**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 be 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/CTP-45-CTNY** Check one: [ ] Progress Report [ ✓ ] Final report

Duration (dates) of entire project, including extensions: From [ 4/1/11 ] to [ 3/31/14 ].

Project Title or Topic: **Systematic Evaluation of Nitrogen Removal by BMPs in the Long Island Sound Watershed**

Principal Investigator(s) and Affiliation(s):
1. Shimon Anisfeld / School of Forestry & Environmental Studies, Yale University
2. Gaboury Benoit / School of Forestry & Environmental Studies, Yale University

**A. COLLABORATORS AND PARTNERS:** *(List any additional organizations or partners involved in the project.)*

The South Central Connecticut Regional Water Authority and the Town of Woodbridge granted us access to their sites.

**B. PROJECT GOALS AND OBJECTIVES:**

1. Evaluate the effectiveness of constructed wetlands and wet ponds in removing nitrogen (N) from stormwater in the LIS watershed.
2. Evaluate how N removal is affected by each of these factors: influent N concentration; season; water residence time; water infiltration; soil/substrate characteristics (texture, organic matter content); vegetation cover
3. Provide recommendations on design of stormwater ponds/wetlands for optimal N removal in the LIS watershed.

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

See progress reports dated 1/31/13 and 3/27/14.

**D. PROJECT PUBLICATIONS, PRODUCTS AND PATENTS**: *(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: *manuscripts in preparation (see below)*

Conference Papers and Presentations:

1. **Lisa Weber, American Museum of Natural History's Student Conference on Conservation Science, New York, NY** (October 10-13, 2012), "Reducing Hypoxia Levels in Long Island Sound with Connecticut Constructed Wetlands"
2. **Lisa Weber, Yale University's Hixon Center for Urban Ecology Fellow Presentation, New Haven, CT** (March 4, 2013), "Inter-storm variability in nitrogen removal in a Connecticut constructed wetland"
3. **Lisa Weber, Connecticut Association of Wetland Scientists: 2013 Annual Meeting, Southbury, CT** (March 21, 2013), "Examining the Efficacy of Connecticut Constructed Wetlands as a Stormwater Best Management Practice"
4. **Lisa Weber, Yale University's Master of Environmental Science Colloquium, New Haven, CT** (April 19, 2013), "Inter-storm variability in nitrogen removal in a Connecticut constructed wetland"
5. **Lisa Weber, University of New Haven's Graduate Course, Wetlands Ecology with Laboratory, Guest Lecture, New Haven, CT** (May 9, 2013), "Inter-storm variability in nitrogen removal in a Connecticut constructed wetland"
6. **Lisa Weber, Milone and MacBroom, Inc., Presentation, Cheshire, CT** (May 22, 2013), "Inter-storm variability in nitrogen removal in a Connecticut constructed wetland"
7. **Zulimar Lucena, Conference on green infrastructure and water management in growing metropolitan areas, Tampa, FL** (January 14, 2014), "Factors controlling biogeochemical removal of nitrogen in constructed wetlands"
8. **Zulimar Lucena, Yale University's Hixon Center for Urban Ecology Fellow Presentation, New Haven, CT** (February 19, 2014), "Factors controlling biogeochemical removal of nitrogen in constructed wetlands"

9. **Zulimar Lucena, Connecticut Association of Wetland Scientists: 2014 Annual Meeting, Southbury, CT** (March 20, 2014), "Factors controlling biogeochemical removal of nitrogen in constructed wetlands"

Other articles, such as proceedings or book chapters:

Web sites, Software, etc.:

Technical Reports / Other Publications:

Other Products (including popular articles):

Planned Publications:

1. **Inter-storm variability in nitrogen removal in a Connecticut constructed wetland,** Lisa Weber, Shimon C. Anisfeld, Gaboury Benoit, and Zulimar Lucena

2. **Inter-site variability in nitrogen removal efficiency in constructed wetlands,** Zulimar Lucena, Shimon C. Anisfeld, Gaboury Benoit, and Lisa Weber

