Assessment Criteria for Nutrients in Selected Northeast Estuaries

January 2014

Developing Nutrient Criteria

Evaluating the role that nutrient levels play in supporting a healthy ecosystem is complex and challenging. Identifying the levels of nutrients and related response indicators that correspond to a healthy ecosystem is equally challenging and requires an understanding of the complex physical/chemical/biological interactions that occur under the unique circumstances present in a particular estuary. USEPA's guidance on developing nutrient criteria (USEPA 2001) recommends that states develop targets on a regional or site specific basis because estuarine systems are so variable and complex. A number of states have established narrative criteria for nutrients that describe the conditions that should be avoided, such as algal blooms, odors and other signs of eutrophication, and a few have translated these into nutrient targets expected to partially or fully achieve the desired conditions for the estuary in question. As a further complicating factor, there is mounting evidence that both nitrogen and phosphorus play a role in eutrophication, including in estuarine systems. For example, in the Chesapeake Bay, phosphorus has been found to be the limiting nutrient in the spring and nitrogen is limiting in the summer (USEPA, 2012). There are also different responses to forms of nutrients among different organisms. For example, blooms of the brown tide organism correlate with specific species of organic nitrogen, but not total nitrogen (Berg, et al, 2008). EPA recommends that, in both fresh and saline waters, numeric criteria related to aquatic life use support should be established for both nitrogen and phosphorus.

EPA suggests using one of two methods to determine nitrogen targets for an estuary (USEPA 2001). In the first method, targets can be based on historic data, if data is available from a time when the condition of the estuary was acceptable.

The other method would be to derive nutrient criteria based on those levels that correspond to target thresholds of indicators of a healthy ecosystem such as dissolved oxygen, chlorophyll-a, and/or water clarity. In Massachusetts, targets for nitrogen were determined based on nitrogen levels found in comparable habitats that had the desired characteristics within the estuary under study.

If there are no regional examples upon which to base targets, EPA guidance suggests that 10 micrograms/Liter (ug/L) of chlorophyll-a is an indication of a eutrophic estuary, 4 - 10 ug/L is mesotrophic and less than 4 ug/L is oligotrophic (USEPA, 2001). Setting nutrient criteria for a particular estuary would then follow developing an understanding of the nutrient levels that would result in the target level of chlorophyll-a, given the specific dynamics of the estuary. This second approach has already been taken in several northeast estuaries. Targets for restoration of the Chesapeake and New Hampshire's Great were set for response indicators and then water quality modeling determined the nitrogen loadings that would achieve those targets.

Comparison of Barnegat Bay to Other Northeast Estuaries

Like all estuaries, Barnegat Bay estuary has characteristics that will affect the nutrient-driven biological responses that are outside of ranges considered acceptable for a healthy ecosystem and

the levels of nutrients that would be associated with achieving a healthy level of biological response. A great deal of research is currently under way to establish the acceptable thresholds and relationships with nutrients in Barnegat Bay. To help inform the ongoing study, work already completed or underway in several other estuaries in the Northeast was examined, fully recognizing that work in other estuaries is not directly transferable to Barnegat Bay.

For example, the Chesapeake Bay is the best studied estuary and there is a wealth of information available from studies of Chesapeake Bay; however, it has very different characteristics compared to the Barnegat Bay. The Chesapeake is more open to the sea, while Barnegat Bay has access limited to relative narrow inlets. The Chesapeake also has great variations in depth, while the Barnegat Bay is primarily a shallow bay with an average depth of 6 feet. The Chesapeake has many miles of small inlets along its shores, giving it many miles of shoreline, while the Barnegat Bay has a simpler coastline. The Delaware Inland Bays are in close proximity to Barnegat Bay, so experience similar climactic conditions, and are also similar in terms of depth.

