Establishing Nitrogen Target Concentrations for Three Long Island Sound Watershed Groupings:

Embayments, Large Riverine Systems, and Western Long Island Sound Open Water

Subtasks F/G. Summary of Empirical Modeling and Nitrogen Target Concentrations

Submitted to:

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Submitted by:

Tetra Tech, Inc.

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This Tetra Tech technical study was commissioned by the United States Environmental Protection Agency (EPA) to synthesize and analyze water quality data to assess nitrogen-related water quality conditions in Long Island Sound and its embayments, based on the best scientific information reasonably available. This study is neither a proposed Total Maximum Daily Load (TMDL), nor proposed water quality criteria, nor recommended criteria. The study is not a regulation, is not guidance, and cannot impose legally binding requirements on EPA, States, Tribes, or the regulated community. The technical study might not apply to a particular situation or circumstance, but it is intended as a source of relevant information to be used by water quality managers, at their discretion, in developing nitrogen reduction strategies.

Subtasks F and G. Summary of Empirical Modeling and Nitrogen Target Concentrations

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Subtask F. Summary of Empirical Modeling

Introduction

The U.S. Environmental Protection Agency (EPA) determined their *management goal* to be reestablishing and maintaining water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish. *Assessment endpoints* for this management goal were determined to be (1) estuarine eelgrass habitat abundance and distribution and (2) benthic and pelagic community diversity and abundance.

Terminology Overview for Nutrient Analyses

Management goal: Statement about the desired condition of ecological values of concern. Designated uses are often considered management goals.

Assessment endpoint: Explicit expressions of the environmental value that is to be protected, operationally defined by an ecological entity and its attributes.

Measures of effect: changes in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed (e.g., seagrass coverage).

Primary response variable: Measures of effect and exposure to nutrient stress (e.g., chlorophyll *a* for seagrass and DO for benthic and pelagic communities).

Primary causal variable: Nutrient stressors in the system inducing adverse responses (e.g., total nitrogen).

Source: USEPA 1998.

The primary response variables considered to characterize the *assessment endpoints* included algal biomass as measured by water column chlorophyll *a* (for its influence on light for seagrass growth and known use as a measure of nutrient effect) and dissolved oxygen (DO) (through its effect on benthic fauna and fishes and its responsiveness to nutrients). Benthic fauna were not explicitly reviewed in the *Literature Review Memo*; this was largely a function of a lack of sufficient data and indicator tools for this group across Long Island Sound (LIS). However, benthic fauna are valued aquatic life dependent on both seagrass and sufficient DO, and their consideration was implicit in the selection of the response variables for which there were abundant data across LIS (i.e., chlorophyll *a*, clarity, and DO). The value of using multiple response variables is that, for those habitats where seagrass might not be expected (e.g., deeper waters), considering DO provided protection of other aquatic life.

To achieve the management goal, EPA developed nitrogen target concentrations (and not loadings) because temporally resolved load measures or estimates (i.e., annual estimates) were not available for each embayment that could be matched to response conditions. Additionally, concentrations could be compared to the temporally varying response variables discussed in the Subtask D Memo, concentrations are directly related to organism response, and concentrations are consistent with EPA guidance. EPA conducted empirical analyses to support development of nitrogen target concentrations for the selected watersheds (Figure F-1). Three complementary empirical approaches (lines of evidence) were used to identify candidate total nitrogen (TN) target concentrations:

- Scientific Literature Analysis: Acquired literature-based nitrogen target concentrations associated with protection of comparable management goals (seagrasses and other aquatic life) in similar estuaries during development of the *Literature Review Memo*.
- Stressor-Response Analysis: Identified chlorophyll *a* primary response variable values from the literature and from empirical statistical models of light availability (Secchi or light attenuation) and DO as a function of chlorophyll *a*. Using these chlorophyll *a* values, developed nitrogen target concentrations from empirical statistical models relating chlorophyll *a* to TN using LIS

surface (depth less than or equal to 4 meters [m]) water quality data (*Subtask D: Summary of Existing Water Quality Data*).

- Distribution-Based Approach:[1] Developed nitrogen target concentrations from 25th percentiles of TN concentration distributions in embayment and open water stations.

From these three lines of evidence, water body-specific nitrogen target concentrations are identified in Subtask G.

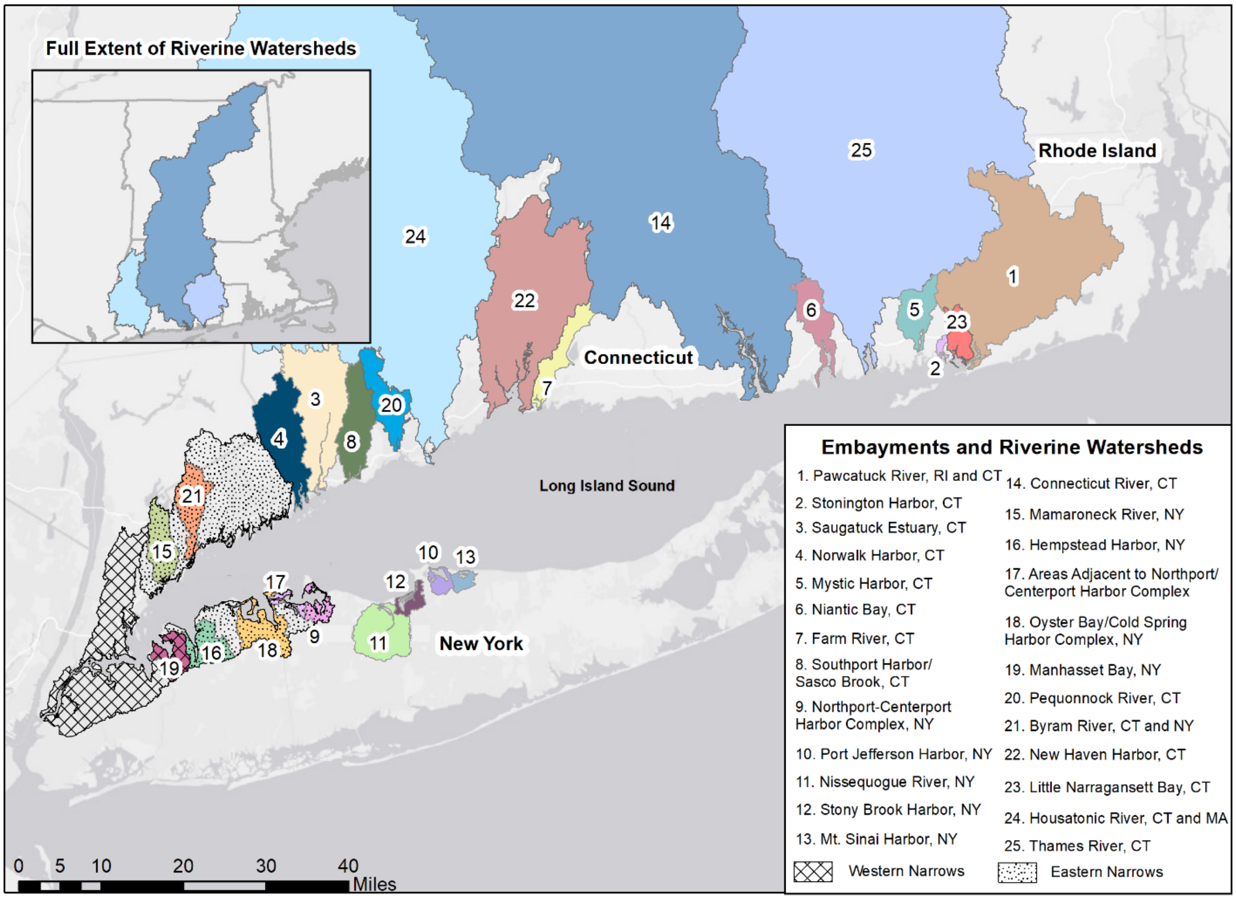

Figure F-1. Map of Study Area Indicating LIS Watersheds Evaluated

Methods

Scientific Literature Analysis

EPA conducted a literature review to evaluate biological, chemical, and physical aspects of possible assessment endpoint measures (seagrass, macroalgae, DO, phytoplankton, harmful algal blooms, and oysters) to protect designated uses. In conducting the search, EPA focused geographically on estuaries and bays from the Chesapeake Bay north to the state of Maine and on studies published since 1980. From the literature search, EPA identified literature-based TN values relevant to protecting designated

[1] The distribution-based approach, often referred to as the *reference-based approach*, has been frequently applied to deriving target concentrations for various applications, including Total Maximum Daily Loads and criteria (USEPA 1999, 2001).

uses in LIS. EPA also identified literature-based light/clarity values relevant to protecting seagrasses and summarized existing DO criteria relevant to protecting aquatic life in LIS. Additional detail is available in the *Literature Review Memo*. A decision was made to focus primarily on values from the most proximate study areas (those in Massachusetts) and not to incorporate values from farther north (Great Bay, NH) or south (Chesapeake Bay) because those systems were considered substantially different—the northern systems being farther from the Virginian province and the southern estuarine system being substantially different in terms of size, geography, hydrodynamics, salinity structure, and climate. The approach assumes that the Massachusetts estuaries' literature-based targets were appropriate for LIS, given their similarities in geography, climate, and species composition (e.g., *Zostera marina*) consistent with similar physical and chemical habitat requirements in both embayment as well as shallow and deeper open water habitats. For the stressor-response line of evidence, EPA selected TN values protective of seagrass and other aquatic life.

A synthesis of the resultant TN values is shown in Table F-1.

For embayments, EPA selected a median value of 0.40 milligram per liter (mg/L) TN to protect the seagrasses. This value is the rounded value of the median TN protective of seagrasses (0.39 mg/L; range: 0.30–0.49 mg/L). Values above the literature review maximum TN concentration of 0.49 mg/L were not considered protective of eelgrass (see Table F-1).

EPA identified a TN concentration of 0.80 mg/L as a severe degradation level for embayments regionally. Generally, at TN concentrations at or above this level: macroalgal accumulation, near or complete loss of DO, and fish kills are observed; benthic communities are often nearly absent during the warmer months or composed of only a few species of the most stress-tolerant species; and seagrasses are generally absent (Howes et al. 2003). Therefore, values at or above 0.80 mg/L were excluded from consideration, leaving 0.60 mg/L as the maximum value (see Table F-1). As a result, for open water segments, EPA used the median of all TN values (0.41 mg/L TN rounded to 0.40 mg/L) and range (0.30–0.60 mg/L TN).

Table F-1. Summary of Literature Review-Based Target Concentrations for Total Nitrogen

	TN (mg/L)	Management Goal	Location	Citation
	0.49	Seagrass transplant survival > 50%	SE Massachusetts estuaries	Benson et al. 2013[a]
	0.39	Seagrass transplant survival > 75%		
	0.42	Healthy seagrass		
	0.34	Seagrass survival		
	0.31	Restoration of eelgrass	Massachusetts estuaries	MEP 2017[b, d]
	0.49	Restoration of eelgrass		
	0.30	Eelgrass present	SE Massachusetts embayments	Howes et al. 2003[c]
	0.39	Eelgrass present		
Median	0.39	Summary for TN target concentrations for seagrass protection and restoration (used for literature line of evidence for embayments, N=8)		
Min	0.30			
Max	0.49			
	0.40	Infaunal habitat protection	Massachusetts estuaries	MEP 2017[d]
	0.60	Infaunal habitat protection		
	0.41	Benthic habitat protection		
	0.91	Benthic habitat protection		
	0.50	Upper end of good/fair conditions and lower end of moderate impairment	SE Massachusetts embayments	Howes et al. 2003[c]
	0.80	Severe ecological degradation begins		
	0.30	No macroalgae		
	0.50	Macroalgae might occur in some regions		
	0.39	DO generally >5 mg/L		
	0.50	DO generally >5 mg/L		
Median	0.41	Summary for TN target concentrations for other aquatic life protection and restoration (excluding values at or above severe degradation level of 0.80, N=16) (used for literature line of evidence for open waters)		
Min	0.30			
Max	0.60			
Median	0.46	Summary for TN target concentrations for non-seagrass protection and restoration (excluding values at or above severe degradation level of 0.80, N=8)		
Min	0.30			
Max	0.60			

Notes: mg/L = milligrams per liter.
[a] Long-term tidally averaged value.
[b] Long-term average.
[c] Long-term, ebb tide average.
[d] See Appendix F1 for additional information about the 33 documents included in this citation.

Stressor-Response Analysis

For the stressor-response method, EPA developed empirical statistical stressor-response relationship models using surface water quality data described in *Subtask D: Summary of Existing Water Quality Data.* EPA identified three watershed groupings: embayments, riverine, and open water. Hierarchical regression was used to model embayment and riverine data together (the Connecticut, Housatonic, and Thames rivers downstream to their areas of influence were included as additional embayments), and multiple linear regression was used to model open water observations. The stressor-response line of evidence was limited to primary response variables for which EPA had sufficient data across LIS, which included chlorophyll *a* and DO. The chlorophyll *a* response was explored in the context of providing enough light for eelgrass growth, which supports aquatic life and, therefore, addresses those management goals. The DO response is also a measure of aquatic life support and addressed that management goal as well. Other potential response measures reviewed in the literature review document (macroalgae, harmful algal blooms, oysters, and phytoplankton assemblage structure) lacked sufficient data across LIS to be modeled as primary responses directly within this line of evidence so were not incorporated into the stressor-response analysis directly.

Hierarchical Models

Hierarchical models are also known as *multilevel models*, *mixed models*, and *mixed-effects models*. These models are "mixed" in that they contain both population (so-called "fixed") parameters and group-adjusted (so-called "random") parameters. Hierarchical models can be viewed as an extension of linear regression models. For example, a linear regression model of chlorophyll *a* as a function of TN takes the following form:

$$Chlorophyll_i = \beta_0 + \beta_1 * TN_i + \beta_2 * X_i + e_i \qquad \text{(Equation 1)}$$

where:

- *TN* is the predictor variable
- chlorophyll *a* is the response variable
- β_0 is the intercept
- β_1 is the nitrogen slope
- *X* is another covariate of interest
- β_2 is the covariate slope
- e_i is the error term
- *i* is an index for each observation or row in the dataset

Linear Models

Multiple linear regression is simply a linear regression model with more than one predictor variable.

One statistical assumption for multiple linear regression is that the data are independent. Statistical independence means that data from different observations do not depend on each other. An example of *dependent* data is repeated measurements of patients' blood pressure over time. In this example, one would expect some level of homogeneity within each patient. This homogeneity or similarity of observations within a group (here, patient ID is the group factor) lowers the *effective* sample size of the model relative to the assumed sample size. This discrepancy can result in the level of uncertainty being underestimated, which leads to overconfidence in the model results.

Dependent data can be accounted for in statistical models. One method is to model the group factor as a "random effect" in a linear mixed-effects model. Multiple linear regression will estimate a single error variance parameter, which is an estimate of how "noisy" the model fit is relative to the observed data. In contrast, a mixed-effects model will estimate an additional error variance for each specified random effect group.

In addition to accounting for data dependency, hierarchical models can use the estimated group variance to estimate the amount each group level differs from the population estimate. For example, consider the following hierarchical model:

$$Chlorophyll_{ij} = \left(\beta_0 + \beta_{0j}\right) + \left(\beta_1 + \beta_{1j}\right) * TN_{ij} + \beta_2 * X_{ij} + e_{ij} \qquad \text{(Equation 2)}$$

where:

- β_0 is the intercept
- β_{0j} are the intercept adjustments for each embayment group
- β_1 is the nitrogen slope
- β_{1j} are the slope adjustments for each embayment group
- β_2 is the covariate slope
- e_{ij} is the error term
- j is an index for each embayment group
- i is an index for each observation within group j

Note that β_0 represents a single estimate, while β_{0j} represents j estimates. β_0, β_1, and β_2 are the fixed effects, and β_{0j} and β_{1j} are the random effects. This model contains both random intercepts and random slopes.

This model is an equivalent hierarchical representation of the above model:

$$Chlorophyll_{ij} = B0_j + B1_j * TN_{ij} + B2 * X_{ij} + e_{ij} \qquad \text{[Level 1]} \qquad \text{(Equation 3)}$$

$$B0_j = \gamma 00 + U0_j \qquad \text{[Level 2, Random Intercepts]}$$

$$B1_j = \gamma 01 + U1_j \qquad \text{[Level 2, Random Slopes]}$$

with

$$\begin{pmatrix} U0_j \\ U1_j \end{pmatrix} \sim N\begin{pmatrix} 0 & \tau 00^2 & \tau 01 \\ 0' & \tau 01 & \tau 10^2 \end{pmatrix} \qquad \text{[Random Effects are Normally Distributed]}$$

$$e_{ij} \sim N(0, \sigma^2) \qquad \text{[Residual Errors]}$$

where the random intercepts and random slopes of U0 and U1 are multivariate normally distributed with a means of zero and a variance-covariance matrix as specified. For this mixed-effect model, the unexplained variance (error) is partitioned into the random intercept variance ($\tau 00^2$), the random slope variance ($\tau 10^2$), and the residual variance (σ^2).

Hierarchical models are appropriate for data that can be organized at multiple levels. For this subtask, grab sample data (level 1) is available across multiple embayments (level 2). Note that open water observations were modeled separately, but the riverine areas of influence were included in the embayment models.

Multilevel datasets can be analyzed in several ways. One method is to ignore the groups, pool all the data together, and use linear regression. This pooling method provides population estimates of intercept and slope but does not produce any insight into potential differences among the groups. Another way to analyze multilevel data is to partition the dataset by group and analyze each group separately using linear regression. This partitioning method provides group-only estimates of intercept and slope. However, statistical power could be greatly reduced (i.e., uncertainty in estimates has increased) because of the smaller sample size for each group-specific model. Uncertainty could also vary greatly across models if group sample sizes are unbalanced.

Hierarchical models represent the best of both the pooled and the partitioned methods. A hierarchical model estimates both population and group-adjusted parameters in one model. One can view the group-adjusted estimates as a compromise between the population fit and the group-only fit (Figure F-2).

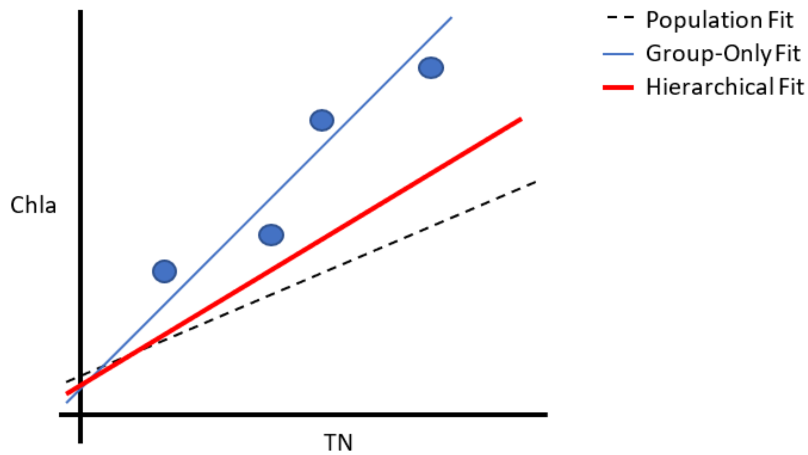

Figure F-2. Illustrative Example of How a Hierarchical Fit is a Weighted Average between the Population Fit and the Group-Only Fit

The group-adjusted, or hierarchical, fit estimates from a hierarchical model are known as "shrinkage" estimates because the group-only estimates produced from partitioned models are shrunk toward the population estimate, as shown in Figure F-3. Note that Figure F-2 and Figure F-3 are complementary. In Figure F-2, one group is shown shrunk toward the population fit. In Figure F-3, all of the groups are shown shrunk toward the population estimate. Groups with fewer observations will be more heavily influenced by the population fit.

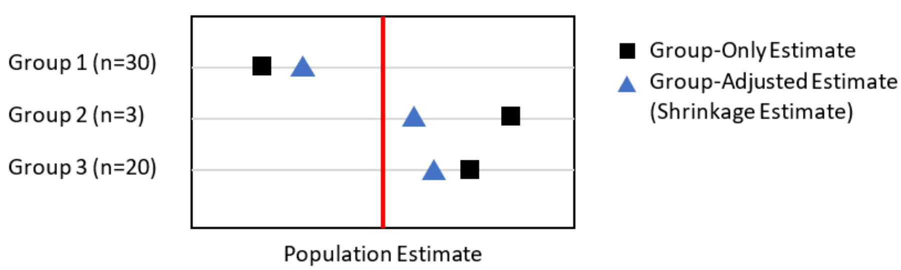

Figure F-3. Illustrative Example of How Group-Only Estimates are Shrunk toward the Population Estimate

Hierarchical models treat the groups as a random effect.

Another option for analyzing multilevel data is to include the groups as a fixed effect in a linear regression model:

$$Chlorophyll\ a_i = \beta_0 + \beta_1 * TN_i + \beta_{2,i} * group_i + e_i \quad \text{(Equation 3)}$$

where β_2 is a set of group-specific intercept estimates.

Modeling the groups as fixed effects is appropriate when all the potential group levels are known and adequately represented in the dataset and the researcher is interested in hypothesis testing for differences among the groups. For example, if the groups are "treatment" and "control" in an experiment and the goal is to see if the difference between the two groups is significant, then modeling the two groups as a fixed effect is appropriate.

Often, however, the dataset does not represent all the potential groups, group representation is severely unbalanced in the dataset (which could amplify heteroscedasticity because of inaccurate variance estimation on under-represented groups), or hypothesis testing among group levels is not of interest. In an experimental study, one anticipates the treatment group to respond differently than the control group. In contrast, the underlying science for many observational studies might suggest a single population trend for the population, with some variation allowed for each group within the population. The variation among groups could be the result of unobserved factors. Hierarchical models are appropriate when one assumes a population trend but also wants the flexibility to account for group variation. A hierarchical model is also better able to handle unbalanced datasets because of its ability to "borrow strength" from the population fit (Figure F-3).

A key benefit of hierarchical models is their ability to make predictions for unobserved groups. Hierarchical models treat the group as "random," meaning it is a random subsample of the larger list of groups. Here, not every LIS embayment has been sampled. If every embayment had been sampled (and the samples were approximately balanced), then a regular linear model would be appropriate. A hierarchical model accounts for the fact that not all embayments have data, via the shrunken estimates. For embayments with no paired data, a hierarchical model produces a population fit that describes an "average" embayment, given the data of observed embayments.

LIS Embayment Hierarchical Models

EPA developed hierarchical regression models to quantify various relationships for selected embayments. Twenty-two embayments and three riverine systems (the Connecticut, Housatonic, and Thames rivers) were identified by EPA as watersheds on which to focus. Data for the Connecticut, Housatonic, and Thames river areas of influence (see *Subtask E: Summary of Hydrodynamic Analysis)* were modeled along with the embayment data, rather than modeled separately, because of the sparsity of paired data for the rivers and the fact that they are essentially embayments that support suitable eelgrass habitat along portions of their estuaries (see Figure F-4) (Vaudrey et al. 2013). Since *Subtask E: Summary of Hydrodynamic Analysis* did not indicate substantial contribution (more than 10 percent) of riverine influence beyond the mouth of each river, EPA used the mouths of the three riverine estuaries to define the southern extent of the riverine area of influence for each riverine embayment. The areas defined by that boundary were used to define the extent of the embayments for subsequent analysis. Data from additional LIS embayments (other than the 22 on which this analysis focused) were also included in the hierarchical models. The additional data reduce error and allow the models to better estimate the overall LIS trend, which in turn will aid in the estimate for embayments, particularly those with few paired observations. EPA uses the term *paired data* for data collected for different parameters (e.g., chlorophyll *a* and nutrients) on the same day and specific location in the water body. Paired data used for the analyses are available in Appendix F2.

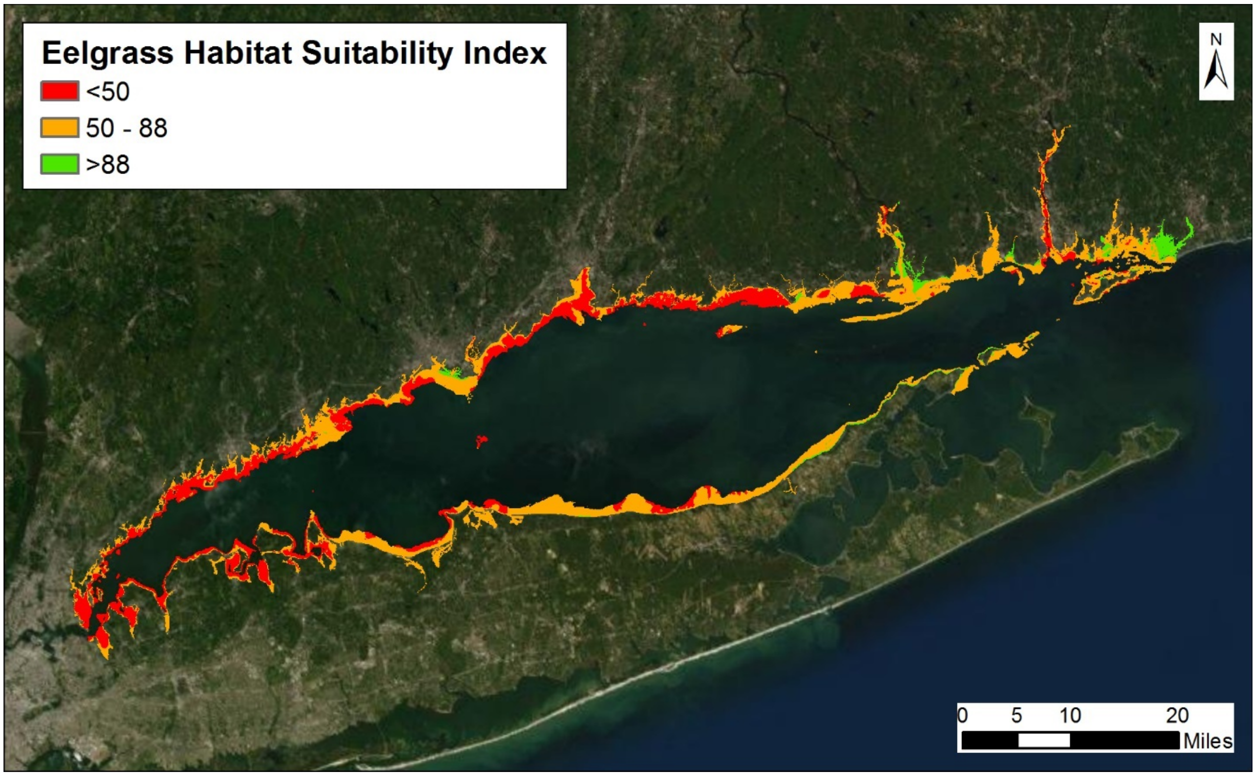

Figure F-4. LIS Map of Eelgrass Habitat Suitability Index (*Source*: Vaudrey et al. 2013)

The goal is to develop nitrogen target concentrations that protect eelgrass and other aquatic life (the management goals) within LIS. A simplified conceptual model of nutrient effects on eelgrass and other aquatic life is shown in Figure F-5. See the *Literature Review Memo* for additional information on various LIS management goals.

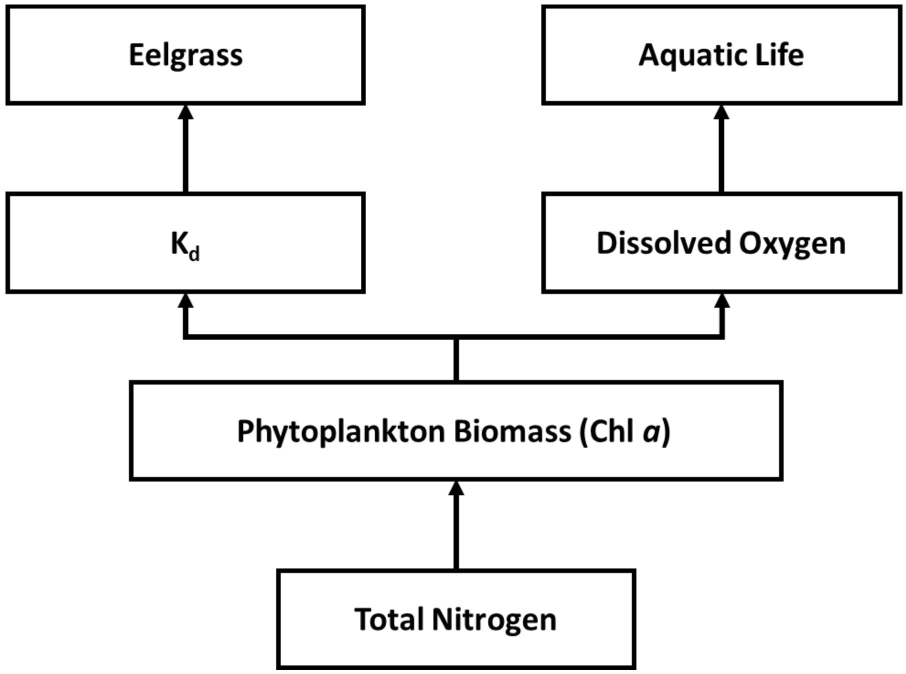

Figure F-5. Simplified Diagram of the Relationship between Key Variables and Management Goals

Eelgrass and aquatic life abundance are directly affected by light availability and DO. Eelgrasses require sufficient surface light reaching colonization depths to grow. If ambient light is attenuated by substances in the water column, including algal biomass (phytoplankton), dissolved organic matter, and/or suspended inorganic sediment, then there might be insufficient light at depth for eelgrass growth and survival. The light attenuation coefficient (K_d) is a function of water clarity. Increased dissolved organic matter and particulates, including phytoplankton biomass, reduce clarity (increase light attenuation) through both light absorbance and scatter. Phytoplankton biomass is quantified by measuring levels of chlorophyll, a primary algal photosynthetic pigment.

The amount of surface light required at maximum colonization depth for eelgrass (*Zostera marina*), the dominant seagrass in LIS, across the Northern Hemisphere ranges from 4 to 44 percent (Latimer et al. 2014), and along the East Coast of the United States, minimum requirements for eelgrass populations range between 15 and 35 percent (Latimer et al. 2014). Latimer et al. (2014) used a mean of 22 percent, which was also cited as a growing season average value in Vaudrey (2008a,b). More recent long-term (more than 100 days) experimental mesocosm research in New Hampshire and Maine found that *Zostera marina* requires more light for seedling development and growth (Ochieng et al. 2010). In that study, seedlings grown at 34 and 58 percent surface irradiance had greater photosynthetic capacity than those grown at 11 percent. Similarly, morphological growth measures (shoots, rhizome growth, and shoot production) critical for long-term survival were significantly higher at 34 and 58 percent than at 11 percent; however, growth at 34 percent was still less than optimal to maintain long-term meadows. The authors concluded that “seedlings exposed to light levels less than 34 percent surface irradiance during the growing season are unlikely to survive winter light and temperature stress,” suggesting that light levels above 34 percent might be necessary for sufficient growth to sustain successful development of seedlings (Ochieng et al. 2010). While seedling growth was less than optimal at 34 percent, however, growth was supported; therefore, a value between 11 percent and 34 percent could still support seedling growth. Another study in Narragansett Bay, RI, also found that *Zostera marina* seedlings grew better at higher light (72 percent of ambient) than at medium light (23 percent) (Bintz and Nixon 2001). Even with some reduction in seedling shoot and root measures, however, seedling growth rates were comparable, and survivorship was 94 percent at 23 percent ambient light, suggesting that an average of 22 percent would support seedling growth in LIS. Additional research could increase confidence in these values, which are higher than surface irradiance values derived from shorter duration field studies (Ochieng et al. 2010; Latimer et al. 2014). Balancing this information for our modeling purposes, EPA used the mean value (22 percent) to derive light attenuation targets to protect seagrasses in each embayment. When we discuss light attenuation values in this text, however, we include how higher percent light levels, including values presented in Ochieng et al. (2010), could be met at various depths for different K_d values. So, while we used the values above to derive K_d values, we discuss how those values might also provide higher light levels for seagrasses across a range of depths.

The Lambert-Beer law quantifies the relationship between light attenuation, depth, and percent surface light, resulting in the following equation:

$$z = \frac{\ln\left(\frac{i_z}{i_o}\right)}{-K_d} \qquad \text{(Equation 4)}$$

where:

- z is the maximum colonization depth
- i_z is light at depth
- $i0$ is light at surface
- K_d is the light attenuation coefficient in m^{-1}

Rearranging yields the following equation to estimate the K_d value:

$$K_d = \frac{\ln\left(\frac{i_z}{i_o}\right)}{-z} \qquad \text{(Equation 5)}$$

As described above, EPA used a value of 0.22 for (i_z/i_0), percent surface light at depth. For the maximum colonization depth (z), EPA took the seagrass habitat suitability map coverages from Vaudrey et al. (2013) (Figure F-4) and mapped them along with embayment bathymetry from the same study. The Vaudrey bathymetry data indicated maximum embayment depths less than 1 m and colonization depths less than 0.5 m for some embayments, values that might not accurately reflect ground conditions based on a review of NOAA charts. Therefore, the maximum and colonization depths of those embayments were set to 1 m and 0.5 m, respectively, to estimate colonization depths for Table F-2 and Table F-3. The maximum colonization depth of suitable habitat (habitat suitability scores greater than 50 based on Vaudrey et al. [2013]) for each embayment was used as an estimate for the colonization depth (z). EPA explored using a minimum habitat suitability score of 88 for calculating the values in Table F-2 and Table F-3. However, EPA is concerned with both protecting existing seagrasses and restoring future seagrasses. Focusing on only areas with values above 88 would have ignored existing seagrass beds that currently maintain populations and merit protection. Only four of the embayments (the Connecticut and Pawcatuck rivers, Niantic Bay, and Stonington Harbor) had suitable habitat areas when a threshold value of 88 was used; but many more embayments still (or are suitable to) maintain and support seagrasses and that capability will continue to increase as ongoing nutrient reduction efforts continue to improve habitat conditions. Moreover, the maximum colonization depths for habitats scoring more than 88 were only 2.10–2.75 m, as low as 25 percent of those depths for index scores of 50, meaning that a smaller portion of potentially suitable habitat would be improved. Furthermore, protecting light levels suitable to depths in areas with index values of 50 and above will inherently protect those areas with values of 88, while also potentially increasing the size of the area with scores of 88, since percent light reaching the bottom is the most heavily weighted factor in the habitat suitability index (see Table 1 in Vaudrey et al. 2013). For these reasons, EPA used the habitat suitability target of 50 to derive light values, providing more light at the bottom to greater area and increasing the potential for habitat area suitable for seagrasses to develop and grow. Given the values for (*iz*/*i0*) and (*z*) as described above, EPA calculated the values of K_d for the embayments (Table F-2). The values in Table F-2 show light attenuation values for 22 percent surface light requirements at *maximum* colonization depths for each embayment. These values can be compared to the values of K_d for the embayments calculated based on the *average* colonization depths for each embayment derived from the same bathymetry coverages (Table F-3). The values in Table F-3 show light attenuation values for 22 percent surface light requirements at average colonization depths for each embayment.

