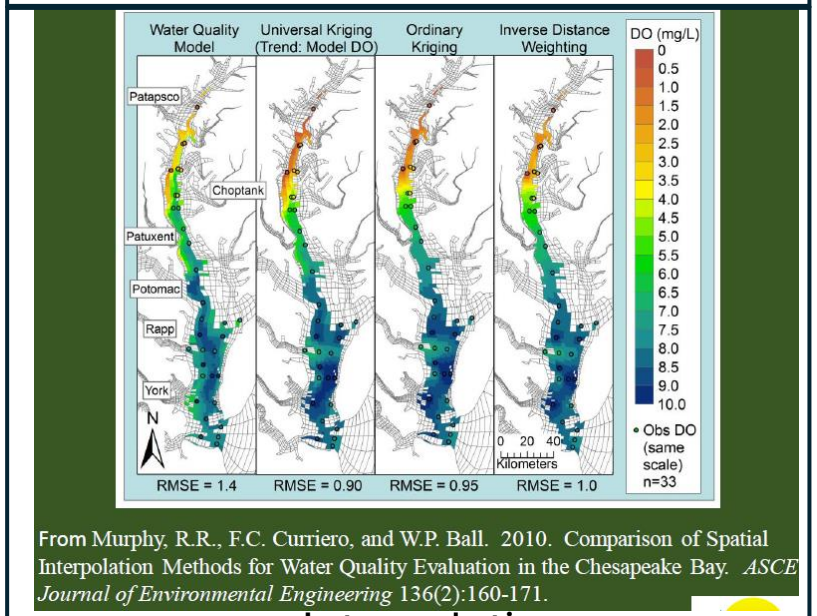
* "To address the need for data that will address the 7-day, 1-day mean and instantaneous minimum criteria components, ***continuous monitors mounted to buoys or piers will be required***."

Recommended: Measure, Interpolate, and Assess

- "*Individual criteria component estimates would be assessed at all fixed locations* ***and interpolated for incorporation in a cumulative frequency distribution***."



Continuous water column data



From Murphy, R.R., F.C. Curriero, and W.P. Ball. 2010. Comparison of Spatial Interpolation Methods for Water Quality Evaluation in the Chesapeake Bay. *ASCE Journal of Environmental Engineering* 136(2):160-171.

Interpolation

From 2003-2022 Time flies when we are having fun!!!

Regular, significant investments aimed at addressing the 2003 proclamation that ‘we need more monitoring’.

- 2004-05 Shallow water monitoring with continuous monitoring becomes grant funded.
- 2008 STAC Panel on 4D interpolation to support assessment – not ready yet.
- 2009 Monitoring Realignment Report – considers assessment method options.
- USEPA 2004, 2007, 2008, 2010 Technical Documents involving criteria assessment protocols
- 2015 Community Science program of the CBP is grant funded (Welcome Chesapeake Monitoring Cooperative!)
- USEPA (2017) summarizes D.O. assessment method options (Included 2015-2016 STAC Reviews).
- 2019-20 GIT funded pilot study of water column sensor array feasibility with new tech (other tech tested over the past decade had limitations). Success! See Carribean Wind 2019 Report with CBTrust)
- 2020-21 CBP STAC Workshop Advanced Monitoring Approaches for Enhanced Monitoring (Report in review!)
- PSC Monitoring Review: In March 2021, the Principals’ Staff Committee (PSC) requested a study and recommendations on how to improve Chesapeake Bay Program (CBP) monitoring networks
- 2022 CBP Report published recognizing long-standing assessment gaps. Hypoxia Collaborative and Bay Oxygen Research Group form to work on addressing monitoring and assessment support

Enhancing the Chesapeake Bay Program Monitoring Networks
A Report to the Principals' Staff Committee



Chesapeake Bay Program
Science. Restoration. Partnership.

Table 1.2. Recommendations to improve Chesapeake Bay Program monitoring with line-item cost projections for a 5-year planning horizon.

CBP Network	Recommendation	Category	Funding				
			Year 1	Year 2	Year 3	Year 4	Year 5
Tidal	Equipment and Supplies for 8 advanced vertical sensor array stations.	Capital Cost	$500,000				
Tidal	Support operation and maintenance of vertical sensor arrays	Operation & Maintenance	$300,000	$315,000	$330,750	$347,288	$364,652
Funder							
Tidal	Sustain Existing Tidal Water Quality Program	Operation & Maintenance	$304,000	$394,000	$484,000	$584,000	$684,000
Funder							
Tidal	4D Interpolator Development	Operation & Maintenance	$60,000	$60,000	$60,000	$60,000	$60,000
Funder							
Tidal	Calibrate and Verify Models for Nutrient Limitation Survey	Operation & Maintenance	$275,000	$275,000			
Funder							

Chesapeake Bay Program. 2022. Enhancing the Chesapeake Bay Program Monitoring Networks - A Report to the Principals' Staff Committee. 103 pages.

