A. Project Title and Numbers:

Project #: NJSGC Project #6610-0005

Project Title:

A Model-Data Synthesis of the Status and Trends of New Jersey's Coastal Wetlands for Sea Level Rise Planning

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B. PROJECT PERSONNEL:

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Scott Haag, M.S., Co-principal Investigator
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Tracy Elsey Quirk, Ph.D., Co-principal Investigator
Assistant Professor, Louisiana State University, Department of Oceanography and Coastal Sciences, Baton Rouge, LA

Danielle Kreeger, Ph.D., Co-principal Investigator
Science Director, The Partnership for the Delaware Estuary, Wilmington, DE.

Kirk Raper, M.S., Technician
Wetland Project Coordinator
Academy of Natural Sciences, Philadelphia, PA

LeeAnn Haaf, M.S., Ph.D. student
Drexel University, Department of Biodiversity, Earth & Environmental Sciences, Philadelphia, PA

Elisabeth Powell, M.S. student
Drexel University, Department of Biodiversity, Earth & Environmental Sciences, Philadelphia, PA

Farzana Rahman, Undergraduate student, Major: Environmental Science, Earth Science concentration
C. Time Interval:

Date of the project: February 1, 2016 – January 31, 2018

Dates of Reporting Period: February 1 2016 – January 31 2017

D. STAKEHOLDER SUMMARY:

Coastal wetlands are an important natural resource for New Jersey – they help reduce coastal storm surges, provide important wildlife habitat and recreational opportunities, support fishery production, and enhance coastal water quality through sediment trapping and nutrient removal and sequestration. Across the Mid-Atlantic region, coastal marshes are in decline. Analyses conducted for a ‘State of the Estuary’ report indicate that Delaware Bay lost an acre per day of tidal wetlands between 1996 and 2006, and a recent analysis of Long Island tidal wetlands shows a loss rate of native marsh vegetation in excess of 10% between the early 1970s and early 2000s. These losses are symptomatic of marsh drowning, and include marsh retreat, edge erosion, marsh island loss, and the development and enlargement of interior dieback areas. The deterioration and fragmentation of fringing coastal marshes leaves housing and infrastructure vulnerable to the impacts of coastal storms.

The objectives of this project are to develop a better understanding of the processes responsible for coastal marsh drowning and to refine the predictive capabilities of decision support tools to help prioritize investments in coastal protection, such as living shoreline installations, sediment addition, and barrier removal projects. We are testing the power of several forecast models to explain current wetland loss patterns using high vs. low quality data inputs, examining the impacts of tidal range on wetland survival with sea level rise, and asking which parameters are most important to assess vulnerability to sea level rise. The co-production of science with end users, including private and public stewardship agencies, makes this project impactful, as well as strong student support that helps train the next generation of environmental scientists and managers.

E. Objectives: There have been no noteworthy changes to the Objectives.

F. Methodology: There have been no noteworthy changes to the Methodology.

G. BUDGET: There have been no noteworthy changes to the Budget. We have requested a no-cost extension for year one, as we had difficulty with setting up needed computers and software for geospatial analyses. Rather than supporting Josh Moody (Drexel Ph.D. student), we have recruited a new Ph.D. student (LeeAnn Haaf) to conduct research for this project.

H. RESULTS/PROGRESS TO DATE:

Goals: The overall goal of the research and outreach activities being conducted by this project is to develop a better understanding of (1) the processes responsible for current high rates of marsh drowning, and to (2) refine predictive capabilities of decision support tools. To accomplish these goals, we are conducting remote
sensing analysis and empirical modeling of coastal wetland sentinel sites in New Jersey where we have been conducting on the ground monitoring for 5+ years (Fig. 1).