Table F-2. Maximum Colonization Depths[a] (m) and K_d Values for Various Light Requirements

Embayment		Maximum Colonization Depth (m)	K_d at 22% Light Requirement (m^{-1})
Pawcatuck River, RI and CT		-4.94	0.31
Stonington Harbor, CT		-5.19	0.29
Saugatuck River, CT		-2.00	0.76
Norwalk Harbor, CT		-2.41	0.63
Mystic River, CT		-2.61	0.58
Niantic Bay, CT		-8.75	0.17
Farm River, CT		-1.00	1.51
Southport Harbor/Sasco Brook, CT		-1.00	1.51
Northport-Centerport Harbor Complex, NY		-3.00	0.50
Port Jefferson Harbor, NY		-8.13	0.19
Nissequogue River, NY		-1.00	1.51
Stony Brook Harbor, NY		-2.00	0.76
Mt. Sinai Harbor, NY		-7.48	0.20
Connecticut River, CT[b]		-8.67	0.17
Mamaroneck River, NY		-1.22	1.24
Hempstead Harbor, NY		-1.38	1.10
Areas Adjacent to the Northport–Centerport Harbor Complex, NY[c]	Huntington Bay, NY	-1.49	1.01
	Huntington Harbor, NY	-1.47	1.03
	Lloyd Harbor, NY	-1.47	1.03
Oyster Bay/Cold Spring Harbor Complex, NY		-1.37	1.10
Manhasset Bay, NY		-1.43	1.06
Pequonnock River, CT		-4.00	0.38
Byram River, CT and NY		-1.00	1.51
New Haven Harbor, CT		-6.59	0.23
Little Narragansett Bay, CT and RI		-3.33	0.45

Embayment	Maximum Colonization Depth (m)	K_d at 22% Light Requirement (m^{-1})
Housatonic River, MA and CT[b]	-2.00	0.76
Thames River, CT[b]	-8.67	0.17

Notes:
[a] Bathymetry depths were for mean lower low water (average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch).
[b] Based on suitable habitat within the area of influence.
[c] Grouped in the report but modeled as separate embayments.

Table F-3. Average Colonization Depth[a] (m) and K_d Values for Various Light Requirements

<table>
<tr><th colspan="2">Embayment</th><th>Average Colonization Depth (m)</th><th>K_d at 22% Light Requirement (m^{-1})</th></tr>
<tr><td colspan="2">Pawcatuck River, RI and CT</td><td>-0.70</td><td>2.16</td></tr>
<tr><td colspan="2">Stonington Harbor, CT</td><td>-1.81</td><td>0.84</td></tr>
<tr><td colspan="2">Saugatuck River, CT</td><td>-0.64</td><td>2.36</td></tr>
<tr><td colspan="2">Norwalk Harbor, CT</td><td>-0.90</td><td>1.68</td></tr>
<tr><td colspan="2">Mystic River, CT</td><td>-0.58</td><td>2.60</td></tr>
<tr><td colspan="2">Niantic Bay, CT</td><td>-3.96</td><td>0.38</td></tr>
<tr><td colspan="2">Farm River, CT</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Southport Harbor/Sasco Brook, CT</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Northport-Centerport Harbor Complex, NY</td><td>-1.08</td><td>1.40</td></tr>
<tr><td colspan="2">Port Jefferson Harbor, NY</td><td>-3.25</td><td>0.47</td></tr>
<tr><td colspan="2">Nissequogue River, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Stony Brook Harbor, NY</td><td>-0.56</td><td>2.68</td></tr>
<tr><td colspan="2">Mt. Sinai Harbor, NY</td><td>-1.62</td><td>0.93</td></tr>
<tr><td colspan="2">Connecticut River, CT[b]</td><td>-1.97</td><td>0.77</td></tr>
<tr><td colspan="2">Mamaroneck River, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Hempstead Harbor, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td rowspan="3">Areas Adjacent to the Northport–Centerport Harbor Complex, NY[c]</td><td>Huntington Bay, NY</td><td>-0.58</td><td>2.63</td></tr>
<tr><td>Huntington Harbor, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td>Lloyd Harbor, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Oyster Bay/Cold Spring Harbor Complex, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Manhasset Bay, NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">Pequonnock River, CT</td><td>-0.68</td><td>2.22</td></tr>
<tr><td colspan="2">Byram River, CT and NY</td><td>-0.50</td><td>3.03</td></tr>
<tr><td colspan="2">New Haven Harbor, CT</td><td>-1.20</td><td>1.26</td></tr>
<tr><td colspan="2">Little Narragansett Bay, CT and RI</td><td>-1.02</td><td>1.48</td></tr>
<tr><td colspan="2">Housatonic River, MA and CT[b]</td><td>-0.54</td><td>2.81</td></tr>
<tr><td colspan="2">Thames River, CT[b]</td><td>-1.57</td><td>0.97</td></tr>
</table>

Notes:
[a] Bathymetry depths were for mean lower low water (average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch).
[b] Based on suitable habitat within the area of influence.
[c] Grouped in the report but modeled as separate embayments.

To model K_d as a function of chlorophyll *a*, an equation converting the value from Secchi depth (SD) in meters, the most common clarity data available, to K_d was needed. There is a large range of published conversion values. Table III-5 in Batiuk et al. (2000) provides a long list of values for the product of K_d x SD ranging from 1.25 to 2.02 (unitless). Other values include those summarized by Koenings and Edmundson (1991) and, for a variety of marine systems, ranging from 1.44 to 1.90. To get the conversion equation, one would divide the product by SD. Batiuk et al. (2000) recommend a value of 1.45 for Chesapeake Bay, which is consistent with turbid seawater estimates from Koenings and Edmundson (1991). Paired SD and K_d measures in LIS were relatively sparse; however, paired values from eight embayments were identified and average products of K_d*SD were calculated for each one (Table F-4). Surface water quality data for the growing season (April–September) were averaged to the site-date level. The overall average of the median and average products was 1.45, identical to the value derived for the Chesapeake Bay; therefore, this was the value used.

Table F-4. Median and Average K_d*SD Values for Eight LIS Embayments

Water body	Count	Median	Average
Lloyd Harbor, NY	1	1.69	1.69
Mamaroneck River, NY	4	1.40	1.46
Milford Harbor, CT	5	1.42	1.42
Niantic Bay, CT	25	1.16	1.16
Pawcatuck River, RI	17	1.93	1.94
Pequonnock River, CT	1	1.41	1.41
Saugatuck Estuary, CT	3	1.52	1.49
Thames River, CT	1	1.00	1.00
Embayment average		1.44	1.45

Using a value of 1.45 yields the following conversion equation:

$$K_d = \frac{1.45}{SD} \qquad \text{(Equation 6)}$$

Observed K_d values were used when available. If SD values were available but K_d values were not, K_d values were calculated using equation 7. The maximum observed K_d value was 2.84. Calculated K_d values above 2.84 were removed to avoid potential extrapolation of inferred values. This approach does not account for attenuation of light by epiphyte growth on the leaf or episodic drifting algae, so it is an underestimate.

DO is an important nutrient-related water quality parameter affecting aquatic life in coastal waters like LIS and its embayments. Consequently, all surrounding states (Connecticut, New York, and Rhode Island) have existing water quality criteria for DO to protect aquatic life. Those criteria were used as initial response variable values for models of chlorophyll versus DO and are as follows:

- Connecticut (class SA and SB): Chronic DO not less than 4.8 mg/L with cumulative periods in the 3.0–4.8 mg/L range as detailed in footnote in Table 1 of the water quality standards; acute DO not less than 3.0 mg/L at any time.

- New York (class SA, SB, and SC): Chronic DO shall not be less than a daily average of 4.8 mg/L (might fall below 4.8 mg/L for a limited number of days, as defined in the formula in the water quality standards); acute DO shall not be less than 3.0 mg/L at any time.
- Rhode Island (class SA, SA{b}, SB, and SB1):
    - For surface waters above a seasonal pycnocline: Instantaneous DO not less than 4.8 mg/L more than once every 3 years, except as naturally occurs.
    - For waters below the seasonal pycnocline: Aquatic life uses are considered to be protected if conditions do not fail to meet protective thresholds, as described below, more than once every 3 years. Waters with a DO concentration above an instantaneous value of 4.8 mg/L shall be considered protective of aquatic life uses. When instantaneous DO values fall below 4.8 mg/L, the waters shall not be (1) less than 2.9 mg/L for more than 24 consecutive hours during the recruitment season, (2) less than 1.4 mg/L for more than 1 hour more than twice during the recruitment season, nor (3) more than the cumulative DO exposure presented in Table 3.A (RIDEM 2006).
    - For waters without a seasonal pycnocline: Aquatic life uses are considered to be protected if conditions do not fail to meet protective thresholds, as described below, more than once every 3 years. DO concentrations above 4.8 mg/L shall be considered protective of aquatic life uses. When instantaneous DO values fall below 4.8 mg/L, the waters shall not be (1) less than 3.0 mg/L for more than 24 consecutive hours during the recruitment season, (2) less than 1.4 mg/L for more than 1 hour more than twice during the recruitment season, nor (3) more than the cumulative DO exposure presented in Table 3.A (RIDEM 2006). Cumulative low DO exposures in the 2.95–4.8 mg/L range shall be evaluated as described in Section II of the water quality standards but shall not exceed the criteria presented in Table 3.B (RIDEM 2006).

Table 3.A. Saltwater DO Criteria for Waters below the Seasonal Pycnocline

24-hour (daily) DO exposure concentration (mg/L)	Daily percent larval mortality (%)	Allowable number of days without exceeding a 5% reduction in seasonal larval recruitment
4.6	4.96	42
4.5	6.05	30
4.4	7.36	24
4.3	8.93	20
4.2	10.79	18
4.1	12.98	16
4	15.55	14
3.9	18.51	12
3.8	21.88	10
3.7	25.69	9
3.6	29.89	8
3.5	34.47	7
3.4	39.36	6
3.3	44.46	5
3.2	49.69	4
3.1	54.92	3
3	60.05	2
2.9	64.97	1

Table 3.B. Saltwater DO Criteria for Waters without a Seasonal Pycnocline

24-hour (daily) DO exposure concentration (mg/L)	Daily percent larval mortality (%)	Allowable number of days without exceeding a 5% reduction in seasonal larval recruitment
4.6	4.96	16
4.5	6.05	14
4.4	7.36	12
4.3	8.93	11
4.2	10.79	10
4.1	12.98	8
4	15.55	7
3.9	18.51	6
3.8	21.88	5
3.7	25.69	4
3.6	29.89	3
3.5	34.47	2
3.4	39.36	1

Source: Rhode Island Department of Environmental Management. 2006. *Water Quality Regulations*. https://www.epa.gov/sites/production/files/2014-12/documents/riwqs.pdf.

Three relationships were modeled separately to determine protective nitrogen target concentrations for eelgrass and other aquatic life (Figure F-6). The DO model addresses the response of the bottom water column. First, K_d versus chlorophyll data from the same site and date (paired) were modeled to determine what level of chlorophyll is associated with levels of K_d that protect eelgrass habitat (left plot). Next, paired DO versus chlorophyll was modeled to determine what level of chlorophyll is associated with levels of DO that protect aquatic life (middle plot). The protective levels of chlorophyll identified in the first two modeling efforts and from the literature were then used in the third modeling effort. Specifically, paired chlorophyll versus TN was modeled.

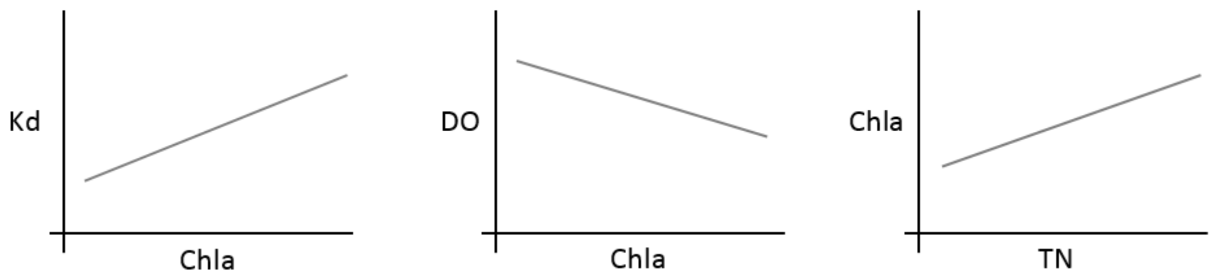

Figure F-6. Idealized Illustrations of the Modeled Stressor-Response Relationships

Separate hierarchical models were developed for each of the three relationships. The data for these models are the same as described in *Subtask D: Summary of Existing Water Quality Data*, which contains observations from 14 organizations and 585 monitoring stations across 19 years. Data preparation for each model was similar. Chlorophyll *a*-corrected (i.e., interference from pheophytin [degraded chlorophyll] is removed) was used for each model rather than uncorrected chlorophyll *a*, as corrected chlorophyll is a better indicator of live algal biomass and more data were available for the corrected measurement. Variables present in the original dataset but not in the statistical model were dropped. Observations without paired data were removed (i.e., rows with missing data were removed).

Additional variables (covariates) that might help better explain the identified relationships were explored. Each additional variable added to the model has the potential to decrease the sample size due to the paired data requirement. Therefore, only variables that did not appreciably reduce the sample size were considered. Salinity, pH, temperature, total suspended solids (TSS), embayment flushing time, and maximum embayment residence time were identified as covariates to consider for inclusion in the models, where applicable. Flushing time and residence time were calculated using empirical equations developed for New England embayments (Abdelrhman 2005). Turbidity was considered but not modeled as it would have severely diminished the paired sample size.

The “lme4” package (Bates et al. 2015) in R software (R Core Team 2019) was used to fit the linear hierarchical models. To account for correlation of observations and repeated measurements made at the same station, station ID was treated as a random effect – essentially a group factor – in the hierarchical models. Embayments were used as the random group, as they are a sample of all the possible embayments in LIS. Natural log and square root transformations for skewed variables were explored. Water temperature, pH, and salinity were evaluated as additional predictors for many of the hierarchical models. These candidate predictors were selected because they had the least impact on paired sample size. Fixed effect p-values were calculated using the Kenard-Roger (Kenward and Roger 1997) method. Fixed effects with a p-value greater than 0.05 were removed. Random intercepts and random slopes were tested using restricted likelihood ratio tests (Crainiceanu and Ruppert 2004) via the "RLRsim" package (Scheipl et al. 2008). Random effects with a p-value greater than 0.05 were removed. Hierarchical models were fit using a restricted maximum likelihood method. Confidence intervals (CIs) for hierarchical models were calculated using 200 bootstrap samples. Model fit was assessed using quantile-quantile plots, residual scatterplots, and observed versus fitted (1:1) plots. Locally weighted scatterplot smoothing (LOWESS) lines were overlaid on residual plots to help identify potential trends. Conditional model predictions based on the estimated random effects were used for model evaluation and trend fitting. Pseudo R-squared for the stressor-response analyses was defined as the square of r (Pearson correlation between observed and fitted values).

LIGHT ATTENUATION VERSUS CHLOROPHYLL RELATIONSHIP

The relationship between K_d and chlorophyll for LIS embayment data was quantified using a hierarchical model. Surface water quality data for the growing season (April–September) were averaged to the station-date level to maximize relational data between available light and incident chlorophyll. Samples from embayment East River, NY and Little Neck Bay were removed as they were not included in the Vaudrey et al. (2013) eelgrass study and presence or potential presence of eelgrass in those waters is unknown. The predictors dissolved organic carbon (DOC) and TSS were included because they have important effects on light attenuation in addition to nutrients.

There were insufficient data on DOC to pair with chlorophyll and TSS. Salinity is frequently used as a surrogate for DOC, so a ln(DOC) versus salinity least squares model was developed for LIS where paired data existed. Paired DOC and salinity data were sparse without including data from East River, NY and Little Neck Bay, so those data were included for the DOC versus salinity fit only. The model contained 4,079 paired observations across 12 embayments and 76 stations, with data observed between 2006 and 2015. The resulting model was significant ($p<0.0001$) and explained 30 percent of the variability between salinity and DOC and confirmed the appropriateness of salinity as a surrogate (Figure F-7).

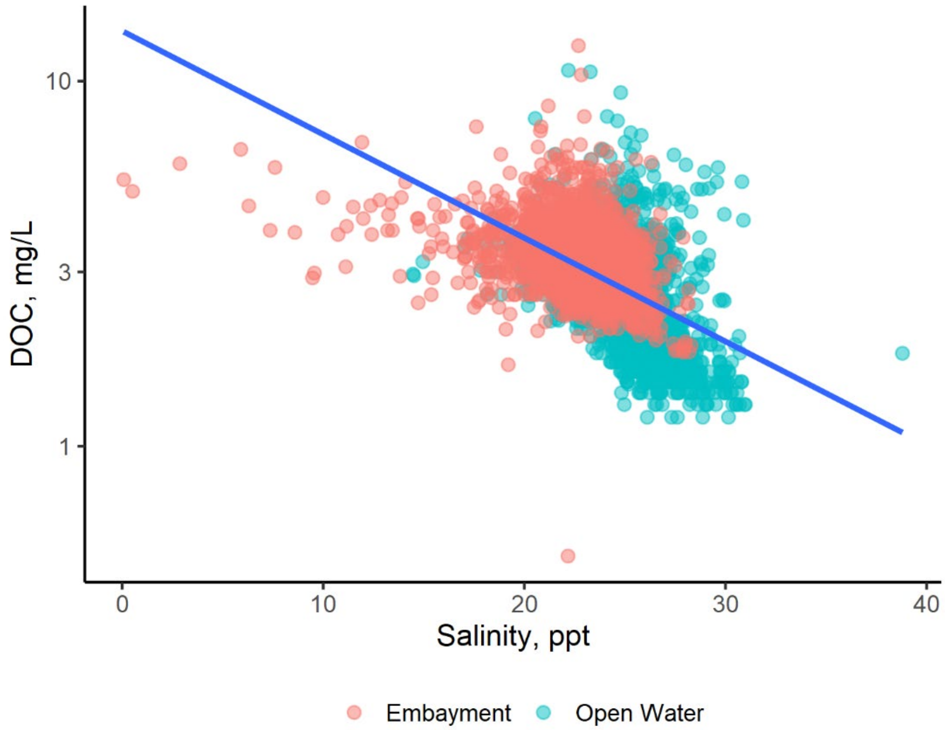

Figure F-7. Relationship between Salinity and DOC Data in LIS Waters

The following is the final K_d versus chlorophyll hierarchical model:

$$K_{d_{ij}} = (\beta_0 + \beta_{0j}) + \beta_1 * \ln(Chla_i) + \beta_2 * \ln(\mathrm{TSS}_i) + \beta_3 * Salinity_i + e_{ij}$$

(Equation 7)

where:

- β_0 is the intercept
- β_{0j} are the intercept adjustments for each embayment group
- β_1 is the chlorophyll slope
- β_2 is the TSS slope
- β_3 is the salinity slope
- e_{ij} is the error term
- *j* is an index for each embayment group
- *i* is an index for each observation within group *j*

The final model contained 136 paired observations across 18 embayments and 41 stations, with data observed between 2006 and 2017 (see Table F-5). Random slopes were not significant and were removed. Random intercepts were significant. Random effect p-values are presented in Table F-6. Fixed effect p-values are presented in Table F-7. Diagnostic plots are shown in Figure F-8, indicating little bias or residual pattern, and the plot of observed versus fitted values from the final model is shown in Figure F-9.

Table F-5. Paired Observations and Station Counts for the K_d vs. Chlorophyll Hierarchical Embayment Model, by Embayment

Embayment	Observation Count	Station Count
Connecticut River, CT	15	5
Hempstead Harbor, NY	22	2
Huntington Bay, NY	3	1
Huntington Harbor, NY	3	1
Little Narragansett Bay, CT and RI	6	3
Mamaroneck River, NY	4	2
Manhasset Bay, NY	32	3
Mt. Sinai Harbor, NY	2	1
Niantic Bay, CT	6	3
Nissequogue River, NY	1	1
Northport-Centerport Harbor Complex, NY	6	2
Pawcatuck River, CT & RI	4	2
Port Jefferson Harbor, NY	8	4
Saugatuck Estuary, CT	4	2
Stony Brook Harbor, NY	2	2
Other Embayments	18	7
Total	**136**	**41**

Table F-6. K_d vs. Chlorophyll Random Effects Variance and P-values

Random Effect	Variance	P-value
Embayment slope	Removed	0.2854
Embayment intercept	0.050	<0.0001
Residual	0.121	-

Table F-7. K_d vs. Chlorophyll Embayment Model Coefficients

Variable	Coefficient	Standard Error	t value	P-value
Intercept	0.436	0.259	1.682	0.0998
ln(Chla) (µg/L)	0.169	0.044	3.810	0.0002
ln(TSS) (mg/L)	0.235	0.048	4.887	<0.0001
Salinity (ppt)	-0.009	0.009	-0.990	0.3310

Note: µg/L = micrograms per liter.

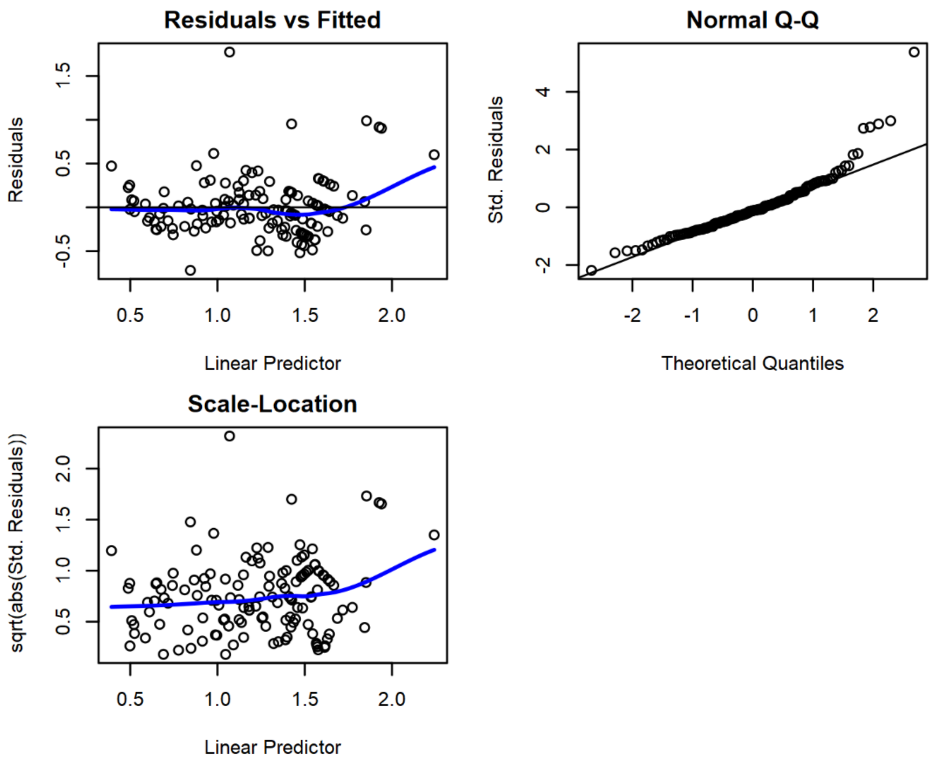

Figure F-8. Model Diagnostic Plots from the K_d vs. Chlorophyll Hierarchical Model

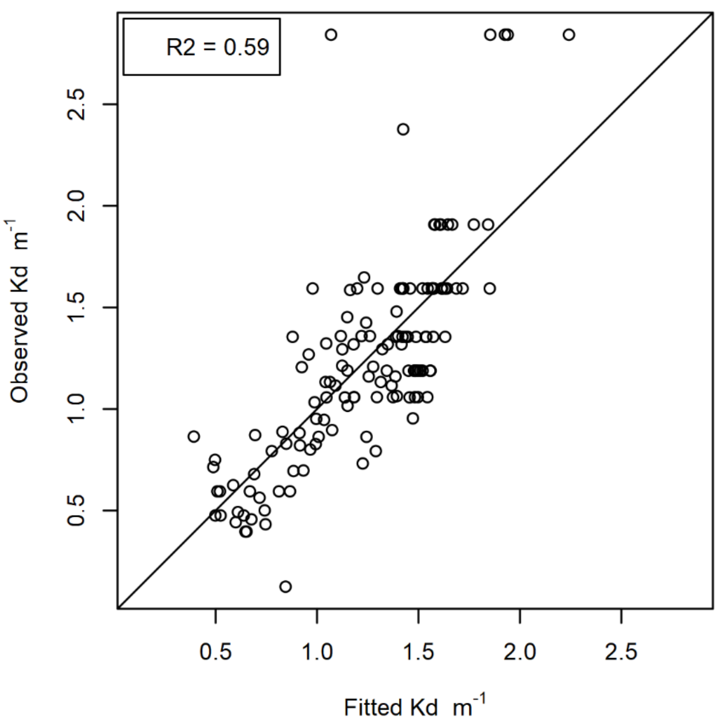

Figure F-9. Observed vs. Fitted (1:1) Plot from the K_d vs. Chlorophyll Model

The model predicted the observations with pseudo R-squared equaling 0.59 (Figure F-9). To solve for embayment conditions under which chlorophyll would exert the strongest effect on light attenuation, which was the focus of concern, EPA set TSS to the 10th percentile embayment value and salinity to the 90th percentile embayment value. The resultant equations were then solved for chlorophyll at embayment specific K_d targets (Tables F-3 and F-4). In addition to the embayment-specific values at maximum and average colonization depths, K_d values of 0.5 and 0.7 were selected for interpolation in the hierarchical models. When K_d is 0.5 per meter, 15 percent of surface irradiance reaches 4 m, 22 percent reaches 3 m, 35 percent reaches 2 m, and 50 percent reaches 1.4 m. This value for K_d results in 14 to 78 percent surface light across the range of average colonization depths (min: 0.5 m, max: 4.0 m) and 61 percent at the mean of embayment average colonization depth (1.0 m) (Table F-3). It provides an average of 33 percent light across the range of maximum colonization depths (Table F-2). The recommended K_d for LIS is 0.7 (Yarish et al. 2006; Vaudrey 2008a,b), which corresponds to 50 percent of water column surface light available to 1.0 m, the average of embayment average colonization depths. This value provides from 6 to 70 percent surface light (mean: 55 percent) across the range of average embayment colonization depths (Table F-3). Chlorophyll values solved for each of the above K_d targets are between 0.7 and 62.4 micrograms per liter (µg/L) (Table F-8). Values outside the range of each model were not solved for chlorophyll.

Table F-8. Chlorophyll Values (µg/L) Solved for Different Values of K_d Using Embayment Specific Hierarchical Models

Embayment	Chlorophyll *a* (µg/L) for the Following Light Attenuation Values			
	K_d = 0.5	K_d = 0.7	K_d at Maximum Colonization Depth[a]	K_d at Average Colonization Depth[a]
Pawcatuck River, RI and CT	0.7	2.3		
Stonington Harbor, CT	2.7	8.8	0.8	19.7
Saugatuck River, CT	1.0	3.3	4.6	
Norwalk Harbor, CT	2.7	8.8	5.8	
Mystic River, CT	2.7	8.8	4.3	
Niantic Bay, CT	2.8	9.4		1.4
Farm River, CT	2.7	8.8		
Southport Harbor/Sasco Brook, CT	2.7	8.8		
Northport-Centerport Harbor Complex, NY		1.0		
Port Jefferson Harbor, NY	3.9	12.9	0.6	3.2
Nissequogue River, NY		0.8		
Stony Brook Harbor, NY	0.6	2.1	2.9	

Embayment		Chlorophyll *a* (µg/L) for the Following Light Attenuation Values			
		K_d = 0.5	K_d = 0.7	K_d at Maximum Colonization Depth[a]	K_d at Average Colonization Depth[a]
Mt. Sinai Harbor, NY		0.6	2.0		8.0
Connecticut River, CT[b]			0.7		1.1
Mamaroneck River, NY		3.4	11.1		
Hempstead Harbor, NY				3.9	
Areas Adjacent to the Northport–Centerport Harbor Complex, NY[c]	Huntington Bay, NY	2.0	6.5	42.6	
	Huntington Harbor, NY	0.8	2.6	18.4	
	Lloyd Harbor, NY	2.7	8.8	62.4	
Oyster Bay/Cold Spring Harbor Complex, NY		2.7	8.8		
Manhasset Bay, NY				2.0	
Pequonnock River, CT		2.7	8.8	1.3	
Byram River, CT and NY		2.7	8.8		
New Haven Harbor, CT		2.7	8.8	0.5	
Little Narragansett Bay, CT and RI		3.7	12.3	2.9	
Housatonic River, MA and CT[b]		2.7	8.8	12.3	
Thames River, CT[b]		2.7	8.8		43.0

Notes:
[a] Bathymetry depths were for mean lower low water (average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch).
[b] Based on suitable habitat within the area of influence.
[c] Grouped in the report but modeled as separate embayments.

The hierarchical models were also solved at the embayment population level by removing the embayment-specific model adjustment for slope or intercept. The population-wide model (Figure F-10) was solved for K_d values of 0.5 and 0.7 and yielded chlorophyll *a* values of 1.4 and 4.5 μg/L, respectively.

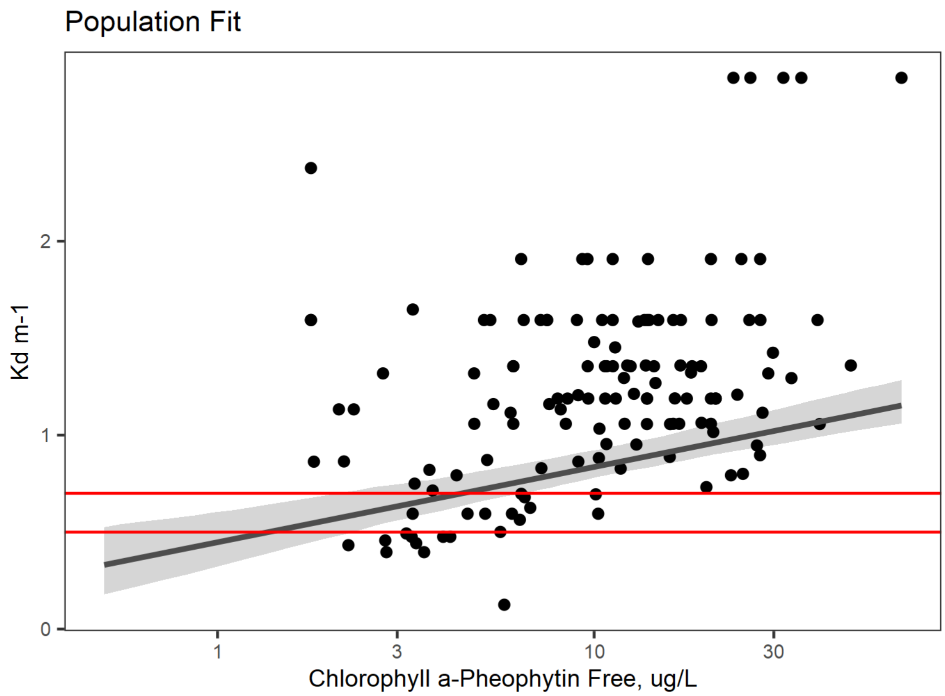

Figure F-10. Embayment Population Hierarchical Model of Growing Season Average K_d vs. Chlorophyll *a* (K_d Values of 0.5 and 0.7 in *Horizontal Red Lines*)

In addition to the individual embayment hierarchical models, EPA performed a linear quantile regression analysis of K_d (with K_d derived from SD using equation 7 versus ln(chlorophyll) at the 10th quantile for all the embayment data pooled together (Figure F-7). Whereas least squares and hierarchical models estimate the conditional mean of the response, quantile regression estimates the conditional quantile of the response and is advocated for use in ecological models in which a response is affected by multiple factors (e.g., suspended sediment or dissolved organic matter, in this case), variances are nonhomogeneous, and one seeks to understand the greatest constraint of one predictor (in this case, chlorophyll) in the absence of the other factors (Cade and Noon 2003).

EPA used the “quantreg” package in R (Koenker 2019) to fit the model. Surface water quality data for the growing season (April–September) were averaged to the station-date level. Samples from embayment East River, NY and Little Neck Bay were removed as they were not included in the Vaudrey eelgrass study (2013). The final quantile regression model contained 1,384 observations across 24 embayments and 93 stations, with data observed between 2006 and 2018 (see Table F-9). Model coefficients are presented in Table F-10.

Table F-9. Paired Observations and Station Counts for the K_d vs. Chlorophyll Quantile Regression Model, by Embayment

Embayment	Observation Count	Station Count
Connecticut River, CT	63	7
Hempstead Harbor, NY	58	2
Huntington Bay, NY	31	2
Huntington Harbor, NY	95	5
Little Narragansett Bay, CT and RI	63	5
Lloyd Harbor, NY	17	2
Mamaroneck River, NY	4	2
Manhasset Bay, NY	86	3
Mt. Sinai Harbor, NY	49	5
Niantic Bay, CT	6	3
Nissequogue River, NY	23	3
Northport-Centerport Harbor Complex, NY	171	10
Oyster Bay / Cold Spring Harbor Complex, NY	34	1
Pawcatuck River, CT & RI	236	6
Pequonnock River, CT	1	1
Port Jefferson Harbor, NY	223	14
Saugatuck Estuary, CT	4	2
Stony Brook Harbor, NY	96	8
Thames River, CT	1	1
Other Embayments	123	11
Total	**1,384**	**93**

Table F-10. K_d vs. Chlorophyll Quantile Model Coefficients

Variable	Coefficient	Standard Error	t value	P-value
Intercept	0.292	0.004	77.132	<0.0001
ln(Chla) (µg/L)	0.172	0.006	31.000	<0.0001

The relationship between chlorophyll *a* and K_d suggests the constraint of algal biomass on K_d is least biased (i.e., less influenced by DOC and TSS interference) at lower quantiles (Figure F-11). This bias is likely lower at the lower quantiles because chlorophyll places the greatest constraints on K_d when minimally influenced by these other factors. The 10th quantile was selected as sufficiently characteristic of the unbiased relationship while also containing enough values to be reasonably estimated. The chlorophyll values associated with these K_d values using the 10th quantile regression model are listed in Table F-11.

