

Connecticut Department of Environmental Protection
Bureau of Water Management and Land Reuse
Planning and Standards Division

Water Quality Standards Revision 2009
Dissolved Oxygen Criteria for Marine Waters
January 12, 2010

As part of the triennial review of Connecticut’s Water Quality Standards, revisions to the water quality criteria for marine dissolved oxygen were proposed. This document provides a description of the revision goals and proposed criteria, as well as a technical evaluation of the proposed criteria including several options for the cumulative exposure criteria interval.

The dissolved oxygen (DO) criteria for marine waters adopted in 2002¹ are as follows:

- Nearshore = not less than 6.0 mg/l (SA waters) and not less than 5.0 mg/l (SB waters)
- Offshore above pycnocline = not less than 6.0 mg/l (SA waters) and not less than 5.0 mg/l (SB waters)
- Offshore within and below the pycnocline = not less than 3.5 mg/l (SA&SB waters)
- Offshore Chronic exposure = Table 1 for cumulative DO exposure between 3.5-4.8 mg/l
- Offshore = depths > 5m mean low water (MLW)

| Table 1. DO Incremental ranges and duration data to be applied to LIS in the area affected to ensure protection of larval recruitment within and below the pycnocline. | | |
|--|---------|--------------------|
| DO Range (mg/L) | | No of Days Allowed |
| Maximum | Minimum | |
| 4.8 | 4.3 | 21 |
| 4.3 | 3.8 | 11 |
| 3.8 | 3.5 | 5 |

A decimal fraction is calculated for each range, e.g., 10.5 days in the 4.3-4.8 range would produce a decimal fraction of 0.5 (10.5days/21days). As long as the sum of those fractions calculated for each range is less than 1.0, resource protection goals are maintained for larval recruitment. It is important to note that the number of days allowed for the 3.8-3.5 interval (5 days) was adjusted down from 7, which is what the calculation actual yields.

The calculation used to determine the number of days allowed is as follows:

$$DO_i = 13.0 / (2.8 + 1.84e^{-0.10t_i})$$

The calculation is applicable to persistent exposure data (24 hour or greater continuous low DO conditions), from Table 6 of the Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras, 2000².

The following two goals were evaluated in order to determine the practicality of revisions to the marine DO criteria.

Goal 1:

Revise DO criteria to be protective of marine resources while considering consistency throughout Long Island Sound (LIS). Both the Long Island Sound Study (LISS) and State of New York (NYS) use an acute DO criteria value of 3.0 mg/l. Connecticut Department of Environmental Protection (CTDEP) has continued to track compliance with the 3.0 mg/l criteria.

- In 2002, when the dissolved oxygen acute criteria were adopted, CTDEP believed that 3.5 mg/l was representative of best achievable conditions (background plus economically and technically feasible). In 2006, a numerical mass balance model of Long Island Sound was implemented as an improvement to the earlier LIS 3.0 hypoxia model. This model, known as the System Wide Eutrophication Model (SWEM) indicates that the minimum DO under pastoral conditions (i.e. no human input of nutrients) was around 4.0 mg/l. Using this SWEM pastoral analysis, best achievable conditions has been estimated to be around 3.0 mg/l. By revising the DO criteria to 3.0 mg/l, the impact of human activities on DO concentrations is only 1.0 mg/l.
- Changing Connecticut's DO criteria to 3.0 mg/l will make the standards consistent across the sound. However, it should be noted that since CT and NY's interpretation of their own criteria vary, the degree of compliance and noncompliance will continue to vary across the state boundary.
- The Environmental Protection Agency's LISS is supportive of CT's change to the acute DO criteria. LISS defines hypoxia in the sound as less than 3.0 mg/l. CTDEP reports DO data in accordance with this standard in the annual "Hypoxia Season Review" report.

Goal 2:

Revise the criteria to be applicable to all Connecticut estuarine waters (inshore and offshore).