New England estuaries in Massachusetts and New Hampshire have also been studied. These waters are colder than New Jersey, but there is useful information that can be gathered from the studies. Massachusetts has many small back bays, and much work has been done assessing the bays and developing TMDLs for nitrogen and related parameters. The importance of taking into account site specific characteristics is illustrated in that the criteria that apply within the various bays within Massachusetts vary spatially. The work in New Hampshire's Great Bay takes a unique approach to dissolved oxygen criteria by including a limit for per cent saturation of dissolved oxygen. This is important because the capacity of water to contain dissolved oxygen is related to temperature. Therefore, selecting a dissolved oxygen criterion must reflect what is attainable in the specific estuary under natural conditions.

Long Island Sound is similar in shape to the Barnegat, but is a much deeper estuary and suffers from episodes of very low dissolved oxygen believed to be caused by excessive nutrients, a significant amount of which is contributed by point sources. The shallow areas of the Long Island Sound have some conditions, for example blooms of *Ulva*, in common with the Barnegat Bay (pers. comm. Lorraine Holdridge NYDEC) however, these areas are not yet well studied.

Although each of these estuaries is unique, it is hoped that a review of the work in the selected estuaries may contribute to the process of selecting water quality targets and management objectives in Barnegat Bay. A state by state summary of assessment methods and water quality targets for these estuaries follows.

<u>Great Bay, New Hampshire</u>

New Hampshire developed a site-specific numeric nutrient criterion for Great Bay (New Hampshire Department of Environmental Services, 2009) using data from the Great Bay National Estuarine Reserve's monitoring program, the University of New Hampshire Tidal Water Quality Monitoring Program, and the National Coastal Assessment. Data was used to develop linear regressions between concentrations of nitrogen and chlorophyll-a, dissolved oxygen and water clarity. Data from continuous monitoring was analyzed for dissolved oxygen impairments. Relationships between water quality and water clarity were quantified based on in situ sensor measurements and hyperspectral imagery.

At four stations throughout the Bay, one centrally located and three near the mouth of the major tributaries, data sondes recorded temperature, depth, salinity, turbidity, pH and dissolved oxygen every 15 minutes. In addition, monthly sampling was performed for dissolved inorganic nutrients, suspended solids, particulate organic matter and chlorophyll-a. A weather station collected data on temperature, precipitation and barometric pressure, relative humidity, photosynthetically active radiation and wind speed and direction. Data is collected year round.

The following thresholds were developed (New Hampshire Department of Environmental Services, 2009):

> …to maintain instantaneous dissolved oxygen concentrations greater than 5 mg/L and average daily concentrations greater than 75% saturation, the annual median total nitrogen concentration should be less than or equal to 0.45 mg/L and the 90^{th} percentile chlorophyll-a concentration should be less than or equal to 10 ug/L.
>
> For the protection of eelgrass habitat, the annual median total nitrogen concentration should be less than or equal to 0.25-0.30 mg/L and the annual median light attenuation coefficient (a measure of water clarity) should be less than or equal to 0.5-0.75 m^{-1}, depending on the eelgrass restoration depth.
>
> Thresholds were not established for phosphorus because nitrogen is the limiting nutrient in the majority of the estuary.

Delaware Inland Bays

In 1998 Delaware had both narrative and numeric criteria for nitrogen. Monitoring was conducted over a three year period, during the growing season and reported as maximum, minimum and average values reported by station. The narrative criteria state that waters should be maintained or restored to a natural condition. The numeric criteria used in the TMDL are as follows (Delaware, 1998):

> *a. Dissolved Oxygen (D.O.):*
> - 5.0 mg/l daily average (from June through September)
> - 4.0 mg/l minimum
>
> *b. Nutrients (Phosphorous and Nitrogen) during submerged aquatic vegetation growth season (March 1 through October 31):*
> - 0.01 mg/l Dissolved Inorganic Phosphorous (DIP)
> - 0.14 mg/l Dissolved Inorganic Nitrogen (DIN)
>
> *c. Total Suspended Solids (TSS) during submerged aquatic vegetation growth season (March 1 through October 31):*
> - 20 mg/l
>
> *e. Temperature:*
> - 86 degree Fahrenheit, maximum daily
> - 84 degree Fahrenheit, mean daily

