NERRS Science Collaborative Progress Report for the Period 09/01/12 through 02/28/13

Project Title: Carbon Management in Coastal Wetlands: Quantifying Carbon Storage and Greenhouse Gas Emissions by Tidal Wetlands to Support Development of a Greenhouse Gas Protocol and Economic Assessment

Working Title: Bringing Wetlands to Market: Nitrogen and Coastal Blue Carbon (BWM: NCBC)

Principal Investigator(s): Alison Leschen, Project Coordinator, Manager, Waquoit Bay National Estuarine Research Reserve (WBNERR)

Project start date: November 15, 2011

Report compiled by: Kate Harvey, Collaboration Assistant and Tonna-Marie Rogers, Collaboration Lead

Contributing team members and their role in the project:

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- Meg Gardner (NERRS Science Collaborative Intern), WBNERR
- Kate Harvey (Collaboration Assistant), WBNERR
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- Thomas Walker, (Economist, Intended User Representative) Manomet Center for Conservation Sciences

A. Progress Overview

This project is designed to address the interaction of two of the most critical management issues currently facing coastal communities, climate change and eutrophication caused by excess nitrogen loading. The project will generate information and tools that coastal decision makers can use to manage nitrogen pollution, design effective wetlands protection and restoration projects, and create policy frameworks and economic incentives to reduce greenhouse gas (GHG).

The third reporting period of project implementation (09/01/12-02/28/13) included continued data collection and an intensive effort to begin analysis of data gathered by team members during the first field season. Analysis of these data sets the stage for further evaluation of data collection and analysis methodologies in anticipation of the second field season beginning in spring 2013; testing of initial hypotheses about the greenhouse gas exchanges in salt marshes; and further honing of the model for predicting carbon storage in wetlands. Additionally, during this reporting period

project team members engaged in outreach to intended users. This outreach included a hands-on field visit for local decision-makers and coastal managers, and multiple educational talks and webinars on the Bringing Wetlands to Market project and potential applications, and completion of several science communication products, including project videos and fact sheets. Further detail on project goals and reporting period tasks are below:

Project Goals	Reporting Period Tasks and Accomplishments
A. Quantify carbon sinks and GHG fluxes in tidal wetlands, and assess the impact of anthropogenic nitrogen loading, sea level rise, and climate on both carbon sequestration and net GHG emissions in tidal wetlands.	• Continued monthly field measurement of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and net ecosystem carbon balance (NECB); • Continued measurement of lateral fluxes of carbon (C) and nitrogen (N); • Continued sediment, water, and plant measurements; • Initial analysis of data gathered in first field season (spring-fall 2012).
B. Develop a carbon sequestration and GHG emissions model for tidal wetlands using the collaboration between end-users and scientists to identify the specific data needs for it, and apply the model to aid the development of a tidal wetlands GHG offset protocol.	• Continued testing of preliminary model using data from other projects; • Began testing of preliminary model using preliminary data from initial field season for the BWM project.
C. Connect the conservation community with guidance on management of carbon and nitrogen and with carbon markets by providing a GHG offset protocol (methodology) that will be adopted by climate registries.	• Continued development of draft of the GHG methodology for review by the RAE methodology team • Educated intended users about coastal blue carbon and potential applications through webinar and presentations.
D. Provide to intended users (resource managers, project developers, policymakers, land use planners, and those involved with carbon markets) data and a GHG offset model that can inform planning for tidal wetlands preservation and restoration.	• Delivered presentations, webinars, events to continue building interest in the BWM project among intended users, including local coastal-decision makers, NERRs staff across the country, salt marsh scientists, and non-governmental partners working in salt marsh restoration and management; • Designed and presented science translation products on key concepts related to the BWM project with input from intended-users. .
E. Conduct an economic assessment of the carbon sequestration and GHG benefits of tidal wetlands, including	• No tasks scheduled for this period based on project timeline.

E. Conduct an economic assessment of the carbon sequestration and GHG benefits of tidal wetlands, including the impact of nitrogen loading, to assess the financial relevance to land conservation decisions.	• No tasks scheduled for this period based on project timeline.
F. Advance the ability of the NERRS, building on its System-Wide Monitoring Program, Biomonitoring and Sentinel Site efforts, to monitor the effects of climate change on coastal ecosystems.	• Delivered presentations, webinars, and events to continue to build understanding of key concepts and potential applications of the BWM project to NERRs across the country. • Initiated work on three transfer- ideas-to-other-NERRS projects: 1) Salt Marsh Symposium on Valuing Ecosystem Services, 2)

B. Working with Intended Users:

Building Interest in the Bringing Wetlands Project Among Intended Users

During this reporting period, the team engaged in outreach to intended users, including the NERRS, local coastal decision-makers, agency and non-governmental coastal resource managers, salt marsh scientists, and the public. In this still early stage of the project, our engagement focused on building understanding of the key concepts related to our project (e.g. coastal blue carbon and its potential relevance to intended users, potential influences of nitrogen on coastal blue carbon, innovative tools and methods used for field science, and the anticipated coastal management tools that will be available from this project). These efforts included:

Greenhouse Gas Methodology
RAE continued to conduct frequent outreach regarding the methodology. In December 2012, RAE led a webinar hosted by the Association of State Wetland Managers and introduced blue carbon concepts and the methodology to participants, which included approximately 25 participants mostly representing state agencies with wetland management responsibilities. Wetland managers are likely to be primary users of the GHG methodology and their input will help inform development of guidance materials for using the methodology. In January 2013, RAE gave a presentation on carbon markets and the methodology on a webinar hosted by WBNERR and the NERRS Science Collaborative. Also, in January 2013, RAE briefed state agency representatives on coastal blue carbon on the North America 2050 via conference call. In February 2013, RAE briefed the annual gathering of EPA's National Estuary Programs. All presentations included significant time for questions and discussion, and opportunities to inform the development of the methodology and guidance documents. Intended users influenced RAE's decision to include an additional component - seagrasses – into the methodology.

