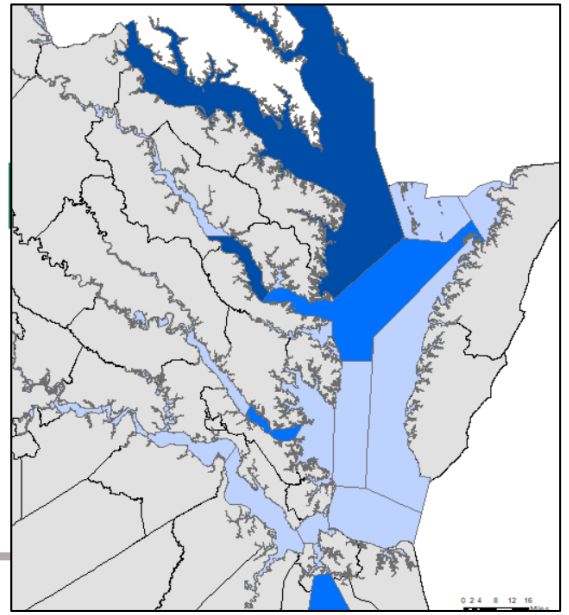
Modeling Analysis Request for Proposed Boundary Extension of the Water Sub-use in Virginia's Mainstem Chesapeake Bay



Tish Robertson and Richard Tian

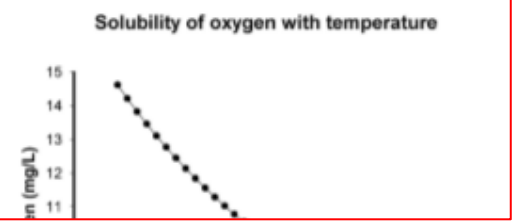
Modeling Workgroup Quarterly Review

July 13, 2022

Achievement of Open Water DO Water Quality Standard

Chesapeake Bay Program
Science, Restoration, Partnership

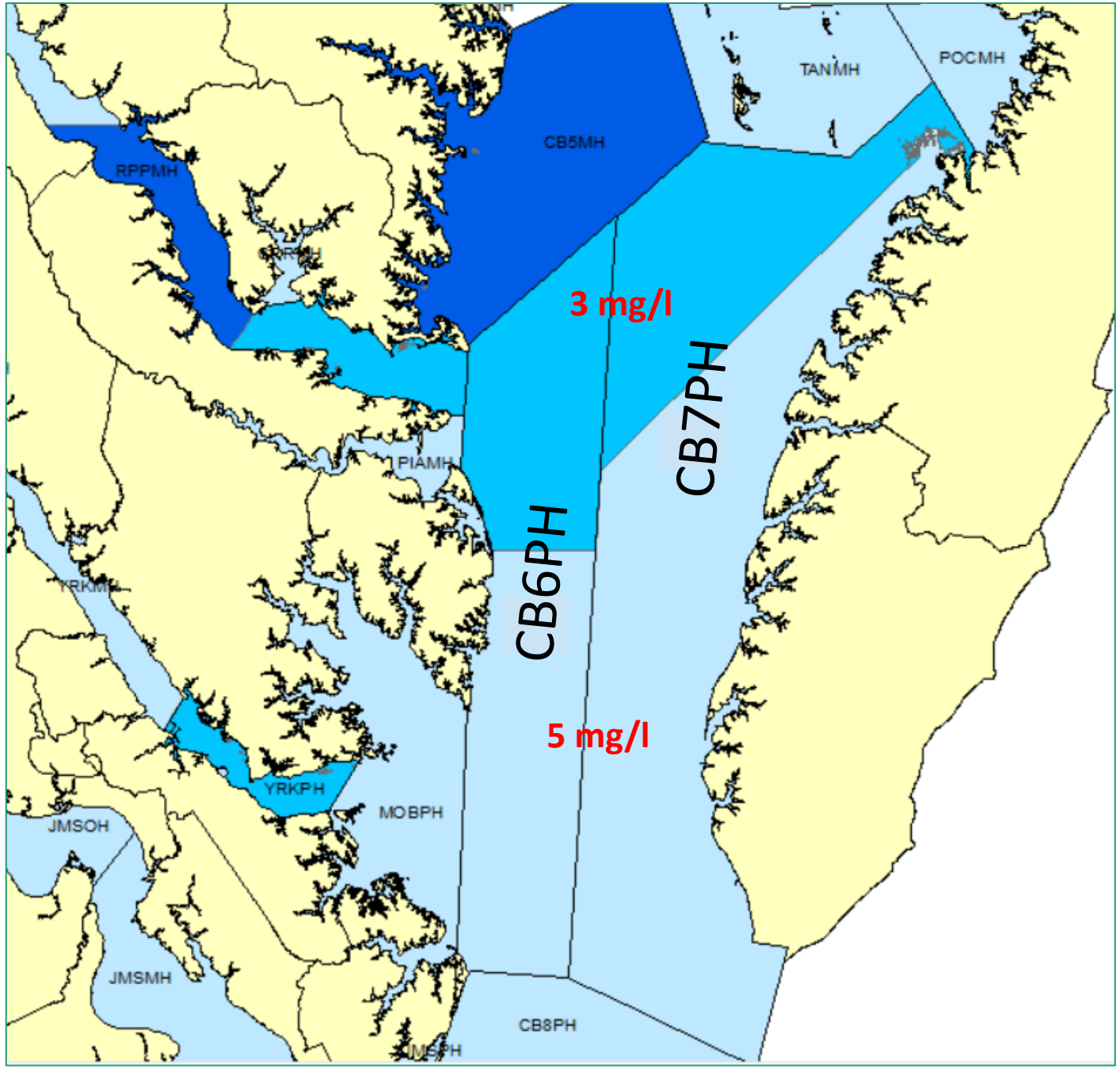
CB Segment	State	2025 Climate 2025 Land Use 204TN 14.0TP 1993-1995 DO Open Water	2035 Climate 2025 Land Use 208TN 14.6TP 1993-1995 DO Open Water	2035 Climate 2035 Land Use 209TN 14.7TP 1993-1995 DO Open Water	2045 Climate 2025 Land Use 212TN 15.4TP 1993-1995 DO Open Water	2045 Climate 2045 Land Use 213TN 15.7TP 1993-1995 DO Open Water	2055 Climate 2025 Land Use 220TN 16.7TP 1993-1995 DO Open Water	2055 Climate 2055 Land Use 222TN 17.1TP 1993-1995 DO Open Water
CB1TF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB2OH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB3MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB4MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB5MH_MD	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB5MH_VA	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB6PH	VA	0.4%	0.7%	0.8%	1.0%	1.1%	1.3%	1.4%
CB7PH	VA	1.1%	1.8%	1.9%	2.8%	2.9%	4.0%	4.1%
CB8PH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BSHOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
GUNOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
MIDOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
BACOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
PATMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
MAGMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
SEVMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
SOUMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		
RHDMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%		



(From Linker, 2020)

Bay Model indicates that TMDL nutrient reductions will bring most of the mainstem Bay into compliance with water quality standards. The exceptions are CB6PH and CB7PH Open Water.