Executive Summary (Peter Tango, USGS, Breck Sullivan USGS, Lee McDonnell EPA, Scott Phillips USGS, Denice Wardrop CRC and Amy Goldfischer CRC)

Section 1: Lee McDonnell (EPA) and Denice Wardrop (CRC)

Section 2: Breck Sullivan (U.S. Geological Survey) and Peter Tango (U.S. Geological Survey)

Section 3: Scott Phillips (U.S. Geological Survey), Peter Tango (U.S. Geological Survey), and Breck Sullivan (U.S. Geological Survey)

Section 4: Peter Tango (U.S. Geological Survey), Breck Sullivan (U.S. Geological Survey) and Amy Goldfischer (CRC)

2022: Hypoxia Collaborative surveys the community

Recommendations on sampling design for the next phase of hypoxia monitoring network development: General locations

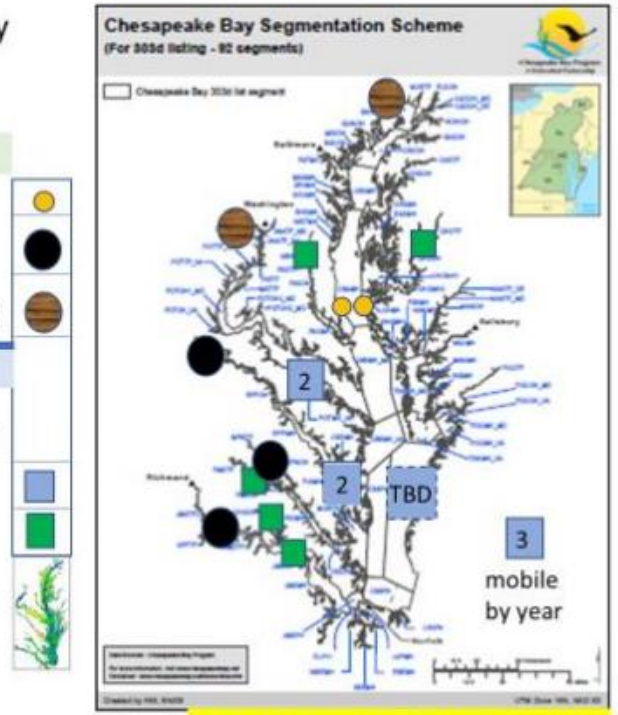
Expanding monitoring and assessment capacity 2021+: High frequency monitoring network

Existing

- NOAA supports 2 vertical sensor arrays
- 3 fully funded river input water quality continuous monitors (VADEQ/USGS)
- 2 river input water quality continuous monitoring sites with support ending, need funding (MD/USGS)

New – proposed and considered for investment

- 2021-22 PSC Monitoring Review proposal for capacity to support unassessed criteria assessment, improved fish habitat assessment, modeling calibration and verification:
  - 8 new tidal water vertical array sites
  - 5 new river input con-mons at tidal/nontidal boundary
  - New 4-D water quality interpolator tool development



Network vision: D.O., Temp, Salinity

- 11 vertical arrays operating in main bay and tidal tributaries
- 10 boundary condition river input continuous monitoring stations
- Sustain existing long-term and targeted shallow water monitoring

- Justification for the present stage of the sampling design reflects
  - fisheries habitat information needs
  - modeling needs
  - research interests, and
  - water quality criteria assessment requirements

- Setting up the network will allow other partners to align data collection and QA with the network efforts to leverage resources

Recommendations on sampling design for the next phase of hypoxia monitoring network development

- Mainstem bay (3)
  -
- Lower tributaries: Potomac and Rappahannock. (4)
  - 2 Potomac arrays
  - 2 Rappahannock arrays
- Mobile, targeted study arrays (4)
  - 3 new as a suite for evaluating scales of variability
  - 1 existing with MD DNR and their Fishing Bay study area

n=11+ arrays.

- Growing the water quality network from "Fair" to "good", addressing high frequency water quality habitat conditions with this level of investment and build out of the program.

