Development of wetland structure, functions and services through tree planting:
A large scale field experiment in Virginia, USA

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Ecological Restoration

• “The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” (SER International Primer on Ecological Restoration 2004)
  
  – Applied science
  
  – Active engagement and intervention

Goals:
- Technically and socially feasible
- Scientifically valid
Return
- Structure
- Function
- Services
- Self Sustaining
- Connectivity
- Resiliency

Aldo Leopold

Figure 1. Graphic representation of the structure–function model. Reproduced with permission from Bradshaw (1984).
Ecological Restoration Challenges

• Knowledge of the ecosystem
  – ‘Acid test’ of ecology

• Determining Success
  – Each project has different goals

• Complexity of possible manipulations
  – And outcomes

Zedler and Callaway 1999

Cortina et al. 2006
Forested Headwater Wetlands
Knowledge of the system

• Landscape position
  – Upper reaches of non-tidal freshwater streams
  – Stream flow < 5ft³/second (33 CFR Section 330.2 (d))
  – 1st and 2nd order streams (Havens et al 2006a, Rheinhardt et al. 2012)
  – 73% of all stream lengths in U.S. (Brinson 1993a)
  – 43% of the vegetated wetlands in VA (Hershner et al. 2003)

• Structure
  – Hydrology: Overland and subsurface flow from uplands
  – Vegetation: Tree biomass accounts for the majority of living (>96%) and total biomass (>57%) (Rheinhardt et al. 2012)
    • Species varies by physiographic province and successional stage
    • Piedmont: *Acer rubrum, Liriodendron tulipifera, Quercus rubra* (Rheinhardt et al. 2009)
Forested Headwater Wetlands

Knowledge of the system

• **Ecosystem Functions**
  – Retention of sediments *(Hupp 1993)*
  – Transformation, cycling and retention of nutrients and pollutants *(Craft and Casey 2000, Noble et al 2011)*
  – Primary and secondary production
  – Water storage
  – Groundwater recharge
  – Plant and animal habitat

• **Ecosystem Services** *(NRC 1995, Mitsch and Gosselink 2007)*
  – Flood mitigation
  – Water quality enhancement
  – Timber production
  – Animal products
  – Aesthetics
  – Maintenance of biodiversity
  – Air quality enhancement
Forrested Headwater Wetlands

Determining Restoration Success

• Measure structure, function and services
  – Ecosystem functions and services are difficult to measure
  – Wetland Functional Assessment Procedures
    • >100 different procedures (Kusler 2006) (Ex. HGM)
• Comparison to reference sites
  – Reference sites are often much older and mature
• Ecological Performance Standards (Mitigation)
  – Based on conditions in reference sites
  – Often measurements of structure
    • Poor indicators of functions (NRC 2001, Cole 2002)
  – Virginia Woody Vegetation Requirements
    • >990 stems/ha (440 stems/acre)
    • 50% of all dominant woody plants FAC or wetter
    • 10% height growth / year (5 ft in 5 years, 10 ft in 10 years)
    • OR 30% canopy closure
Forested Headwater Wetlands

Restoration

• Degraded, damaged or destroyed
  – 42% of wetlands have been lost in VA (many forested)
  – Agriculture, forestry, urban/suburban development

• Purposes of forested wetland restoration
  – State and federal laws and regulations (mitigation)
  – Failed farming
  – Timber production
  – Reclamation of disturbed habitat
  – State and federal goals (Chesapeake 2000)
  – Conservation or enhancement

• Restoration Failure
  – Moreno-Mateos et al. 2012 – Meta-analysis
    • 621 sites up to 100 years old
    • Structure and functioning was lower than reference sites
  – Reasons for failure
    • Numerous restoration techniques (procedures) that interact in complex ways
The purpose of this study is to determine how these factors influence planted tree establishment, structure, and functioning (growth), in restored forested headwater wetlands therefore enhancing the probability of replacing lost ecosystem structure, function and services.

*RPM
Seven Species

Betula nigra (River Birch) (FACW)

Liquidambar styraciflua (Sweetgum) (FAC)

Platanus occidentalis (Sycamore) (FACW)

Salix nigra (Black willow) (FACW)

Quercus bicolor (Swamp white oak) (FACW)

Quercus palustris (Pin oak) (FACW)

Quercus phellos (Willow oak) (FAC)

63 Unique Combinations (n=44)
Chapter Descriptions

• Treatment: Species and stocktype selection (various environmental conditions)

• Chapter 1. Structure
  – Height and canopy growth
    • Compare Ecological performance standards

• Chapter 2. Function
  – Primary Productivity

• Chapter 3. Services
  – Carbon, nitrogen, phosphorus temporary and long term storage
Results

• Survival
  – Gallons typically greater than bare root and tubeling (dropping below 58% in ~3 yr)
  – Primary successional species did slightly better (Except *P. occidentalis* and *Q. bicolor*)
  – *Q. palustris* and *Q. phellos* fell below 58% (~3 yr)

• Height Growth
  – Differences initially (gallon high) – All 3 converge through time
  – Some bare-root and tubeling initially below 10% (Approach 10% ~4 yr)
  – Primary species higher typically

• Canopy Diameter
  – Gallons typically larger but other stocktypes catching up (*P. occidentalis* bare root and tubeling surpassing)
  – Primary species reaching CD performance standard in ~3yr
  – Oaks not reaching CD performance standard in ~4yr

• CD Growth
  – Bare-roots and tubelings high initially – All 3 converge through time
  – Oaks have slower canopy growth
Preliminary Chapter 2 Results

- Significant relationship between stem basal area and above and belowground biomass
- Use stem basal area as surrogate for biomass to suggest differences in primary production among species
- Primary species have rapid increase in basal area compared to secondary species (Oaks)
For all species
p<0.001
t²= 0.7446

Betula nigra: p<0.001 t²=0.8596 n=45
Liquidambar styraciflua: p<0.001 t²=0.7918 n=51
Platanus occidentalis: p<0.001 t²=0.7883 n=54
Salix nigra: p<0.001 t²=0.5429 n=46
Quercus bicolor: p<0.001 t²=0.4099 n=52
Quercus palustris: p<0.001 t²=0.7248 n=50
Quercus phellos: p<0.001 t²=0.8236 n=52
Conclusions

• Stocktype is important for survival (only initially for growth)
  – Suggests that stocktype is not an important factor for restoring primary production following establishment

• Stocktypes have differences in structure (gallon typically bigger CD)
  – May support other functions
    • Animal habitat
    • Plant habitat (nurse species - shade)

• Primary species increase in basal area suggest that they may quickly restore primary productivity

• Restoration Applications
  – Balance costs with survival
  – Established bare roots may eventually (~3 years) have similar primary production to gallon stocktypes
  – Plant variety of species and stocktypes to insure restoration of several functions (biodiversity)
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