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January 2, 2018

VIA EMAIL
Douglas E. Fine
Assistant Commissioner for Water Resources
MassDEP
One Winter Street
Boston, MA 02108

RE: MassDEP Letter Regarding DO Criteria Update for the Taunton Estuary System

Dear Mr. Fine:

The City of Taunton has reviewed your November 13, 2018 letter regarding the State's ongoing plans to update the dissolved oxygen (DO) water quality criteria for marine waters, notably the Taunton Estuary and Mount Hope Bay. As the technical-regulatory consultants to the City on Clean Water Act matters, they have asked us to respond on their behalf.

Background

As you know, the City supports the development of scientifically defensible DO criteria that are protective of aquatic life in our estuarine waters and appreciates MassDEP's efforts in this regard. We greatly appreciate that MassDEP has determined that the existing chronic criteria averaging period should be addressed (i.e., the "at any time" statement should be replaced with the correct averaging period, e.g., 30-day average as identified in the EPA Marine DO Criteria document) and acute (short term) criteria, likely in the range of 3 mg/L, should be adopted. However, we believe that other technical concerns discussed in the letter are misplaced (e.g., EPA's 2000 Marine DO criteria are likely not protective of sturgeon and the Taunton system remains significantly impaired for DO) and respectfully suggest that your staff reconsider the position based on a more detailed review of the referenced information discussed herein.
Your letter indicates that more stringent criteria (in comparison to EPA's Virginian Province Approach for marine DO Criteria) are likely necessary to protect sturgeon as noted in the excerpt below:

> Existing data and studies indicate that DO concentrations below 5.0 mg/L are documented to lead to avoidance behaviors and reduced metabolic and feeding rates to Atlantic sturgeon.[1] NMFS currently considers DO levels of 5.0 mg/L and above

> as protective of sturgeon.[2] Therefore, a chronic DO criterion of 5.0 mg/L is likely the minimum criteria that would protect the Atlantic sturgeon. EPA approved the marine DO criteria in RI, CT, and NY prior to the listing of the Atlantic sturgeon in 2012, and consultation with NMFS and USFWS did not occur on those criteria with respect to the sturgeon.
>
> While the criteria review process is not complete, based on the information presented above, preliminary results do not support changing chronic marine DO criteria values in MassDEP's current water quality standards (which currently are 5.0 mg/L for SB Waters, 6.0 mg/L for SA Waters). EPA confirmed during our discussion with the technical team on June 13, 2018 that DO chronic criteria below 5.0 mg/L are not likely protective of the federally-listed Atlantic sturgeon.

The two references were generally cited in support of this statement above are:

1. The Nature Conservancy, 2016. *Potential Impacts of Dissolved Oxygen, Salinity, and Flow on the Successful Recruitment of Atlantic Sturgeon in the Delaware River*.
2. Kahn, J. and M. Mohead. 2010. *A Protocol for Use of Shortnose, Atlantic, Gulf, and Green Sturgeons.* NOAA Technical Memorandum NMFS-OPR-45.

We believe that a more in-depth review of these documents would yield revised conclusions.

<u>Review of References Cited by MassDEP as Technical Basis for DO Criteria Development</u>

The Nature Conservancy report, referenced as a primary basis for MassDEP's position on the need for more stringent DO criteria to protect the Atlantic sturgeon, states in its introduction:

> The Nature Conservancy was approached by regional sturgeon experts to examine the potential impacts of flow, dissolved oxygen (DO) and salt water encroachment on the successful recruitment of Atlantic sturgeon in the Delaware River. […] *Recommendations for estuarine habitats are outside of the scope of this report.* (Nature Conservancy, 2016 - Section 1. Introduction; Emphasis supplied)

As noted in the introduction to the Nature Conservancy report, the report is inapplicable to estuarine and marine waters and therefore the utility of this unpublished report in developing marine DO criteria in Massachusetts is not apparent. Likewise, the concern over "avoidance behaviors and feeding rates" (Mass DEP Letter at 2-3) is generally not an organism endpoint of concern for Section 304(a) water quality criteria. The longstanding endpoints of concern used to develop all protective water quality criteria are growth, reproduction, and survival. As stated in EPA's "bible" of water quality criteria development - National Criteria Development Guidelines published in 1985, at 4: "It is important to note that this is a threshold of unacceptable effect, not a threshold of adverse effect." Thus, EPA has for decades only employed endpoints that induce a significant adverse impact on the organism – and "avoidance" and "feeding rate" are not such endpoints. Of course, if a condition precluded or significantly impaired the acceptable habitat for the endangered species, that would be a concern. These documents, however, do not provide such evidence. In fact, the very limited data presented in the Nature Conservancy report indicate species

recovery in the Delaware Bay system at DO levels significantly poorer than those in existence in the Taunton Estuary or Mount Hope Bay. In addition, the report indicates that sturgeon recruitment was observed in a freshwater segment of the Delaware River at minimum DO levels comparable to those recorded in the Taunton Estuary (Attachment 1).
Your letter also notes that MassDEP's observations relied on the NOAA Technical Memorandum by Kahn & Mohead to support its preliminary conclusion regarding the applicability of the Virginian Province Approach to Massachusetts saline waters. We note that the Kahn & Mohead technical memorandum was not intended to derive or recommend DO criteria for sturgeon:

> *The goal of the National Marine Fisheries Service (NMFS) protocols for the use of sturgeon is standardization of research practices* to benefit the recovery of Gulf of Mexico (Gulf), green, Atlantic, and shortnose sturgeon while also minimizing potentially negative impacts of research. As with A Protocol for the Use of Shortnose and Atlantic Sturgeon (Moser et al. 2000a), these protocols provide guidelines for consistent and safe sampling methods when conducting research on sturgeon.
> (Kahn & Mohead, 2010 at 1; Emphasis supplied)

We are not aware of any other instance in which this type of document (i.e., sampling protocols) was referenced as the basis for proposing scientifically defensible water quality criteria. Rather, as a matter of course, the use of peer-reviewed, published articles, presented as referenced in the Kahn & Mohead report, must be specifically cited as the basis for any EPA or state criteria derivation. Our preliminary review of the cited work on Atlantic sturgeon sensitivity to DO shows that at least one study cited as the basis for the recommendations in the Technical Memorandum relates to the sensitivity of young-of-year sturgeon (See, e.g., Niklitschek and Secor, 2009a[1]). The Nature Conservancy report (at 5) presents a clear summary of the Atlantic sturgeon life cycle, which shows that young-of-year and first-year juveniles reside in fresh water. Consequently, DO criteria based on the sensitivity of young-of-year do not apply to marine waters. If the references cited in the Technical Memorandum are used as the basis for a revised marine DO criterion, care must be taken to ensure that only the studies relevant to the marine life stages of the sturgeon species to be protected are utilized. Moreover, the categorization of Atlantic sturgeon as endangered is only pertinent if the organism is sensitive to DO. The available data suggest that the juvenile and adult sturgeon that inhabit marine waters are far less sensitive to low DO. Therefore, the listing of Atlantic sturgeon as endangered in 2012 is not pertinent to the development of updated marine DO criteria.

Your letter also noted that "the science has evolved significantly" since the 2000 EPA Marine DO Criteria. The last extensive effort was the Chesapeake Bay DO Criteria (*Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries* (EPA, 2003)[2] - Attachment 2) where EPA thoroughly reviewed and ultimately

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[1] Niklitschek, E.J. and D.H. Secor. 2009a. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory results. Journal of Experimental Marine Biology and Ecology 381: S150 – S160.
[2] EPA. April 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. Available at https://www.chesapeakebay.net/content/publications/cbp_13142.pdf

approved the criteria for waters where sturgeon are also present (see also, Attachment 3 – 2017 Dr. Robert J. Diaz Evaluation of DO Criteria Development). Therefore, it is apparent that the Chesapeake Bay DO Criteria should be reviewed and referenced in the development of DO criteria in Massachusetts.

Stratification Requires Further Consideration in DO Criteria Development

You noted that low DO is still present in Mount Hope Bay and that it was caused by excessive plant growth. This conclusion is somewhat misplaced. Stratification has been identified as a natural condition driver of low DO conditions in this system (see, 2017 NBEP Report[3] at 279: "In addition, [Narragansett] Bay is often density stratified, meaning there are distinct layers with relatively warm and lower salinity surface water overlying colder and saltier deep water (Codiga 2012). Wet weather tends to increase freshwater discharge to an estuary, which increases nutrient loading and further enhances stratification due to the density differences of water, leading to decreased mixing. This results in increased likelihood of hypoxic events following rainstorms, as stratification can isolate the bottom waters from sources of oxygen near the surface." See also, Attachment 4), and the effects of stratification have been specifically accounted for in EPA's Chesapeake Bay DO Criteria (at 12-13):

> The Chesapeake Bay dissolved oxygen criteria directly reflect natural oxygen dynamics. For example, instantaneous minimum to daily mean criterion values reflect short-term variations in oxygen concentrations, and seasonal application of deep-water and deep-channel criteria account for the natural effects of water-column stratification on oxygen concentrations. Oxygen dynamics and natural low- to no-oxygen conditions also were taken into account in developing the refined tidal-water designated uses (see Appendix A; U.S. EPA 2003a), which factor in natural conditions leading to low dissolved oxygen concentrations.

Accordingly, Delaware, Virginia, Maryland, and the District of Columbia updated their designated use boundary definitions for open water to account for stratified waters (defined by the presence of a pycnocline) in their water quality standard regulations (*Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries, 2017 Technical Addendum* at 88):

> From June 1 through September 30, the open-water designated use includes tidally influenced waters extending horizontally from the shoreline to the adjacent shoreline. If a pycnocline is present and, in combination with bottom bathymetry and water-column circulation patterns, presents a barrier to oxygen replenishment of deeper waters, the *open water fish and shellfish designated use extends down into the water column only as far as the measured upper boundary of the pycnocline*. (Emphasis supplied)

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[3] Narragansett Bay Estuary Program (NBEP). 2017. State of Narragansett Bay and Its Watershed. Technical Report. Providence, RI.

Because the Taunton Estuary and Mount Hope Bay have documented, recurring occurrences of stratification, we suggest that MassDEP adopt an approach similar to the Chesapeake Bay DO Criteria that takes into account the impacts of stratification on DO and the location of sensitive species and life stages in relation to the pycnocline.

