Marine Dissolved Oxygen (DO) Criteria (continued discussion)

New Hampshire Water Quality Standards Advisory Committee, April 11, 2019

Ken Edwardson
NH Dept. of Environmental Services
Marine Dissolved Oxygen (DO) Criteria (continued discussion)

1. EPA Process for Approving New Criteria (EPA)
2. Marine Species list sent to EPA (NHF&G)
3. VA Province DO Model Status (EPA)
4. VA Province DO Model Limitations
5. Critical Habitat designation for Atlantic sturgeon
6. Delaware Estuary DO Review Process
7. Update on MA marine DO discussions
8. Discussion and Next Steps
EPA Process for Approving New Criteria
Discussion?
Marine Species List - Cheri Patterson (NHF&G)

- Species identified for New Hampshire’s estuarine waters
- When/Where/What they are doing
- Preliminary DO review
- Provided to species list to EPA on December 17, 2018
Fish Known to Be In Great Bay Estuary - Examples

**Endangered/Threatened**

**Federal and/or State Species of Special Concern**

- Rainbow Smelt
- Anadromous Alosids (alewife, blueback herring, American shad)
- American Eel
- Sea Lamprey

**Two Sturgeon species**
Example of Complex Life Stages of these Species in the Great Bay Complex

<table>
<thead>
<tr>
<th>Marine Species documented in Great Bay Complex (Piscataqua River and Tributaries)</th>
</tr>
</thead>
</table>

**Endangered Species**

- Threatened Species
- State Species of Concern
- Federal and State Species of Concern

**NIF - No Information Found for life stage**

**YOY - Young of Year**

<table>
<thead>
<tr>
<th>FINFISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documented Presence (Surveys or Literature) in Great Bay</td>
</tr>
<tr>
<td>January</td>
</tr>
</tbody>
</table>

### Threatened and Endangered

- **STURGEON, ATLANTIC (GOM DPS)**: Acipenser oxyrhynchus - Subadult, Adult
- **STURGEON, SHORTNOSE**: Acipenser brevirostrum - Subadult, Adult

### State and Federal Species of Concern - Diadromous Fish

<table>
<thead>
<tr>
<th>ALEWIFE</th>
<th>Alosa pseudoharengus</th>
<th>Adult</th>
<th>overlap</th>
<th>YOY/Juvenile</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEL, AMERICAN</td>
<td>Anguilla rostrata</td>
<td>Adult/Luv</td>
<td>YOY and Juvenile</td>
<td>Adult/Luv</td>
</tr>
<tr>
<td>HERRING, BLUEBACK</td>
<td>Alosa aestivalis</td>
<td>Adult</td>
<td>overlap</td>
<td>YOY/Juvenile</td>
</tr>
<tr>
<td>LAMPREY, SEA</td>
<td>Petromyzon marinus</td>
<td>Adult</td>
<td>overlap</td>
<td>YOY/Juvenile</td>
</tr>
<tr>
<td>SHAD, AMERICAN</td>
<td>Alosa sapidissima</td>
<td>Adult</td>
<td>overlap</td>
<td>YOY/Juvenile</td>
</tr>
<tr>
<td>SMELT, RAINBOW</td>
<td>Osmerus mordax</td>
<td>Adult/Juvenile</td>
<td>Adult/eggs</td>
<td>YOY/Juvenile</td>
</tr>
</tbody>
</table>
Letters present where NH species overlap with DE species and Drexel researched species/life stage sensitivity.

Many gaps in species and life stage information – filled in as more data mining and research occurs.
Invertebrates Known to Be In Great Bay Estuary - Examples

- Soft Shell Clam
- Eastern Oyster
- Horseshoe Crab
- American lobster
- Red and Jonah Crabs
Letters present where NH species overlap with DE species and Drexel researched species/life stage sensitivity.

Gaps in overlap. (Currently closed 2 of the gaps)

Invertebrates important to commercial and recreational fisheries.