Engaging the NERRS
Reserve and Project Manager Alison Leschen gave an "Ignite!" talk at the annual NERRS meeting in November 2012. In an Ignite! talk the speaker has 5 minutes to deliver 20 slides that automatically advance every 15 seconds, with no text allowed on the slides, so the message must be concise and visual. The talk was well received and generated a lot of interest in the project. NERRS staff

followed up with general and specific questions about the project and expressed interest in the upcoming BWM webinar described below.

With the Science Collaborative, project team members also delivered a webinar to participants from nine NERRS on the BWM Project. The webinar provided an overview of the project, described the innovative techniques used by the team, and reported early findings related to the quantification of greenhouse gas emissions and carbon sequestration in coastal wetlands. The webinar included discussion on how assessment of blue carbon storage may help coastal resource managers design effective wetland protection and restoration projects, and policy options.

Engaging Intended Users in Field Science

Led by the Collaboration Lead, the project team organized a Science Field Visit for project intended users. The field visit was held in November 2012 during a period of active field measurements by scientists. The field visit provided opportunity for exchange between intended users and scientists. Participants learned about the cutting edge research being done as part of the BWM project; received updates from the project team on ongoing science at the reference (Sage Lot Marsh) and nitrogen gradient sites; explored new instrumentation used for data collection and WBNERR's innovative temporary salt marsh boardwalk; and helped to collect soil and water samples and observe gas flux in real time. They also shared their questions and potential applications of the data with scientists. Specifically, intended users were interested in the tools and techniques used by science investigators and they requested to be informed as findings become available. Twenty intended users attended the field visit including local officials from Cape Cod towns; agency scientists from U.S. EPA, the National Seashore, and Massachusetts Department of Ecological Restoration; local land owners; non-profit organizations; a local land trust; and representatives from the regional planning commission.

Science Translation and Multimedia Tools

Under the supervision of the Collaboration Lead, Meg Gardner, project intern graduate student from the TIDES Program at University of New Hampshire, engaged in a collaborative process to develop several multimedia tools for the project. Her collaborative process included assessing intended users' knowledge of blue carbon and nitrogen impacts in wetlands, gathering feedback from intended users on the types of information that they might benefit from, developing products, conducting a focus group of intended users to get feedback on the products, and revising the materials based on intended user feedback. Meg completed a four-part video series on the project, which included: 1) Project Overview 2) Research 3) Tools and Approaches 4) Collaboration. Her videos integrated science team and intended-users perspectives and continue to be used as educational tools at events and on the project website. Meg also created an overview video and a "how to" video on WBNERR's boardwalk, as well as a video on the November 2012 stakeholder science field visit. Additionally, Meg finalized a Blue Carbon fact sheet, which provides an overview of the concept and potential applications of coastal blue carbon, and worked with Kate Harvey, Collaboration Assistant to draft a concept board for a public display on the project. She also presented her work at two conferences – the 2012 RAE Conference and the 2013 Association for the Sciences of Limnology and Oceanography Conference.

The Collaboration Assistant continued to update the project website (www.wbnerrwetlandscarbon.net) which includes project updates, educational materials, team

information, and general findings. The website is intended to be a resource for the general public and intended users and other researchers seeking basic information on the project.

Public Events

Alison Leschen partnered with Tom Stone of the Woods Hole Research Center and Chris Powicki of the Cape and Islands Renewable Energy Collaborative to deliver a forum at the Reserve entitled "Losing Cape Cod: Sea Level, Salt Marshes, Wastewater, Land Use & Climate Change." Tom presented about land use change on Cape Cod from forest to development since 1950, and projections for climate change and sea level rise. Alison described the BWM project and greenhouse gas analysis conducted of the Reserve, and how both highlight the need for preservation and restoration of natural ecosystems, particularly salt marshes. After the talk, there were three other requests for repeating it in other locations, one of which has already been delivered, in Orleans, MA. The nitrogen connection and implications for wastewater treatment options is of particular interest to local audiences.

Intended Users Engagement Objectives for the Next Six Months

- In March 2013 the entire project team will convene for their annual check-in and planning meeting. This will be an opportunity to more thoroughly assess progress and plans than is possible on the team's monthly conference calls. The agenda will include planning the next year's engagement with intended users around the science, model, methodology, and economic and policy analyses; further discussion on the scope of the economic and policy analyses; evaluation of the first season's fieldwork and discussions on the need for any adjustments; planning for the upcoming field season, including WBNERR staff support for field efforts; and discussion on the process for calculating carbon fluxes and other natural processes. The Collaboration Lead and Assistant will use input from this meeting to determine the exact timing for different engagement options/actions with different intended user groups that have been conceptualized in the project stakeholder engagement plan.
- Alison Leschen will attend a special working session of the Annual Program Managers Meeting related to NOAA's Policy Analysis of the Applications of Ecosystem Services Values project on Thursday, February 28 in Washington DC. This project is intended to assist state and territorial CZM programs and others to incorporate ecosystem service values into program implementation.
- At workshops, field visits, and through conversation, intended users expressed interest in learning more about the nitrogen impacts on salt marshes. To address this interest, the Collaboration Lead and Assistant will convene a Wetlands and Wastewater Workshop to share the state of knowledge on the impact of nitrogen on salt marshes and the policy implications that that these impacts. The workshop will target BWM project intended users, such as local decision makers, and include discussion of the BWM research.
- Throughout this project, intended users have asked to be kept informed about project findings and potential applications to their work and at the Getting Things Done workshop, many participants indicated that they would like to receive email updates on the project. To respond to this request, the Collaboration Lead and Assistant will develop an E-Newsletter to share preliminary findings, solicit feedback, and communicate opportunities for future engagement.
- The project team will kick-off a series of "road show" presentations to intended users, such as town boards and/or state agencies, to share information about the BWM project and to solicit