DEQ



Deep Channel

Deep Water

Open Water only

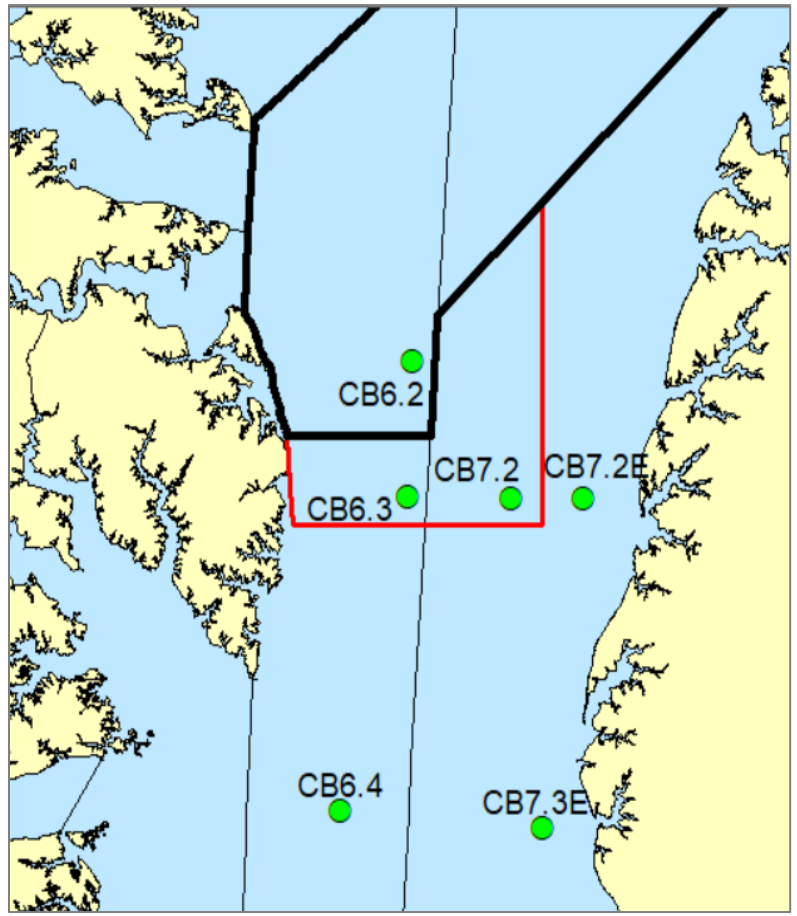
30-Day Mean Criteria

"Tidally influenced waters located…in areas where the measured pycnocline, in combination with bottom bathymetry and water circulation patterns, presents a barrier to oxygen replenishment of deeper waters. In some areas where a lower boundary of the pycnocline is not calculated, the **deep water designated use** extends from the measured depth of the upper boundary of the pycnocline down through the water column to the bottom sediment-water interface." – *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability (2003)*

"If a pycnocline is present but other physical circulation patterns (such as influx of oxygen rich oceanic bottom waters) provide for oxygen replenishment of deeper waters, the **open-water fish and shellfish designated use** extends down into the water column to the bottom water sediment interface." - *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability (2003)*

Historical and contemporary monitoring datasets indicate that the Deep Water Habitat is present at CB6.3 and CB7.2 based on the following criteria:

- Bathymetry
- Intensity/persistence of stratification
- Persistence and thickness of bottom hypoxic layer



