Drought and Construction Techniques Influence Ecosystem-Level Restoration of a Brackish Marsh

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Introduction

Compensatory habitat restoration can be a useful mitigation tool, but different restoration methods may vary in ecological success. Restoration construction designs vary in terms of soil placement and elevation gradients. These designs may alter features such as erosion and accretion rates and connectivity between habitat types, and may subsequently influence the development of plant and animal communities.

Habitat restoration success is often gauged by assessing a few prominent plant canopy characteristics. However, recovery of these structural canopy features may not correspond with the development of ecological functions such as food web support, nutrient cycling, or carbon storage. To evaluate the restoration of these functions, the standard practice of measuring percent plant cover may need to be augmented by concurrently documenting the development of soil and water characteristics in restored areas and comparing those characteristics to a reference site.

In concept, the ecological development of restored habitats will follow a trajectory towards reference conditions. However, variability in biotic and abiotic conditions over space and time may influence succession patterns in restored habitats. In particular, extreme environmental conditions, such as the exceptional drought in Texas in 2011, may cause restored habitats to diverge from reference conditions. Alternatively, drought may create uniformly stressful conditions and lead to convergence of reference and restored habitats.

Questions

- **Does plant canopy development correspond with the development of soil and water characteristics in a restored brackish marsh?**
- **Does habitat construction method influence ecological restoration trajectories?**
- **Is the influence of habitat construction method on marsh restoration altered by drought conditions?**

Methods

The study site (Fig. 1) included a ***reference*** marsh and restored emergent marshes that were constructed in 2007-2008 using three soil sources and designs: 1) mounds created using soil ***excavated*** from adjacent subtidal habitat, 2) mounds excavated then surrounded by dredge material to decrease surrounding water depth (***filled***), and 3) mounds created from dredge material ***pumped*** in directly from a nearby canal. Each habitat type was surrounded by vegetated containment terraces constructed with soil from an upland dredge disposal site.

Plant, soil, and water characteristics were measured quarterly beginning in January 2009; destructive sampling of soil and belowground biomass was performed once/year. To compare overall ecosystem structure among sites, discriminant function analyses were performed for the August 2009, September 2010, and September 2011 datasets.

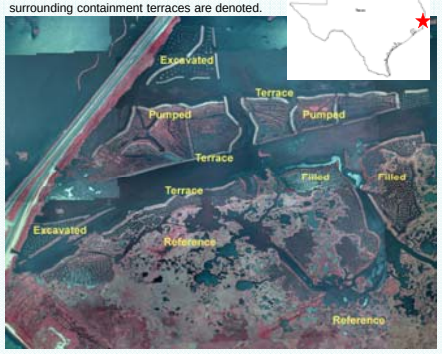
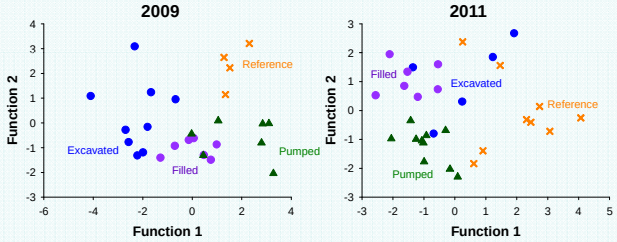


Figure 1: Study site in the Lower Neches Wildlife Management Area in Texas, USA. A reference area and three restoration construction methods with surrounding containment terraces are denoted.

Results

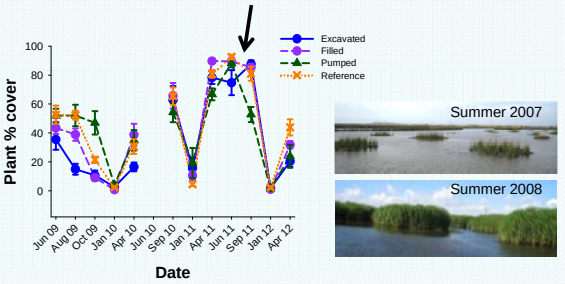
Emergent plants:

- Classification success decreased from 88.9% in 2009 to 80.6% in 2011
  - By 2011, there was more overlap among habitat types, but restored areas converged on each other and diverged from the reference site



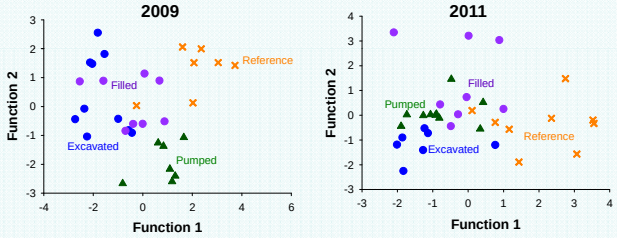
In 2009, discriminant function 1 (70.0% of the variability) was most strongly related to plant cover, and function 2 (28.2%) was related to belowground biomass. In 2011, discriminant function 1 (64.0%) was most strongly related to belowground biomass, and function 2 (31.5%) was related to plant cover.

