***DRAFT* Model Choice Justification Report**

October 27, 2016

Jamie Vaudrey, Ph.D.

Assistant Research Professor

Department of Marine Sciences

University of Connecticut

1080 Shennecossett Road

Groton, CT 06340

[jamie.vaudrey@uconn.edu](mailto:jamie.vaudrey@uconn.edu)

860-405-9149

Interim report for the TAC

Project: Data Synthesis and Modeling of Nitrogen Effects on Niantic River Estuary

Contents

[1 Goals and Text from the Proposal 1](#_Toc465362466)

[2 Watershed Models 1](#_Toc465362467)

[3 Review of In-Estuary Models 2](#_Toc465362468)

[3.1 Buzzards Bay Project Nitrogen Loading Methodology 3](#_Toc465362469)

[3.2 Cape Cod Commission Nitrogen Loading/Critical Loads Methodology 3](#_Toc465362470)

[3.3 Linked Model – used in Massachusetts Estuary Project 4](#_Toc465362471)

[3.4 EcoGEM Box Model 4](#_Toc465362472)

[4 Plan for Niantic River Estuary 5](#_Toc465362473)

[5 Works Cited 6](#_Toc465362474)

*This report is provided as a Microsoft Word document to allow for easy commenting and editing. This interim report will eventually become part of the final technical report. Feedback is appreciated; please forward comments to* [*jamie.vaudrey@uconn.edu*](mailto:jamie.vaudrey@uconn.edu)*.*

*Suggested citation*: Vaudrey, J.M.P. (2016) *DRAFT* Model Choice Justification Report. University of Connecticut, Department of Marine Sciences, Groton, CT. prepared for the Niantic Nitrogen Work Group. 7 p.

# Goals and Text from the Proposal

This report is a review of the in-estuary modeling options for the project, with the intent of informing the TAC of the justification for choices and providing background to allow for discussion. This report addresses *Task 2: Model Development: Utilize existing data to develop an ecosystem model (biogeochemical model coupled to a physical mixing model). Two models will be evaluated, including Vaudrey’s work modeling Narragansett Bay (Brush 2002; Brush and Nixon 2010; Kremer et al. 2010; Vaudrey 2014) and the Massachusetts Estuary Project model (Howes et al. 2001).* Additionally, the sediment biogeochemistry models reviewed in Wilson et al. (2013) will be assessed for use in NRE as part of the modeling process (not covered in this report).

# Watershed Models

The watershed portion of the model characterizes the nitrogen load reaching the edge of the estuary. Three watershed models were reviewed by Howes et al. (2001) as part of the Massachusetts Estuary Project: Massachusetts Estuary Project Linked Model, Buzzards Bay Project Nitrogen Loading Methodology, Cape Cod Commission Nitrogen Loading/Critical Loads Methodology. Howes and colleagues reviewed the models by applying them to five embayments in Massachusetts. The Long Island Sound Nitrogen Loading Model (LIS NLM) is also presented in Table 1. Watershed models will not be reviewed further; we will use the LIS NLM.

Table 1: Review of key parameters in four watershed nitrogen load models. The first three are taken from Table III-1 in Howes et al. (2001). The LIS NLM information is from Vaudrey.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | MA Estuary Project Linked Model | Buzzards Bay Project Nitrogen Loading Methodology | Cape Cod Commission Nitrogen Loading Methodology | Long Island Sound Nitrogen Loading Model |
| LOADING FACTORS (as delivery to estuary, includes attenuation) | | | | |
| Septic Systems | 1.80 kg N / person | 2.67 kg N / person | 2.67 kg N / person | 1.54 ± 0.5 kg N / person 5 |
| Lawns | 1.36 kg N / lawn1 | 1.7 kg N /  lawn1 | 1.7 kg N /  lawn1 | 1.72 ± 0.4 kg N / lawn 4 |
| Precipitation to impervious surface that reaches groundwater | 0.75 mg/L 2 | 0.75 mg/L 2 | 0.75 mg/L 2 | 0.81 mg/L |
| Precipitation to roadways that reaches groundwater | 1.5 mg/L 2 | 1.5 mg/L 2 | 1.5 mg/L 2 | 0.81 mg/L |
| N Load Validation |  |  |  |  |
| ATTENUATION FACTORS | | | | |
| attenuation in freshwater systems and surface water inflows | 30 to 60% | 30% | 0% | 50 to 70% |
| attenuation in groundwater | 0% 3 | 30% | 0% | 0 to 88% 6 |

1 Nitrogen added to residential lawns assumed to be 3 lb / 1000 square feet, with lawn sizes assumed to be 5000 square feet. Leaching is assumed to be 20% in Linked Model, 25% on Buzzards Bay model, and 25% in Cape Cod Commission model

2 Only 90% of precipitation to surface reaches groundwater

3 A series of studies conducted in MA estuaries indicates attenuation in groundwater does not occur.

4 Units of LIS NLM output have been converted to be consistent with results from Howes et al. (2001). The LIS NLM varies lawn size by watershed and zone within watershed. The value shown includes all attenuation, the load to the estuary is shown.