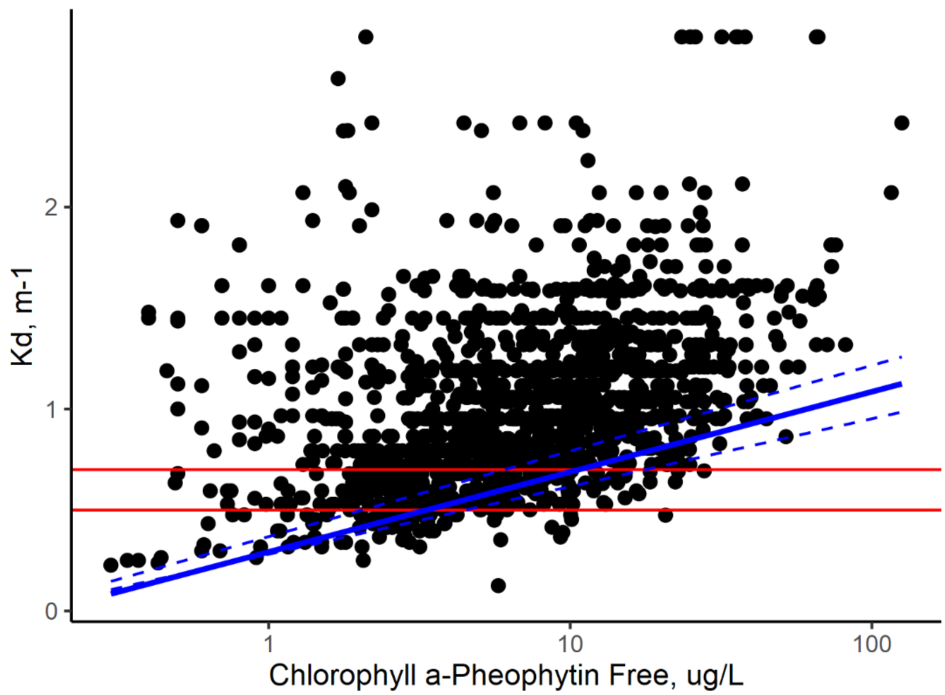

Figure F-11. K_d vs. Chlorophyll (10th Quantile Regression Fit (*Solid Blue Line*), CI = 5th and 20th Quantiles (*Dashed Blue Line*), K_d values of 0.5 and 0.7 (*Red Lines*)

Table F-11. K_d Values and Associated Chlorophyll *a* Values, Based on 10th Quantile Regression Model

K_d	Associated Chlorophyll *a* Value Based on 10th Quantile (µg/L)
0.5	3
0.7	10

The chlorophyll *a* estimates from the earlier analyses—the four specific embayment values in Table F-8, the population level hierarchical model solutions at K_d values of 0.5 and 0.7, and the quantile regression model solutions at K_d values of 0.5 and 0.7—were averaged with the LIS-wide target of 5.5 µg/L developed by Vaudrey et al. (2008a, b). Any value above 10 µg/L was excluded as exceeding that growing season average considered protective of regional estuarine embayments (Howes et al. 2003). The results are shown in Table F-12.

Table F-12. Light Attenuation-Based Chlorophyll *a* Targets by Embayment

Embayment	Chlorophyll *a* (µg/L)
Pawcatuck River, RI and CT	4.4
Stonington Harbor, CT	4.3
Saugatuck River, CT	4.6
Norwalk Harbor, CT	4.1
Mystic River, CT	4.0
Niantic Bay, CT	4.8

Embayment		Chlorophyll *a* (µg/L)
Farm River, CT		4.3
Southport Harbor/Sasco Brook, CT		4.3
Northport-Centerport Harbor Complex, NY		3.6
Port Jefferson Harbor, NY		4.4
Nissequogue River, NY		5.0
Stony Brook Harbor, NY		4.8
Mt. Sinai Harbor, NY		5.2
Connecticut River, CT[a]		4.2
Mamaroneck River, NY		5.5
Hempstead Harbor, NY		4.5
Areas Adjacent to the Northport–Centerport Harbor Complex, NY[b]	Huntington Bay, NY	5.1
	Huntington Harbor, NY	5.4
	Lloyd Harbor, NY	4.3
Oyster Bay/Cold Spring Harbor Complex, NY		4.3
Manhasset Bay, NY		4.3
Pequonnock River, CT		4.3
Byram River, CT and NY		4.3
New Haven Harbor, CT		4.3
Little Narragansett Bay, CT and RI		4.3
Housatonic River, MA and CT[a]		4.5
Thames River, CT[a]		4.3

Notes:
[a] Applicable within the area of influence.
[b] Grouped in the report but modeled as separate embayments.

DO VERSUS CHLOROPHYLL RELATIONSHIP

The relationship between DO and chlorophyll for LIS embayment data was explored using a hierarchical model. Surface water quality data for the growing season (April–September) were averaged to the station-date level. Samples from embayment East River, NY were removed as that area was more heavily influenced by riverine exchange and did not behave like an embayment. The predictors pH, salinity, temperature, TSS, flushing time, and maximum residence time were included to see if they would significantly improve the fit of the model. Turbidity was considered but not modeled as it would have severely diminished the paired sample size. Fixed effects with a p-value greater than 0.05 were removed from the final model. Following is the final model:

$$DO_{ij} = (\beta_0 + \beta_{0j}) + (\beta_1 + \beta_{1j}) * ln(Chla_{ij}) + \beta_2 * \text{pH\_i} + \text{β\_3} * \text{Salinity\_i} + e_{ij} \quad \text{(Equation 8)}$$

where:

- β_0 is the intercept
- β_{0j} are the intercept adjustments for each embayment group
- β_1 is the chlorophyll slope
- β_{1j} are the slope adjustments for each embayment group
- β_2 is the pH slope
- β_3 is the salinity slope

- e_{ij} is the error term
- *j* is an index for each embayment group
- *i* is an index for each observation within group *j*

In the above mixed-effects model, "embayment groups" are random effects. Thus, the model has a random intercept for each embayment (B_{0j}) and a random chlorophyll slope for each embayment. The final model contained 1,117 observations across 28 embayments and 130 stations (Table F-13), with data observed between 2007 and 2019. Embayments have a significant influence on the model, as evidenced by significant slope and intercept effects (Table F-14). In addition, chlorophyll, temperature, and salinity were all significant fixed effects (Table F-15). There was little bias or residual pattern as indicated by diagnostic plots and observed versus fitted values from the final model (Figure F-12 and Figure F-13).

Table F-13. Paired Observations and Station Counts for the Dissolved Oxygen vs. Chlorophyll Embayment Model, by Embayment

Embayment	Observation Count	Station Count
Connecticut River, CT	16	5
Hempstead Harbor, NY	44	2
Housatonic River, MA and CT	30	6
Huntington Bay, NY	30	2
Huntington Harbor, NY	58	4
Little Narragansett Bay, CT and RI	49	9
Lloyd Harbor, NY	16	2
Mamaroneck River, NY	5	5
Manhasset Bay, NY	66	3
Mt. Sinai Harbor, NY	40	6
Mystic Harbor, CT	39	2
Niantic Bay, CT	8	7
Nissequogue River, NY	26	5
Northport-Centerport Harbor Complex, NY	131	9
Oyster Bay / Cold Spring Harbor Complex, NY	6	3
Pawcatuck River, CT and RI	133	11
Pequonnock River, CT	1	1
Port Jefferson Harbor, NY	177	12
Saugatuck Estuary, CT	6	4
Stonington Harbor, CT	24	4
Stony Brook Harbor, NY	64	7
Thames River, CT	1	1
Other Embayments	147	20
Total	**1,117**	**130**

Table F-14. Dissolved Oxygen vs. Chlorophyll Random Effects Variance and P-values

Random effect	Variance	P-value
Embayment slope	1.317	<0.0001
Embayment intercept	0.127	<0.0001
Residual	2.332	-

Table F-15. Dissolved Oxygen vs. Chlorophyll Embayment Model Coefficients

Variable	Coefficient	Standard Error	t value	P-value
Intercept	-7.691	1.198	1031.544	<0.0001
ln(Chla) (µg/L)	-0.567	0.106	24.249	<0.0001
Temperature (˚C)	2.240	0.158	1112.582	<0.0001
Salinity (ppt)	-0.062	0.011	1043.315	<0.0001

Notes: ˚C = degrees Celsius; ppt = parts per thousand.

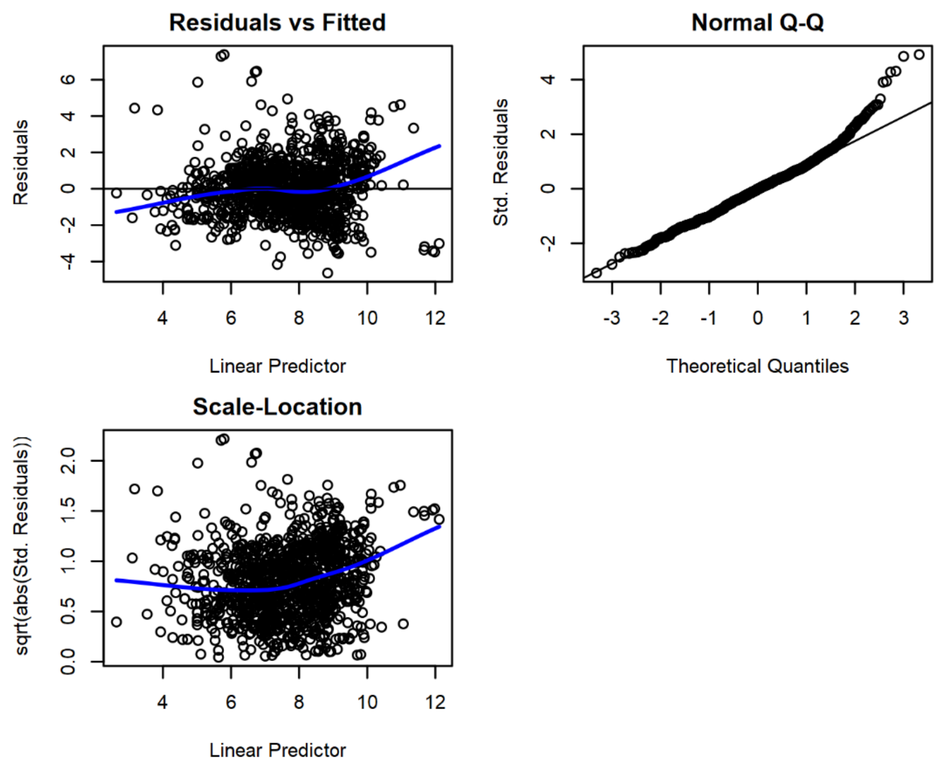

Figure F-12. Model Diagnostic Plots from the Dissolved Oxygen vs. Chlorophyll Hierarchical Model

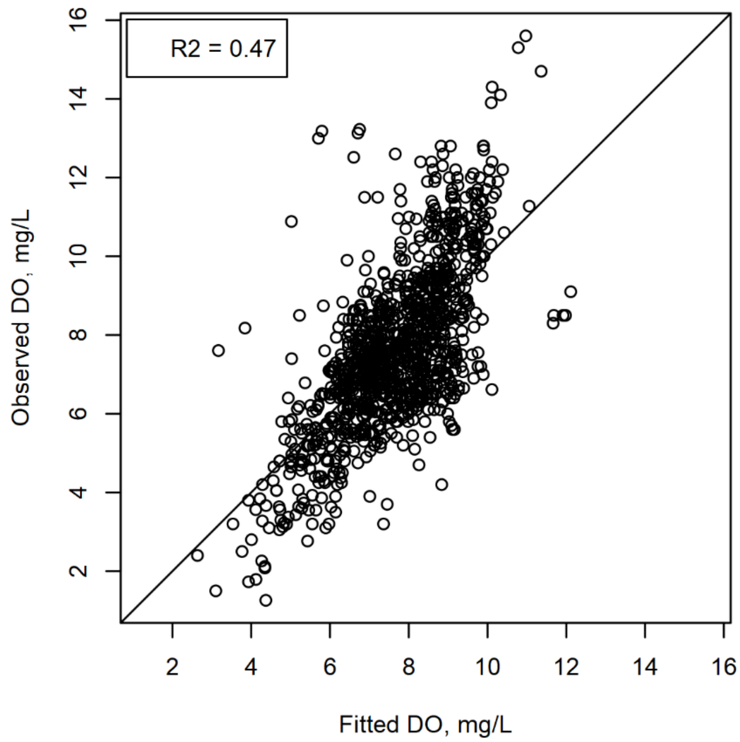

Figure F-13. Observed vs. Fitted (1:1) Plot from the DO vs. Chlorophyll Model

Chlorophyll explained a sufficient portion of the variance in DO (pseudo R-squared = 0.47) (Figure F-13). Although the model predicted more low DO values at high chlorophyll levels, high DO also occurred at high chlorophyll (Figure F-14).

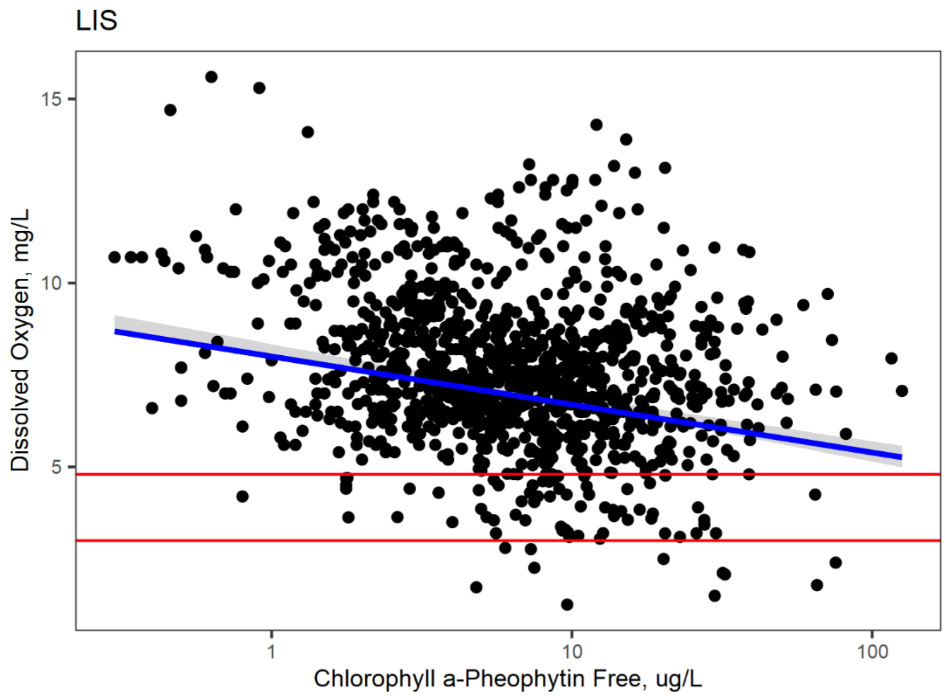

Figure F-14. DO vs. Chlorophyll Plot with Hierarchical Population Fit (*Blue Line*) and 80% CI (*Gray Area*)

The relationship between DO and phytoplankton is complex. Phytoplankton can contribute to DO through photosynthesis and can deplete DO through either respiration by the phytoplankton themselves or by other organisms consuming the organic matter they produce. DO levels, as a result, fluctuate daily, tending to be highest in late afternoon and lowest in early morning. Grab samples of DO are, therefore, of little use in gaging the complete manifestation of metabolic effects on DO. Profile DO levels can be more informative during stratification but need to be paired with chlorophyll data. Moreover, it is difficult in an open system such as LIS to expect a linkage between surficial chlorophyll and a benthic DO response at any one location. There were sparse data available for paired samples taken at the bottom of the water column across LIS (40 observations). These daytime grab sample DO values, therefore, likely obscure the effects of metabolism on DO. In addition, other factors also affect DO levels. For example, it is possible that the DO levels of the embayments are largely influenced by each embayment's residence time, mixing with the open sound, and reaeration. For these reasons, EPA was unable to derive a chlorophyll response variable value for the DO versus chlorophyll relationship.

CHLOROPHYLL VERSUS TN RELATIONSHIP

The relationship between chlorophyll and TN for LIS embayment data was explored using a hierarchical model. Surface water quality data for the growing season (April–September) were averaged by embayment and date. Embayment date is used to preserve the most data while producing TN values more closely tied to the temporal scale of the response and the assessment scale. Samples from embayment East River, NY and Little Neck Bay were removed as that area was not included in the Vaudrey et al. (2013) eelgrass study and presence or potential presence of eelgrass in those waters is unknown. The predictors pH, salinity, temperature, TSS, flushing time, and maximum residence time were included to see if they would significantly improve the fit of the model. Turbidity was considered but not modeled as it would have severely diminished the paired sample size. Fixed effects with a p-value greater than 0.05 were removed from the final model. Temperature and TN appeared collinear in the model. To determine whether TN can independently model chlorophyll or whether TN is a surrogate for temperature, we split the dataset into five partitions based on temperature bins of roughly equal sample size. This controls for temperature because each dataset has roughly the same temperature. We then modeled ln(chlorophyll) versus ln(TN) for each dataset. For each model, ln(TN) was significant (the largest p-value was 0.0058). Therefore, we concluded that TN can independently model chlorophyll and removed temperature as a predictor. The following is the final model:

$$Chlorophyll_{ij} = \left(\beta_0 + \beta_{0j}\right) + \beta_1 * TN_{ij} + e_{ij}$$

(Equation 9)

where:

- β_0 is the intercept
- β_{0j} are the intercept adjustments for each embayment group
- β_1 is the nitrogen slope
- β_2 is the pH slope
- β_3 is the temperature slope
- e_{ij} is the error term
- *j* is an index for each embayment group
- *i* is an index for each observation within group *j*

In the above mixed-effects model, "embayment groups" are random effects. Therefore, the model has a random intercept for each embayment (B_{0j}).

The final model contained 417 observations across 29 embayments (Table F-16, Table F-17, Figure F-15, and Figure F-16), with data observed between 2006 and 2019. Random slopes were not significant and were removed. Random intercepts were significant. There were significant differences among embayments, as evidenced by significant random effects (intercept); however, slopes did not differ among embayments (Table F-17). Chlorophyll increased significantly with TN concentration (Table F-18). Diagnostic plots indicate little bias or residual pattern (Figure F-15) and the model fit observed values well (Figure F-16).

Table F-16. Paired Observations for the Chlorophyll vs. Total Nitrogen Embayment Model, by Embayment

Embayment	Observation Count
Connecticut River, CT	12
Hempstead Harbor, NY	9
Housatonic River, MA and CT	5
Huntington Bay, NY	16
Huntington Harbor, NY	16
Little Narragansett Bay, CT and RI	40
Lloyd Harbor, NY	17
Mamaroneck River, NY	4
Manhasset Bay, NY	9
Mt. Sinai Harbor, NY	13
Mystic Harbor, CT	23

Embayment	Observation Count
New Haven Harbor, CT	1
Niantic Bay, CT	4
Nissequogue River, NY	10
Northport-Centerport Harbor Complex, NY	16
Oyster Bay / Cold Spring Harbor Complex, NY	4
Pawcatuck River, CT and RI	71
Pequonnock River, CT	1
Port Jefferson Harbor, NY	19
Saugatuck Estuary, CT	4
Stonington Harbor, CT	21
Stony Brook Harbor, NY	10
Thames River, CT	2
Other Embayments	90
Total	**417**

Table F-17. Chlorophyll vs. Nitrogen Random Effects Variance and P-values (NS = Not Significant)

Random Effect	Variance	P-value
Embayment slope	NS	NS
Embayment intercept	0.050	0.0022
Residual	0.489	-

Table F-18. Chlorophyll vs. Nitrogen Embayment Model Coefficients

Variable	Coefficient	Standard Error	t value	P-value
Intercept	2.500	0.102	24.568	<0.0001
ln(TN) (mg/L)	0.645	0.096	6.721	<0.0001

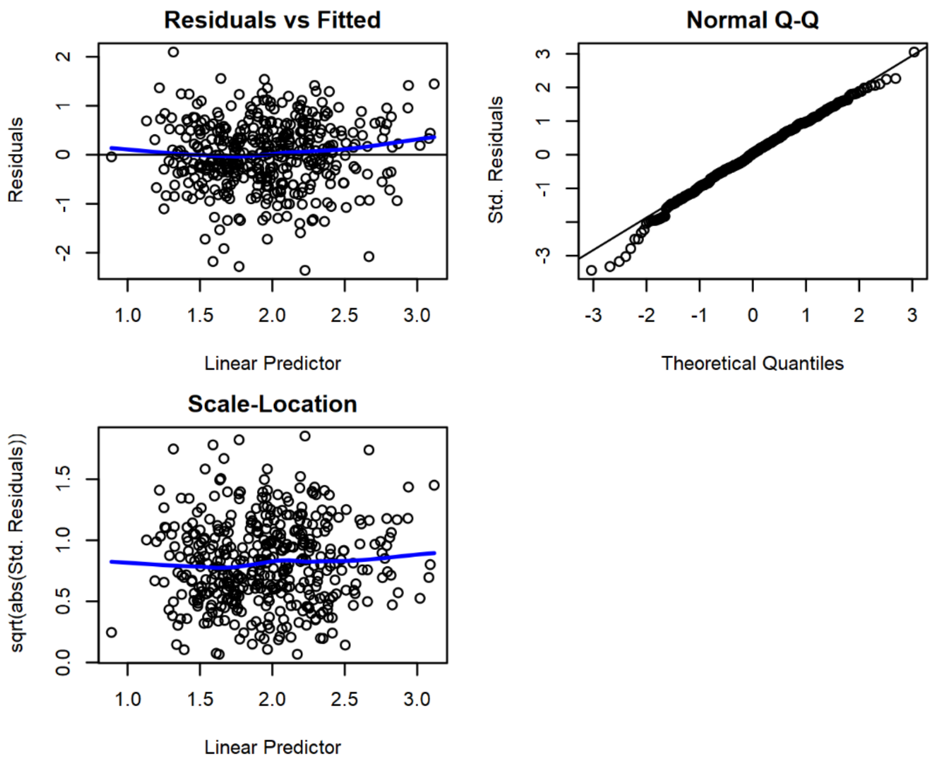

Figure F-15. Model Diagnostic Plots from the Chlorophyll vs. Nitrogen Hierarchical Model

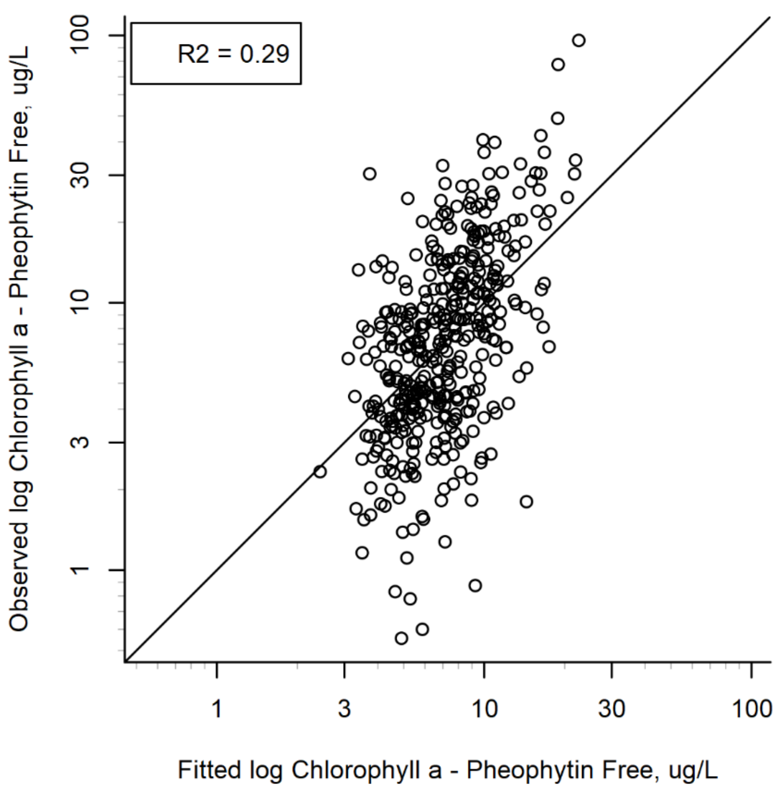

Figure F-16. Observed vs. Fitted (1:1) Plot from the Chlorophyll vs. Total Nitrogen Model.

EPA constructed embayment-specific plots and solved for TN concentrations associated with three chlorophyll *a* primary response variables: 1.0 µg/L, 10 µg/L, and an embayment-specific value derived from the K_d versus chlorophyll models output. The 1.0 µg/L concentration was derived from the minimum chlorophyll derived using embayment-specific chlorophyll versus light attenuation models described above and reported in Table F-8, and the 10 µg/L concentration is the chlorophyll value derived from the chlorophyll versus light attenuation model using a value of K_d = 0.7 (Table F-11), the recommended K_d value for LIS provided by Vaudrey (2008a,b). The embayment-specific values provided in Table F-12.

For each embayment, a scatterplot with an embayment-specific trend line and 80 percent CIs of the chlorophyll versus TN relationship is presented in *Subtask G: Nitrogen Target Concentrations*. The trend line depends on the embayment's mean values of the covariates (non-chlorophyll predictors). If no data for a covariate were available for a given embayment, the grand mean (the mean of means) of the other embayments was used. CIs in a statistical model represent the range of uncertainty in the average chlorophyll values (y-axis) the model predicts, given a TN value (x-axis). The uncertainty in the predicted values stems from the uncertainty in the estimated model parameters. CIs vary per embayment due to the use of hierarchical modeling and the varying covariate values for each embayment. A LIS-wide population fit is presented in Figure F-17. Embayment-specific population fits are provided in *Subtask G: Nitrogen Target Concentrations* for embayments without any paired data (see *Hierarchical Models* on page F-5 for more information on hierarchical population fits).

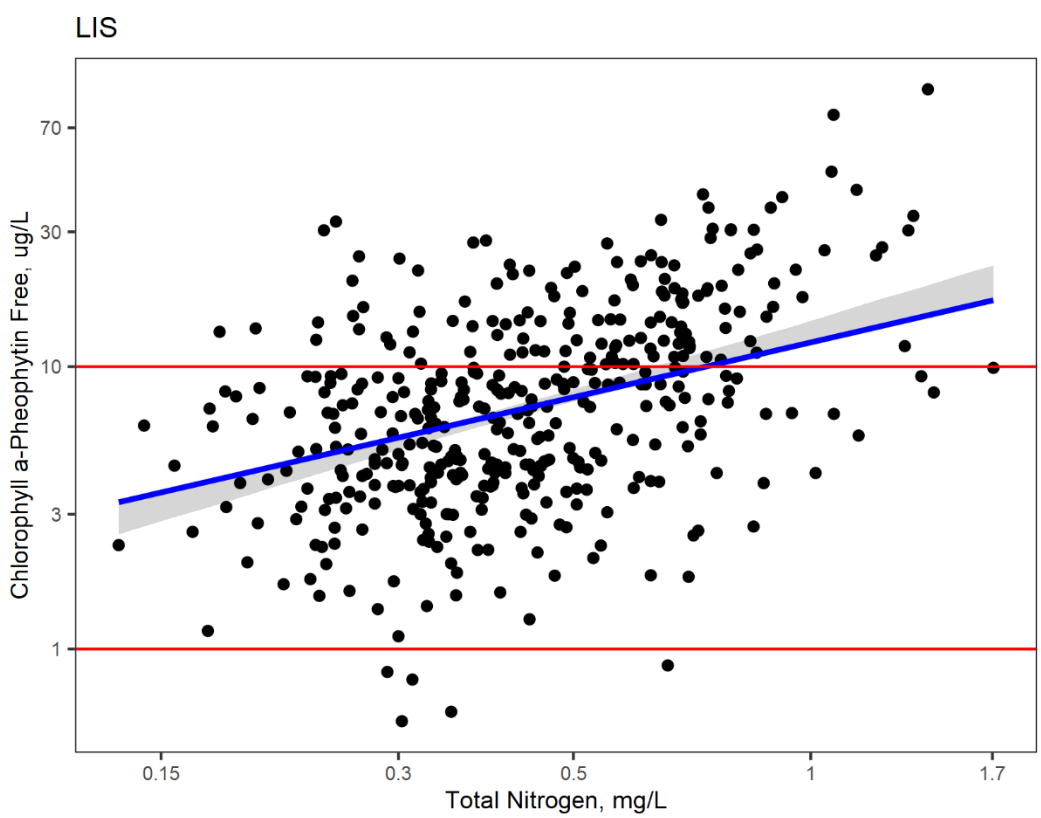

Figure F-17. Chlorophyll vs. Nitrogen (Hierarchical Population Fit (*Blue Line*) for all of LIS; 80% CI (*Gray Areas*)

LIS Open Water Models

In addition to the embayment models, EPA developed regression models to quantify various relationships for open water portions of LIS, which from west to east consists of the Western Narrows, Eastern Narrows, and Eastern LIS. Water quality data observed from embayments within the Eastern and Western Narrows were not considered open water data. Paired data for bottom samples were also limited (n=1; less than 1 percent of available data), so only surface observations were included in this analysis.

The methodology used for the open water models followed the methodology outlined for the embayment models, with some exceptions. The management goal of protecting eelgrass was not considered in the deeper open water region, because it is not seagrass habitat, but could be considered applicable for shallow open water areas outside of embayments given that these areas contain habitat suitable for eelgrass (Vaudrey et al. 2013) and water in these areas readily mixes with other open water habitat. Also, there were only three potential group levels—Western Narrows, Eastern Narrows, and Eastern LIS—for the open water data. For hierarchical models, at least five levels are needed to accurately estimate the group variance. Therefore, least squares regression was used to model the open water groups and interaction with chlorophyll.

DO VERSUS CHLOROPHYLL RELATIONSHIP

The relationship between surface water DO and chlorophyll for LIS open water data was explored using a least squares model to see if a relationship would inform nitrogen threshold development. Data for the growing season (April–September) were averaged to the station-date level. Samples from embayment East River, NY were removed as that area was not like open water areas but was more riverine in behavior. The predictors pH, salinity, temperature, and TSS were included to see if they would significantly improve the fit of the model. Turbidity was considered but not modeled as it would have severely diminished the paired sample size. Following is the final model:

$$sqrt(DO)_i = \beta_0 + \beta_1 * \ln(Chlorophyll_i) + \beta_2 * \ln(TSS_i) + \beta_3 * \text{sqrt}(Temperature_i)$$

$$+\beta_4 * \text{WaterGroup} + \beta_5 * \text{WaterGroup:}\ln(Chlorophyll) + e_i \qquad \text{(Equation 10)}$$

where:

- β_0 is the intercept
- β_1 is the ln(chlorophyll) slope
- β_2 is the ln(TSS) slope
- β_3 is the temperature squared slope
- β_4 is the open water group categorical variable
- β_5 is the interaction between the open water group and ln(chlorophyll)
- e_i is the error term
- *i* is an index for each observation

The final model contained 2,035 observations across 77 stations (Table F-19), with data observed between 2006 and 2015. Final model coefficients are presented in Table F-20. A plot of the population-wide DO versus chlorophyll model is shown in Figure F-18, observed versus fitted values are shown in Figure F-19, and model diagnostics plots are shown in Figure F-20.

Table F-19. Paired Observations and Station Counts for the Dissolved Oxygen vs. Chlorophyll Open Water Model, by Open Water Group

Open Water Group	Observation Count	Station Count
Western Narrows	1,119	12
Eastern Narrows	344	19
Eastern LIS	572	46
Total	**2,035**	**77**

Table F-20. Dissolved Oxygen vs. Chlorophyll Open Water Model Coefficients

Variable	Coefficient	Standard Error	t value	P-value
Intercept	2.94	0.030	99.12	<0.0001
ln(Chla) (µg/L)	0.12	0.009	13.72	<0.0001
Temperature^2 (˚C)	-0.0016	0.00004	-43.33	<0.0001
ln(TSS) (mg/L)	-0.03	0.009	-3.45	0.0006
Water group[a]	-	-	415.34	<0.0001
Water group:ln(Chla)[a]	-	-	19.18	<0.0001

Note:
[a] F-values instead of t values reported for categorical predictors.

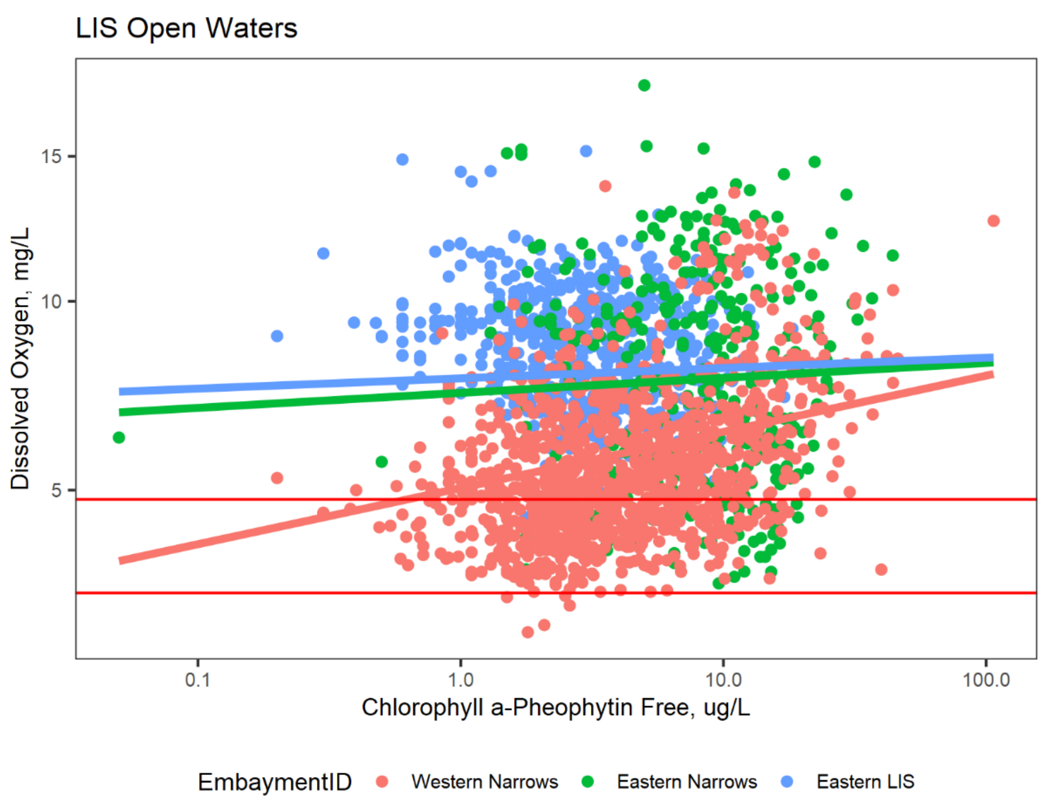

Figure F-18. Population-Wide Model of DO vs. Chlorophyll Model

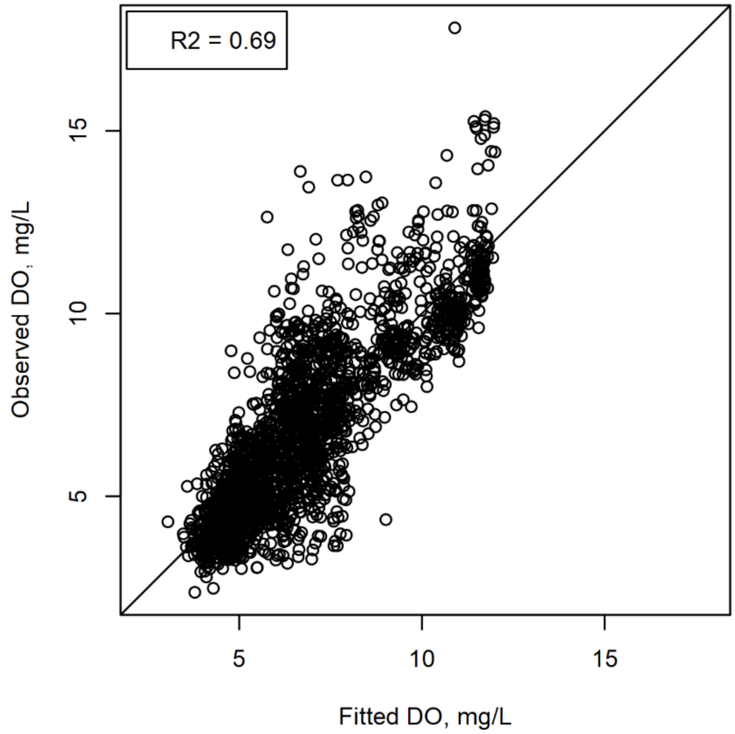

Figure F-19. Observed vs. Fitted (1:1) Plot from the DO vs. Chlorophyll Model

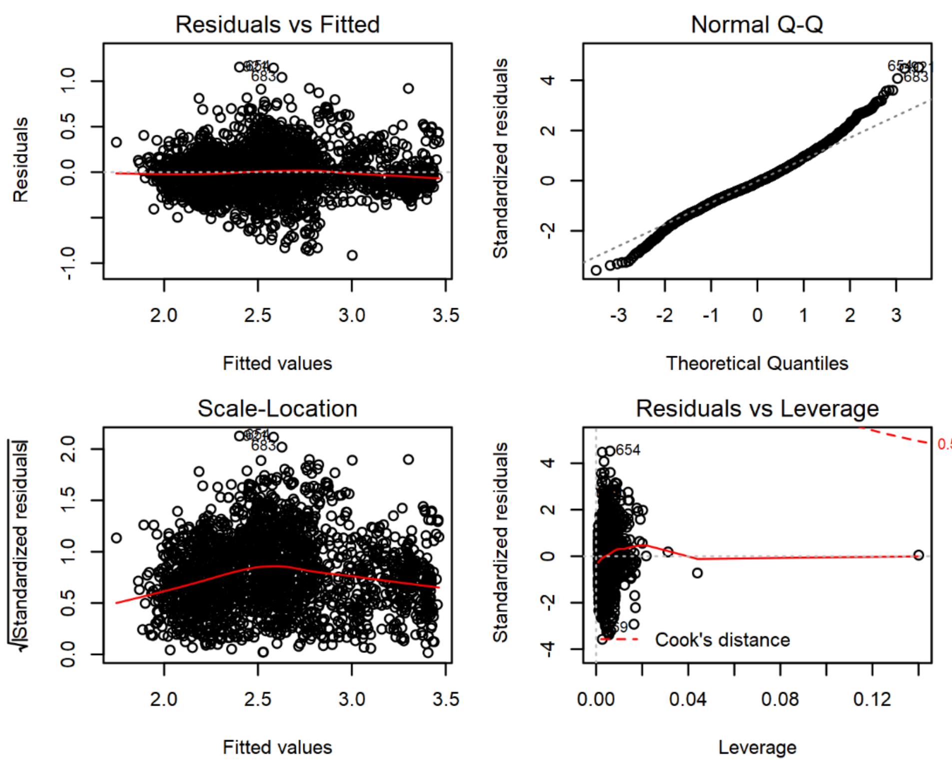

Figure F-20. Diagnostic Plots from the DO vs. Chlorophyll Model

Chlorophyll explained DO response variability well (pseudo R-squared = 0.69). The coefficient for chlorophyll was positive, reflecting increases in daily surface DO levels with chlorophyll, which is not unexpected. The fitted model predicted relatively high values of DO for Eastern Narrows and Eastern LIS even at extremely low chlorophyll levels. The relationships did not lend themselves to deriving a chlorophyll target, however, since excess DO targets do not generally exist. Ideally, we would have linked chlorophyll to DO deficits in the bottom layers, where this effect might be expected. The lack of paired bottom DO samples with chlorophyll data was a limitation. There was plenty of bottom DO data, as evidenced by the hypoxia maps drawn for LIS, but this analysis was unable to find adequate paired bottom DO with chlorophyll samples to build this relationship. Moreover, the organic matter (including algal biomass) driving respiration in any location is displaced in space and time, further confounding relationships between chlorophyll and DO in any one location. As a result, a chlorophyll response variable value was not able to be derived for the DO versus chlorophyll relationship.