input on how the model and policy analyses could be developed to meet users' needs. This effort will be coordinated by the Collaboration Lead and Assistant.
- The project team will complete a public display board that communicates information about the BWM project, key science concepts, and potential applications. This display board will be available for display in the WBNERR Visitor Center, "road show" presentations and conferences. This effort will be led by the Collaboration Assistant.

C. Progress on Project Objectives for this Reporting Period

Greenhouse Gas Methodology

RAE is developing a GHG offset methodology for tidal wetlands restoration in the U.S. Over this reporting period RAE continued to work with an expert methodology team to draft the first tidal wetlands restoration GHG offset methodology. This team included noted wetland scientists Dr. Pat Megonigal, Smithsonian Environmental Research Center, Dr. Brian Needelman, University of Maryland, and Dr. Steve Crooks, an independent wetlands carbon consultant; estuary restoration specialist, Dr. Doug Myers from the Puget Sound region; and carbon offsets expert Igino Emmer of Silvestrum.

The goal in this reporting period was to develop a draft of the methodology for external review by the Verified Carbon Standard. This goal was not met. Several challenging scientific questions slowed the pace of the methodology team during the past six months. These included the carbon accounting requirement that the methodology account separately for allochthonous carbon, derived from outside of the aquatic system such as plant and soil materials, and autochthonous carbon, derived from the aquatic system such as algae and microbes, and the best means to set a default value for carbon sequestration in tidal wetlands. Methodology team members are reviewing scientific literature and engaging in discussions with colleagues to arrive at rigorous approaches for addressing these questions.

RAE also worked to include seagrass restoration in the methodology, another contributing factor to the extra time needed to draft the methodology. Outreach to a seagrass expert and seagrass restoration project team revealed their strong interest in carbon credits and carbon finance. A methodology project team member is a seagrass scientist and a representative of an intended user (a restoration organization) and is working with the team to help insure the applicability of the methodology to seagrass restoration.

Methodology Objectives for the Next Six Months

- In the next few months, the final draft of the GHG methodology will be completed and it will be submitted to two validators on the list approved by the Verified Carbon Standard. This will be accomplished through regular phone/skype calls and email. Once the draft is submitted to the validators, it will take an anticipated six-nine months for their approval.
- Begin to plan outreach to intended users on the methodology guidance document, including for the NERRS annual conference in Fall 2013.
- RAE will also play a lead role in the Science Collaborative RFI Transfer project - Blue Carbon Demonstration and Dialogue which is described in Section E.

WBNERR Field and Technical Support

WBNERR played an integral role in the site infrastructure and *in situ* data collection. Staff assisted whenever possible in the vertical flux sampling and soil property measurements over the last six months. Also, the vertical GHG flux fieldwork at the nitrogen gradient sites required the construction and rotation of forty-five "planks" to help minimize physical impacts on the sensitive salt marsh plant community. These wooden structures illustrated below (Figure 1) are for temporary use only, and, therefore are set-up and removed before and after each site visit. With the help of WBNERR's temporary research intern, Katelyn Cadoret, staff moved subsets of planks to each of the sites for the biweekly or monthly measurement sequences.

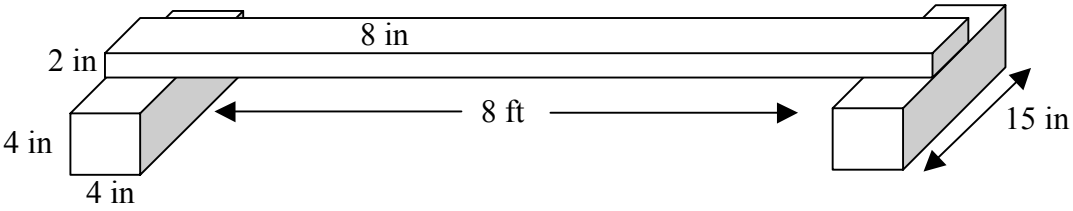

Figure 1: Pressure-treated wooden planks were designed and created for nitrogen gradient sites to reduce physical impacts on the fragile salt marsh plant community. There are roughly 45 units in total, however; between 10 and 24 are used at each of the three privately-owned marshes, Eel Pond, Great Pond, and Hamblin Pond. The planks are for temporary use only; they are set-up on the marsh before vertical greenhouse gas flux measurements begin and are removed afterward.

Additionally, due to the malfunctioning of Onset temperature soil probes owned by MBL, WBNERR supplied Onset HOBO temperature pendants (Model # UA-002-08) to capture air temperature and light intensity during vertical flux measurements in November and December 2012. This data was downloaded and sent to Kate Morkeski, Research Assistant at the MBL, for database management and analysis.

