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Background and Approaches to Dissolved Oxygen Assessment Methodologies (Part I): Instantaneous Criteria Review

The Oxygen Chronicles: Tales from the Watery Depths

- Leah Ettema
- EPA Region 3, Water Division

- 12/08/2025

How to determine instantaneous criteria impairment with high-frequency datasets?

How many exceedances are allowed?

What are minimum data sizes?

Outline

- How to generally determine allowable exceedances
- Review the 2003 CB DO Criteria Document
  - Are exceedances of instantaneous minimum allowed?
  - Recommended assessment method
- Considerations for alternative methods for assessment:

  -> Appropriate exceedance frequency?

  -> Designated Use specific insights into potential allowable exceedances
- Part II ?

How to determine allowable frequency of exceedance in assessment?

WQS Components: Magnitude, **Frequency,** and Duration

Frequency often not defined in WQS

If frequency is not expressed in EPA WQS, where would EPA discuss it?

- EPA criteria specific implementation guidance documents
  - i.e., Guidance for Implementing the January 2001 Methymercury Water Quality Criterion
- EPA Integrated Reporting Memoranda (IRG) discusses considerations and recommendations for assessment

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum $\geq$ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Criteria and Implementation Documents

Table 3-1. Chesapeake Bay water quality criteria and designated use related documentation and addenda

Document title	Month/year published	Document content and description
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. EPA 903-R-03-002. [USEPA 2003a]	April 2003	Original Chesapeake Bay water quality criteria document.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability. EPA 903-R-03-004. [USEPA 2003d]	October 2003	Original Chesapeake Bay tidal waters designated uses document.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2004 Addendum. EPA 903-R-03-002. [USEPA 2004a]	October 2004	Addresses endangered species protection, assessment of DO criteria, derivation of site-specific DO criteria, pycnocline boundary delineation methodology, and updated water clarity criteria/SAV restoration acreage assessment procedures.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability—2004 Addendum. EPA 903-R-04-006. [USEPA 2004e]	October 2004	Addresses refinements to Bay tidal waters designated use boundaries, segmentation boundaries, and Potomac River jurisdictional boundaries; documents SAV no-grow zones, restoration goal, and shallow-water acreages.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003. EPA 903-R-04-008. CBP/TRS 268-04. [USEPA 2004b]	October 2004	Details documentation on the history of the segmentation schemes and provides coordinates, georeferences, and narrative descriptions of the 2003 segmentation scheme.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003: 2005 Addendum. EPA 903-R-05-004. CBP/TRS 278-06. [USEPA 2005]	December 2005	Addresses methods used to subdivide the segments by jurisdiction and provides coordinates, georeferences, and narrative descriptions for those subdivided segments.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Addendum. EPA 903-R-07-003. CBP/TRS 285-07. [USEPA 2007a]	July 2007	Addresses refinements to the Bay water quality DO, water clarity/SAV, and chlorophyll a criteria assessment methodologies and documents the framework for Bay tidal waters 303(d) list decision making.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Chlorophyll Criteria Addendum. EPA 903-R-07-005. CBP/TRS 288/07. [USEPA 2007b]	November 2007	Publishes a set of numerical chlorophyll a criteria for Chesapeake Bay and the supporting criteria assessment procedures.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2008 Technical Support for Criteria Assessment Protocols Addendum. EPA 903-R-08-001. CBP/TRS 290-08. [USEPA 2008a]	September 2008	Addresses refinements to the Bay water quality DO, water clarity/SAV and chlorophyll a criteria assessment methodologies and documents the 2008 92-segment scheme for Bay tidal waters.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2010 Technical Support for Criteria Assessment Protocols Addendum. EPA 903-R-10-002. CBP/TRS 301-10. [USEPA 2010a]	May 2010	Addresses refinements to procedures for defining designated uses, procedures for deriving biologically based reference curves for DO criteria assessment and chlorophyll a criteria assessment procedures.
Technical Addendum Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries	Nov 2017	Provides previously undocumented features of the present procedures for assessing attainment of the Chesapeake Bay water quality criteria as well as refinements and clarifications to the previously published Chesapeake Bay water quality criteria assessment procedures