<table>
<thead>
<tr>
<th>INVERTEBRATES (of current commercial and recreational importance)</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAMS, SOFTSHELL</td>
<td>Mya arenaria</td>
</tr>
<tr>
<td>CRAB, HORSESHOE</td>
<td>Limulus polyphemus</td>
</tr>
<tr>
<td>CRAB, JONAH</td>
<td>Cancer borealis</td>
</tr>
<tr>
<td>CRAB, ROCK</td>
<td>Cancer productus</td>
</tr>
<tr>
<td>LOBSTER, AMERICAN</td>
<td>Homarus americanus</td>
</tr>
<tr>
<td>OYSTER, AMERICAN</td>
<td>Crassostrea virginica</td>
</tr>
</tbody>
</table>
Great Bay Estuary Marine Species

• Species identified for New Hampshire’s estuarine waters
• When/Where/What they are doing
• Preliminary DO needs review
• Provided species list to EPA on December 17, 2018
Discussion?
EPA - VPA Model Approach and Existing Data Analyses for The Great Bay Estuary
Discussion?
VPA Limitations

• Thresholds are for juvenile survival, larval growth. Larvae assumed expendable.
• Only one study on reproductive effects.
• Daily swings not addressed (behavior and physiological stress).
• Avoidance
  • “The effects include low DO avoidance, changes in locomotion, burrowing and feeding activity; and altered predator-prey behaviors.” (EPA, 2000)
  • ~4 mg/L (Buchheister et al. 2013 and others)
  • ~5 mg/L for sturgeon (MassDEP Nov. 2018 citing TNC 2016)
VPA Limitations

Endangered Species –

• *Threatened and endangered species*—In cases where a threatened or endangered species occurs at a site, and sufficient data exist to suggest that it is more sensitive at concentrations above the criteria, it is appropriate to consider development of site-specific criteria based on this species. (EPA, 2000)
VPA Limitations

Lab studies as basis for thresholds

• Unlimited food.
• No sediments $\rightarrow$ no sulfide and no methylmercury.
• No tandem pH correction.
  • $N_2$ sparge to lower DO $\rightarrow$ Decreased $CO_2$ and increased pH (see Golblor work).
• Single stressor
• Points to applying a margin of safety on any thresholds derived from lab studies.
Discussion?
Sturgeon
Shortnose Sturgeon

- Federal and State Endangered Species,
  - Federally Listed in 1967
- NOAA Fisheries is currently conducting a status review for shortnose sturgeon to ensure that the original classification as an endangered species is still appropriate.
Shortnose Sturgeon

• “Distribution: …They were also once thought to be common in the Piscataqua River.” (NHF&G)

• “A tagged individual was recently detected by an acoustic telemetry receiver deployed for an unrelated project in Great Bay.” (NHF&G)

• “Current Distribution and Abundance
There are very few records of any sturgeon being captured in the Piscataqua River. Dadswell et al. (1984) reported a single shortnose sturgeon captured in the Piscataqua River since 1818 recorded in 1971. Prior to 1818 landing records did not distinguish between shortnose and Atlantic sturgeon therefore it is difficult to determine the presence or abundance of shortnose sturgeon.” (SSSRT, 2010)

(https://wildlife.state.nh.us/fishing/profiles/shortnose-sturgeon.html)
Atlantic Sturgeon

Atlantic sturgeon swimming in the Virginia Aquarium and Living Museum. Photo credit: Edith Carson, NOAA

(https://www.greateratlantic.fisheries.noaa.gov/protected/atlsturgeon/docs/sturgeonfactsheetfinal.pdf)
Atlantic Sturgeon

• Federal and State Threatened Species
Atlantic Sturgeon –
Gulf of Maine Distinct Population Segments (DPS)

• Regarding Critical Habitat areas – The entire Piscataqua, Salmon Falls, and Cocheco Rivers

• “The 2007 Atlantic sturgeon status review provided information on directed effort to catch Atlantic sturgeon in the Piscataqua River, and incidental capture of a large, ripe female Atlantic sturgeon near the head of tide in the Salmon Falls River in 1990. Between 2010 and 2016, three Atlantic sturgeon were detected in the Piscataqua River using passive acoustic array (M. Kieffer, USGS, pers. comm.)”

• “While there is no current evidence that Atlantic sturgeon are spawning in Gulf of Maine rivers other than the Kennebec and Androscoggin, captures of sturgeon in the Merrimack, Penobscot and Piscataqua/Salmon Falls/Cocheco rivers indicate that there is the potential for spawning to occur in these rivers. “

Atlantic Sturgeon – Additional areas

• NH F&G
  • “In June of 1981, one subadult Atlantic sturgeon was captured by New Hampshire Fish and Game (NHFG) at the mouth of the Oyster River in Great Bay (NH Fish and Game, 1981).”

• Acoustic Tagging
  • NOAA / USGS / UNH / UNE / MeDMR / Navy / SBU
  • Sensor arrays that pick up tagged fish.
  • Both Shortnosed and Atlantic sturgeon frequent the Piscataqua River up to the Salmon Falls dam.
  • Both Shortnosed and Atlantic sturgeon visit Little Bay.