Progress:

End-User Collaboration – Research shows that collaboration between researchers and end users is beneficial for effective coastal science and policy interfaces, and that some iteration between knowledge producers and end users is beneficial. Our guiding principal in conducting outreach is to involve end users at the beginning of the process so they can have an active voice in tailoring the research towards their needs. We have solicited input to help guide the project from the following stakeholders: The Barnegat Bay Partnership, the Partnership for the Delaware Estuary, the U.S. Fish and Wildlife Service, New Jersey’s coastal program, PSE&G, and The Nature Conservancy (south New Jersey office) through individual meetings with stakeholders and end users. We also will solicit input at a forthcoming presentation at the North Atlantic Landscape Conservation Cooperative in Gloucester, MA in April of 2017 focused regional (rather than site-specific) model applications for coastal conservation.

The specific information we have solicited from these organizations uses an interactive model of science co-production. In compiling feedback, I asked broad open-ended questions about: (1) how the stewardship organization that they worked with was likely to use sea level rise models in management decisions, (2) began an open discussion on the strengths and weaknesses of sea level rise models, and (3) asked groups to identify potential knowledge gaps for the region related to sea level rise impacts on coastal wetlands and maritime forests. I then provided a brief overview of my funded project, telling the end-user about our wetland monitoring project and findings, with a brief overview of the funded analyses. I ended with very specific questions that focused on the timescales of greatest interest and how the outputs could be tailored to the needs of their organization. For instance, I asked about the usefulness of focusing on various time scales (e.g., last several decades vs. longer historic period), the specific sea level rise and sediment availability modeling scenarios that would be most relevant to the work of their agency, and finally, in what format outputs would be most useful, and where they should be deposited. We are in the process of compiling this feedback and developing action items to guide the modeling phase of the project.

Model Parameterization – We are parameterizing and comparing three sea level rise models (SLAMM, MEM, Krone), which use different approaches to evaluate future impacts of sea level rise on wetlands for our established network of eight tidal wetlands in New Jersey (four spanning the salinity gradient of the Delaware Estuary and four in Barnegat Bay) (Fig. 1).

**Figure 1.** Research sites showing geographic location, salinity, and tidal range (m).

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Tidal range</th>
<th>Salinity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswicks</td>
<td>Bordentown, NJ</td>
<td>2.49</td>
<td>0.1</td>
</tr>
<tr>
<td>Dividing Creek</td>
<td>Dividing Creek, NJ</td>
<td>1.78</td>
<td>16.7</td>
</tr>
<tr>
<td>Dennis Creek</td>
<td>South Dennis, NJ</td>
<td>1.72</td>
<td>15.9</td>
</tr>
<tr>
<td>Maurice River</td>
<td>Bivalve, NJ</td>
<td>1.73</td>
<td>11.2</td>
</tr>
<tr>
<td>Island Beach</td>
<td>Seaside Park, NJ</td>
<td>0.66</td>
<td>26.8</td>
</tr>
<tr>
<td>Reedy Creek</td>
<td>Brick, NJ</td>
<td>0.10</td>
<td>20.2</td>
</tr>
<tr>
<td>Horse Point</td>
<td>West Creek, NJ</td>
<td>0.62</td>
<td>25.6</td>
</tr>
<tr>
<td>West Creek</td>
<td>West Creek, NJ</td>
<td>0.60</td>
<td>25.6</td>
</tr>
</tbody>
</table>
Data Collection – We have collected several additional classes of data inputs to facilitate model sensitivity testing, including elevation data, water level data, and GIS coverages. Previous studies have revealed positive elevation bias in as-delivered LiDAR can result in large inaccuracies in model predictions. When LiDAR is collected at high tide, or when plant cover is great, the light bounces off the top of the plants or water, causing the coastal elevation to appear higher than it actually is (resulting in signed error, or positive residual error values). This positive bias in coastal elevations inherent in LiDAR collections means that models will assume that vulnerability is much lower than it actually is. To help identify and eliminate positive elevation biases introduced by LiDAR, we have conducted new elevation surveys at our study marshes. We conducted elevation surveys using survey-grade GPS receivers (Leica Viva GS14 GNSS receivers) outfitted with connections for real-time kinematic elevation surveys, with absolute accuracy of ~3cm. Elevation surveys were conducted adjacent to our monitoring stations, and laid out along a 50 m by 50 m grid. Approximately 500 points were surveyed per marsh. This data has been downloaded and adjusted to the NAVD88 Geoid 12A datum. Future plans will include comparing survey-derived elevations with LiDAR derived elevations, and comparing predictions made with as-delivered LiDAR vs. post-processed elevation models. In addition to aiding in developing realistic model outputs, this sensitivity testing has important applications for where stewardship organizations invest their resources. Many agencies are investing in elevation surveys for sea level rise planning, but little data is available on whether this is necessary and the extent to which post-processing LiDAR data can help improve existing data to much higher standards.