Determining an exceedance frequency

- EPA Criteria document takes priority over EPA IR guidance

Assessment Methodology Considerations

IR Guidance States:

- Assessment methodology must be consistent with WQS
- State should clarify exceedance frequency in assessment method (if not specified in standards)
- Exceedance frequency should be based in scientific rationales

Consistency with standards example: EPA 2016 NY D.O. 303d overlist:

- NY WQS: **“shall not be less than 4.0 mg/L at any time.”**
- NY proposed delisting two streams with **continuous monitoring** data:
  - (1) **98% compliance** between 2015-2017 with the 4.0 mg/L D.O. standard in Spring Creek, and
  - (2) **99% compliance** between 2014-2017 with the 4.0 mg/L D.O. standard in Paerdegat Basin.
- “Because New York’s applicable water quality criterion for dissolved oxygen is expressed as “shall not be less than 4.0 mg/L *at any time*” (emphasis added), **the criterion must be met 100% of the time. Any other interpretation would not be consistent with the expression of this criterion**.”
- “In other words, percent attainment rules are not appropriately applied if their application is not consistent with the manner in which the applicable water quality criteria are expressed.”

2003 CB Criteria:
Yes, Some DO Exceedances Allowed

2003 Bay Criteria: Executive Summary

- “Even if the Chesapeake Bay ecosystem is fully restored, it is unlikely that a circumstance of ‘zero violation’ of these criteria will ever be observed, given natural Bay processes and extreme weather events.”

Chapter vi (Implementation Procedures):

- “A description of successful criteria attainment recognizing that 100 percent attainment is not necessary to protect designated and existing uses;”

But does this include instantaneous criteria?

Yes (Hard to decipher from 2003 Criteria Document)

2003 Implementation Procedures ch vii:

- “It is recommended that separate attainment curves be developed for each criteria component, for subsequent application in every spatial assessment unit (CB segment/designated use) and for at least one full assessment period of three years.”

Deep Channel assessment currently uses reference curve

Reference curves define allowable exceedances

- “The CFD methodology for defining criteria attainment addresses the circumstances under which the criteria may be exceeded in a small percentage of instances.”
- “It is assumed that the designated uses can be attained even with some limited level of criteria exceedances and thus, the reference curves define those criteria exceedances deemed to be allowable.”

Space is an important component of Bay criteria evaluation (2003)

- Different Designated Uses based on space
- “Criteria attainment should be presented in terms of *spatial extent*, i.e., the percentage of the volume (dissolved oxygen) or surface area (water clarity, chlorophyll *a*) of the particular designated use habitat in each Chesapeake Bay Program segment that meets or exceeds the applicable criteria.”
- “those criteria exceedances deemed to be allowable—chronic in time but over small areas, or infrequent occurrences over large areas.”
- “The 10-percent rule is not directly applicable in the context of CFD.. It was designed for samples collected at one location.. Only reflect time.”