CHLOROPHYLL VERSUS TN RELATIONSHIP

Seeing as no chlorophyll *a* target could be derived from surface DO response based on this available surface water quality dataset and this empirical modeling effort, deriving a chlorophyll–nitrogen concentration model for open waters was not pursued in this effort.

Distribution-Based Analysis

There are multiple methods for using a distribution-based analysis to develop nutrient target concentrations. The results of distribution-based analysis are being applied in this application within a multiple lines of evidence approach that includes scientific literature and empirical stressor-response models linking nitrogen concentrations to response variables for the different water bodies.

The distribution-based line of evidence refers to evaluating distributions of nitrogen concentrations in different watersheds and using those values to inform protective nitrogen target concentrations. EPA has used the distribution of nutrient concentrations from minimally disturbed reference watersheds for setting nutrient target concentrations for several applications, including total maximum daily loads (TMDLs) and permitting (USEPA 1999, 2001, 2015, 2016). The same concept can be extended to distributions from other nutrient concentration populations as well, including those from time periods known to be supporting uses (i.e., temporal reference) (USEPA 2010) and from populations known to be supporting their designated uses, especially aquatic life uses (USEPA 2015). In this way, identifying distributions of nitrogen concentrations for embayments known to exhibit good water quality conditions can provide a line of evidence for concentrations that protect uses and, thus, provide a line of evidence for developing nitrogen target concentrations.

The term *reference condition* refers to the condition that supports biological integrity, defined as:

> the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region (Frey 1977).

Another definition of *biological integrity* is:

> the ability of an aquatic community to support and maintain a structural and functional performance comparable to the natural habitats of a region (Frey 1977; Karr and Dudley 1981).

Because the true reference condition for biological integrity (i.e., the natural habitat condition absent human disturbance) rarely exists because of the history of human activity and existing pervasive impacts (e.g., atmospheric pollutants) and because we have insufficient historical data to re-create it, biological integrity must often be estimated and the reference condition replaced with a surrogate using a least or minimally disturbed condition (Stoddard et al. 2016).

Distribution-based approaches have been used to estimate reference conditions for nutrients in two ways: (1) as an upper percentile of least disturbed reference conditions or conditions known to be supporting uses and (2) as a lower percentile of distributions representing all similar waters. In the former case, an upper percentile is used because the distribution is expected to include waters meeting uses and the corresponding nutrient conditions are expected to be supportive. EPA's recommended percentile from least disturbed reference conditions has been the 75th percentile (USEPA 2001). In the latter case, the lower percentile is used because the distribution is expected to contain degraded waters since it is an entire population. This latter option is most useful in regions where the number of reference water bodies (i.e., undisturbed) is usually very small such as in highly developed land-use areas like those surrounding LIS. EPA's recommendation in this case is usually the 25th percentile (USEPA 2001). In either case, the selection of percentile should reflect confidence in the degree of degradation represented by either population. If almost all waters are impacted to some extent, then the 5th percentile might be used to approximate natural conditions. The actual sample size and distribution of the observations also are determinants of the percentile selected. Because the distribution-based approach approximates a reference condition, it implicitly addresses the management goal and associated assessment endpoints.

Other elements to consider in interpreting distributions are where and when the data were gathered. If the sample size is large enough, the time of year the individual samples were taken might not matter; either all seasons will be represented or most of the data will cluster around an appropriate index season. Similarly, surface grab or depth-selected samples or composite samples might not matter if the diverse dataset is large enough. For this application, the depth criteria used for the stressor-response analysis also were applied here; for timeframe, the entire range of dates was considered given the size of the available dataset, but focus was placed on the growing season for consistency with other lines of evidence.

Methods

EPA calculated reference values using the 25th percentile of all samples because of the long history of enrichment in LIS, the listing and ongoing implementation of a TMDL for nitrogen, and present knowledge related to continuing nutrient impacts in LIS.

After extracting the water quality data (*Subtask D: Summary of Existing Water Quality Data*), the average seasonal (April–September) surface water TN geometric means were calculated for each year at a station. Cumulative distributions of resultant average TN were calculated along with distribution statistics that include the 25th percentile values for embayment waters and open waters. These values were then used as the distribution-based target concentrations for embayments and open waters.

As additional supporting information, EPA identified two embayments (Niantic Bay and Mystic Harbor) within which seagrass coverage increased consistently between 2002 and 2012 (Tiner et al. 2013). Nutrient data from within these embayments were compiled and reviewed for concentrations as supporting information.

Results

Stations for the distribution-based analysis were spread across embayments and open water (Figure F-21 and Table F-21). The data from these stations were extracted and the distribution-based values estimated as described above. Distributions of values for embayments were higher than those for open water, as expected (Figure F-22). The distributional statistics are given in Table F-22.

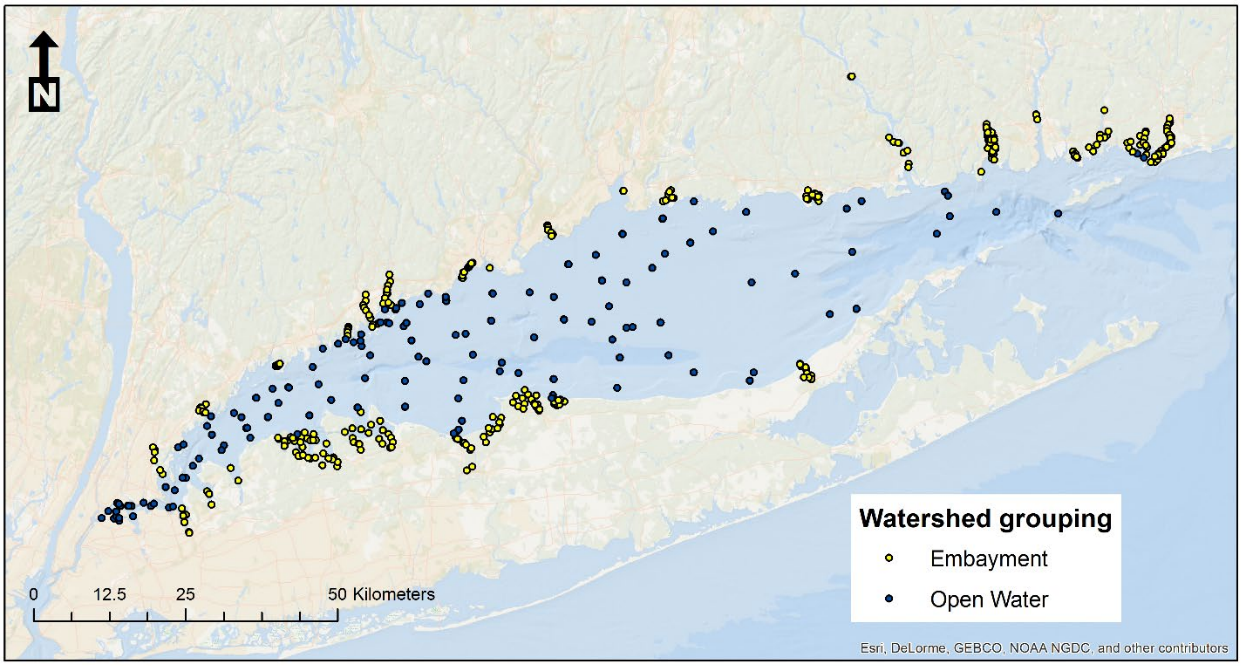

Figure F-21. Water Quality Stations Used in Distribution-Based Analysis

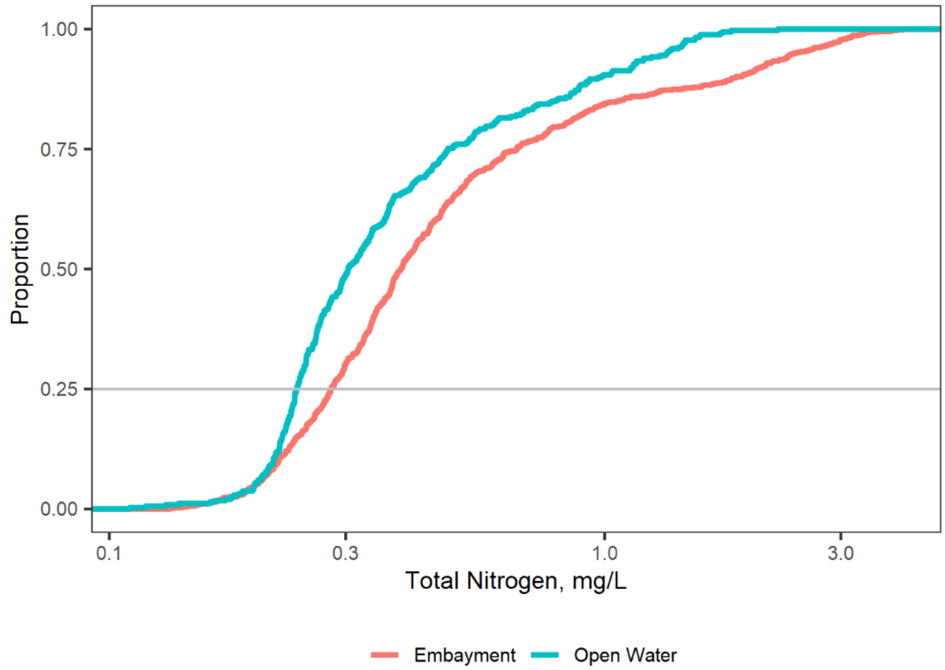

Figure F-22. Cumulative Distribution of Station Year Seasonal (April–September) Geometric Mean Total Nitrogen (mg/L) Values in Open Water vs. Embayment Stations

Table F-21. Number of Observations and Sites from LIS Embayments Used in Estimating Distribution-Based Values

Embayment	Observation Count	Station Count
Bebee Cove, CT	2	2
Connecticut River, CT	16	11
Conscience Bay, NY	9	2
Eastchester Bay, NY	6	5
Hempstead Harbor, NY	2	1
Housatonic River, MA and CT	6	6
Huntington Bay, NY	14	2
Huntington Harbor, NY	26	4
Little Narragansett Bay, CT and RI	31	11
Lloyd Harbor, NY	8	2
Mamaroneck River, NY	12	6
Manhasset Bay, NY	2	1
Mattituck Creek, NY	32	9
Milford Harbor, CT	9	6
Mill Neck Creek, NY	50	10
Mt. Sinai Harbor, NY	31	6
Mystic Harbor, CT	15	4
New Haven Harbor, CT	2	2
Niantic Bay, CT	18	13
Nissequogue River, NY	21	8

Northport-Centerport Harbor Complex, NY	59	9
Oyster Bay / Cold Spring Harbor Complex, NY	68	17
Pawcatuck River, RI and CT	54	11
Pequonnock River, CT	1	1
Port Jefferson Harbor, NY	89	14
Saugatuck Estuary, CT	8	4
Stonington Harbor, CT	16	5
Stony Brook Harbor, NY	52	9
Thames River, CT	3	3
Williams Cove, CT	15	5
Total	**677**	**189**

Table F-22. Distributional Statistics of Total Nitrogen (mg/L) for all Embayment Sites or Only Open Water Sites (25th percentile of Station_Year seasonal [April–September] Geometric Means Values [*Boldface*])

Watershed Grouping								
Percentile	5%	10%	25%	Median	75%	90%	95%	N
All embayments	0.20	0.22	**0.28**	0.39	0.66	1.84	2.41	677
All open water	0.20	0.21	**0.24**	0.30	0.48	0.98	1.33	346
All embayments + Narragansett	0.20	0.22	**0.29**	0.41	0.65	1.29	2.24	882

EPA also looked at the effect of expanding the population to include embayments along Narragansett Bay, CT. Adding in values from that system had essentially no effect on the 25th percentile TN value (0.28 mg/L) (Table F-22).

As additional supporting information for estimating TN concentrations consistent with those known to be supporting desired conditions in LIS embayments, the long-term median TN concentrations in Niantic Bay, Mystic River, and Stonington Harbor embayments, all three of which were found to have exhibited areal seagrass increases from 2002 to 2012 (Tiner et al. 2013), were 0.26 mg/L, 0.53 mg/L, and 0.33 mg/L (N=112, N=112, and N=77), respectively, based on available water quality data (see Subtask D Memo). The average of these values (0.37 mg/L) is higher but similar to the 25th percentile from the distribution-based values above (0.27 mg/L) and similar to the median literature-based line of evidence indicated above (0.39 mg/L). Notably, Niantic Bay, which was the embayment exhibiting the greatest total increase in eelgrass acreage from 2002 to 2012 in the Tiner et al. (2013) study, had the lowest of these TN concentrations. This result supports the conclusion that the distribution-based values here and literature-based values from above are reasonable and consistent with those known to support increases in eelgrass growth in LIS.

Subtask F Sources Cited

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Appendix F1: TN Concentrations Found in Massachusetts Estuary Project Reports

Location	Pages	Full Citation
Three Bays (Town of Barnstable)	154	Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Town of Barnstable, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/3Bays/3Bays_MEP_Final.pdf.
Wild Harbor Embayment System (Town of Falmouth)	128	Howes B., E.M. Eichner, S. Kelley, R.I. Samimy, J.S. Ramsey, D.R. Schlezinger, and P. Detjens. 2013. *Massachusetts Estuaries Project Linked Watershed-Embayment Modeling Approach to Determine Critical Nitrogen Loading Thresholds for the Wild Harbor Embayment System, Town of Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/WildHarbor/WildHarbor_MEP_FINAL-6MB.pdf.
Bass River Embayment (Towns of Yarmouth and Dennis)	175	Howes, B., S. Kelley, J.S. Ramsey, E. Eichner, R. Samimy, D. Schlezinger, and P. Detjens. 2011. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Bass River Embayment System, Towns of Yarmouth and Dennis, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/BassRiver/BassRiver_MEP_FINAL13MB.pdf.
Centerville River (Town of Barnstable)	145	Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, and E. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Town of Barnstable, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Centerville/Centerville_MEP_Final.pdf.
Stage Harbor/ Oyster Pond, Sulphur Springs/ Bucks Creek and Taylors Pond/Mill Creek (Chatham)	63	Howes, B.L., E.M. Eichner, S.W. Kelley, J.S. Ramsey, and R.I. Samimy. 2007. *Linked Watershed-Embayment Model to Re-evaluate Critical Nitrogen Loading Thresholds for Stage Harbor/Oyster Pond, Sulphur Springs/Bucks Creek and Taylors Pond/Mill Creek, Chatham, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Chatham/Chatham_Re-eval_Report.pdf.
Edgartown Great Pond System (Edgartown)	101	Howes B.L., J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, and E.M. Eichner. 2007. *Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Edgartown Great Pond System, Edgartown, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/EGP/EGP_MEP_Final_Report.pdf.
Great/Perch Pond, Green Pond, and Bournes Pond (Falmouth)	170–174	Howes B., J.S. Ramsey, S.W. Kelley, R. Samimy, D. Schlezinger, and E. Eichner. 2005. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Great/Perch Pond, Green Pond, and Bournes Pond, Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/GGB/GGB_MEP_Final_Report.pdf.

Location	Pages	Full Citation
Falmouth Inner Harbor Embayment System (Town of Falmouth)	104	Howes B., R.I. Samimy, R. Acker, E.M. Eichner, J.S. Ramsey, D. Schlezinger. 2013. *Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Falmouth Inner Harbor Embayment System, Town of Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/FalmouthHarbor/FalmouthHbr_MEP_FINAL-5MB.pdf.
Farm Pond System (Town of Oak Bluffs)	108	Howes, B.L., J.S. Ramsey, R.I. Samimy, D.R. Schlezinger, and E.M. Eichner. 2010. *Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Thresholds for the Farm Pond System, Town of Oak Bluffs, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/FarmPond/FarmPond_MEP_Final_Report.pdf.
Fiddlers Cove and Rands Harbor Embayment Systems (Town of Falmouth)	139	Howes, B.L., E.M. Eichner, S. Kelley, J.S. Ramsey, R. Samimy, and D. Schlezinger. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Fiddlers Cove and the Rands Harbor Embayment Systems, Town of Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/FiddlersRands/Fiddlers-Rands_MEP-FINAL-7MB.pdf.
Herring River Embayment System (Harwich)	144	Howes, B., H.E. Ruthven, J.S. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Herring River Embayment System, Harwich, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/HerringRiver/HerringRiver_MEP_FINAL-10MB.pdf.
Lewis Bay Embayment System (Barnstable/ Yarmouth)	177–179	Howes, B.L., H.E. Ruthven, E.M. Eichner, J.S. Ramsey, R.I. Samimy, and D.R. Schlezinger. 2007. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable/Yarmouth, Massachusetts.* SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Lewis_Bay/Lewis_Bay_MEP_Final.pdf.
Little Namskaket Marsh Estuarine System (Orleans)	97	Howes, B.L., E.M. Eichner, S.W. Kelley, J.S. Ramsey, R.I. Samimy, D.R. Schlezinger. 2007. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Little Namskaket Marsh Estuarine System, Orleans, Masssachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Orleans/Little_Nam_MEPrpt_final.pdf.
Little Pond System (Falmouth)	115–116	Howes, B.L., J. Ramsey, E.M. Eichner, R.I. Samimy, S.W. Kelley, and D.R. Schlezinger. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Little Pond System, Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Little_Pond/Little%20Pond_MEP_Final.pdf.

Location	**Pages**	**Full Citation**
Namskaket Marsh Estuarine System (Orleans)	104	Howes, B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, E.M. Eichner, and D.R. Schlezinger. 2007. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Namskaket Marsh Estuarine System, Orleans, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Orleans/Namskaket_MEPrpt_final.pdf.
Nantucket Harbor (Town of Nantucket)	156–157	Howes, B.L., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, and E.M. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Nantucket Harbor, Town of Nantucket, Nantucket Island, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Nantucket/Nantucket_Hbr_MEP_Final.pdf.
Oak Bluffs Harbor System (Oak Bluffs)	110	Howes, B.L., S. Kelley, H. Ruthven, R.I. Samimy, D.R. Schlezinger, E.M. Eichner, and J.S. Ramsey. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Oak Bluffs Harbor System, Town of Oak Bluffs, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/OakBluffsHarbor/OakBluffs_MEP_FINAL-5MB.pdf.
Oyster Pond System (Falmouth)	103	Howes, B.L., S.W. Kelley, J.S. Ramsey, E.M. Eichner, R.I. Samimy, and D.R. Schlezinger. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Oyster Pond System, Falmouth, Massachusetts.* SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Oyster_Pond/OysterPond_FINAL_Report.pdf.
Parkers River Embayment System (Yarmouth)	136	Howes, B.L., S. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2010. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Parkers River Embayment System, Yarmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed August 2019. http://www.yarmouth.ma.us/DocumentCenter/View/1435/2010-Final-Mass-Esturaries-Project-Report-?bidId=.
Phinneys Harbor, Eel Pond and Back River System (Bourne)	117–118	Howes, B.L., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Phinneys Harbor, Eel Pond and Back River System, Bourne, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/PhinneysHbr_BackRiver/PhinneysHbr_MEP_Final.pdf.
Pleasant Bay System (Orleans, Chatham, Brewster and Harwich)	209	Howes, B.L., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, and E.M. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Orleans, Chatham, Brewster and Harwich, Massachusetts. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Pleasant_Bay/PleasantBay_MEP_Final.pdf.

Location	Pages	Full Citation
Popponesset Bay (Mashpee and Barnstable)	123	Howes, B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, E.M. Eichner, D. Schlezinger, and J. Wood. 2004. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Popponesset/PopponessetMEPrpt_final.pdf.
Quashnet River, Hamblin Pond, and Jehu Pond in the Waquoit Bay System (Mashpee and Falmouth)	131–132	Howes, B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, D. Schlezinger, T. Ruthven, and E. Eichner. 2005. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System in the Towns of Mashpee and Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Quashnet/Quashnet_MEP_Final_Report.pdf.
Quissett Harbor Embayment System (Falmouth)	102	Howes, B.L., S. Kelley, J.S. Ramsey, E. Eichner, R. Samimy, D. Schlezinger, and P. Detjens. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quissett Harbor Embayment System, Town of Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Quissett/Quissett_MEP_FINAL-6MB.pdf.
Rock Harbor Embayment System (Orleans)	102	Howes, B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, D.R. Schlezinger, and E.M. Eichner. 2007. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Orleans/Rock_Harbor_MEPrpt_final.pdf.
Rushy Marsh (Barnstable)	88	Howes, B.L., H. Ruthven, J. Ramsey, R. Samimy, D. Schlezinger, and E.M. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Rushy Marsh Pond, Barnstable, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Rushy/Rushy_MEP_Final.pdf.
Sengekontacket Pond System (Oak Bluffs and Edgartown)	128	Howes, B.L., E.M. Eichner, T. Ruthven, R.I. Samimy, J.S. Ramsey, and D.R. Schlezinger. 2010. *Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Sengekontacket Pond System, Towns of Oak Bluffs and Edgartown, Massachussetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Senge/Senge_MEP_Final_Report.pdf.
Sesachacha Pond (Nantucket)	86	Howes, B.L., S.W. Kelley, M. Osler, J.S. Ramsey, R.I. Samimy, D. Schlezinger, and E.M. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Sesachacha Pond, Town of Nantucket, Nantucket Island, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Sesachacha/Sesachacha_MEP_Final.pdf.

Location	Pages	Full Citation
Swan Pond River Embayment System (Dennis)	130–131	Howes, B.L., E.M. Eichner, H. Ruthven, R. Samimy, D. Schlezinger, and J.S. Ramsey. 2012. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Swan Pond River Embayment System, Town of Dennis, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/SwanPond/SwanPond_MEP_FINAL-7MB.pdf.
Tisbury Great Pond/Black Point Pond System (Chilmark and West Tisbury)	147	Howes, B.L., E.M. Eichner, R.I. Samimy, S. Kelley, J.S. Ramsey, and D.R. Schlezinger. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Tisbury Great Pond / Black Point Pond System, Chilmark and West Tisbury, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/TisburyGP/Tisbury_MEP_FINAL-7MB.pdf.
Waquoit Bay and Eel Pond Embayment System (Falmouth and Mashpee)	191–192	Howes, B.L., S. Kelley, E. Eichner, R. Samimy, J.S. Ramsey, D. Schlezinger, and P. Detjens. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Waquoit Bay and Eel Pond Embayment Systems, Towns of Falmouth and Mashpee, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/Waquoit/Waquoit_MEP_FINAL-12MB.pdf.
West Falmouth Harbor (Falmouth)	134	Howes, B.L., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, and E.M. Eichner. 2006. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for West Falmouth Harbor, Falmouth, Massachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed February 2018. http://www.oceanscience.net/estuaries/report/WestFalmouth/WestFalmouth_MEP_Final.pdf.
Westport River Embayment System (Westport)	176	Howes, B.L., E. Eichner, R. Acker, R. Samimy, J. Ramsey, and D. Schlezinger. 2013. *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Westport River Embayment System, Town of Westport, Masssachusetts*. SMAST/DEP Massachusetts Estuaries Project. Massachusetts Department of Environmental Protection, Boston, MA. Accessed August 2019. https://www.mass.gov/files/documents/2016/08/wj/mep-westport-bb.pdf.

Appendix F2: Paired Data for Stressor-Response Modeling

See Excel file.

Subtask G. Nitrogen Target Concentrations

Introduction

To calculate TN target concentration ranges, EPA used multiple lines of evidence from scientific literature, stressor-response, and distribution-based values to the maximum extent supported by the data. EPA considered each individual line of evidence equally and developed a target concentration using each one. These target concentrations consisted of the following (for each line of evidence):

- Scientific literature analysis: The calculated median TN value of literature-based values protective of seagrass and other aquatic life.
- Stressor-response analysis: The mean TN value associated with chlorophyll *a* primary response variables protective of seagrass using the stressor-response models.
- Distribution-based approach: The 25th percentile distribution-based TN value protective of seagrass and other aquatic life.

Uncertainty around the literature review line of evidence was estimated using the minimum and maximum values from Table F-1. For the embayments, EPA used literature review values for seagrass protection (a range of 0.30–0.50 mg/L; median of 0.39 mg/L rounded to 0.40 mg/L); and for open water, EPA used literature values for other aquatic life (a range of 0.30–0.60 mg/L; median of 0.41 mg/L rounded to 0.40 mg/L).

The stressor-response line of evidence was developed based on relationships between TN and chlorophyll. Chlorophyll *a* primary response variables for embayments were developed from stressor-response models of chlorophyll and light levels (K_d) necessary to protect and restore seagrasses in embayments (*Subtask F: Summary of Empirical Modeling*). EPA constructed embayment-specific plots and solved for TN concentrations associated with three chlorophyll *a* primary response variable values: a minimum of 1.0 µg/L based on the minimum value from across embayment-specific models, an embayment-specific value based on the average of a range of K_d-derived chlorophyll targets and the recommended LIS-wide chlorophyll value of 5.5, and a 10 µg/L maximum derived from the chlorophyll versus light attenuation model described above using a value of $K_d = 0.7$ (9.83 rounded to 10 µg/L), the recommended K_d value for LIS provided by Vaudrey (2008).

Stressor-response models of chlorophyll and DO were not derived for embayments or open water as explained in *Subtask F: Summary of Empirical Modeling* and, therefore, no chlorophyll *a* primary response variables were generated from that analysis. The stressor-response uncertainty ranges in the tables for each embayment were the 80th percentile CIs around the modeled target concentration limited to the highest and lowest observed TN values (2.52 mg/L and (0.06 mg/L), respectively) in the empirical LIS dataset.

For the distribution-based line of evidence, EPA selected the 25th percentile of all samples (Table F-10) (from *Subtask F: Summary of Empirical Modeling*). The TN target concentrations derived using this approach were 0.28 mg/L (all embayments and riverine systems) and 0.24 mg/L (open water). No uncertainty estimates around these values were calculated.

Table G-1 provides a summary of how each line of evidence supports the analysis, relates to selected management goals and assessment endpoints, which waters the lines of evidence are applicable to, and ultimately how each line of evidence led to a TN target concentration.

Table G-1. Summary of Lines of Evidence

Line of Evidence	Management Goal	Assessment Endpoint	Primary Response Variable	Applicable Water Body	TN Primary Causal Variable Target Concentration[a]
Scientific literature analysis	Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish			All embayments Riverine	Median value (range)
				All embayments Riverine Open water	Median value (range)
Stressor–response analysis		Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll a)	Chlorophyll *a*: 3.5 µg/L, 5.5 µg/L, and/or 10 µg/L	All embayments Riverine	Interpolated TN concentration (90th percent CI)
		Benthic and pelagic community diversity and abundance (measure of effect: DO)	State DO criteria	N/A	N/A
Distribution-based approach				All embayments Riverine	25th percentile value
				All embayments Riverine Open water	25th percentile value

Notes: N/A = not applicable; DO models were insignificant and/or counterintuitive, so were not pursued further.
[a] See tables later in this document for TN target concentrations for each water body.

G.1 Pawcatuck River, CT and RI

Figure G-1 shows a map of the Pawcatuck River watershed. Paired data for the embayment included 71 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model included chlorophyll *a*-corrected and TN.

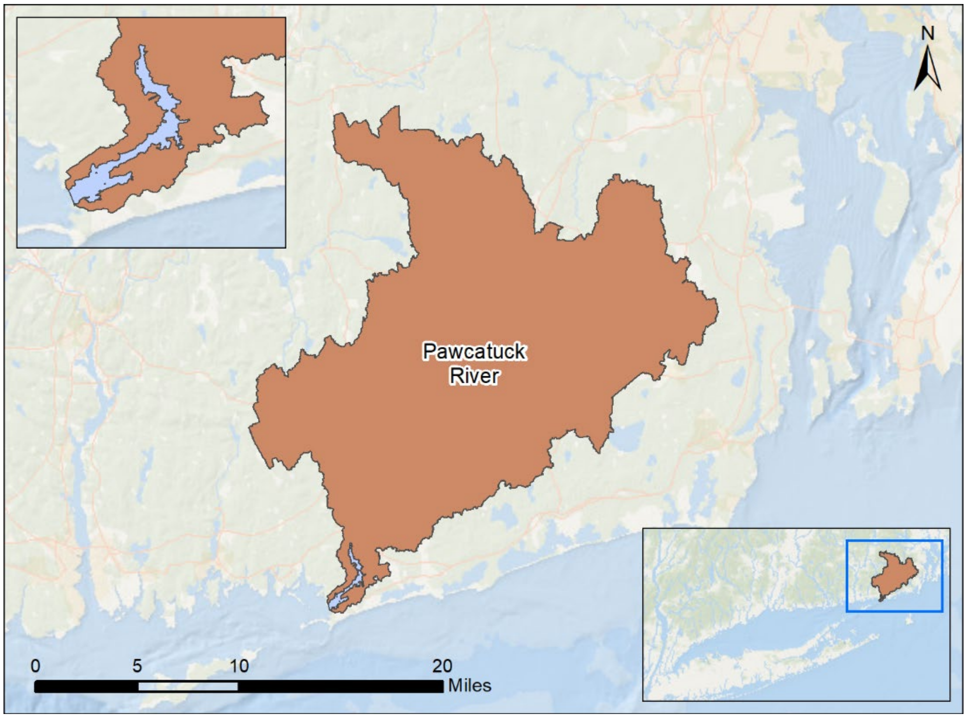

Figure G-1. Pawcatuck River Watershed, RI and CT

TN target concentrations for the Pawcatuck River watershed are presented in Table G-2. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-2. Paired data for the Pawcatuck River embayment are plotted.

Table G-2. TN Primary Causal Variable Target Concentrations for Pawcatuck River, RI and CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll a-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.0	**0.18**[a] (0.17–0.24)
			10	**0.74**[a] (0.63–0.80)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

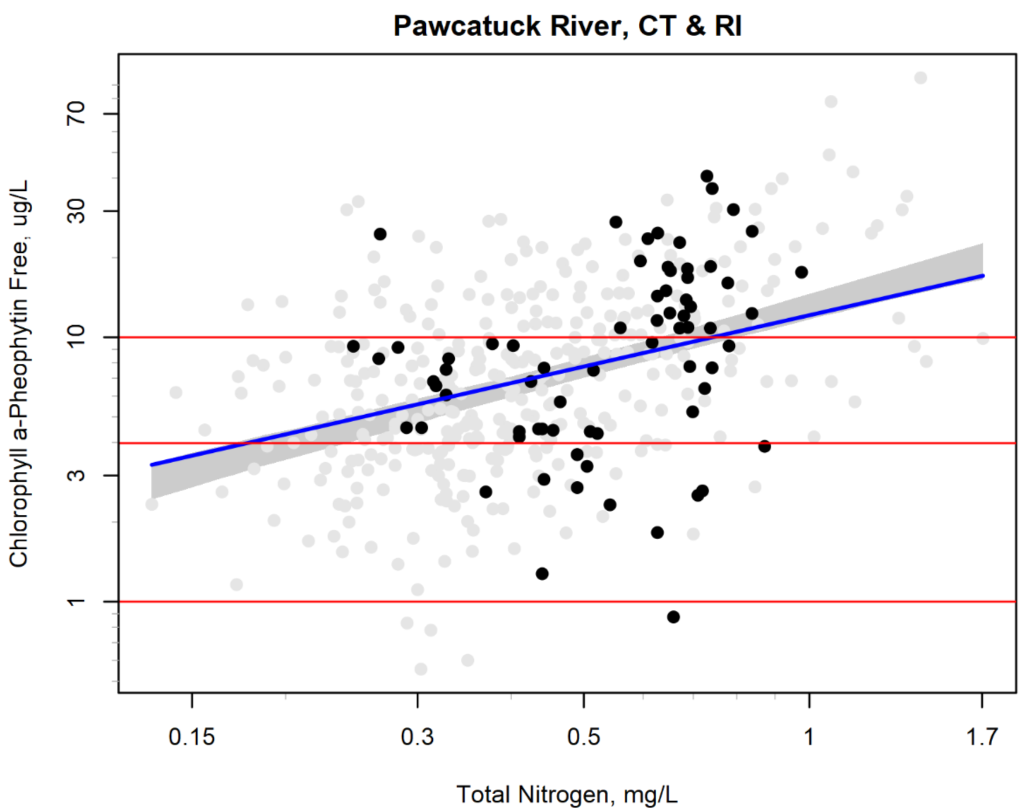

Figure G-2. Chlorophyll vs. Total Nitrogen Relationship for Pawcatuck River Watershed, RI and CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are provided in Table G-2.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.18 mg/L to 0.74 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.0 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.2 Stonington Harbor, CT

Figure G-3 shows a map of the Stonington Harbor watershed. Paired data for the embayment included 21 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model included chlorophyll *a*-corrected and TN.