(EPA, R1. Re: Re-Issuance of the National Pollutant Discharge Elimination System (NPDES) General Permit for Remediation Activity Discharges – The Remediation General Permit (RGP); NPDES Permit MAG910000 and NHG910000. December 28, 2016.)
Acoustic array and detections (2010-2017)

1990-ATS capture

Shorthose sturgeon (N = 20)

Atlantic sturgeon (N = 23)

(Micah Kieffer et al. Shortnose and Atlantic sturgeon use of the Piscataqua River System. 2018 Maine Sustainability & Water Conference Maine Sustainability & Water Conference, March 29, 2018)
(Micah Kieffer et al. Shortnose and Atlantic sturgeon use of the Piscataqua River System. 2018 Maine Sustainability & Water Conference Maine Sustainability & Water Conference, March 29, 2018)
Atlantic Sturgeon – NMFS Critical Habitat Areas

Adults – Potentially throughout.

Spawning – Potentially Cocheco and Salmon Falls Rivers.

(https://www.greateratlantic.fisheries.noaa.gov/regs/2017/August/17criticalhabitatdpssatlanticsturgeongarmapdeck.pdf)

From: Maps of Atlantic Sturgeon Critical Habitat Units in the Greater Atlantic Region. August 16, 2017. NMFS)
Atlantic Sturgeon – EPA Life Stages Recognition

4) **Piscataqua River**– According to the ASSRT, few Atlantic sturgeon have been captured in the Piscataqua River (Atlantic Sturgeon Status Review Team, 2007). Although the Atlantic Sturgeon Status Review Team and NHFG biologists concluded that the Great Bay Atlantic sturgeon population is likely extirpated, individuals from other populations may forage in the Piscataqua River. Also, according to NMFS, spawning potentially occurs in the Salmon Falls and Cocheno rivers based on the presence of features necessary to support reproduction and recruitment, as well as the historic capture of an adult female in spawning condition. Subadult and adult foraging is assumed to occur wherever suitable forage is present.\(^8\) Therefore, contact between subadults and adult (and potentially all life stages of) Atlantic sturgeon in the Piscataqua River and the projected transient RGP discharge plumes may occur.

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6 See footnote 5, above.

7 See footnote 5, above.

8 See footnote 5, above.

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(EPA, R1. Re: Re-Issuance of the National Pollutant Discharge Elimination System (NPDES) General Permit for Remediation Activity Discharges – The Remediation General Permit (RGP); NPDES Permit MAG910000 and NHG910000. December 28, 2016.)
Sturgeon – Dissolved Oxygen

• In the life stages for which there are data, sturgeon are very sensitive to low DO.

• DO sensitivity is only available for a few of the sturgeon lifestages (juvenile and a little larvae data, not adults, not eggs).

• Any newly proposed criteria will require National Marine Fisheries Service consultation and will need to be protective of sturgeon.

• “Threatened and endangered species—In cases where a threatened or endangered species occurs at a site, and sufficient data exist to suggest that it is more sensitive at concentrations above the criteria, it is appropriate to consider development of site-specific criteria based on this species.” (Virginia Province Approach, EPA, 2000)
Discussion?
Delaware River Basin

- 2017 Resolution (Goal) – Increase DO criteria
- A UAA to upgrade their DO criteria
- Approach – Biological needs, System DO modeling,
- Fish species – Drexel Work
- Fisheries Biologist TAC – Just starting

From 1967 Standards

<table>
<thead>
<tr>
<th>Zone</th>
<th>River Mile</th>
<th>Aquatic Life Use</th>
<th>Migratory Fishes</th>
<th>24-hour average D.O. Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>108.4 – 133.4</td>
<td>maintenance and propagation of resident fish and other aquatic life</td>
<td>passage of anadromous fish</td>
<td>5.0 mg/l</td>
</tr>
<tr>
<td>3</td>
<td>95 – 108.4</td>
<td>maintenance of resident fish and other aquatic life</td>
<td>passage of anadromous fish</td>
<td>3.5 mg/l</td>
</tr>
<tr>
<td>4</td>
<td>78.8 – 95</td>
<td>maintenance of resident fish and other aquatic life</td>
<td>passage of anadromous fish</td>
<td>3.5 mg/l</td>
</tr>
<tr>
<td>5</td>
<td>70 – 78.8</td>
<td>maintenance and propagation of resident fish and other aquatic life</td>
<td>passage of anadromous fish</td>
<td>3.5 mg/l</td>
</tr>
<tr>
<td>6</td>
<td>0 – 48.2</td>
<td>maintenance and propagation of resident fish and other aquatic life</td>
<td>passage of anadromous fish</td>
<td>6.0 mg/l</td>
</tr>
</tbody>
</table>

Urbanized portion of Delaware Estuary

Interim goal zones where they hope to increase the DO criteria.

