How will sea-level rise driven shifts in wetland vegetation alter carbon and nitrogen based ecosystem services?

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Background

- Coastal salt marshes are one of the largest carbon (C) sinks on the planet,[1] and filter nitrogen (N) from surface runoff via plant uptake and denitrification, mitigating downstream eutrophication[2,3]
- C- and N-based services of Long Island Sound (LIS) marshes are being altered by
  - Sea level rise (SLR)
    - Direct effects- increased salinity and extended hydroperiods alter C mineralization[4,5] and denitrification rates[6,7]
    - Indirect effects- shifts in plant biomass allocation patterns[8,9] and species composition, as high marsh species are replaced by low marsh species[10,11]

Figure 1. *Phragmites australis* invades brackish and tidally-restricted marshes in LIS coastal marshes. This invader reduces plant and wildlife diversity, but the impact and magnitude of these changes on C- cycling and N removal are largely unknown.

- *Phragmites australis* expansion (Fig. 1) & management
  - *Phragmites* prolific biomass production and slow decomposition rates may increase C storage and enhance vertical accretion[12], and its rhizosphere oxidation may promote N removal via coupled nitrification and denitrification[13]
  - Tradeoffs in ecosystem services (diversity vs. C storage & N removal) need to be carefully considered by coastal managers that increasingly have limited financial resources
- Impacts of plants on wetland biogeochemistry (Fig. 2)
  - Plant traits associated with inputs of C (above- and below-ground biomass production) and oxygen (root porosity, pressurized ventilation) should relate to microbial competition for organic C and influence denitrification, C mineralization, and CH_4 production/oxidation

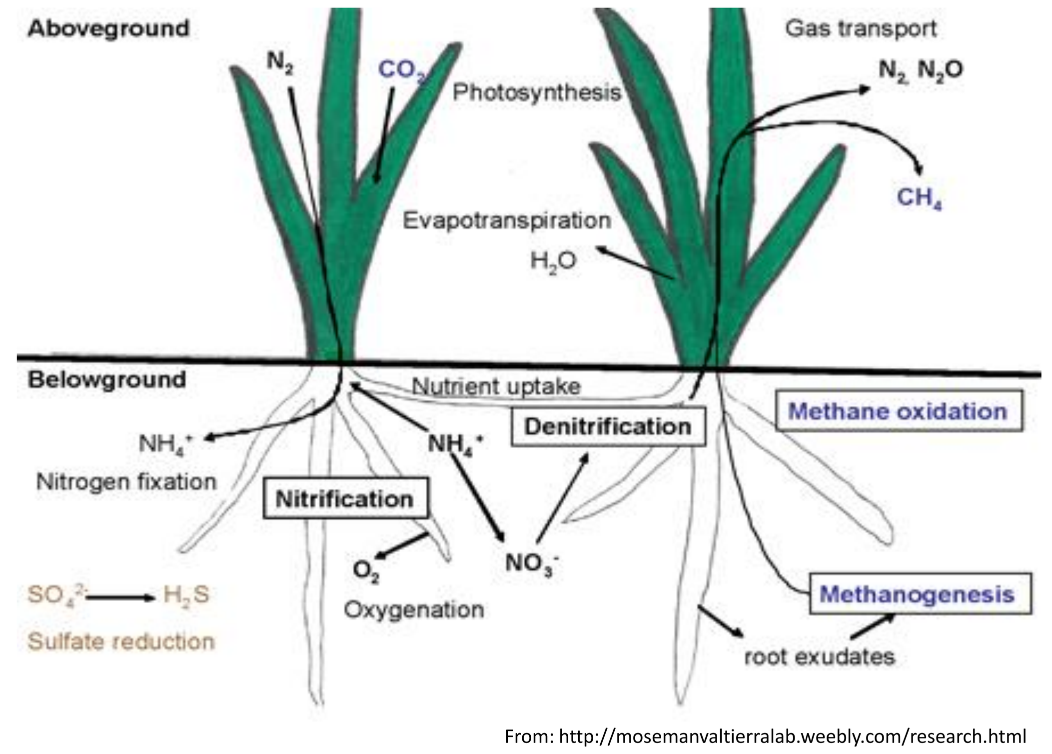

Figure 2. Biological and biogeochemical processes that underlie the ecosystem services provided by coastal wetlands.