Technical support projects included several basic GIS-based maps, the installation of a meteorological station, and the development of a high-resolution habitat map of the Sage Lot salt marsh. The GIS maps of the sites were made available for documentation and presentations. First, a map displaying the location of the four research sites was designed as reference for information pamphlets and presentations. Second, a revised map of the boardwalk and sampling locations was created as a resource for the science investigators and research assistants. Lastly, a map of the digital elevation model, done in March 2012 with an Integrated Laser and Real Time Kinematic (RTK) Geographic Position System (GPS), is currently being developed to delineate the small-scale watershed at Sage Lot Pond for the lateral and vertical GHG flux field teams.

The meteorological station (or MET station) was officially installed on February 6th, 2013 in Section 2 of the Salt Marsh Observatory at Sage Lot Pond, where all the GHG flux measurements are studied. It took several weeks to assemble all the essential hardware and accessories for the station. The station consists of four Onset sensors: wind speed and direction, photosynthetically active radiation (PAR), pyranometer (full spectrum solar radiation), and rain gauge. Each of the four sensors connects to a separate port within the Onset "Microstation" which holds four alkaline batteries and can store over a year's worth of data (at 10 minute data recording intervals). The

applied science investigators and modeler proposed adding several soil temperature probes to the station at varying depths and WBNERR is looking into the best way to accomplish this.

Lastly, aerial photos (True Color RGB and Near-Infrared at 0.25m resolution; provided by GeoVantage Co.) were acquired in October 2012 of the reference salt marsh site, the Salt Marsh Observatory at Sage Lot Pond located in Mashpee. The imagery has undergone automated segmentation as a means to more rapidly delineate the major habitat zones, such as pooled areas and marsh borders.

WBNERR Field and Technical Support Objectives for the Next Six Months

- Continue to support science team with field and technical assistance;
- Investigate addition of soil temperature probes on MET station;
- Monitor the MET station and download data every 1-2 months;
- Continue to evolve aerial imagery. Digitize features by hand using GIS to develop a fine-scale map of the dominant plant community types in the salt marsh (e.g., low marsh *Spartina alterniflora* and high marsh *Distichlis spicata*).

Science Investigation and Field Research

Lateral Flux Measurements

Full seasonal and annual budgets of tidal material exchange at four salt marshes requires a large effort, and the expanded team that has been working on the effort continued to collaborate during this reporting period (Table 1).

Table 1. Direct participants in lateral fluxes effort

Name	Role	Institution
Kevin Kroeger	Principal Investigator	USGS Woods Hole
Neil Ganju	Co-Principal Investigator	USGS Woods Hole
John Pohlman	Co-Principal Investigator	USGS Woods Hole
Adrian Green	Research Technician	USGS Woods Hole
Sandra Baldwin	Research Technician	USGS Woods Hole
Wally Brooks	Research Technician	USGS Woods Hole
Michael Casso	Research Technician	USGS Woods Hole
Charles Worley	Research Technician	USGS Woods Hole
Aleck Wang	Collaborator—inorganic carbon system analyst	Woods Hole Oceanographic Institution (WHOI)
Amanda Spivak	Collaborator—organic carbon system analyst	WHOI
Elizabeth Brannon	Summer intern; fluorescent dissolve organic matter (FDOM) calibration	Coastal Carolina University

With regard to lateral flux measurements, at the Sage Lot Pond site the team has near continuous data on several chemical parameters beginning in April 2012 until present, and near continuous water fluxes beginning in July 2012 until present. The team has conducted comprehensive sample

collections during 14 hour full tidal cycle deployments at Sage Lot Pond in April, July and November 2012, to calculate net exchanges of carbon and GHG between marsh and estuary.

The team has acquired most of the sensors required for continuous measurements of exchange at the four study sites: 2 YSI EXO2, 2 Wetlabs Triplets, 3 Sontek IQ ADCPs (a 4th has been ordered). The team is presently investigating dissolved CO2 sensors to allow continuous measurement of that key GHG and an additional component of the digital image correlation (DIC) system. During this reporting period the team continued data processing and begun calculations of fluxes of some parameters.

During summer 2012, a WHOI Summer Student Fellow (undergraduate intern), Elizabeth Brannon (of Coastal Carolina University), participated in BWM field research. Her internship was very successful, and she decided to continue working on this subject in a graduate program. She has applied to graduate programs at URI, to work with S. Moseman-Valtierra, and at WHOI, to work with A. Wang or A. Spivak.

Preliminary Findings

- Can the team rely on its sensor data and measured proxies to provide accurate concentration data? One of the key parameters is dissolved organic carbon (DOC), which is likely to be a dominant export. Figure 1, illustrates the team's test of the utility of FDOM measurements as a proxy for DOC. Although FDOM is only a portion of DOC, at a given site it may be tightly correlated with total DOC. Figure 2 illustrates that FDOM and DOC have strong positive correlation and that FDOM/DOC vary seasonally, which indicates that the team's sensor data and measured proxies reliably provide accurate concentration data.