Review of 2016-18 Taunton Estuary and Mount Hope Bay Water Quality Data

As a final note, your letter references water quality data for 2017 that "demonstrates that the low DO resulted from algae blooms that were caused by excessive nutrients." While we are not intending to debate the nutrient impairment designation of Mount Hope Bay, the chlorophyll-a peaks of 25 to 100 µg/L – from a remote buoy in the Rhode Island portion of Mount Hope Bay using light transmittance readings – are greatly in excess of the data we are aware of (See, NBEP, 2017). We suspect these reported higher values are not reliable measurements – as has occurred in other systems using remote sensing technology. It would be appreciated it you could provide the quality control-reviewed data and any analyses you have conducted to show that the claimed algal blooms are real.

With regards to utility of these data to the Taunton Estuary:

1. It is not reasonable to use this location in Mount Hope Bay as indicative of Taunton Estuary conditions, and

2. These high chlorophyll-a readings in Mount Hope Bay are *dramatically* higher than the values found in the Taunton Estuary for 2018 which averaged about 5 ug/L throughout the growing season (Attachment 5). As you know, a 5 ug/L chlorophyll-a growing season average is considered "excellent to good" water quality in Massachusetts estuarine systems (SMAST, 2003, at 21).[4]

Therefore, one would not consider the Taunton Estuary nutrient-impaired based on this most current information.

Please let us know if you have any questions regarding our comments.

Sincerely,

William T. Hall

William T. Hall

Attachments
cc: Mayor Thomas Hoye
Joseph Federico, Beta Engineers
John C. Hall, H&A

[4] SMAST, Howes, B.L., Samimy, R., and B. Dudley. July 21, 2003. Massachusetts Estuaries Project, Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators Interim Report.

Attachment 1 –

Figure 5 from The Nature Conservancy, 2016. Potential Impacts of Dissolved Oxygen, Salinity, and Flow on the Successful Recruitment of Atlantic Sturgeon in the Delaware River.

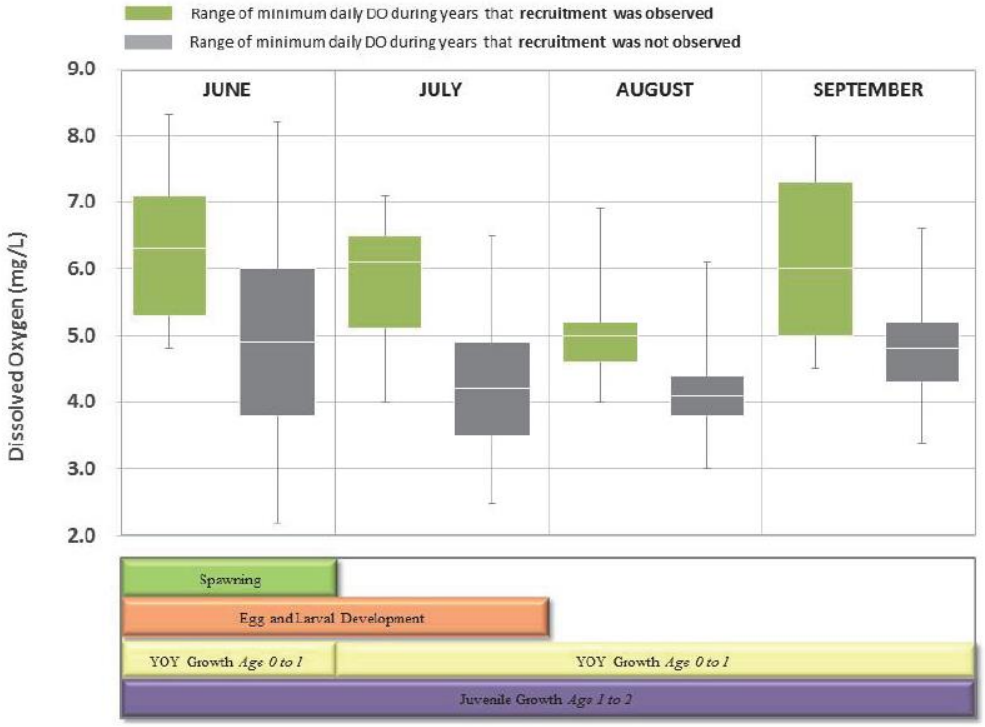


Figure 5. A comparison of the range of minimum daily DO concentrations at Ben Franklin Bridge (RM 100) between years when recruitment was observed (2009, 2011 and 2014) and years recruitment was not observed (2005-8, 2010, 2012, 2013). A box blot distribution represents the maximum and minimum values as represented by the upper and lowermost points, and the distribution of the 75th, 50th (median), and 25th percentiles as represented by the bottom, center and top of the box respectively.