- Maximum increase above natural condition: 4 degree Fahrenheit

Massachusetts Estuary Project

The Massachusetts coastline is comprised of a complicated series of back bays. The Massachusetts Estuary Project is undertaking an assessment of water quality in 89 southeastern Massachusetts back bays. Approximately 30 studies have been completed. Nitrogen thresholds were determined by measuring nitrogen levels that support healthy habitats similar to the areas that are being studied. Two indicators of habitat health were used, SAV coverage and health or, in areas where SAV would not naturally occur, benthic infauna (Brian Dudley, Mass DEP, pers comm.). They have found that the nitrogen thresholds can vary by as much as 50% for the same habitat quality depending on the characteristics of the habitat (Commonwealth of Massachusetts DEP, 2003). The site specific nitrogen targets range from 0.38 to 0.552 mg/L. For each back bay, at least three years of baseline water quality data (chlorophyll-a, dissolved oxygen, salinity temperature, and secchi depth) was collected to calibrate the model. The model used is the MEP (Massachusetts Estuary Project) linked model based on Army Corps RMA-2 (water quality) and RMA-4 (hydrodynamic) models (Commonwealth of Massachusetts, 2004, 2006 a, b, 2007 a, b, c, d, 2008 a).

After the baseline data was collected, continuous monitoring for chlorophyll-a and dissolved oxygen was done to characterize each area as excellent, good or poor habitat quality. Samples were taken for calibration and each site had a 35-day deployment. Data was analyzed to determine the % time above and below benchmarks (<6<5<4<3mg/L for dissolved oxygen and >5>10>15>20>25ug/l for chlorophyll-a). The characterizations were determined based on professional judgment; there are no numerical guidelines for the % of time below the standards would that would constitute a poor or fair characterization (Brian Dudley, Mass DEP, pers comm.).

Table 1: Characterization Guidelines

Health	**Nitrogen (mgN/L)**	**Dissolved Oxygen (mg/L)**	**Chlorophyll -a (µg/L)**	**Water Clarity (secchi depth)**	**Descriptive**
Excellent	below 0.30	greater than 6.0	less than 3	<3 meters	
Excellent to Good	0.30-0.39	not less than 6.0 mg/L	3 to 5		
Moderately Impaired	0.50 – 0.70	not below 4	10		Eelgrass is not sustainable, macro-algae blooms
Significantly Impaired Health	0.60 - 0.70	periodic hypoxia	20		Stressful oxygen conditions, major phyto-plankton blooms, and absence of eelgrass,

					periodic hypoxia, loss of diverse benthic animal populations periodic fish kills, significant macro-algal accumulation
Severely Degraded	>0.80	near complete loss of oxygen occurs periodically in bottom waters	macroalgal blooms		Periodic fish kills occur and benthic communities are often nearly absent

Chesapeake Bay

The Chesapeake Bay TMDL states the following "…[chlorophyll-a, dissolved oxygen and water clarity] criteria serve as surrogate numeric criteria for nitrogen, phosphorus, and sediment". The TMDL targets are for parameters affected by nitrogen. Nitrogen load reductions needed to achieve the targets are calculated based on modeling of the bay, establishing the relationship between nitrogen and the response parameter. Because the Chesapeake Bay is large and has a broad range of spatially varied conditions, there is a series of site-specific thresholds that have been developed. The criteria are summarized as follows:

- DO: based on designated use, ranges from 6 mg/L, 7 day mean with 5 mg/L instantaneous for fish spawning to ≥1 mg/L deep channel (for details see Table 3 below).
- Water clarity criteria (percent light-through-water) ranges from 13 to 22% depending on salinity.
- Chlorophyll-a thresholds range from 4 to 22ug/L depending on location. Chesapeake Bay narrative chlorophyll *a* criteria are as follows:

> Concentrations of chlorophyll-*a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences—such as reduced water clarity, low dissolved oxygen, food supply imbalances, proliferation of species deemed potentially harmful to aquatic life or humans or aesthetically objectionable conditions—or otherwise render tidal waters unsuitable for designated uses (USEPA, 2001).