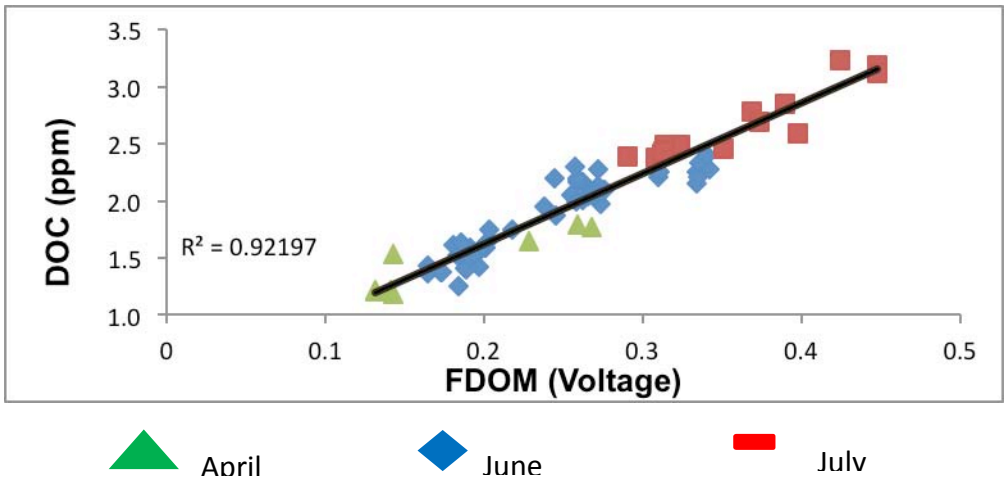

Figure 2: DOC and FDOM Measurements in April, June, and July 2012. The figure illustrates that FDOM and DOC have strong positive correlation and that FDOM and DOC vary seasonally.

- Continuous measurement is important. High sensitivity of flux calculations to small differences in concentration at times of major water flux is a critical feature and limitation. Insufficient frequency of measurements or insufficient accuracy could contribute to the lack of consensus in the literature about the role of coastal wetlands as exporters or importers

of carbon. Continuous data appears to be necessary, given the high degree of variability on daily timescales and sensitivity of calculations to small differences in concentration between flood and ebb tide, and to temporal variations in the water budget. That point has been reinforced with analysis of simultaneous measurements of chemistry and water fluxes (see figure 3).

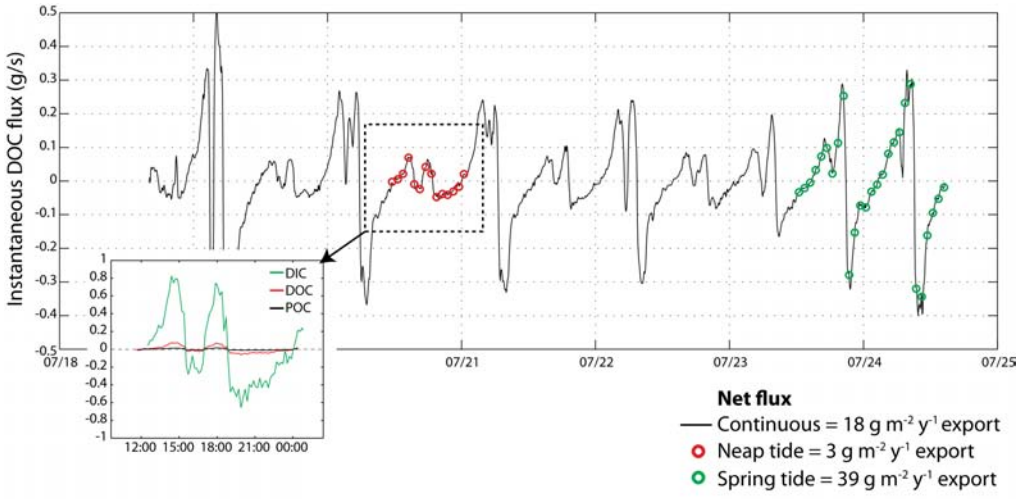

Figure 3: Analysis of Simultaneous Measurements of Chemistry and Water Fluxes - This figure illustrates analysis of instantaneous DOC flux over a period of days (and tidal cycles). It shows variability in DOC fluxes which can change day-to-day, minute-to-minute, and tide-to-tide. These short term fluctuations in water flux rate and direction have a large impact on calculated flux rates and even the net direction of flux (import vs. export) for a given tidal cycle.

- Role of saline wetland porewater: Saline wetland porewater may be the major source for CO_2, DIC and DOC, with flux rates influenced by tidal amplitude. Reduced salinity (groundwater-influenced) porewater is likely the major source for high CH_4 concentrations at low tide. See figures 4 and 5 below.

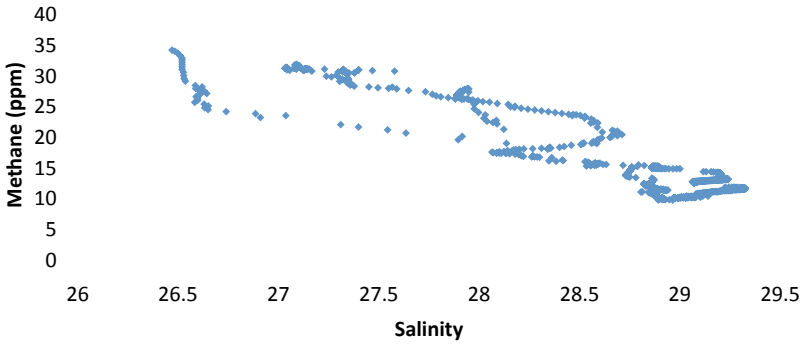

Figure 4: Methane and Salinity Relationship- This figure illustrates a correlation between salinity and CH_4, suggesting that freshened groundwater conveys methane.