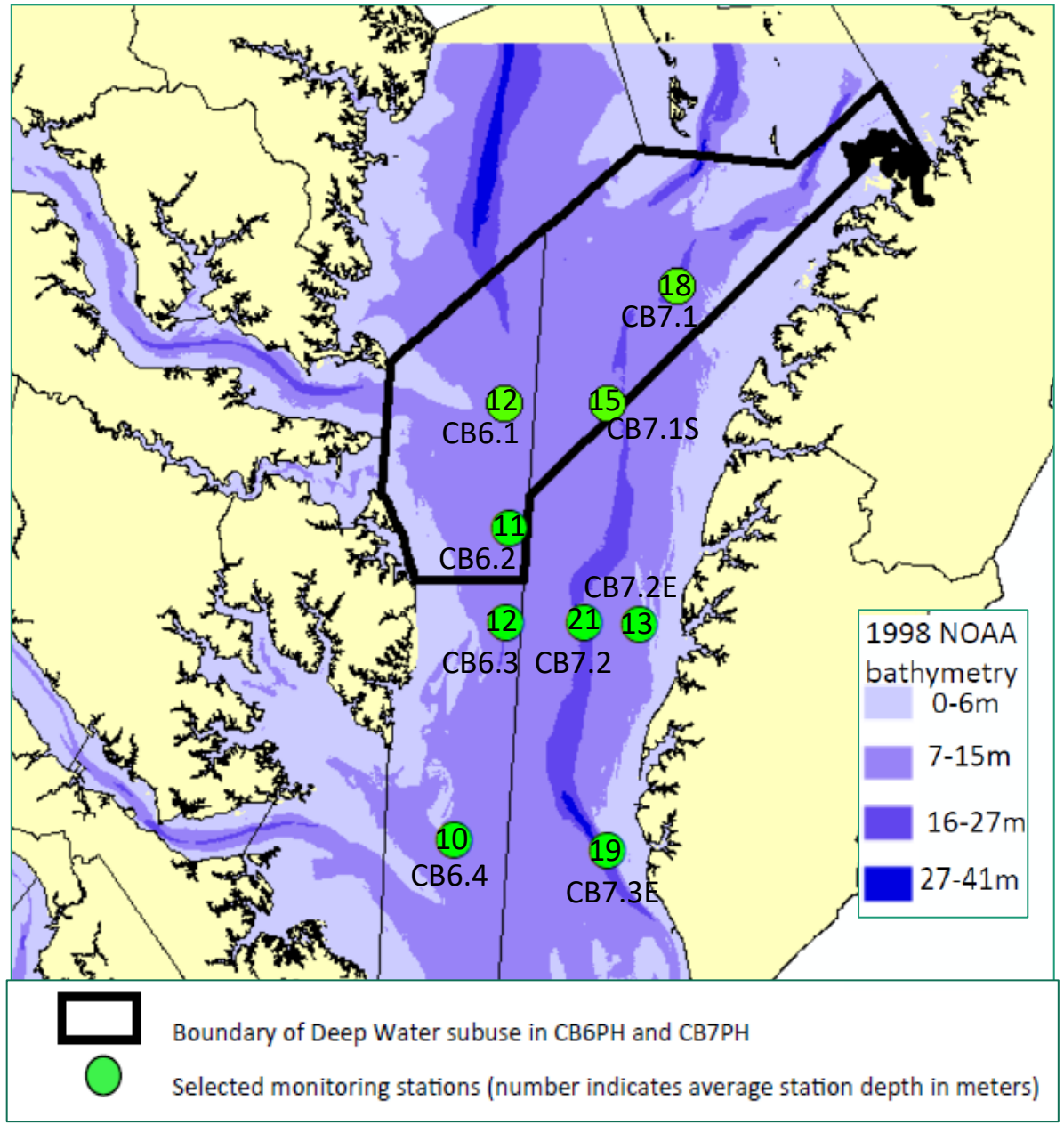
Current DW boundary

An alternative DW boundary

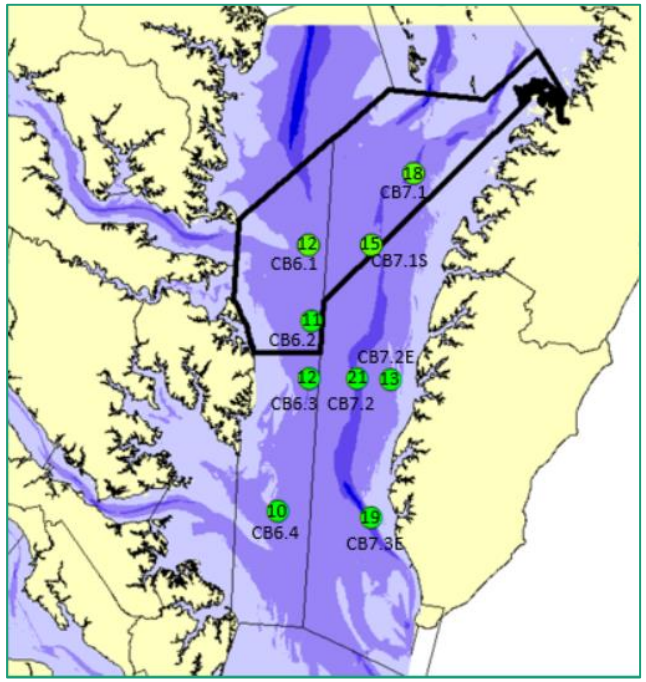
DEQ

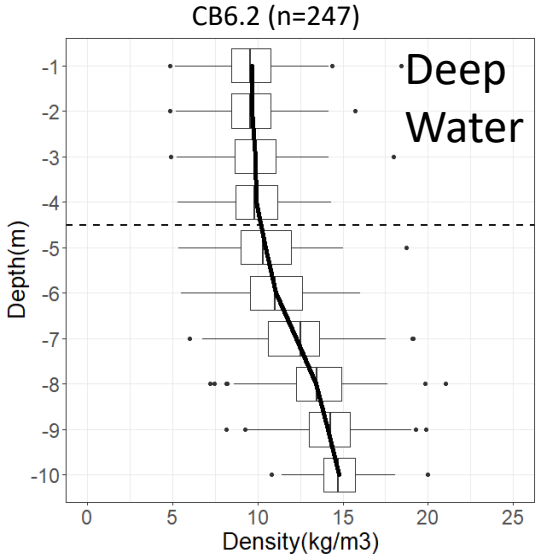
Bathymetry

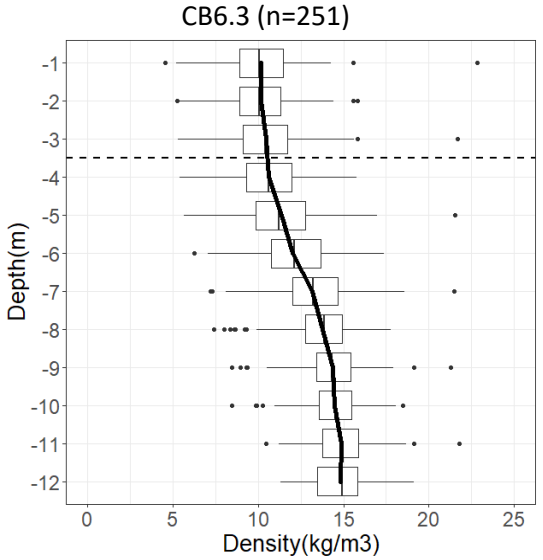
Open Water stations in CB6PH and CB7PH are just as deep as the Deep Water stations.

