Factors influencing subsurface wetland dynamics in coastal Louisiana: Implications for wetland response to sea-level rise and restoration

Coastal wetlands are among the most ecologically valuable ecosystems in the world, providing economically important services that support fisheries, recreation, and protection of coastal infrastructure (Barbier et al. 2011). Despite their ecological and economic importance, approximately 47% of the worlds coastal wetland area has been lost since the 1900s (Davidson 2014) due to a variety of factors including sea-level rise, subsidence, human development, and changes to river and tidal hydrology and sediment dynamics. Louisiana has approximately 40% of the coastal wetland area of the continental United States largely due to deltaic deposits from the Mississippi River, as well as smaller rivers such as the Atchafalaya, Calcasieu and Sabine rivers. Both the direct deposition from river distributaries and deposition from longshore currents and wave energy have provided the foundation for emergent coastal wetland vegetation and vast ecosystems that grade in salinity from freshwater swamp to salt marsh. Across much of the Louisiana coast, wetlands are highly vulnerable to submergence and erosion. Precise measures of elevation and accretion dynamics therefore, are key for predictions of future wetland function with relative sea-level rise and coastal restoration as outlined ***Louisiana's Comprehensive Master Plan for a Sustainable Coast*** (CPRA 2017).

The Louisiana Coastwide Reference Monitoring System is a large network of coastal wetland monitoring stations with standardized measures and fixed sampling schedules for the collection of data including surface elevation change, surface accretion rate, water levels, vegetation, and soil characteristics across a range of wetland types (n ≈ 390; Steyer et al. 2003; CPRA 2018). Based upon a subset of these data, surface elevation change rates are highly variable across wetlands with standard deviations almost always greater than the mean (e.g., overall: 3.8 ± 7.4 mm/yr, n = 274; *in* Jankowski et al. 2017). Nested within this variation are changes occurring on the wetland surface via net accretion ((deposition + root growth) – decomposition)) and changes occurring below the depth of accretion measurement (i.e., subsurface). While many wetlands are experiencing subsurface subsidence due to processes such as decomposition and compaction, others are experiencing an expansion in the subsurface soil over time. While the spatial and temporal dynamics and the mechanisms of these process are unclear, it is important to our overall understanding of wetland elevation trajectories, as subsurface processes can play a large role in

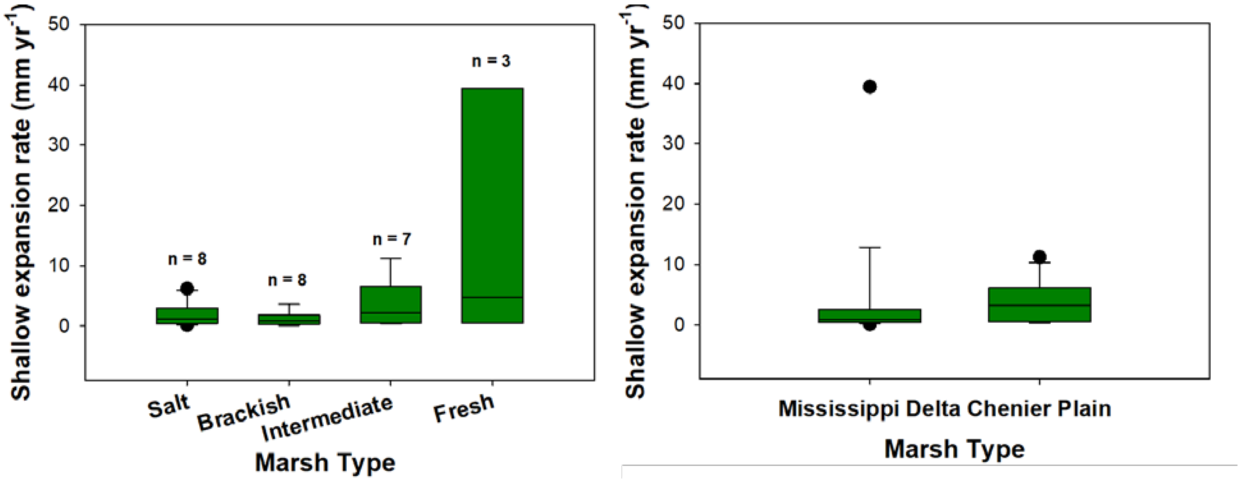

Figure 1. Preliminary data of shallow expansion rates in different coastal wetland types (left) and wetlands in different regions (right) of Louisiana (CRMS data; Jankowski et al. 2017).

