The Effect of Open Marsh Water Management Practices on the Carbon Balance of Tidal Marshes in Barnegat Bay, New Jersey

Coastal wetlands are a transition zone between marine and terrestrial ecosystems found in low-energy and low-slope coastal environments (Rochlin et al., 2012). These ecosystems provide valuable ecosystem services such as serving as fish nurseries, nutrient removal via denitrification, shoreline protection, and carbon sequestration (Rochin et al., 2012). Vegetated coastal habitats bury an estimated 100 Tg of carbon per year, primarily in their richly organic and anoxic soils that build up over time (Hopkinson et al., 2012). This flux is relatively small compared to the amount of carbon emitted to the atmosphere per year via fossil fuel burning (Pendleton et al., 2012), but significant compared to other natural carbon sinks, such as terrestrial forests and deep sea oceanic burial (Mcleod et al., 2011). Thus, recent scientific attention has been focused on the science of **Blue Carbon** – specifically, *the potential for climate change mitigation of vegetated coastal habitats through maintaining their carbon sequestration capacity and reducing losses to disturbance* (Pendleton et al., 2012). This focus is especially timely, as about one-third of mangrove, seagrass, and salt marsh ecosystems have been lost globally due to reclamation, deforestation, engineering, urbanization, and aquaculture (Mcleod et at., 2011). Such disturbances are known to convert habitats from carbon sinks to carbon sources (Mcleod et al., 2011).

Salt marsh physical structure has been modified in order to control mosquito populations since the early 1900s (Lathrop et al., 2000). Open marsh water management (OMWM) was a technique first applied in New Jersey in the 1950s (Ferringno et al., 1968). OMWM was developed as a technique to overcome many of the negative habitat impacts that had been associated with ditching, which reduced marsh groundwater levels and mosquito breeding, but also had negative effects on wildlife through reduced fish populations (Kennish, 2001). The major objective of OMWM was to eliminate mosquito breeding while simultaneously improving habitat for fish populations and other wildlife (Ferringno et al. 1968). This practice has been extensively used in the mid-Atlantic and is also seen in Massachusetts, New York, Connecticut, Florida, and Louisiana (Quirk et al., 2015). This practice involves excavation of areas of marsh, making shallow ponds in order to bring mosquito larvae-eating fish to reduce the population of mosquitos in a given area (Quirk et al., 2015).

Figure 1. *Ponds and ditching associated with OMWM practices in Barnegat Township, NJ.*

Since the early 2000s, nearly 10,000 ponds have been constructed in Barnegat Bay, NJ in order to reduce mosquito breeding (L. Perez, The Academy of Natural Sciences, unpublished data; Fig. 1). While the New Jersey Mosquito Commission reports this large-scale habitat alteration has successfully reduced mosquito populations (Candeletti, 2007) local wetland scientists and managers are increasingly concerned about consequences of OMWM to valued ecosystem functions, such as nutrient removal and carbon sequestration, and nesting of obligate salt-marsh breeding bird species (Wolfe, 1996).

Natural coastal wetlands are very productive ecosystems. Wetland vegetation capture and store carbon in plant tissue via photosynthesis and also bury carbon within anaerobic sediments (Kuehn et al., 2004). The anaerobic sediments are important for carbon storage because organic decomposition by microbes is slow without oxygen (Kuehn et al., 2004). The construction of ponds within marsh habitats likely have many potential impacts on net carbon sequestration of these areas (Drake et al., 2015). First, as ponds replace wetland vegetation, habitats will shift from net carbon sequestration to net carbon mineralization as vegetation is replaced by open water (Moseman Valtierra et al., 2016). When marsh plants die, they no longer take up carbon through growth. Secondly, wetland soils build up over long-time periods (Hopkinson et al., 2012). When ponds are dug, the carbon sequestered over past decades is deposited on the marsh surface, which exposes it to oxidation (Mcleod et at., 2011). Also, because methane production is linked with the soil oxidative state (Chmura, 2003), methane production may ramp up within the footprint of newly conducted ponds.

This proposed research will thus address an unstudied impact of OMWM on carbon sequestration, a valued ecosystem function of coastal marshes. This research is specifically needed because of the overwhelming spatial extent of pond construction in New Jersey coastal marshes, and because the managers need information on impacts of OMWM techniques to ecosystem functions in order to decide whether the practice should be continued. This research project that I propose thus will fill an important wetland management need, by ***examining the impacts of OMWM practices on the carbon balance of coastal wetlands***. In my masters thesis project, I will *measure emissions of carbon dioxide and methane from ponded areas, intact marsh, and in areas where plants have died due to disturbance* to identify changes in carbon sequestration associated with OMWM practices, and secondly *scale up these measurements using analysis and classification of remotely sensed imagery*.