Attachment 2 –

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

Table III-10. 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

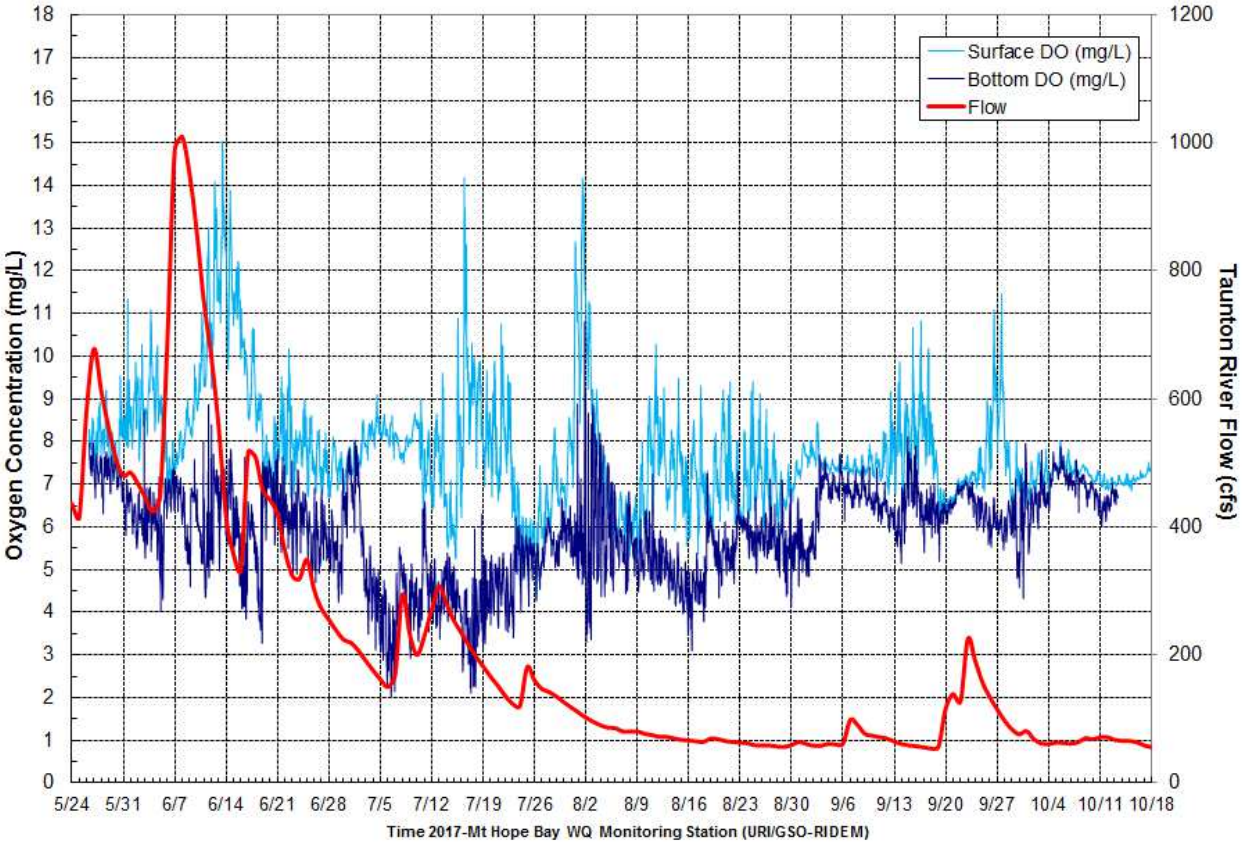
[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Attachment 3 –

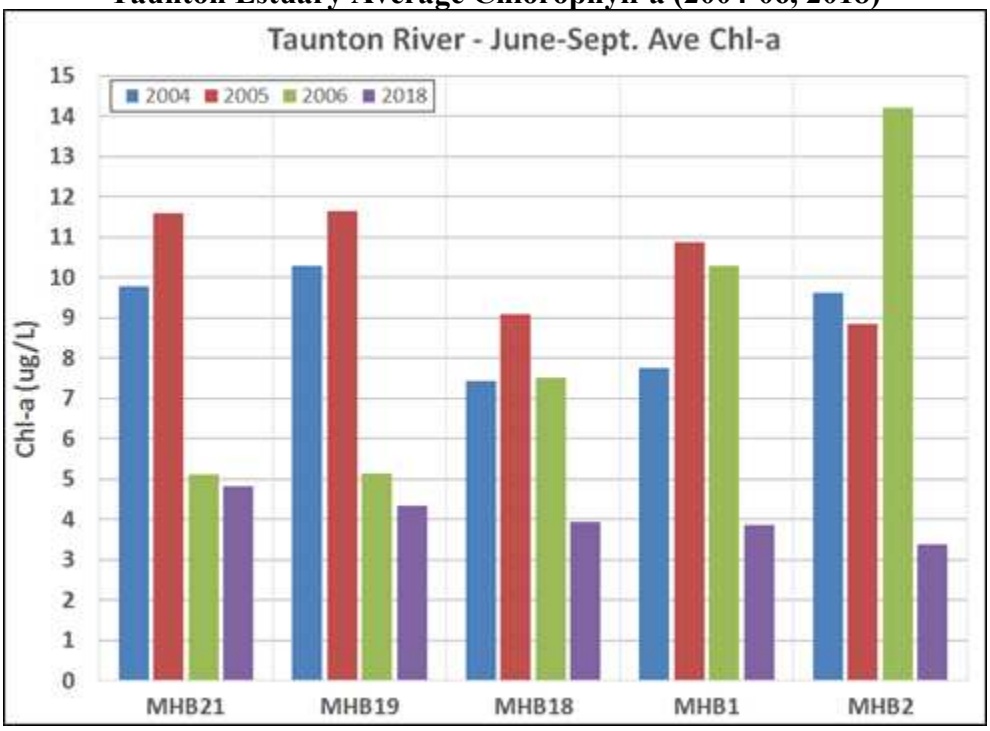
February 14, 2017 Dr. R.J. Diaz - Reply to New Hampshire Marine DO Criteria Update Letter Dated December 28, 2016

Attachment 4 –

Narragansett Bay Water Quality Monitoring Network - 2017 MHB Buoys DO Data Displaying Stratified Conditions Following Elevated Taunton River Flows



Attachment 5 –
Taunton Estuary Average Chlorophyll-a (2004-06, 2018)



R.J. DIAZ AND DAUGHTERS
6198 DRIFTWOOD LANE
P. O. BOX 114
WARE NECK, VA 23178

February 14, 2017

Dean Peschel
Peschel Consulting LLC
59 Sleeper Circle
Fremont, NH 03044

RE: New Hampshire Marine DO Criteria Update

Dear Dean:

I understand that New Hampshire would like to update the State's dissolved oxygen criteria, in particular for Great Bay Estuary. My initial opinions on the issues you listed in your December 28, 2016 letter are attached.

