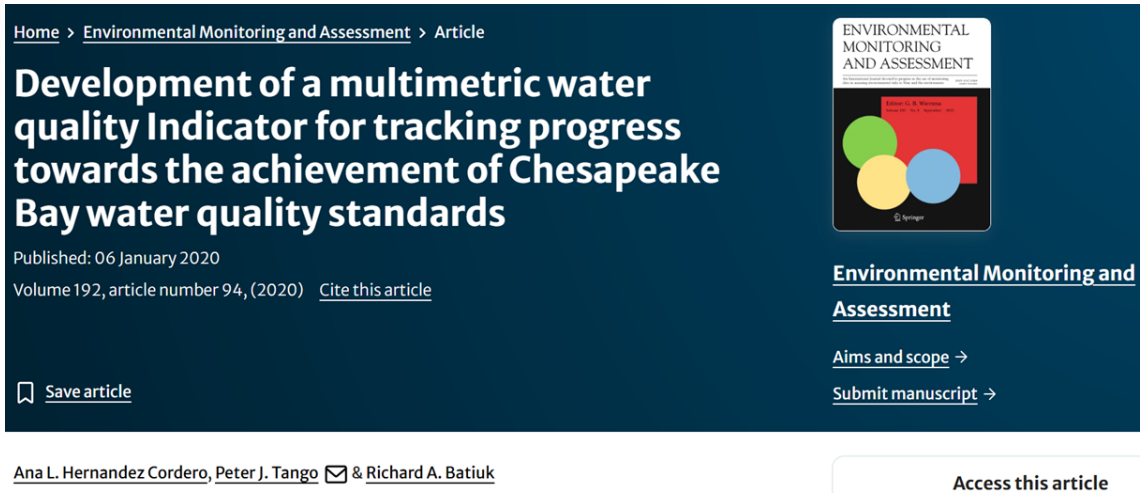
The CBP Water Quality Stds Multimetric Indicator Story

Peter Tango and Qian Zhang plus a cast of at least hundreds...

February 9, 2026

Criteria Assessment Protocol Workgroup Meeting

Colonial Beach, VA



The Indicator Design

- The indicator is an accounting translator to describe bay conditions; turning a lot of 1's and 0's in the stoplight plots into one number used to communicate an estimate of status for Bay water quality.

- The framework was adopted from the work underpinning the Chesapeake Bay Program community's established approach for setting allocation targets in the TMDL; i.e., what nutrient and sediment loads are need to meet DO, water clarity and chla criteria for all the designated uses in all 92 segments.

Before the 2014 Watershed Agreement…
1983, 1987, 1992, 1997, 2000, 2009 EO target improving Bay health

Developing a New Chesapeake Bay Water Quality Indicator for Tracking Progress toward Bay Water Quality Standards Achievement

Water Quality Goal Implementation Team Conference Call
November 13, 2012
Annapolis, MD

Liza Hernandez
University of Maryland Center for Environmental Science at the Chesapeake Bay Program Office

Chesapeake Bay Executive Order's Water Quality Outcome

- CBP Partnership needs to develop a combined indicator to measure progress towards the water quality outcome
- It could supplement or replace the individual dissolved oxygen, water clarity and chlorophyll *a* indicators currently reported by CBP

L. Hernandez, WQGIT, 2012
https://www.chesapeakebay.net/files/documents/draft_cb_wq_indicator_wqgit_2012.11.05_final.pdf

Before the WQ Stds Indicator…

HEALTH 38%

RESTORATION 61%

Bay Barometer

A Health and Restoration Assessment of the Chesapeake Bay and Watershed in 2008

CBP/TRS 293-09 EPA-903-R-09-001 March 2009

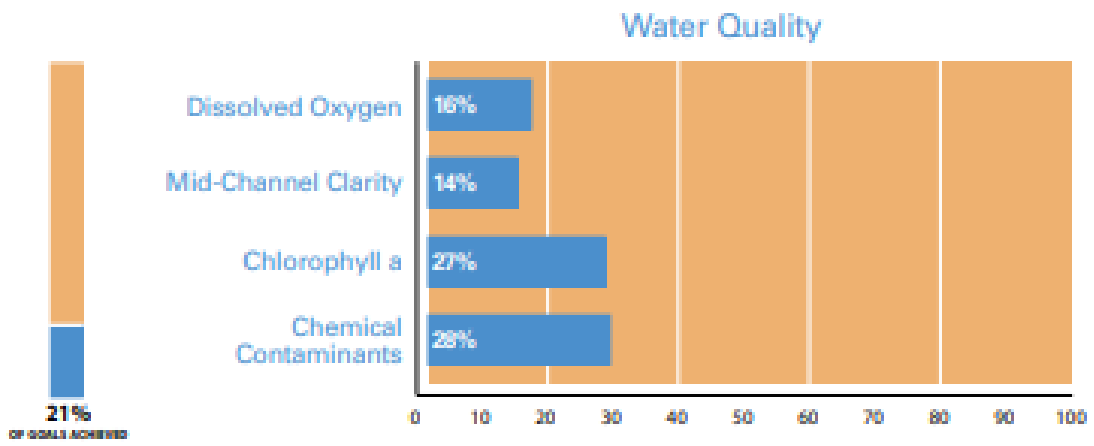
Chesapeake Bay Program
A Watershed Partnership

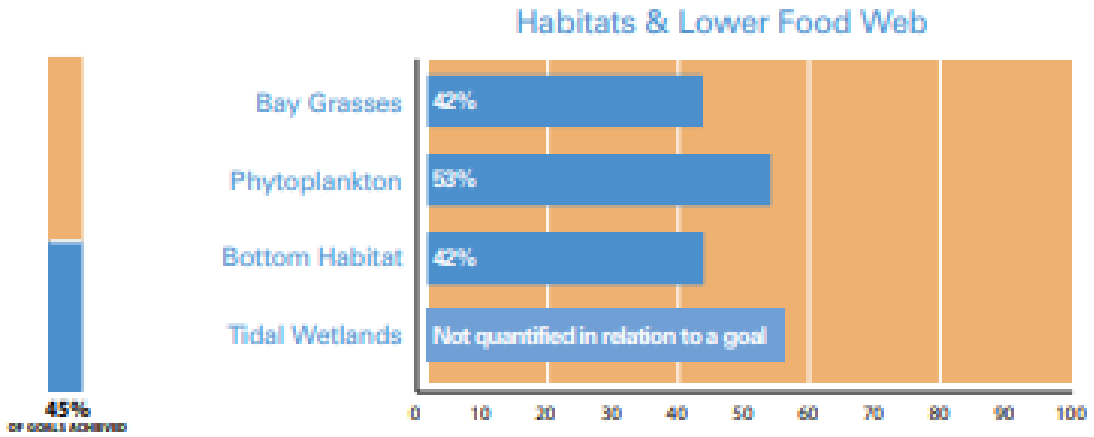
www.chesapeakebay.net

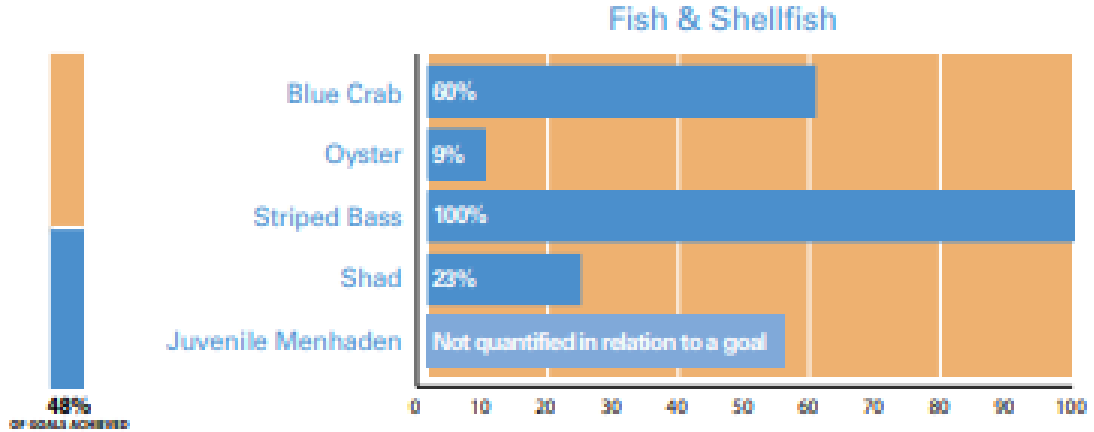
Historically (2008, 09, 10…) there were only separate reportings with progress on D.O., water clarity, chla

