CONNECTICUT SEA GRANT PROJECT REPORT

Please complete this progress or final report form and return by the date indicated in the emailed progress report request from the Connecticut Sea Grant College Program. Fill in the requested information using your word processor (i.e., Microsoft Word), and e-mail the completed form to Dr. Syma Ebbin syma.ebbin@uconn.edu, Research Coordinator, Connecticut Sea Grant College Program. Do NOT mail or fax hard copies. Please try to address the specific sections below. If applicable, you can attach files of electronic publications when you return the form. If you have questions, please call Syma Ebbin at (860) 405-9278.

Please fill out all of the following that apply to your specific research or development project. Pay particular attention to goals, accomplishments, benefits, impacts and publications, where applicable.

Project #: **R/CE-32-CTNY** Check one: [ ] Progress Report [x] Final report

Duration (dates) of entire project, including extensions: From [3/1/2011] to [2/28/2013].

Project Title or Topic: Comparative Analysis of Eutrophic Condition and Habitat Status in Connecticut and New York Embayments of Long Island Sound.

Principal Investigator(s) and Affiliation(s):

1. Jamie Vaudrey, University of Connecticut

2. Charles Yarish, University of Connecticut

3.

4.

A. COLLABORATORS AND PARTNERS: *(List any additional organizations or partners involved in the project.)*
Not applicable.

B. PROJECT GOALS AND OBJECTIVES:

For the majority of the more than 60 embayments of LIS, very little is known about their current eutrophic condition, dominant habitat type, potential to support submerged aquatic vegetation (SAV), or changes in community structure due to climate change effects. Small coastal embayments are the receiving waters for much of the nonpoint source nitrogen (N) being delivered into LIS. This nitrogen input has been identified as a major contributing factor to eutrophication and the loss of SAV in estuaries. By sampling in many sites across a range of nitrogen loads, the relationship between stressors (N, temperature, flushing time) and estuarine response (hypoxia, macroalgae blooms, loss of SAV) can be investigated. This data set can also be used to examine sites for the potential to support SAV and serve as a baseline for future work related to eutrophication issues and climate change effects.

Objectives:

1. Survey the habitat characteristics in 8 embayments of Long Island Sound.

2. Utilize standard indicators of estuarine water quality and eutrophication status (EPA, NOAA) to assess the relative "health" of these estuaries, comparing within Long Island Sound and to estuaries throughout the nation.

3. Assess these sites for their potential to support *Zostera marina* L. (eelgrass).

4. Identify the links between stresses to the embayments (nitrogen load, temperature), contributing factors (freshwater flushing time, size), and estuarine response (indices from #2, habitat characteristics).

5. Compare the habitat characteristics to historic data, where available. This includes evaluating changes in temperature and pH as possible indicators of climate change effects.

6. Develop a baseline set of data for future researchers working in Long Island Sound.

7. Present results to the scientific community, Long Island Sound managers, and stakeholders.

8. Introduce 6 undergraduate students (3 / y) to ecological field research, lab techniques, and data analysis for use in informing management and scientists on ecosystem status of small embayments.

C. PROGRESS: (*Summarize progress relative to project goals and objectives. Highlight outstanding accomplishments, outreach and education efforts; describe problems encountered and explain any delays.)*

1. All 8 sites were sampled once during the predicted height of hypoxia (end of July & early August) in 2011 and 2012. Data have been synthesized into a summary file, linked to individual data files.
2. Field data were used to compare the embayments for eutrophic status using the NOAA ASSETS model (http://eutro.org/, http://www.eutro.org/register/). This approach includes an estimate of nitrogen loading, flushing time, and information on key indicators (primary symptoms: chlorophyll *a*, macroalgae; secondary symptoms: dissolved oxygen, nuisance and toxic algae blooms, submerged aquatic vegetation).
3. Sites were assessed for *Zostera marina* suitability using a GIS based site suitability model, completed as part of a LISS/NEIWPCC funded project (Vaudrey and Yarish are PIs on this project). Data from this project were used to enhance the data input for the GIS model. The final report for the NEIWPCC project, including presentation of the model results, will be posted at the UConn Digital Commons site (http://digitalcommons.uconn.edu/). The report has been submitted and will be released on the site shortly (once all authors send in acceptance of the submission agreement).
4. Links between stresses to the embayments (nitrogen load, temperature), contributing factors (freshwater flushing time, size), and estuarine response (indices from #2, habitat characteristics) were identified. A summary of findings is provided in the results section below.
5. Habitat characteristics were compared with historic data, where possible. In many sites, a comparable data set (similar time of year, similar techniques) were not available.
6. A baseline set of data was developed and will be available for future researchers working in Long Island Sound. The data will be made available through the UConn Digital Commons, upon completion of the peer-reviewed journal articles which will utilize the data. Data are available

upon request. For example, a Ph.D. student working with Dr. Melanie Fewings at UConn is using the temperature data form deployed sensors to estimate heat budgets in Long Island Sound embayments.