Our overarching objectives for this 2017-2019 project are to:

1) **Quantify C and N cycling services provided by LIS tidal marshes**
2) **Project how those services will change under SLR and management scenarios**
3) **Develop educational materials to better communicate these changes to the public**

Objective 1: Quantify C and N-based services provided by dominant coastal marsh plant species

We will implement field surveys across vegetation zones in restored and reference marshes and conduct an *in situ* marsh organ experiment to test:

H1- Coastal marsh vegetation zones dominated by different plant species will provide different C sequestration and N removal services that are related to dominant plant traits (i.e., above- and below-ground biomass production, root porosity)

H2- Restoration practices targeting invasive *Phragmites* will influence the delivery of C and N services by altering plant species composition

H3- Increased flooding frequencies, water depths, and salinity associated with SLR will alter C and N services provided by dominant species.

2017 Field survey

We will collect plant and soil samples from CT coastal marsh complexes (Fig. 3) to examine the impacts of:

Vegetation zones
- *Spartina alterniflora* (low marsh)
- *Spartina patens* (high marsh)
- *Phragmites* (brackish marsh /transition)

Wetland management:
- Tidal flow restoration sites (n=10)
- *Phragmites* control sites (n=10)
- Reference (no restoration) sites (n=10)

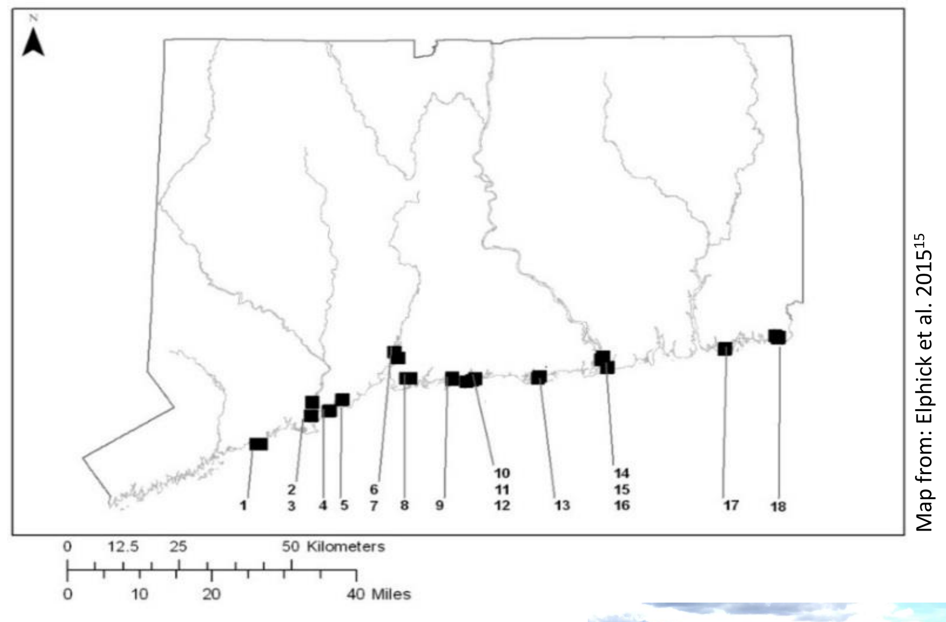

Figure 3. Candidate coastal CT marsh complexes to address Objective 1. We will use a 3-m resolution map[14] to identify candidate areas dominated by species of interest within each marsh.