Recommendations on sampling design for the next phase of hypoxia monitoring network development

- Mainstem bay (3)
  -
- Lower tributaries: Potomac and Rappahannock. (4)
  - 2 Potomac arrays
  - 2 Rappahannock arrays

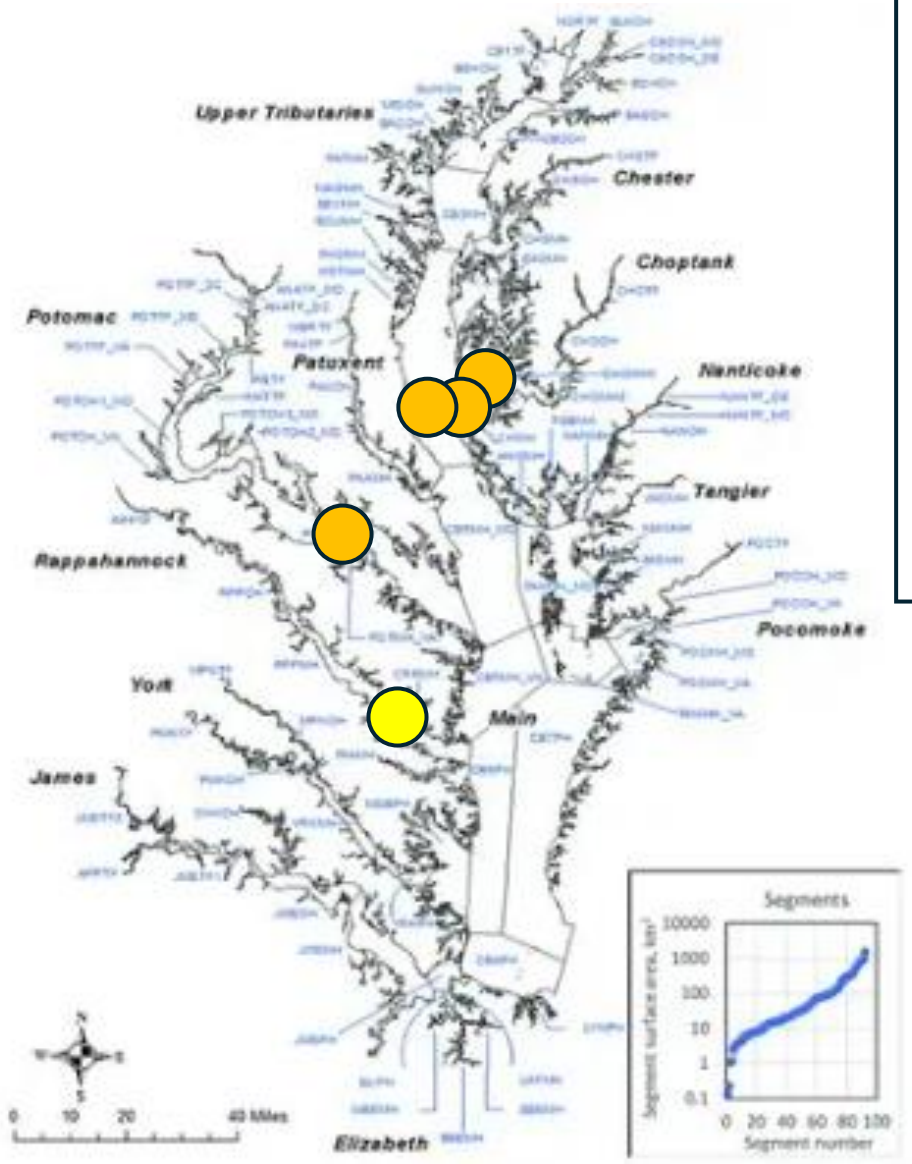
2025: Choptank River

- Mobile, targeted study arrays (4)
  - 3 new as a suite for evaluating scales of variability
  - 1 existing with MD DNR and their Fishing Bay study area

n=11+ arrays.

- Growing the water quality network from "Fair" to "good", addressing high frequency water quality habitat conditions with this level of investment and build out of the program.

Recent focus segments with the new vertical arrays



- Ongoing interest in returning to a mainbay site:
  - The focus has been on CB4 near mouth of Choptank
  - We had a summer of east and west CB4 deployments
- We spent a year in the Lower Potomac
- We received priority requests for the Lower Rappahannock
- 2025: Lower Choptank – limited resources