7. Present results. A list of presentations is included in section D of this report.
8. Six students were funded fully or partially by this project during the summer of 2011 and five students worked on the project during the summer of 2012. Two to five students worked part time during the school year throughout the project.

D. <u>PROJECT PUBLICATIONS, PRODUCTS AND PATENTS</u>: *(Include published materials with complete references, as well as those which have been submitted but not yet published and those in press. Please attach electronic versions of any journal articles not previously provided.)*

Journal Articles:

Conference Papers and Presentations:

Vaudrey, J.M.P. (2014) *Eutrophic condition and habitat status in Connecticut and New York embayments of Long Island Sound.* invited presentation, Southern Connecticut State University.

Vaudrey, J.M.P. (2014) *The Breathing of the Bays: a journey into green water.* invited presentation, Faulkners Light Brigade Lecture Series, Guilford.

Vaudrey, J.M.P. (2013) *Using Nitrogen Budgets as a Tool to More Effectively Manage Long Island Sound Embayments*. 2nd Workshop on Using Cultivated Seaweed and Shellfish for Nutrient Bioextraction in LIS and the Bronx River Estuary, Mamaroneck, NY.

Vaudrey, J.M.P. (2013) *Marine Ecosystem Ecology.* invited presentation at the "Women In Science" program for middle school girls, The Sound School.

Vaudrey, J.M.P. and C. Yarish (2013) *Nitrogen loading to embayments of Long Island Sound: method review and potential utility to management*. Presentation to the Long Island Funders Collaborative Meeting, New York City, NY. 01 Mar 2013.

Vaudrey, J.M.P. and C. Yarish (2012) C*omparative Analysis of Eutrophic Condition and Habitat Status in Connecticut and New York Embayments of Long Island Sound*. Presentation to the LISS STAC, 16 Nov 2012.

Yarish, C. and J. Vaudrey (2011) C*omparative Analysis of Eutrophic Condition and Habitat Status in Connecticut and New York Embayments of Long Island Sound*. Presentation to the LISS STAC, 18 Nov 2011.

Other articles, such as proceedings or book chapters:

Web sites, Software, etc.:

Technical Reports / Other Publications:

Other Products (including popular articles):

Zaretsky, M. (8/4/13) *Low oxygen levels present even in bays in eastern estuary, UConn researchers find.* interview, article, and photos for the New Haven Register. (http://www.nhregister.com/general-news/20130804/low-oxygen-levels-present-even-in-bays-in-eastern-estuary-uconn-researchers-find; http://photos.newhavenregister.com/2013/08/01/photos-marine-researcher-studies-l-i-sound-oxygen/#1)

Vaudrey, J.M.P. (2012) *The Breathing of the Bays*. Wrack Lines (Spring/Summer 2012): 5-7.

Vaudrey, J. and C. Yarish (2012) *Taking the Pulse of Long Island Sound's Embayments*. Short article submitted to the 2012 Sound Health Indicators report for the Long Island Sound Study.

Planned Publications:

Vaudrey, J.M.P., A. Chlus, A. Branco, C. Yarish, J. Kremer (in prep) Nitrogen inputs to Long Island Sound embayments from the NLM (Nitrogen Loading Model): estimates vary with methods used for estimating population.

Vaudrey, J.M.P., J. Kim, C. Yarish (in prep) Macrophyte elemental composition indicates the degree of nitrogen loading to embayments.

-- evaluation of hypoxia in embayments relative to Long Island Sound

-- evaluation of hypoxia in embayments relative to stressors (N-load, flushing time, etc.)