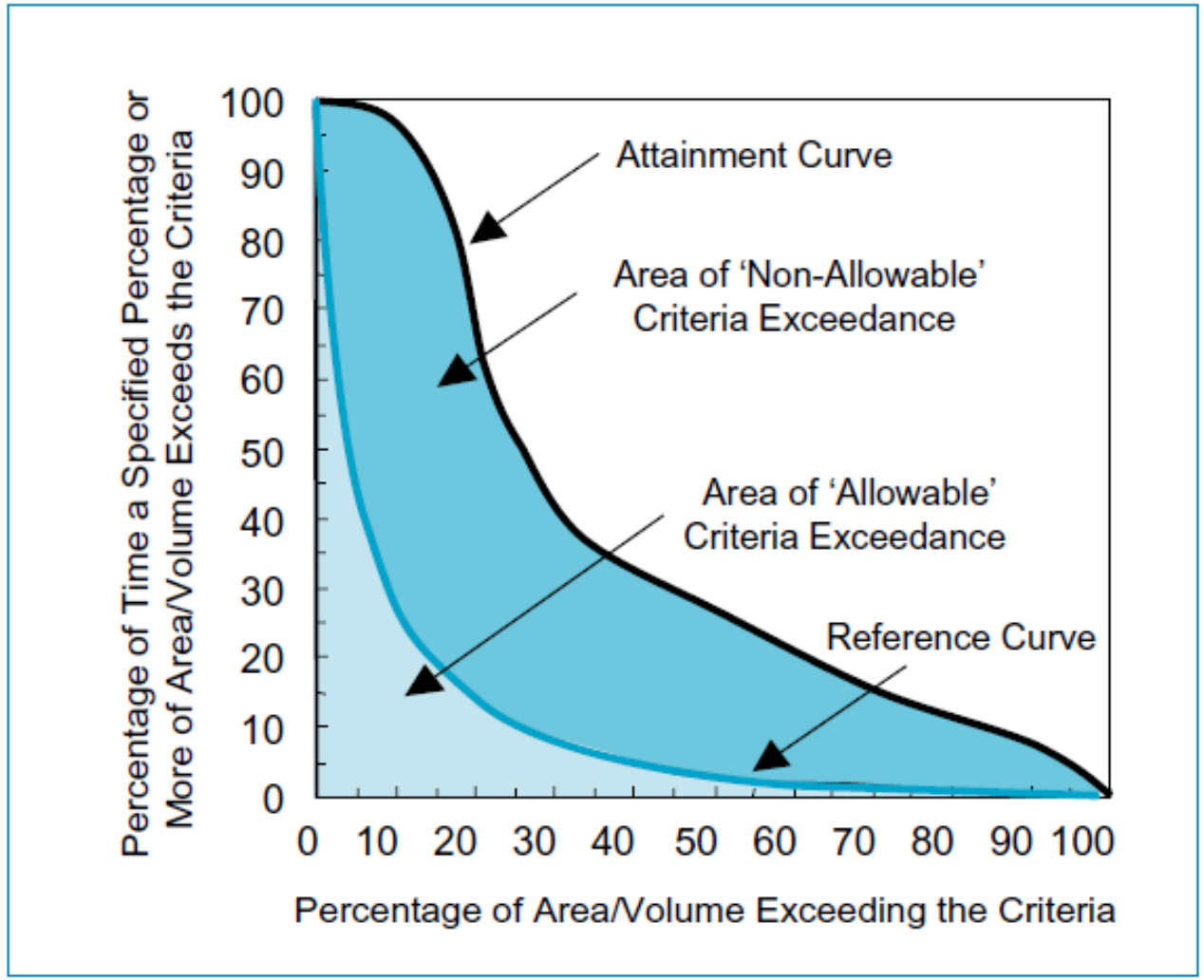


Figure VI-9. Light area reflects amount of 'allowable' criteria exceedance defined as the area under the reference curve (light line). Dark area reflects the amount of 'non-allowable' criteria exceedance defined as the area between the attainment curve (black line) and the reference curve.

First (Basic) Conclusions

- Yes, allowable exceedances of instantaneous min is consistent with criteria implementation documentation
- Space is an important component of Bay assessment
- Recommended assessment method: reference curve and CFD evaluation (space - time assessment)

Considerations for alternative methodologies

2017 Technical Addendum includes non-CFD methods for Open Water

Table II-6. Recommended methods for assessing attainment of the short duration Chesapeake Bay dissolved oxygen criteria.

Designated Use	Assessment Scale		Assessment Method	Criteria	Supporting Documentation
All Designated Uses	Segment		**Direct Assessment with Enhanced Monitoring** Collecting data beyond the existing fixed station monitoring network using vertical water quality profilers, autonomous underwater vehicles, citizen science, etc.	All	U.S. EPA 2003a, U.S. EPA 2004a, this document
			Conditional Attainment with Monitoring Data Meet the longest duration mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment of the short duration dissolved oxygen criterion/criteria		
Open-water Designated Use	Full segment assessed with shoreline to shoreline Application	Segment	**Conditional Attainment with Bimonthly Monitoring Data** Meet the 30-day mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment of the 7-day mean dissolved oxygen criterion	7-day mean	U.S. EPA 2003a, U.S. EPA 2004a, CBP STAC 2012, this document
			Meet the 30-day mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment for the instantaneous minimum criterion	Instantaneous minimum	
	Sub-segment approach application	Zone 1: Open, well-mixed waters	**Zone 2 and Zone 3 Attainment Decision Rule** If sub-segments Zone 2 and Zone 3 pass, then the Zone 1 sub-segment is deemed passing and the entire segment is considered in attainment for the instantaneous minimum criterion	Instantaneous minimum	This document
			Conditional Attainment Meet the 30-day mean dissolved oxygen threshold associated with a a defined level of acceptable risk of nonattainment of the 7-day mean dissolved oxygen criterion	7-day mean, Instantaneous minimum	U.S. EPA 2003a, U.S. EPA 2004a, CBP STAC 2012, this document
		Zone 2: Shallow-water waters	**Continuous Monitoring** 15 minute interval data collected over the entire summer season with no more than two consecutive days with 10% time exceedance	Instantaneous minimum	This document
		Zone 3: Isolated Waters	**Discrete Sampling** 10 sample events per year collected over 3 years assessed based on 10% allowable exceedance	Instantaneous minimum	This document
Deep-water Designated Use	Segment		**Conditional Attainment with Bimonthly Data.** Meeting the deep water 30-day mean criterion ensures attainment of the short duration criteria	1-day mean, Instantaneous minimum	U.S. EPA 2004a