WQ score = (#DO + #midchannel clarity + #chla + #toxics)/4

Health was not based on WQ stds attainment







Decisions…

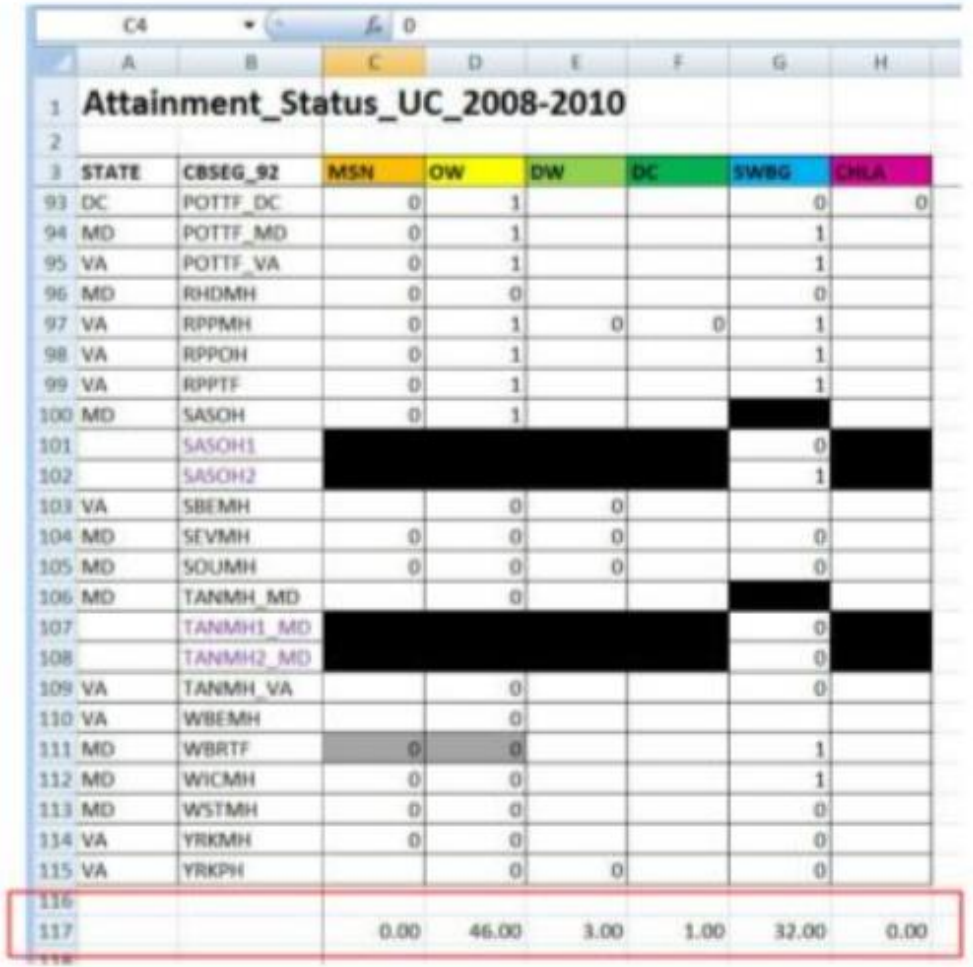
1. How do we address the fact that the CBP Partnership has not fully developed, reached agreement on, published nor adopted into the tidal water jurisdictions' water quality standards regulations a full set of criteria assessment procedures for all the applicable dissolved oxygen criteria?

2. Do we take an area-based (or volume-based) approach vs. a count approach as the basis to reporting the water quality indicator?

L. Hernandez, WQGIT, 2012
https://www.chesapeakebay.net/files/documents/draft_cb_wq_indicator_wqgit_2012.11.05_final.pdf

Our Bay Modeling community was already doing it for nearly a decade by using “stoplight plots” to communicate to the CBP community test results of different levels of nutrient reduction scenarios to see what it takes to achieve bay water quality criteria

The original **stoplight plot** – how to turn 1’s(pass) and 0’s (fails) into an indicator



Attainment_Status_UC_2008-2010

	STATE	CBSEG_92	MSN	OW	DW	DC	SWBG	CHLA
93	DC	POTTF_DC	0	1			0	0
94	MD	POTTF_MD	0	1			1	
95	VA	POTTF_VA	0	1			1	
96	MD	RHDMH	0	0			0	
97	VA	RPPMH	0	1	0	0	1	
98	VA	RPPOH	0	1			1	
99	VA	RPPTF	0	1			1	
100	MD	SASOH	0	1				
101		SASOH1					0	
102		SASOH2					1	
103	VA	SBEMH		0	0			
104	MD	SEVMH	0	0	0		0	
105	MD	SOUMH	0	0	0		0	
106	MD	TANMH_MD		0				
107		TANMH1_MD					0	
108		TANMH2_MD					0	
109	VA	TANMH_VA		0			0	
110	VA	WBEMH		0				
111	MD	WBRTF	0	0			1	
112	MD	WICMH	0	0			1	
113	MD	WSTMH	0	0			0	
114	VA	YRKMH	0	0			0	
115	VA	YRKPH		0	0		0	
116								
117			0.00	46.00	3.00	1.00	32.00	0.00

Stoplight demystified: Published reference to the stoplight plot concept and its application supporting the setting of the Bay TMDL

Appendix M. Chesapeake Bay TMDL. Dec 29, 2010.

Appendix M. Chesapeake Bay Water Quality/Sediment Transport Model Management Scenario Criteria Attainment Assessment Results and 2008 303(d) List Assessment Results

This appendix presents the Chesapeake Bay water quality criteria attainment assessment results of various Chesapeake Bay Water Quality and Sediment Transport Model (Bay Water Quality Model) management scenarios in the stoplight format used by the U.S. Environmental Protection Agency and its partner jurisdictions in developing the Chesapeake Bay TMDL.

The stoplight spreadsheets summarize the percentage of space and time exceeding the four Bay jurisdictions' water quality criteria for each of the 92 Chesapeake Bay segments. The spreadsheets are produced from an assessment of Bay Water Quality Model outputs and Bay water quality monitoring data as described in Sections 6.2.4 and 6.4.4. The spreadsheets were used to evaluate whether a management scenario met all applicable criteria across all designated use-segments. Green highlighted percentages represent attainment of the applicable water quality standards. Red highlighted percentages represent a violation or an exceedance of applicable water quality standards

Appendix O. 2010 TMDL documentation.
Stoplight Plot example: Critical period evaluations of chlorophyll criteria attainment in the James River using the “stop light plot” communication tool.

Cbseg	190 Loading Scenario 190TN, 12.7TP, 6030TSS '91-'93 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '92-'94 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '93-'95 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '94-'96 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '95-'97 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '96-'98 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '97-'99 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '98-'00 CL Spring Seasonal
JMSTFL	0%	0%	2%	2%	2%	0%	0%	0%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	4%	4%	4%	0%	5%
JMSMH	3%	1%	0%	0%	0%	0%	0%	0%
JMSPH	0%	0%	0%	0%	0%	0%	0%	0%
Cbseg	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**
JMSTFL	0%	0%	0%	0%	5%	15%	15%	8%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	0%	0%	0%	0%	0%
JMSMH	0%	0%	0%	0%	0%	0%	15%	14%
JMSPH	0%	0%	0%	0%	0%	0%	11%	11%

For this scenario, the James River Basin allocation is 26.6 mpy TN and 2.7 mpy TP.
Failure to attain WQS is shown in red text as percent nonattainment.

Notice: “1%” out of attainment is green, considered good enough for planning purposes.

That translates to an 11% buffer instead of default 10%.

(Our indicator does not do that.)

Indicator: Segment-specific and then Bay-wide roll up of percent attainment outputs

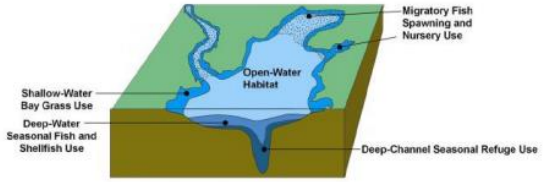
Calculating Segment Level Percent Attainment: (SA in attainment ÷ Total SA) * 100

CB4MH

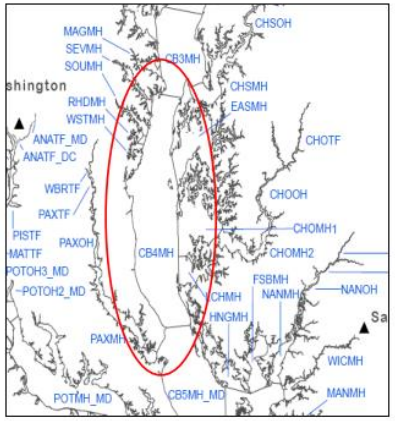
Segment surface area (SA) = 908,847,238.56 km²

Applicable Designated Uses (DU):

- ✓ Migratory Fish Spawning and Nursery
- ✓ Open Water
- ✓ Deep Water
- ✓ Deep Channel
- ✓ Shallow Water Bay Grasses



DU	Total SA (km²)	Attainment Status	SA in Attainment (km²)
MSN	908,847,238.56	No	0.00
OW	908,847,238.56	No	0.00
DW	908,847,238.56	No	0.00
DC	908,847,238.56	No	0.00
SW	908,847,238.56	No	0.00
Total	**4,544,236,193.00**	---	**0.00**
Percent Attainment for CB4MH			**0.00 %**



Calculating Baywide Percent Attainment: (Σ SA in attainment ÷ Σ Total SA) * 100

All Segments Combined

Σ surface area (SA) of each segment's applicable designated use and criteria = 40,740,997,335.07 km²

Designated Uses (DU) and Criteria:

- ✓ Migratory Fish Spawning and Nursery
- ✓ Open Water
- ✓ Deep Water
- ✓ Deep Channel
- ✓ Shallow Water Bay Grasses
- ✓ Chlorophyll-a

DU	Σ SA of DU Segments & Criteria (km²)	Σ SA of DU Segments & Criteria in Attainment (km²)
MSN	5,565,101,169.36	0.00
OW	11,660,174,083.95	0.00
Chl-a	620,327,627.29	0.00
DW	6,932,558,324.18	0.00
DC	4,404,190,644.45	83,660,695.00
SW	11,558,645,485.84	2,616,220,341.04
Total	**40,740,997,335.07**	**2,699,881,036.04**
BAYWIDE Percent Attainment		**7%**

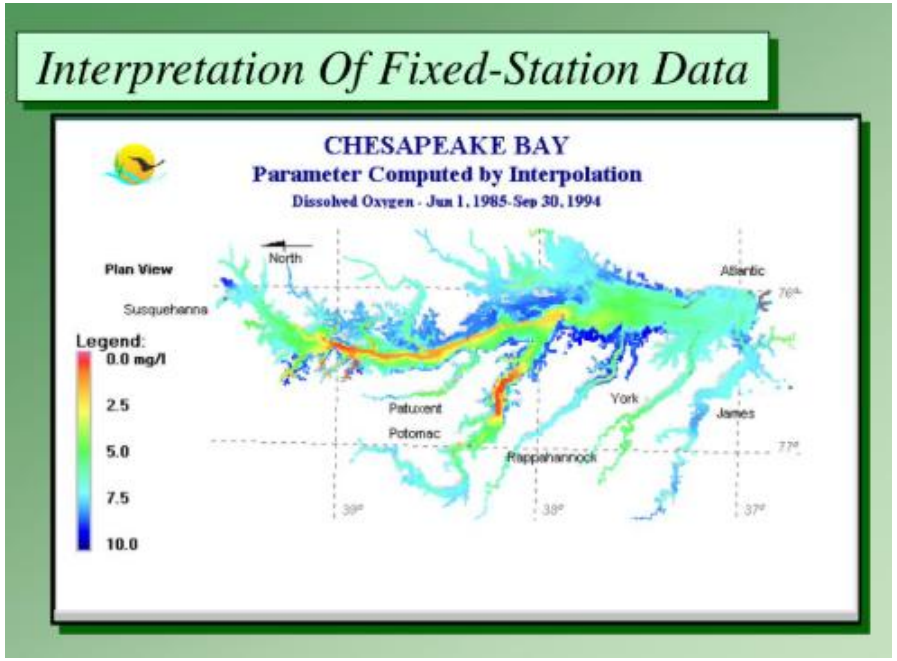
The Indicator Design

- The indicator is an accounting translator to describe bay conditions; turning a lot of 1's and 0's in the stoplight plots into one number used to communicate an estimate of status for Bay water quality.