If you need additional detail on any issue please let me know.

Sincerely,

Robert J. Diaz

Reply to New Hampshire Marine DO Criteria Update Letter Dated December 28, 2016

Issue: *Is the existing DO saturation criterion, minimum 75% saturation (daily average) necessary to ensure aquatic life use protection?*
Opinion: A dissolved oxygen (DO) criterion set at 75% air saturation is likely overly protective for almost all estuarine species that would utilize Great Bay. From the 2000 Marine DO Criteria assessment of chronic growth impairment in tests that ranged from 7 to 21 days (Table 2 in EPA 2000), only some larvae and juveniles stages of summer flounder, American lobster, and Say mud crab showed some impairment above 75% saturation, which at summer temperatures is close to 5 mg O_2/L (Figure 1). The impairment was not consistent across all larval and juvenile stages tested. No species evaluated had acute sensitivity (exposure ranging from 24 to 96 hours) above 2 mg O_2/L, which is the most frequently used starting point for hypoxia. Comparing data from Table 1 (EPA 2000) to the nomogram below it would seem that a 50-60% saturation, or 3-4 mg O_2/L, would also be protective for most species.

The use of DO saturation does complicate criteria application as DO saturation is primarily a function of temperature and salinity, with a minor effect from barometric pressure. Current literature (including EPA's freshwater and marine DO criteria documents) would support the use of concentration-based criteria to ensure appropriate criteria are set across habitats. Concentration combined with the proper averaging period for measuring DO will ensure the most defensible criteria that provide an appropriate level of protection for various fishery resources.

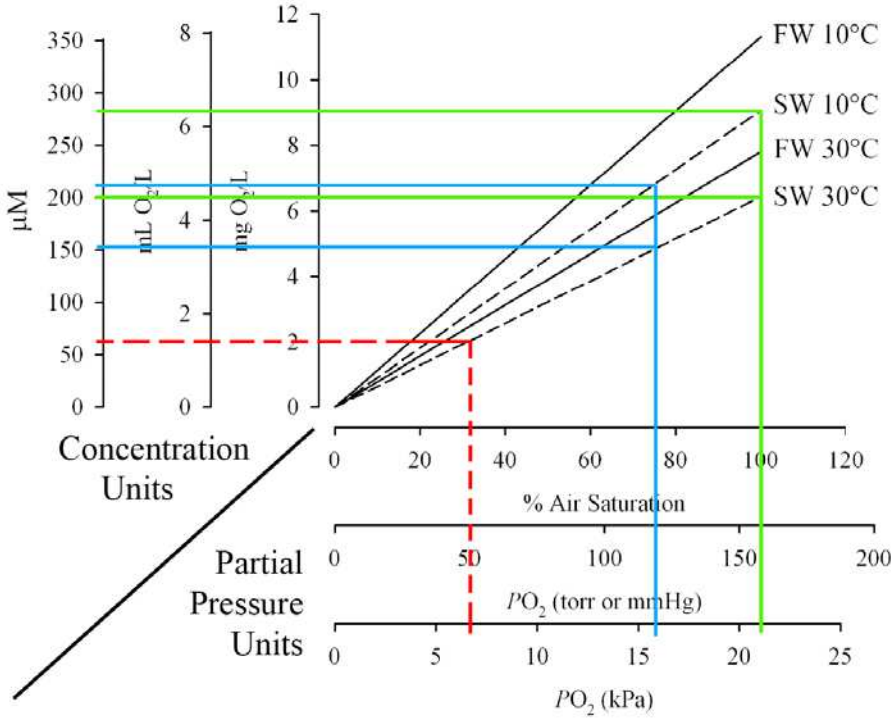


Figure 1. Nomogram for dissolved oxygen in freshwater (FW) and sea water (SW) at 10ºC and 30ºC (from Diaz and Breitburg, 2009). Concentration units are on Y-axis, and partial pressure units are on X-axis. Red line is most frequently used starting point for hypoxia at 2 mg O_2/L. Green line is 100% solubility of oxygen in sea water between 10º to 30ºC. Blue line is existing DO criteria of 75% saturation.

Issue: *If the DO saturation criterion is not necessary to protect aquatic life, is there an alternative 24 hour DO (i.e., chronic) criterion that would be appropriate to ensure aquatic life use protection in this estuarine system? For example, would a 5 mg/l (daily average) concentration be considered protective? Would another chronic DO criterion of a longer averaging period (e.g., 7-day, 30-day) be appropriate to ensure aquatic life protection?*
Opinion: This is a complex set of questions. First, it should be pointed out from the oxygen nomogram that 5 mg O_2/L is about 75% saturation for seawater at 30ºC. For individual species the range of DO between acute and chronic effects can be as large as 3 to 4 mg O_2/L or about a 50% change in saturation. But there is a common and predictable range of responses to declining DO (Figure 2). All but the most sensitive mobile species will not move to avoid habitats that are above 4 mg O_2/L. By the time a habitat is at 2 mg O_2/L mobile fishes have left and by 1.5 mg O_2/L benthic species are showing signs of stress. This basic response model would need to be refined to be more representative of Great Bay species. The best way to approach DO criteria would be a combination that assess temporal concentrations (instantaneous, daily, weekly, etc.) and seasonal use by key species. This is how DO criteria were set in Chesapeake Bay, with the addition of designated use zones (see Figure 3 and Batiuk et al. 2009 for details).

