Maryland’s large-scale eelgrass (*Zostera marina*) restoration: A retrospective analysis of techniques, costs and monitoring

Becky Raves Golden  
August 5th, 2011
• Chesapeake 2000 Agreement
  – By 2002, implement a strategy to accelerate protection and restoration of SAV beds in areas of critical importance to the Bay’s living resources.

• Strategy to Accelerate the Protection and Restoration of Submerged Aquatic Vegetation in the Chesapeake Bay
  – Accelerate SAV restoration by planting 1,000 acres of new SAV beds by December 2008.
Project Goals

- Identify sites for restoration
- Conduct large-scale restoration with eelgrass seeds
- Evaluate associated factors
- Produce a final, technical analysis
Light attenuation + Dissolved Inorganic Nitrogen + Dissolved Inorganic Phosphorus + Total Suspended Solids + Chlorophyll

Percent Light at Leaf Model

Percent Light at Water Model

Water Quality

Historical Bay Grass Coverage

Bay Grass Restoration Potential

Depth × Shellfish Harvesting Area × Existing Bay Grass Coverage ×
Restoration Site Selection

- Patuxent R.
- Potomac R.
- Piankatank R.
- York R.
- Coastal Bays
MARYLAND DEPARTMENT OF NATURAL RESOURCES

Seed Dispersal – Technique 1
Seed Dispersal – Technique 2

Fall Seed Broadcast

Seeds
• Seed collection yield is variable
• Mechanical more efficient than manual collection using snorkeling/SCUBA

<table>
<thead>
<tr>
<th>Collection</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection method</td>
<td>Manual</td>
<td>Mechanical</td>
<td>Mechanical</td>
<td>Manual</td>
<td>Mechanical</td>
<td>Total</td>
</tr>
<tr>
<td>No. of collection days</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Z. marina yield (L)</td>
<td>22796</td>
<td>89918</td>
<td>204482</td>
<td>1451</td>
<td>2467</td>
<td>3918</td>
</tr>
<tr>
<td>Collection rate (L/day)</td>
<td>2849</td>
<td>9991</td>
<td>22720</td>
<td>181</td>
<td>617</td>
<td>392</td>
</tr>
</tbody>
</table>

| Processing and Storage      |          |          |          |          |          |          |
| Volume of Z. marina seeds processed (L) | N/A      | 71.9     | 109.8    | 32.5     | 48.8     | 70.3     |
| Viable Z. marina seeds remaining after storage (no. and (% of total)) | 345000 (16) | 1058400 (7) | 2527000 (20) | 349888 (87) | 540867 (21) | 961567 (60) |

| Dispersal                    |          |          |          |          |          |          |
| Seeds dispersed through spring seed bag method (%) | 0        | 92       | 71       | 38       | 6        | 0        |
| Seeds dispersed through fall broadcast method (%) | 100      | 8        | 29       | 62       | 94       | 100      |

Busch et. al, 2010
## Cost Comparison

### Spring Seed Buoy

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Cost of Method</th>
<th>Total Number of Seeds</th>
<th>Cost per seed dispersed</th>
<th>Cost per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>$48,194</td>
<td>2,155,000</td>
<td>$0.02</td>
<td>$4,473</td>
</tr>
<tr>
<td>2005</td>
<td>$30,464</td>
<td>2,255,000</td>
<td>$0.01</td>
<td>$2,702</td>
</tr>
<tr>
<td>2006</td>
<td>$21,413</td>
<td>108,000</td>
<td>$0.20</td>
<td>$39,654</td>
</tr>
<tr>
<td>2007</td>
<td>$2,850</td>
<td>17,500</td>
<td>$0.16</td>
<td>$32,571</td>
</tr>
<tr>
<td>Mean</td>
<td>$25,730</td>
<td>1,133,875</td>
<td>$0.10</td>
<td>$19,850</td>
</tr>
</tbody>
</table>

### Fall Seed Broadcast

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Cost of Method</th>
<th>Total Number of Seeds</th>
<th>Cost per seed dispersed</th>
<th>Cost per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>$125,616</td>
<td>374,500</td>
<td>$0.34</td>
<td>$67,085</td>
</tr>
<tr>
<td>2005</td>
<td>$153,294</td>
<td>1,802,500</td>
<td>$0.09</td>
<td>$17,009</td>
</tr>
<tr>
<td>2006</td>
<td>$110,056</td>
<td>349,500</td>
<td>$0.31</td>
<td>$62,979</td>
</tr>
<tr>
<td>2007</td>
<td>$142,718</td>
<td>540,000</td>
<td>$0.26</td>
<td>$52,859</td>
</tr>
<tr>
<td>2008</td>
<td>$117,708</td>
<td>961,567 (800,000)</td>
<td>$0.12</td>
<td>$24,473</td>
</tr>
<tr>
<td>Mean</td>
<td>$129,878</td>
<td>802,613</td>
<td>$0.22</td>
<td>$44,881</td>
</tr>
</tbody>
</table>

### Grand Mean

<table>
<thead>
<tr>
<th>Total Cost</th>
<th>Total Number of Seeds</th>
<th>Cost per seed dispersed</th>
<th>Cost per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>$77,804</td>
<td>969,744</td>
<td>$0.17</td>
<td>$32,365</td>
</tr>
</tbody>
</table>
Project Summary

- 2003-2008
- 2 Rivers, 10 sites
- ~13 million eelgrass seeds
- 66 acres
- $0.17/seed (~$32,000/acre)
• Eelgrass monitoring: May, August, October
• Spatial & Temporal Habitat monitoring: April – October
• Compare by Seed dispersal method, Year & Site
Seedling Establishment

- % of seeds observed as seedlings
- Highly variable (0 – 8%)
- 80% of sites with observed seedlings

% Seedlings Observed

- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 10
• No correlation with seedling establishment

• Summer shoot density was inversely related to summertime exceedences of habitat tolerances (Golden et al., 2010)

• 20% of sites remain vegetated
  – up to 6 years

Golden et al., 2010
Project Goals

• Identify sites for restoration
• Conduct large-scale restoration with eelgrass seeds
• Evaluate associated factors
• Produce a final, technical analysis
• Restoration site selection is critical
  – determining restoration site potential takes several years
  – refinement of SAV habitat criteria for restored populations of Z. marina is needed

• Seed collection and storage is labor intensive and donor beds are unpredictable

• Monitoring plant health and water quality on meaningful frequencies is time consuming and expensive
Lessons Learned

• The use of seeds is a **practical option** for large-scale *Z. marina* restoration in the Chesapeake Bay

• The cost to seed one acre of unvegetated bottom was consistently **cheaper utilizing the buoy-deployed spring seed bags than the fall seed broadcast method**

• **Fall seed broadcast resulted in greater seedling establishment** and plant densities than with the spring seed bag method
Considerations

• The role of long-term trends and regional events or extremes in SAV habitat conditions must be considered in restoration projects

• Monitoring frequency and scale is crucial to provide sufficient resolution in order to explain observed changes in eelgrass shoot density and long-term survival

• How do you define successful SAV restoration?
Maryland Park Service
Maryland Conservation Corps
Many, many volunteers