- The framework was adopted from the work underpinning the Chesapeake Bay Program community's established approach for setting allocation targets in the TMDL; i.e., what nutrient and sediment loads are need to meet DO, water clarity and chla criteria for all the designated uses in all 92 segments.

The Indicator Design

- The stoplight plots were the communication tool of choice familiar to the community to express attainment and nonattainment of criteria in the segments and designated uses, derived from output of the 3D interpolator



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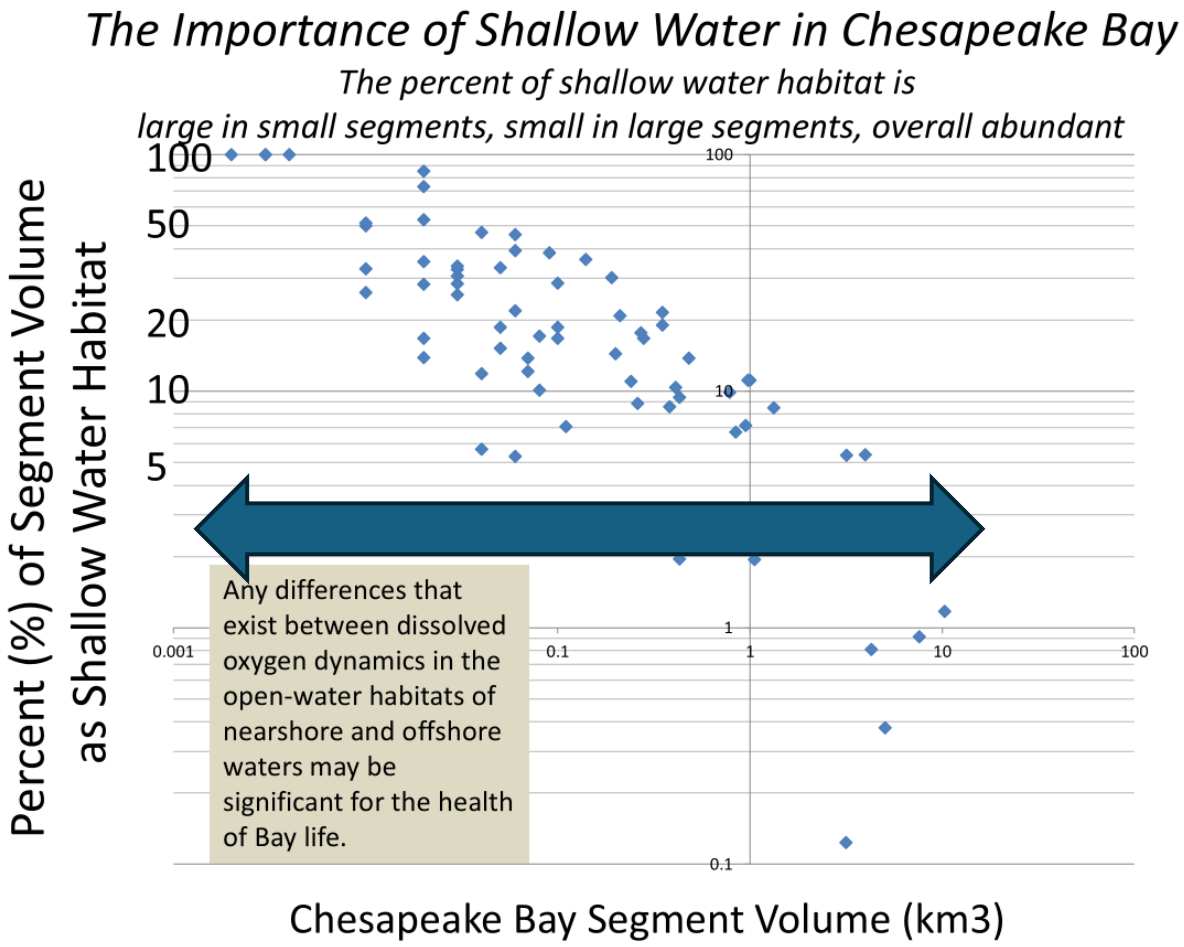
For this scenario, the James River Basin allocation is 26.6 mpy TN and 2.7 mpy TP.
Failure to attain WQS is shown in red text as percent nonattainment.

The Indicator had to create rules to account for missing criteria assessments (mainly D.O.)

- The model is “all-knowing” because water quality is available in hourly time steps in all cells of the 50,000+ cell grid.

- The estimated attainment indicator structure had to lean on the best available science for water quality relationship rules if there was no explicit measure available or approved protocol for its assessment,
  - e.g., if the open water 30-day mean criterion is met, we use an umbrella approach to say that the 7-day mean is also being met (USEPA 2004 gives support to this concept as did USEPA 2017).
  - Note: *the rules being used have always been intended to be temporary*. As our community approves and adopts methods for previously unassessed criteria, those methods are meant to replace the missing-data rules being used now to create outputs from the indicator.
    - Eventually (for 2030 and beyond now), the indicator will equal the full assessment by replacing temporary rules with approved assessment outputs. That has always been the vision.

Indicator accounting –
Understanding how much of the bay is attaining was more important than numbers of segments to the community because segments differ in size over 4 orders of magnitude.



Volumes from
0.001 to >10 cubic kms

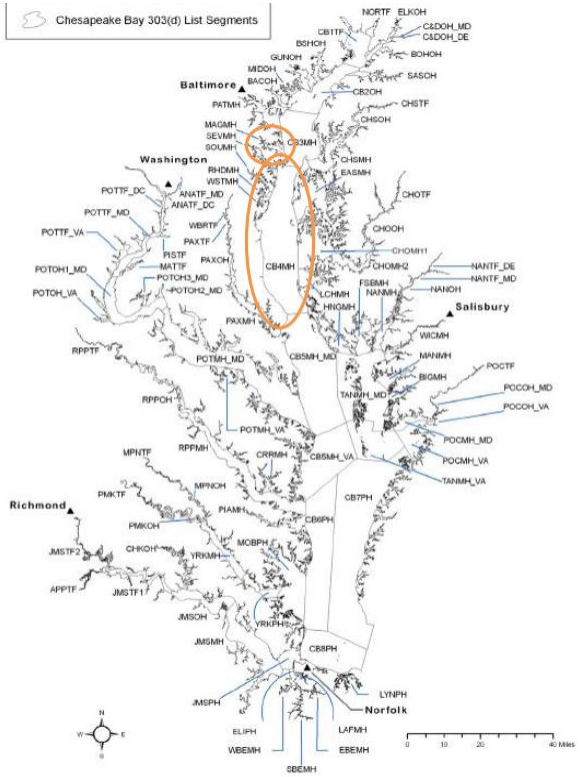
Attainment Accounting Options

1. Count-approach
   - Weighs segments equally
   - Does not provide an honest measure of how much of the Bay tidal waters are achieving water quality standards

COUNT APPROACH			
289 Designated Use Segments (making up the 92 CBP Segmentation Scheme)			
Designated Use	Total# DU Segments	# DU Segments IN ATTAINMENT	% in Attainment
Migratory Fish Spawning and Nursery	72	0	0
Open Water - DO	92	0	0
Open Water CHLA (spring + summer)	7	0	0
Deep Water - DO	10	1	10
Deep Channel - DO	18	0	0
Shallow-Water Bay Grasses - SAV/Water Clarity	90	27	30
Baywide Percentage of WQS Attainment	**289**	**28**	**10**

Attainment Accounting Options

2. Weighted-approach
   - Considers segment size differences (i.e., Magothy River vs. Middle Central Chesapeake Bay)
   - Area- vs. volume-based?