Given the way organisms respond to declining DO, either in a chronic or acute sense, setting a criteria based on a single day average of 5 mg O_2/L would be a very conservative (protective). However, a higher DO protection level should apply when and where migrating fishes spawn as noted in the 2000 Marine DO and Chesapeake Bay criteria. It does not seem appropriate to set a criteria at 5 mg O_2/L for 24-hour interval. As criteria must be met at “all times and places” this would mean that no single 24 hour period may average DO less than 5 mg O_2/L. EPA’s Marine DO and Chesapeake Bay criteria recognize that the “chronic” criteria averaging period should be on the order of 30 days. But it is also important to ensure a protective “instantaneous minimum” is set. Available information would indicate that depending on the organism and habitat, anywhere from about 1.5-4 mg O_2/L instantaneous minimum would ensure that acute impacts are minimal. Our approach in Chesapeake Bay was to set DO levels supported by data from published literature for major habitats within Chesapeake Bay. No new data, outside the EPA sponsored monitoring program, was collected to develop or set criteria.

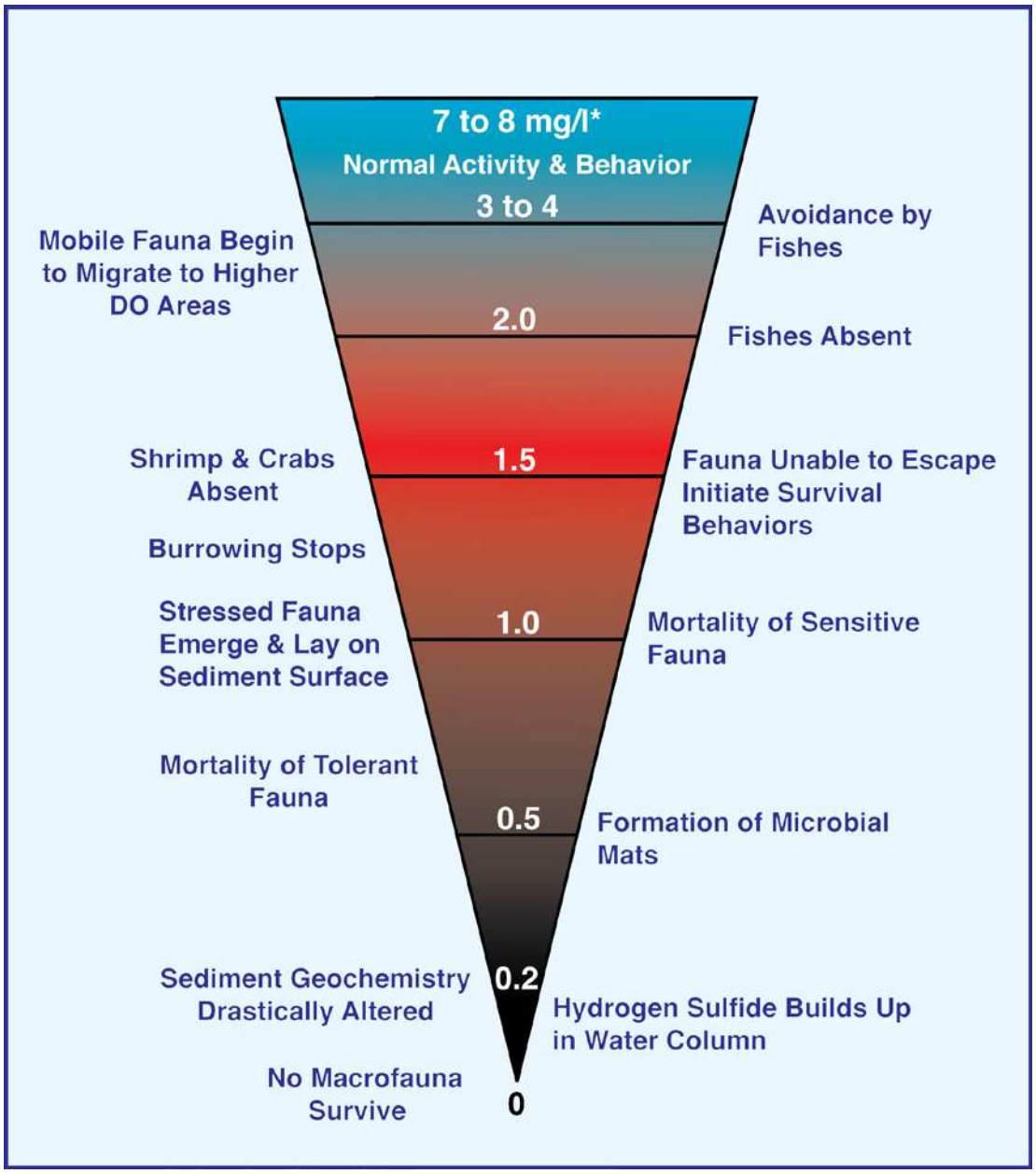


Figure 2. Cone of faunal response to declining oxygen concentration. Based on data from Díaz and Rosenberg (1995), Rabalais et al. (2001), Vaquer-Sunyer and Duarte (2008).