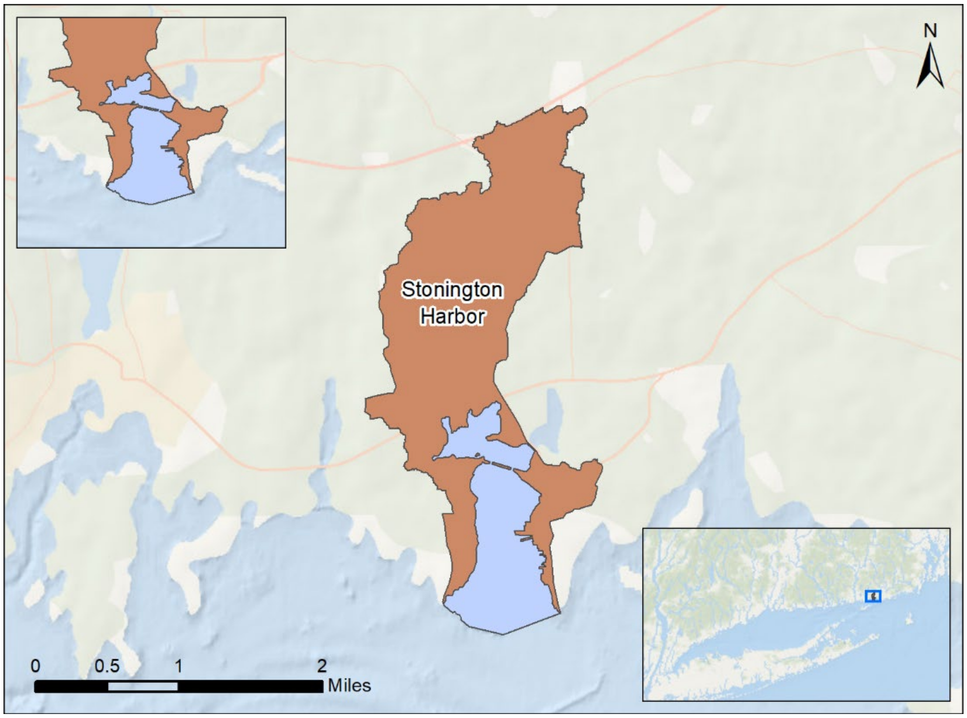

Figure G-3. Stonington Harbor Watershed, CT

TN target concentrations for the Stonington Harbor watershed are presented in Table G-3. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-4. Paired data for the Stonington Harbor embayment are plotted.

Table G-3. TN Primary Causal Variable Target Concentrations for Stonington Harbor Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.7	**0.36** (0.26–0.36)
			10	**1.19**[a] (0.68–1.08)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

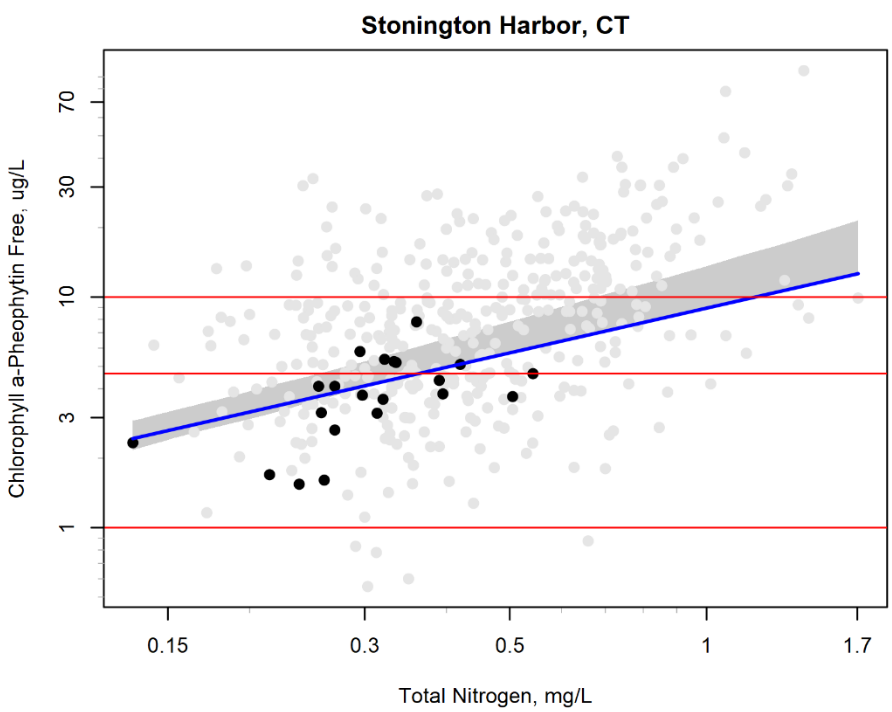

Figure G-4. Chlorophyll vs. Total Nitrogen Relationship for the Stonington Harbor Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are provided in Table G-3.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.36 mg/L to 1.19 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.7 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered to be on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.3 Saugatuck Estuary, CT

Figure G-5 shows a map of the Saugatuck Estuary watershed.[2] Paired data for the embayment included four paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

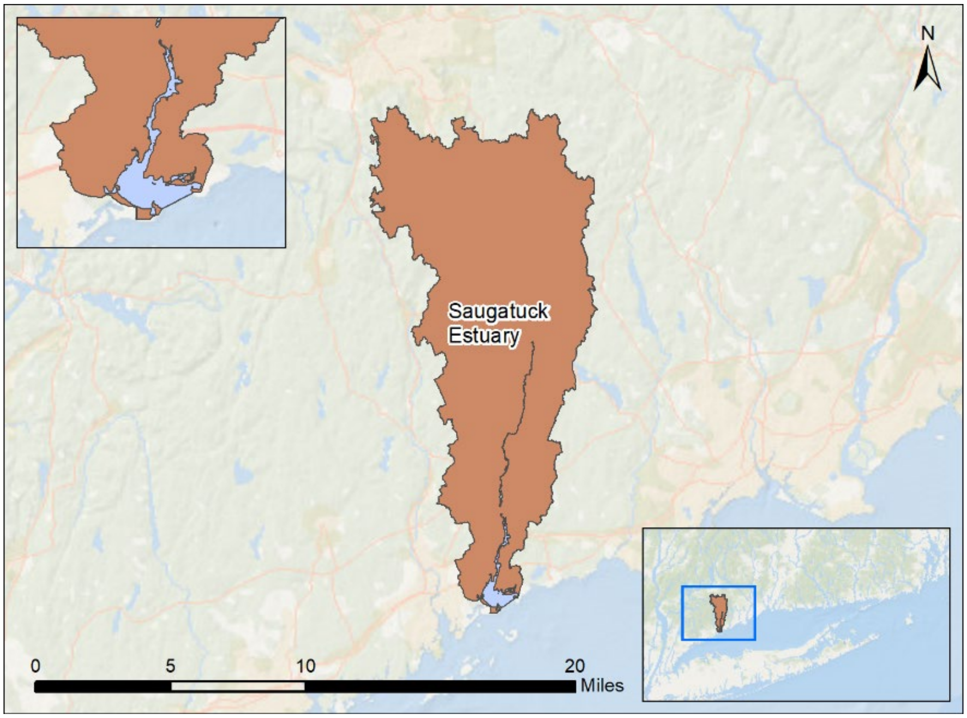

Figure G-5. Saugatuck Estuary Watershed, CT

TN target concentrations for the Saugatuck Estuary watershed are presented in Table G-4. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-6. Paired data for the Saugatuck Estuary embayment are plotted.

[2] Includes two Vaudrey et al. (2016) embayments: Saugatuck River, CT, and Saugatuck River, North, CT (freshwater).

Table G-4. TN Primary Causal Variable Target Concentrations for Saugatuck Estuary Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor–response model mean (80th percent CI)	4.2	**0.17**[a] (0.17–0.24)
			10	**0.63**[a] (0.59–0.80)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

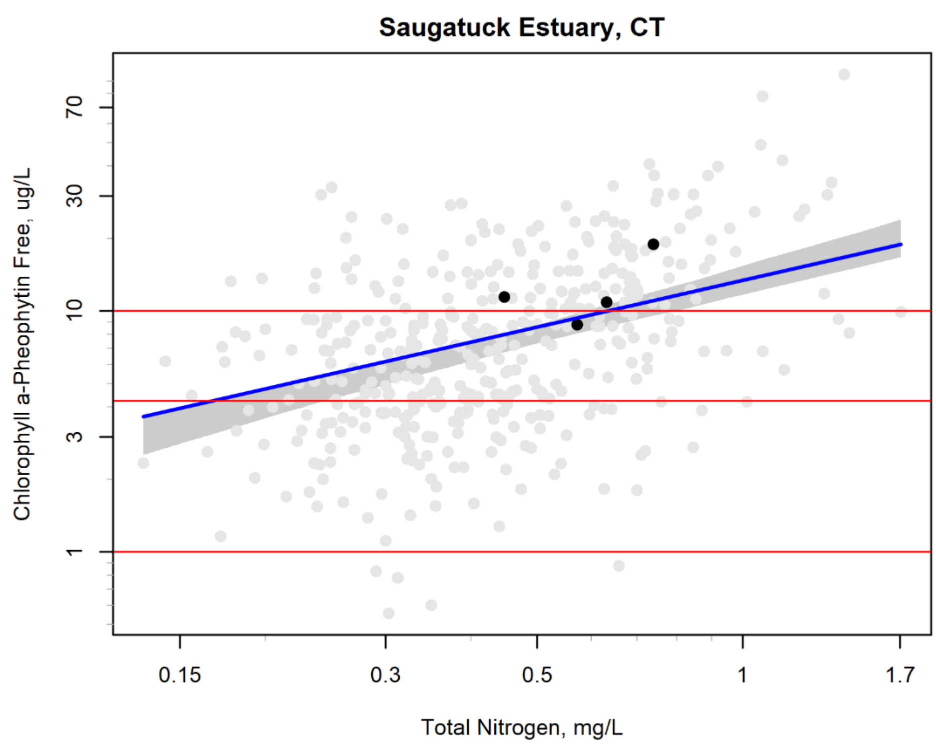

Figure G-6. Chlorophyll vs. Total Nitrogen Relationship for the Saugatuck Estuary Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are provided in Table G-4.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.17 mg/L to 0.63 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.4 Norwalk Harbor, CT

Figure G-7 shows a map of the Norwalk Harbor watershed. No paired data were available for the embayment within the growing season (April–September). Therefore, the population fit was used for the stressor-response analysis. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

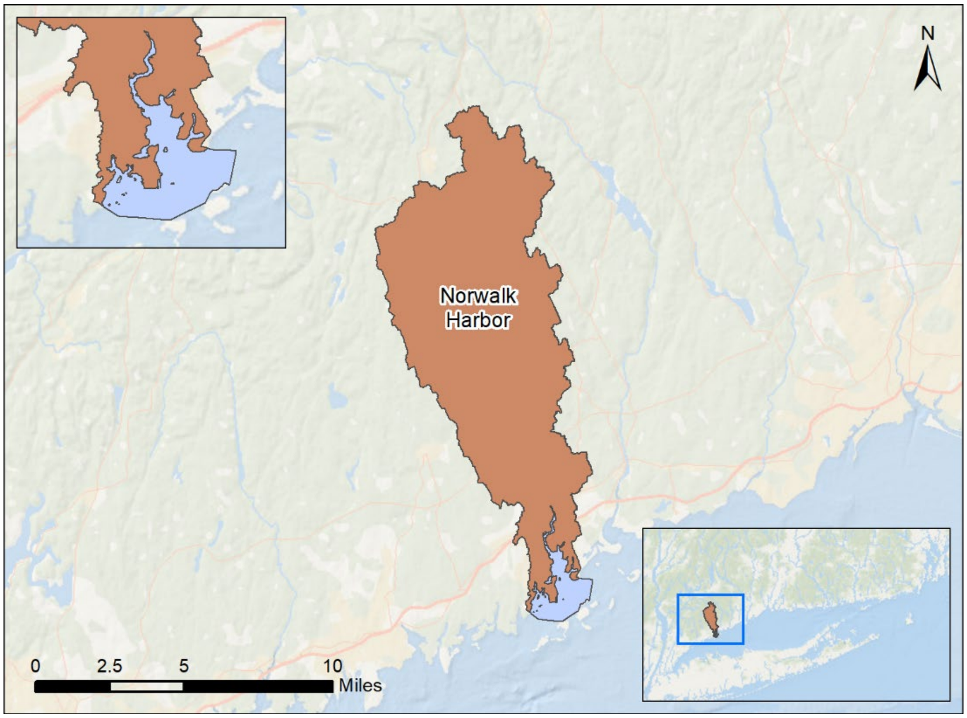

Figure G-7. Norwalk Harbor Watershed, CT

TN target concentrations for the Norwalk Harbor watershed are presented in Table G-5. A plot of the chlorophyll versus TN relationship is presented in Figure G-8. As no paired data were available for the Norwalk Harbor embayment, the population trend line is shown.

Table G-5. TN Primary Causal Variable Target Concentrations for Norwalk Harbor Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.3	**0.27** (0.27–0.31)
			10	**0.74**[a] (0.63–0.75)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

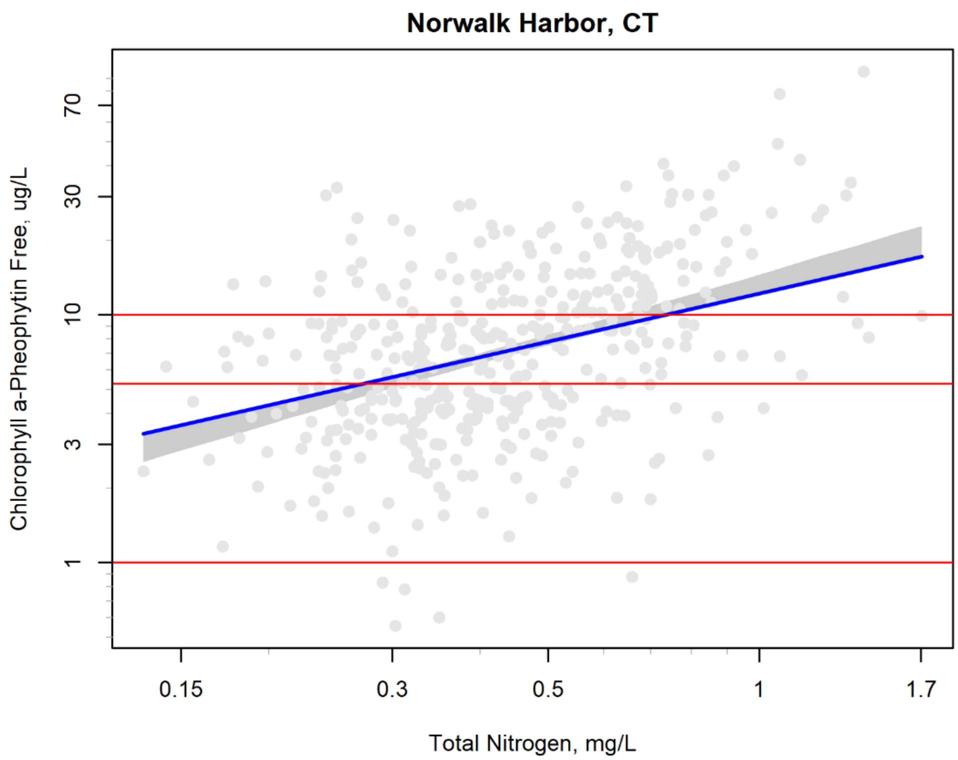

Figure G-8. Chlorophyll vs. Total Nitrogen Relationship for the Norwalk Harbor Watershed, CT (Other Embayments in the Model [*Gray Points*], No Paired Growing Season Observations were Available for the Embayment, Population Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-5.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.74 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 5.3 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.5 Mystic Harbor, CT

Figure G-9 shows a map of the Mystic Harbor watershed. Paired data for the embayment included 23 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

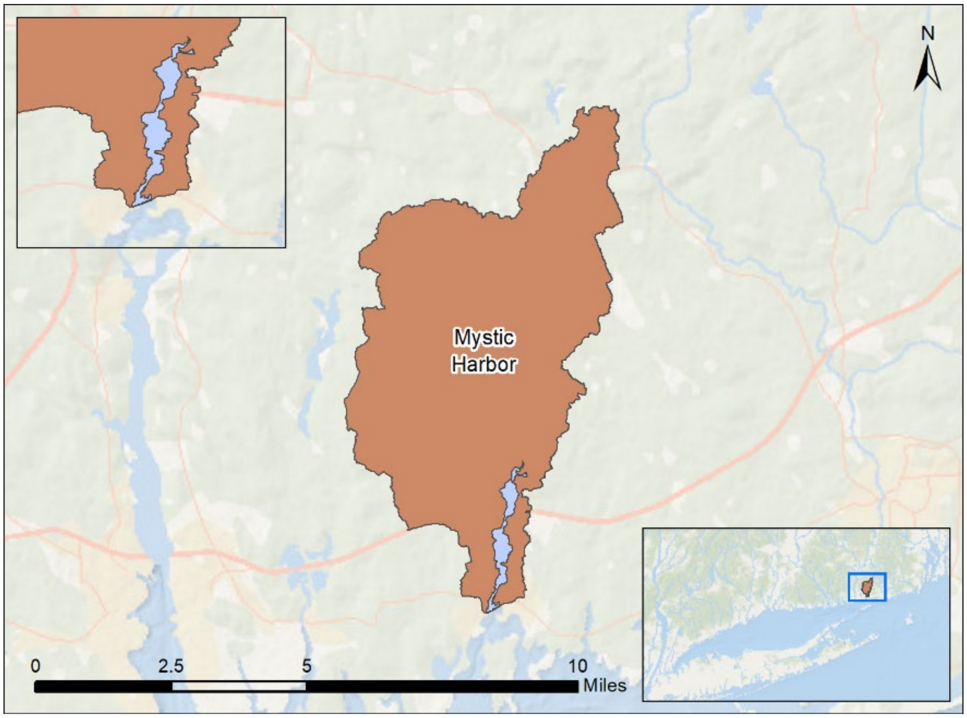

Figure G-9. Mystic Harbor Watershed, CT

TN target concentrations for the Mystic Harbor watershed are presented in Table G-6. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-10. Paired data for the Mystic Harbor embayment are plotted.

Table G-6. TN Primary Causal Variable Target Concentrations for Mystic Harbor Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.1	**0.23** (0.22–0.31)
			10	**0.65**[a] (0.57–0.79)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.27**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

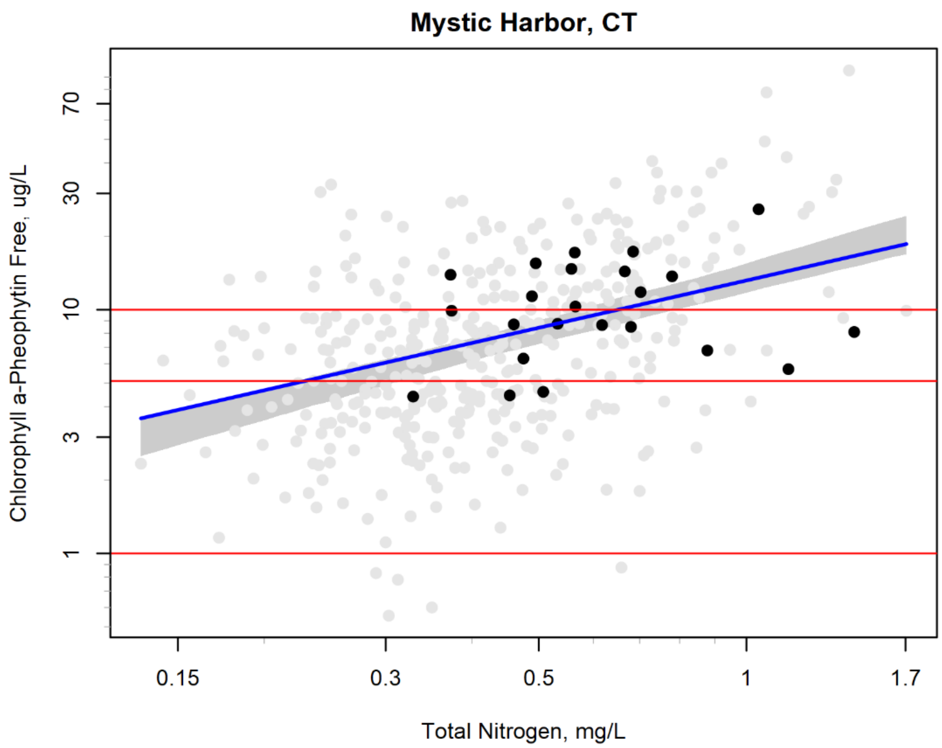

Figure G-10. Chlorophyll vs. Total Nitrogen Relationship for the Mystic Harbor Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-6.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.23 mg/L to 0.65 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 5.1 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered to be on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.6 Niantic Bay, CT

Figure G-11 shows a map of the Niantic Bay watershed.[3] Paired data for the embayment included four paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

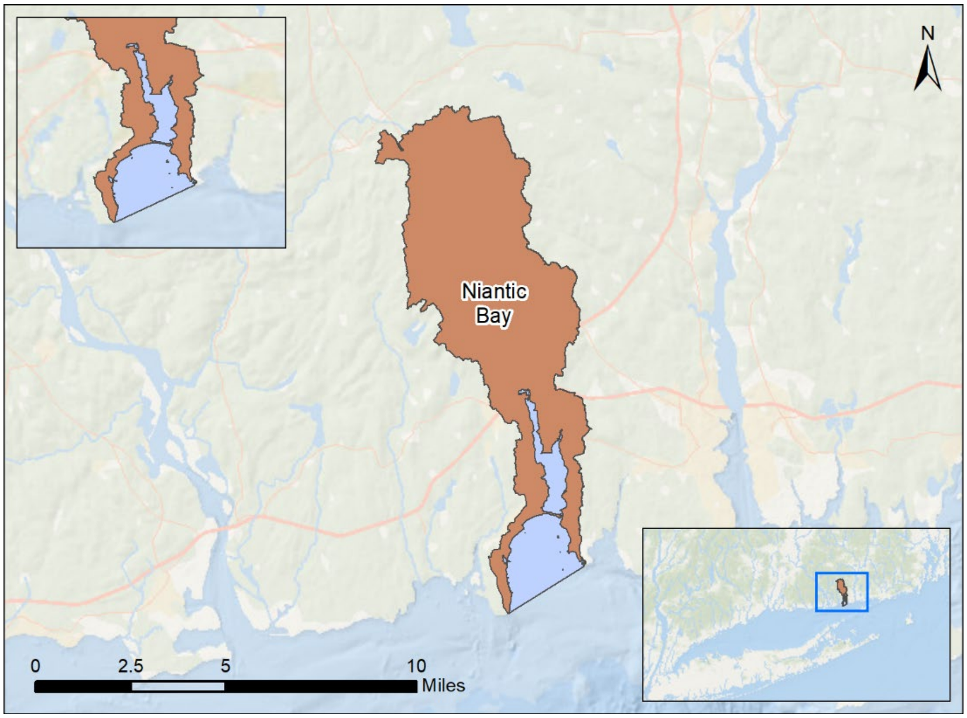

Figure G-11. Niantic Bay Watershed, CT

TN target concentrations for the Niantic Bay watershed are presented in Table G-7. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-12. Paired data for the Niantic Bay embayment are plotted.

[3] Includes two Vaudrey et al. (2016) embayments: Niantic River, CT, and Niantic Bay, CT.

Table G-7. TN Primary Causal Variable Target Concentrations for the Niantic Bay Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.8	**0.27** (0.23–0.30)
			10	**0.84**[a] (0.61–0.80)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

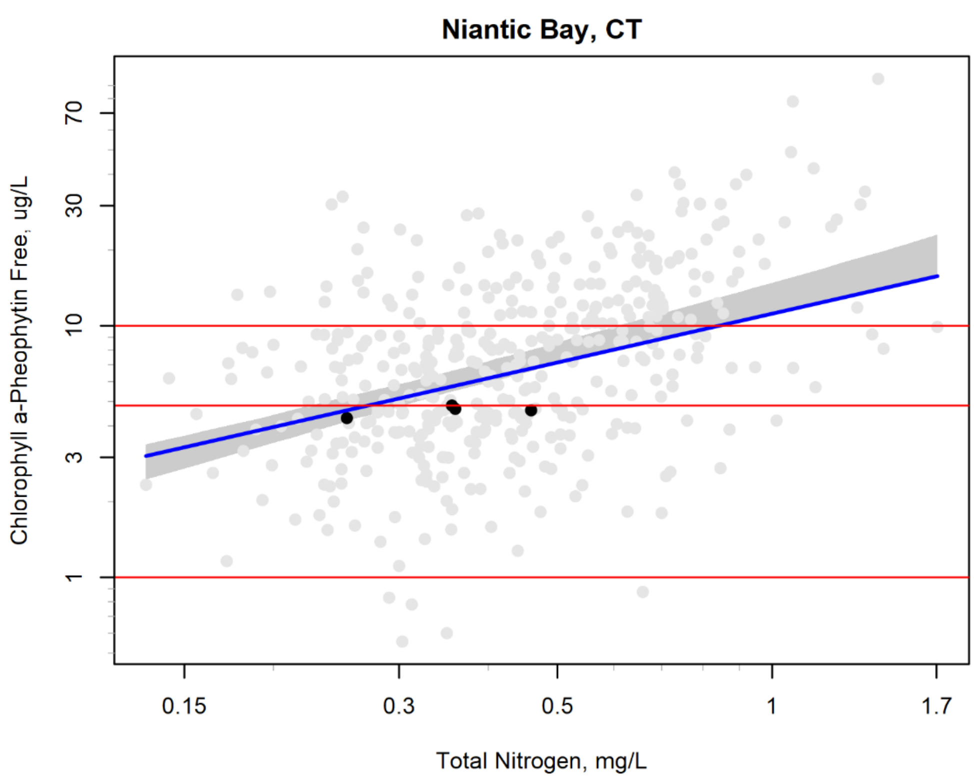

Figure G-12. Chlorophyll vs. Total Nitrogen Relationship for the Niantic Bay Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-7.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.84 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.8 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.7 Farm River, CT

Figure G-13 shows a map of the Farm River watershed. No paired data were available for the embayment within the growing season (April–September). Therefore, the population fit was used for the stressor-response analysis. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

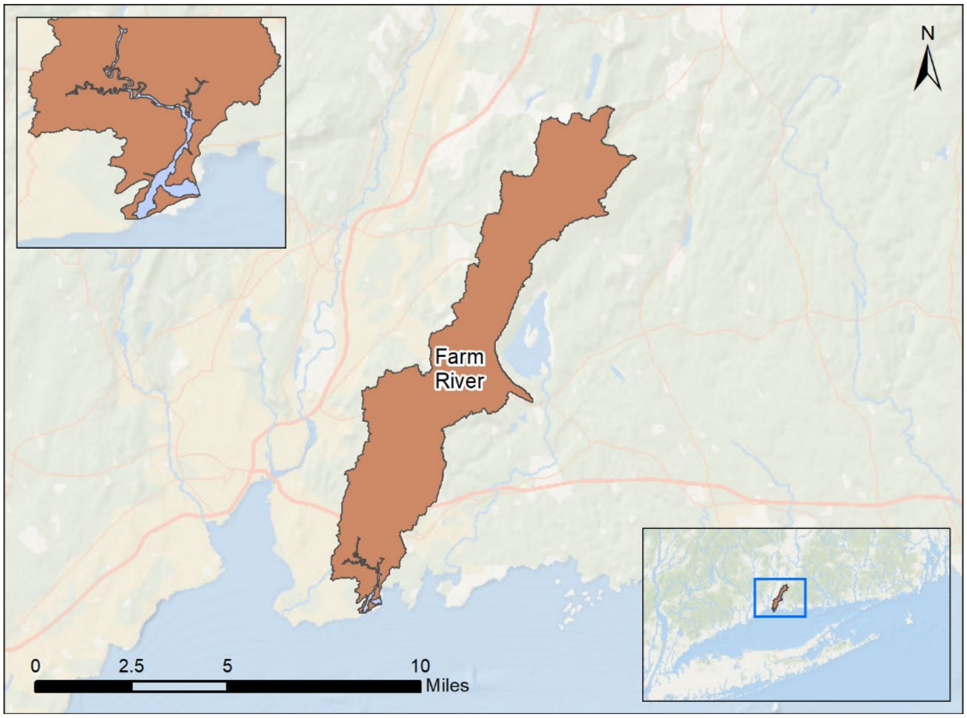

Figure G-13. Farm River Watershed, CT

TN target concentrations for the Farm River watershed are presented in Table G-8. A plot of the chlorophyll versus TN relationship is presented in Figure G-14. As no paired data were available for the Farm River embayment, the population trend line from the model is presented.

Table G-8. TN Primary Causal Variable Target Concentrations for the Farm River Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.27** (0.26–0.31)
			10	**0.74**[a] (0.63–0.75)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

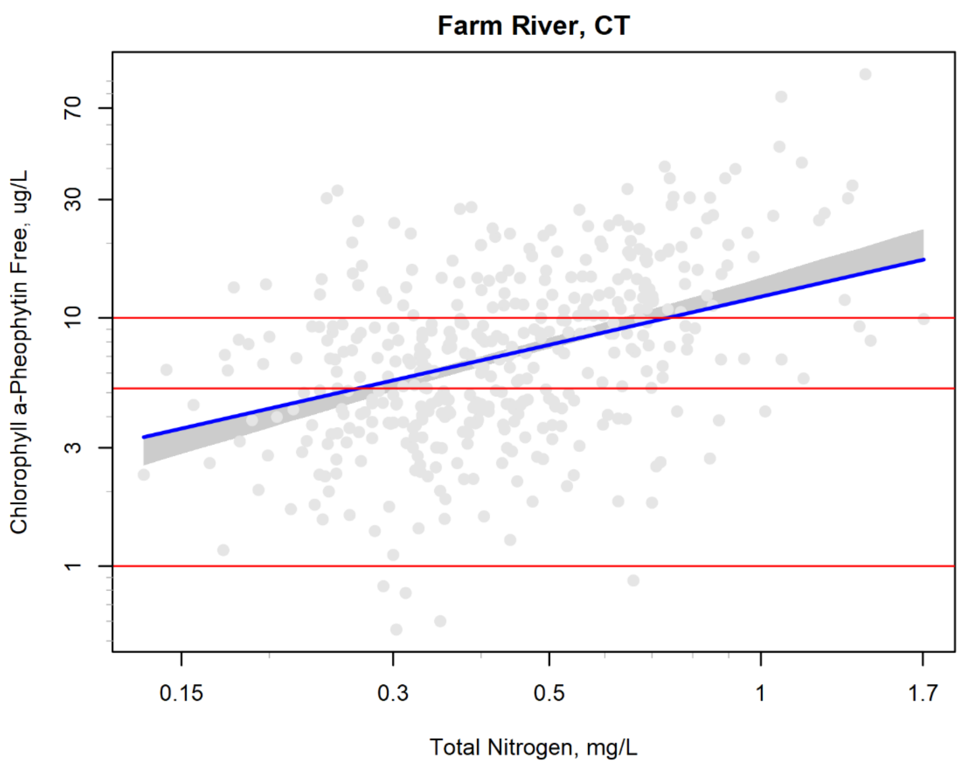

Figure G-14. Chlorophyll vs. Total Nitrogen Relationship for the Farm River Watershed, CT (Other Embayments in the Model [*Gray Points*], No Paired Growing Season Observations Available for the Embayment, Population Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-8.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.74 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.8 Southport Harbor/ Sasco Brook, CT

Figure G-15 shows a map of the Southport Harbor/ Sasco Brook watershed.[4] No paired data were available for the embayment within the growing season (April–September). Therefore, the population fit was used for the stressor-response analysis. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

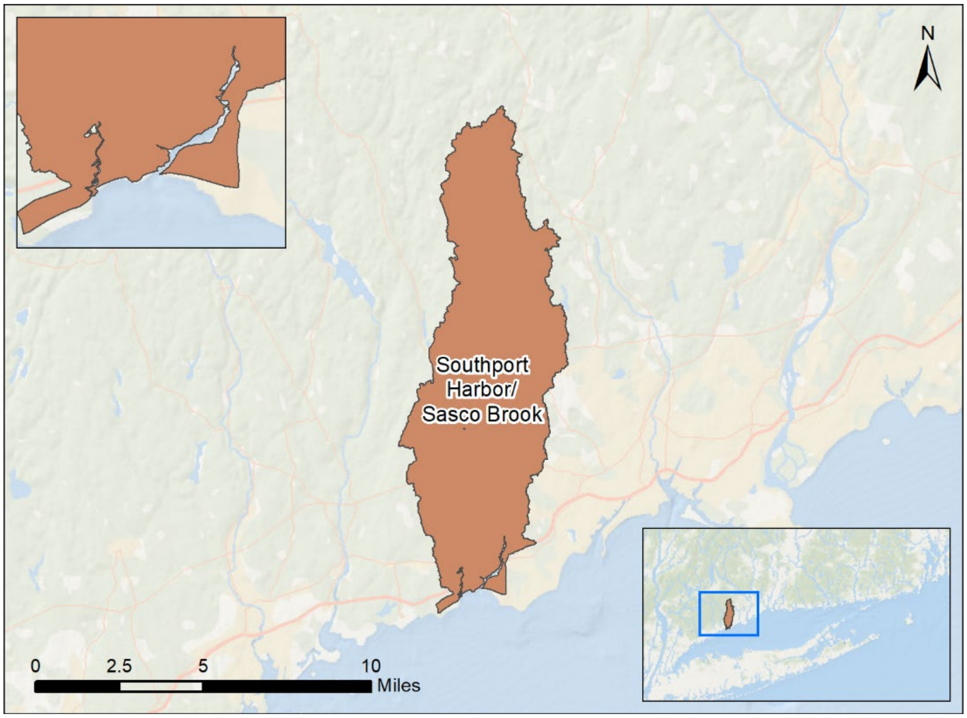

Figure G-15. Southport Harbor/Sasco Brook Watershed, CT

TN target concentrations for the Southport Harbor/Sasco Brook watershed are presented in Table G-9. A plot of the chlorophyll versus TN relationship is presented in Figure G-16. As no paired data were available for the Southport Harbor embayment, the population trend line from the model is presented.

[4] Includes two Vaudrey et al. (2016) embayments: Mill River, CT, and Sasco Brook, CT.