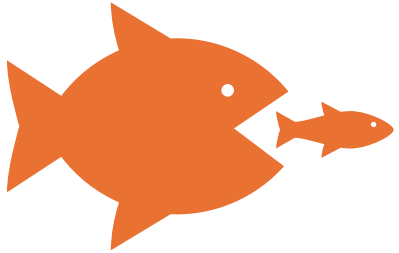
Considerations for non-CFD approach

- What exceedance frequency is allowed?
- What rationale can we provide for exceedances?
- What is consistent with WQS?

➢ Let’s dive into each use: Review Criteria Derivation

Why establish different durations of criteria?

Different durations protect different endpoints



Longer duration criteria: growth, recruitment, etc

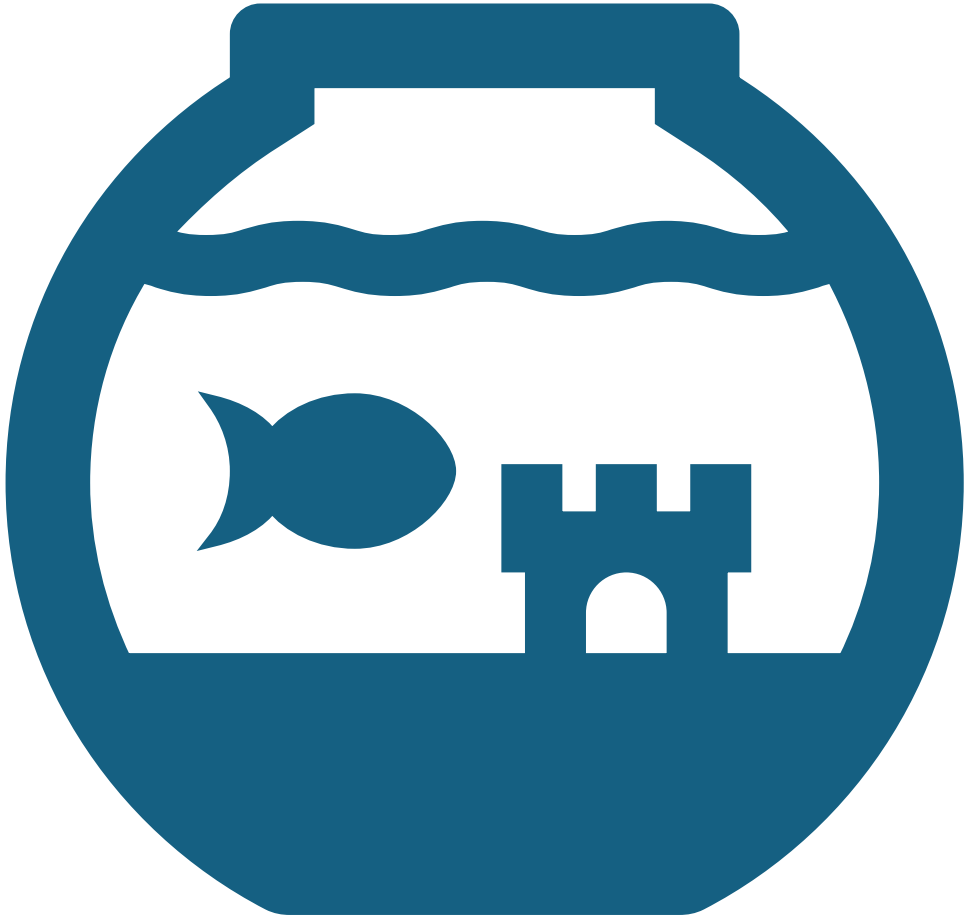
Instantaneous criteria: mortality

2003 Chapter iii: “Instantaneous Min vs Daily Mean”

- “Asphyxia, as stated above, has been reported at dissolved oxygen concentrations well below the reported LC50 concentrations. To ensure full protection of each of the five designated uses, an instantaneous minimum criterion has been recommended.”
- “Oxygen concentrations below those that result in the standardly calculated 50% mortality in 24 to 96 h exposure test can lead to mortality in minutes to a few hours.”
- “The *effects of exposure duration* … are thus very important to consider in setting water quality standards for dissolved oxygen concentration, *highlighting the need to set absolute minima*, instead of time-averaged minima…”

What science drives the instantaneous criteria magnitudes?

- Look at each designated use



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	Instantaneous minimum $\geq$ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
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[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Deep Channel: Instantaneous Min

- “In the case of bottom-dwelling organisms, it is not the average condition that is most detrimental to the organisms but the absolute minimum dissolved oxygen. When dissolved oxygen drops significantly below 1 mg/l for even short periods of time **(on the order of hours)** mortality increases, even for tolerant species.”
- No longer duration criterion: growth other times of year compensates for any lack of summer growth

Table III-8. Deep-channel designated use criteria effects data.

Effects Observed	Concentration	Source
– Mesohaline community mortality of moderately tolerant species	1 mg liter^{-1}	Numerous references cited in Diaz and Rosenberg 1995
– Mesohaline community mortality of more tolerant species	0.6 mg liter^{-1}	Numerous references cited in Diaz and Rosenberg 1995