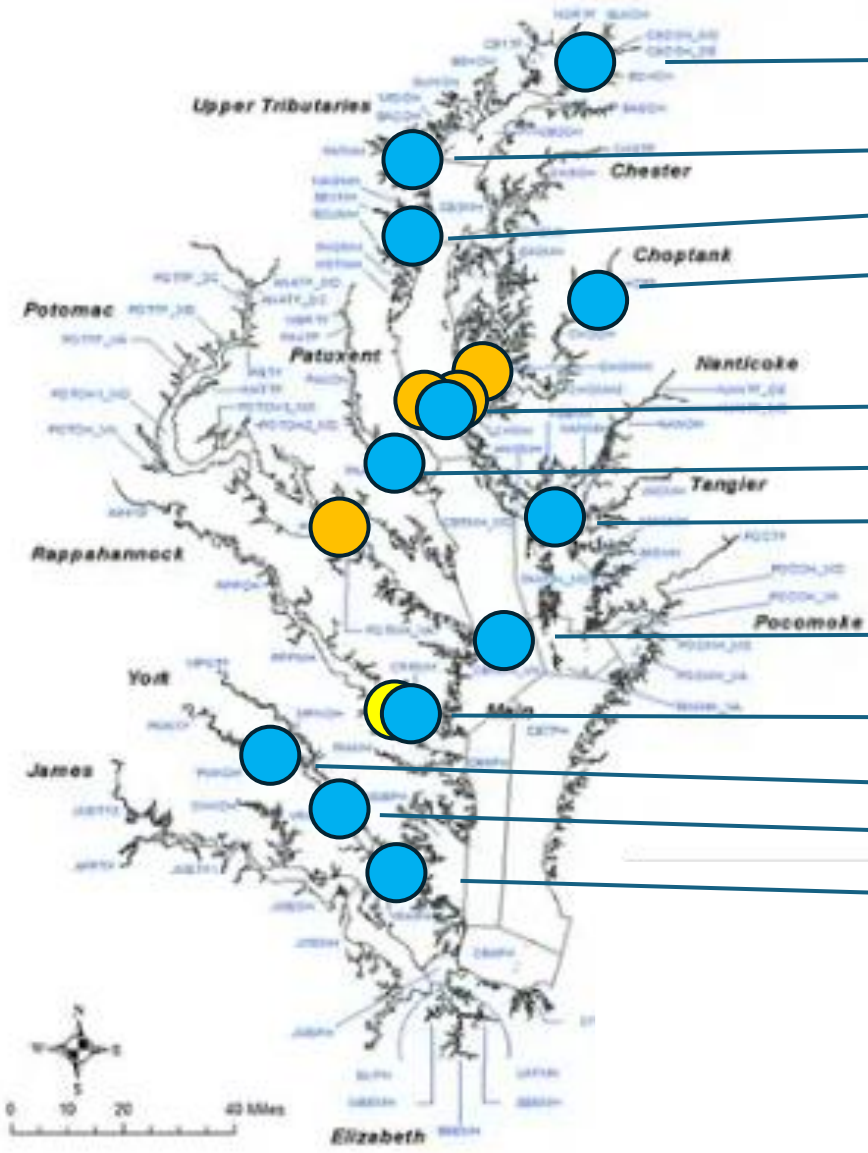
Considerations:

- For Water Quality Standards attainment purposes, assessments involve monitoring in the same segment for 3 years.

* For Modeling – we have heard the value of maintaining monitoring at a site as a continuous reference or sentinel station; "mobile" sites can provide support for short duration insights

- For Fisheries – we could use habitat characterization –
  - Duration on location commitment flexibility? ("Mobile"

Workshop 2025: MD and VA segment recommendations for sampling design focus



Elk R. OH

Patapsco R. MH

Magothy R. MH

Choptank R. TF

CB4 MH

Patuxent R. MH

Fishing Bay MH

CB5 MH

Lower Rappahannock MH

Pamunkey OH

York R OH

York R MH

Workshop 2025: MD and VA segment recommendations for sampling design focus
Details of consideration

Maryland:

1. Fishing Bay Mesohaline - It has a ton of data that will be good for testing a validation of their model. Plus it has some very narrow tidal tribs that would be good for the model to be able to deal with. Has 3 designated uses.
2. Chesapeake Bay Mainstem 4 Mesohaline - This is a large segment with all 5 designated uses and plenty of stratification. Figured this would be good to include as it represents one extreme of the Bay segment spectrum for MD.
3. Choptank River Tidal Fresh - Would represent the opposite end of the salinity spectrum from #1 and 2 and is characterized by narrow tidal channels without a large open embayment. There again, this would provide some variety for the model design effort. Has only 3 designated uses.
4. Magothy River Mesohaline - We felt that we needed a western shore tributary. Plus this segment has 4 designated uses (it lacks a deep channel DU) so it provides something unique to the top four segments mentioned here.
5. Patapsco River Mesohaline - This segment has all 5 designated uses, and has a good bit of data already being collected regularly so it could serve as a good validator for the model.
6. Patuxent Mesohaline - This segment has 4 designated uses (no deep channel) and has a different shape and likely tidal dynamics than some of the other wider mesohaline segments.
7. Elk River Oligohaline - We don't have any other oligohaline segments on this list. It has 3 designated uses and is higher up in the watershed than any of our other chosen segments.