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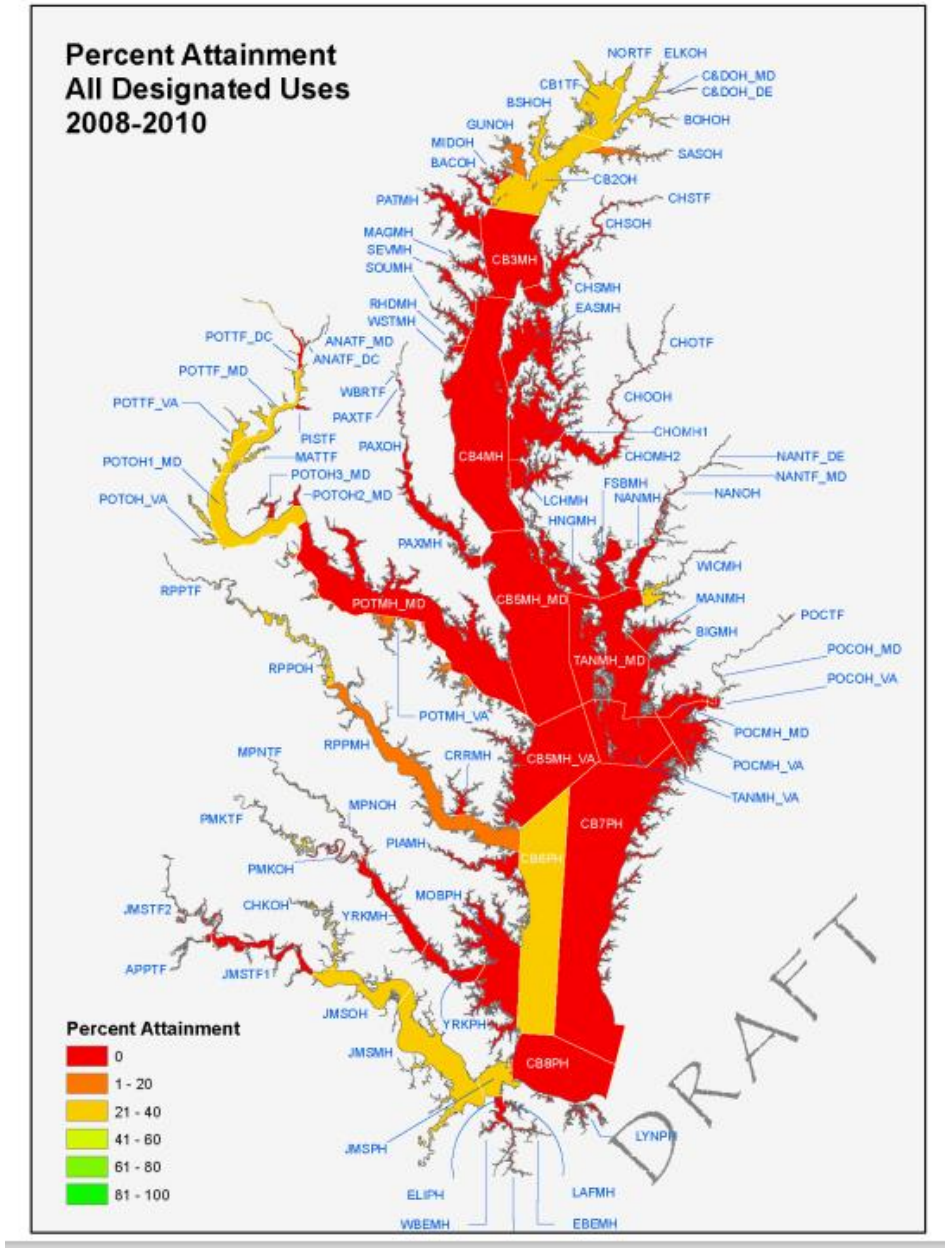
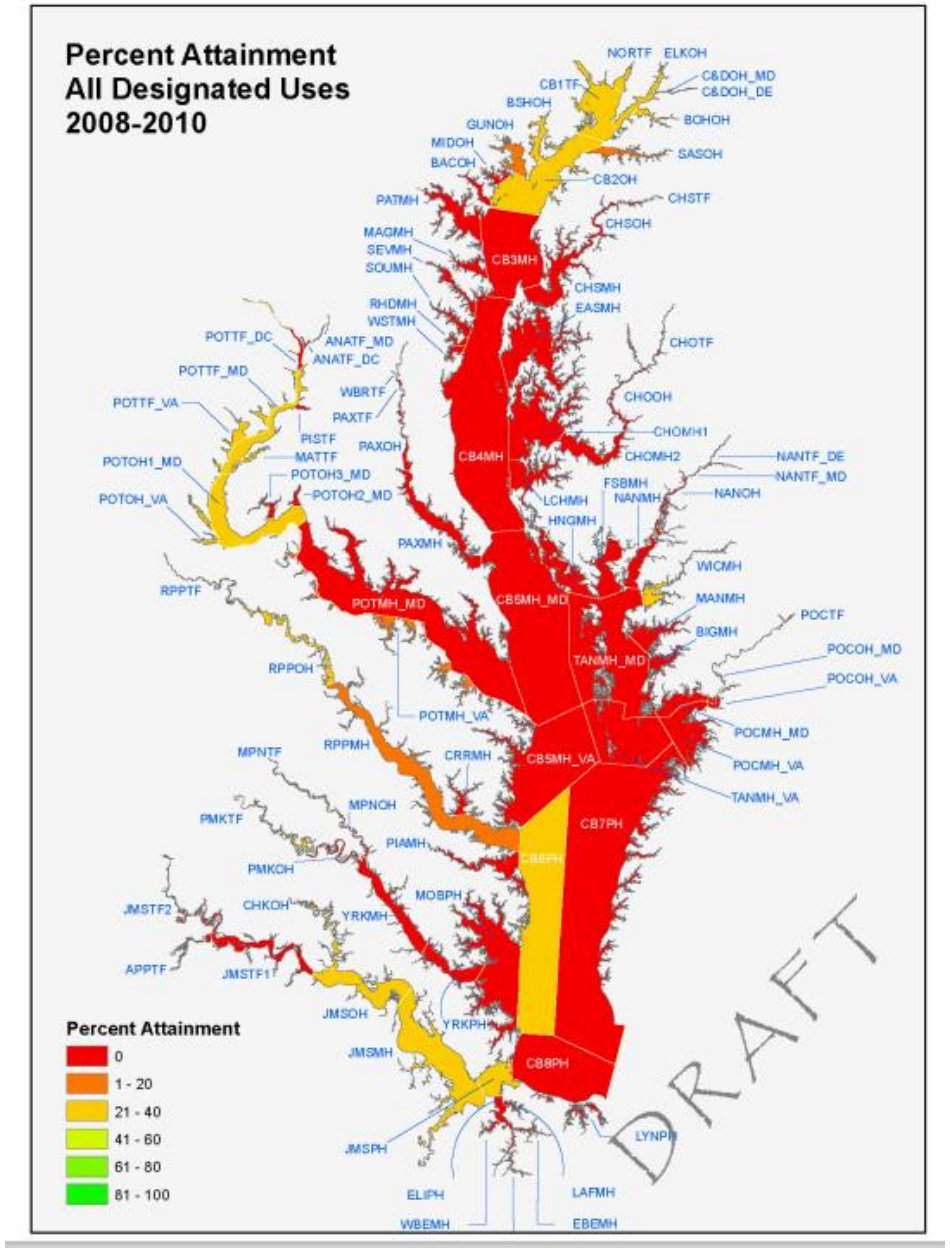


Indicator Recommendations

- Based on an accounting of attainment of all Bay water quality criteria applicable to the 289 number of designated-use segments
- Reported annually as a baywide percentage based on a weighted-approach
- Where a full suite of dissolved oxygen assessment procedures have not been agreed to by the Partnership, those respective designated use segments where these dissolved oxygen criteria apply will be considered to be in non-attainment
- The indicator will be graphically illustrated

L. Hernandez, WQGIT, 2012
https://www.chesapeakebay.net/files/documents/draft_cb_wq_indicator_wqgit_2012.11.05_final.pdf



Indicator Recommendations

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Note: In practice, we found this unsatisfactory and wanted to apply the best available science indicating we could make some conditional rules based on tech document published relationships about criteria attainment at different temporal scales

L. Hernandez, WQGIT, 2012
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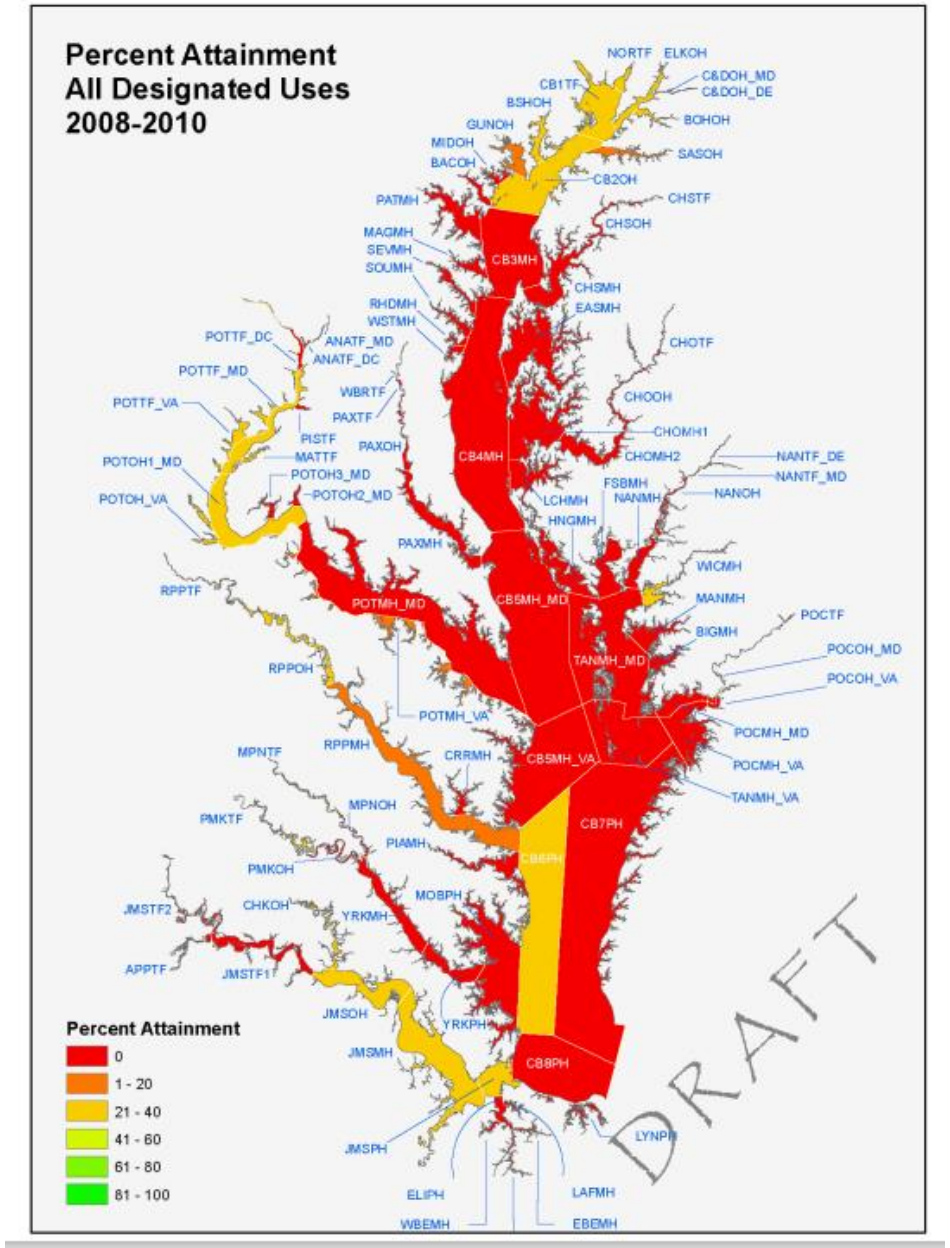

Recommended Next Steps

- Work up a refined set of visual illustrations of the indicator and work to address any comments/ concerns raised by WQGIT members.