Drought impacts on emergent plants were small and similar among habitat types

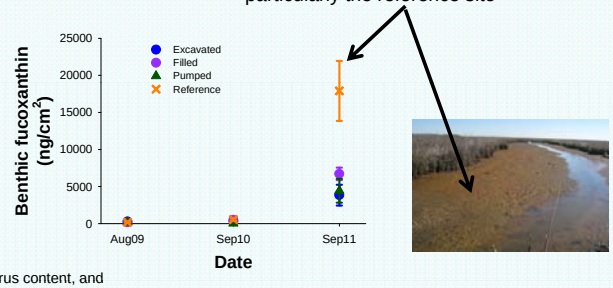


Soil characteristics:

- Classification success decreased from 87.5% in 2009 to 76.5% in 2011
  - By 2011, there was more overlap among habitat types, but restored areas converged on each other and diverged from the reference site



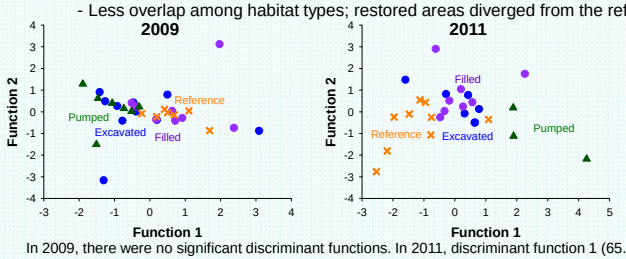
Drought caused blooms of benthic diatoms in all habitat types, particularly the reference site



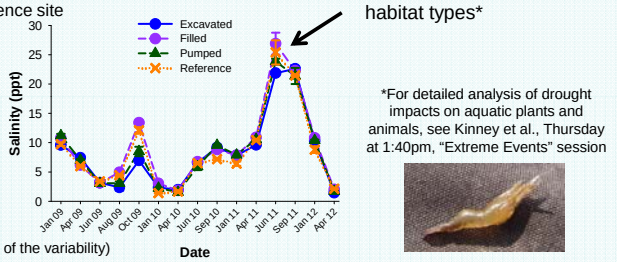
In 2009, discriminant function 1 (59.0% of the variability) was most strongly related to soil phosphorus content, and function 2 (34.7%) was related to soil nitrogen, sand, and organic contents. In 2011, discriminant function 1 (64.1%) was the only significant function, and it was most strongly related to benthic fucoxanthin and chlorophyll *a* concentrations.

Water characteristics:

- Classification success increased from 40.6% in 2009 to 70.4% in 2011
  - Less overlap among habitat types; restored areas diverged from the reference site



Drought caused a spike in salinity and a phytoplankton bloom in all habitat types*

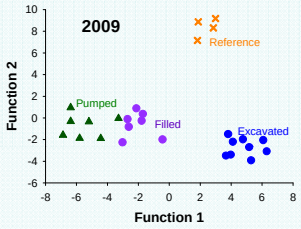


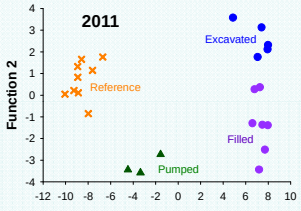
*For detailed analysis of drought impacts on aquatic plants and animals, see Kinney et al., Thursday at 1:40pm, "Extreme Events" session

In 2009, there were no significant discriminant functions. In 2011, discriminant function 1 (65.6% of the variability) was most strongly related to suspended solids and water column chlorophyll *a* concentration.

Ecosystem-level analysis:

- Includes plant, soil and water characteristics
- 100% classification success throughout the study period
  - All habitat types were unique
  - None of the restored areas converged on the reference area, even in drought conditions
  - Restored areas diverged from the reference site





In 2009, discriminant function 1 (51.1% of the variability) was most strongly related to emergent plant metrics, especially plant cover. Function 2 (38.4%) was related to soil characteristics, particularly soil phosphorus content. In 2011, discriminant function 1 (89.1%) was most strongly related to the concentration of suspended solids, and function 2 (5.6%) was related to emergent plant cover, plant belowground biomass, and water column chlorophyll *a* concentration.

Conclusions & Implications

- **At the emergent plant level, each construction approach successfully yielded at least some plant characteristics that were similar to the reference site, demonstrating that brackish marsh restoration is achievable on the short-term.**
- **As the suite of measured variables increased in complexity, the dissimilarity between the reference and restored sites increased.**
  - **Marsh recovery does not appear to be on a trajectory towards reference conditions.**
- **At the ecosystem level, each of the restoration types was unique relative to the others, and none of them resembled the reference site.**
- **Drought impacts were minor for emergent vegetation, but caused high salinity and blooms of benthic and planktonic microalgae, possibly altering trophic pathways in the marsh.**

Acknowledgements

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