Virginia:

Segment	Reasoning
Rappahannock Mesohaline	* Has all four designated uses (though not all in the same locations) * Nonattainment of Deep Water and Deep Channel uses is marginal with current monitoring data. * Successful Vertical Profiler deployment in the past
York Polyhaline	* Deep Water * Nonattainment of Deep Water is marginal with current monitoring data * Successful Vertical Profiler deployment in the past. *CB-NERR maintains a shallow water conmon in this segment, making nearshore-offshore comparisons possible.
York Mesohaline	* Migratory Fish Spawning Use * Marginal nonattainment of the Open Water 30-day use with current monitoring data *CB-NERR maintains a shallow water conmon in this segment, making nearshore-offshore comparisons possible.
Pamunky OH	* Migratory Fish Spawning Use * Marginal nonattainment of the Open Water 30-day use with current monitoring data *CB-NERR maintains a shallow water conmon in this segment, making nearshore-offshore comparisons possible. * Only one long-term station, positioned towards the lower end of the segment
CB5MH	* Shared between MD and VA * Deep Water and Deep Channel * Enhanced data in this segment may also inform assessments of other Middle and Lower Bay segments.

Sampling Design Boundaries for Scenario Considerations in comparing deployment strategies

- Long term monitoring stations – continue
- 1-3 vertical arrays in a segment
- 1-6 nearshore fixed site continuous monitors
- Community Science/alternative non-continuous
  - E.g., Weekly monitoring at a fixed site
  - E.g., weekly monitoring at multiple fixed sites

And here we are today… ☺

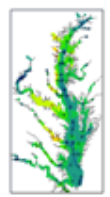
- Create the short list of areas of interest/priority segments to inform deployment sampling designs
- Familiarize ourselves with the process, outputs when creating design options
- Understand our resources and limitations on design options
- Co-produce geographic filtering of locations we can’t deploy sampling equipment

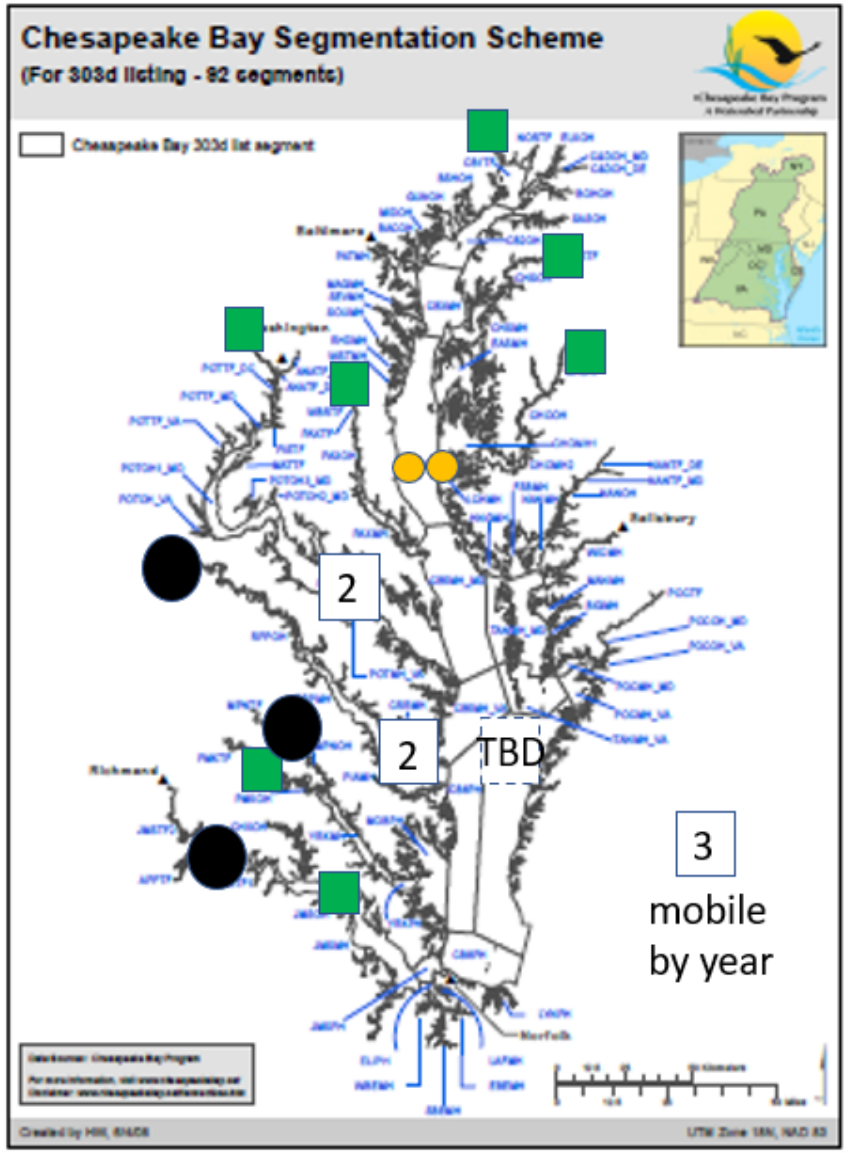
Good work!
Thank you all!!! ☺

Addressing high temporal frequency data needs issues by expanding monitoring and assessment capacity 2021+