Proposed Research and Objectives

The research that I propose will address the following specific research objectives: (1) measure the gas fluxes of methane and carbon dioxide in the areas that have been excavated for ponds, intact marsh, and in dead plant areas above-mentioned habitats**;** (2) scale up the gas flux measurements to the spatial extent of the ponded areas in Barnegat Bay using classification of remotely sensed imagery.

Field Based Measurements of Gas Exchange

I will measure fluxes of methane and carbon dioxide using static and floating flux chambers connected to a Los Gatos Research (LRG) Ultraportable Greenhouse Gas Analyzer. The gas analyzer will be connected to the chambers via nylon tubing to create a closed system, thus the change in gas concentration can be measured over time. The change in gas concentration will be measured in real time on an IPad. There will be three study sites within Barnegat Bay, sites will be spatially arranged from north to south. Within each of the study sites, flux measurements will be replicated in triplicate for each habitat (i.e. ponded areas, intact marsh, and dead plant areas). Flux measurements will be performed during daylight hours during low tide and within areas of homogenous vegetation. The field sampling will be carried out on a monthly basis from April to September of 2017 and the incubation time for the measurement will range from 5 to 10 minutes per plot (Martin et al., 2015). The chambers, gas analyzer, and the PVC bases have already been purchased and tested.

Spatial Analysis

I will then scale up these measurements to the spatial extent of ponded areas in Barnegat Bay using multi-scale object-oriented image segmentation classification (Lathrop et al., 2006). These practices would include the delineation of homogenous objects (i.e. Ponds, Figure 1), which will include three habitat classifications: pond, intact marsh vegetation, and unvegetated marsh habitat, and I plan to include at least two time periods of satellite imagery, although the exact spatial and temporal extent of the study may need to be adjusted based on the how time consuming the classification process is. First, eCognition software will be used to delineate and segment the imagery into homogenous shapefiles. Once the images are segmented, user-prescribed (decision tree) or an empirical model (forest classification) will then be used to automate classification for the entire spatial extent of the research area. It will be important to focus on as broad an area as possible as quantitative data on the extent of pond construction (area, number of ponds) is currently lacking, although previous, partial work has suggested that the ponds number in the thousands (L. Perez, personal communication). Image segmentation is more accurate than using pixel-based classification of aerial photographs, and less time consuming than heads up digitization (Drăguţ et al., 2006). The eCognition software suite – while costly – is the state of the art for remote sensing analysis, and is rapidly becoming adopted by monitoring agencies such as NOAA (Carter et al., 2015).

Benefit to Coastal Wetlands Management

Currently, the Department of Environmental Protection in New Jersey is uncertain whether to allow continued pond construction, to leave ponds alone but no allow new pond construction, or even whether to try to remediate ponds that have previously been dug. More information on impacts of OMWM activities to valued marsh ecosystem functions – such carbon sequestration – is necessary in order to balance the large scale habitat disturbance that OMWM poses against nuisance mosquito populations, and potentially human health. Since mosquito control will always be a prominent management problem in New Jersey, the results of this research could be used to support ecosystem-based management practices in these coastal wetland areas. Coastal wetlands need to be preserved especially in regards to climate change mitigation. It is imperative to preserve these ecosystems as they serve as immense natural carbon sinks and this research could show that disturbances convert them from carbon sinks to carbon sources (Mcleod et at., 2011).

How Funds Will Be Utilized

The funds will be used for travel to all the field sites. Coastal wetlands in New Jersey are very expansive (e.g., 5-10km in width), and necessitate access via a small boat.

Item	**Charge Per Day**	**Number of Days**	**Total Cost**
Small Boat Rental	$225	18	$4,050.00
Tow-capable vehicle rental ($0.85/mile x 117 miles)	$100	18	$1,800.00
		Total Cost	**$5,850.00**
		Total Requested	**$5,000.00**

This research is an ambitious project for a masters thesis, and I am fortunate that the rest of the funding could be supplemented by my advisor via support from the U.S. Environmental Protection Agency. In addition to an ambitious masters thesis, I also have limited funding available for support of my student status. I am not funded by a typical TA- or RA-ship but rather am working part time as a consultant and research technician to cover my tuition and living expenses. Funding from The Garden Club America will help support an important and management-relevant wetland research project, apply new landscape ecology tools to wetland problems, and provide support to a graduate student whose resources and time are currently stretched thin.

Broader Impacts

I plan on presenting my findings with the scientific community through publication in a peer-reviewed journal and also plan to present this research at the Coastal & Estuarine Research Federation (CERF) 24th Biennial Conference in the fall of 2017. I believe that this research could provide insight to the detrimental effects to the carbon balance of the wetlands when they have been disturbed while also providing new methods to quantify the spatial extent of the disturbance using eCognition software.

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