Figure 1 below depicts the minimum oxygen levels needed by various species to survive in the Chesapeake Bay.

.

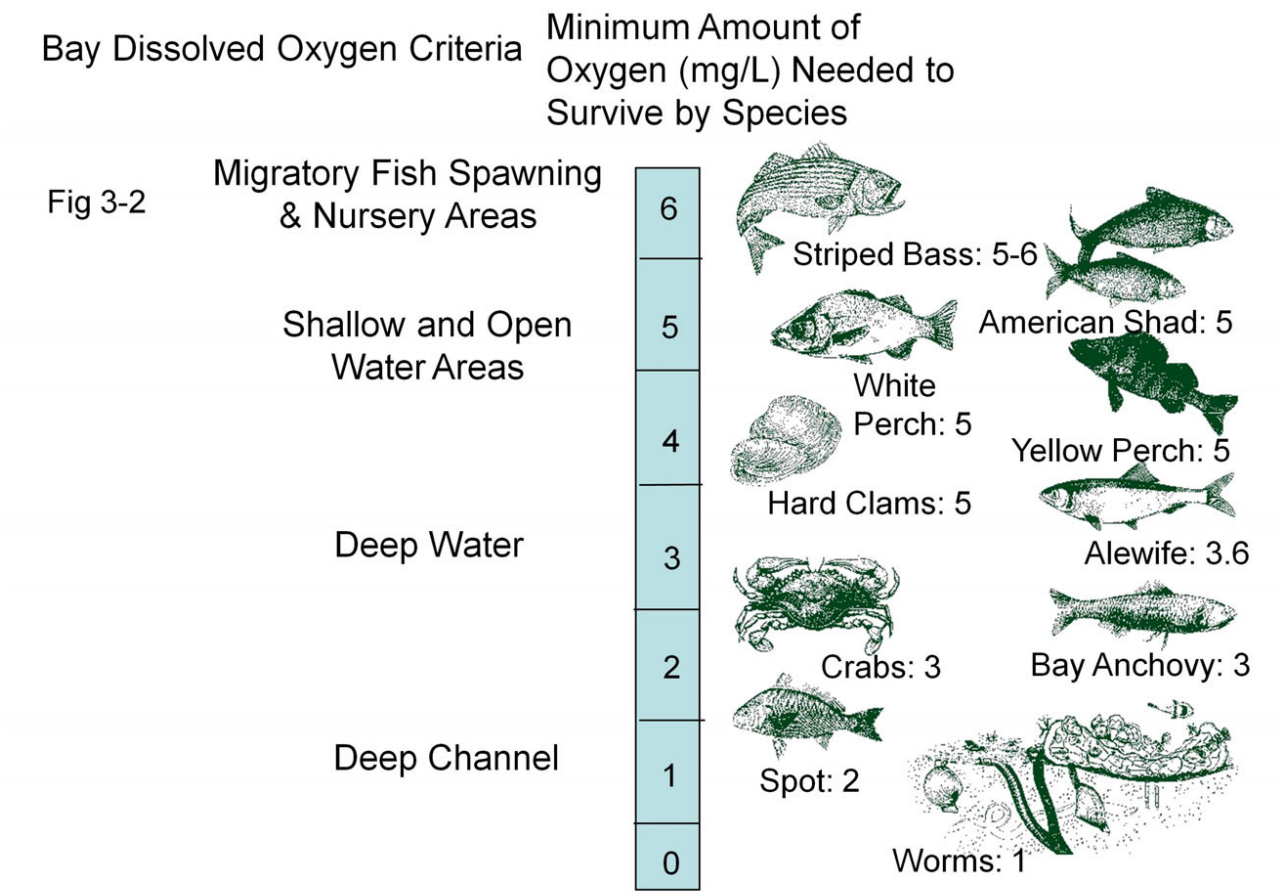

Figure1. Dissolved oxygen concentrations (mg/L) required by different Chesapeake Bay species and biological communities. (Source: USEPA 2010)

