Management of Coastal Ecosystem Restoration Sites under Increased Climatic Extremes: Effects of Hurricane Katrina on Wetlands Restoration Projects in Coastal Mississippi

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Climate change & coastal ecosystems

Low-lying coastal ecosystems are at the forefront of climate change:

- Projected increase in sea level rise in the southeastern US
- Salt water intrusion
- Surge from intensifying tropical storms

Negative effects on plant species:

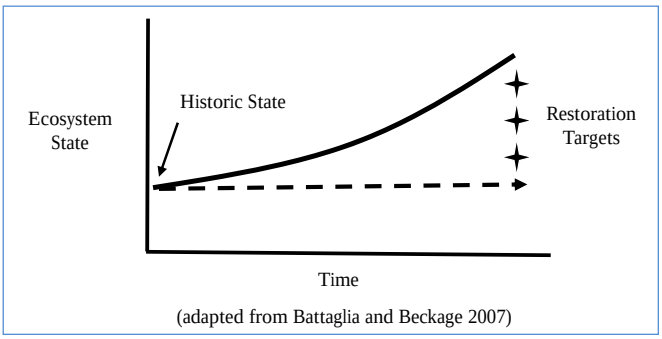
- Intolerant of environmental changes following storm surge events
- Incapable of reestablishing thereafter

Restoration & mitigation banking

Role of historic reference conditions:

- often used for restoration targets
- form the basis of mitigation performance metrics

Resiliency of the restored ecosystems may be insufficient to maintain target plant community composition in extreme disturbance events.



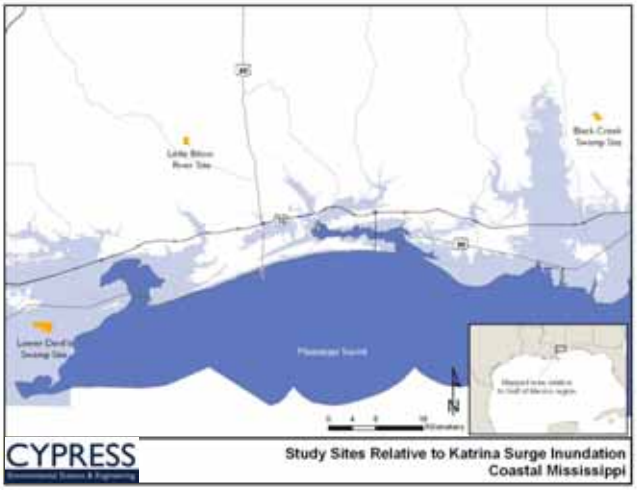
(adapted from Battaglia and Beckage 2007)

Study objectives

- Evaluate responses of target assemblages in restored habitats subject to different magnitude and type of hurricane disturbance
- Quantify compositional shifts in the community most impacted by this disturbance event
- Examine composition relative to restoration targets (reference conditions)
- Take advantage of a natural experiment – Hurricane Katrina

Study sites

- Three mitigation bank sites in coastal Mississippi
- Pine savanna restoration areas
- Under management since 2000:
  - annual prescribed burning
  - drum chopping and herbicide treatment of areas affected by exotic species invasion
- All sites impacted by hurricane-force winds during Hurricane Katrina event
- Lower Devil's Swamp was inundated with ~2.5m of storm surge



Target plant community

Wet pine / bunchgrass savannas

- Sparse slash pine (*Pinus elliottii*) and longleaf pine (*Pinus palustris*) overstory.
- Minimal shrub layer.
- Highly diverse understory with forbs and graminoids.
- Disturbance-dependent system adapted to frequent fire and can be managed with prescribed burning.

Field methods

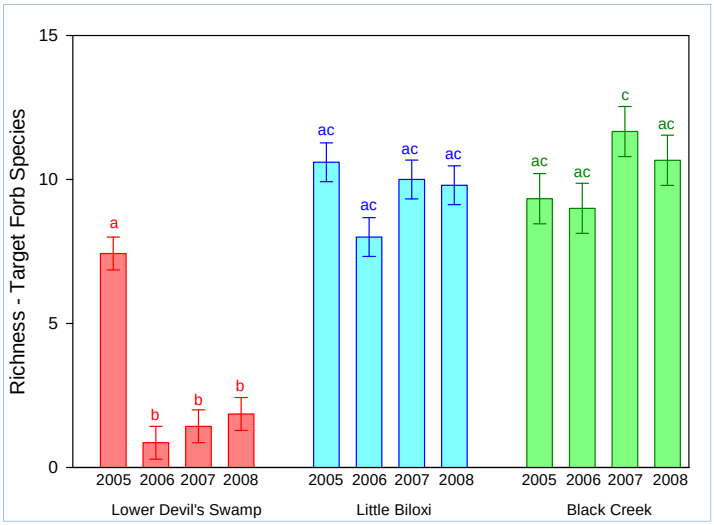
- Annual mitigation compliance monitoring data collected 2005 – 2008.
- Checklist of target forb species.
- Presence and absence of the target forb taxa are recorded each year within a 5-m radius of each sampling point.
- At the Lower Devil's Swamp site supplemental data were collected on percent cover of dominant (≥ 5% percent cover by visual estimate) species.