Patents: *(List those awarded or pending as a result of this project.)*

E. FUNDS LEVERAGED: *(If this Sea Grant funding facilitated the leveraging of additional funding for this or a related project, note the amount and source below.)*

F. STUDENTS: ***(****Document the number and type of students supported by this project.)*
Note: ***"Supported"*** *means supported by Sea Grant through financial or other means, such as Sea Grant federal, match, state and other leveraged funds. If a student volunteered time on this project, please note the number of volunteer hours below.*

Total number of **new*** K-12 students who worked with you: 0
Total number of **new** undergraduates who worked with you: 6 in 2011; 4 in 2012
Total number of **new** Masters degree candidates who worked with you: 0
Total number of **new** Ph.D. candidates who worked with you: 0

Total number of **continuing**** K-12 students who worked with you: 0
Total number of **continuing** undergraduates who worked with you: 0 in 2011; 3 in 2012
Total number of **continuing** Masters degree candidates who worked with you: 0
Total number of **continuing** Ph.D. candidates who worked with you: 0

Total number of volunteer hours: 0

*(Note: ***New*** students are those who have not worked on this project previously. ****Continuing*** students are those who have worked on this project previously.)*

In the case of graduate students, please list student names, degree pursued, and thesis or dissertation titles related to this project.

Student Name:
Degree Sought:
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation:

G. PICTORIAL: Provide high resolution images/photos of personnel at work, in the field or laboratory, equipment being used, field sites, organism(s) of study. Attach images as separate files (do not embed). Include links to websites associated with the research project. Please include proper photo credits and a caption with date, location, names of people, and activity. These images are useful to document your project in future CTSG publications, websites and presentations.

see photos included with the report submitted in 2012

FOR FINAL REPORTS ONLY, PLEASE COMPLETE THIS SECTION:

H. PROJECT OUTCOMES AND IMPACTS

RELEVANCE OF PROJECT: *(Describe briefly the issue/problem / identified need(s) that led to this work.)*

This work originated from a need to assess the eutrophic status of embayments in Long Island Sound. Monitoring of the main stem of Long Island Sound is ongoing, frequent, spatially extensive, and data produced are of excellent scientific quality. Data from the embayments tends to be temporally and spatially inconsistent and methods are often not comparable as different organizations conduct the work.

RESPONSE: *(Describe briefly what key elements were undertaken to address the issue, problem or need, and who is/are the target audience(s) for the work.)*

We developed a relatively rapid assessment method to evaluate the eutrophic status of embayments. The goal was to inform the research and management community of Long Island Sound as to the extent and degree of eutrophic symptoms in Long Island Sound. In addition, many community groups and foundations in the Long Island Sound region have expressed an interest in the results.

RESULTS: *(Summarize findings and significant achievements in terms of the research and any related education or outreach component; cite benefits, applications, and uses stemming from this project, including those expected in the future. Include qualitative and quantitative results.)*

All 8 sites (Figure 1) were sampled once during the predicted height of hypoxia (end of July & early August) in 2011 and 2012. Data have been synthesized into a summary file, linked to individual data files. The field data were used to assign a value to the eutrophic status each embayment. The nitrogen loading based on land use was estimated for each embayment. Additional forcing factors such as temperature and restrictions to water flow within the embayments were characterized. **The overall goal was to develop a better understanding of the linkages between the forcing factors and the expression of eutrophication.**

Figure 1: Map of embayments samples as part of the project.

A. Assigning a value to the eutrophic status for each embayment.

Field data were used to compare the embayments for eutrophic status using the NOAA ASSETS model (http://eutro.org/, http://www.eutro.org/register/). This approach is based on an estimate of nitrogen loading, flushing time, and information on key indicators (primary symptoms: chlorophyll *a*, macroalgae; secondary symptoms: dissolved oxygen, nuisance and toxic algae blooms, submerged aquatic vegetation). As consistent information on nuisance and toxic algae blooms were not available in all sites, "unknown" was entered into the model for all sites.

The NOAA ASSETS model ideally takes data which reflects the annual average. Thus, results are not directly comparable to sites with year-round data but can be used to compare among the sites sampled only during the summer (Figure 2).