- Work through the CAP Workgroup and: 1) bring forward a recommend suite of approaches to illustrating the results of this water quality indicator, 2) seek final WQGIT review at the January 14, 2013 WQGIT conference call, and 3) ask for approval to bring the new indicator forward to the Management Board for final Partnership adoption.

Commitment by Partnership

- By 2015, EPA and its seven jurisdictional partners are committed to working collaboratively on developing, subjecting to independent scientific peer review, agreeing to, and then publishing criteria assessment procedures for the remaining dissolved oxygen criteria currently without Partnership approved assessment procedures.

L. Hernandez, WQGIT, 2012

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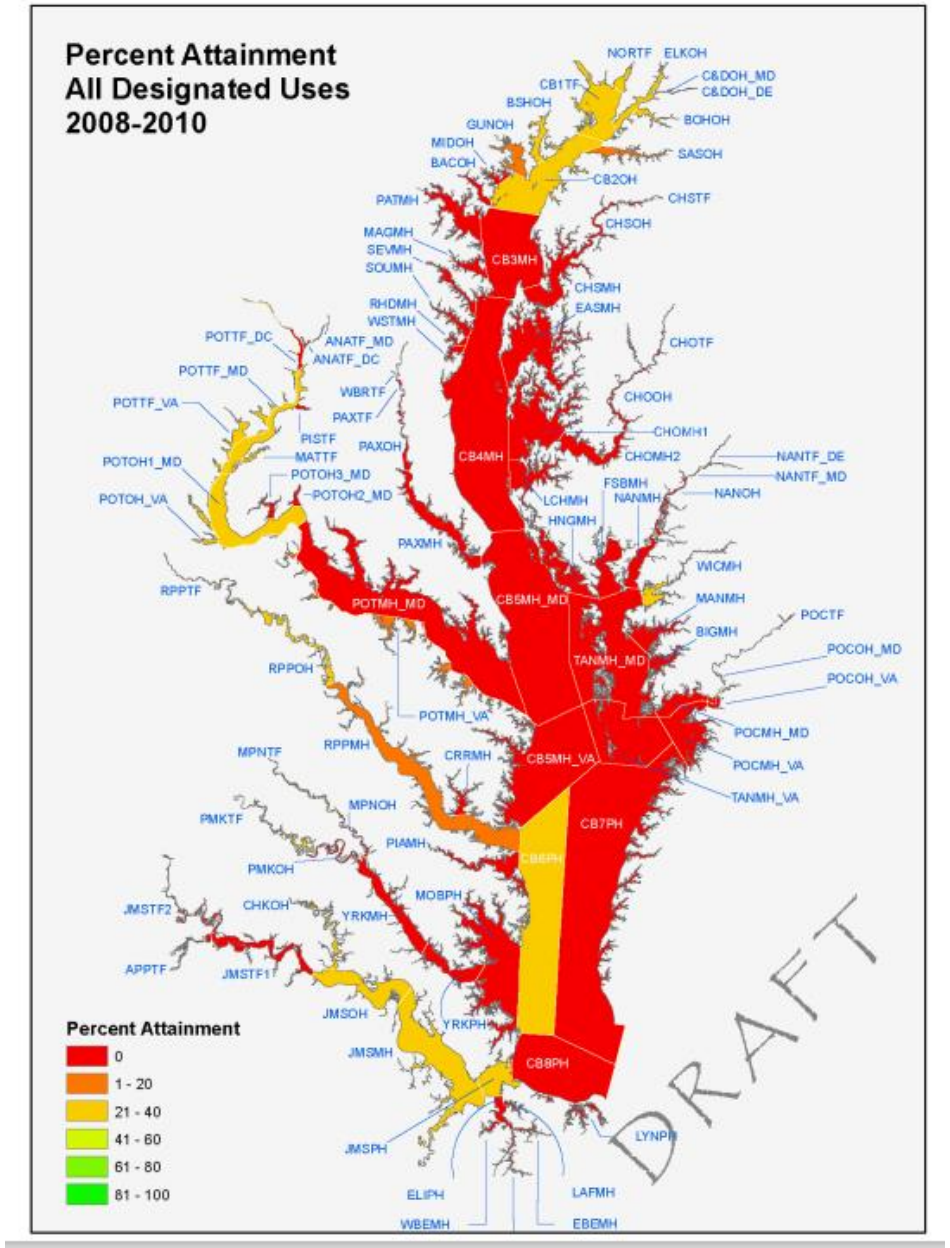

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That is USEPA (2017)

L. Hernandez, WQGIT, 2012

https://www.chesapeakebay.net/files/documents/draft_cb_wq_indicator_wqgit_2012.11.05_final.pdf

2015: CAPWG, STAC and EPA Review underway

Criteria Assessment Protocol WG: Review copy of the 2015 Ambient WQ Criteria Technical Addendum

Peter Tango
USGS @ CBPO
August 12, 2015

Summary

- Chapter 1: Introduction
- Chapters 3-7: Old news to everyone here but updated language for your review regarding
  - Missing segment volumes resolved
  - Multi-metric indicator demystified
  - Underwater grasses water quality standards-based acreage goal
  - Interim rules for the BIBI in Chesapeake Bay
  - Protocol for nontraditional partners to support dissolved oxygen assessments.
- And then there is **Chapter 2: Short duration D.O. criteria assessment.**
  - **This is where we need your focused attention.**

Review time! Pushing to the finish line for publishing in late 2015.

Review Process Underway

- **CBP-STAC, EPA and CAP WG have received the updated Technical Addendum. (July 31, 2015)**
  - CAP WG should anticipate comments from CBP-STAC in autumn. Waiting to hear officially what their review schedule will be.
  - EPA acknowledged receipt of the document. A team that has been working with the CBPO regarding the new document will be reviewing it this summer.
  - CAP WG: Comments requested by September 30, 2015.
- **October CAP WG meeting we will review comments.**
- **Goal of Nov 2015 having a final version ready for online publication.**

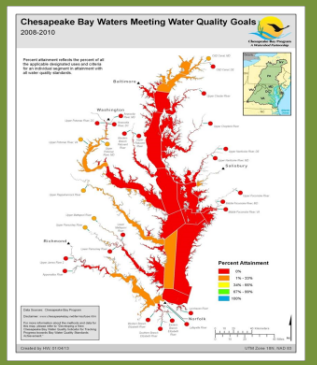
Multimetric indicator = “Old news” by 2015

2016 STAC Review – including the indicator.
A sample of one of several presentations over 2 years.

Content Overview of the next Chesapeake Bay Ambient Water Quality Criteria Technical Addendum

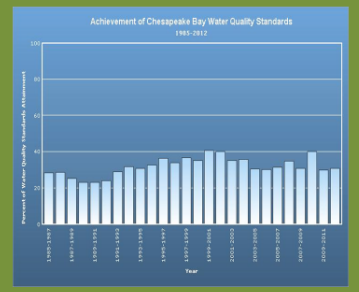
Peter Tango
USGS@CBPO
February 12, 2016
STAC Criteria Addendum Review Panel

Chapter 4. Multimetric Water Quality Standards Indicator for Supporting Progress Tracking in Bay Restoration



Issue:

- Provide a composite status measure of water quality standards attainment results for DO, water clarity/SAV and chlorophyll a.
- Communicate progress to the public, managers and decision-makers.



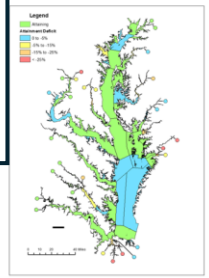
By 2016 CBP was using the yet-to-be-fully published indicator for tracking and reporting status and change in estimated WQ Stds Attainment

Estimated Achievement of Water Quality Standards in tidal waters of Chesapeake Bay

Scott Phillips, Peter Tango and Laura Free
WQGIT meeting preview
August 2016

WQGIT 2016

Dissolved Oxygen – Attainment Deficit and its trends.
Summer 30-day means (Open water, deep water) and instantaneous minimum (Deep Channel).



