**Can ribbed mussels augment coastal restoration projects in a world of rising seas?**

Coastal wetlands are critical ecosystems that provide multiple ecological, physical and socio-economic benefits to coastal communities throughout the world. Globally, these ecosystems are being lost at increasing rates as a result of sea level rise and other factors. Louisiana has among the largest extents of coastal marshes in the United States but also the highest rates of relative sea level rise (SLR) and wetland loss with more than 4,800 $km^2$ lost since the 1930s and an additional 4,500 $km^2$ predicted to be lost in the next 50 years. Given sufficient sediment supply, wetlands are capable of accreting sediment and maintaining their elevation relative to rising sea levels. They also dampen wave energy, providing significant protection against storms. Thus restoration efforts must take a multifaceted approach that targets restoration of natural plant communities, maximizes sediment capture and accretion, stabilizes shorelines, and bolsters the ecosystem services provided by coastal wetlands. Two of the most common mechanisms used by managers to prevent or slow wetland loss are marsh reconstruction, and river diversions. Key to the success of both of these approaches in promoting resilient marshes and coastal systems is ensuring healthy coastal marsh ecosystems. While marsh vegetation health and extent often serve as success indicators, the processes governing their ability to remain productive in the face of rising sea levels depends on many factors including interactions between flooding, vegetation and marsh organisms (i.e., bivalves) that can impact the final outcomes of marsh restoration.

While marsh creation and sediment diversions have become core components of the Louisiana Coastal Master Plan, the use of living shorelines to further stabilize marshes, and potentially enhance shoreline vegetation productivity has become a key tool. In Louisiana alone, over a dozen such projects have been completed, with an 11-mile living shoreline currently in engineering design (extension of PO-148). This approach aims to stabilize shorelines with native marsh vegetation to combat erosion and often uses hard substrates, such as artificial or constructed oyster reefs, in shallow near shore waters to reduce wave energy. One major benefit of this approach is that connectivity between aquatic and terrestrial habitats is maintained. To date, living shoreline projects in Louisiana have focused on the use of oyster reefs, however, recent research suggests that ribbed mussels (*Geukensia* spp.) are relatively ubiquitous across the coastal brackish salinity zone and may serve a similar role but across a wider range of salinities within Louisiana coastal environments.

Ribbed mussels (*Geukensia* spp.) are unique in that they exhibit qualities of both autogenic and allogenic ecosystem engineers; they change their environment by anchoring to nearby shells and belowground plant organs via byssal threads that contribute to sediment strength and erosion prevention, and transform nutrients into more bioavailable forms for plant uptake that can lead to increase plant productivity. Recent studies by our research group have shown that increases in Gulf ribbed mussel (*G. granosissima*) density leads to increases in aboveground live stems, leaves, and overall biomass of *Spartina alterniflora* as well as increases in belowground biomass. Further, our studies show that gross $CO_2$ uptake increases as well as the availability of inorganic N which leads to increases in N cycling rates with increased mussel density. Taken together these and other studies conducted with *G. demissa* on the east coast suggest that the incorporation of ribbed mussels into living shoreline projects might benefit coastal restoration efforts. Recent surveys in Barataria and Terrebonne basins have demonstrated that *G. granosissima* is relatively ubiquitous across the marsh edge in intermediate to brackish waters with presence recorded at over 60% of sites surveyed (N > 500; Roberts lab, unpubl. data; Honig et al. 2015). Despite the potentially critical, but largely undocumented role of *G. granosissima* in supporting coastal marsh vegetation productivity and shoreline stability, and their common presence throughout our coastal landscape, ribbed mussels are rarely considered in coastal marsh restoration projects. Further, no studies have examined how any potential benefits of the presence of ribbed mussels on marsh shorelines might change as sea level continues to rise.

In this proposed CSAP project, we aim to recruit a student to advance our understanding of the processes that contribute to elevation gain including interactions between flooding and vegetation that produce shallow expansion. This work will directly inform the Master Plan by documenting the potentially large, but unmeasured role of *G. granosissima* in promoting vegetation production, shallow expansion and marsh edge stability. Given the observed ubiquity, but overlooked presence of *G. granosissima* across our coastal landscape, this project would directly inform implementation of living shoreline projects, and help ensure more resilient or stable shorelines. Dr. Roberts and is requesting funding to support a MS student that will be co-advised by Dr. Megan La Peyre in the School of Renewable Natural Resources at LSU. The recruited student would specifically address two broad and related questions about the potential utility of incorporating ribbed mussels into living shoreline projects under increased sea level conditions. We expect the student to play an active role in the design of their thesis project.

**Fig. 5.** Marsh organs. From NOAA (image by Jim Morris, Univ. SC).

The student will conduct two separate experiments using marsh "organs" (Fig. 1) for two growing seasons to vary the periods of inundation and exposure being experienced by vegetation. In the fall prior to the experiment, a wooden rack with shelves at 5 elevations will be constructed at the site. These elevations will tentatively include average relative elevations of +5cm, 0cm, -5cm, -10cm, and -15cm which approximate inundation times of 20, 40, 60, 80, and 100%, respectively and correspond to expected mean marsh elevations in 2010, 2020, 2030, 2040, and 2050 based on a 5mm $y^{-1}$ relative sea level rise rate projected for the region. For each experiment, 30-cm long PVC pipes will be capped at one end and filled with local wetland soil. Three individual young S. alterniflora plants (20±5 cm height) collected at the nearby marsh will be planted in each tube. Four replicate tubes at each organ level will randomly receive one of 5 different levels of mussel densities spanning the range observed along marsh shorelines in the region (Roberts lab, unpublished data): 0, 1, 2, 4, and 8 per tube (0, 127, 254, 509, 1018 mussels $m^2$). In the second experiment (year 2), the student will only examine 2 mussel densities (0 and high (8 per tube = 1018 mussels/m2) but will also examine how plants respond to growing in created marsh sediments (typically significantly lower in soil organic matter content, Roberts, unpublished data) versus natural marsh sediments with 4 replicates of each sediment type. The created marsh sediments will come from the Lake Hermitage Marsh Creation Project (BA-0042) where the Roberts lab is currently involved in a NOAA RESTORE funded project examining marsh food webs. In each experiment, the student will conduct live and dead stem counts and heights, leaf size and density, and plant reproductive structures, and measurements of photosynthetic yield (via PAM fluorometry), spectral characteristics (via a Unispec), and light and dark CO2 and CH4 gas fluxes to determine GPP and R rates (via a LGR greenhouse gas analyzer). At the end of the growing season (October), tubes will also be destroyed for porewater, soil, and belowground sampling. Aboveground and belowground plant as well as porewater and soil pools of C, N, and P will also be determined at the end of each experiment. Taken together these two studies will form the core of the recruited students MS thesis.