Long Island Sound

Dissolved oxygen criteria used for the Long Island Sound TMDL reflect the criteria in use at the time the TMDL was developed in the participating states. The dissolved oxygen targets 5mg/L (New York) and 6 mg/L (Connecticut) in TMDLs completed in the year 2000 (New York State and State of Connecticut, 2000). New York and Connecticut subsequently revised their standards to match EPA's requirements more closely, greater than or equal to 4.8 mg/L with time limits on lower values (State of Connecticut DEP, 2011), but the TMDL for Long Island Sound has not been revised to reflect the statewide criteria. Because anoxic conditions exist in the Sound, the focus has been dissolved oxygen. Anoxia is defined as less than 3mg/L. Dissolved oxygen is reported in terms of the number of days below the anoxic threshold, known as "hypoxic days". Nitrogen levels have not been well monitored. Modeled results for nitrogen were used to develop loadings (pers. comm. Lorraine Holdridge NYDEC). This information is

provided here for completeness however, the issues in the Long Island Sound are too different from those in the Barnegat Bay to provide any useful comparisons.

Summary of Criteria Used in Northeast Estuary Studies

For ease of comparison, the criteria from the various estuary studies are summarized in Table 2, below.

Table 2: Summary of Criteria and Assessment Methods

State	Parameter	Criteria	Sampling	Assessment
Massachusetts Back Bays (Commonwealth of Massachusetts)	Nitrogen	Site specific: 0. 38 to 0. 552 mg/L	Samples were collected once every two weeks at ebb tide from mid-June to mid-September.	A yearly mean was calculated for each station and then an overall mean was calculated for each station using the yearly means from each year of sampling (usually three years).
	Dissolved Oxygen	Not less than 6. 0 mg/L	Three years of baseline data collected and analyzed as N above.	A yearly mean was calculated for each station and then an overall mean was calculated for each station using the yearly means from each year of sampling (usually three years).
			Electronic sensor systems at critical locations within each estuary during July and August done after the baseline data collection to be used for characterization.	Continuous monitoring with samples taken for calibrations, 35 day deployment, % time above and below benchmarks and temporal trends observed <6,<5<4<3 mg/L DO.
	Chlorophyll-a	<5 ug/L	July and August continuous monitoring with samples taken for calibrations, 35 day deployment done after the baseline data	A yearly mean was calculated for each station and then an overall mean was calculated for each station using the yearly means from each year of sampling (usually three years). Continuous

			collection to be used for characterization.	monitoring % time above and below benchmarks >5>10>15>20>25 ug/L, Temporal trends observed
New Hampshire, Great Bay (New Hampshire DES, 2009)	Nitrogen	0.25- 0.45 mg/ L	Year round	Monthly, four locations in Bay (Great Bay monitoring website)
	Dissolved Oxygen	Maintain instantaneous concentrations greater than 5 mg/L and average daily concentrations greater than 75% saturation.	Daily minimum Year round	Measured by datasond every 15 minutes at four stations (Great Bay Monitoring Website)
	Chlorophyll-a	10 ug/L	Year round Measured monthly 4 stations	90^{th} percentile concentration should be less than or equal to 10 ug/L
	Water clarity	Annual median light attenuation coefficient (a measure of water clarity) should be less than or equal to 0.5-0.75 m-1 depending on the eelgrass restoration depth	March to December	Instantaneous samples daily average, number of samples varied greatly dependent on location