2012-14
Open water
Summer 30-day mean
Attainment status

	1985-2014 ATTAINMENT DEFICIT				1985-2014 TRENDS IN THE DEFICIT	
DU (SEGMENTS)	At/Near Attainment	Small Deficit	Medium Deficit	High Deficit	Improving (↑)	Degrading (↓)
OW (92)	36	23	21	12	4	12
DW (18)	4	2	10	2	1	1
DC (10)	1	0	3	6	0	4

By 2016 CBP was using the yet-to-be-fully published indicator for tracking and reporting status and change in estimated WQ Stds Attainment

We were already reporting on "Attainment deficit" and patterns and trends in attainment deficits to extend use of available data

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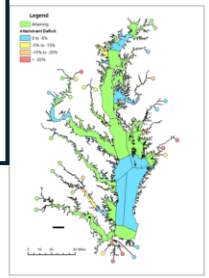

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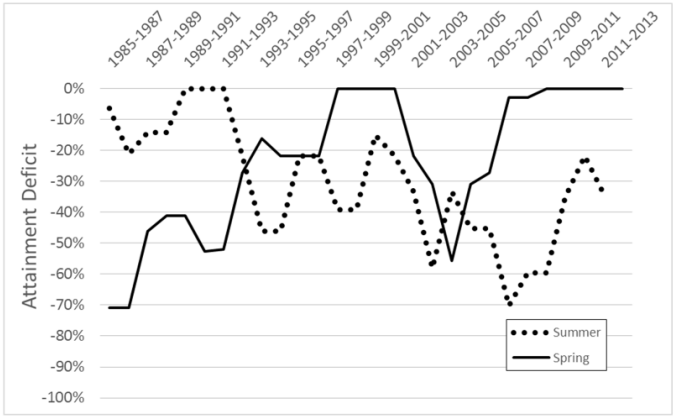
DU (SEGMENTS)	At/Near Attainment	Small Deficit	Medium Deficit	High Deficit	Improving (↑)	Degrading (↓)
OW (92)	36	23	21	12	4	12
DW (18)	4	2	10	2	1	1
DC (10)	1	0	3	6	0	4

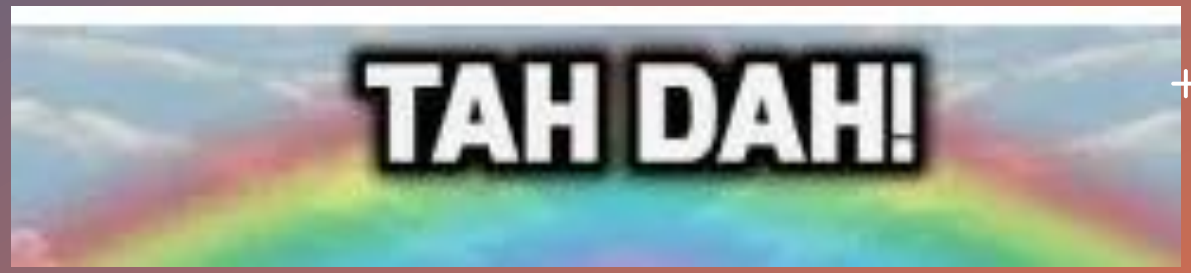
Example of long term patterns of change in the attainment deficit for the James River Polyhaline chlorophyll *a* standards assessment.

- Improving conditions in spring have led to steady attainment of the Spring standard since the late 2000s.
- Degrading conditions occurred in summer season since the early 1990s, however, more recent years suggest a rebound from its worst condition.



And then, 2017, the fully vetted (CAP WG, WQGIT, STAC and EPA) and approved “Blue Bible” is published in support of the “Midpoint Assessment”

Mid-point assessment = (CBP evaluation between the 2010 TMDL to 2025 target dates of the 2014 Watershed Agreement)

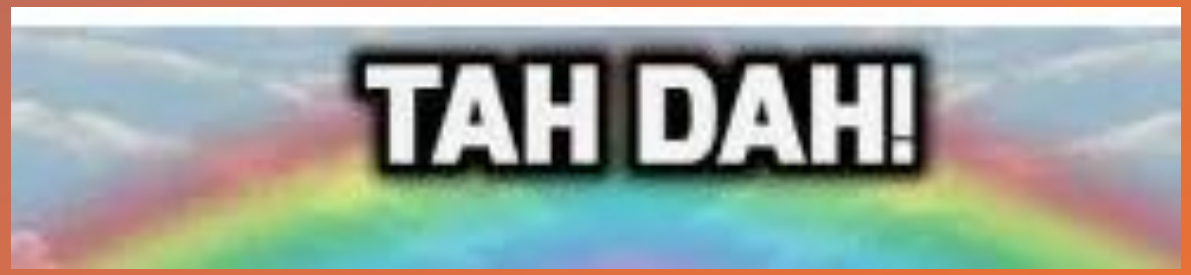


2017

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

2017 Technical Addendum

November 2017



2018 continued reporting to the CBP community and rolled out the first journal publications using the indicator to report on bay condition patterns, status, and trends, led by Qian Zhang supported by the CBPO monitoring team

Assessing Incremental Progress using Chesapeake Bay Water Quality Standards Non-Attainment Results

Chesapeake Bay Senior Managers Meeting 7/5/2018

Peter Tango USGS@CBPO

Representing the rest of the team: Qian Zhang (UMCES), Rebecca Murphy (UMCES), Mindy Forsyth (UMCES), Richard Tian (UMCES), Jeni Kiesman (USGS) and Emily Trentacoste (USEPA)

frontiers in Marine Science

ORIGINAL RESEARCH
published: 21 November 2018
doi: 10.3389/fmars.2018.00422

Chesapeake Bay Dissolved Oxygen Criterion Attainment Deficit: Three Decades of Temporal and Spatial Patterns

Qian Zhang[1], Peter J. Tango[2], Rebecca R. Murphy[1], Melinda K. Forsyth[3], Richard Tian[1], Jennifer Keisman[4] and Emily M. Trentacoste[5]*

Science of the Total Environment 637–638 (2018) 1617–1625

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

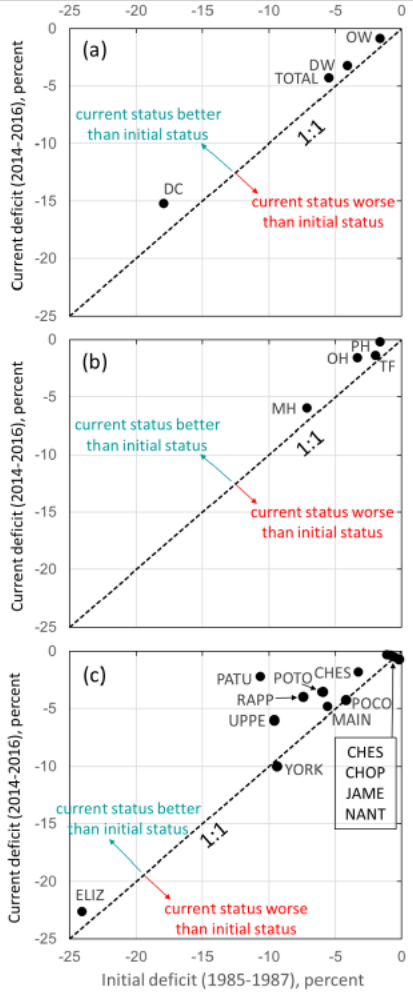
ELSEVIER

Short Communication

Chesapeake Bay's water quality condition has been recovering: Insights from a multimetric indicator assessment of thirty years of tidal monitoring data

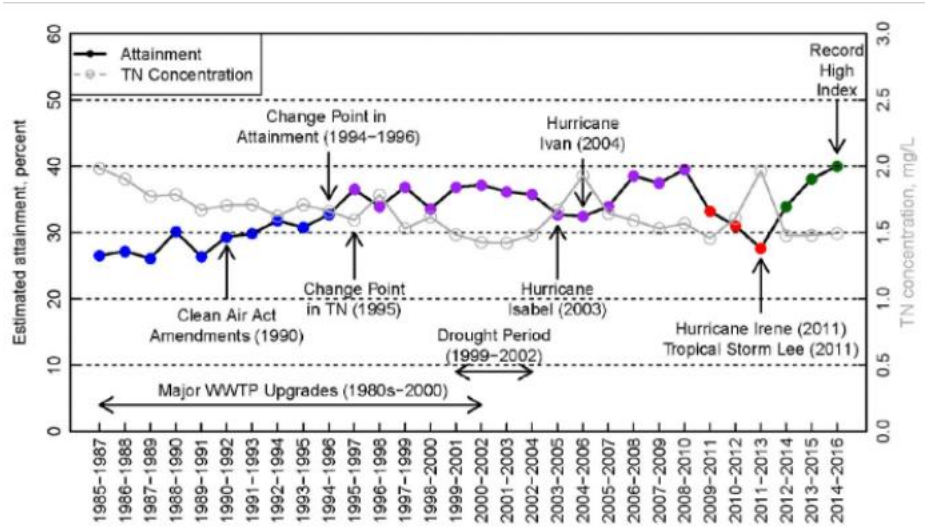
Qian Zhang [a,*], Rebecca R. Murphy [a], Richard Tian [a], Melinda K. Forsyth [b], Emily M. Trentacoste [c], Jennifer Keisman [d], Peter J. Tango [e]

The indicator and its extended products have been used for almost 15 years in the CBP to explain progress and relate stressors to patterns of change over time



Zhang et al 2018

The majority of system level results shows improved conditions compared to 30 years ago.



Zhang et al. 2018
Indicator results show relationship with patterns of TN loads

The >2 decade journey from USEPA 2003 to 2009 EO to 2012 WQGIT presentation to 2017 Tech Report publication to 2018-25 journal publications and ongoing use as CBP annual indicator (1985-2025)

2012

Chesapeake Bay Executive Order's Water Quality Outcome

- CBP Partnership needs to develop a combined indicator to measure progress towards the water quality outcome
- It could supplement or replace the individual dissolved oxygen, water clarity and chlorophyll *a* indicators currently reported by CBP

2017

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

2017 Technical Addendum

November 2017

Home > Environmental Monitoring and Assessment > Article

Development of a multimetric water quality Indicator for tracking progress towards the achievement of Chesapeake Bay water quality standards

Published: 06 January 2020

Volume 192, article number 94, (2020) Cite this article

Save article

2020

Environmental Monitoring and Assessment

Aims and scope →

Submit manuscript →

Ana L. Hernandez Cordero, Peter J. Tango & Richard A. Batiuk

Water Quality Standards Attainment (1985-2023)

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

2025 report

Method details are updated annually on Chesapeake Progress

Chesapeake Bay Program | Indicator Analysis and Methods Document

Water Quality Standards Attainment

Updated May 2025

Indicator Title: Water Quality Standards Attainment Indicator

Relevant Outcome(s): Water Quality Standards Attainment and Monitoring

Relevant Goal(s): Water Quality

Location within Framework (i.e., Influencing Factor, Output or Performance): Performance

26 pages of details regarding the method, its analysis and history. The information has been publicly available since Chesapeake Progress was established by the CBP about a decade ago.