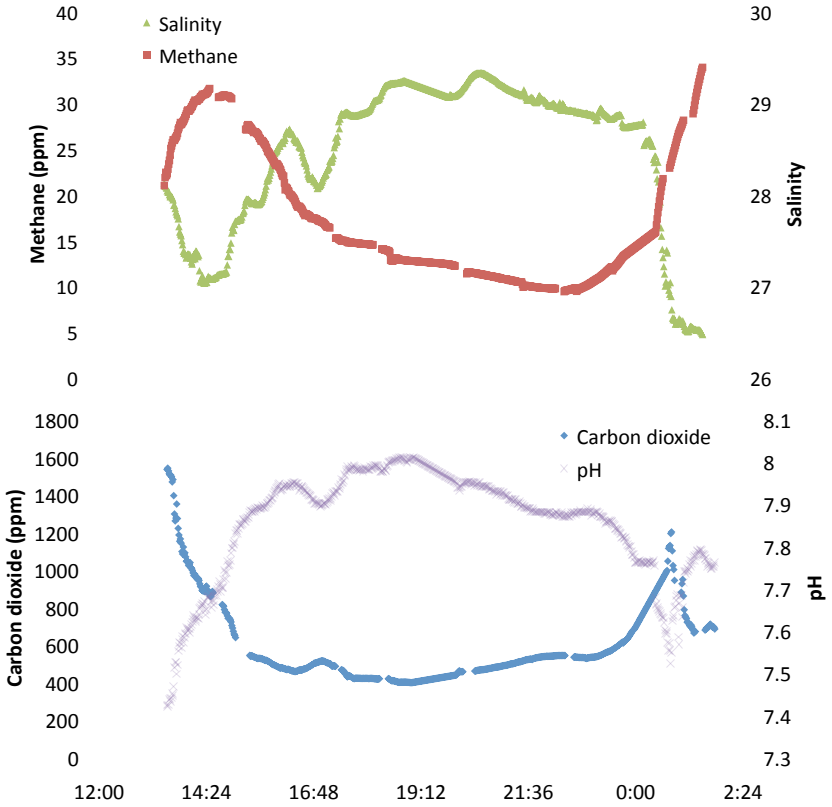

Figure 5: April 9, 2012—Full tidal cycle with gas measurements. The figure illustrates that the methane (CH_4) peak at the end of the tide follows after the peak in carbon dioxide, CO_2, and after freshened water starts to flow out of the creek. Together with the findings illustrated in Figure 4, the team believes that CO_2 is primarily carried by saline porewater and CH_4 primarily by freshened porewater that is influenced by groundwater discharge.

Vertical Flux Measurements

The team collected GHG (CO_2, CH_4, and N_2O) emissions along with air and soil temperature from four salt marsh sites. Through the end of the growing season (late October), the team measured GHG emissions and associated soil properties along the four sites comprising the N gradient every other week. During the winter season (Nov.-March), the team made these measurements monthly. The team continued to use the large, novel chamber system (2 ft X 2 ft X 2 ft (60 cm per side or 0.180 cubic meters) to measure vertical gas flux. This chamber was connected to the state-of-the-art gas measurement systems for in-situ measurement of N_2O (Los Gatos Research) and CO_2 and CH_4 fluxes (Picarro, Inc.). Air inside the chamber was circulated and concentration was measured in real time and recorded electronically. The team then calculated gas fluxes based on the rate of concentration change.

In tandem with vertical gas flux measurements, plant properties (density, average height, plant species composition) and soil properties (pH, , temperature, salinity, and porewater nutrient concentration) were also measured.

Throughout the project reporting period, science investigators analyzed data from the summer and shared a summary with the project team members and modeler in January 2013. They

continued to improve the algorithm to calculate GHG emissions. They found that N2O emissions were very low at some sites and the analyzer, though very sensitive, could not detect the small signal. However, these N_2O emissions may have been higher in the high nitrogen loading sites earlier in the season when temperature was high.

Table 2. Direct participants in vertical fluxes effort		
Name	**Role**	**Institution**
Kate Morkeski	Research Assistant	MBL
Jessie Gunnard	Research Assistant	MBL
Katelyn Cadoret	Intern	WBNERR
Matthew Manning	Intern	USGS
Rose Martin	Graduate Student	URI

Preliminary Findings

- Nitrogen loading and CO2 relationship: CO2 uptake in salt marshes may increase with N loading, but CH_4 and N_2O emissions also increase with N loading. Figures 6 and 7.

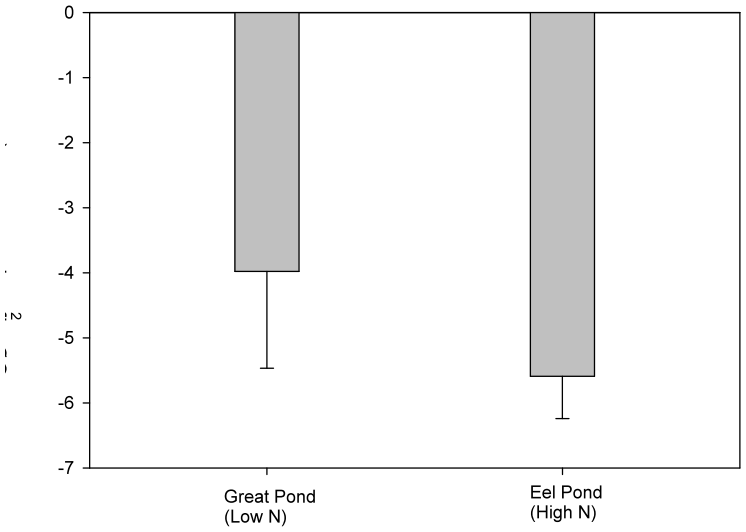

Figure 6: CO2 Uptake in Salt Marshes: Initial measurements indicate that CO2 uptake was about 5.6 µmol m^{-2} s^{-1} in the high N loading site and about 4.0 µmol m^{-2} s^{-1} in the low N loading site.