Another area where large uncertainties are present in sea level rise models outputs involves derivation of tidal datums. SLAMM and MEM necessitate converting elevations from digital elevation models to tidal datums. This is currently conducted for the US using a NOAA product called VDatum, which converts between orthometric and tidal heights based on data from existing tide stations and coastal bathymetry. Many factors can lead to inaccurate datums being generated: many locations are outside the ADCIRC bathymetry mesh, meaning data is unavailable, tides for backbarrier estuaries are highly inaccurate, and where there are few tide stations tied into orthometric datums (such as in New Jersey), accuracy is low. These factors often lead to tidal datums being grossly inaccurate, which can then introduce errors of up to a meter or more into sea level rise models. To help ascertain whether this issue is important in New Jersey, we have used pressure transducers to measure water levels. We deployed two Hobo U20L pressure transducers in tidal channels at our research sites, logging at 15 minute intervals, for a period of ~4 months. Pressure data was barometrically compensated, and adjusted to the NAVD88 datum using point measurements of water levels using RTK-enabled GPS receivers. Tidal datums for each marsh (relative to the National Tidal Datum Epoch) were computed using the modified-range-ratio method, using the nearest tide station as a control station.

Another area where data inputs may bias results are with respect to National Wetlands Inventory cover classes. NWI cover categories do not discriminate in a detailed way between areas with intact vegetation and areas undergoing dieback or erosion. Here we are comparing model outputs with NWI data in comparison with detailed remote-sensing based vegetation maps. We also used logistic regression to better define the cut-off where vegetation is expected to dieback under current flooding patterns, as the elevation threshold where plants are expected to die is not well developed by most platforms. Rather, the packages define the dieback elevation as the minimum elevation where vegetation is found today. To more accurately determine this elevation, which we define as the probably of vegetation presence of 50% (LD50), we used bionomial
logistic regression models. Cutoffs were determined for \( p \) of presence at 0.5 (50% likelihood), and were calculated following the formulation for logistic regression:

\[
p = \frac{1}{1 + e^{-(\beta_0 + \beta_x x)}}
\]

rearranged for \( p = 0.5 \) so that

\[
p(0.5) = -\frac{\beta_0}{\beta_x}
\]

where \( p \) is the probability of habitat presence, and \( \beta \) are the coefficients for the constant (\( \beta_0 \)) and elevation variables (\( \beta_x \)), respectively.

Below are summarized the models we are comparing.

**Marsh Equilibrium Model** – Model inputs needed for the MEM model include the elevation of peak biomass production, suspended sediment concentration, the elevation of mean high water and tidal range, marsh elevation, the root to shoot ratio, and soil cores where organic content has been measured at depth. These factors have been measured by our ongoing wetland monitoring program over the past five years, with several data points available. This is a 1-D model, but can be applied to a model grid using LiDAR.

**Sea Levels Affecting Marshes Model (SLAMM)** – SLAMM is a landscape model which simulates inundation and inland coastal wetland migration due to long-term sea level rise. Key data inputs include accurate elevation data (digital elevation models based on coastal LiDAR are ideal), marsh elevation change over time, geospatial habitat coverages, and accurate tidal datums (mean sea level and mean range of tide).