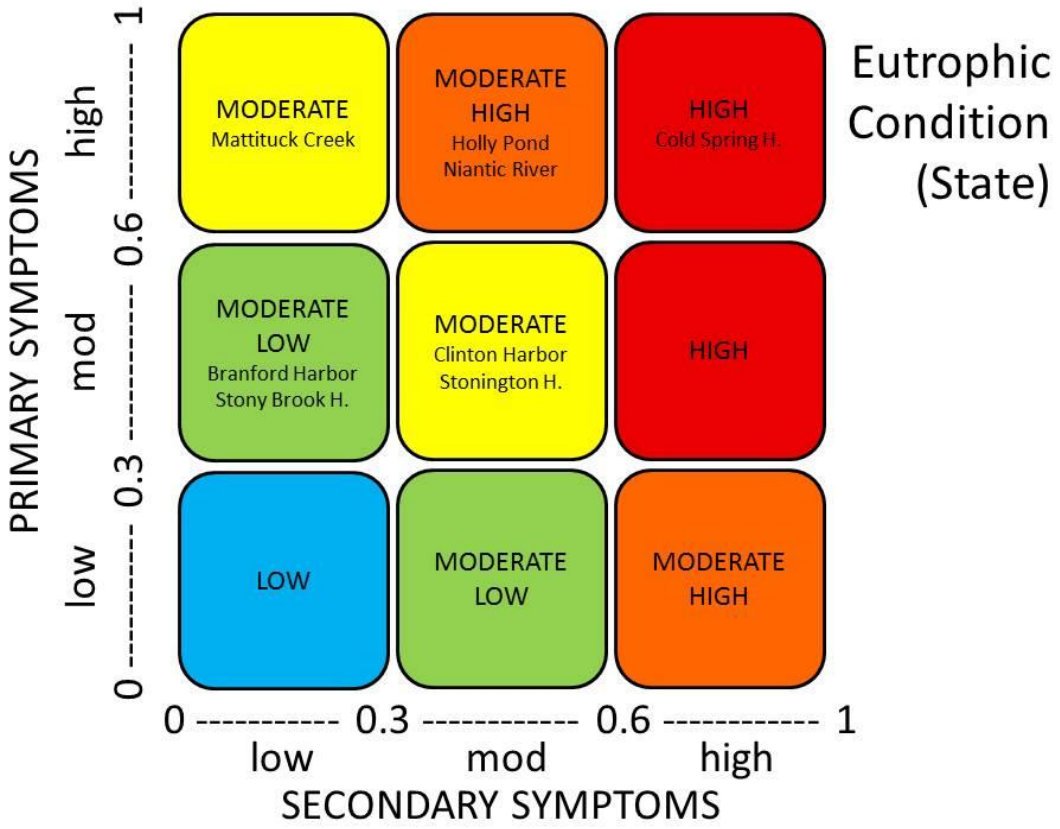

Figure 2: Eutrophic Condition as estimated by the NOAA ASSETS model, using site specific field data.

B. Estimating the nitrogen load to each embayment.

The nitrogen loads to the embayments were estimated using a land-use based model developed by Ivan Valiela[1] and modified by James Latimer and Michael Charpentier[2]. A paper is in draft form, detailing the model, comparing a variety of population estimates used for model input, and providing the N load for each of the embayments included in the study. The N load includes an estimate of nitrogen input based on land use category and population within the watershed. Sources were identified as wastewater inputs (septic and wastewater treatment facilities, WWTFs); fertilizer to homes, recreational fields, and agricultural fields; and atmospheric deposition to the watershed and directly to the surface of the embayment. Load estimates include both organic and inorganic forms of nitrogen and are the total delivered to the edge of the embayment. Load estimates include transformation and attenuation of N as it passes through the groundwater, but do not include any transformation or attenuation of N that occurs in saline water. The N load is presented as the total load to the embayment (Figure 3) and as the total load normalized to the area of the embayment receiving the nitrogen (Figure 4).

[1] Valiela, I., Collins, G., Kremer, J.N., Lajtha, K., Geist, M., Seely, B., Brawley, J., Sham, C.-H., 1997. Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. Ecol. Appl. 7(2), 358-380.

[2] Latimer, J.S., Charpentier, M., 2010. Nitrogen inputs to seventy-four southern New England estuaries: application of a watershed nitrogen loading model. Estuar. Coast. Shelf Sci. 89, 125-136.