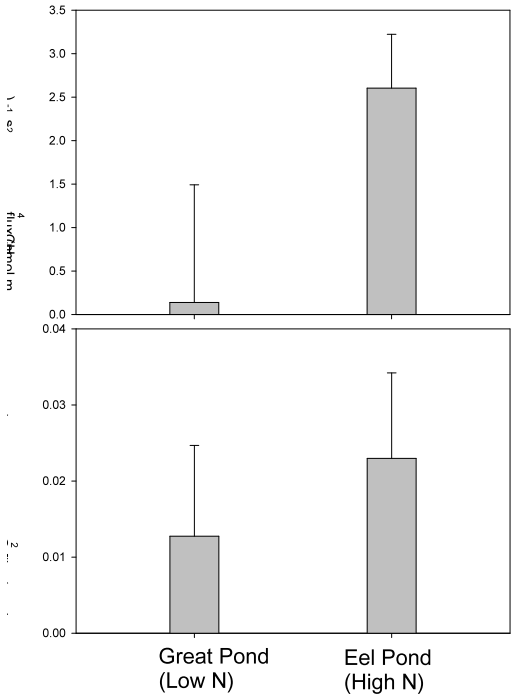

Figure 7: CH_4 and N_2O emissions in salt marshes: The figure shows that both CH_4 and N_2O emissions were higher in the high N site and the low N site.

Science Investigation and Field Research Objectives for the Next Six Months

- The team will continue to analyze environmental field data from the first field season.
- The next six months will be the team's second major field season. The team will extensively measure GHG emissions from all sites on a biweekly basis. The team will collect plant samples and soil samples frequently. Diurnal and tidal cycles will be considered for their influence on GHG emissions.
- The team will complete plant biomass analyses (needed for gross primary production) and prepare to expand the environmental measurements (possibly obtaining new probes, improving methods) for the summer 2013 field season.
- The team expects to fully implement the sensor deployments and discrete sample collections schedule described below (Table 3), and collect a full year of flux data in tandem with vertical flux measurements.
- For lateral flux measurements the team plans to purchase, install and maintain sensors at the four study sites comprising the nitrogen loading gradient to collect the data that will be the backbone of carbon budget calculations. The sensors (Table 2) are being purchased with USGS funds, and will cover several of the needed parameters. However, there are some critical parameters, particularly N_2O and CH_4, that cannot be measured continuously using sensors. Thus, the sensor data will be supplemented with a schedule of 1) full tidal cycle (14 hour) measurements of all chemical parameters including measurements of dissolved GHG using the Picarro and Los Gatos gas analyzers (approximately 3 per year per site), and 2) weekly to biweekly sample collections of ~3 to 4 hours each at particular portions of the tidal cycle. In addition to the sensors mentioned, USGS has purchased a Picarro CO2 and CH_4 stable isotope analyzer that will be available at no cost to the project.

Table 3. Parameters to be measured continuously at each site using sensor deployments		
Parameter	**Proxy for:**	**Manufacturer**
Integrated water velocity	Water flux	Sontek
Colored dissolved organic matter (CDOM)	Dissolved organic carbon	YSI or WetLabs
Suspended particles	Particulate organic carbon; sediment	YSI or WetLabs
pH	Carbon dioxide (under investigation)	YSI
Chlorophyll a	Phytoplankton biomass	YSI or WetLabs
Dissolved oxygen		YSI
Salinity		YSI
Temperature		YSI
Oxidation/reduction potential		YSI
Pressure	Water depth	YSI
pCO_2	Respiratory carbon dioxide; possibly dissolved inorganic carbon (DIC) proxy with pH	Pro Oceanus

Biogeochemical Model

A theoretical version of the proposed user-friendly GHG emissions and C-sequestration model was previously developed and was evaluated during the reporting period. In preparation for testing the proposed model, the team analyzed large scale GHG emissions data from eight deciduous forest sites of USA to obtain insights into the relevant biogeochemical processes. The model team worked to reconstruct partial sequestration data and broke apart different variables to construct potential time-based scenarios. The team conducted various analyses using advanced statistics such as principal component analysis and multiple linear regression models. The team worked to eventually identify an optimal set of variables to predict C sequestration. The analysis is still underway; however, the team has important findings that they hope to present to the scientific community through peer-reviewed publications.

Much data from field sites were collected by the science team in 2012 and are currently being revised to emerge into final formats. The model team analyzed the datasets prepared by the science team to-date and provided important feedbacks on trends and correlations of GHG fluxes with environmental variables. Insights obtained from the preliminary analysis were shared with the team members to augment the future field campaigns by collecting data on new variables such as soil porosity, light and soil temperature.

Biogeochemical Model Objectives for the Next Six Months

- The model team will work with the field scientists to obtain the final data sets of the field sites;
- The model team will then test and apply the theoretical model for application to tidal wetland systems and hone a beta version for use by coastal decision-makers;
- The project team will begin initial planning for intended user participation in testing and refining a beta version of the model.

Economic and Policy Analyses
No work was done during this reporting period.

Economic and Policy Analyses Objectives for the Next Six Months
- Develop a work plan for economic and policy analyses;
- Begin outreach to intended users to gather feedback on scope of analyses;
- Coordinate with modeler and science investigators to develop scenarios of potential data needs.