There is reason to evaluate inshore waters for chronic conditions using the cumulative exposure method. Such an approach would allow for determination of impacts as well as the observation of trends from improved water quality due to nitrogen reduction measures. Attached is a 2009 news article that includes an interview with R. Harris of HW/RW. Mr. Harris notes that his group does not find fish in inshore trawl surveys when DO levels fall below 3.0 mg/l. In addition, since 1999 several continuous DO reading instruments have been deployed in inshore areas of LIS. The revised DO criteria with applicable cumulative exposure table will allow for better analysis of this data.

The following questions were posed to evaluate the implications of the above goals.

Question 1:

-How does the area and duration of hypoxia analyses compare between DO of not less than 3.5mg/L and DO of not less than 3.0mg/L?

The real difference is in the area analysis. The maximum area of nonattainment is decreased by almost half but a large change in the numbers of days of nonattainment is not observed.

| 2008 LIS monitoring data | DO not <3.5 mg/L | DO not <3.0 mg/L |
|--------------------------|------------------|------------------|
| Hypoxia start date | June 30 | July 3 |
| Hypoxia end date | September 20 | September 19 |
| Duration_days | 83 | 79 |
| Maximum Area_mi2 | 360.0 | 180.1 |

Question 2:

-How should the DO interval presented in Table 1 (page 1) be adjusted to include a greater periodic excursion range?

A larger interval reduces the number of days allowed to exceed. The NYS Criteria support document³ recommends a larger interval for data that may be inadequate to determine a daily average (NYS determination of compliance requires the use of daily average DO concentrations that reflect the diurnal fluctuations in the DO concentrations). EPA recommends using a 0.5 mg/l interval due to the temporal limitations of most monitoring programs. Smaller or larger intervals can be used depending on frequency of sampling.

In order to better understand the impact of interval size on nonattainment, a fake dataset of 40 points (see below) was created to compare the results of compliance with the criteria using a variety of intervals and the exposure intervals adopted in 2002. The 0.6 mg/l interval establishes even increments between three levels. The 0.5 mg/l interval leaves one odd increment either at the high end or low end. Two options for varying the intervals were explored, 0.2 mg/l increments or 0.4 mg/l increments over 3.6 and one 0.6 mg/l increment between 3.0 and 3.6 mg/l. Lastly, the data was analyzed using a 0.1 mg/l interval table.

2002 Adopted Criteria
DO Interval = 0.5 mg/l

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.3 | 21 | 11 | 0.523809524 |
| 4.3 | 3.8 | 11 | 14 | 1.272727273 |
| 3.8 | 3.5 | 5 | 6 | 1.2 |
| | | 37 | 31 | 2.996536797 |

Options for DO Criteria Increments

DO Interval = 0.6 mg/l

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.2 | 18 | 13 | 0.722222222 |
| 4.2 | 3.6 | 8 | 15 | 1.875 |
| 3.6 | 3 | 2 | 12 | 6 |
| | | 28 | 40 | 8.597222222 |

DO Interval = 0.5 mg/l
and (one) 0.3 mg/l at
bottom

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.3 | 21 | 11 | 0.523809524 |
| 4.3 | 3.8 | 11 | 14 | 1.272727273 |
| 3.8 | 3.3 | 5 | 7 | 1.4 |
| 3.3 | 3 | 2 | 8 | 4 |
| | | 39 | 40 | 7.196536797 |

DO Interval = 0.5 mg/l
and (one) 0.3 mg/l at top

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.5 | 30 | 5 | 0.166666667 |
| 4.5 | 4 | 14 | 14 | 1 |
| 4 | 3.5 | 7 | 12 | 1.714285714 |
| 3.5 | 3 | 2 | 9 | 4.5 |
| | | 53 | 40 | 7.380952381 |

DO Interval = 0.2 mg/l
and (two) 0.6 mg/l

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.6 | 43 | 3 | 0.069767442 |
| 4.6 | 4.4 | 25 | 4 | 0.16 |
| 4.4 | 4.2 | 18 | 6 | 0.333333333 |
| 4.2 | 3.6 | 8 | 15 | 1.875 |
| 3.6 | 3 | 2 | 12 | 6 |
| | | 94 | 40 | 8.438100775 |

DO Interval = 0.4 mg/l
and (one) 0.3 mg/l

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.4 | 25 | 7 | 0.28 |
| 4.4 | 4 | 14 | 12 | 0.857142857 |
| 4 | 3.6 | 8 | 9 | 1.125 |
| 3.6 | 3 | 2 | 12 | 6 |
| | | 49 | 40 | 8.262142857 |