**Krone Model** – This modeling approach is a process-based marsh elevation simulation model. This simulation model calculates marsh elevation change as a function of over-marsh water levels, settling velocity, sediment density, and suspended sediment concentrations. This simulation model calculates change in marsh elevation (\( \Delta E \)) as the sum of mineral sedimentation (\( \Delta S \)) and sub-surface compaction and consolidation (\( \Delta P \)).

\[
\Delta E = \Delta S - \Delta P
\]

This simulation model calculates marsh deposition as:

\[
\frac{\int V_s C \, dt}{\rho_d}
\]

where \( V_s \) is settling velocity, \( C \) is suspended sediment concentration and \( \rho_d \) is non-organic sediment dry density. Concentration of sediment was set at an ambient maximum concentration specified by the user, but was allowed to vary over time steps, as suspended sediment settles out, or is replaced, as water levels over the marsh increase. During rising tides, change in concentration is calculated as:

\[
\frac{dC}{dt} = \frac{V_s (C_0 - C) \frac{d\eta}{dt}}{\eta - E}
\]

where \( C_0 \) is the initial suspended sediment concentration, \( C \) is the time-step specific suspended sediment concentration, \( \eta \) is water level, and \( E \) is marsh elevation. During falling tides, change in concentration is calculated as:
\[
\frac{dC}{dt} = \frac{V_s C}{\eta - E}
\]

The constant in the settling velocity equation was calibrated against observations:

\[V_s = a C^7\]

where \(V_s\) is settling velocity, \(C\) is suspended sediment concentration, and \(a\) is a constant. To calibrate \(a\), we used the suspended sediment concentration based on 81 observations of channel suspended sediment concentrations for water surface grab samples collected from September 2010 through September 2016 at each of the study sites. The constant in the settling velocity equation was calibrated empirically using three dated sediment cores collected from different elevation zones in 3 study sites, based on best fit.

**Trends Analysis** – Pending inputs from stakeholders on timescale of interest for trends analysis, and recently received computers, our work has focused on assessing patterns of marsh migration by assessing forest health along wetland transgression margins. We measured forest health along the wetland transgression zone in Delaware Bay. Trangression margins (TM) were established using Sea Level Affecting Marsh Migration (SLAMM) model outputs download from NOAA’s Digital Coast online data repository (Fig. 2). TMs were defined as the land area that becomes inter-tidal for sea level rise predictions of 1-3 ft, but which are not currently classified as estuarine by New Jersey’s Land Use Land Cover database. LANDSAT imagery (Landsat 8) tiles were downloaded for 20 August 2016, during the height of the growing season, utilizing cloud-free scenes. The image tiles were processed using the Forest Health Analysis Tool (ENVI version 5.4, Harris GeoSpatial, Broomfield, CO) as function of the Normalized Difference Vegetation Index, Anthocyanin Reflectance Index, Moisture Stress, and Structural Insensitive Pigment Index (Fig. 3).

**Figure 2.** Transgressive margins of current estuarine wetlands along Delaware Bay, NJ. **Figure 3.** Forest health index for points along the transgression boundary (highest values are healthiest)
Over 1800 random points were generated within the study area; 50.2% of these points were within the TM. Points were then categorized by generalized habitat types: agricultural lands, dry coniferous forest, coniferous swamps, dry deciduous forest, deciduous swamps, as well as brackish and Phragmites dominated coastal wetlands. Health index values were then extracted to each point. A two-way ANOVA was used to test for differences in the forest health index among habitats using R, did not find significant statistical differences in forest health in and outside the transgression zone, although visual differences were apparent.

I. Interactions:

We have solicited input to help guide the project from the following stakeholders: The Barnegat Bay Partnership, the Partnership for the Delaware Estuary, New Jersey’s coastal program, PSE&G, and The Nature Conservancy.

We were invited to by New Jersey Sea Grant to take part in the South Camden Family Fishing Day, in Camden, NJ. We (PI Elizabeth Watson and undergraduate technician Farzana Rahman) set up a wetland model and taught children how wetlands help improve water quality. We also brought information on wetland monitoring projects being conducted by the Academy of Natural Sciences. It was really fun! There were about 100 attendees And I think we made connections between healthy waters and healthy fish with the attendees and had lots of fun with the kids.