5 Units of LIS NLM output have been converted to be consistent with results from Howes et al. (2001). The LIS NLM identifies population on septic within each zone of the watershed and applies attenuation factors according to zone. The value shown includes all attenuation, the load to the estuary is shown.

6 Attenuation depends upon land use category and location within the watershed.

# Review of In-Estuary Models

Each model is reviewed for certain key characteristics. While each of these models includes subtle details not presented here, this comparison serves to highlight the differences among the models. Information on the Buzzards Bay and Cape Cod Commission models are summarized from the comparison presented in Howes et al. (2001). These two models essentially lack an in-estuary model. The models are presented side-by-side to facilitate comparison.

The Massachusetts Estuary Project uses the RMA-4 water quality module, coupled with the RMA-2 hydrodynamic model. The documentation on this model is vague in the online technical information and is not well described by Howes et al. (2001). Looking into the water quality modeling section of an embayment technical report provides more detail on the actual application of the model (e.g. Chp. 6 of Howes et al. 2006). Vaudrey created EcoGEM, information is provided from personal experience and is documented in Vaudrey (2014).

|  |  |
| --- | --- |
| Buzzards Bay Project Nitrogen Loading MethodologyRequired Inputs  * estimates of nitrogen load from the watershed * estimate of freshwater flushing time  Hydrodynamics Not included. Freshwater flushing time is used to evaluate the residence time of nitrogen in the estuary. Nutrient Inputs from Boundaries Only includes the nutrient load as generated by the watershed loading model, which includes groundwater and surface water. Nutrient inputs are distributed to the whole system as a bulk number. Time Frame Annual estimate. Calibration None. Verification None. Setting Nitrogen Thresholds The thresholds are determined by allowing the estimated nitrogen load from the watershed to flush conservatively though the estuary. No in-estuary processes are included. | Cape Cod Commission Nitrogen Loading/Critical Loads MethodologyRequired Inputs  * estimates of nitrogen load from the watershed * estimate of freshwater flushing time  Hydrodynamics Not included. Freshwater flushing time is used to evaluate the residence time of nitrogen in the estuary. Nutrient Inputs from Boundaries Only includes the nutrient load as generated by the watershed loading model, which includes groundwater and surface water. Nutrient inputs are distributed to the whole system as a bulk number. Time Frame Annual estimate. Calibration None. Verification None. Setting Nitrogen Thresholds The thresholds are determined by allowing the estimated nitrogen load from the watershed to flush conservatively though the estuary. No in-estuary processes are included. |
| Linked Model – used in Massachusetts Estuary ProjectRequired Inputs  * boundary conditions and dispersion coefficients output as a table from RMA‑2 * estimates of nitrogen load from the watershed * measurements of benthic flux of nitrogen during summer * measurements of nitrogen in the water column during summer  Hydrodynamics Uses a finely resolved, 2-D hydrodynamic model (RMA-2), which would include thousands of grid cells when applied to Niantic River. Each of these grid cells is equivalent to the coarsely resolved ecological model mentioned for the EcoGEM model. Nutrient Inputs from Boundaries Includes nutrients entering from freshwater surface flow, marine boundary (e.g. Long Island Sound for Niantic River), and groundwater. Nutrient inputs are distributed to each grid cell as appropriate. For example, groundwater enters throughout the spatial area of the embayment while surface flow enters at the location of streams and rivers. Time Frame The model has a spin-up of 28 days, followed by 7 days for the model run. The 28-day period allows the model domain to reach steady state, this period is not considered model output. Calibration Calibration of the model is in reference to the nitrogen concentrations measured in the water column. The dispersion coefficients are tuned until the model output matches the in-estuary concentration. Verification To verify the model is operating as expected, salinity output from the model are compared to salinity data from the estuary. Setting Nitrogen Thresholds Only nitrogen is modeled directly. Dissolved oxygen, eelgrass, and benthic infauna (when eelgrass was not present) are used to set targets for nitrogen loads, using actual data from the system. A site within the system is chosen as a sentinel site such that improvement in water quality in that location will restore habitat to the desired condition. For example, eelgrass may be desired at an inner station (landward). To set a nitrogen threshold, the nitrogen level at existing eelgrass beds in that system are used to set the target nitrogen concentration for the water column. The nitrogen load form the watershed is adjusted until the desired condition is achieved at the sentinel station. | EcoGEM Box ModelRequired Inputs  * boundary conditions and dispersion coefficients from the Officer Box Model approach to determining hydrodynamics * light, wind, temperature * estimates of nitrogen load from the watershed * estimates of benthic flux of nitrogen * measurements of state variables in the incoming water and within the estuary: salinity, chlorophyll, nitrogen, phosphorus, benthic carbon, dissolved oxygen  Hydrodynamics Uses a coarsely resolved, 3-D box model approach to determining mixing within the embayment. We expect to include three boxes in Niantic River Estuary, each with a surface and bottom layer. This coarse resolution is more appropriate to the scale of ecological processes, allowing us to average over larger scales and verify model estimates with field data (Kremer et al. 2010). Ideally, a fine-scale hydrodynamic model would be used to estimate the mixing among the three boxes, though the Officer box model approach has been used in many estuaries (Officer 1980; Officer and Kester 1991). Nutrient Inputs from Boundaries Includes nutrients entering from freshwater surface flow, marine boundary (e.g. Long Island Sound for Niantic River), and groundwater. Nutrient inputs are distributed to each model box as appropriate. For example, groundwater enters throughout the spatial area of the embayment while surface flow enters at the location of streams and rivers. Time Frame The model will cover multiple years, and the model will be responsive to changes in temperature, light, and wind. Calibration Calibration of the model is in reference to the chlorophyll, nutrients, and dissolved oxygen measured in the water column. The respiratory coefficient of the water column and benthos are the only items tuned to achieve a goodness of fit. Verification To verify the model is operating as expected, salinity output from the model are compared to salinity data from the estuary. Setting Nitrogen Thresholds The model provides estimates of nutrients, chlorophyll, and dissolved oxygen. Macroalgae and seagrass will be added to the model. A result of the model is an estimate of the light attenuation coefficient in the water column. Estimates of the light reaching the bottom will predict success for eelgrass. Scenarios of changing nutrient loads in the context of increasing temperatures will provide estimates for nitrogen thresholds responsive to predicted water column warming. |