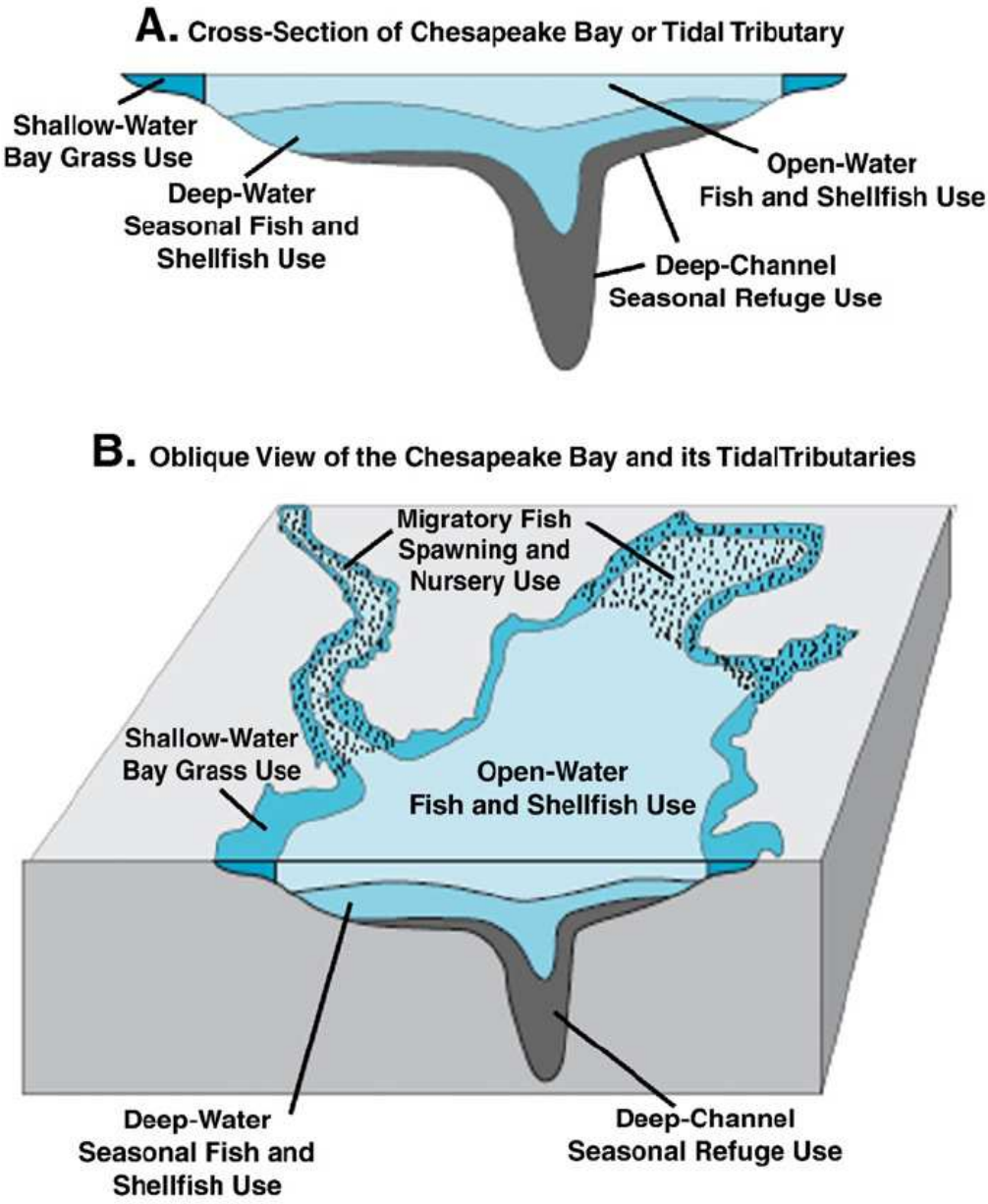


Figure 3. Conceptual illustration of the five Chesapeake Bay tidal water designated uses zones (From Batiuk et al. 2009).

Issue: *Is a 5 mg/L instantaneous minimum DO necessary to ensure aquatic life use protection in estuarine waters?*
Opinion: Based on the 2000 Marine DO Criteria and other literature summaries of DO impacts, 5 mg O_2/L is overly protective of all species for acute impacts and most species for chronic impacts. In Chesapeake Bay, a concentration of 5 mg O_2/L and above were set as criteria only for migratory fish spawning and nursery designated use zones by season. See Table 1.

Table 1. Chesapeake Bay dissolved oxygen water quality criteria for the protection of tidal water designated uses against adverse effects on survival, growth, larval recruitment, freshwater species and threatened/endangered species (From Batiuk et al. 2009).