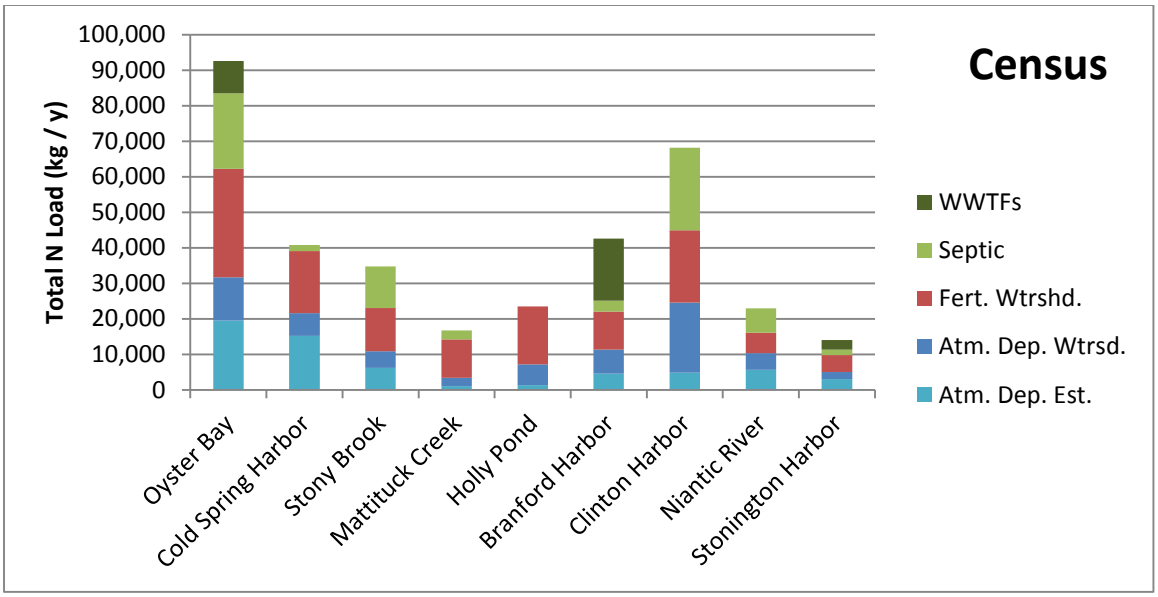

Figure 3: Results of Nitrogen Loading Estimates. Note that units are the total nitrogen load to the embayment.

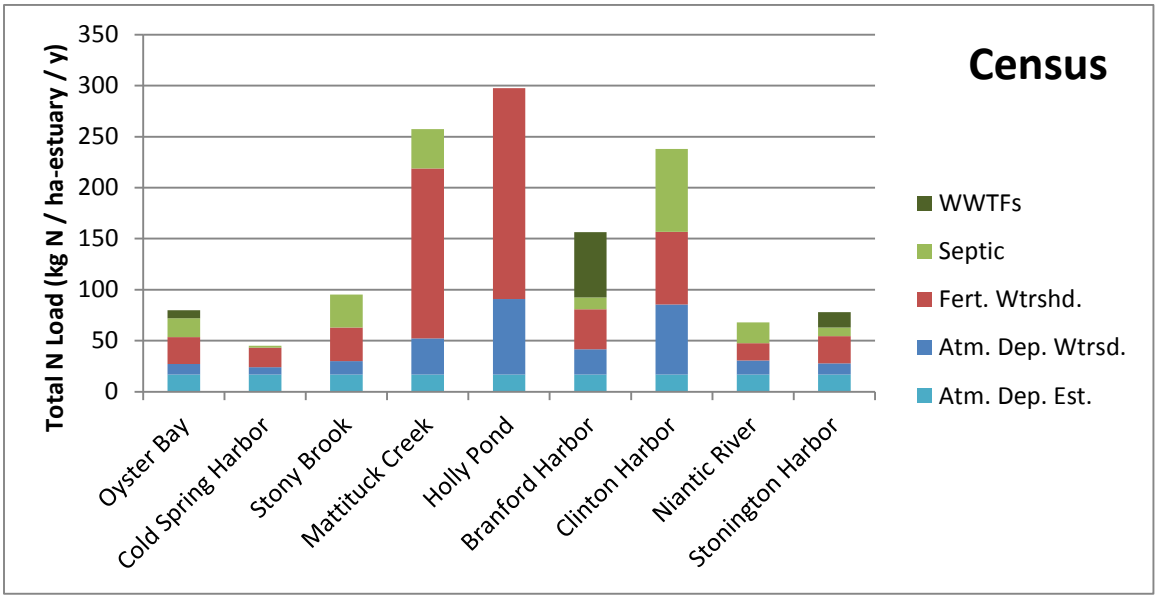

Figure 4: Results of Nitrogen Loading Estimates. Note that units are the total nitrogen load to the embayment normalized to the area of the embayment. Thus large loads to a large system (such as Oyster Bay) yield a lower per hectare$_{estuary}$ load while small loads to a very small area (such as Holly Pond) can yielda higher per hectare$_{estuary}$ load.

C. Investigating temperature as a factor influencing expression of eutrophic symptoms.

High temperatures in embayments have the potential to exacerbate the symptoms of eutrophication. In order to evaluate differences among sites and identify this possible effect, we deployed temperature sensors in the sites, at locations chosen based on the dawn sampling for hypoxia conducted in 2011. Most sensors remain deployed at this time and are downloaded every few months. The plan is to keep as many deployed as possible, to begin a long term record of temperature in these sites. A graduate

student in the Department of Marine Sciences working with Dr. Melanie Fewings has proposed to use these data to examine the heat budget in shallow systems.