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.)*

Carpenter-Sperry Fellowship (Yale FES) awarded to Lisa Weber: **$2500**
Hixon Center Fellowship (Yale FES) awarded to Lisa Weber: **$7000**
Michael Lefor Grant (CT Association of Wetland Scientists) awarded to Lisa Weber: **$1000**
Hixon Center Fellowship (Yale FES) awarded to Zulimar Lucena: **$7000**
Michael Lefor Grant (CT Association of Wetland Scientists) awarded to Zulimar Lucena: **$1000**
Students paid from other accounts to work on this project (1290 hours): **$19,354**

**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:
Total number of **new** undergraduates who worked with you:
Total number of **new** Masters degree candidates who worked with you: 12
Total number of **new** Ph.D. candidates who worked with you:

Total number of **continuing**** K-12 students who worked with you:
Total number of **continuing** undergraduates who worked with you:

Total number of **continuing** Masters degree candidates who worked with you:
Total number of **continuing** Ph.D. candidates who worked with you:

Total number of volunteer hours:

*(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: Lisa Weber
Degree Sought: MESc
Thesis or Dissertation Title: **Inter-storm variation in nitrogen removal in constructed wetlands**
Date of thesis completion: May 2013
Expected date of graduation: May 2013

Student Name: Zulimar Lucena
Degree Sought: MESc
Thesis or Dissertation Title: **Inter-site variability in nitrogen removal efficiency in constructed wetlands**
Date of thesis completion:
Expected date of graduation: May 2014

Student Name: Michelle Camp
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2015

Student Name: Kris van Naerssen
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2014

Student Name: Kevin Sherrill
Degree Sought: MESc
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: January 2015

Student Name: Tatiana Hayek
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2014

Student Name: Jocelyn Mahone
Degree Sought: MF
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2013

Student Name: Sarah Barbo
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2013

Student Name: Bunyod Holmatov
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2013

Student Name: Ariel Patashnik
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2012

Student Name: Alison Schaffer
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: May 2012

Student Name: Kavita Sharma
Degree Sought: MEM
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation: September 2012

**FOR FINAL REPORTS ONLY, PLEASE COMPLETE THIS SECTION:**

## G. PROJECT OUTCOMES AND IMPACTS

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

Constructed wetlands and other structural stormwater best management practices (BMPs) can potentially play an important role in mitigating nonpoint sources of nitrogen to Long Island Sound (LIS). Previous research has established that BMP effectiveness in N removal is highly variable, but little has been done to explore the drivers of spatial and temporal variability. Understanding these drivers would allow better design and implementation of these systems.

**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 measured nitrogen removal at five constructed wetland sites by measuring water flows and nitrogen concentrations in inflows and outflows, using weirs, water level loggers, and autosamplers. At each site, nitrogen removal was measured over a number of storm events (9-92 per site, for a total of 175 events), ranging in storm size, nitrogen concentration, and season (Table 1). Differences among sites in plant cover and soil properties were also characterized.

We found a special challenge in two aspects of the project: (a) identifying suitable sites (no complete centralized BMP database exists for LIS or CT); and (b) accurately measuring water flows (our sites were not designed for ease of hydrologic measurements and required the construction of customized weirs).

Table 1. Number of storms sampled and number of samples collected. Note that some smaller storms produced only inflow and no outflow, so the number of storms sampled at the inlet is generally smaller than the number sampled at the outlet.

| Site | Time Period | Number of storms | Number of samples |
|---|---|---|---|
| Davis In | June-Dec 2011 | 23 | 60 |
| Davis Out | June-Dec 2011 | 18 | 42 |
| Davis QC and dry period | June-Dec 2011 | NA | 57 |
| Davis In | April-Dec 2012 | 57 | 112 |
| Davis Out | April-Dec 2012 | 41 | 73 |
| Davis QC and dry period | April-Dec 2012 | NA | 25 |
| Davis In | April-Oct 2013 | 12 | 20 |
| Davis Out | April-Oct 2013 | 9 | 10 |
| Davis QC and dry period | April-Oct 2013 | NA | 8 |
| **Davis Total** | **June 2011 – Oct 2013** | **92** | **407** |
| Thornton In | Sep – Dec 2012 | 17 | 24 |
| Thornton Out | Sep – Dec 2012 | 7 | 11 |
| Thornton In | Apr-Aug 2013 | 23 | 23 |
| Thorton Out | Apr-Aug 2013 | 18 | 18 |