Designated use	Criteria concentration/duration	Protection provided	Temporal application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6.0 mg L^{-1} (tidal habitats with 0–0.5 salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species	February 1–May 31
	Instantaneous minimum $\geq$ 5.0 mg L^{-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 L^{-1} (tidal habitats with 0–0.5 salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species	Year-round
	30-day mean $\geq$ 5 mg L^{-1} (tidal habitats with>0.5 salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species	
	7-day mean $\geq$ 4 mg L^{-1}	Survival of open-water fish larvae	
	Instantaneous minimum $\geq$ 3.2 mg L^{-1}	Survival of threatened/endangered sturgeon species[a]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg L^{-1}	Survival and recruitment of bay anchovy eggs and larvae	June 1–September 30
	1-day mean $\geq$ 2.3 mg L^{-1}	Survival of open-water juvenile and adult fish	
	Instantaneous minimum $\geq$ 1.7 mg L^{-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 L^{-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

[a] At temperatures considered stressful to shortnose sturgeon (29 °C), DO concentrations above an instantaneous minimum of 4.3 mg L^{-1} will protect survival of this listed sturgeon species. Source: U.S. EPA, 2003a.

Issue: *If the 5 mg/L instantaneous minimum DO criterion is not necessary to protect aquatic life, is there an alternative short-duration (i.e., acute) DO concentration that would be appropriate to ensure aquatic life use protection from such short term DO variations? For example, would a 3.5 mg/l or 4 mg/l 1-hour average standard be considered protective?*
Opinion: This is an interesting question. For benthos and most pelagic species, 5 mg O_2/L is protective based on published laboratory and field data. But what combination of concentration and exposure would be workable for protecting species in the field? A big part of these issues involves where DO is measured (surface, midwater, 1m off bottom, 10cm off bottom), when (day vs. night), for how long a period (instantaneous, hours, days, weeks, months), at what intervals (minutes to hours). There is little consistency in the literature as to how DO is measured and how low DO is assessed, so some thinking will be needed to answer these questions. From all the DO time-series I have seen there are obvious daily fluctuations in DO and most have an obvious tidal components along with season. In Chesapeake Bay a combination of instantaneous minimum, 1-day, 7-day, and 30-day means were used to set criteria based on species sensitivity and habitat use. Whether an organism is benthic or not, the criteria apply to the overlying water column the organism is exposed to. However, DO requirements for deep-channel refuge are different from overlying open-water column that would be well aerated (Figure 3 and Table 1).

Issue: *The USEPA 2000 Marine DO Criteria and 2003 Chesapeake Bay DO criteria address a number of components (chronic, acute, stratified conditions, spawning areas, etc.) that appear to require some detailed knowledge of the system to properly apply. Please address the following questions:*

1- Are there components of the 2000 Marine DO Criteria or 2003 Chesapeake Bay criteria that could be applied to New Hampshire waters without substantial changes; for example, due to similarity of taxonomic groups to be protected?
Opinion: I think a hybrid of the 2000 Marine DO Criteria and Chesapeake Bay criteria would fit New Hampshire's needs. The start would be to identify key species in Great Bay and determine what is know about their DO requirements.

2- What changes (e.g., studies, data collection, organism adjustments), if any, are required to make other components of these criteria applicable to the Great Bay Estuary?
Opinion: To combine elements from both sets of DO criteria will require that you consider the following:

1. Understand the dynamics of DO within Great Bay to included temporal and spatial elements. A thorough evaluation of NEERS water quality data for Great Bay would be a starting point.
2. Identify key species that need protection with an understanding of support species they need.
3. Identify when and where key species and their life-histories use Great Bay.
4. Set realistic DO concentrations that are obtainable through best management practices. By this I mean do not set criteria above what is natural for Great Bay.

3- How should standards application vary in stratified versus unstratified waters?
Opinion: I am not sure this will be a problem. It is rare for an unstratified waterbody to have low DO or become hypoxic. Chesapeake Bay did partition the Bay into zone based on species use. The boundary between the open-water fish and shellfish use zone and the deep-water seasonal fish and shellfish use zones do correspond roughly to where the summer pycnocline lies. If Great Bay has a similar structure then separate DO criteria could be used.

Citations:

Batiuk, R. A., D. L. Brietburg, R. J. Diaz, T. M. Cronin, D. H. Secor, and G. Thursby: Derivation of habitat-specific dissolved oxygen criteria for Chesapeake Bay and its tidal tributaries. J. Exp. Mar. Biol. Ecol. 381:S204-S215, 2009.

Diaz, R. J. and Breitburg, D. L.: The hypoxic environment, in: Richards, J. G., Farrell, A. P., and Brauner, C. J. (eds.), Fish Physiology, Vol. 27, Academic Press, Burlington, 1-23, 2009.

Diaz, R. J. and Rosenberg, R.: Marine benthic hypoxia a review of its ecological effects and the behavioural responses of benthic macrofauna, Oceanogr. Mar. Biol. Ann. Rev., 33, 245-303, 1995.

Rabalais, N. N., Smith, L. E., Harper, D. E., Jr., and Justić, D.: Effects of seasonal hypoxia on continental shelf benthos, in: Rabalais, N. N. and Turner, R. E. (eds.), Coastal Hypoxia Consequences for Living Resources and Ecosystems, Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D. C., 211-240, 2001.

U.S. EPA: Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras. EPA-822-R-00-012. Office of Water, Office of Science and Technology, Washington, D.C. and Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, Rhode Island. 2000.

Vaquer-Sunyer, R. and Duarte, C. M.: Thresholds of hypoxia for marine biodiversity, Proc. Natl. Acad. Sci., U.S.A., 105, 15452–15457, 2008.