Data analyses

- Species richness comparison over time and across sites
  - Repeated measures ANOVA
  - *a posteriori* pairwise comparisons of least-squares means with Bonferroni correction
- Evaluation of compositional trends in target forb assemblages
  - NMDS ordination
  - Vector fitting to evaluate composition relative to species richness
- Comparison of community composition across sites and time
  - Repeated measures PERMANOVA for target forbs at all sites across all years
  - Repeated measures PERMANOVA for target forbs and graminoids at the flooded site (Lower Devil's Swamp)

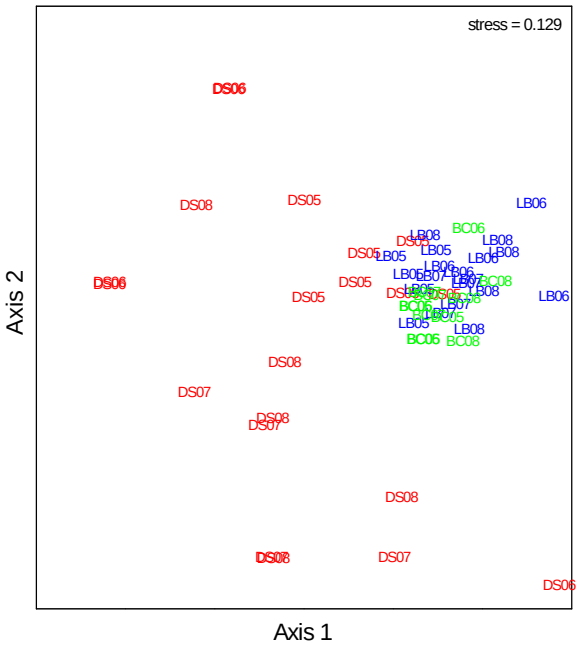
Results: Forb richness

- Repeated Measures ANOVA
- Richness of savanna forbs at the Lower Devil's Swamp site declined significantly following Hurricane Katrina and has not yet recovered
- Little Biloxi and Black Creek sites did not differ in average forb richness and were similar to that of the pre-Katrina Lower Devil's Swamp community
- Significant time x site interaction for richness of target forb species ($F_{6, 36} = 11.20, p < 0.0001$)



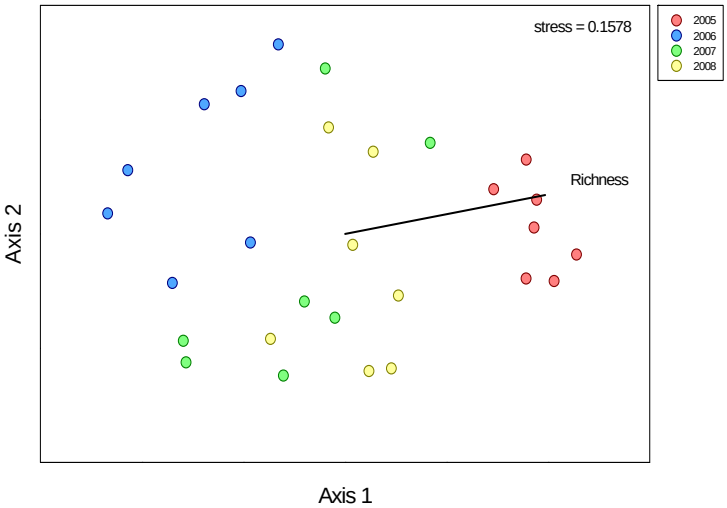
Results: Community composition

- NMDS ordination and Repeated Measures PERMANOVA
- Target forb assemblages at Little Biloxi and Black Creek sites were similar to each other and to the pre-Katrina community at Lower Devil's Swamp
- Composition at Lower Devil's Swamp diverged significantly after the storm to a lower diversity subset assemblage
- Significant time x site interaction for forb community composition (pseudo $F_{6, 29} = 3.85$, $p = 0.001$)



Results: Flooded site

- NMDS ordination, vector fitting, and Repeated Measures PERMANOVA
- Compositional changes were most pronounced between 2005 and 2006
- Assemblages were still variable in 2007 and 2008 but appeared to be shifting back toward pre-storm composition
- Major trend in the ordination was significantly correlated with species richness ($r = 0.9553$, $p < 0.0001$)
- Significant compositional shifts with time (pseudo $F_{3, 24} = 9.16$, $p = 0.001$)



Discussion: Disturbance effects

- Degree of disturbance caused by Hurricane Katrina varied substantially across coastal Mississippi
- All three study sites were exposed to hurricane-force winds, but only the site that experienced storm surge shifted significantly over time in richness and community composition
- Trajectories suggest limited recovery in understory
- Assemblages have not achieved pre-Katrina richness
- Uncertain whether community composition will return to historic reference conditions

Discussion: Mitigation implications

Historic reference standards:

- Quantifiable objectives needed to measure the success of conservation and restoration
- Restoration to historic reference conditions may be expensive or not ecologically feasible if a major state change occurs related to climate change

Flexible restoration targets:

- Restoration design that integrates the potential to respond to future natural disturbances may increase the capacity of these ecosystems to respond to climate change and provide a long-term cost-effective approach
- Incorporation of flexible restoration contingencies into the criteria for mitigation banking may be the most pragmatic solution

Research is needed on resiliency of coastal ecosystems to climate change

- To inform and enhance the mitigation and restoration process
- To strengthen the capacity of restored ecosystems to respond to climate change and associated extreme disturbance events

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