Published Bay condition assessment support derived from information created using the WQStds Indicator: Estimated Attainment, Attainment Deficit, Attainment Buffers.

Zhang, Q., R. Tian, Z. Wei, R.R. Murphy, K.S. Gootman, and P.J. Tango. (2025). A novel threshold-based indicator for assessing dissolved oxygen criteria attainment deficits, buffers, and trends in estuarine waters. *Env. Res.: Water. April 2025*

Zhang, Q., R.R. Murphy, R. Tian, and P.J. Tango. 2025. Geography, trajectories, and controls of coastal water quality: more rapid improvement in the shallow zone of the Chesapeake Bay. Environ. Sci. Technol. 59:553-564. https://doi.org/10.1021/acs.est.4c07368

Zhang, Q., R.R. Murphy, R. Tian, K.S. Gootman, and P.J. Tango. 2024. Dissolved oxygen criteria attainment in Chesapeake Bay: Where has it improved since 1985? Sci. Total Env. 957:177617 https://doi.org/10.1016/j.scitotenv.2024.177617

Hernandez, A., P. Tango, R. Batiuk. 2020. Development of the Multi-metric Water quality indicator. Environmental Management and Assessment. 192:94-110.

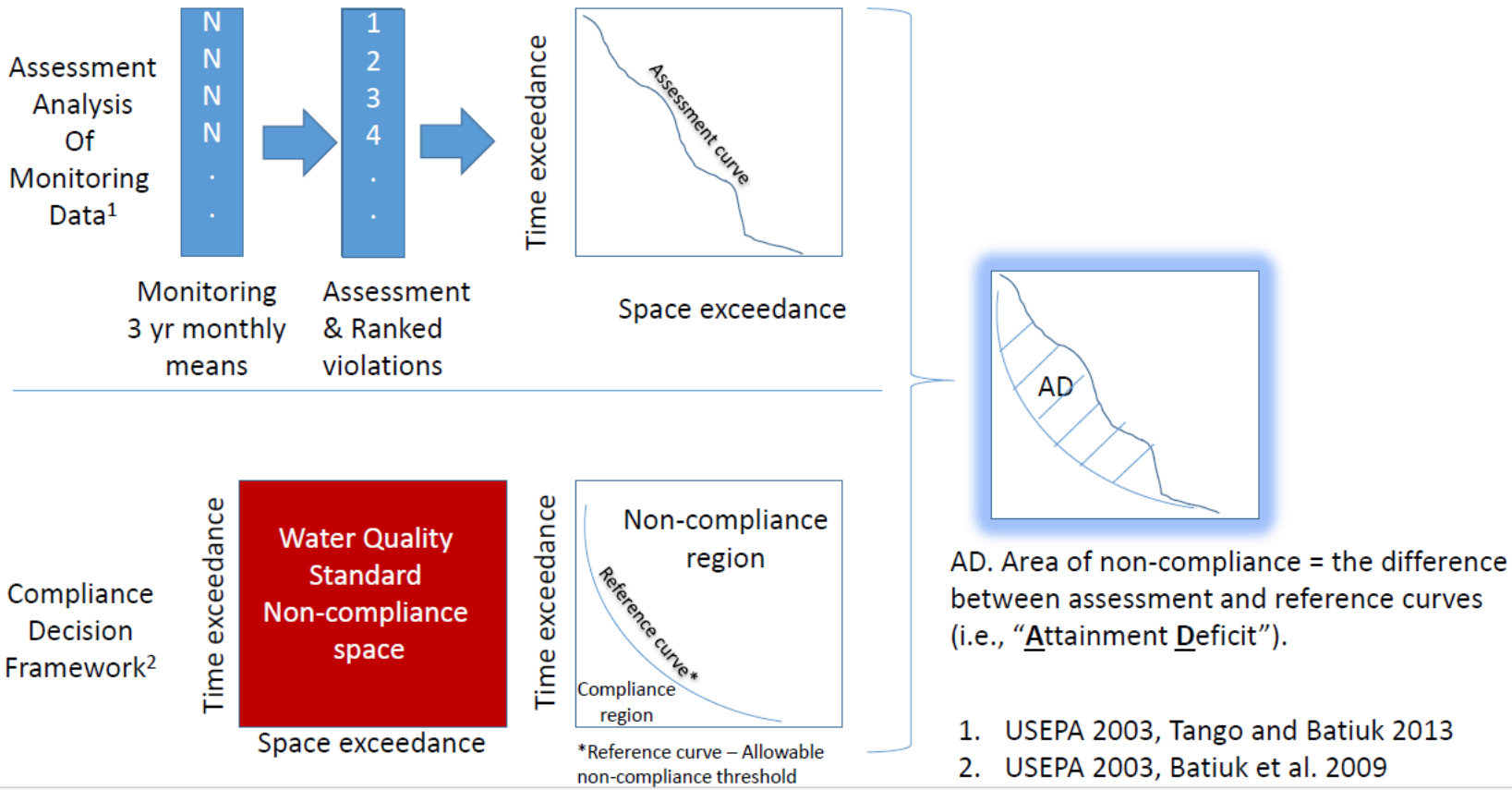
Zhang, Q., P. Tango, R.R. Murphy and others. 2018. Attainment Deficit: Three decades of Temporal and Spatial Patterns in Chesapeake Bay Dissolved Oxygen Criterion Nonattainment. Frontiers in Marine Science. 5:422. Published 21 November 2018. Doi: 10.3389/fmars.2018.00422.

Zhang, Q., R.R. Murphy, R. Tian, M. K. Forsyth, E. M. Trentacoste, J. Keisman, and P.J. Tango. 2018. Chesapeake Bay's water quality condition has been recovering: Insights from a multi-metric indicator assessment of thirty years of tidal monitoring data. Science of the Total Environment. 637-638 (2018) 1617-1625.

Extra slides

Visualizing Our Assessment of Criterion Attainment Deficit

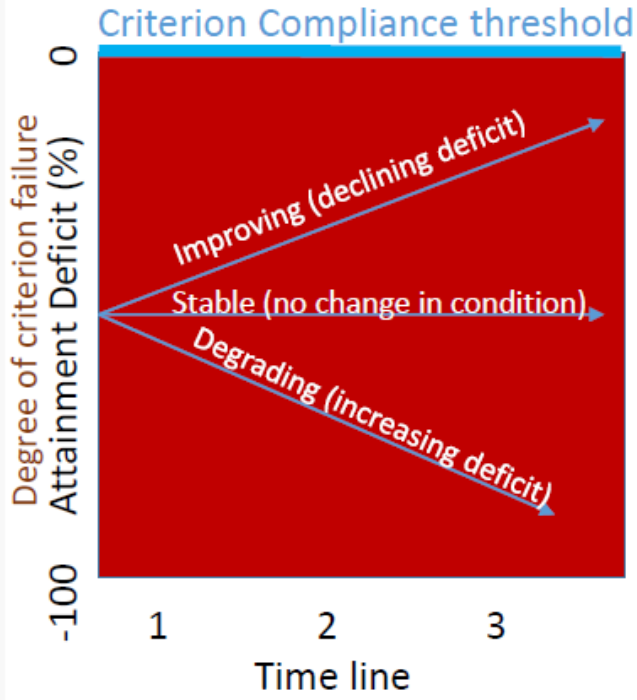
Dissolved oxygen 30 day mean example



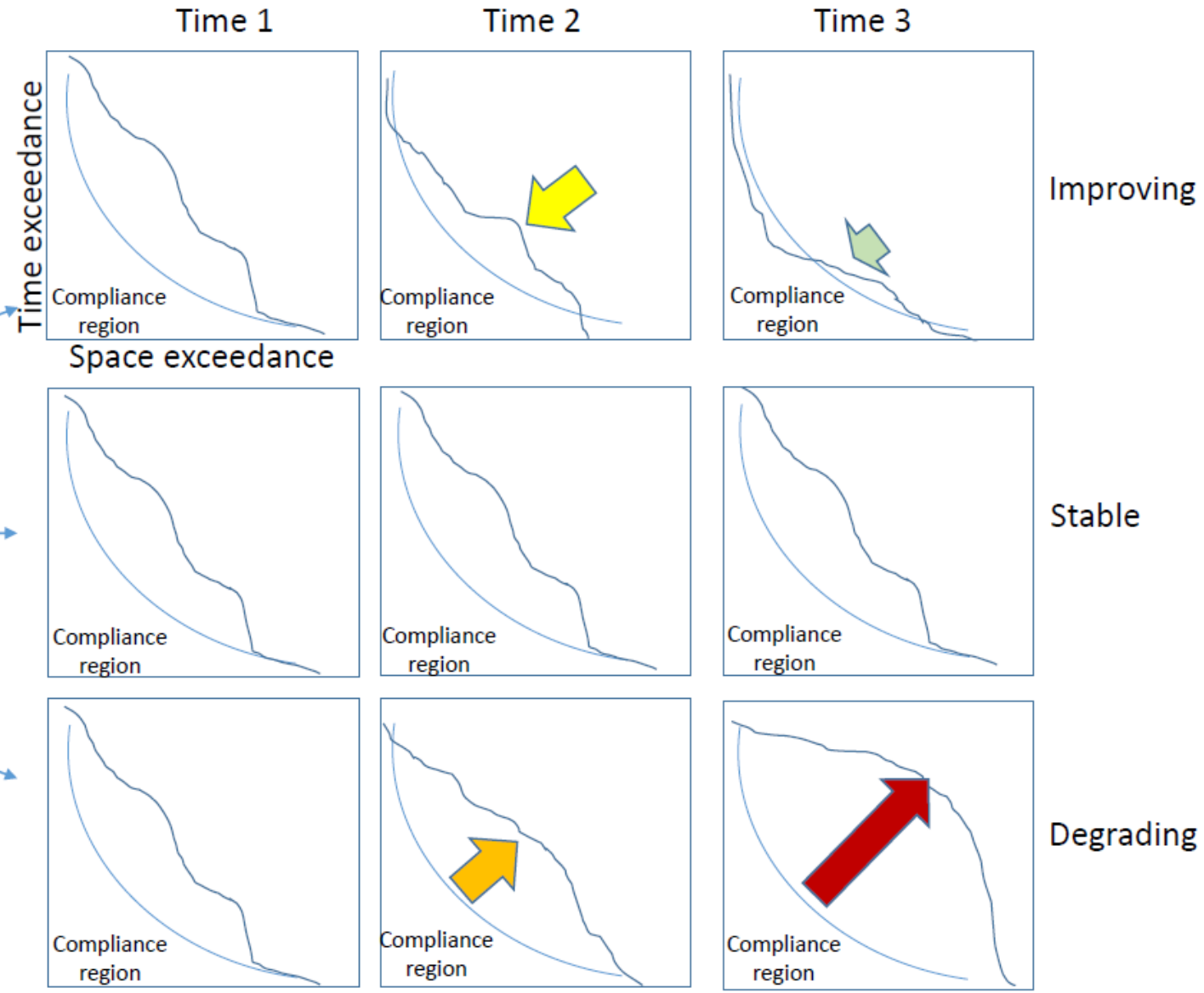
AD. Area of non-compliance = the difference between assessment and reference curves (i.e., "**A**ttainment **D**eficit").