Funds Leveraged: Having this funding did not allow us to obtain additional funding, although it has facilitated compilation and analysis of environmental data collected under previous awards from foundations and public sources, including the PSE&G Foundation, and the U.S. Environmental Protection Agency.

J. PROJECT PUBLICATIONS, PRODUCTS, PRESENTATIONS, AND PATENTS:

Publications: No publications have yet resulted from this project. We have the following manuscript drafts in preparation:


Presentations and Posters (upcoming, presenting authors underlined):


Other Documents: We anticipate that a website will be online soon.

Patents: N/A

K. HONORS AND AWARDS:

Elisabeth Powell, M.S. student partially supported by this project, has been awarded The Garden Club of America Award for Fieldwork in Coastal Wetlands, a $4,000 scholarship

LeeAnn Haaf, Ph.D student supported by this project, received the Outstanding Student Poster Award for The Utility of Long Term Reference Data for Understanding Elevation Dynamics and Designing Thin Layer Placement Projects in New Jersey Coastal Marshes at the Delaware Estuary Science and Environmental Summit

Farzana Rahman, undergraduate student who has contributed to this project as a research technician received a Wetland Foundation travel grant of $1500 for presentation of her research at the Society of Wetland Scientists Meeting in San Juan, Puerto Rico.

L. STUDENTS:

Student Name: LeeAnn Haaf
Receive Sea Funding: Yes
Major: Environmental Science
Current Status: Doctoral Student
Participation Status: New
Date of Graduation: Anticipated 2020
Student Involvement: Dissertation
Thesis / Dissertation Title: Spacio-temporal patterns in coastal wetland transgression, and interactions with physical and biotic factors
Future Plans of Student: Advance to candidacy Fall 2017

Student Name: Scott Haag
Receive Sea Funding: Yes
Major: Computing and Informatics
Current Status: Doctoral Student
Participation Status: New
Date of Graduation: Anticipated 2019
Student Involvement: Project guidance on geospatial analysis
Thesis / Dissertation Title: TBD
Future Plans of Student: Continued nonprofit employment

Student Name: Elisabeth Powell
Receive Sea Funding: Yes
Major: Environmental Science
Current Status: Master’s Candidate
Participation Status: New
New Jersey Sea Grant Consortium
Sea Grant Progress Report Summary

Date of Graduation: Anticipated December 2017 or March 2018
Student Involvement: Internship
Thesis / Dissertation Title: The effect of open marsh water management practices on the carbon balance of tidal marshes in Barnegat Bay, New Jersey
Future Plans of Student: Pursue doctoral studies

Student Name: Farzana Rahman
Receive Sea Funding: Yes
Major: B.S. Environmental Science, Earth Science Concentration
Current Status: Undergraduate
Participation Status: New
Date of Graduation: Anticipated August 2017
Student Involvement: Internship
Thesis / Dissertation Title: Impacts of nutrient load, source, and residence time on nitrogen stable isotope ratios in estuarine soils and biota
Future Plans of Student: Graduate study

M. VOLUNTEER HOURS:

Volunteers were not involved with conducting research.

N. Additional Metrics: No additional metrics are available.

O. PICTORIAL:

Watson Photo 1 Caption: Fringing coastal wetlands help protect coastal populations from storm surges. When wetlands fragment and drown, coastal communities are left more vulnerable to extreme events. Photo credit: Elizabeth Watson/Drexel University

Watson Photo 2 Caption: Measurement of coastal marsh elevation change using a surface elevation table, or SET. Project scientists are monitoring marsh elevation change and sediment deposition at more than three dozen locations in regional estuaries. This photo also shows how marshes are migrating into coastal forests with sea level rise, resulting in a ‘ghost forest’ with a marsh understory. Photo credit: Elizabeth Watson/Drexel University

P. PROJECT ACCOMPLISHMENTS (Outcomes) AND IMPACTS:

Our project has not yet resulted in accomplishments and impacts worthy of statements.