- NOAA supports 2 vertical sensor arrays
- Virginia DEQ/USGS coordinate on 3 river input continuous monitors

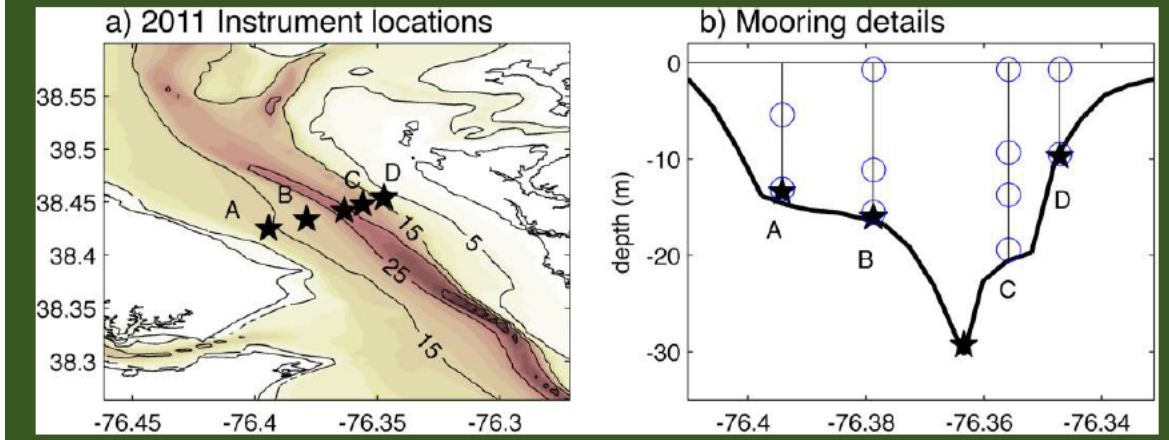
- 2021-22 PSC Monitoring Review proposal for capacity to support unassessed criteria assessment, improved fish habitat assessment, modeling calibration and verification:
  - 8 new tidal water vertical array sites
  - 7 new river input con-mons at tidal/nontidal boundary
  - New 4-D water quality interpolator tool development

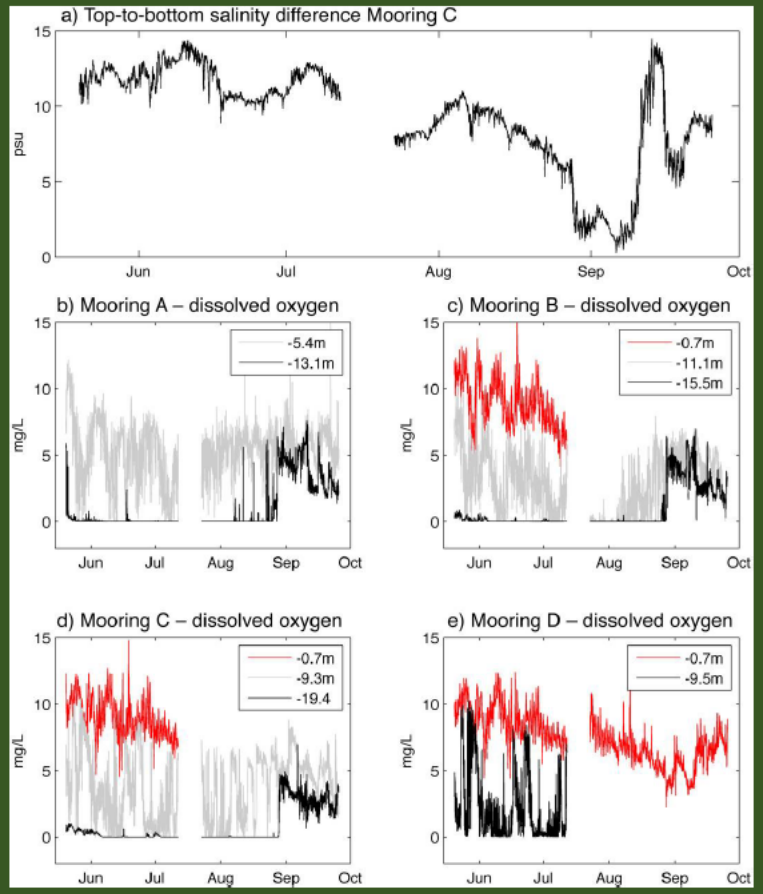




Vertical Profilers: Mainstem Bay. Precursor work to today.

M. Scully 2016. Mixing of dissolved oxygen in Chesapeake Bay driven by the interaction between wind-driven circulation and estuarine bathymetry





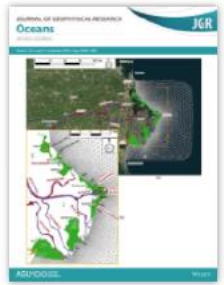
JGR: Oceans, Volume: 121, Issue: 8, Pages: 5639-5654, First published: 13 July 2016, DOI: (10.1002/2016JC011924)

Open Water:
Monitoring needs at high frequency – how much?