Some sensors have been lost, so gaps in the data are present. The Holly Pond sensor was lost without any data retrieved. This sensor was never redeployed due to the difficulty of deploying in this site (no docks present, sensor would have been exposed at low tide). The sensors in Stonington Harbor and Mattituck Creek were both lost due to dock movement and repairs, but both have been replaced. The sensor deployed in Cold Spring Harbor was exposed at low tide; only data for times when the sensor was deployed from a floating dock are presented.

The weekly trends in temperature are relatively consistent among sites, reflecting a commonality to weather and temperature throughout the Long Island Sound region, though some differences among sites are evident and expected (Figures 5 and **6**). In almost all sites, the temperature sensors were deployed at the head of the estuary, where hypoxia was most likely to occur. The exception was Stony Brook Harbor, where the sensor was deployed mid-way down the embayment. Niantic River and Mattituck Creek tend to be the two warmest stations (Figure **6**). Branford Harbor and Clinton Harbor are variable, occasionally exhibiting some of the highest temperatures and at other times, the coolest temperatures. Stonington Harbor is consistently cooler than other sites.

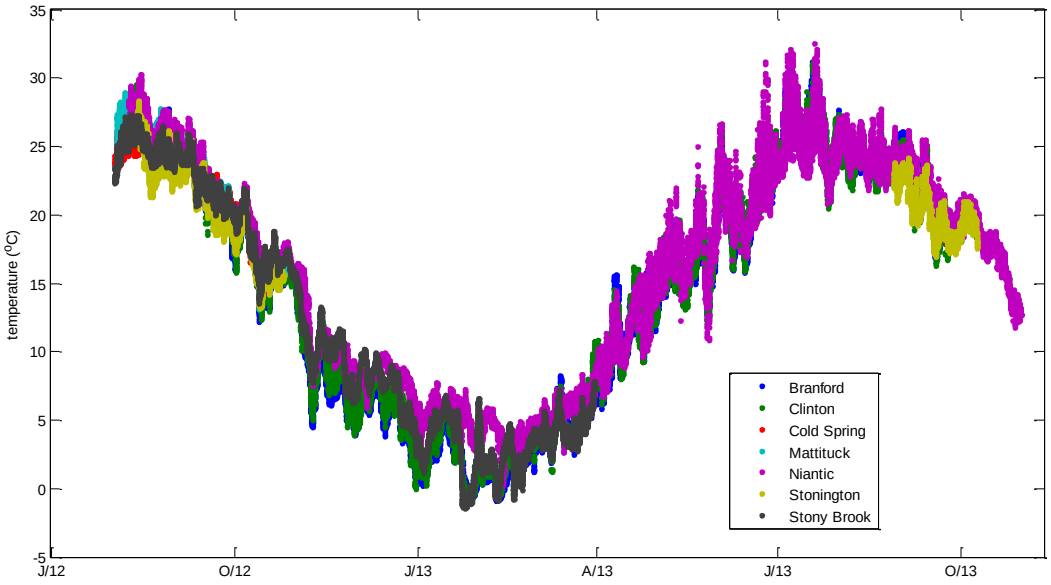

Figure 5: Temperature records from embayments. The sensor were deployed ~70 cm below the surface, suspended from a floating dock (actual depth of each sensor is available).