1. USEPA 2003, Tango and Batiuk 2013
2. USEPA 2003, Batiuk et al. 2009

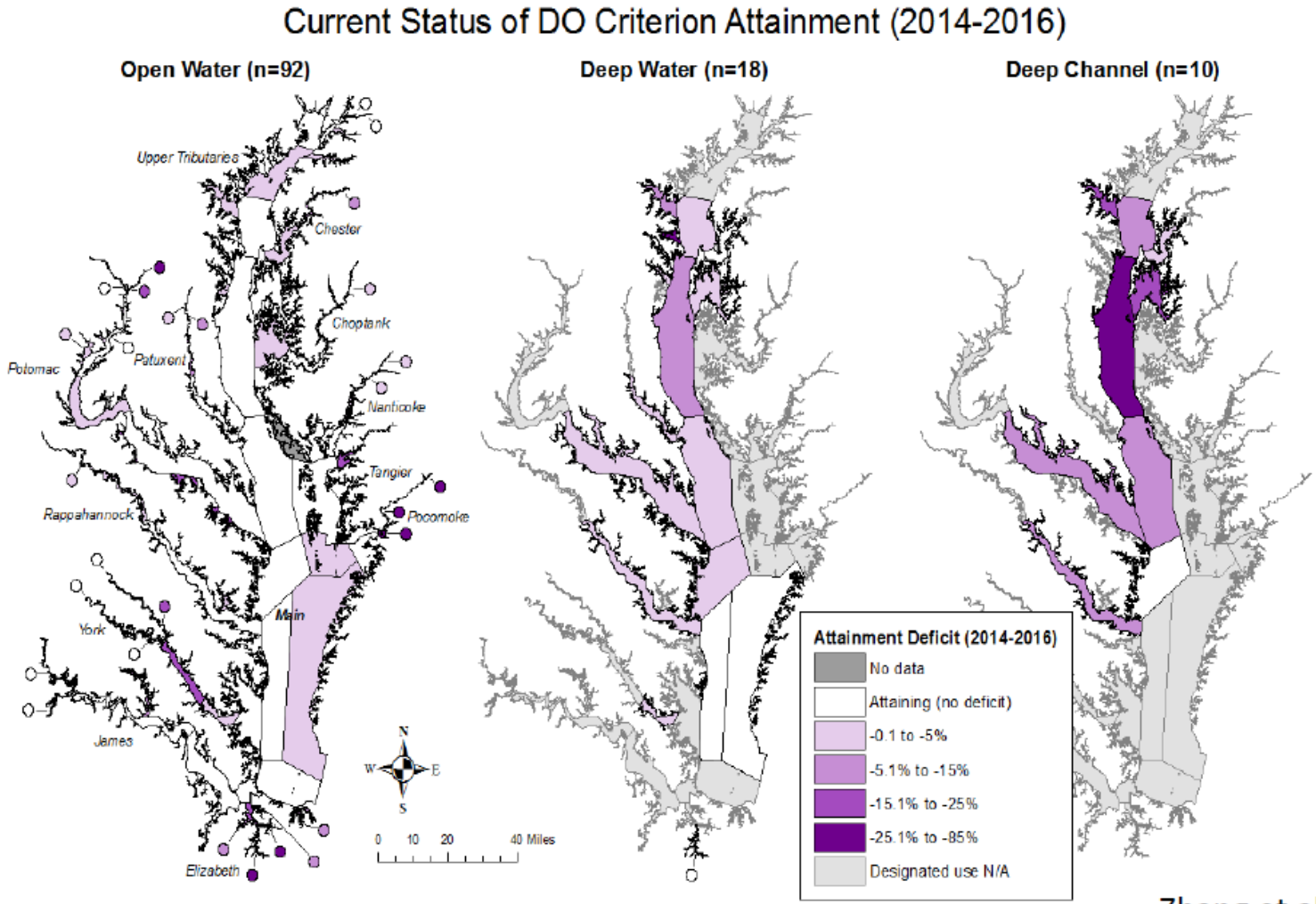
Attainment Deficit Trends in time. Incremental progress assessment when all you otherwise see is a result saying "Impaired". All the results below are in the "impaired" category, however, patterns of ecosystem response are informative if we quantify and track the deficit



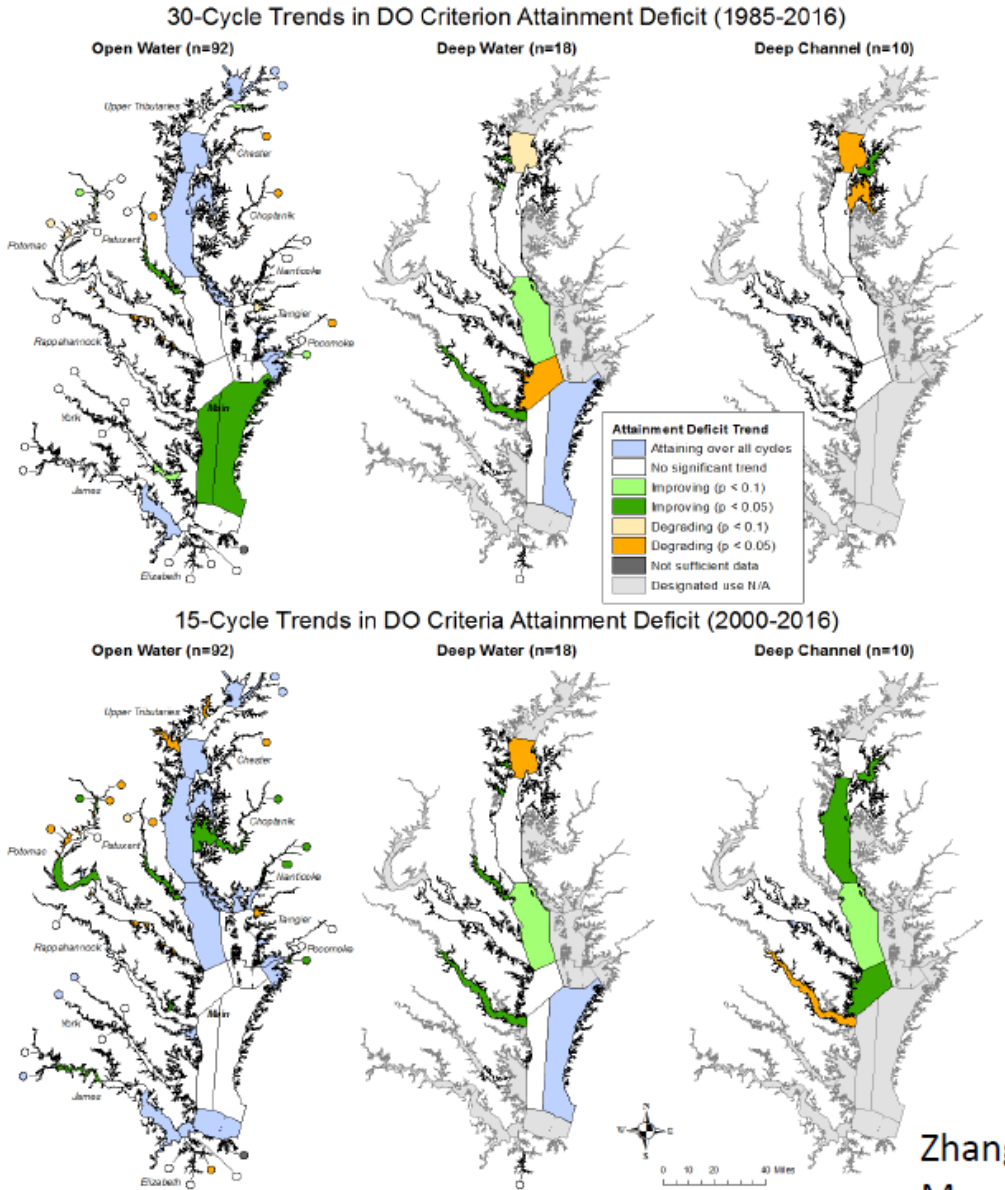
Translation of Attainment Deficit Trends to Time Series of CFD Space-Time Plots



Present STATUS – large regions attaining select criteria, large number of areas non-attaining.



Zhang et al 2018 DRAFT
Maps by E. Trentacoste



Long-term TRENDS

Mixed picture of stable, improving and degrading conditions.

Short-term TRENDS

Zhang et al 2018 DRAFT

Maps by E. Trentacoste