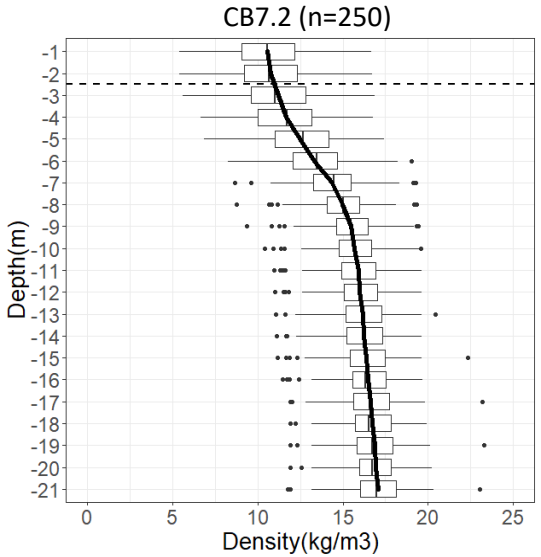


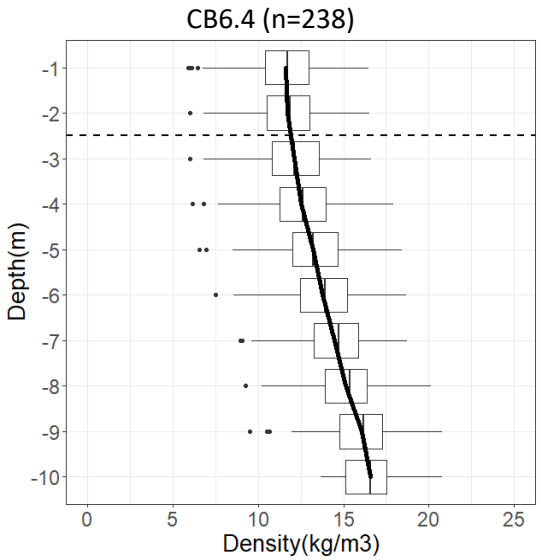
Stratification

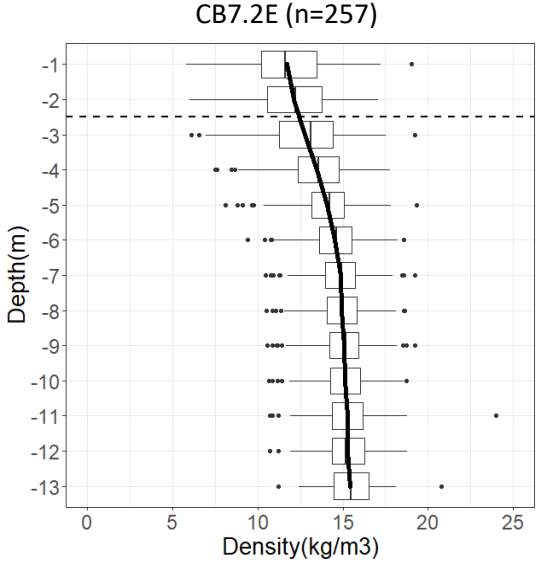


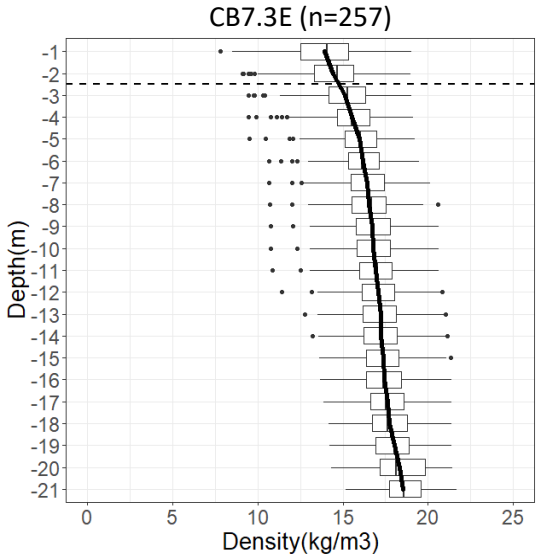






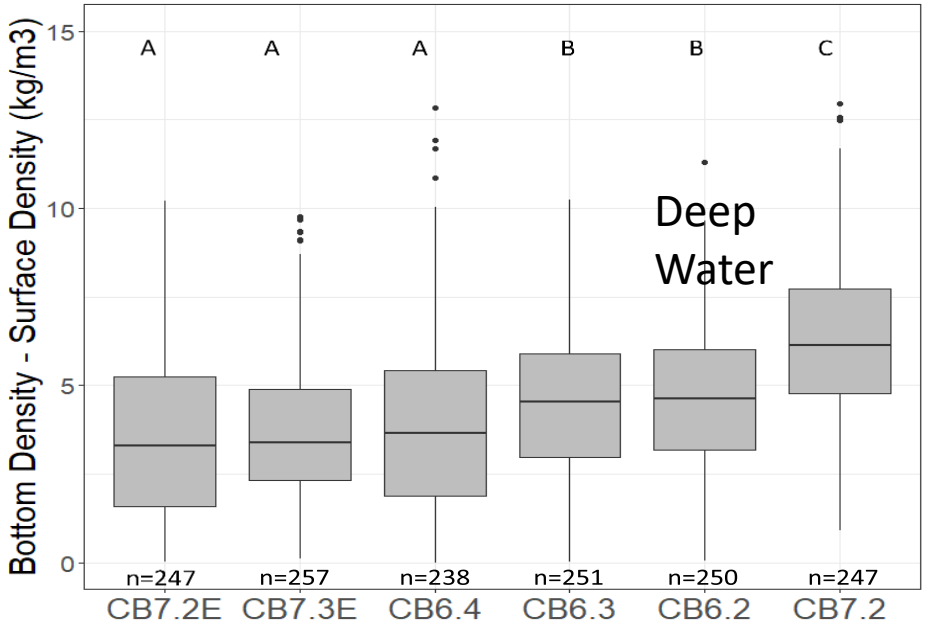


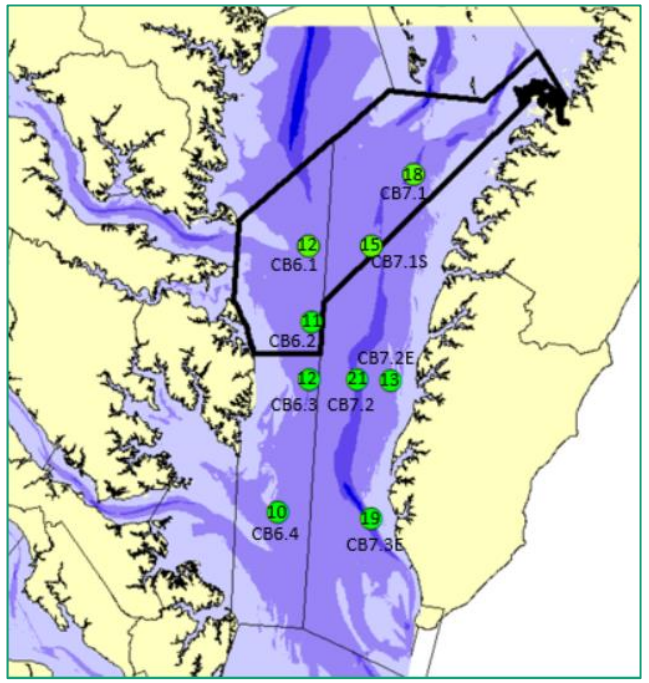




Boxplots of water density with depth at selected Bay stations, developed from monitoring datasets collected June-September 1985-2021. The black curve is the average density profile and the dashed horizontal line corresponds to the median uppermost depth of the pycnocline. Density and pycnocline depths were calculated according to the procedure described in Chapter III of USEPA (2008). n = number of monitoring events.