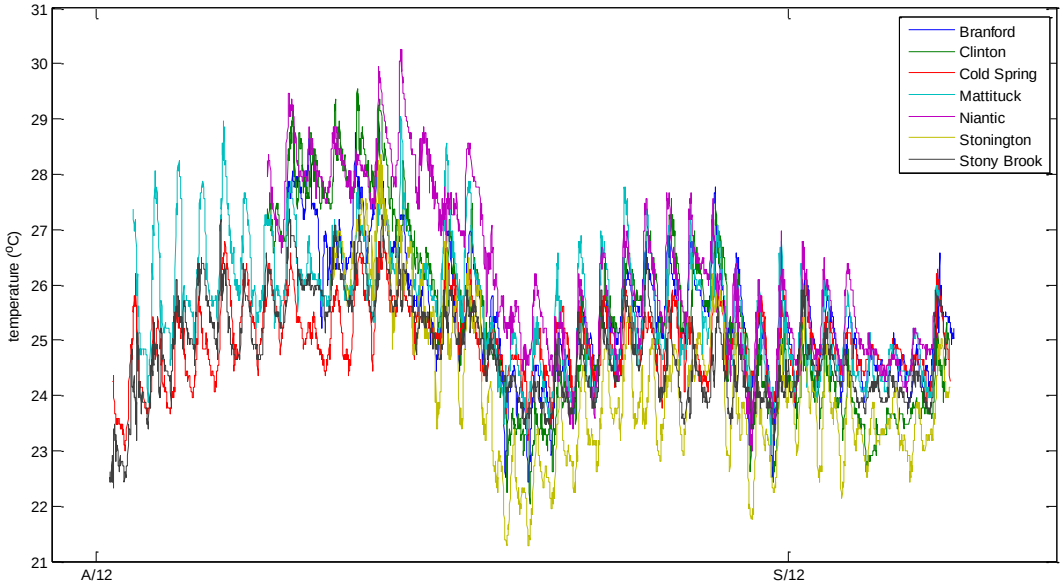

Figure 6: One month of temperature records from embayments, end of summer 2012. The figure shows a subset of the data presented in Figure 5. The sensors were deployed ~70 cm below the surface, suspended from a floating dock (actual depth of each sensor is available).

D. Key findings on the linkages between the forcing factors and the expression of eutrophication.

The estimate of eutrophic condition (Figure 2) correlates well with nitrogen load (Figure 4), if the flow restrictions in certain sites are taken into account. Cold Spring Harbor, Holly Pond, Niantic River, and Stonington Harbor all have some constriction restricting flushing of the embayment with long Island Sound water in some part of the embayment. Stonington has a train bridge separating the upper third of the estuary from the well-flushed southern portion. Niantic River has a train bridge at the southern end of the embayment and reduced flow in the upper fjord-like arm of the estuary, as well as a roadway bridge at the northern end further reducing flow to the northern tip of the embayment. Holly Pond has a dam at the southern limit of the embayment. Cold Spring Harbor has a sand bar separating the southern end of the embayment from the better flushed northern portion of the embayment.

For embayments with no flow restriction, the order from highest N load (kg N $ha_{estuary}^{-1}$ y^{-1}) to lowest is: Mattituck Creek, Clinton Harbor, Branford Harbor, Stony Brook. For embayments with a flow restriction which causes greater expression of eutrophic symptoms, the order from highest N load (kg N $ha_{estuary}^{-1}$ y^{-1}) to lowest is: Holly Pond, Stonington Harbor, Niantic River, and Cold Spring Harbor. For embayments with no flow restriction, the eutrophic condition is well-correlated with the trend in nitrogen loading. For those systems with a flow restriction, the correlation does not hold up as well. The temperature differences in these sites do assist with identifying eutrophic condition relative to N load. For example, Niantic River and Stonington Harbor have similar area normalized nitrogen loads (Figure 4), but the higher temperature in Niantic contributes to a eutrophic condition of “moderate high” while the cooler temperature of Stonington Harbor contributes to the “moderate” designation.

Early indication of these trends (following 2011) led to the development of a proposal to more thoroughly evaluate the nitrogen loading and eutrophic status in embayments of LIS, taking into account these flow restrictions. The proposal was funded and work commenced in summer of 2013.

Additional Results of Note:

While visiting the 8 embayments, Dr. Yarish collected macroalgae samples. As part of independent and self-supported efforts, Dr. Yarish and his colleagues(including Prof. Yun-Xiang MAO and R. Wilson) conducted DNA analysis of the samples to determine the presence of non-native species. In Holly Pond, the entire area has been overtaken by the invasive *Gracilaria vermiculophylla* (an invasive from the western Pacific). We have now confirmed that the dominant Gracilaria in the Mattituck Creek, Cold Spring Harbor and Stony Brook Harbor systems are the native cogenorer, *Gracilaria tikvahiae*. We also have some exciting results on some of the Ulvalean algae we have collected, but are waiting for Prof. Mao to decide how he wishes to publish that information.

During the summer of 2012, the massive amounts of algae washing up along the eastern shore of Stonington Borough (Ash Street beach) resulted in complaints from local residents. Vaudrey and Yarish (as well as marine scientists from Williams-Mystic, CT Sea Grant, and University of Rhode Island) consulted with town officials regarding the source of the problem. Our work in the area provided some context for the source of the problem – the massive blooms of macroalgae occurring in Little Narragansett Bay. The macroalgae bloom is fueled by nutrients entering the system, with the most likely source being the Pawcatuck River. A UConn undergraduate has applied for a UConn Summer Undergraduate Research Fellowship and a UConn IDEA grant to further identify the source of the nitrogen and characterize the extent of the macroalgae bloom. Her proposal developed out of her work on this grant and a desire to further explore this issue.

Consider the following as they apply to your research and any related outreach/education.