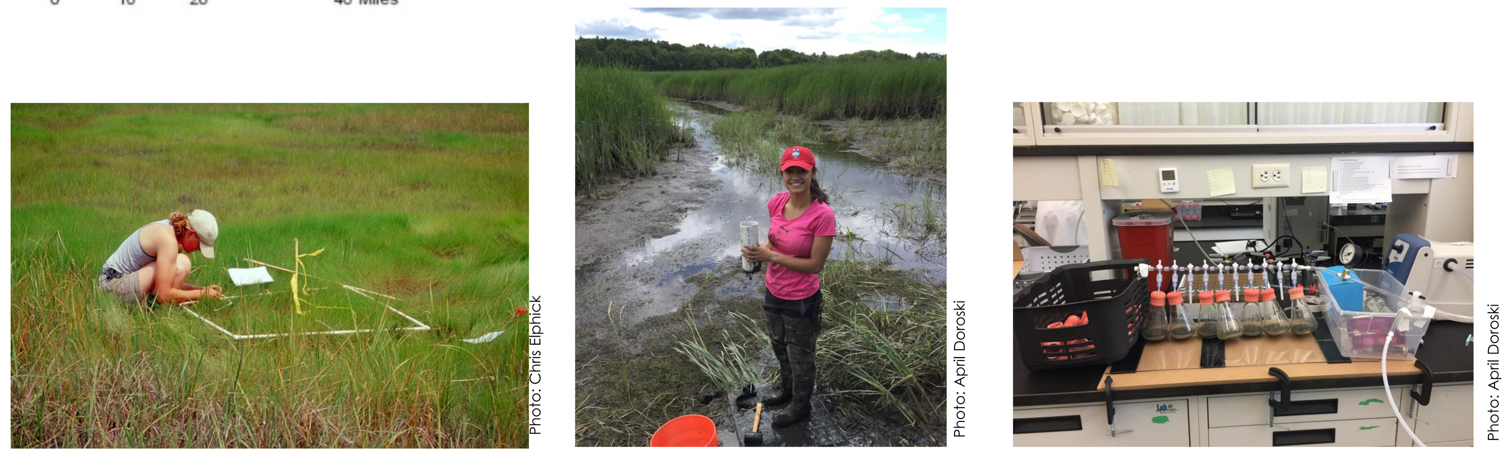

Figure 4. Within each vegetation zone (n=3) at each site (n=30), we will quantify: plant species abundance (% cover, biomass), plant and soil %C and %N, soil microbial process rates (C mineralization, DEA), and pertinent soil ions (SO_4^-, Cl^-, NH_4^+, NO_3^-).

2018 Marsh Organ Experiment

- To test how hydroperiod and salinity affect plant biomass allocation and biogeochemical processes, we will implement an *in situ* "marsh organ" experiment (Fig. 5) at Barn Island Wildlife Management Area (Stonington, CT)
- We will quantify above- and below-ground production, root porosity, plant and soil %C and %N, soil microbial process rates (C mineralization, DEA), soil salinity, pertinent soil ions (SO_4^-, Cl^-, NH_4^+, NO_3^-), and C and N fluxes (CO_2, CH_4, N_2, N_2O).

(Photo credit: http://oceanservice.noaa.gov/facts/marsh-organ.html)

Figure 5. A marsh organ experiment composed of PVC pipes at different elevations planted with focal species will be implemented to mimic sea level rise impacts.

Objective 2: Forecast how shifts in dominant marsh species will alter ecosystem services provision of LIS coastal wetlands

SLR projections[16] + high-resolution LIS wetland vegetation map[14] + empirical data

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Extrapolate vegetation-related shifts in C and N services using empirical relationships derived from field surveys & experimental manipulations

- Create maps of C and N services provided by LIS coastal marshes under different management scenarios and SLAMM[16] projections for climate change scenarios (2025, 2055, 2085, and 2100)

Figure 6. Strong vegetation zonation driven by salt- and inundation-tolerance of dominant species at Barn Island, CT

Objective 3: Promote understanding of the complex interactions among climate change, SLR, coastal wetlands, and ecosystem services among diverse audiences in LIS region

We will **enhance STEM education** and connect multiple user groups in the LIS region by:

a) Providing field-based, analytical, and experimental research opportunities for high school and graduate students from diverse backgrounds
   - Train and promote the professional development of **two graduate students**
   - Engage **two high school students** in coastal conservation research through the Natural Resource Conservation Academy (NRCA)

Figure 7. Students collecting vegetation data in Hammonasset Marsh, CT

b) Developing an inquiry-based teaching module for high school teachers that will highlight key concepts linking climate change and coastal ecosystems
   - Partner with two regional high school teachers to **create inquiry-based high school climate change curricula that meets Next Generation Science Standards**
   - Promote and distribute climate change teaching module to hundreds of high school teachers in region through established networks associated with CT Sea Grant and NRCA; module will be publically available at climate.uconn.edu

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