– Behavioral to lethal responses observed	0.5-1 mg liter^{-1}	Llanso 1992; Llanso and Diaz 1994; references cited in Holland et al. 1989
– Behavior, growth and production effects observed	< 2 mg liter^{-1}	Diaz et al. 1992
– Epifaunal community survival	0.5-2 mg liter^{-1}	Sagasti et al. 2000

Deep Channel Instantaneous Min

Criteria: Little justification for allowing exceedances when hours of exceedance increase mortality

Assessment: CFD approach used for assessment of instantaneous min

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Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival of open-water fish larvae.	
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[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Migratory Fish Spawning and Nursery Use:
5.0 mg/l instant min

- 2003: "**consistent with** the instantaneous minimum duration for the **5 mg/l** concentration criterion value from the **EPA freshwater dissolved oxygen criteria** (Table III-4; U.S. EPA 1986)."

Table III-5. Migratory fish spawning and nursery designated use dissolved oxygen criteria components.

Criteria Components	Concentration	Duration	Source
Protection against growth effects	> 4.8 mg liter^{-1}	-	U.S. EPA 2000
Protection against larval recruitment effects	> 4.6 mg liter^{-1} > 3.4-3.5 mg liter^{-1} > 2.7-2.8 mg liter^{-1}	30 to 40 days 7 days instantaneous minimum	U.S. EPA 2000
Protection of early life stages for resident tidal freshwater species	~~> 6 mg liter^{-1}~~ > 5 mg liter^{-1}	7-day mean instantaneous minimum	U.S. EPA 1986
Protection against effects on threatened/endangered species (shortnose sturgeon)	> 5 mg liter^{-1} > 3.5 mg liter^{-1} > 3.2 mg liter^{-1} [1] > 4.3 mg liter^{-1} [2]	30 days 6 hours 2 hours 2 hours	Secor and Niklitschek 2003; Niklitschek 2001; Secor and Gunderson 1998; Jenkins et al. 1993; Campbell and Goodman 2003
Additional published findings - Growth effects on striped bass - Protect early life stages - Intermediate striped bass survival - Full survival - Preferred concentrations	< 3 to 4 mg liter^{-1} > 5 mg liter^{-1} > 3mg liter^{-1} >5 mg liter^{-1} ≥ 6 mg liter^{-1}	- - 72 hours 72 hours -	Brandt et al. 1998; references in text Krouse 1968 Krouse 1968 Hawkins 1979; Christie et al. 1981; Rothschild 1990

[1] Protective of survival at nonstressful temperatures.
[2] Protective of shortnose sturgeon at stressful temperatures (>29°C).