Delaware Inland Bays (Delaware, 1998)	Nitrogen Phosphorus	0.01 mg/L Dissolved Inorganic Phosphorous (DIP) - 0.14 mg/L Dissolved Inorganic Nitrogen (DIN)	March 1 through October 31 Max, min, average reported by station	a. A waterbody is considered fully supporting its designated uses when at least 90 percent of the observations meet applicable water quality standards. b. A waterbody is considered partially supporting its designated uses when between 75 to 90 percent of the observations meet applicable water quality standards. c. A waterbody is considered to not support its designated uses when less than 75 percent of the observations meet applicable water quality standards. (Delaware Surface Water Quality Standards, 1993)
	Dissolved Oxygen	5.0 mg/L daily average (from) - 4.0 mg/L minimum	Average daily concentration June through September Max, min, average reported by station	
	Chlorophyll-a	20 ug/l also narrative, must have no evidence of adverse conditions	During growing season Max, min, average reported by station	
	TSS	20 mg/L	During submerged aquatic vegetation growth season (March 1 through October 31), Max, min, average reported by station	

Long Island Sound (New York State Department of Environmental Conservation and Connecticut Department of Environmental Protection, 2000)	Dissolved Oxygen	CT: DO 6 mg/L, NY: 5 mg/L original TMDL Currently using EPA marine standards.	Monthly samples taken year round Water column profiles June – September.	Continuous monitoring, time weighted average Number of "anoxic days" is the measure of concern. (pers. comm. Lorraine Holdridge NYDEC)
Chesapeake Bay	Chlorophyll-a	4 to 22 ug/L depending on location	The mean annual cycle based on monthly means and standard errors for a range of climate conditions a mean annual cycle with seasonal resolution	The state-adopted concentration-based chlorophyll *a* criteria values are threshold concentrations that should only be exceeded infrequently (e.g., <10%) since a low number of naturally occurring exceedances occur even in a healthy phytoplankton population. (See note 1.)
	DO	Based on designated use, ranges from 6 mg/L, 7 day mean with 5 mg/L instantaneous for fish spawning to ≥1 mg/L deep channel	See table 3	See table 3
	Water clarity criteria (percent light-through-water)	Ranges from 13 to 22% depending on salinity	SAV growing season measured using a Secchi disk or a light meter	Based on monitoring data collected over a 3-year period in each spatial assessment unit. (See note 2.)

Chesapeake Note 1: To assess attainment of the State adopted numerical chlorophyll-*a* concentration based criteria, it was necessary to establish a reference curve for use in the cumulative frequency diagram criteria attainment assessment process (USEPA 2003, 2007). In the case of chlorophyll-a criteria, where a biologically-based reference curve is not available, EPA recommends the states' use of the default reference curve originally described in Chapter 2, Figure II-4 and Equation 1 in US EPA 2007.

Chesapeake Note 2: The spatial exceedances of criteria are determined using a grid cell-based data interpolation software application that enables estimation of water quality values for the entire Bay using monitored data at specific points. The temporal extent of exceedances is determined by calculating the probability that an observed percent exceedance will be equaled or exceeded. To calculate that probability, the percent of spatial exceedances are sorted and ranked, and a cumulative probability is calculated for each spatial exceedance value (USEPA, 2010).

Table 3: Current Chesapeake Bay DO criteria

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

Source: USEPA 2010

References

G. M. Berg et. al. *Understanding Nitrogen Limitation in* Aureococcus Anophagefferens *(Pelagophyceae) Through Cdna And Qrt-Pcr Analysis*, Journal of Phycology Vol 44, Issue 5, pages 1235–1249, October 2008
http://onlinelibrary.wiley.com/doi/10.1111/j.1529-8817.2008.00571.x/abstract

Commonwealth of Massachusetts, Executive Office Of Environmental Affairs, Massachusetts Department Of Environmental Protection *Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators Interim Report.* December 22, 2003
http://www.mass.gov/eea/docs/dep/water/resources/n-thru-y/nitroest.pdf