Team Coordination
The project team continued to use Basecamp as a communication and project management tool. Throughout the reporting period, the team held monthly conference calls facilitated by the Collaboration Lead to share project updates, discuss intended user feedback, and provide input on project tools and resources (e.g. website, multimedia communication and science translation products).

D. Benefit to NERRS and NOAA
During this reporting period, WBNERR initiated work on three transfer- ideas-to-other-NERRS projects: 1) Salt Marsh Symposium on Valuing Ecosystem Services, 2) Blue Carbon Demonstration and Dialogue, 3) BWM module development for Teachers on the Estuary Program. The goal of these projects is to transfer lessons and ideas from the BWM project to other NERRS.

Valuing Ecosystem Services in Salt Marshes Symposium - WBNERR received funding from the Science Collaborative for "A Symposium on C/N Cycling and Ecosystem Valuation of Tidal Wetlands in the Northeast" to transfer ideas from the Bringing Wetlands to Market project and the Wells Reserves' Quantifying the Economic Value of Natural Resources and Services project to other NERRS. The Symposium was held at WBNERR in January 2013 and included forty participants from regional NERRS (WBNERR, Great Bay, Wells, Narragansett, and Jacques Cousteau) and local research institutions. The event included thirteen presentations and discussion on related research on C/N cycling in salt marshes and how to link research to management decisions through valuing salt marshes and ecosystem services. Presentations included:
- Valuing Salt Marshes: The Importance of Linking Physical and Social Science Research *Peter Wiley, Economist, Coastal Service Center, National Ocean and Atmospheric Administration (NOAA)*
- Choices and Tradeoffs: Quantifying the Economic Value of Natural Resources and Services *Dr. Christine Feurt, Coastal Training Coordinator, Wells National Estuarine Research Reserve and Director, Center for Sustainable Communities, University of New England*

Dr. Robert Johnston, Director and Research Professor, The George Perkins Marsh Institute, and Professor of Economics, Clark University

- Combining Economic and Ecological Indicators to Prioritize Salt Marsh Restoration Actions
  Dr. Marisa Mazzotta, Environmental & Resource Economist, U.S. EPA - Atlantic Ecology Division
- Coastal Eutrophication as a Driver of Salt Marsh Loss
  Dr. David Johnson, Research Associate, The Ecosystems Center, Marine Biological Laboratory
- Understanding and Measuring Accretion Processes in Tidal Salt Marshes
  Dr. Inke Forbrich, Postdoctoral Scientist, The Ecosystems Center, Marine Biological Laboratory
- Bringing Wetlands to Market – Nitrogen and Coastal Blue Carbon
  Alison Leschen, Manager, Waquoit Estuarine Research Reserve
  Dr. Jim Tang, Assistant Scientist, The Ecosystems Center, Marine Biological Laboratory
  Dr. Kevin Kroeger, Associate, U.S. Geological Survey
  Melanie Garate, University of Rhode Island
- Responses of Microbial Communities to Increases in Nitrogen Loads in Salt Marshes
  Dr. Jennifer Bowen, Assistant Professor, Biology Department, University of Massachusetts at Boston
- Greenhouse Gas Fluxes in Tidally Restricted and Restored Salt Marshes
  Dr. Robinson W. Fulweiler, Assistant Professor Joint Appointment Earth and Environment and Biology Department , Associate Director of Marine Program, Boston University
- Valuing New Hampshire Salt Marshes: An Approach to Measuring Ecosystem Services
  Dr. David Burdick, Research Associate Professor, Marine Wetland Ecology and Restoration, Department of Natural Resources and the Environment, University of New Hampshire

- *Blue Carbon Dialogue and Demonstration Project*: The second Science Collaborative funded transfer project will take place at WBNERR in March 2013. Steve Crooks and Steve Emmett-Mattox of RAE will demonstrate how a land-holding entity could take a project through the process of making it eligible for C offsets. Participants will include NERRS staff from Great Bay, Wells, Waquoit Bay, and Narragansett Bay Reserves along with several agency and NGO restoration practitioners. Steve Crooks and Steve Emmett-Mattox will use participant feedback to develop a template that will help potential intended users to determine if they should consider blue carbon project(s) and what steps they might take to further evaluate potential project opportunities. The team will also develop a video on how Reserves and salt marsh managers can evaluate blue carbon project potentials.

- *BWM Teachers on the Estuary Module Development* - With support from a NERRS Science Collaborative Transfer Grant, Joan Muller, Education Coordinator at WBNERR and Tom Gaskill, Education Coordinator at the South Slough NERR in Oregon, are developing an education unit for middle and high school teachers and students about the BWM project. The module will include concepts, findings, and interesting attributes related to the science, technology, and economic aspects of the project. The modules will be available for use by the TOTE program in summer 2013.

E. Describe any activities, products, accomplishments, or obstacles not addressed in other sections of this report that you feel are important for the Science Collaborative to know.

This project has contributed to a number of other follow-on proposals involving members of the Team. These include:

- A National Science Foundation (NSF) proposal by Kroeger et al. delving further into understanding lateral flux;
- A proposal to the U.S. Climate Science Center by Moseman-Valtierra and Tang to study warming impacts on nitrogen and carbon sequestration;
- A NSF proposal by Abdul-Aziz to further develop the biogeochemical model;
- A NSF proposal led by Robert Chen of UMass Boston that includes many of the Science Investigators and WBNERR team and many others doing a global assessment of salt marsh carbon across spatial and temporal scales;
- A proposal to the Science Collaboration by South Slough NERR on coastal blue carbon.