1986 EPA Dissolved Oxygen Criteria

Daily minimum DO: no acute mortality of sensitive species occurs as a result of lack of oxygen.

Table 8. Water quality criteria for ambient dissolved oxygen concentration.

	Coldwater Criteria		Warmwater Criteria	
	Early Life Stages[1,2]	Other Life Stages	Early Life Stages[2]	Other Life Stages
30 Day Mean	NA[3]	6.5	NA	5.5
7 Day Mean	9.5 (6.5)	NA	6.0	NA
7 Day Mean Minimum	NA	5.0	NA	4.0
1 Day Minimum[4,5]	8.0 (5.0)	4.0	5.0	3.0

1 These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. The 3 mg/L differential is discussed in the criteria document. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

2 Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching.

3 NA (not applicable).

4 For highly manipulatable discharges, further restrictions apply (see page 37)

5 All minima should be considered as instantaneous concentrations to be achieved at all times.

2. Nonsalmonid Waters

a. Early Life Stages

- No Production Impairment = 6.5
- Slight Production Impairment = 5.5
- Moderate Production Impairment = 5
- Severe Production Impairment = 4.5
- Limit to Avoid Acute Mortality = 4

b. Other Life Stages

- No Production Impairment = 6
- Slight Production Impairment = 5
- Moderate Production Impairment = 4
- Severe Production Impairment = 3.5
- Limit to Avoid Acute Mortality = 3

3. Invertebrates

- No Production Impairment = 8
- Some Production Impairment = 5
- Acute Mortality Limit = 4

What does EPA 1986 document say about frequency of exceedance?

1986 DO criteria on Minimum Exceedance

- During periodic cycles of DO, minima lower than acceptable constant exposure levels are tolerable so long as:
  - The average concentration attained meets or exceeds the criterion
  - Average DO is calculated as recommend
  - The minima are not unduly stressful and clearly are not lethal
- "Because repeated exposure to DO mg/L at or near the acute lethal threshold will be stressful and because stress can indirectly produce mortality or other adverse effects (eg disease), *the criteria are designed to prevent significant episodes of continuous or regularly recurring exposures" at those thresholds*.
- "This protection is achieved by setting daily minimum for early life at the subacute lethality threshold, by the use of a 7-day averaging period of minimums for early life stages, by stipulation of a 7-day mean minimum value for other life stages…"

1986 EPA DO Criteria Document on Minimum Exceedance

- Significance of exceedance event depends largely upon five factors:
  - Duration of the event
  - Magnitude of DO depression (most important)
  - Frequency of recurrence
  - Proportional area of site failing to meet criteria
  - Biological significance of the site where the event occurs
- Evaluating the extent, duration, and magnitude of an event must be a function of the spatio-temporal frequency of the data
  - “A single deviation below the criterion takes on considerably less significance where continuous monitoring occurs than where sampling is comprised of once-a-week grab samples”
  - “This is so because based on continuous monitoring, the event is probably small, but with the much less frequent sampling, the event is not probably small and can be considerably worse than indicated by the sample”

MFSN Instantaneous Basis: EPA 1986 DO criteria

EPA 1986 DO criteria: Exceedance of instantaneous criterion allowed in some circumstances (ie 7-day mean attains, 5 factors)

How many exceedances are allowed?

How many exceedances are allowed?

EPA Integrated Reporting Guidance

EPA Integrated Reporting Assessment Guidance

2004 IRG: When is use of the "10% rule" an appropriate assessment methodology?

- "On the other hand, **it is questionable to apply the decision** rule that a water is not impaired if "criteria (are) exceeded in < 10 percent of measurements" **to WQC expressed as "the instantaneous concentration of the pollutant shall not be greater than** ___ :g/L, at any time."