- What new tools, technologies, methods or information services were developed from this work? Have any been adopted / implemented for use and by whom?

  While not wholly new, we have demonstrated that a rapid assessment approach (a single day of sampling per site) can be used to compare the eutrophic status of embayments. Ideally, sampling of these systems would occur multiple times a year and carry on for multiple years. However, a day of sampling during the height of the hypoxic season provides information on the status of these systems. This single day of sampling proves useful because many of the indicators used integrate over a longer time period, for example, macroalgae persists for weeks to months in a system.

- What are the environmental benefits of this work? Have policies been changed? How has conservation (of ecosystems, habitats or species) been improved?

  The environmental benefits of this work include a much clearer and accurate understanding of the habitat characteristics in embayments and the dynamics of nutrient input and eutrophication.

- What are the social payoffs of this work? Who has benefited from this work? Have attitudes / behaviors of target audience changed? Elaborate. Have policies been changed?

  One benefit not highlighted in the results section is the identification of the sources of nitrogen in the embayment watersheds. For example, in the Cold Spring Harbor watershed, a large fraction of

the estimated nitrogen load originates from fertilizer applied to recreational fields (Figure 7). If assumptions of the model are correct (amount of fertilizer applied, amount of area fertilized), a reduction of fertilizer to these fields would assist with the reduction of nutrients to this system. Results from this project will be made available to groups with interest in nutrient reductions, if such groups within a watershed can be identified. When groups within a watershed do not exist, these data will be provided to Save the Sound of CT Fund for the Environment in Connecticut and the Citizens Campaign Fund for the Environment in NY.

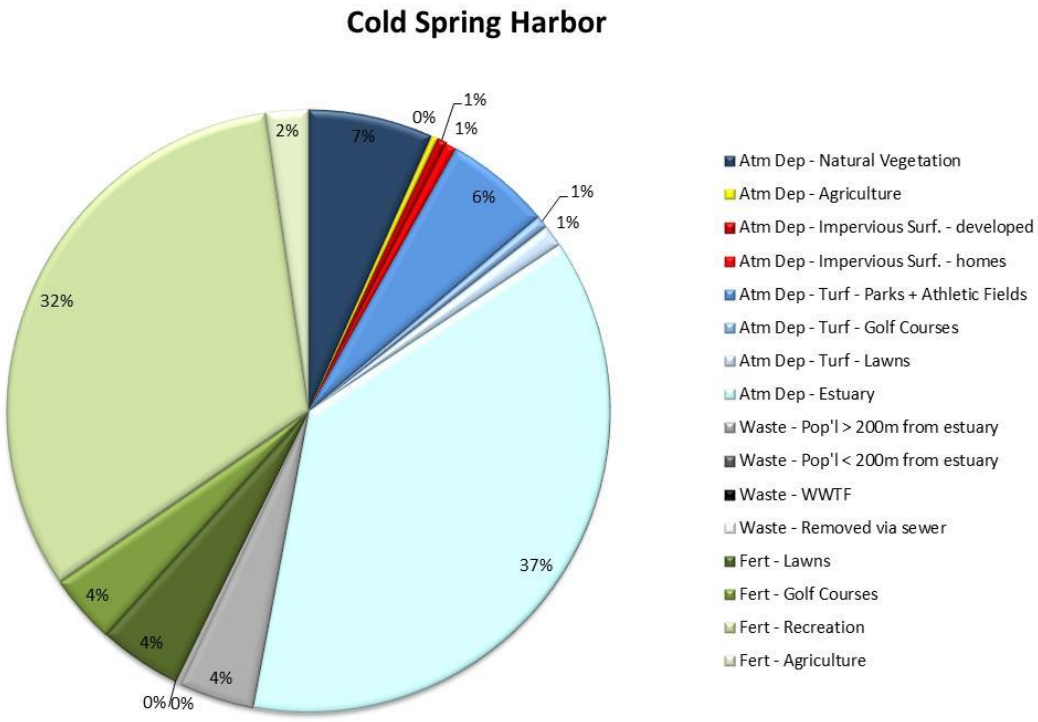

Figure 7: Sources of nitrogen delivered to Cold Spring Harbor

- What are the economic implications / impacts of this work? (Where possible, please quantify.) Have new businesses been created /or existing businesses retained as a result of this research? Have new jobs been created or retained? Are new businesses or jobs anticipated?

  No new jobs or businesses have been created as a result of this work. The economic implications bear upon the mandate for nutrient reductions entering Long Island Sound. Results from this work can be used to target systems most in need of mitigation efforts and also help to identify key sources of non-point source nitrogen within each watershed.