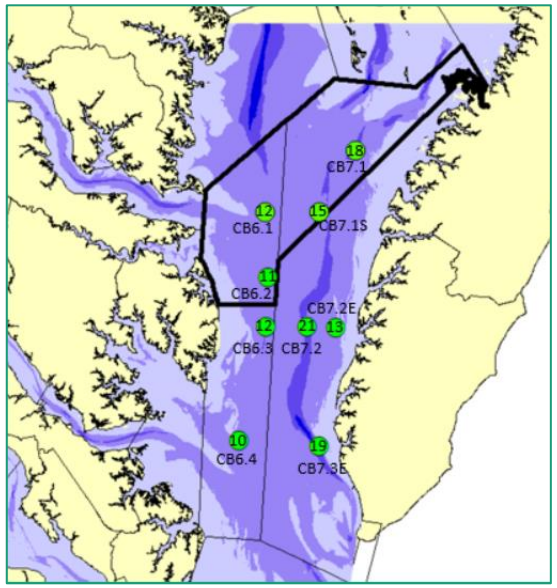
Stratification

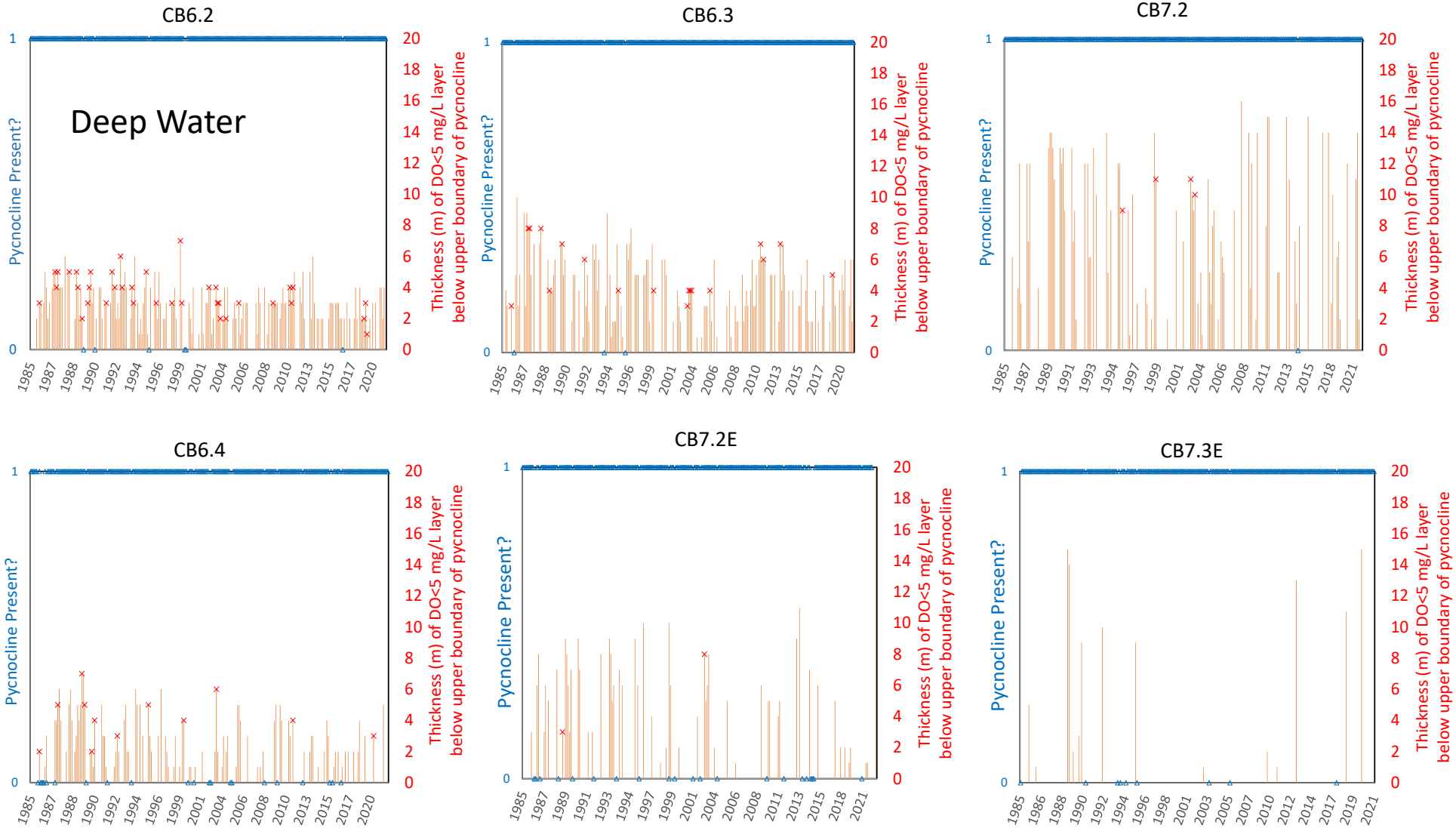




Boxplots of surface-to-bottom differences in water density computed from vertical profile data collected June-September 1985-2021. Letters represent statistically different groups ($p<0.05$, Kruskal-Wallis test, post-hoc Conover-Iman test). n = number of monitoring events.

Hypoxia Below Upper Boundary of Pycnocline





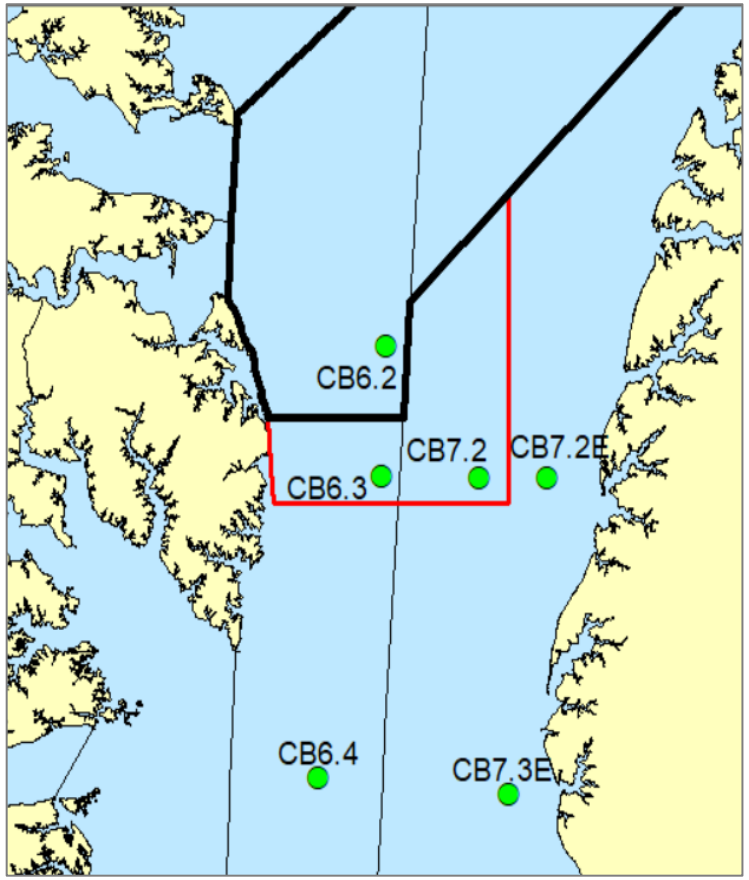
Pycnocline occurrence and thickness of the hypoxic layer below the upper boundary of the pycnocline computed from vertical profile data collected June-September 1985-2021. A pycnocline value of 0 signifies that no pycnocline was present at a particular monitoring event. “X” indicates those hypoxic events for which a DO concentration less than 3 mg/L was recorded at one or more depths.