Commonwealth of Massachusetts, Executive Office Of Environmental Affairs, Massachusetts Department Of Environmental Protection, *Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek Total Maximum Daily Loads For Total Nitrogen* (Report # MA96- TMDL Control # CN206.0), November 17, 2004
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth of Massachusetts, *Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit Bay System Total Maximum Daily Loads for Total Nitrogen* (Report # 96-TMDL-5 Control #218.0), January 31, 2006 a
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *Great, Green and Bournes Pond Embayment Systems Total Maximum Daily Loads For Total Nitrogen* (Report # 96-TMDL-6 Control #181.0) April 6, 2006 b
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth Of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *West Falmouth Harbor Embayment System Total Maximum Daily Loads For Total Nitrogen* (Report # 95-TMDL-1 Control #243.0) November 19, 2007 a
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth Of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *FINAL Phinneys Harbor Embayment System Total Maximum Daily Loads For Total Nitrogen* 95-TMDL-2 CN#247.0, November 26, 2007 b
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth Of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *FINAL Pleasant Bay System Total Maximum Daily Loads For Total Nitrogen* (Report # 96-TMDL-12,Control #244.0), May, 2007 c
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth Of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *FINAL Three Bays System Total Maximum Daily Loads For Total Nitrogen* (Report # 96-TMDL-10 Control #242.0) September 7, 2007 d
http://www.epa.gov/region1/eco/tmdl/pdfs

Commonwealth Of Massachusetts, Executive Office of Energy And Environmental Affairs, Massachusetts Department of Environmental Protection Bureau of Resource Protection, *FINAL Centerville River - East Bay System Total Maximum Daily Loads For Total Nitrogen* (Report # 96-TMDL-14 Control #248.0) January 29, 2008 a
http://www.epa.gov/region1/eco/tmdl/pdfs

Delaware Department of Natural Resources and Environmental Control; *Total Maximum Daily Load (TMDL) Analysis For Indian River, Indian River Bay, And Rehoboth Bay, Delaware;* December 1998
http://www.dnrec.delaware.gov/swc/wa/Documents/TMDL_TechnicalAnalysisDocuments/19_InlandBaysTMDLAnalysis.pdf

Great Bay National Estuarine Reserve Monitoring website
http://www.greatbay.org/programs/monitoring.htm

New Hampshire Department of Environmental Services, *Numeric Nutrient Criteria for the Great Bay Estuary*, June 2009
http://www.epa.gov/region1/eco/tmdl/pdfs

New York State Department of Environmental Conservation and Connecticut Department of Environmental Protection, *A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound* December 2000
http://www.epa.gov/region1/eco/tmdl/pdfs

State of Connecticut DEP, Water Quality Standards, February 25. 20011
http://www.ct.gov/dep/lib/dep/water/water_quality_standards/wqs_final_adopted_2_25_11.pdf

USEPA , *Nutrient Criteria Technical Guidance Manual Estuarine Coastal and Marine Waters, Office of Water*, EPA-822-B-01-003, October, 2001
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/marine/index.cfm

USEPA, *Decision Rationale Total Maximum Daily Loads for Upper and Middle Chester Rivers for Nitrogen and Phosphorus in Kent and Queen Anne's Counties, Maryland*, April 4, 2007
http://www.epa.gov/region1/eco/tmdl/pdfs

U.S. Environmental Protection Agency. 2003. *Ambient Water Quality Criteria for Dissolved*

Oxygen, Water Clarity and Chlorophyll a for Chesapeake Bay and Its Tidal Tributaries. EPA 903-R-03-002. Region III Chesapeake Bay Program Office, Annapolis, MD. http://www.epa.gov/region3/chesapeake/baycriteria/Criteria_Final.pdf

USEPA *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and its Tidal Tributaries 2007 Addendum* July 2007 http://www.chesapeakebay.net/content/publications/cbp_27849.pdf

USEPA *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment* December 29, 2010 http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf

USEPA, Fact Sheet, *Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria* Office of Water, 820-S-12-002 MC 4304T, December 2012 http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/NandPfactsheet.pdf