Table G-9. TN Primary Causal Variable Target Concentrations for the Southport Harbor/Sasco Brook Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.27** (0.26–0.31)
			10	**0.74**[a] (0.63–0.75)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

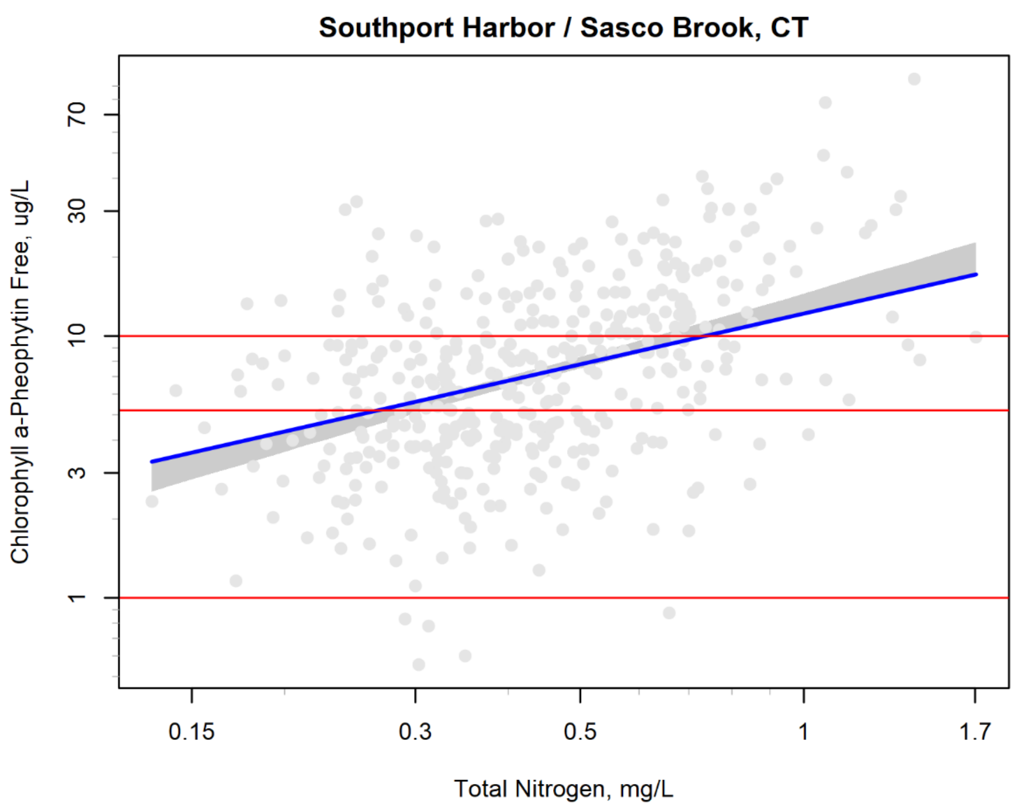

Figure G-16. Chlorophyll vs. Total Nitrogen Relationship for the Southport Harbor/Sasco Brook Watershed, CT (Other Embayments in the Model [*Gray Points*], No Paired Growing Season Observations Available for the Embayment, Population Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-9.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.74 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.9 Northport-Centerport Harbor Complex, NY

Figure G-17 shows a map of the Northport-Centerport Harbor Complex watershed.[5] Paired data for the embayment included 16 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

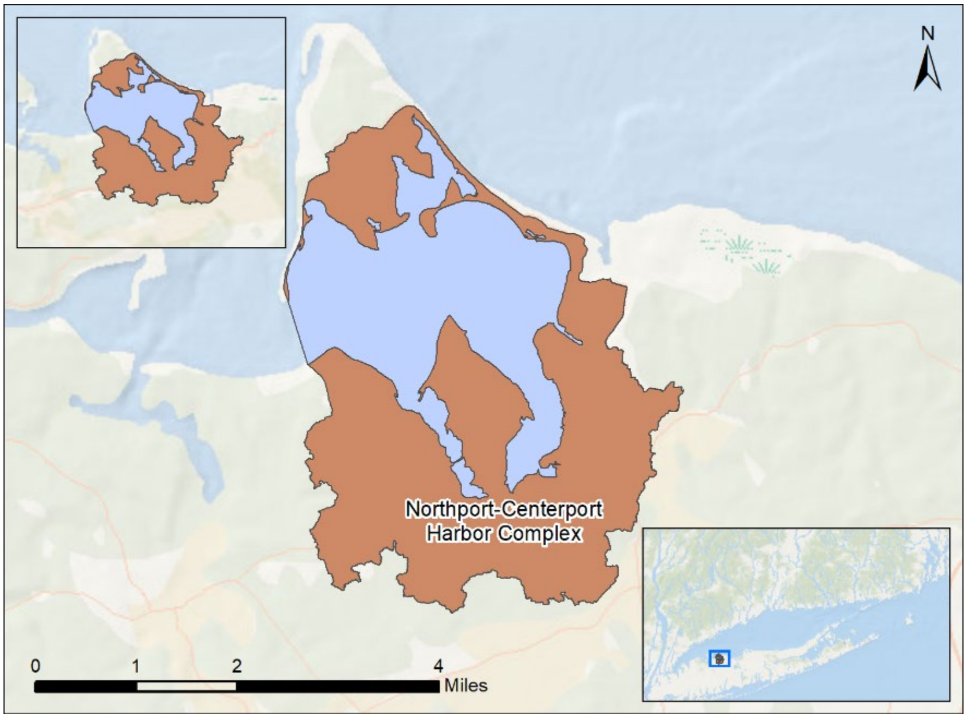

Figure G-17. Northport-Centerport Harbor Complex Watershed, NY

TN target concentrations for the Northport-Centerport Harbor Complex watershed are presented in Table G-10. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-18. Paired data for the Northport-Centerport Harbor Complex embayment are plotted.

[5] Includes three Vaudrey et al. (2016) embayments: Centerport Harbor, NY; Northport Bay, NY; and Northport Harbor, NY.

Table G-10. TN Primary Causal Variable Target Concentrations for the Northport-Centerport Harbor Complex Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.3	**0.16**[a] (0.16–0.24)
			10	**0.60**[a] (0.53–0.72)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.27**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

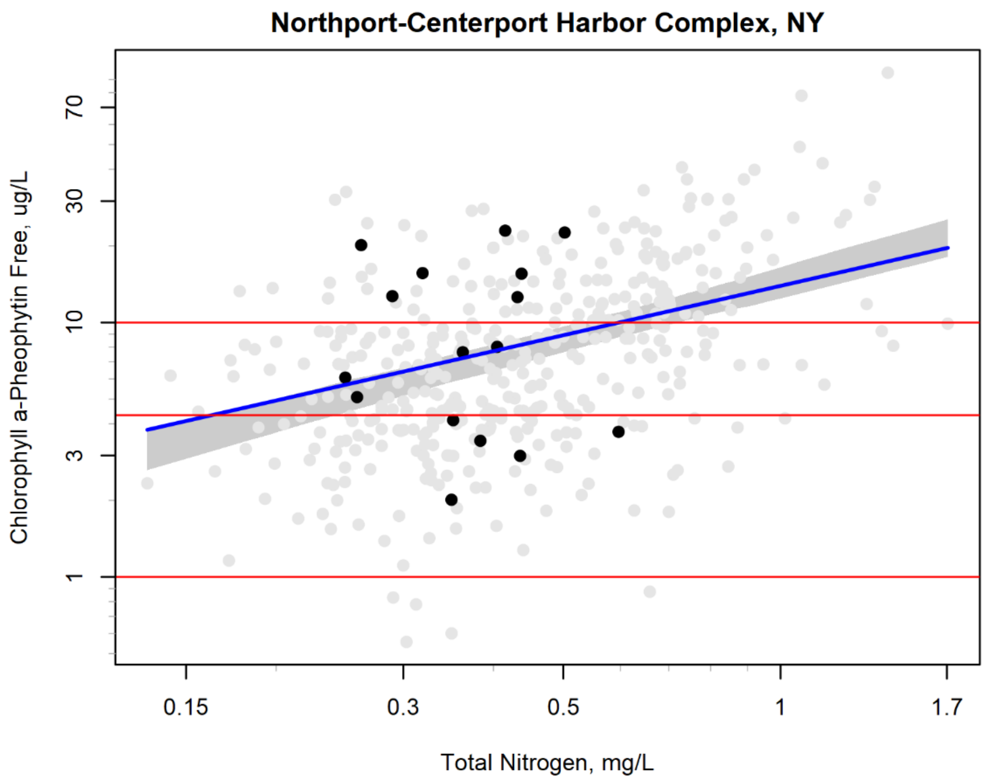

Figure G-18. Chlorophyll vs. Total Nitrogen Relationship for the Northport-Centerport Harbor Complex Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-10.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.16 to 0.60 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.3 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.10 Port Jefferson Harbor, NY

Figure G-19 shows a map of the Port Jefferson Harbor watershed. Paired data for the embayment included 19 paired observations within the growing season (April– September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

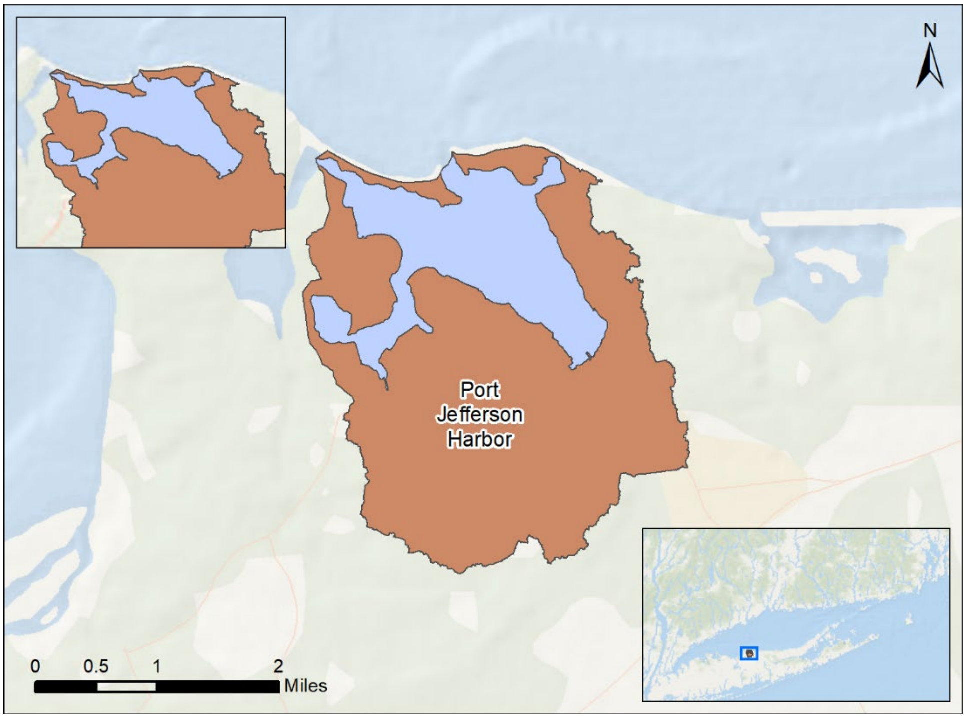

Figure G-19. Port Jefferson Harbor Watershed, NY

TN target concentrations for the Port Jefferson Harbor watershed are presented in Table G-11. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-20. Paired data for the Port Jefferson Harbor embayment are plotted.

Table G-11. TN Primary Causal Variable Target Concentrations for the Port Jefferson Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.1	**0.23** (0.19–0.26)
			10	**0.91**[a] (0.63–0.91)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

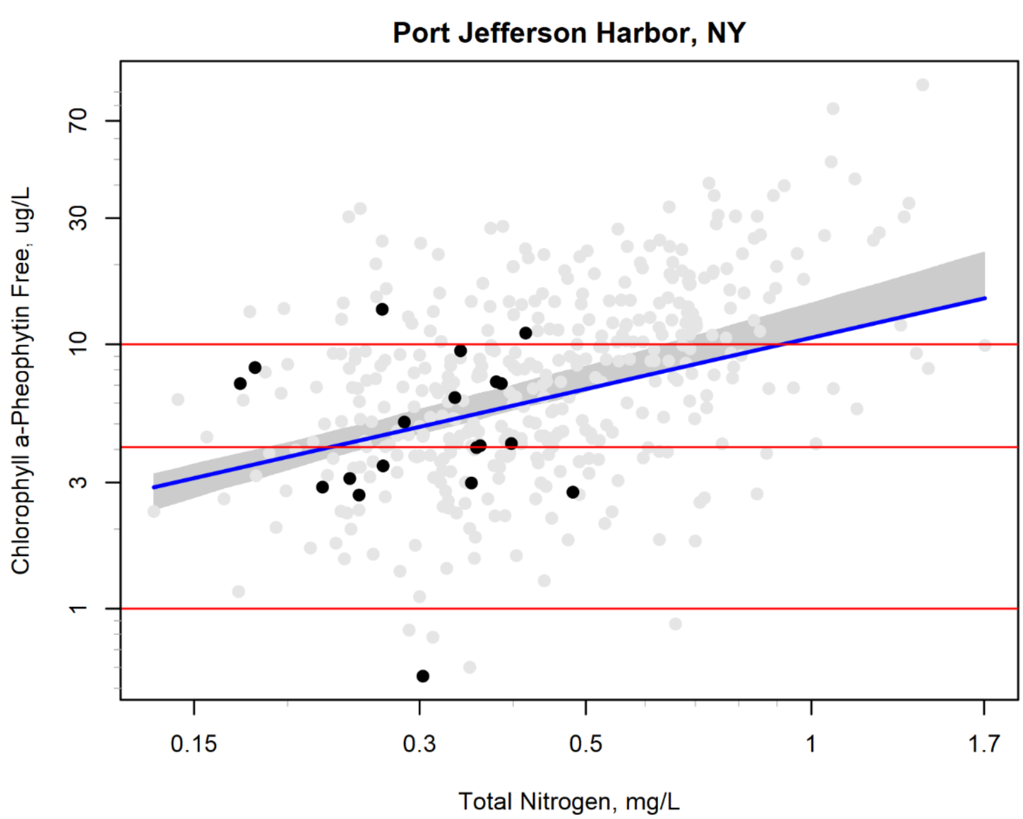

Figure G-20. Chlorophyll vs. Total Nitrogen Relationship for the Port Jefferson Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-11.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.23 mg/L to 0.91 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.1 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.11 Nissequogue River, NY

Figure G-21 shows a map of the Nissequogue River watershed. Paired data for the embayment included 10 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

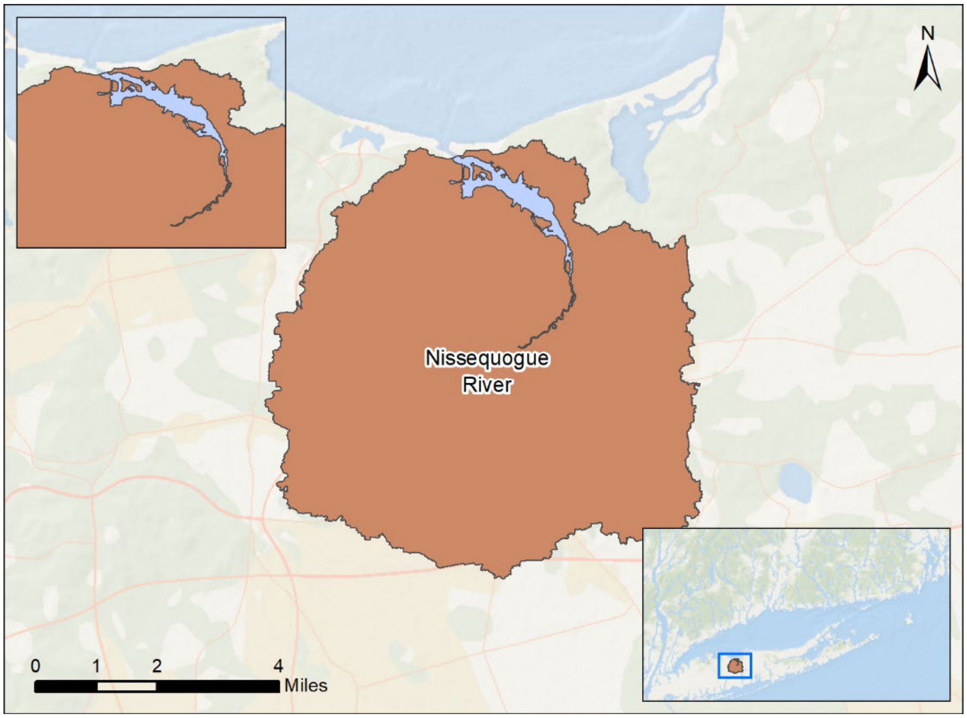

Figure G-21. Nissequogue River Watershed, NY

TN target concentrations for the Nissequogue River watershed are presented in Table G-12. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-22. Paired data for the Nissequogue River embayment are plotted.

Table G-12. TN Primary Causal Variable Target Concentrations for the Nissequogue River Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.3	**0.30** (0.21–0.30)
			10	**1.11**[a] (0.65–0.98)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

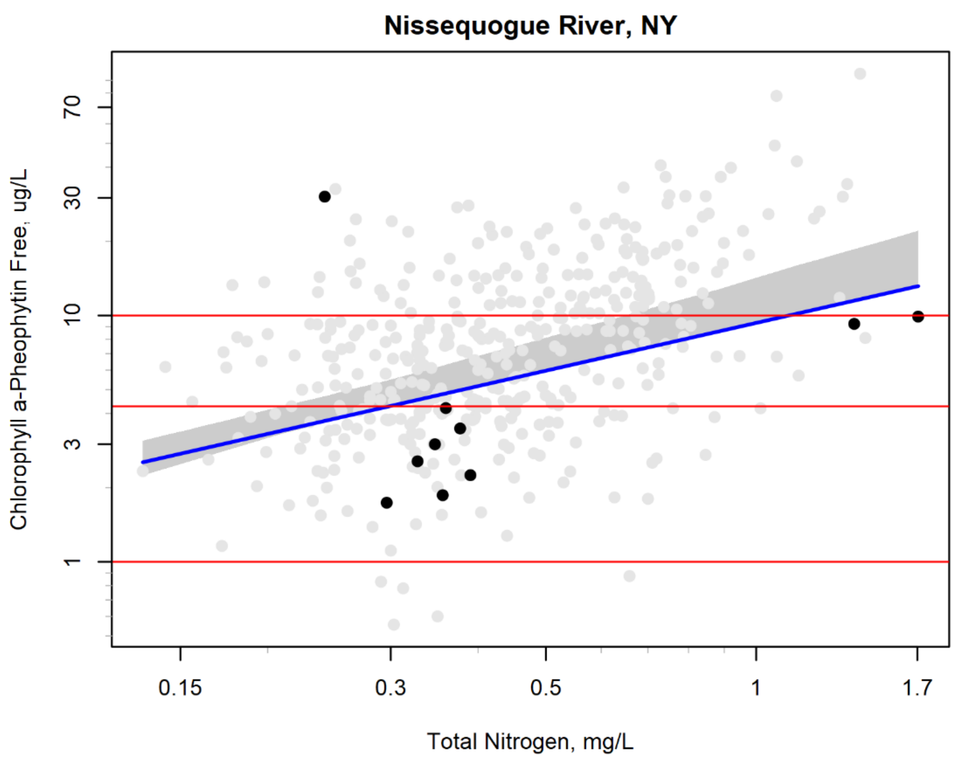

Figure G-22. Chlorophyll vs. Total Nitrogen Relationship for the Nissequogue River Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-12.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.30 mg/L to 1.11 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.3 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.12 Stony Brook Harbor, NY

Figure G-23 shows a map of the Stony Brook Harbor watershed. Paired data for the embayment included 10 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

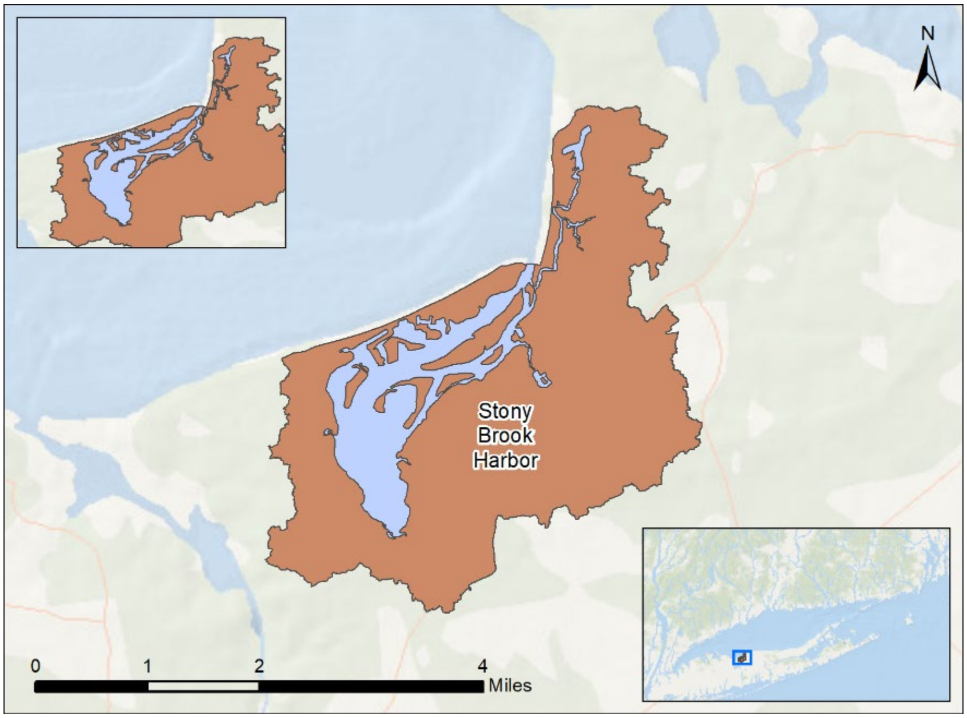

Figure G-23. Stony Brook Harbor Watershed, NY

TN target concentrations for the Stony Brook Harbor watershed are presented in Table G-13. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-24. Paired data for the Stony Brook Harbor embayment are plotted.

Table G-13. TN Primary Causal Variable Target Concentrations for the Stony Brook Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	3.8	**0.21** (0.17–0.23)
			10	**0.92**[a] (0.62–0.87)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

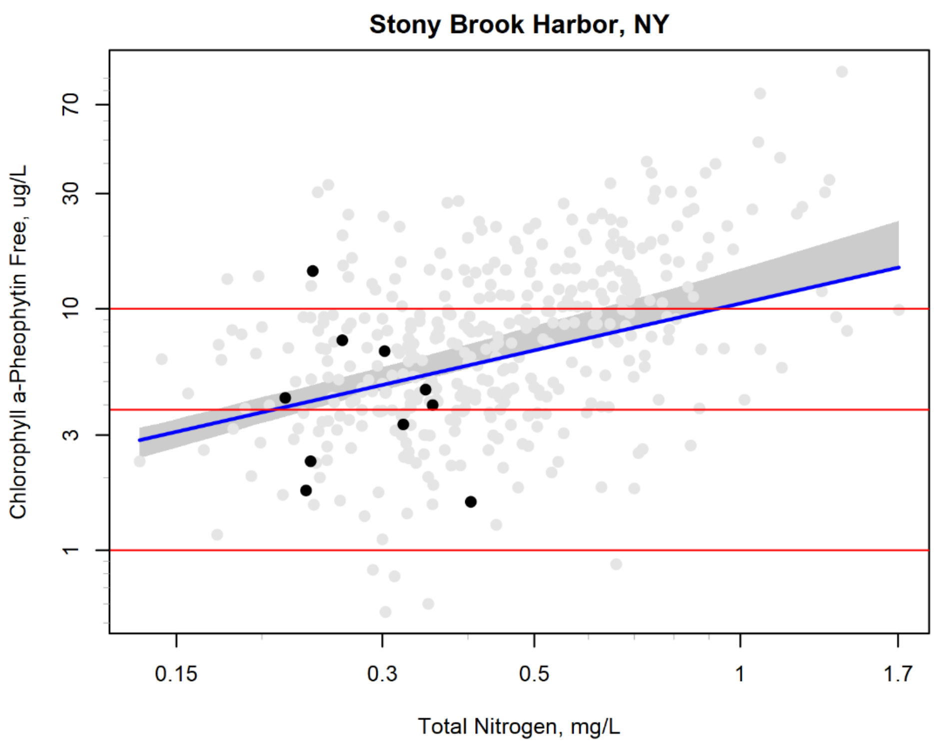

Figure G-24. Chlorophyll vs. Total Nitrogen Relationship for the Stony Brook Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-13.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.21 mg/L to 0.92 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 3.8 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.13 Mt. Sinai Harbor, NY

Figure G-25 shows a map of the Mt. Sinai Harbor watershed. Paired data for the embayment included 13 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

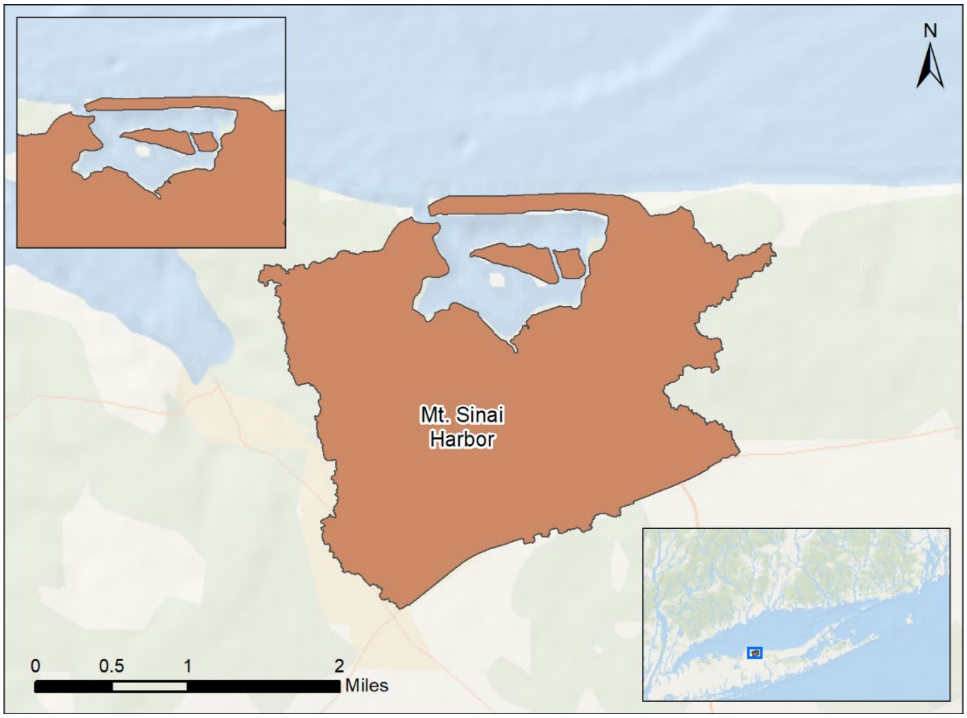

Figure G-25. Mt. Sinai Harbor Watershed, NY

TN target concentrations for the Mt. Sinai Harbor watershed are presented in Table G-14. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-26. Paired data for the Mt. Sinai Harbor embayment are plotted.

Table G-14. TN Primary Causal Variable Target Concentrations for the Mt. Sinai Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.4	**0.27** (0.22–0.30)
			10	**0.95**[a] (0.63–0.92)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

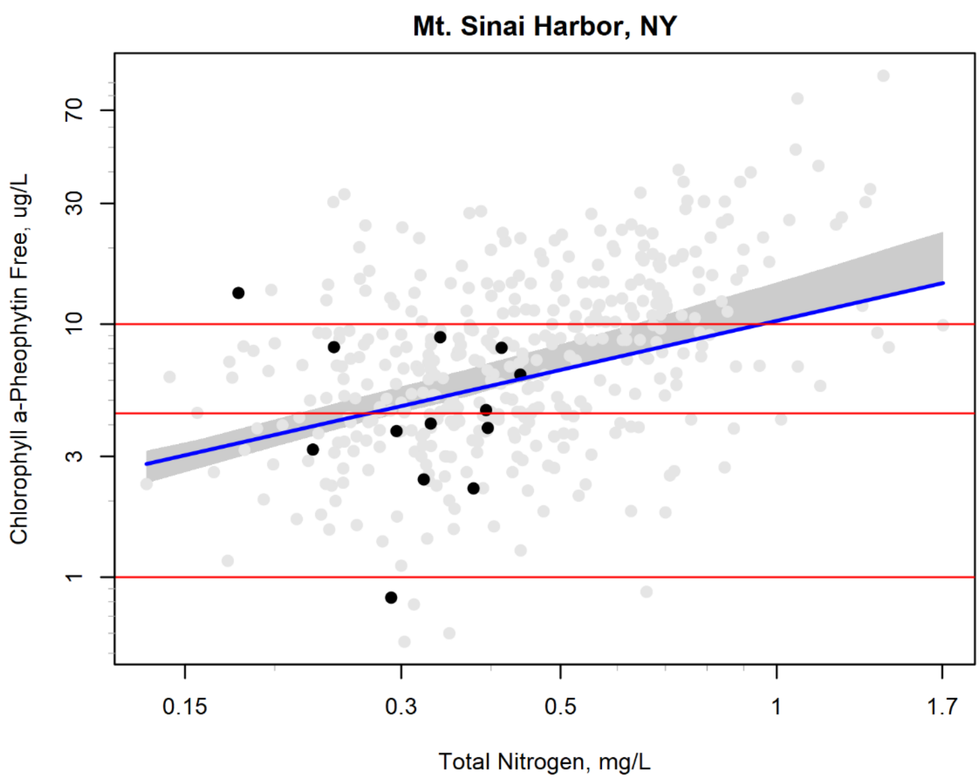

Figure G-26. Chlorophyll vs. Total Nitrogen Relationship for the Mt. Sinai Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-14.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.95 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.4 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.14 Eastern and Western Narrows (Combined), CT and NY

Figure G-27 shows a map of the Eastern and Western Narrows watersheds (combined). Paired data for the open water included 1,157 open water observations across 18 water quality stations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the model include chlorophyll *a*-corrected, TN, and pH where available. However, stressor-response models were not significant for the open water segments, as described in Subtask F.

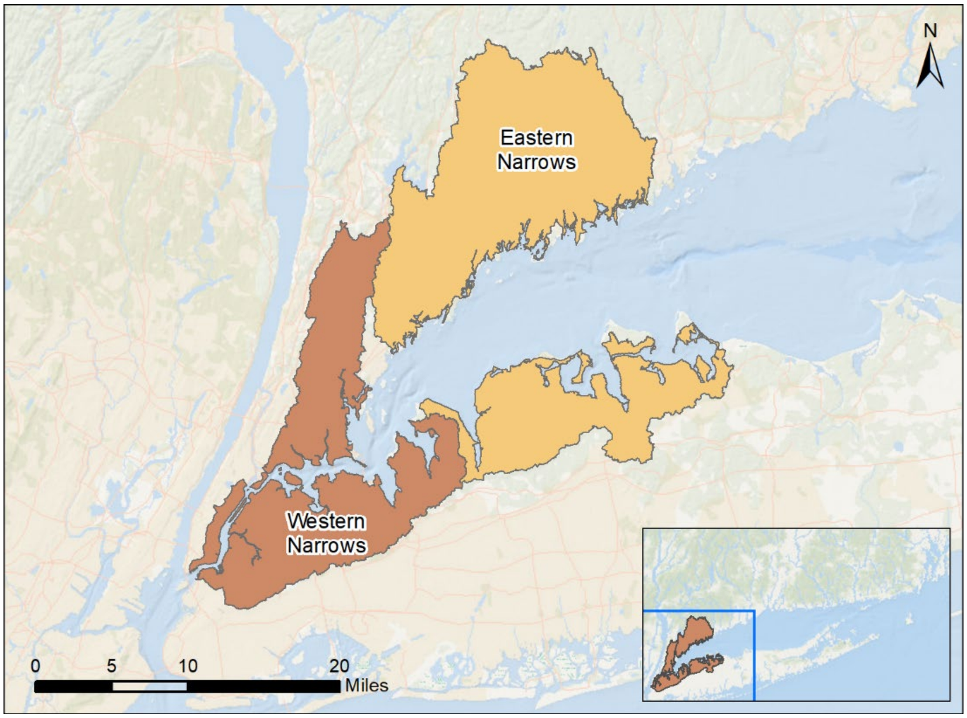

Figure G-27. Eastern and Western Narrows (Combined) Watersheds, CT and NY

Open water TN target concentrations for the Eastern and Western Narrows watersheds (combined) are presented in Table G-15.

Table G-15. TN Primary Causal Variable Target Concentrations for the Eastern and Western Narrows (Combined) Watersheds, CT and NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All open water 25th percentile		**0.24**

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-15.

Literature review and distribution-based lines of evidence yield TN values of 0.40 mg/L and 0.24 mg/L, respectively (0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L). These values represent regionally relevant TN concentrations for protecting comparable aquatic life uses (e.g., seagrasses and benthic fauna) based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in open water expected to support aquatic life uses, including seagrasses and benthic fauna.

G.15 Connecticut River, CT

The Connecticut River is treated as an embayment for the purposes of this effort because, while the main channel has characteristics unique to flowing water systems, the tidally influenced, especially lower Connecticut River ecosystem as a whole includes tidal creeks, marshes, and sub-embayment areas with abundant suitable habitat for seagrasses (Vaudrey et al. 2013). Therefore, it has similar requirements to other embayments in terms of protecting the light environment and was included in that population for this work.

Figure G-28 shows a map of the Connecticut River where it enters LIS. The estuarine area of influence of the Connecticut River as described in the memo for *Subtask E: Summary of Hydrodynamic Analysis* and indicated on this figure was the focus of the stressor-response modeling and of the resulting values. Paired data for the embayment included 12 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

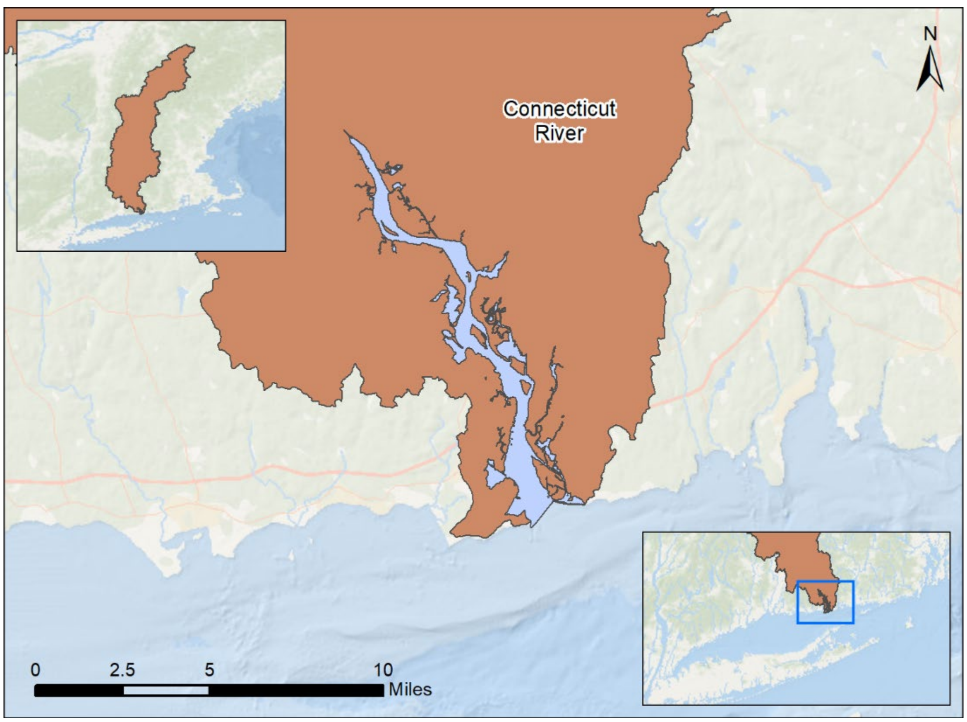

Figure G-28. Connecticut River, CT

TN target concentrations for the Connecticut River embayment are presented in Table G-16. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-29. Paired data for the Connecticut River embayment are plotted.