Takeaways from Monitoring Datasets

- Deep Water habitat definitely exists at stations CB6.3 and CB7.2.

- CB6.4 and CB7.2E show features of Deep Water habitat, but not as prominently as the upstream stations.

So how far does the Deep Water habitat extend into CB6PH and CB7PH ?



"Minimal" alternative DW boundary

We could extend the boundary so that it includes only those areas where there is strong empirical evidence of Deep Water habitat.

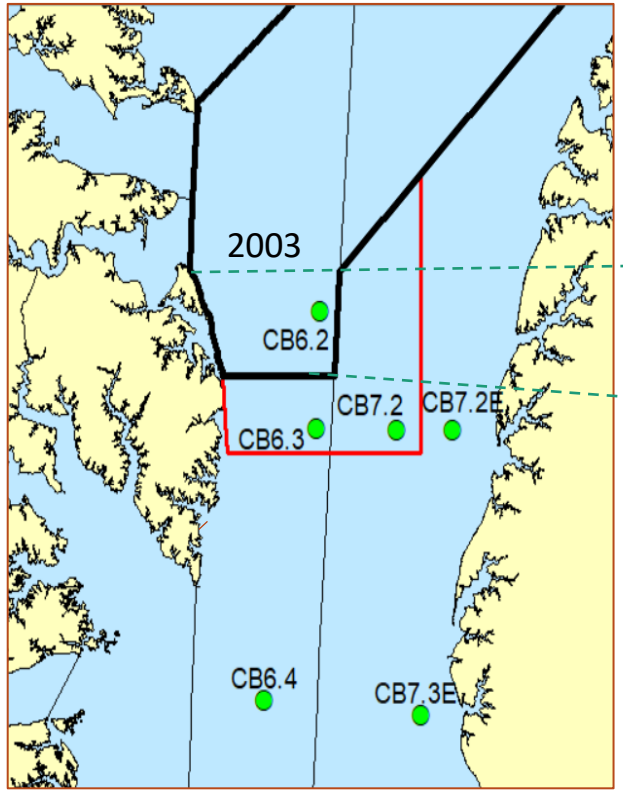
But Deep Water habitat may exist beyond CB6.3 and CB7.2.

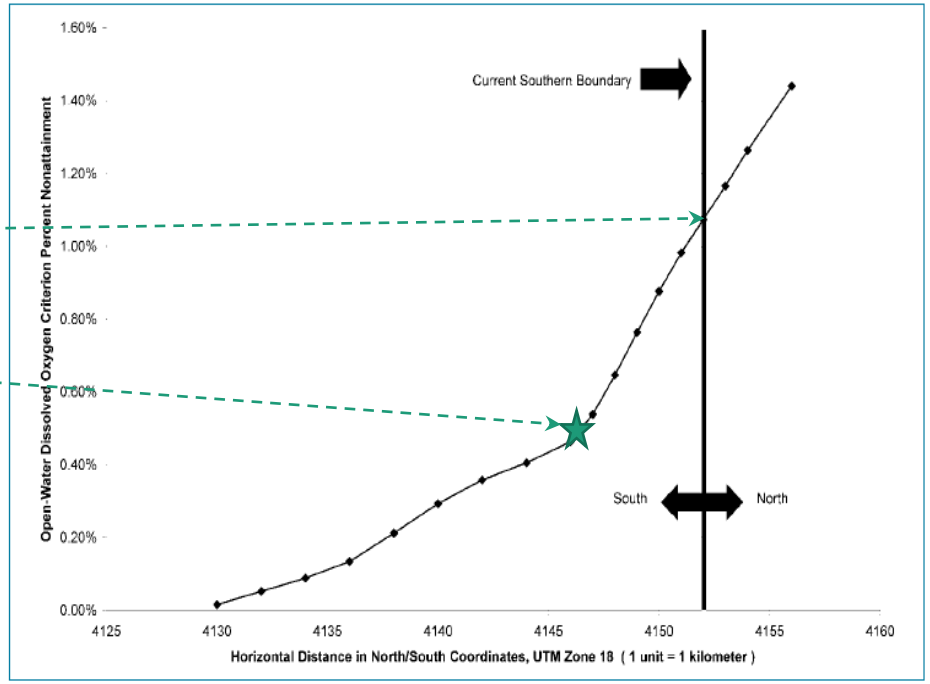
Virginia DEQ has asked the CBPO Modeling Team to provide assistance with defining a proper boundary.

