A comparison of vegetation and soils of restored streams and their references in the NC Piedmont

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References are unrestored, generally undisturbed streams used as models for stream restoration design.
Disturbance Promotes Invasion!

Fluctuating Resource Theory - A plant community becomes more susceptible to invasion whenever there is an increase in the amount of unused resources.

Community invasibility increases when there are surplus resources and invasive propagules present. Disturbance promotes invasion because it increases resource availability both directly and indirectly. - Davis et al., 2000


*Rosa rugosa* seedlings in disturbed dune habitats had up to 95% greater biomass after 2 years than seedlings in undisturbed dunes. - Kollmann et al., 2007
a very basic question –

What happens at these sites once the monitoring is over?
11 Restorations – 4 to 12 years old

6 References – unrestored streams used as models in restoration design
Are the restoration sites more invaded than the reference sites?

- Presence of herbaceous and woody exotic species, in terms of number of species, percent cover, frequency, and density

Exotic species are those “introduced by whatever means and demonstrably established and reproducing (sexually or vegetatively) as a component of the flora” (Weakley, 2010)

- Presence of woody native species, in terms of number of species, percent cover, frequency, and density
2x2 m plots: n=283, determined % cover of all exotic spp. and native woody spp. growing in or hanging over

4 m wide belt transects: recorded the presence and dbh of all woody plants taller than 1.3 m
Do the restoration site soils resemble the natural riparian soils?

- **Chemical and physical properties**: P, Ca, Mg, Zn, Cu, Fe, Na, Mn, K, S, CEC, base saturation, Mehlich buffer pH, pH, bulk density, humic matter, weight per volume, % sand, % clay, % silt

- **Morphological properties**: horizons present, horizon thickness, boundaries, matrix color, presence and color of mottles, texture, ped grade, ped size, ped shape, moist consistence, wet consistence, presence of roots
The restoration sites are more invaded than the references.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Restorations</th>
<th>References</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # Exotic spp.</td>
<td>51</td>
<td>22</td>
<td>0.008</td>
</tr>
<tr>
<td>Mean % Cover Exotic spp.</td>
<td>34</td>
<td>10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Density of Exotic spp. (stems/ha)</td>
<td>833</td>
<td>418</td>
<td>0.087</td>
</tr>
<tr>
<td>Total # Native Woody spp.</td>
<td>85</td>
<td>65</td>
<td>0.269</td>
</tr>
<tr>
<td>Mean % Cover Native Woody spp.</td>
<td>48</td>
<td>143</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Density of Native Woody spp. (stems/ha)</td>
<td>5878</td>
<td>2715</td>
<td>0.010</td>
</tr>
<tr>
<td>Exotic Species</td>
<td>Restorations</td>
<td>References</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
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<td>------------</td>
<td></td>
</tr>
<tr>
<td>Japanese stiltgrass</td>
<td>56</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Japanese honeysuckle</td>
<td>40</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>porcelain berry</td>
<td>26</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Asiatic dayflower</td>
<td>17</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ground ivy</td>
<td>15</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sericea lespedeza</td>
<td>14</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Chinese privet</td>
<td>13</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>spotted ladysthumb</td>
<td>13</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Japanese hops</td>
<td>12</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>white mulberry</td>
<td>11</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>turf grass</td>
<td>10</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>mimosa</td>
<td>10</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>white clover</td>
<td>10</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>
• **17 (37%)** of the species planted at the restorations were **not found** at the references.

• **11** additional planted species had **<5%** frequency in the reference plots.

**Morella cerifera** (wax myrtle) was planted at one restoration, but it is considered **exotic** in the NC Piedmont.
Did the restoration site soils resemble natural riparian soils?

These soil properties **differed** by site type:

- bulk density
- Mehlich buffer pH
- calcium
- copper
- manganese
- CEC
- pH
- magnesium
- iron
- phosphorus
- base saturation
- humic matter
- zinc
- sodium

These soil properties **did not differ** by site type:

- potassium
- sulfur
- % clay
- % silt
- % sand
Is this important news?
Some of these differences were very large:
calcium was 2.7x higher

copper was 3.5x higher

zinc was 5.6x higher

in the restoration site soils than the reference site soils
Other differences were significant, but had smaller magnitudes. These were higher in the restoration site soils:

- **Bulk density** - $1.1 \times$ higher
- **CEC** - $1.6 \times$ higher
- **Base saturation** - $1.4 \times$ higher
- **Phosphorus** - $1.7 \times$ higher
- **Sodium** - $1.3 \times$ higher
Three properties had higher values in the reference site soils than the restoration site soils:

- iron - \(1.3\times\) higher
- manganese - \(1.4\times\) higher
- humic matter - \(1.2\times\) higher
Reference plots

Restoration plots
These soil morphological characteristics differed by **site type** in the first horizon:

- horizon thickness
- horizon boundary
- matrix hue
- color (name)
- texture
- ped size
- ped shape
- moist consistence

These soil morphological characteristics differed by **site** in the first horizon:

- matrix hue
- texture
- ped size
- moist consistence
- stickiness
- plasticity
Soil properties accounted for:

20% of the variation in exotic species cover

\[ \text{ESP} = f(\text{humic matter, pH, Mn, Cu}) \]

34% of the variation in native woody species cover

\[ \text{NSP} = f(\text{bulk density, Ca, Mg, Mn}) \]
Do we care about form? function? or both?
Invasives can also

- alter stream channel morphology (Richardson et al. 2007)
- affect soil community composition (Wolfe and Klironomos 2005)

A lot can change with time, but these invasives can be persistent.

>50% tolerate partial shade
25% tolerate full shade
Southeastern projects in the National River Restoration Society Synthesis database:

- 18% did not state any goals
- 29% listed one goal

Interviews with S.E. US restoration project managers:

- 65% projects had success criteria
- 28% had measurable criteria
- Soils were never listed as a monitored variable

(from Sudduth et al. 2007.)
Implications for Restoration

• Invasive control might need to be increased

• Planting species that are suited for the riparian habitats is important

• Soil testing and amending can be done

• Reference sites are not uninvaded

• Explicit structural and/or functional goals with measurable performance criteria can be set