Evaluating the Effectiveness of Stream Restoration in Maryland: Integrating Existing and New Data from Restoration Monitoring

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Research Questions

1. How does effectiveness of stream restoration at reducing nutrient and sediment loads vary among different projects implemented in MD?

2. What factors influence project performance?
Potential factors influencing restoration performance

• Stream position in watershed
• Watershed imperviousness
• Catchment size (area)
• Restoration design
• Magnitude of discharge
• Loading concentrations, dominant species of N and P
• Catchment topography, channel slope
Objectives

• To use pre- and post-restoration data from a number of streams in MD monitored with compatible methodology to determine changes in nutrient and sediment loads.

• Calculate effectiveness in terms of removal rates (kg/ha/yr) and relative removal (% of load in pre-restoration stream/site).

• Examine potential factors influencing project performance.
## Study Streams

<table>
<thead>
<tr>
<th>Stream</th>
<th>Drainage area (ha)</th>
<th>Imperviousness (%)</th>
<th>Position in watershed</th>
<th>Watershed</th>
<th>Physiographic region</th>
<th>New Data Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dividing Cr.</td>
<td>89</td>
<td>32</td>
<td>Lowland</td>
<td>Magothy</td>
<td>Coastal Plain</td>
<td>YES</td>
</tr>
<tr>
<td>Cabin Br. (Saltworks)</td>
<td>49</td>
<td>55</td>
<td>Lowland</td>
<td>Severn</td>
<td>Coastal Plain</td>
<td>YES</td>
</tr>
<tr>
<td>Church Cr.</td>
<td>227</td>
<td>56</td>
<td>Lowland</td>
<td>South</td>
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<td>YES</td>
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<tr>
<td>Cypress Cr.</td>
<td>143</td>
<td>46</td>
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<td>Magothy</td>
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</tr>
<tr>
<td>Howard's Br.</td>
<td>96</td>
<td>11</td>
<td>Lowland</td>
<td>Severn</td>
<td>Coastal Plain</td>
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</tr>
<tr>
<td>Wilelinor</td>
<td>106</td>
<td>48</td>
<td>Lowland</td>
<td>South</td>
<td>Coastal Plain</td>
<td>NO</td>
</tr>
<tr>
<td>Linnean</td>
<td>13</td>
<td>27</td>
<td>Headwater</td>
<td>Rock Cr.</td>
<td>Piedmont</td>
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<tr>
<td>Park Drive</td>
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<td>Headwater</td>
<td>Anacostia</td>
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</tr>
<tr>
<td>Clements Cr. (C. Hills)</td>
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<td>Headwater</td>
<td>Severn</td>
<td>Coastal Plain</td>
<td>NO</td>
</tr>
<tr>
<td>Red Hill Br.</td>
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<td>-</td>
<td>Headwater</td>
<td>Patuxent</td>
<td>Coastal Plain</td>
<td>NO</td>
</tr>
</tbody>
</table>
Monitoring Designs

Before-After restoration

Control = Before

Above-Below restoration

Control = Above

Paired-catchments

Control = Similar catchment

Before/After/Control/Impact (BACI)

Control = Similar catchment before and after
Methods used for data collection: Rain, discharge and water quality

Measuring rain and discharge

Rain gauges

Water sampling

Base flow

Stormflow
Important monitoring attributes

- Data were collected for at least 1 year before and 1 year after restoration.
- Data were collected during base flow and stormflow conditions.
- Base flow samples were collected monthly to quarterly.
- Stormflow samples were collected for at least 8 storm events per year in each site.
- Rain depths and stream flow were recorded continuously.
- Rain data were collected on site for each catchment.
Restored streams were effective at reducing most pollutant loads but reductions varied.
Effectiveness of headwater channels was higher than of lowland channels

TSS
- 76 to 91%
- 0 to 49%

TN
- 36 to 82%
- 0 to 34%

TP
- 51 to 76%
- 0%
Effectiveness was correlated with catchment size.

- **TSS retention vs catchment area**: $R^2 = 0.3764$
- **TN retention vs catchment area**: $R^2 = 0.4576$
- **TP retention vs catchment area**: $R^2 = 0.7724$
Effectiveness decreased with increased imperviousness in catchment

TN retention vs imperviousness

R² = 0.5297

TSS retention vs imperviousness

R² = 0.6036

TP retention vs imperviousness

R² = 0.5577
Stormflow was a dominant component of annual discharge in smaller and more impervious catchments.
Stormflow concentrations decreased substantially in headwater channels.
Restored stream capacity to reduce loads in stormflow tend to decrease with rain size.

Example from a headwater channel

Example from a lowland channel
Rain events > 1 in were rare but contributed to ~ half of the total annual rain in catchments.
Summary

1. 80-90% of the restored streams examined reduced TSS and TN loads, but only 40% reduced TP loads.

2. Load reduction was relatively higher in headwater channels.

3. Project performance was associated with stream position in watershed, % imperviousness, and size of catchment.

4. Stormflow contributed most of the annual discharge in headwater streams; in lowland channels base flow was important as well.

5. Performance of headwater channels was based on their capacity to reduce loads in stormflow.

6. Performance of lowland channels was based on their capacity to reduce loads in both base flow and stormflow.
Final Remarks

1. Despite inferior performance of lowland channels, they can potentially reduce large loads given their size.
2. Trade-offs associated with lowland channels should be carefully considered.
3. Other factors are likely to influence restoration performance.
4. Synthesis and evaluation of monitoring data is essential to improve our capacity to predict the outcomes of restoration projects as well as to develop more cost-effective monitoring strategies.
Acknowledgments
Filoso
Translation Slides
What does this mean for me?

- The efficacy of stream restoration at reducing nutrient and sediment loads varies among projects.
- Upland streams restored with RCS are generally more effective than valley channels.
- TN, TP, and TSS were consistently reduced in upland systems, while only TN and TSS were reduced in valley systems, but at lower rates.
- Efficacy is associated with the capacity of streams to retain nutrients and sediments during a wide range of storm sizes.
- Restoration improves retention in upland projects during small and large storms, but ONLY in smaller storms in valley channel projects.
- The frequency of storms > 1 inch was only 9% during the monitoring period but they contributed almost 50% of the total rain volume.
What does this mean for me?

What do I take from this if I am a practitioner?
• Implement projects in headwater areas where feasible to maximize nutrient/sediment reductions.
• Upland stormwater best management practices and upland stream restorations may decrease the effect of high flows on downstream areas (e.g. 2018).

What do I take from this if I am a regulator?
• Consider site location as an important factor when reviewing potential projects.