DEQ

CBPO Modeling Team DW Boundary Analyses

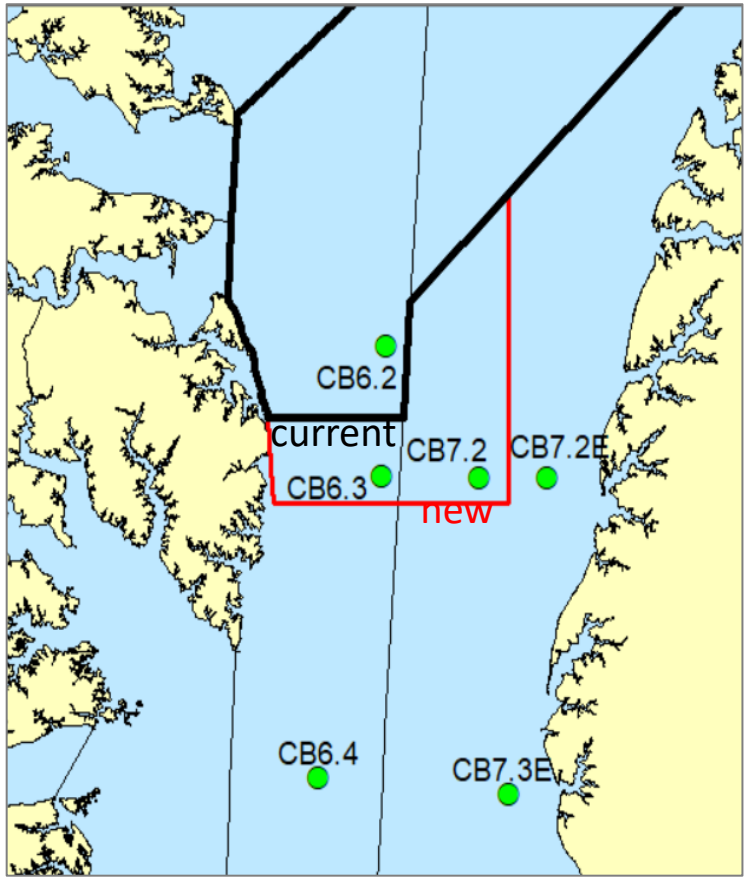
- Analysis #1: Test of multiple boundaries on criteria nonattainment





From the 2004 addendum
(This was used to select current boundary)

Preliminary Results



DO Criteria Nonattainment Rates for Three Scenarios and Three Boundaries

		Historical			Historical		WIP3 2055 Climate Change		
		1993_1995			2018_2000		1993_1995		
		Current Boundary	New Boundary	No Boundary	Current Boundary	New Boundary	Current Boundary	New Boundary	No Boundary
Cbseg	State								
CB6PH	VA	2.40%	1.95%	0.00%	0.02%	0.00%	1.46%	1.20%	0.00%
CB7PH	VA	5.46%	2.93%	0.00%	2.40%	0.43%	4.72%	2.21%	0.00%
Cbseg	State	Deep Water	Deep Water	Deep Water	Deep Water	Deep Water	Deep Water	Deep Water	Deep Water
CB6PH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CB7PH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

DEQ

CBPO Modeling Team DW Boundary Analyses

- Analysis #2: Mapping of stratification and oceanic inflow predicted under simulated 2025 and 2035 climate change

Where in CB6PH and CB7PH do we find…

- A high frequency of pycnoclines?
- A large surface-bottom DO gradient?

↓

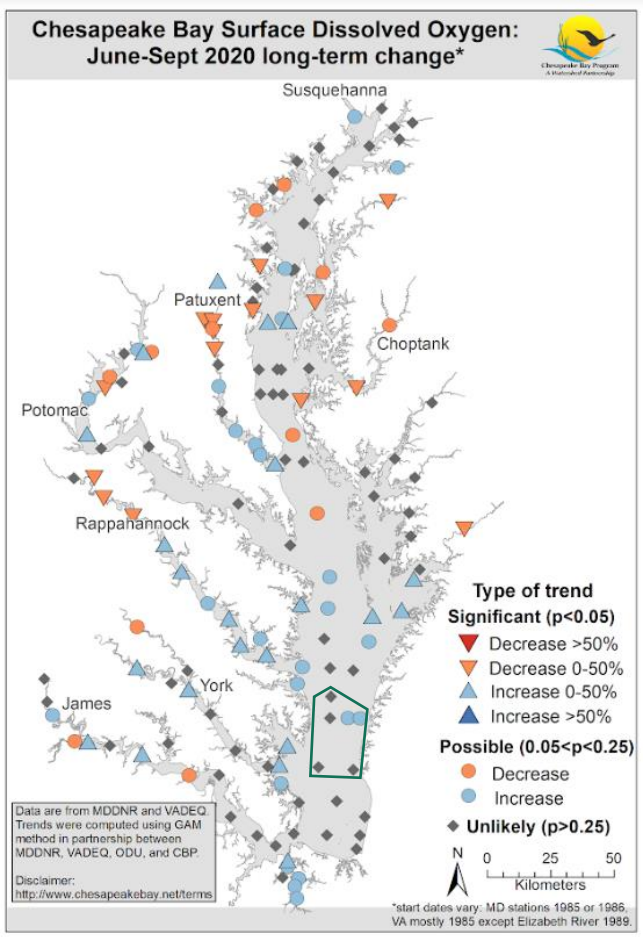
Deep Water Habitat

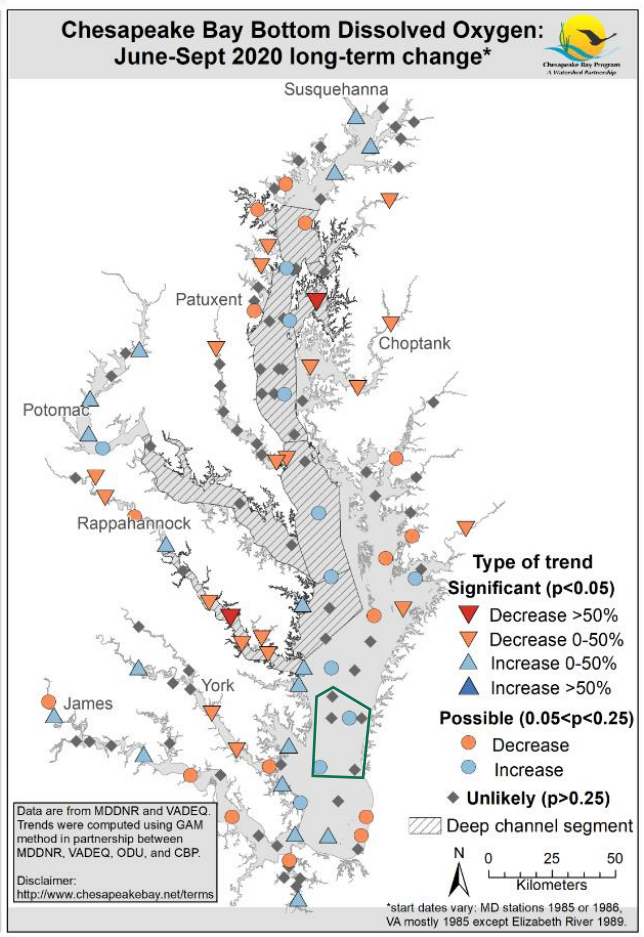
DEQ

The goal is to have DEQ and CBPO's work published in a new technical addendum, which Virginia would incorporate by reference into its WQS regulation.

DEQ

Questions?