DO Interval = 0.1 mg/l

| Maximum | Minimum | Days Allowed | Days in Range | Fraction |
|---------|---------|--------------|---------------|-------------|
| 4.8 | 4.6 | 43 | 3 | 0.069767442 |
| 4.6 | 4.5 | 30 | 2 | 0.066666667 |
| 4.5 | 4.4 | 25 | 2 | 0.08 |
| 4.4 | 4.3 | 21 | 4 | 0.19047619 |
| 4.3 | 4.2 | 18 | 2 | 0.111111111 |
| 4.2 | 4.1 | 16 | 4 | 0.25 |
| 4.1 | 4 | 14 | 2 | 0.142857143 |
| 4 | 3.9 | 12 | 2 | 0.166666667 |
| 3.9 | 3.8 | 11 | 4 | 0.363636364 |
| 3.8 | 3.7 | 9 | 3 | 0.333333333 |
| 3.7 | 3.6 | 8 | 0 | 0 |
| 3.6 | 3.5 | 7 | 3 | 0.428571429 |
| 3.5 | 3.4 | 6 | 1 | 0.166666667 |
| 3.4 | 3.3 | 5 | 0 | 0 |
| 3.3 | 3.2 | 4 | 2 | 0.5 |
| 3.2 | 3.1 | 3 | 3 | 1 |
| 3.1 | 3 | 2 | 3 | 1.5 |
| | | 234 | 40 | 5.369753012 |

This exercise resulted in the following findings:

- Use of the larger interval table results in a higher sum of fractions and seems to provide a more conservative approach for determining compliance with the criteria.
- Use of the 0.5 mg/l interval favors progress by allowing greater excursions at the higher range, and this approach is recommended in EPA's DO criteria document.
- Using the 0.6 mg/l interval reduces the total number of days allowed from 37 to 28.
- It appears that small variations in the intervals results in only small changes to the fractional sum. The real difference was seen between using the 0.6 mg/l and 0.1 mg/l interval. Where the 0.6 mg/l interval resulted in a fractional sum of 8.6 and

the sum for the 0.1 mg/l interval was 5.4. Use of any of the higher interval options will result in a more conservative estimate than the 0.1 mg/l interval option.

Based on the technical evaluation and findings presented above, the following DO criteria are proposed for both inshore and offshore waters of Long Island Sound:

Acute criteria: not < 3.0 mg/l at any time.

Chronic criteria: not < 4.8 mg/l with allowable excursions.

Proposed DO Interval Table:

| Table 1. DO Incremental ranges and duration data to be applied to LIS in the area affected to ensure protection of larval recruitment. | | |
|--|---------|--------------------|
| DO Range (mg/l) | | No of Days Allowed |
| Maximum | Minimum | |
| 4.8 | 4.5 | 30 |
| 4.5 | 4.0 | 14 |
| 4.0 | 3.5 | 7 |
| 3.5 | 3.0 | 2 |

*As long as the sum of the decimal fraction is less than 1.0, resource protection goals are maintained for larval recruitment.

Although this proposed criteria increases the number of allowable excursion days, it does continue to provide a more conservative assessment of variable data while favoring progress by allowing more excursion days in the higher DO interval.

Question 3:

-How do we provide for the interpretation of continuous data where daily averages can be calculated?

Provide guidance in the CALM for use of a smaller interval (like 0.1 mg/l) shown below, and reference to the EPA DO criteria document.

| DO Incremental range of 0.1 mg/l and duration data to be applied to continuous data for LIS. | | |
|--|---------|--------------------|
| DO Range (mg/L) | | No of Days Allowed |
| Maximum | Minimum | |
| 4.8 | 4.6 | 43 |
| 4.6 | 4.5 | 30 |
| 4.5 | 4.4 | 25 |
| 4.4 | 4.3 | 21 |
| 4.3 | 4.2 | 18 |
| 4.2 | 4.1 | 16 |
| 4.1 | 4.0 | 14 |
| 4.0 | 3.9 | 12 |
| 3.9 | 3.8 | 11 |

| | | |
|-----|-----|---|
| 3.8 | 3.7 | 9 |
| 3.7 | 3.6 | 8 |
| 3.6 | 3.5 | 7 |
| 3.5 | 3.4 | 6 |
| 3.4 | 3.3 | 5 |
| 3.3 | 3.2 | 4 |
| 3.2 | 3.1 | 3 |
| 3.1 | 3.0 | 2 |