determining whether wetlands drown or remain above sea-level. Preliminary CRMS data show differences among wetland types in the rate of subsurface expansion **(Figure 1)**, but a much more comprehensive study is required to determine how subsurface processes influence elevation change, how rates and directions vary across the landscape, and how environmental conditions (e.g., hydrology, soil texture, structure, and porosity, belowground biomass morphology, etc.) influence rates of shallow subsidence and expansion.

Research Objectives- Leveraging the tremendous dataset afforded by the CRMS stations, as well as our capability for additional field studies, we have two main objectives: (1) examine the spatial variation in subsurface changes and its relative impact on rates of elevation change; and (2) examine relationships between predicted drivers and subsurface change rates. ***These objectives directly support the priority area to advance the evaluations of processes that contribute to elevation gain including interactions between flooding and vegetation that produce shallow expansion.***

Approach

(1) *Spatial and temporal variation in subsurface changes and its impact of rates of elevation change*

Using the large (n ≈ 390) CRMS dataset, we will examine subsurface change rates and directions (i.e., subsidence, expansion, or null) at both spatial (e.g., categorical variables: region, wetland type, vegetation community, soil types, etc.) and temporal scales. Questions that will be addressed include: 1. Are there spatially clumped distributions of subsurface process rates and directions; 2. Are there differences among region, wetland type, vegetation community, and soil types in subsurface processes rates and directions; 3. Do rates and directions of subsurface processes change over time in individual sites; and 4. What is the relationship between subsurface vs surface processes on elevation change rates. Statistical analyses will consist of GLM models be performed using the R Environment (R Project v3.6.1 and, in addition, we will employ a spatial analysis approach using ArcGIS (v.10.7.1). Products of this effort will include maps and figures illustrating distributions of wetland vertical processes.

(2) *Processes influencing subsurface changes*

Many factors can influence wetland soil expansion or contraction including elevation within the tidal frame, root and rhizome growth, morphology of the root system, decomposition, water fluxes including evapotranspiration, and soil porosity and organic matter content (Cahoon et al. 2006; Paquette et al. 2004). We will use a combination of CRMS data and new field data collected at a subset of sites that span the range of subsurface expansion and subsidence to examine the mechanisms of changes in soil volume. From the CRMS data, we will examine the relative influence of salinity, vegetation (species composition, biomass), soil properties, and channel hydrology on subsurface change rates using a Structural Equation Modelling approach. Depending on the outcomes of this global analysis and *Objective 1*, we will select approximately 9 wetlands in each wetland type binned into groupings of high rates of subsidence (HS; n = 3), no subsurface change (NC; n = 3), high rates of shallow expansion (SE; n = 3). For each study site, we will collect additional vegetation data focused on the belowground biomass and morphology and soil data such as porosity and sediment texture. At one of each grouped site (HS, NC, SE) within each marsh type, continuous *subsurface* water levels will be recorded using *In-situ* water level loggers, as marsh subsurface hydrology is not accurately represented by channel hydrodynamics. Intensive measures of root in-growth and decomposition rates will be measured at a sub-set of marshes representing the range of subsurface change values using standard ingrowth and litterbag techniques. At these sites, net ecosystem exchange and ecosystem respiration rates will be measured and gross primary productivity will be calculated from carbon dioxide fluxes using static chambers and a continuous CO_2 gas analyzer (PP Systems, Inc.). Thus, we will be able to test relationships between subsurface processes and carbon gas fluxes.

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