Chesapeake Bay Surface Dissolved Oxygen:
June-Sept 2020 long-term change*
Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James
Type of trend
Significant (p<0.05)
Decrease >50%
Decrease 0-50%
Increase 0-50%
Increase >50%
Possible (0.05<p<0.25)
Decrease
Increase
Unlikely (p>0.25)
Data are from MDDNR and VADEQ. Trends were computed using GAM method in partnership between MDDNR, VADEQ, ODU, and CBP.
Disclaimer: http://www.chesapeakebay.net/terms
N
0 25 50
Kilometers
*start dates vary: MD stations 1985 or 1986, VA mostly 1985 except Elizabeth River 1989.


Chesapeake Bay Bottom Dissolved Oxygen:
June-Sept 2020 long-term change*
Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James
Type of trend
Significant (p<0.05)
Decrease >50%
Decrease 0-50%
Increase 0-50%
Increase >50%
Possible (0.05<p<0.25)
Decrease
Increase
Unlikely (p>0.25)
Deep channel segment
Data are from MDDNR and VADEQ. Trends were computed using GAM method in partnership between MDDNR, VADEQ, ODU, and CBP.
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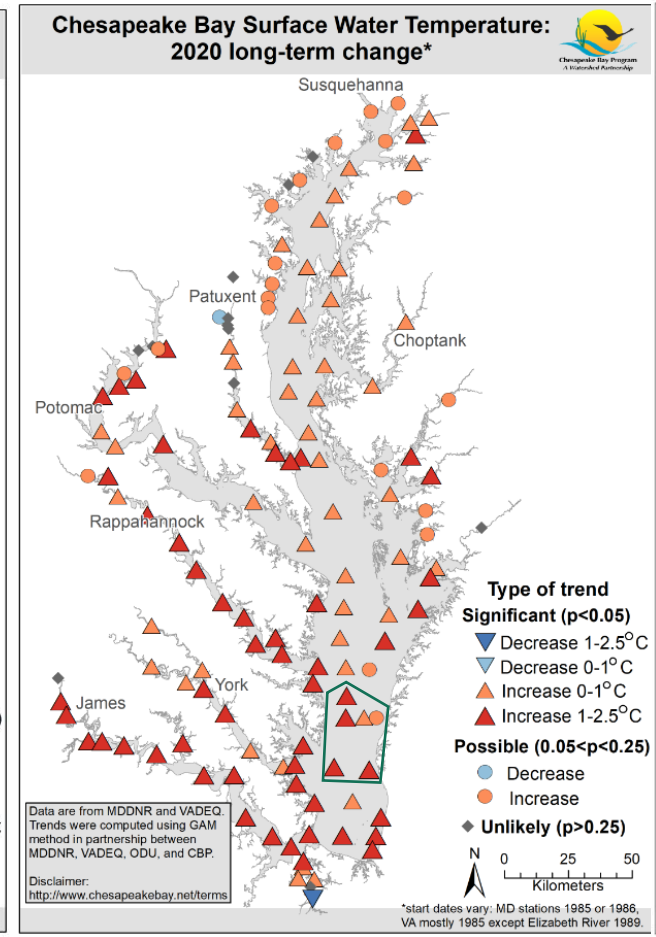
N
0 25 50
Kilometers
*start dates vary: MD stations 1985 or 1986, VA mostly 1985 except Elizabeth River 1989.


Chesapeake Bay Surface Water Temperature:
2020 long-term change*
Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James
Type of trend
Significant (p<0.05)
Decrease 1-2.5°C
Decrease 0-1°C
Increase 0-1°C
Increase 1-2.5°C
Possible (0.05<p<0.25)
Decrease
Increase
Unlikely (p>0.25)
Data are from MDDNR and VADEQ. Trends were computed using GAM method in partnership between MDDNR, VADEQ, ODU, and CBP.
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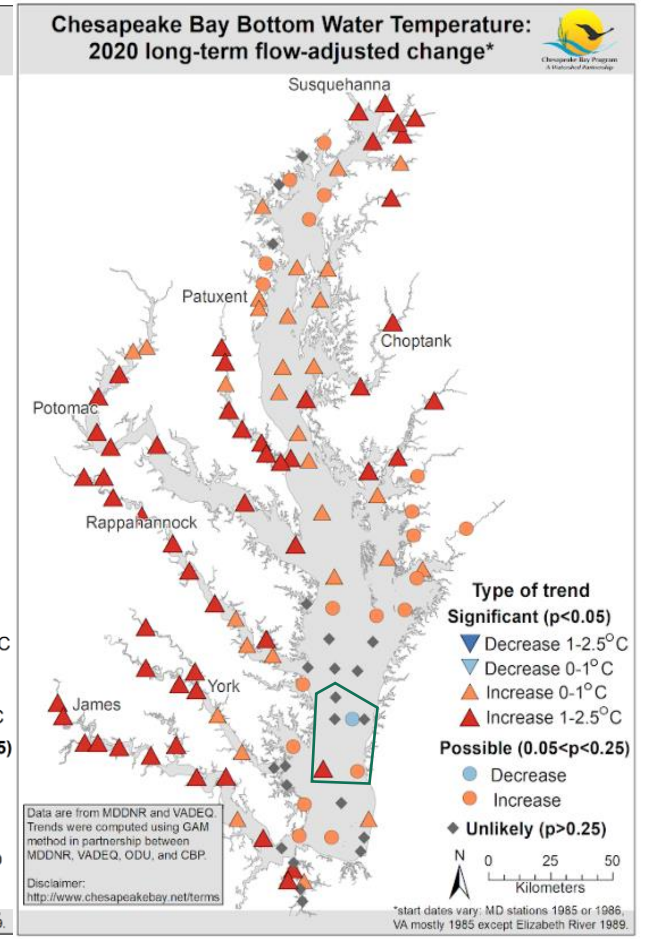
N
0 25 50
Kilometers
*start dates vary: MD stations 1985 or 1986, VA mostly 1985 except Elizabeth River 1989.


Chesapeake Bay Bottom Water Temperature:
2020 long-term flow-adjusted change*
Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James
Type of trend
Significant (p<0.05)
Decrease 1-2.5°C
Decrease 0-1°C
Increase 0-1°C
Increase 1-2.5°C
Possible (0.05<p<0.25)
Decrease
Increase
Unlikely (p>0.25)
Data are from MDDNR and VADEQ. Trends were computed using GAM method in partnership between MDDNR, VADEQ, ODU, and CBP.
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N
0 25 50
Kilometers
*start dates vary: MD stations 1985 or 1986, VA mostly 1985 except Elizabeth River 1989.

DEQ