| **Thornton Total**[1] | **Sep 2012 – Aug 2013** | **40** | **76** |
|---|---|---|---|
| Lois In and Out | Aug 2011 – June 2012 | 7 | 130[2] |
| Lois In | June-Nov 2013 | 12 | 14 |
| Lois Out | June-Nov 2013 | 10 | 10 |
| Lois In | April-May 2014 | 3 | 8 |
| Lois Out | April-May 2014 | 3 | 5 |
| **Lois Total** | **Aug 2011 – May 2014** | **22** | **167** |
| Marion In | Aug-Dec 2013 | 7 | 9 |
| Marion Out | Aug-Dec 2013 | 7 | 9 |
| Marion In | Mar-May 2014 | 6 | 14 |
| Marion Out | Mar-May 2014 | 6 | 13 |
| **Marion Total** | **Aug 2013 – May 2014** | **13** | **45** |
| Elderslie In | Nov-Dec 2013 | 6 | 8 |
| Elderslie Out | Nov-Dec 2013 | 1 | 1 |
| Elderslie In | June 2014 | 3 | 3 |
| Elderslie Out | June 2014 | 2 | 2 |
| **Elderslie Total** | **Nov 2013 – June 2014** | **9** | **14** |
| **Total** | | **175** | **709** |

**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.)*

Nitrogen removal by constructed wetlands can be differentiated into hydrologic removal (water storage and infiltration leading to reduced nitrogen *mass* export) and biogeochemical removal (reduction of nitrogen *concentrations* through uptake and denitrification). Biogeochemical removal is arguably preferable to hydrologic removal, since the fate of infiltrated nitrogen is unknown.

All but one of the sites showed *hydrologic* removal, at least for smaller storms, during which all the influent was captured by the pond and infiltrated into the sub-surface. The one exception was the Marion site, which is poorly designed, with the effluent pipe being located immediately adjacent to the influent pipe.

However, only two of the five sites sampled (Davis and Thornton) had statistically significant *biogeochemical* N removal. We suggest – though we cannot definitively prove – that better removal at Davis and Thornton is a function of the more complex nature of these systems,

[1] This does not include 46 samples collected before installation of the weirs.
[2] The high number of samples per storm at Lois is due to the fact that we did not composite samples at this site at this time.

which have a mix of both open water and vegetated portions (as opposed to the other sites, which are dominated by vegetation). All the other site parameters that we measured – soil carbon, soil nitrogen, plant diversity, treatment ratio – did not appear to explain the differences among sites in N removal.

For all sites, the inter-storm variability in N removal was very large. For the two sites with significant N removal overall, the main driver of inter-storm variability appeared to be influent N concentration, with N removal being higher when influent N concentrations were higher.

Based on these results, we suggest the following simple guidelines for constructed wetland construction and siting for N removal in the LIS watershed:
1. BMPs are likely to be most effective where stormwater N concentrations are highest.
2. BMPs are likely to be most effective when they include a mix of open water and vegetated areas.

The logistics of carrying out this project lead us to offer two additional recommendations:
1. BMPs should be designed with monitoring in mind, as this would vastly simplify the collection of effectiveness data.
2. There is an urgent need for a more complete database on BMP sites.

*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?

  We refined the construction of customized weirs for use in stormwater pipes.

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

  A better understanding of N removal in constructed wetlands should lead to better siting and construction of these BMPs, which should lead to lower N loads to LIS, which should in turn lead to improvements in dissolved oxygen status.

- 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?

  Target audience is primarily municipal and state decision-makers responsible for stormwater BMPs. Changes in N loading will have social benefits through improved health of LIS.

- 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?

  Indirect economic benefits of this project would be those resulting from a cleaner LIS, including improved recreation, fisheries, etc.