This is the only estuarine zone that fully supports the designated use.

[Zone 6 - & Not below 5 mg/L at any time]

1. Dissolved Oxygen.
   a. 24-hour average concentration shall not be less than 6.0 mg/l;
   b. not less than 5.0 mg/l at any time unless due to natural conditions.
How do the Delaware Zones” relate to Great Bay Estuary?
Interim goal zones where they hope to increase the DO criteria.

(1999-2016 Salinity from https://johnyagecic.shinyapps.io/BoatRunExplorer/)
Freshwater (18 Zones)

Not less than (5, 4) mg/L at any time unless naturally occurring.

Daily average of (6, 5) mg/L

Interim goal zones where they hope to increase the DO criteria.

Zone 6

Daily average of 6 mg/L

Mile 0 = Cape May to Cape Henlopen

Not less than 5 mg/L at any time unless naturally occurring.

Figure 2. Delaware River Basin Commission (DRBC) dissolved oxygen criteria along the Delaware Estuary in 1968 [22].

(Gerald J. Kauffman. The Cost of Clean Water in the Delaware River Basin (USA). Water 2018, 10, 95.)
How have they done (Zone 3)?
“Weak and inconsistent spawning by Atlantic Sturgeon, and limited spatial recovery in spawning and rearing by American Shad and Striped Bass, suggested that full restoration of the “propagation” use is not supported by the current available data.”

(DRBC. Existing Use Evaluation for Zones 3, 4, & 5 of the Delaware Estuary Based on Spawning and Rearing of Resident and Anadromous Fishes, September 30, 2015.)
No successful recruitment years when Minimum Daily DO less than 4 mg/L.

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.
DRBC Resolution NO. 2017 – 4

• “To conduct an analysis to determine the attainability of DO requirements and water quality standards that would result in an upgrade in the designated aquatic life use in this 38-mile section of the river, including technical, social, and economic factors;”

• Prepare a schedule for completing a full draft analysis of attainability within 3.5 years (10/2020) from the effective date of the resolution.

• Final rule and an implementation strategy within 6 years of the adoption of this resolution (4/2023).
Delaware – Take-away points

• The DRBC expects full designated use support when;
  • Fresh waters; 6, 5 mg/L daily average and 5, 4 mg/L Instantaneous.
  • Marine (polyhaline); 6 mg/L daily average and 5 mg/L Instantaneous.

• The DRBC expects less than full designated use support when;
  • Tidal oligohaline/mesohaline waters; 3.5, 4, 5, 6 mg/L daily average and no
    instantaneous minimum.

• 2017 Resolution – Increase DO criteria in Tidal oligohaline/mesohaline
  waters.

• Approach – Biological needs and in-depth System DO modeling.

• Fish species – Drexel species / DO needs has data gaps\(^1\).

• Fisheries Biologist TAC – Just starting

(1-A Review of Dissolved Oxygen Requirements for Key Sensitive Species in the Delaware
Discussion?
Massachusetts (MassDEP)

• Started DO review in Spring 2017
• ~$100,000s
• Anticipated review completion and marine DO criteria recommendation in late 2019.
• Recommendation likely to be implemented as part of the next triennial review
• Hired consultants to assist and worked with EPA (RI, HQ, & Atlantic Ecology Div/ORD), MA Coastal Zone Management, MA F&G, RI DEM, URI, USGS, & GBNERR

• Considered Approaches
  • Reference Condition
  • Virginia Province (VPA) (EPA 2000)
  • Chesapeake Bay (EPA 2003)
Virginian Province Approach – Study Area:

Species List

- Consider species not included in EPA (2000)
- Develop a list of species present in the waterbody
  - Include seasonal residents, anadromous species, and species that use the area for spawning or other life stages
  - Identify previously reported toxicity values; search literature for newly generated toxicity values
  - Identify local species for which acute or chronic growth data are available

- 81 species identified
- 68 species in final list

Massachusetts DEP marine species list.

Given overlaps, NH may be able to borrow some research.