Table G-16. TN Primary Causal Variable Target Concentrations for the Connecticut River Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	3.8	**0.16**[a] (0.16–0.22)
			10	**0.73**[a] (0.60–0.83)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

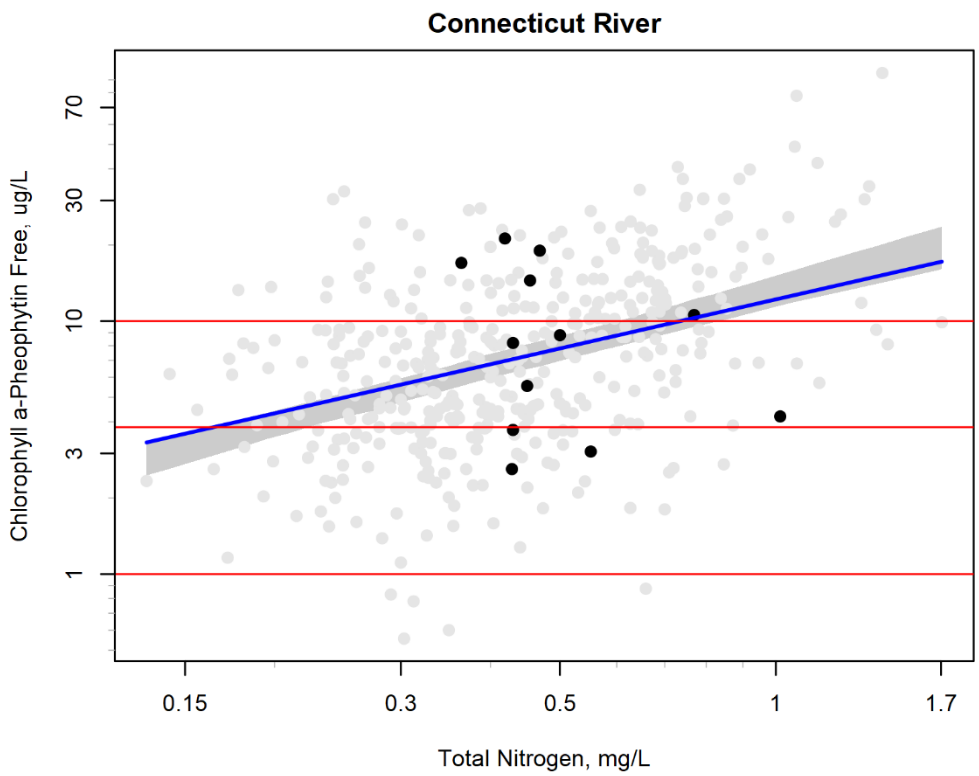

Figure G-29. Chlorophyll vs. Total Nitrogen Relationship for the Connecticut River Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*]

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-16.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.16 mg/L to 0.73 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 3.8 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.16 Mamaroneck River, NY

Figure G-30 shows a map of the Mamaroneck River watershed. Paired data for the embayment included four paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

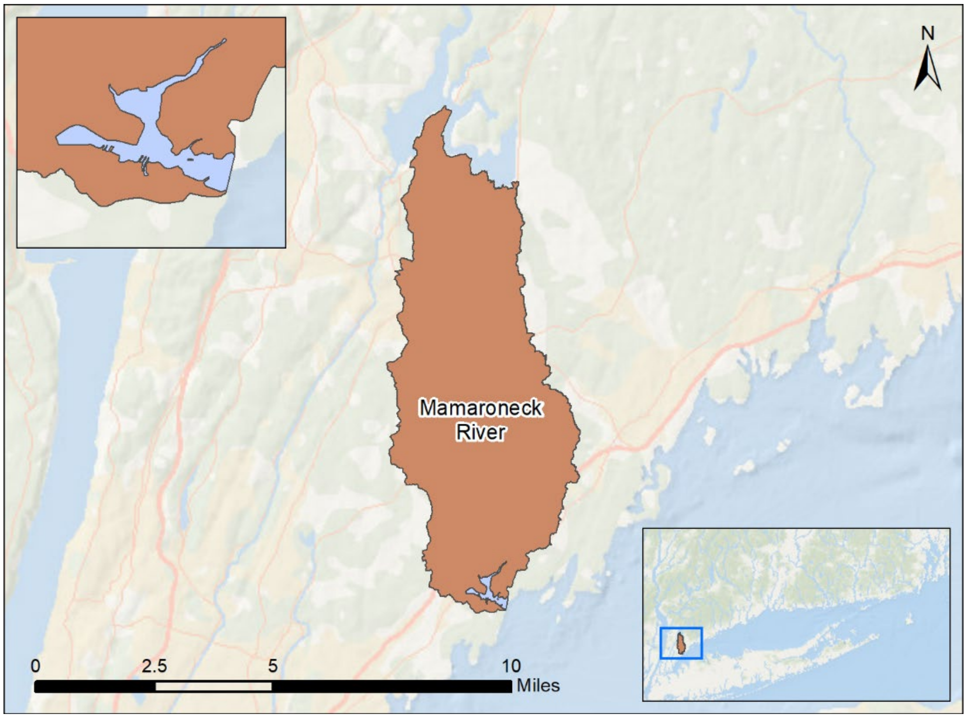

Figure G-30. Mamaroneck River Watershed, NY

TN target concentrations for the Mamaroneck River watershed are presented in Table G-17. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-31. Paired data for the Mamaroneck River embayment are plotted.

Table G-17. TN Primary Causal Variable Target Concentrations for the Mamaroneck River Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.7	**0.24** (0.22–0.29)
			10	**0.77**[a] (0.61–0.82)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

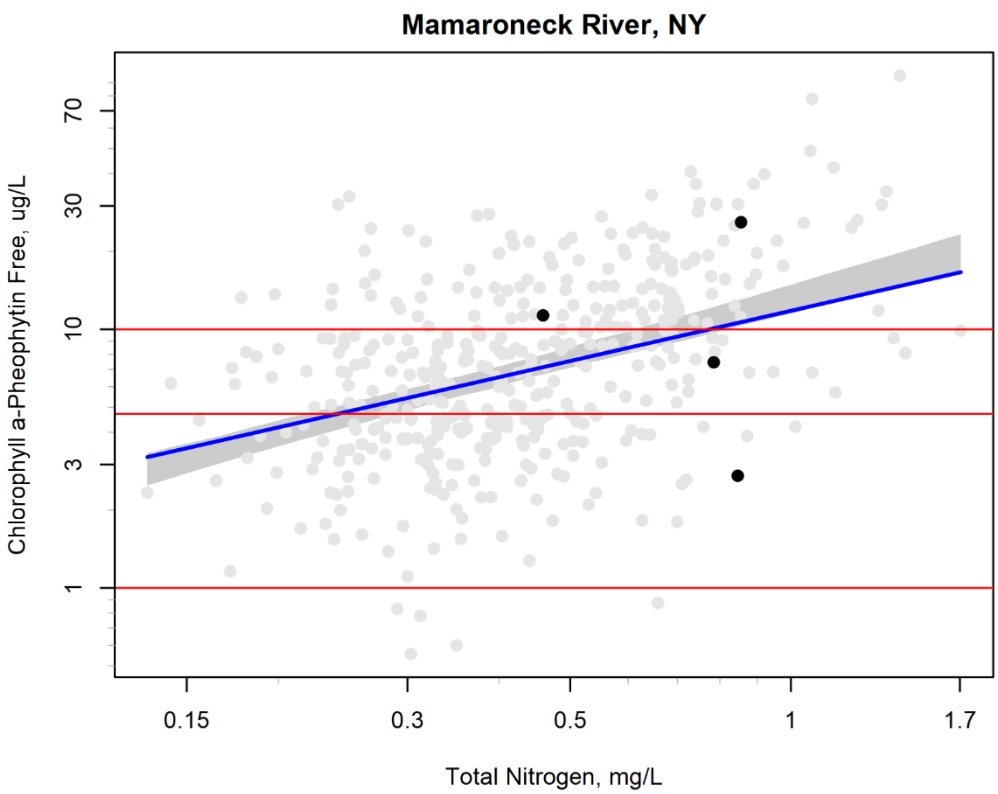

Figure G-31. Chlorophyll vs. Total Nitrogen Relationship for the Mamaroneck River Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-17.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.24 mg/L to 0.77 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.7 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.17 Hempstead Harbor, NY

Figure G-32 shows a map of the Hempstead Harbor watershed. Paired data for the embayment included nine paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

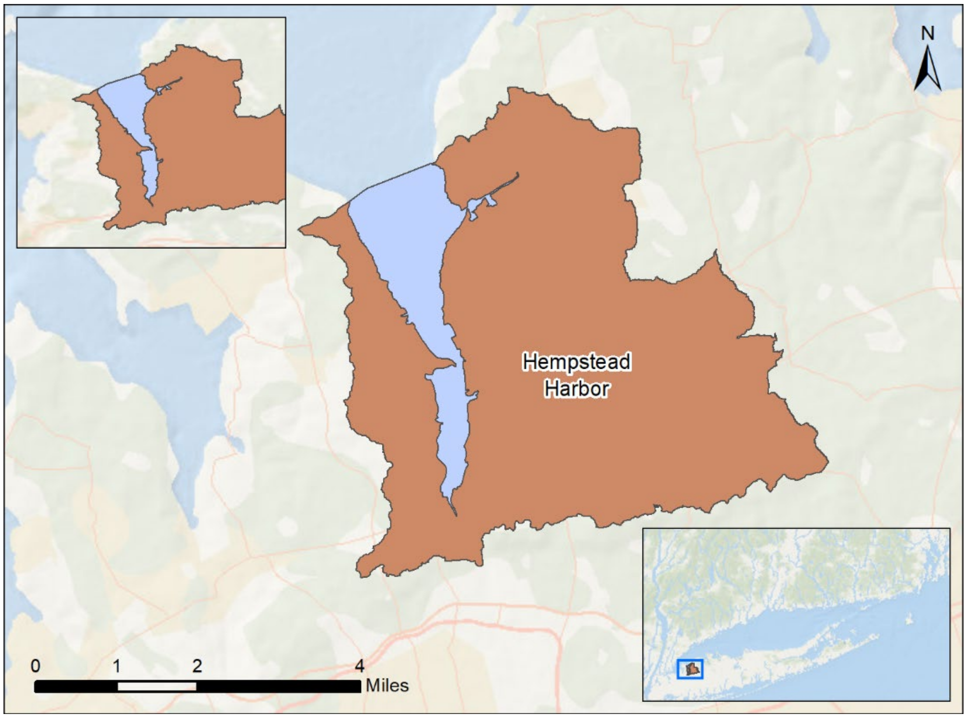

Figure G-32. Hempstead Harbor Watershed, NY

TN target concentrations for the Hempstead Harbor watershed are presented in Table G-18. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-33. Paired data for the Hempstead Harbor embayment are plotted.

Table G-18. TN Primary Causal Variable Target Concentrations for the Hempstead Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.8	**0.19**[a] (0.19–0.29)
			10	**0.59** (0.56–0.76)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

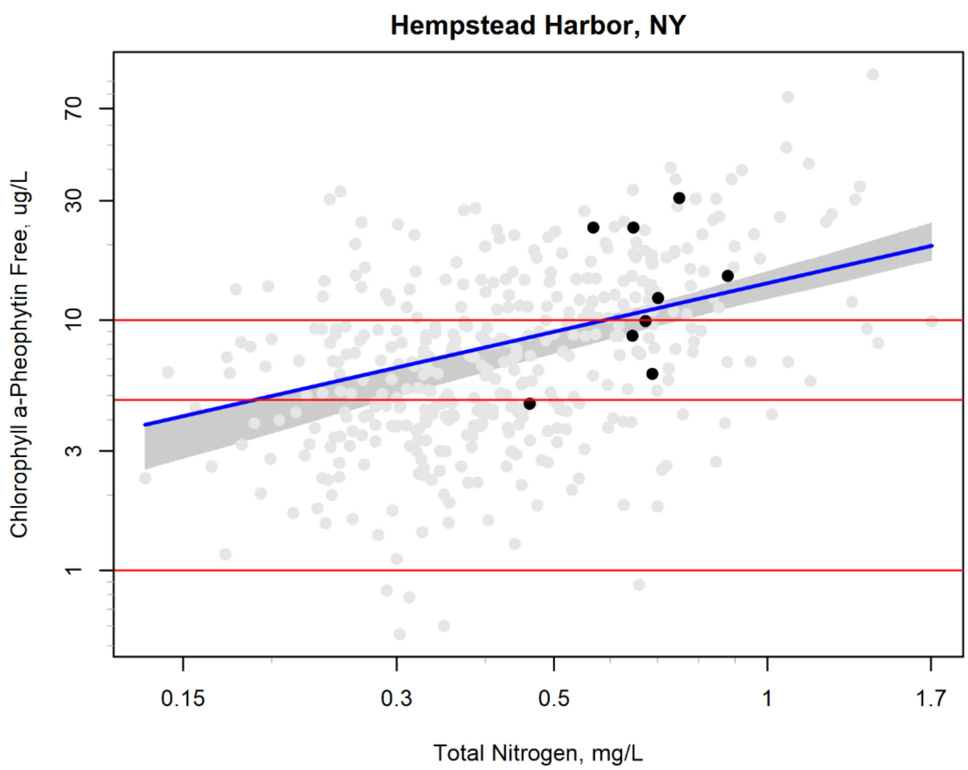

Figure G-33. Chlorophyll vs. Total Nitrogen Relationship for the Hempstead Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-18.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.19 mg/L to 0.59 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.8 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.18 Areas Adjacent to the Northport–Centerport Harbor Complex, NY

Figure G-34 shows a map of the Northport-Centerport Harbor Complex watershed, which is composed of three embayments modeled separately: Huntington Bay, Huntington Harbor, and Lloyd Harbor. Paired data for the embayments included 16, 16, and 17 paired observations, respectively, for the three embayments within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

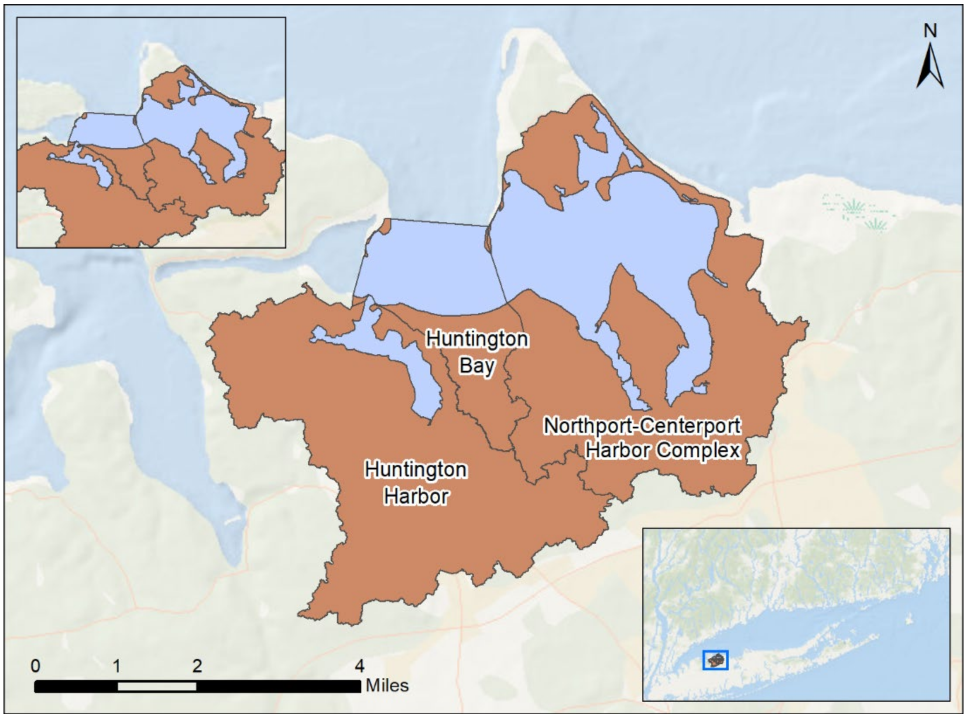

Figure G-34. Northport–Centerport Harbor Complex Watershed, NY

TN target concentrations for the Northport-Centerport Harbor Complex embayments are presented in Tables G-19, G-20, and G-21. Scatterplots of the chlorophyll versus TN relationship are presented in Figures G-35, G-36, and G-37. Paired data for each embayment are plotted.

Table G-19. TN Primary Causal Variable Target Concentrations for the Huntington Bay Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.8	**0.27** (0.22–0.30)
			10	**0.84**[a] (0.60–0.84)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

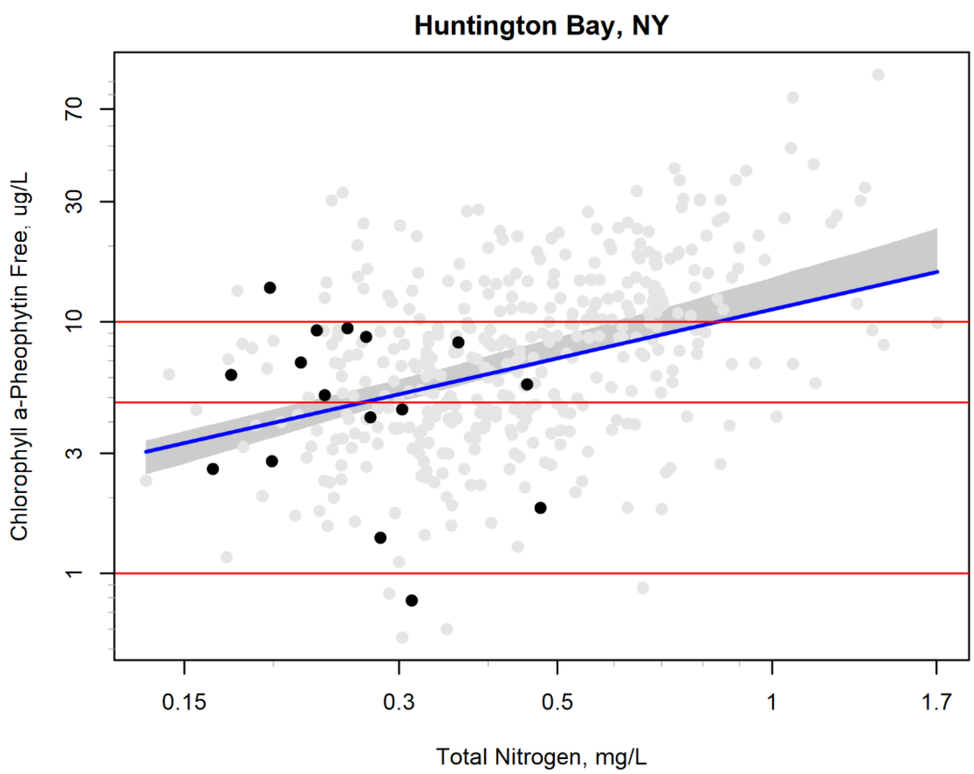

Figure G-35. Chlorophyll vs. Total Nitrogen Relationship for the Huntington Bay Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

Table G-20. TN Primary Causal Variable Target Concentrations for the Huntington Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	10	**0.54**[a, b] (0.50–0.73)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Notes:
[a] Where an interpolation of TN values based on the local model could not be made (i.e., the local embayment model did not intersect the chlorophyll *a* target), the population model was used instead for the calculation.
[b] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

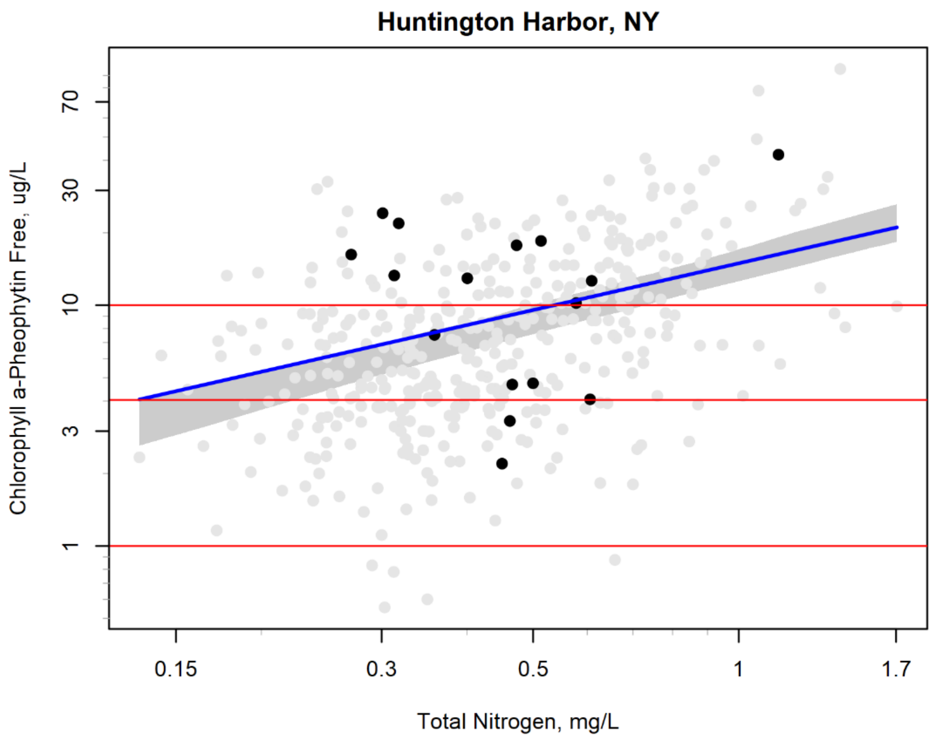

Figure G-36. Chlorophyll vs. Total Nitrogen Relationship for the Huntington Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

Table G-21. TN Primary Causal Variable Target Concentrations for the Lloyd Harbor Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.31** (0.25–0.34)
			10	**0.84**[a] (0.62–0.84)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

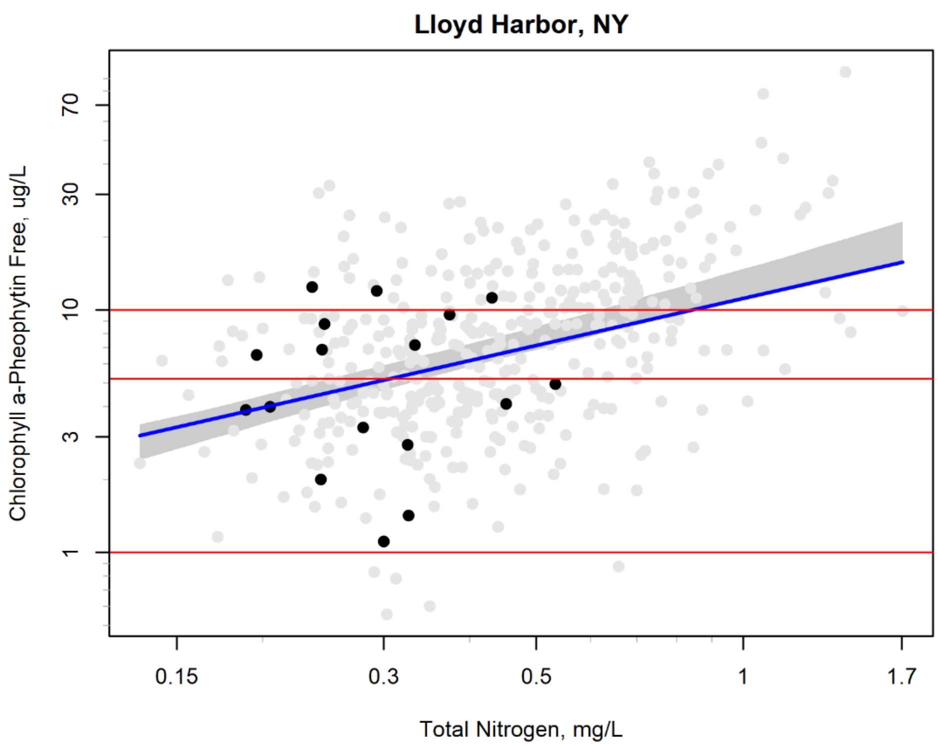

Figure G-37. Chlorophyll vs. Total Nitrogen Relationship for the Lloyd Harbor Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Tables G-19 to G-21.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.84 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.8 μg/L (Huntington Bay), 5.2 μg/L (Lloyd Harbor), and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. Note that the model could not resolve a TN target concentration for Huntington Harbor as it fell outside the experience of the model. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration tables above for these embayments and resulting stressor-response ranges should be interpreted appropriately.

G.19 Oyster Bay/Cold Spring Harbor Complex, NY

Figure G-38 shows a map of the Oyster Bay/Cold Spring Harbor Complex watershed. Paired data for the embayment included four paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

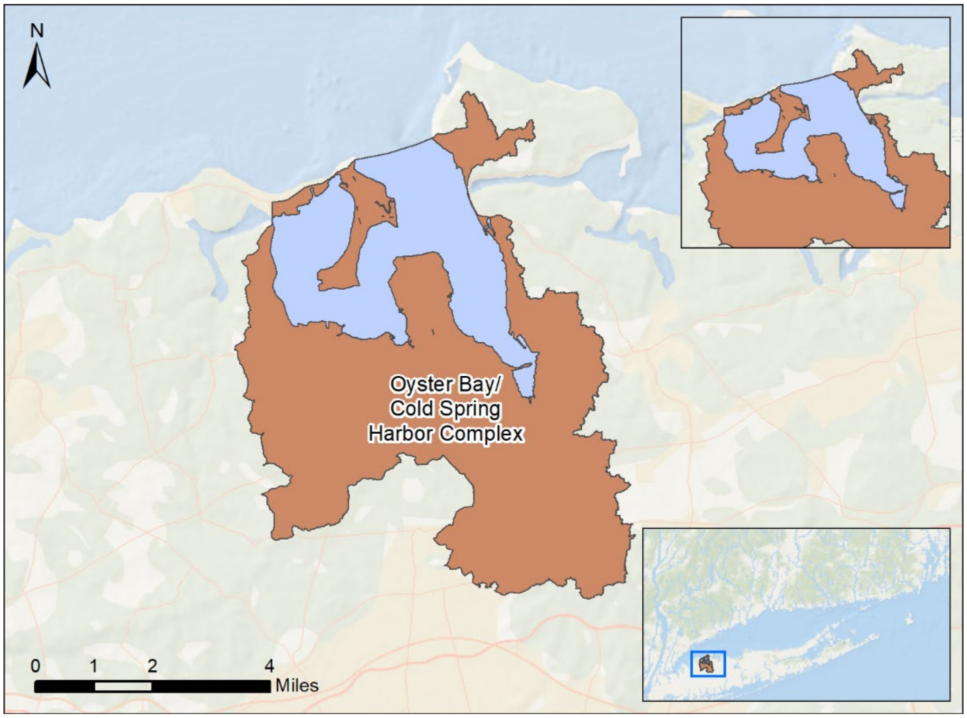

Figure G-38. Oyster Bay/Cold Spring Harbor Complex Watershed, NY

TN target concentrations for the Oyster Bay/Cold Spring Harbor Complex embayment are presented in Table G-22. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-39. Paired data for the Oyster Bay/Cold Spring Harbor Complex embayment are plotted.

Table G-22. TN Primary Causal Variable Target Concentrations for the Oyster Bay/Cold Spring Harbor Complex Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.16**[a] (0.16–0.31)
			10	**0.43** (0.55–0.72)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

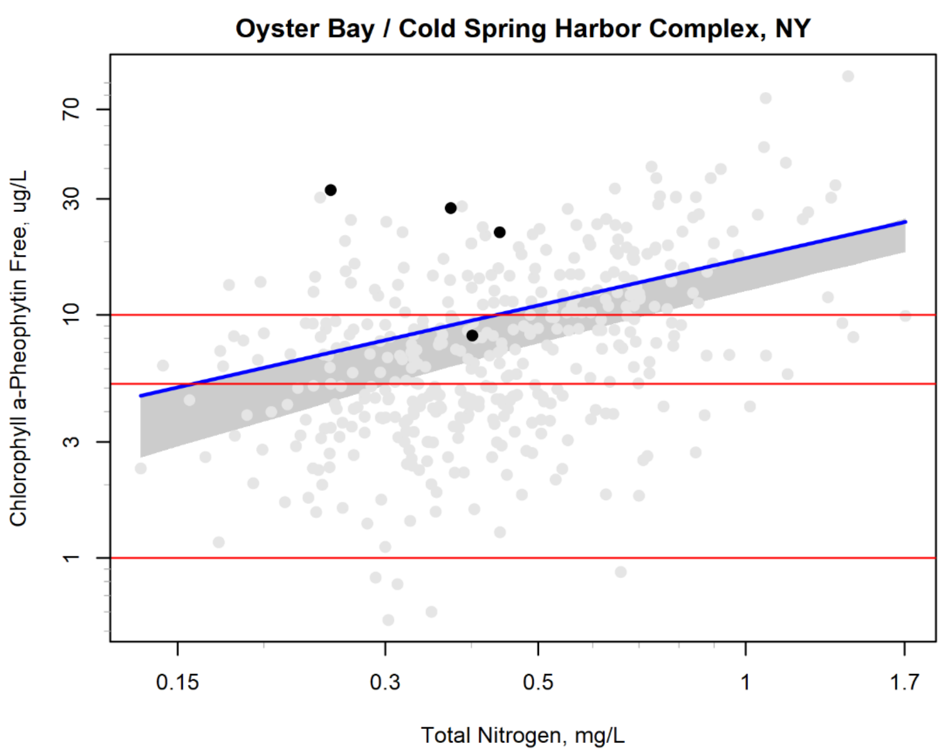

Figure G-39. Chlorophyll vs. Total Nitrogen Relationship for the Oyster Bay/Cold Spring Harbor Complex Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-22.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.16 mg/L to 0.43 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.20 Manhasset Bay, NY

Figure G-40 shows a map of the Manhasset Bay watershed. Paired data for the embayment included nine paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

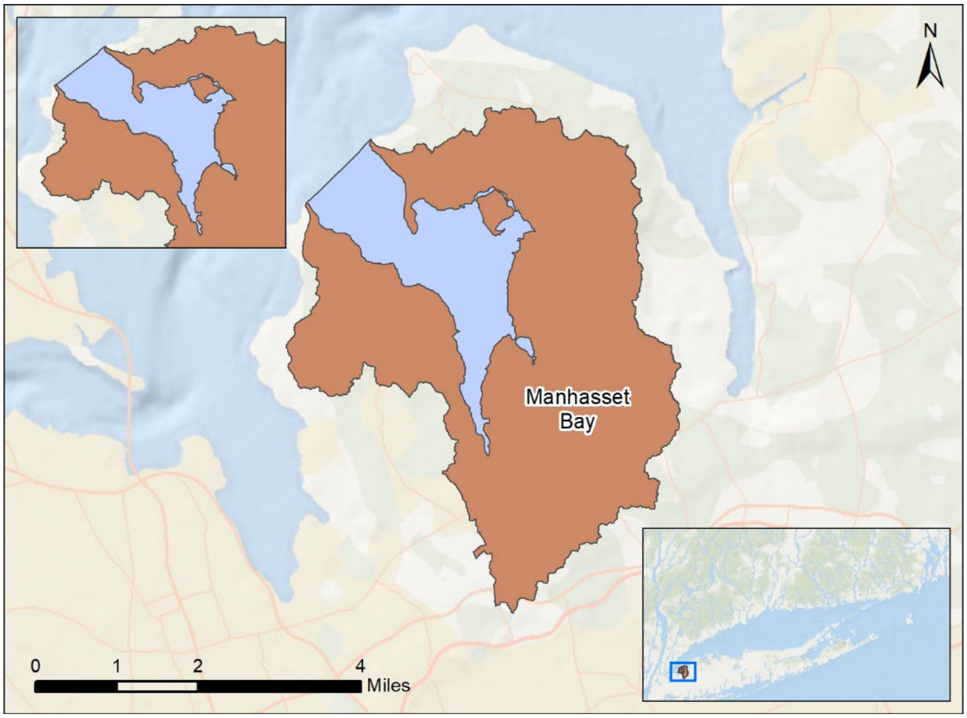

Figure G-40. Manhasset Bay Watershed, NY

TN target concentrations for the Manhasset Bay embayment are presented in Table G-23. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-41. Paired data for the Manhasset Bay embayment are plotted.