- If a State intends to use the "10%" rule in conjunction with WQC expressed as "the instantaneous concentration of the pollutant shall not be greater than ___ :g/L, at any time," **the State will need to provide a rationale for why such an application of the rule is a reasonable approach to evaluation of data against water quality standards**."

2004 IRG: When is use of the "10% rule" an appropriate assessment methodology?

- "Past EPA guidance (1997 305(b) and 2000 CALM) recommends making non-attainment decisions for conventional pollutants where more than 10% of samples exceed applicable WQS. This guidance was intended to provide a simple "**rule of thumb**" in evaluating data sets of limited size for assessment purposes and **is intended to account for measurement error and the potential that small data sets may not be fully representative of receiving water conditions**. States should be cautious in applying the 10% rule."

Extending the concept:

-> High frequency datasets may be more representative, may have less error and thus warrant a lower exceedance frequency

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[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Open Water
Instantaneous 3.2 mg/l protects:

- **“Endangered Species (Sturgeon): 3.2 mg/l** protects against lethal effects from short-term exposures to low DO for both Bay species of sturgeon”

Table III-6. Open-water fish and shellfish designated use dissolved oxygen criteria components.

Criteria Components	Concentration	Duration	Source
Protection against larval recruitment effects	> 4.6-4.8 mg liter^{-1} > 3.4-3.6 mg liter^{-1} > 2.7-2.9 mg liter^{-1}	30 to 40 days 7 days < 24 hours	U.S. EPA 2000
Protection against growth effects	> 4.8 mg liter^{-1}	-	U.S. EPA 2000
Protection of juvenile/adult survival	> 2.3 mg liter^{-1}	24 hours	U.S. EPA 2000
Protection for resident tidal freshwater species	> 5.5 mg liter^{-1} > 4 mg liter^{-1} > 3 mg liter^{-1}	30 days 7 days instantaneous minimum	U.S. EPA 1986
Protection against effects on threatened/endangered species (shortnose sturgeon)	> 5 mg liter^{-1} ~~> 3.5 mg liter^{-1}~~ > 3.2 mg liter^{-1} [1] ~~> 4.3 mg liter^{-1} [2]~~	30 days ~~6 hours~~ 2 hours ~~2 hours~~	Secor and Niklitschek 2003; Niklitschek 2001; Secor and Gunderson 1998; Jenkins et al. 1994; Campbell and Goodman 2003
Additional published findings			
– Preferred striped bass juvenile habitat	> 5 mg liter^{-1}	-	Kramer 1987; Breitburg et al. 1994
– Juvenile striped bass growth, feeding effects	< 4 mg liter^{-1}	-	Kramer 1987; Breitburg et al. 1994
– Juvenile striped bass mortality	< 3 mg liter^{-1}	-	Chittenden 1972; Coutant 1985; Krouse 1968
– Total fish biomass declining	< 3.7 mg liter^{-1}	-	Simpson 1995
– Total fish species richness	< 3.5 mg liter^{-1}	-	Simpson 1995

[1] Protective of survival at nonstressful temperatures.
[2] Protective of shortnose sturgeon at stress temperatures (> 29°C).

Open Water Basis: Sturgeon Protection

2-hour duration of associated lab test- > Inform Exceedances?

What about volume of area exceeding?

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum $\geq$ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Deep Water: Instantaneous Min

Protect anchovy early life stages: recruitment

- Virginian Province Criteria (EPA 2000); combined egg/larval recruitment effects curve intercepted the y-axis (Figure III-7). Given that the y-axis intercept reflects 'time zero,' an instantaneous min duration was applied to the 1.7 mg/l criterion value.