Overview: Marine DO Criteria

Draft DO Criteria Calculation

- EPA (2000): CMC (2.3 mg/L) and CCC (4.8 mg/L)
- Virginian Province Approach – Study Area:

<table>
<thead>
<tr>
<th>Draft DO Criteria (mg/L)</th>
<th>Value (DO mg/L)</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC (with Sturgeon)</td>
<td>3.2 (21)</td>
<td>1-4</td>
</tr>
<tr>
<td>CMC (without Sturgeon)</td>
<td>2.8 (20)</td>
<td>1-4</td>
</tr>
<tr>
<td>CCC</td>
<td>4.8 (10)</td>
<td>7-30</td>
</tr>
</tbody>
</table>

- Chesapeake Bay Approach – Study Area:

<table>
<thead>
<tr>
<th>Draft DO Criteria (mg/L)</th>
<th>Riverine*</th>
<th>Shallow</th>
<th>Benthic</th>
<th>Pelagic</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC</td>
<td>3.4 (10)</td>
<td>2.8 (20)</td>
<td>3.0 (18)</td>
<td>3.1 (5)</td>
</tr>
<tr>
<td>CCC</td>
<td>NA (2)</td>
<td>4.8 (9)</td>
<td>4.9 (6)</td>
<td>5.4 (6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Draft DO Criteria (mg/L)</th>
<th>Spring* (March 19-June 19)</th>
<th>Summer (June 20-Sept 19)</th>
<th>Fall (Sept 20-Dec 20)</th>
<th>Winter (Dec 21-March 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC</td>
<td>3.3 (20)</td>
<td>3.2 (21)</td>
<td>3.2 (21)</td>
<td>2.3 (19)</td>
</tr>
</tbody>
</table>

*Values in brackets indicate total genera with data; the 4 most sensitive genera with data were used to derive draft DO CMC and CCC.

Massachusetts DEP DRAFT marine DO criteria based on 3 methods.
MassDEP’s criteria review has considered EPA’s Virginian Province Approach (VPA), which has been the basis for DG criteria developed and adopted in the mid-2000s by other states on the East Coast (including CT, NY, and RI). Through the review process, we have learned that the science has evolved significantly since EPA’s guidance for this approach was published in 2000. In consultation with EPA, we have developed an approach that builds on the VPA while considering new information from the National Marine Fisheries Service (NMFS) and other literature sources. Additional factors that need to be considered in the VPA are whether; 1) there is the occurrence of a threatened or endangered species; and 2) sufficient data exist to suggest that higher DO concentrations are needed to support the growth and reproduction of aggregate fish communities.

Massachusetts DEP appears to have a new approach coming.
Overview: Marine DO Criteria
Draft DO Criteria Calculation

- EPA (2000): CMC (2.3 mg/L) and CCC (4.8 mg/L)
- Virginian Province Approach – Study Area:

<table>
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<th>Value (DO mg/L)*</th>
<th>Duration (days)</th>
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<tbody>
<tr>
<td>CMC (with Sturgeon)</td>
<td>3.2 (21)</td>
<td>1.4</td>
</tr>
<tr>
<td>CMC (without Sturgeon)</td>
<td>2.8 (20)</td>
<td>1.4</td>
</tr>
<tr>
<td>CCC</td>
<td>4.8 (10)</td>
<td>7.26</td>
</tr>
</tbody>
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- Chesapeake Bay Approach – Study Area:

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</tbody>
</table>

Unlikely that we will see this as the most defensible criteria/current approach when MassDEP finishes their process.

*Values in brackets indicate total genera with data; the 4 most sensitive genera with data were used to derive draft DO CMC and CCC.
Massachusetts (MassDEP)

• Approach seen in March 2018 does not seem to be what will move forward.
• Mass DEP staff are planning to present a draft of their current approach at two public meetings in May (Boston and Worcester). *Specific locations/dates/times TBD*
Discussion?
Next Steps

Fall

• White paper on revised theoretical Marine DO Criteria.
Considerations

• VP approach
• Chesapeake approach
• Delaware process
• Massachusetts process and possible outcomes
• Endangered and Threatened species
• State Species of Concern (Alewife, Am. Eel, Herring, Shad*, Smelt*)
• Direction gleamed from NMFS ESA discussions
• Criteria that lets aquatic life do more than survive
• Weighting the impacts of science gaps
  • Missing DO requirements for NH species and life stages
  • Avoidance
  • Implications of VP approach being all lab studies
  • Uncertainty in the VP approach
  • ESA Species life stage DO requirement gaps
  • Relationships in DO needs between life stages

• Assessment Methods and Compliance.
• Other
Discussion?