JGR Oceans

Research Article | Open Access

Volume 123, Issue 9
September 2018
Pages 6392-6407
This article also appears in:
The U.S. IOOS Coastal and Ocean Modeling Testbed 2013-2017



Estimating Hypoxic Volume in the Chesapeake Bay Using Two Continuously Sampled Oxygen Profiles

Aaron J. Bever, Marjorie A. M. Friedrichs, Carl T. Friedrichs, Malcolm E. Scully

First published: 27 August 2018 | https://doi.org/10.1029/2018JC014129 | Citations: 3

Figures References Related Information

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Abstract

Low levels of dissolved oxygen (DO) occur in many embayments throughout the world and have numerous detrimental effects on biota. Although measurement of in situ DO is straightforward with modern instrumentation, quantifying the volume of water in a given embayment that is hypoxic (hypoxic volume (HV)) is a more difficult task; however, this information is critical for determining whether management efforts to increase DO are

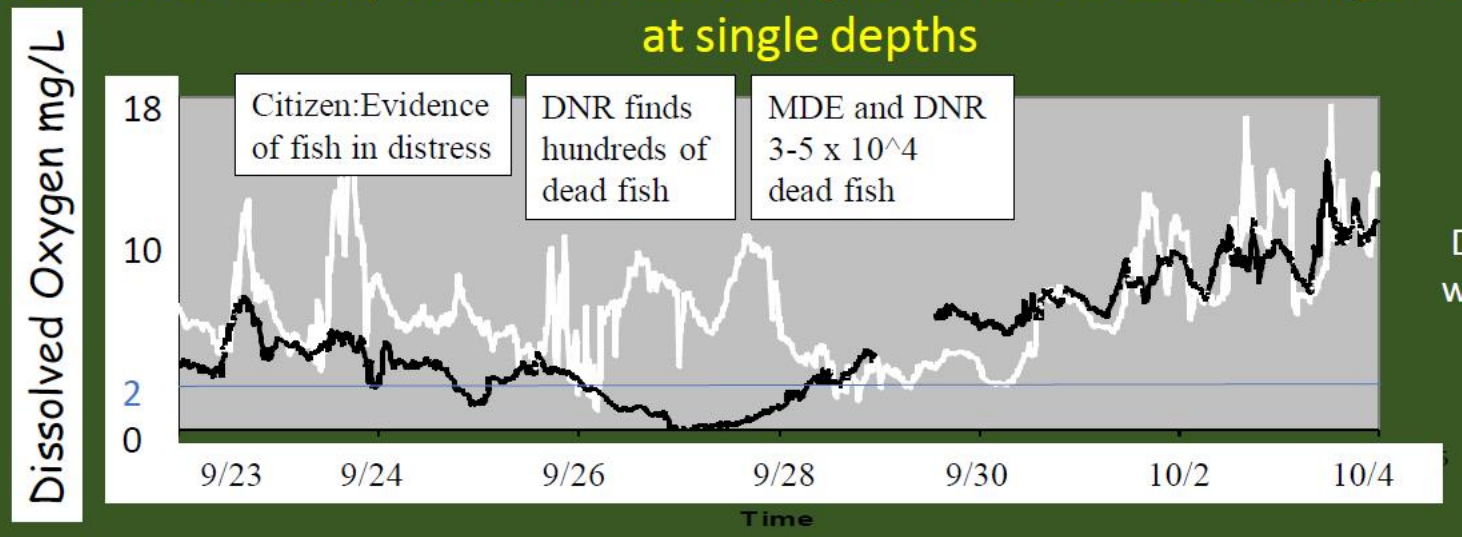
Metrics

Citations: 3

Am score 1

Details

We have done very well with monitoring nearshore habitats in high frequency at single depths