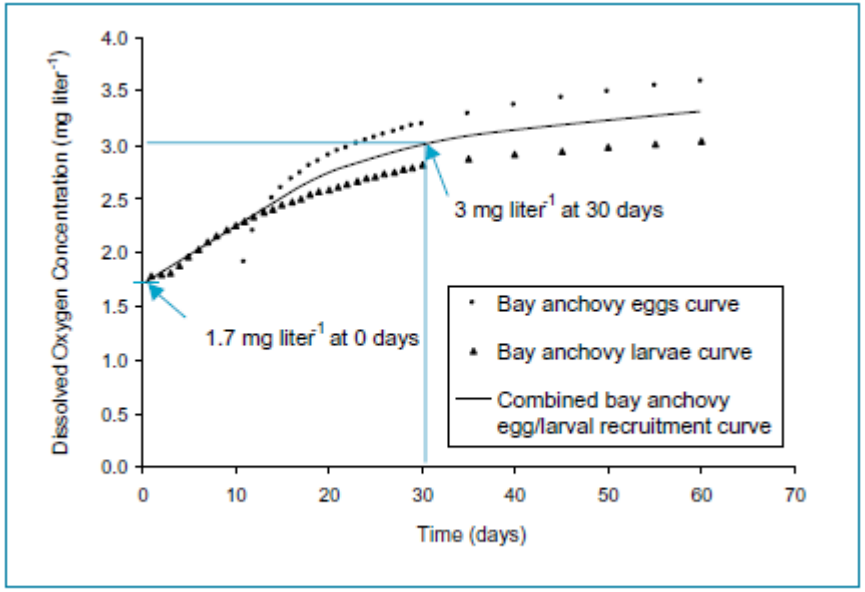

Figure III-7. Chesapeake Bay bay anchovy egg and larval recruitment effects curves.

Table III-7. Deep-water seasonal fish and shellfish designated use criteria components.

Criteria Components	Concentration	Duration	Source
Protection against egg/larval recruitment effects	~~3 mg liter^{-1}~~ 1.7 mg liter^{-1}	30 days instantaneous minimum	Chesney and Houde 1989; Breitburg 1994; U.S. EPA 2000
Protection of juvenile/adult survival	> 2.3 mg liter^{-1}	24 hours	U.S. EPA 2000
Additional literature findings			
- 50 percent mortality for hogchoker, northern sea robin, spot	0.5-1 mg liter^{-1}	24 hours	Reviewed in Breitburg et al. 2001
- 50 percent mortality for tautog, windowpane flounder adults	> 1 mg liter^{-1}	24 hours	Reviewed in Breitburg et al. 2001; Pihl et al. 1991;
- 50 percent mortality for menhaden, summer flounder, pipefish, striped bass adults	1.1-1.6 mg liter^{-1}	24 hours	Reviewed in Breitburg et al. 2001; Pihl et al. 1991; Poucher and Coiro 1997; U.S. EPA 2000
- 50 percent mortality for skilletfish, naked goby, silverside larvae	1-1.5 mg liter^{-1}	24 hours	Breitburg 1994; Poucher and Coiro 1997
- 50 percent mortality for red drum, bay anchovy, striped blenny larvae	1.8-2.5 mg liter^{-1}	24 hours	Saksena and Joseph 1972; Breitburg 1994; Poucher and Coiro 1997
- Zooplankton habitat avoidance	< 1 mg liter^{-1}	-	Roman et al. 1993
- Reduced copepod nauplii abundance	< 1 mg liter^{-1}	-	Qureshi and Rabalais 2001
- 50 percent mortality for *Acartia tonsa* and *Eurytemora affinis*	0.36-1.4 mg liter^{-1}	2 hours	Vargo and Sastry 1977
- Mortality for *Acartia tonsa* and *Oithona colcarva*	< 2 mg liter^{-1}	24 hours	Roman et al. 1993
- 100 percent mortality for copepods	0.71 mg liter^{-1}	24 hours	Stalder and Marcus 1997
- Reduced survival for copepods	<.86-1.3 mg liter^{-1}	24 hours	Stalder and Marcus 1997
- *Acartia tonsa* survival	> 1.43 mg liter^{-1}	24 hours	Stalder and Marcus 1997

Deep Water: Anchovy Larval Recruitment model

Instantaneous criterion is derived using the same method as 30 day-mean.

If 30-day mean is met, is there a chronic problem of instantaneous min not being attained?

Take aways – Alternate Assessment Method

- Can sound rationale be developed for allowable exceedances?
  - Different DO exceedance frequencies may be justified for different Bay designated uses
  - Different DO exceedance frequencies may be justified for different monitoring types (10% was intended for small datasets)
  - Could describe circumstances where instantaneous minimum exceedance is acceptable (ie 30-day mean achieved, not high magnitude or long duration event?)
- Would more recent literature have additional insights?

Reactions and Thoughts

Part II?