Table G-23. TN Primary Causal Variable Target Concentrations for the Manhasset Bay Watershed, NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.5	**0.17**[a] (0.17–0.27)
			10	**0.59**[a] (0.58–0.77)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

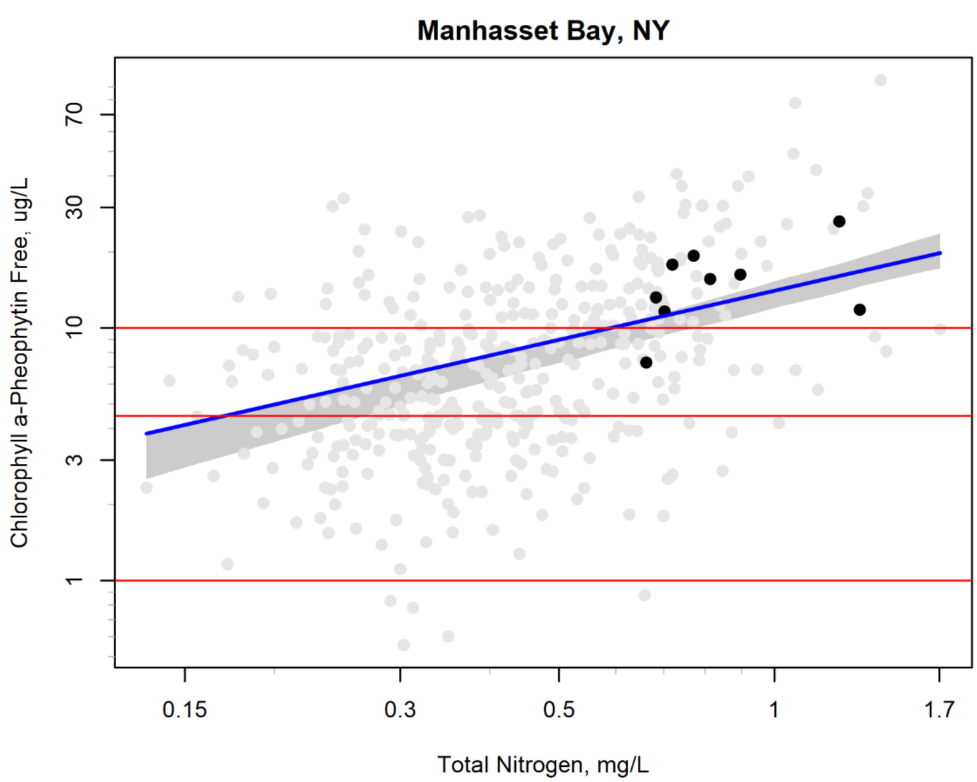

Figure G-41. Chlorophyll vs. Total Nitrogen Relationship for the Manhasset Bay Watershed, NY (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-23.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.17 mg/L to 0.59 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.5 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.21 Pequonnock River, CT

Figure G-42 shows a map of the Pequonnock River watershed. Paired data for the embayment included 1 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

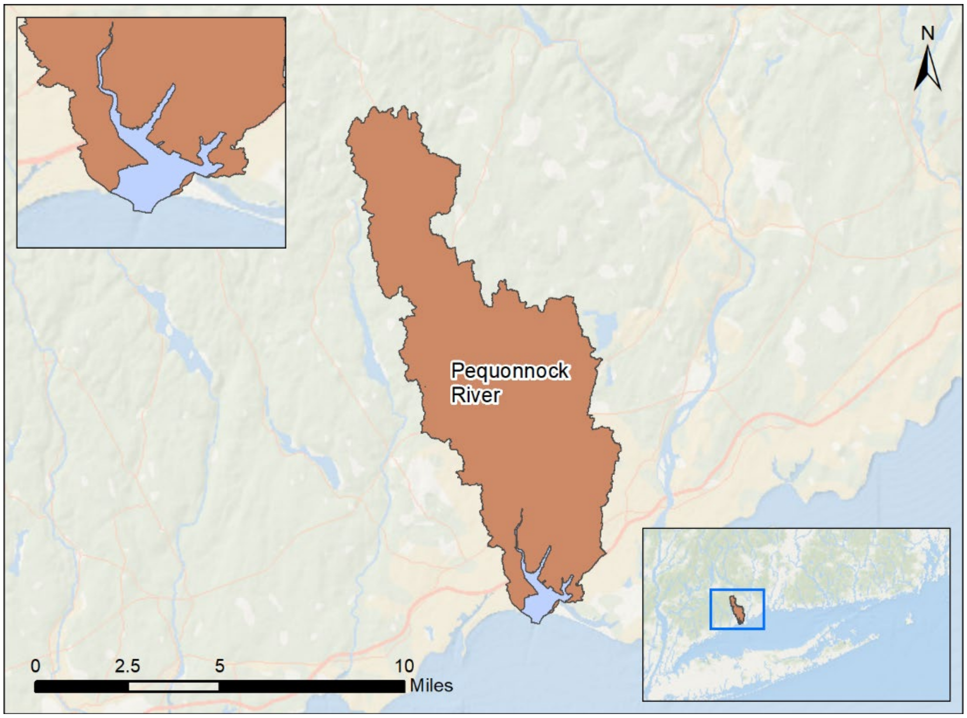

Figure G-42. Pequonnock River Watershed, CT

TN target concentrations for the Pequonnock River embayment are presented in Table G-24. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-43. Paired data for the Pequonnock River embayment are plotted.

Table G-24. TN Primary Causal Variable Target Concentrations for the Pequonnock River Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.7	**0.22** (0.22–0.28)
			10	**0.70**[a] (0.62–0.77)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

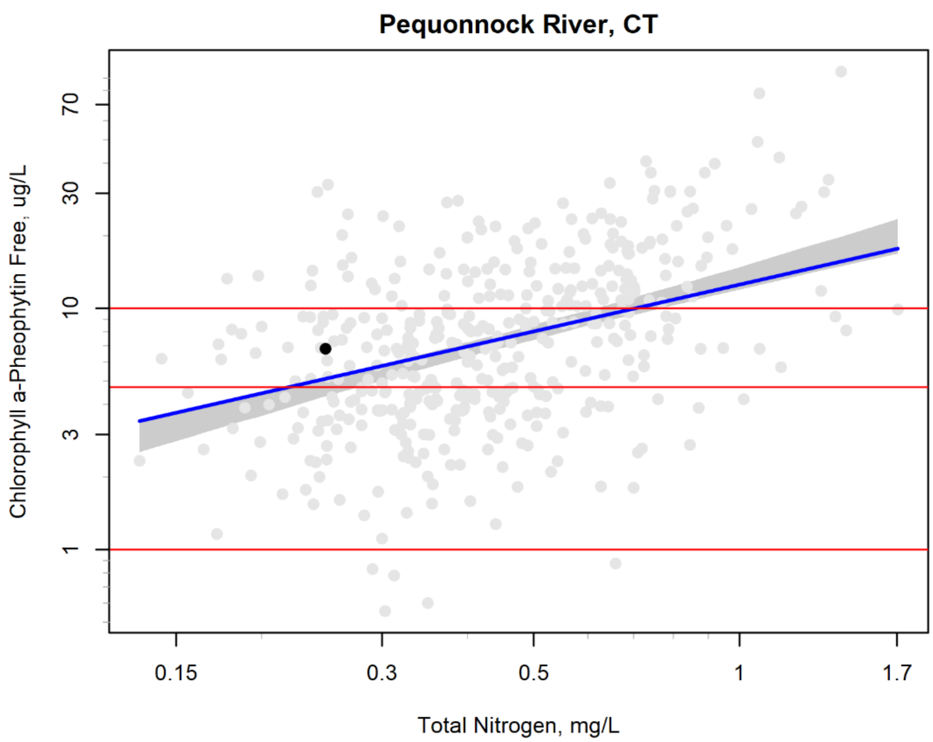

Figure G-43. Chlorophyll vs. Total Nitrogen Relationship for the Pequonnock River Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-24.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.22 mg/L to 0.70 mg/L. These values are based on the embayment-specific chlorophyll *a* response variable value of 4.7 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.22 Byram River, CT and NY

Figure G-44 shows a map of the Byram River watershed. No paired data were available for the embayment within the growing season (April–September). Therefore, the population fit was used for the stressor-response analysis. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

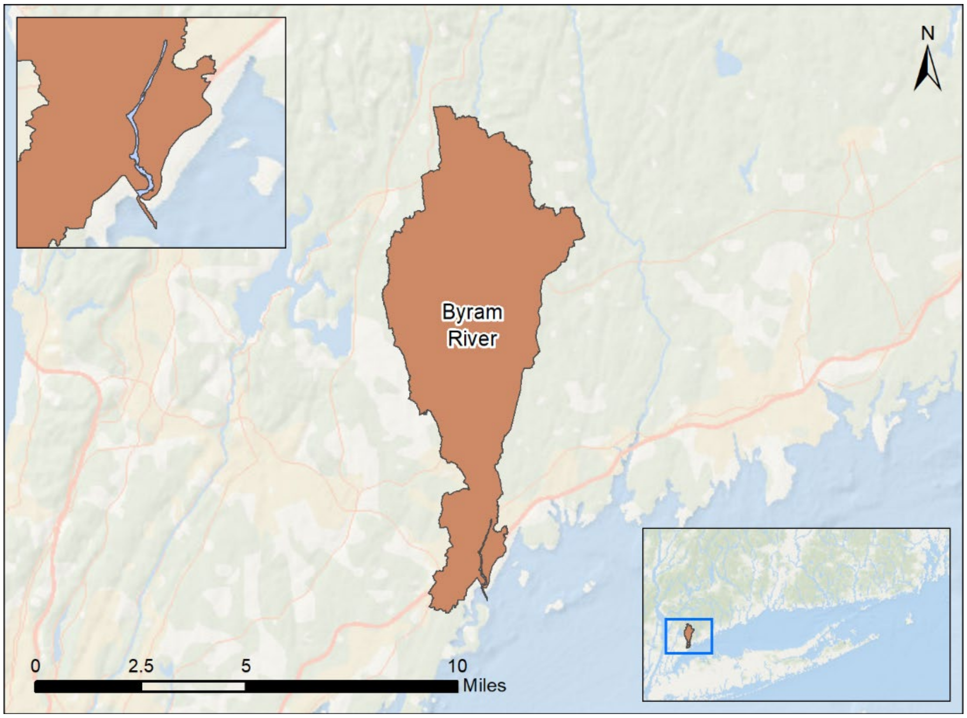

Figure G-44. Byram River Watershed, CT and NY

TN target concentrations for the Byram River embayment are presented in Table G-25. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-45. As no paired data were available for the Byram River embayment, the population trend line is shown.

Table G-25. TN Primary Causal Variable Target Concentrations for the Byram River Watershed, CT and NY

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.27** (0.26–0.31)
			10	**0.74**[a] (0.63–0.75)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

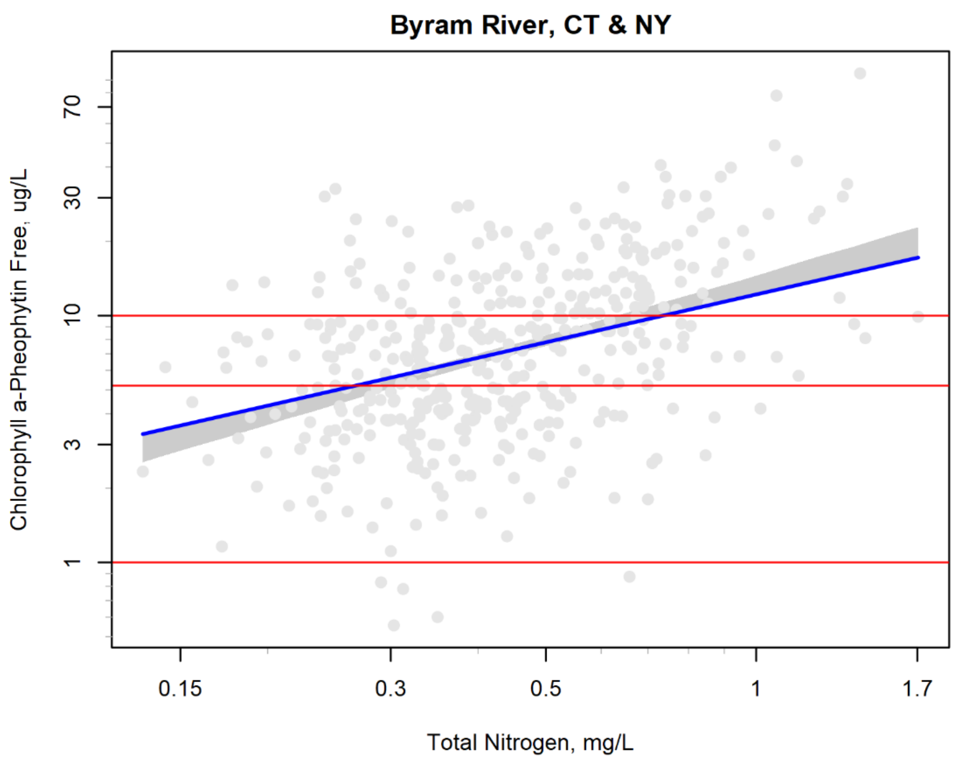

Figure G-45. Chlorophyll vs. Total Nitrogen Relationship for the Byram River Watershed, CT and NY (Other Embayments in the Model [*Gray Points*], No Paired Growing Season Observations were Available for the Embayment, Population Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-25.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.27 mg/L to 0.74 mg/L. These values are based on the embayment-specific chlorophyll a response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.23 New Haven Harbor, CT

Figure G-46 shows a map of the New Haven Harbor watershed. Paired data for the embayment included 1 paired observation within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

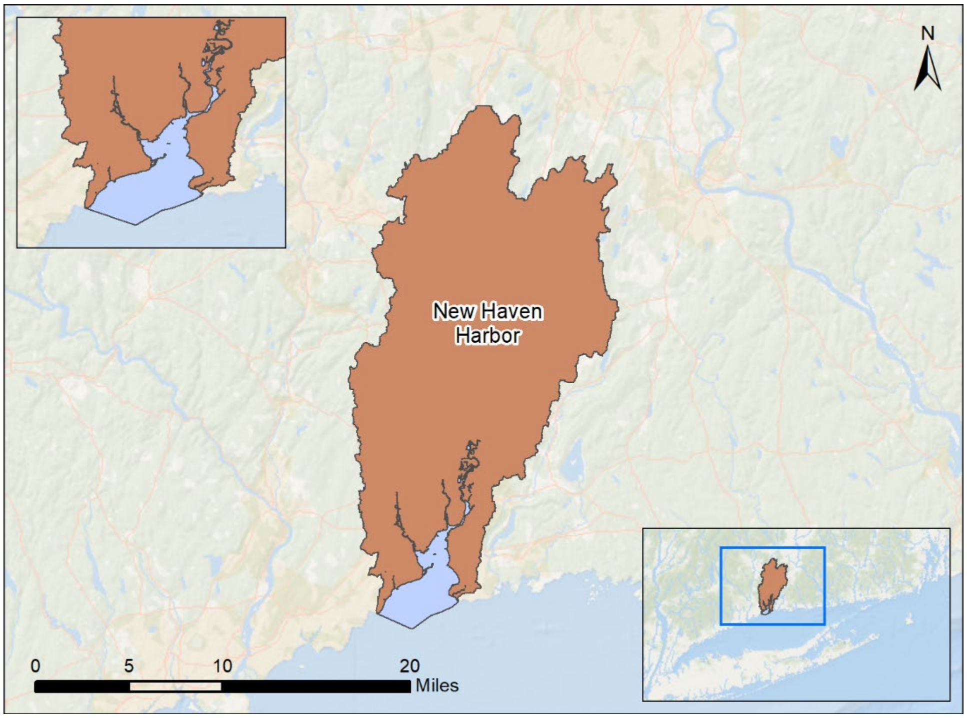

Figure G-46. New Haven Harbor Watershed, CT

TN target concentrations for the New Haven Harbor embayment are presented in Table G-26. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-47. Paired data for the New Haven Harbor embayment are plotted.

Table G-26. TN Primary Causal Variable Target Concentrations for the New Haven Harbor Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.6	**0.20** (0.22–0.27)
			10	**0.66**[a] (0.62–0.77)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

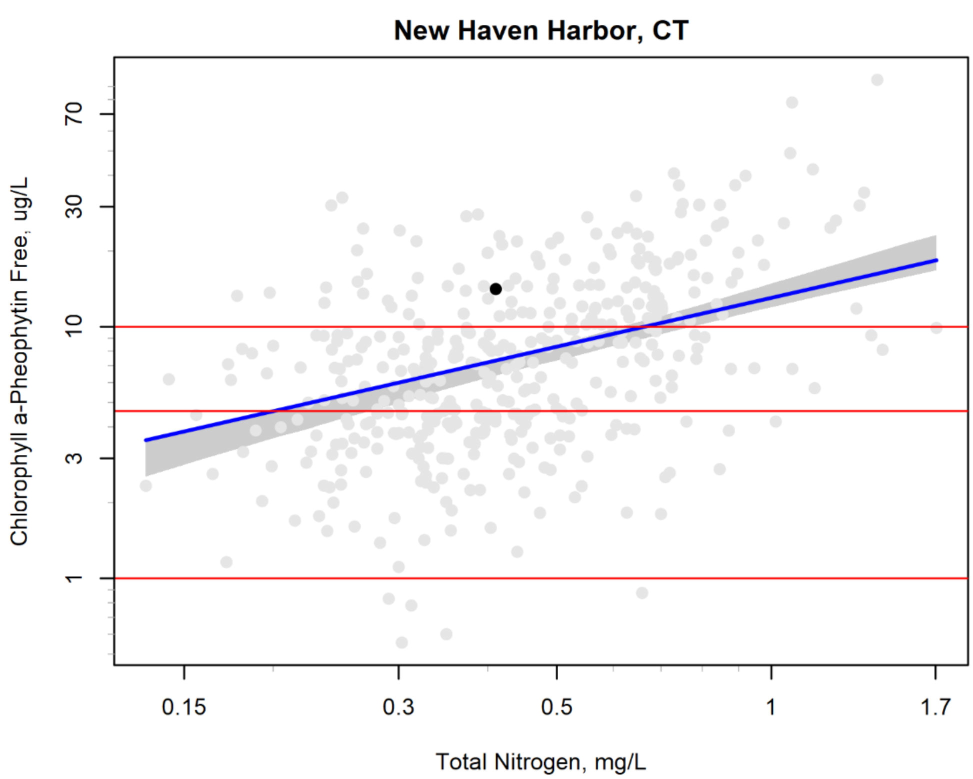

Figure G-47. Chlorophyll vs. Total Nitrogen Relationship for the New Haven Harbor Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-26.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.20 mg/L to 0.66 mg/L. These values are based on the embayment-specific chlorophyll a response variable value of 4.6 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.24 Little Narragansett Bay, CT and RI

Figure G-48 shows a map of the Little Narragansett Bay watershed. Paired data for the embayment included 40 paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

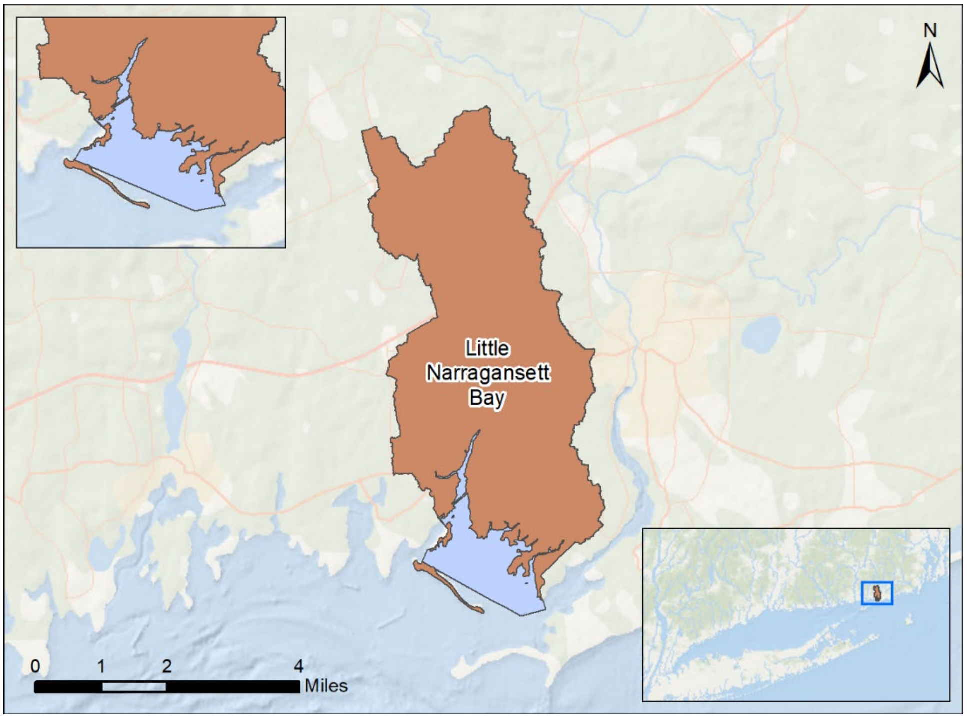

Figure G-48. Little Narragansett Bay Watershed, CT and RI

TN target concentrations for the Little Narragansett Bay embayment are presented in Table G-27. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-49. Paired data for the Little Narragansett Bay embayment are plotted.

Table G-27. TN Primary Causal Variable Target Concentrations for the Little Narragansett Bay Watershed, CT and RI

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	4.5	**0.23** (0.21–0.29)
			10	**0.80**[a] (0.63–0.85)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

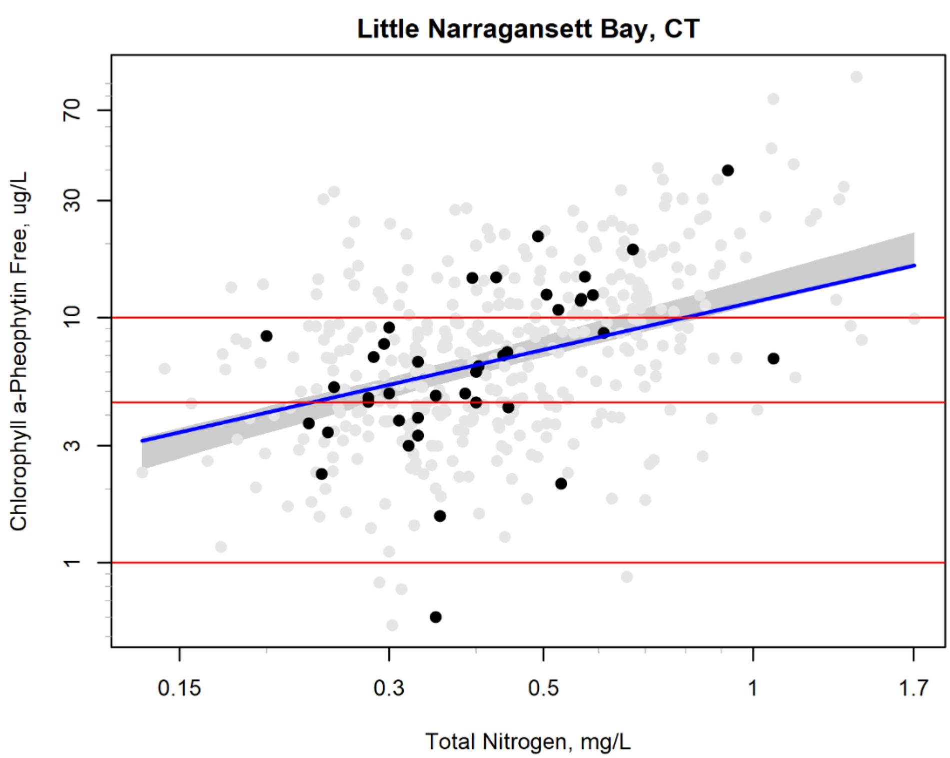

Figure G-49. Chlorophyll vs. Total Nitrogen Relationship for the Little Narragansett Bay Watershed, CT and RI (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-27.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.23 mg/L to 0.80 mg/L. These values are based on the embayment-specific chlorophyll a response variable value of 4.5 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.25 Housatonic River, MA and CT

Figure G-50 shows a map of the Housatonic River watershed. Paired data for the embayment included five paired observations across seven water quality stations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

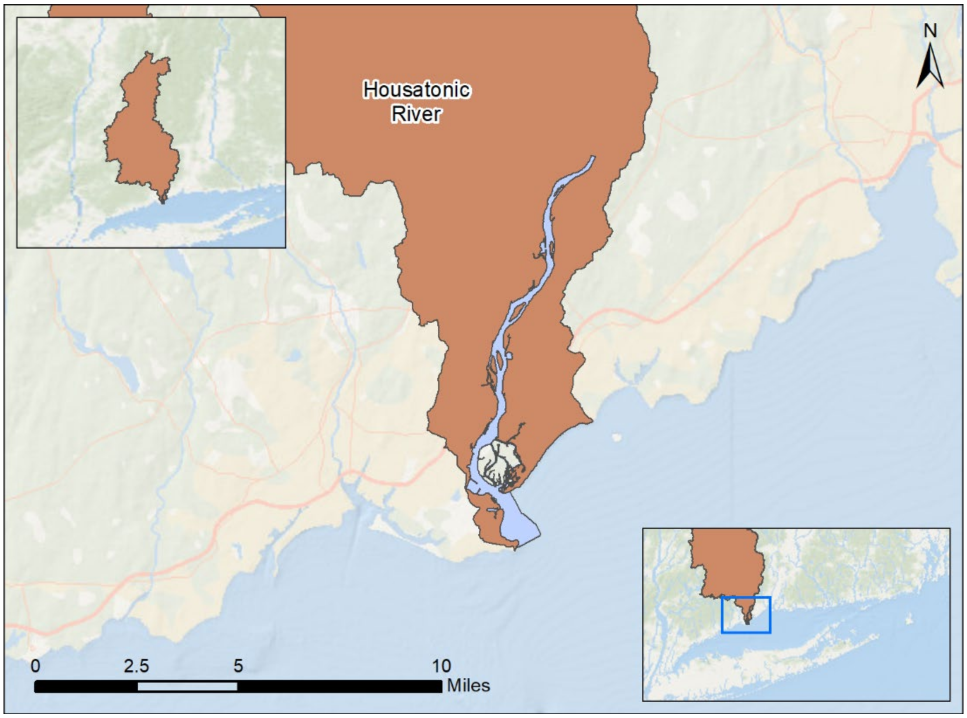

Figure G-50. Housatonic River Watershed, MA and CT

TN target concentrations for the Housatonic River embayment are presented in Table G-28. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-51. Paired data for the Housatonic River embayment are plotted.

Table G-28. TN Primary Causal Variable Target Concentrations for the Housatonic River Watershed, MA and CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.28** (0.25–0.33)
			10	**0.76**[a] (0.60–0.80)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

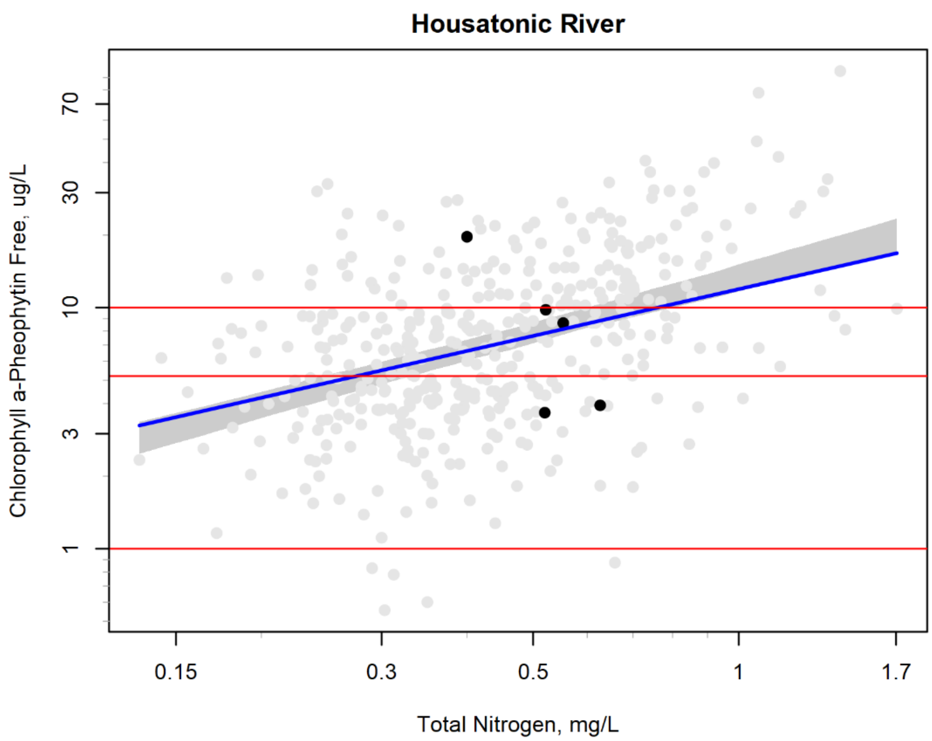

Figure G-51. Chlorophyll vs. Total Nitrogen Relationship for the Housatonic River Watershed, CT and MA (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-28.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.28 mg/L to 0.76 mg/L. These values are based on the embayment-specific chlorophyll a response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

G.26 Thames River, CT

Figure G-52 shows a map of the Thames River watershed. Paired data for the embayment included two paired observations within the growing season (April–September). These data were obtained from the water quality data used to analyze the watershed in Subtask D. As described in Subtask F, parameters used in the hierarchical model include chlorophyll *a*-corrected and TN.

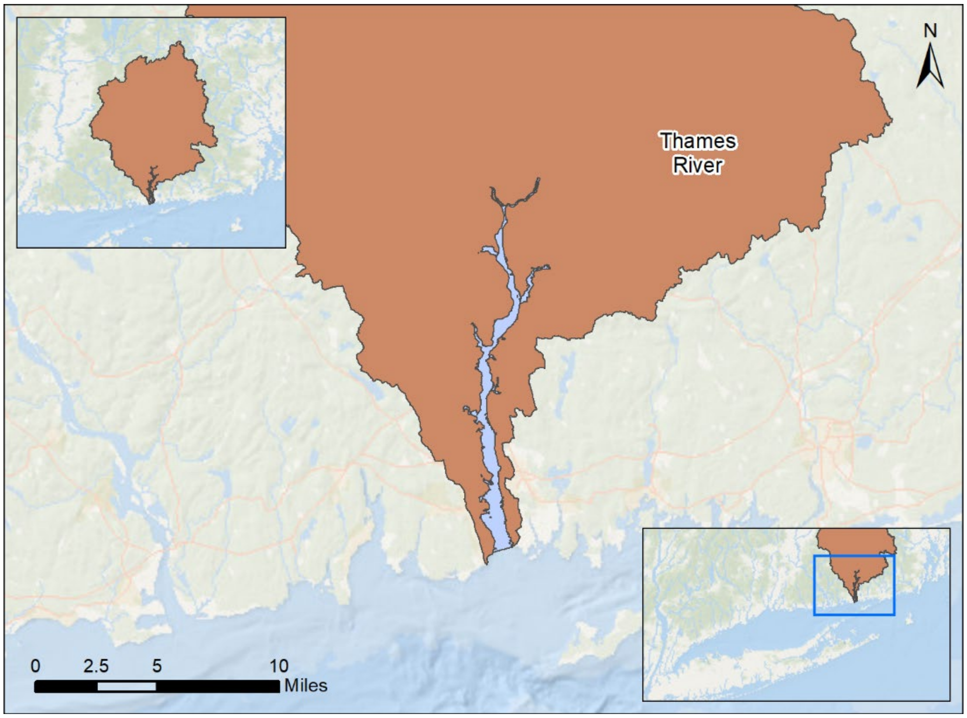

Figure G-52. Thames River Watershed, CT

TN target concentrations for the Thames River embayment are presented in Table G-29. A scatterplot of the chlorophyll versus TN relationship is presented in Figure G-53. Paired data for the Thames River embayment are plotted.

Table G-29. TN Primary Causal Variable Target Concentrations for the Thames River Watershed, CT

Management Goal	Assessment Endpoint	Lines of Evidence	Chlorophyll *a*-Corrected Primary Response Variable (µg/L)	TN Primary Causal Variable Target Concentration (mg/L)
Reestablish and maintain water quality and habitat conditions to support diverse self-sustaining commercial, recreational, and native fish, water-dependent wildlife, and shellfish	Estuarine eelgrass habitat abundance and distribution (measure of effect: chlorophyll *a*)	Stressor-response model mean (80th percent CI)	5.2	**0.25** (0.25–0.32)
			10	**0.69**[a] (0.60–0.76)
		Literature review median (range)		**0.40** (0.30–0.50)
		Distribution-based approach–All embayments 25th percentile		**0.28**
	Benthic and pelagic community diversity and abundance (measure of effect: DO)	Literature review median (range)		**0.41** (0.30–0.60)
		Distribution-based approach–All embayments 25th percentile		**0.28**

Note:
[a] As per the literature review and noted in Table F-1, values exceeding 0.49 mg/L are not considered protective of eelgrass (Howes et al. 2013) and above 0.60 mg/L are not protective of other aquatic life (Howes et al. 2010). Values below 0.20 mg/L are considered below background levels (NHDES 2009).

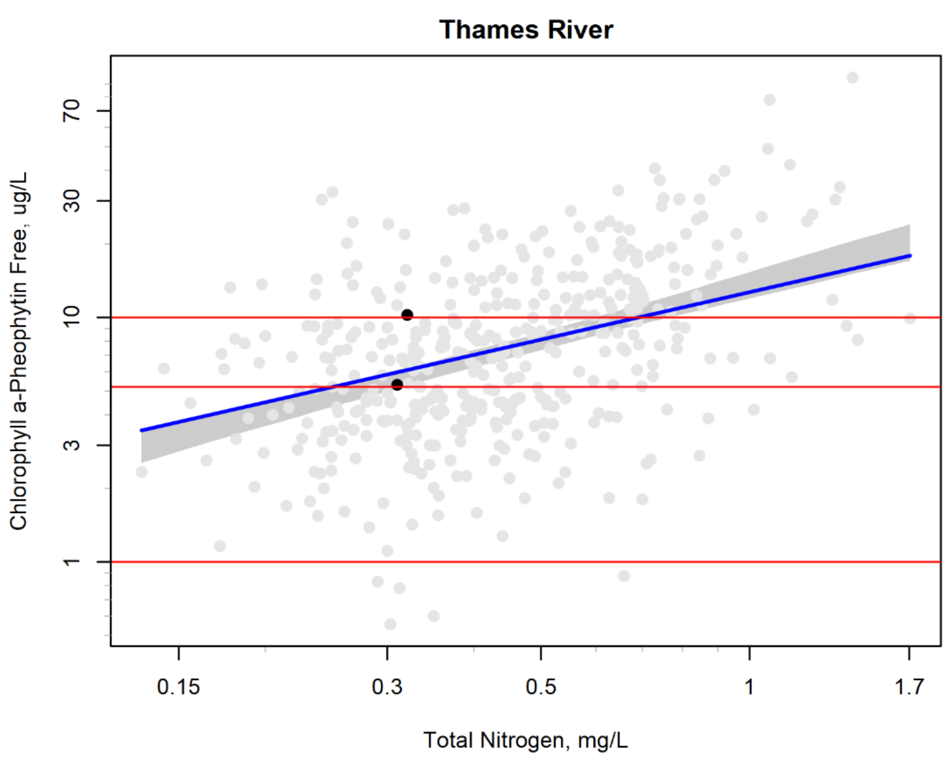

Figure G-53. Chlorophyll vs. Total Nitrogen Relationship for the Thames River Watershed, CT (This Embayment [*Black Points*], Other Embayments in the Model [*Gray Points*], Embayment-Adjusted Fit [*Blue Line*], Chlorophyll Response Variables [*Red Lines*], and 80% CI [*Gray Area*])

TN Target Concentrations Discussion

The resulting values for each line of evidence are given in Table G-29.

Literature review and distribution-based lines of evidence yielded TN values of 0.40 mg/L and 0.28 mg/L, respectively, for protecting and restoring seagrass. Note that 0.40 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.50 mg/L. The same literature review and distribution-based lines of evidence yielded TN values of 0.41 mg/L and 0.28 mg/L, respectively, to protect and restore other aquatic life. Note that 0.41 mg/L is the median literature value, with a minimum of 0.30 mg/L and a maximum of 0.60 mg/L. These values are based on water quality modeling and ecological research (Howes et al. 2003), as well as on the conditions in water bodies expected to support aquatic life uses, including seagrasses and benthic fauna.

For this embayment, the relevant stressor-response TN target concentration necessary to protect light levels needed by the seagrasses ranges from 0.25 mg/L to 0.69 mg/L. These values are based on the embayment-specific chlorophyll a response variable value of 5.2 μg/L and LIS-wide maximum of 10 μg/L (consistent with a K_d of 0.7, a value considered on the upper end for protecting light levels necessary for seagrasses in LIS [Vaudrey 2008]). This value is further explained and justified in Subtask F. For various reasons, including model variability, the embayment stressor-response models sometimes produced TN values that were outside the experience of the model or model-building dataset, below background concentrations, or over the upper maximum TN of 0.49 mg/L considered protective of eelgrass. Instances in which this occurred are noted in the target concentration table above for this embayment and resulting stressor-response ranges should be interpreted appropriately.

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