# Plan for Niantic River Estuary

* The Long Island Sound Nitrogen Loading Model will be used to determine the watershed loading rate for nitrogen. Further evaluation of the other three watershed models is beyond the scope of this project.
* The Buzzards Bay and Cape Cod Commission model essentially do not have an in-estuary model. We will have estimates of the flushing time of the embayment, and can thus apply these methods for setting criteria (basically, a flushing of the nitrogen through the system).
* The benefit of the Linked Model used in the MA Estuary Project is the application of a fine-scale hydrodynamic model. Application of that model is beyond the scope of this project in terms of both time and money.
* The EcoGEM model operates over multiple years and can estimate the impacts of climate factors on water quality.
* We will compare estimates using a procedure similar to the Linked Model approach by substituting the mixing coefficients derived from the Officer box model approach used for EcoGEM.

# Works Cited

Brush, M.J. 2002. Development of a numerical model for shallow marine ecosystems with application to Greenwich Bay, RI. Doctoral Dissertation, Univeristy of Rhode Island Narragansett, RI.

Brush, M.J., and S.W. Nixon. 2010. Modeling the role of macroalgae in a shallow sub-estuary of Narragansett Bay, RI (USA). *Ecological Modelling* 221: 1065–1079.

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 West Falmouth Harbor, Falmouth, Massachusetts: Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

Howes, B.L., J.S. Ramsey, and S.W. Kelley. 2001. Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis: prepared for: Massachusetts Department of Environmental Protection Bureau of Resource Protection and U.S. Environmental Protection Agency Region I.Project #00-06/104.

Kremer, J.N., J.M.P. Vaudrey, D. Ullman, D.L. Bergondo, N. Nasota, C. Kincaid, D.L. Codiga, and M.J. Brush. 2010. Simulating property exchange in estuarine ecosystem models at ecologically appropriate scales. *Ecological Modelling* 221: 1080-1088.

Officer, C.B. 1980. Box models revisited. In *Estuarine and Wetland Processes with Emphasis on Modeling*, ed. P. Hamilton and R.B. McDonald, 65-114. New York: Plenum Press.

Officer, C.B., and D.R. Kester. 1991. On estimating the non-advective tidal exchanges and advective gravitational circulation exchanges in an estuary. *Estuarine, Coastal and Shelf Science* 32: 99-103.

Vaudrey, J.M.P. 2014. 2014 working report on the Narragansett Bay EcoGEM model, 68: University of Connecticut.