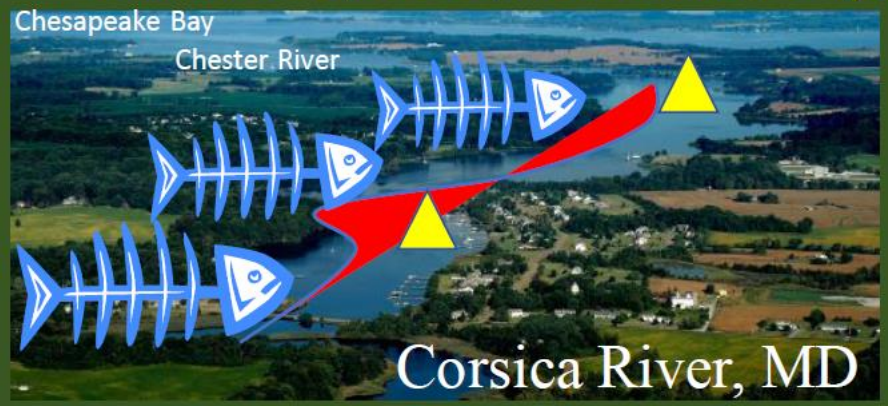


D.O. Dynamics within a 2 week period

Fish Kill in the Corsica

September 28, 2005

Estimated 30,000-50,000 fish dead; 15 species affected



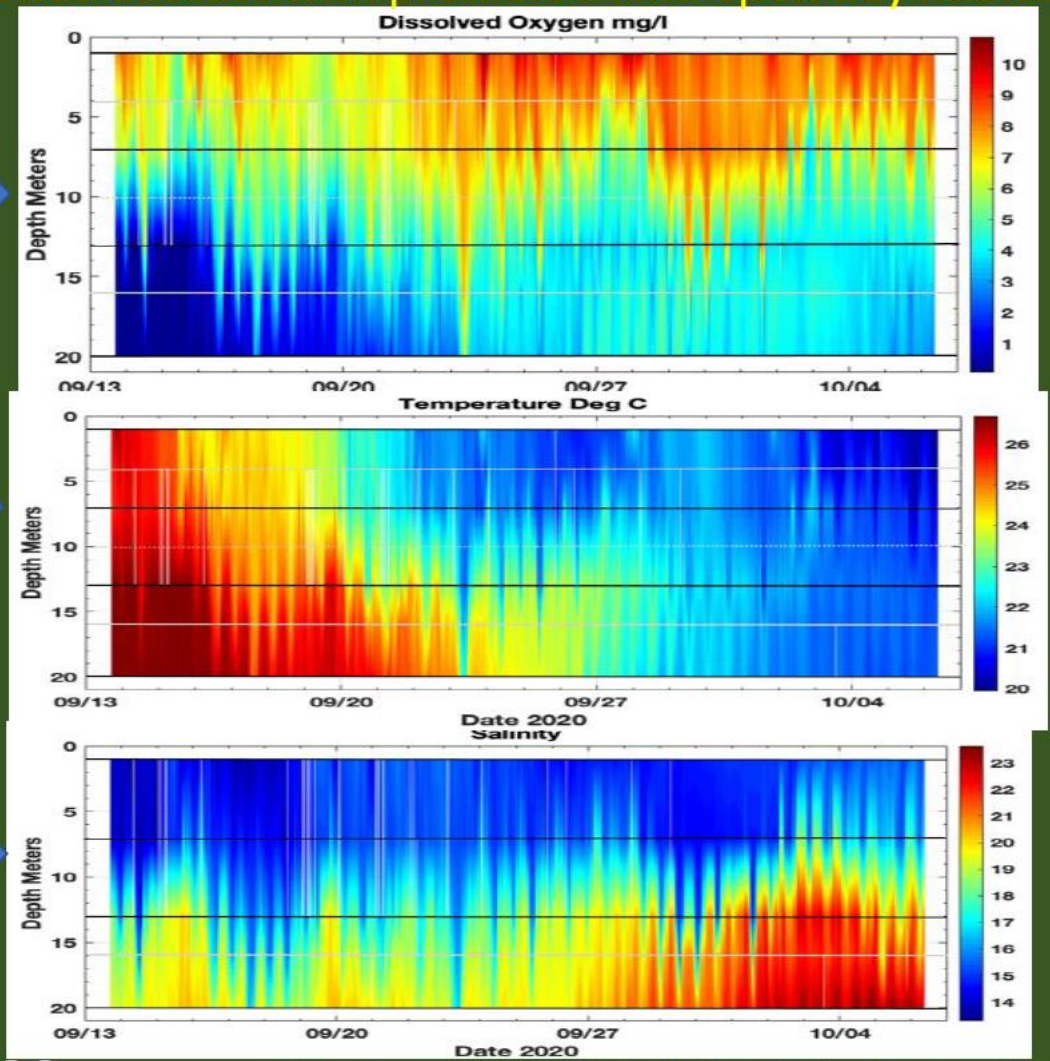
▲ = DNR Continuous Monitoring Stations ■ = Dead fish

USGS

Chesapeake Bay Program

Dissolved oxygen: We have had success with profilers in the open bay habitats

- Dissolved oxygen – water at this station becomes oxygenated
- Temperature stratification is lost and becomes isothermal
- Salinity stratification declines before oxygen rich high salinity water moves into the bottom waters



~ $50K Instrument with high data return on investment

4-5K per sensor

USGS science for a changing world

September 2020

D. Wilson 2020. CBT GIT-funded pilot project data

Chesapeake Bay Program
A Watershed Partnership