References:

1. Connecticut Department of Environmental Protection, 2002. *Connecticut Water Quality Standards*. Bureau of Water Management, 79 Elm Street, Hartford, CT 06106-5127.
2. U.S. Environmental Protection Agency, 2000. *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*. U.S. EPA-822-R-00-012.
3. New York State Department of Environmental Conservation. Interpretation Guidance for Marine Dissolved Oxygen (DO) Standard. Phil O' Brien, Division of Water - Water Quality Section.

(email dated 9/9/2009)

A Fragile Sound is examined weekly by dedicated team /Norwalk News The Hour-

Development along the Norwalk and Saugatuck rivers just before reaching Long Island Sound has altered the condition of those estuarial waters, and one local expert knows why.

Dick Harris, director of Harbor Watch/River Watch, a program out of Earthplace in Westport, said the desire for waterfront property has drastically changed those waters, and the creatures in them.

"What's happened is the marshes have been taken out on both sides of the rivers, all the way up," Harris said. "That loss of marshland creates a weak current coming out into the Sound. It's a mistake developing those areas, when you lose the buffer of the marsh."

With those concerns in mind, Harris takes two or three trips a week with his crew up and down those rivers and around Norwalk Harbor, measuring oxygen levels and recording the numbers of fish.

The crew -- also on board "Annie" on Friday were HW/RW assistant director Pete Fraboni, HW/RW coastal studies technician Eric Sroka, volunteer Betsy Carlucci and intern Josh Cooper -- uses a metal cage that holds a fine-mesh net and is skimmed just off the bottom to capture a glimpse of the sea life.

"We try to be as scientific as possible," Harris said. "We use GPS and a depth finder. Just dragging the cage along the bottom doesn't show us what we want to see."

Harris and his crew visit pre-marked grid "boxes," 300 meters square, and drag the cage through that area. The netted life forms are then dumped into an examination box on the side of the boat, and catalogued.

"The (state Department of Environmental Protection) set up the boxes," Harris said. "We've been hitting them hard. When we troll, the cage stays in the water for three minutes. We're looking for what hatched this year."

Another team, Gerry and Karen Laroque, go out on weekdays to measure oxygen levels and record that data. **Any readings below three parts per million of oxygen means fish won't be there, Harris said.**

"If we find fish in say, box B, we know the oxygen levels are not below three (parts per million), or fish wouldn't be there," Harris said.

Three boxes were trolled Friday, with some unusual findings, according to Harris. Two winter flounder up to two years old were brought up, along with a winter flounder born this year, and a pipe fish.

The pure numbers don't necessarily concern Harris. Since June 23, when 23 fish were pulled up, the daily haul has reached double figures just twice in 15 trips. It's what's being brought up, or rather, what's not being caught, that worries Harris.

"With three more flounder we're up to 118 fish for the year, and that's been reasonably good," Harris said. "But there's not enough species. We haven't had a fish kill, and it's too late in the year for that now."

A fish kill is a situation where too many fish try to inhabit an area where oxygen levels are barely enough to handle a small number of fish.

"Last year, from Wall Street to the I-95 bridge, we lost about 10,000 fish," Harris said. "In the summer of 2005 we lost two million. The area above the Maritime Aquarium used to be a prime fishing area, with people catching up to 50 fish a day. That spot has never come back."

One of the biggest mysteries this year is the stark absence of bunkers, the bait fish that attract bluefish and striped bass into the harbor and beyond.

"No one has seen any bunkers," Harris said. "Now there's no incentive for blues and stripers to come in the harbor and feed. Those fishing coming in help the water quality."

Harris said his expeditions are the "only survey of this kind going on" in Connecticut, and he shares the data with state agencies.