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

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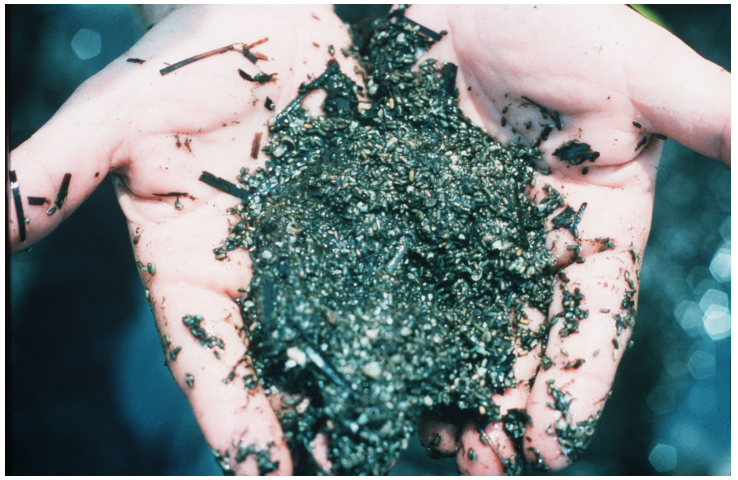
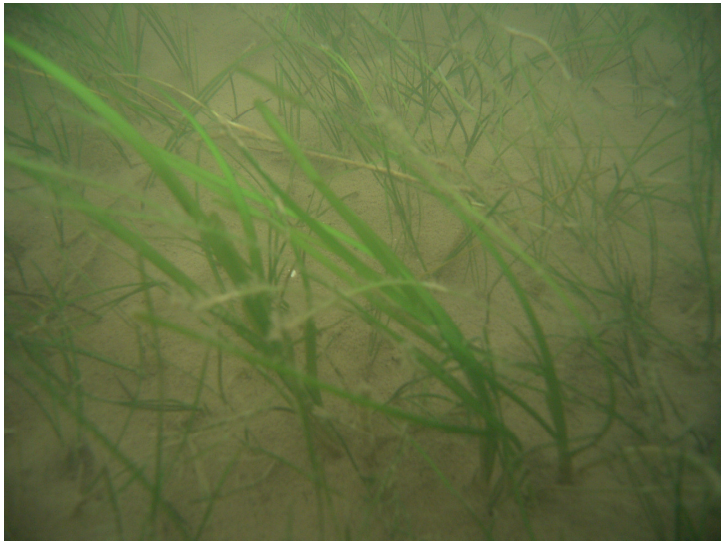
SAV Restoration in Chesapeake Bay

- 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.*

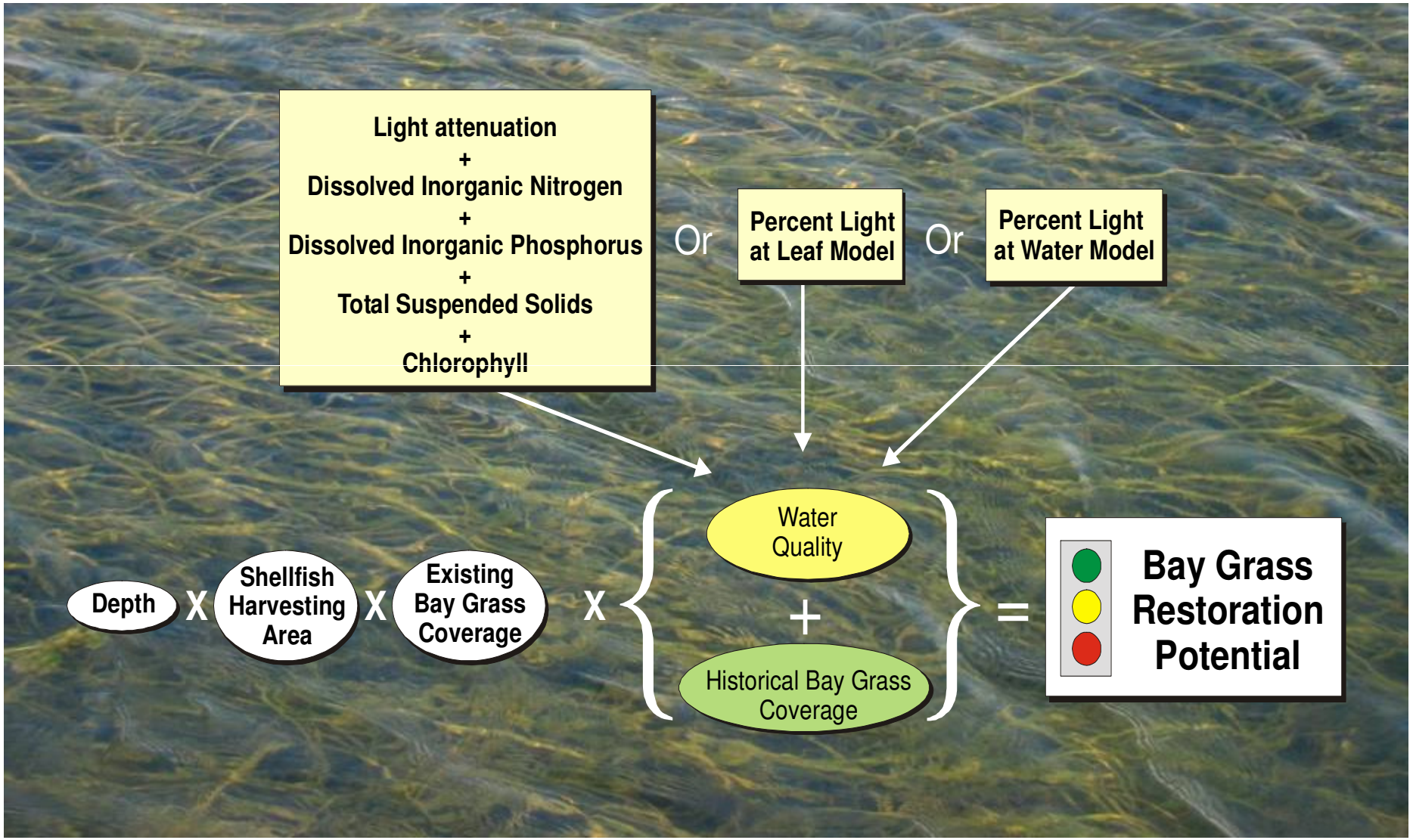
Project Goals

- Identify sites for restoration
- Conduct large-scale restoration with eelgrass seeds
- Evaluate associated factors
- Produce a final, technical analysis





Restoration Site Selection



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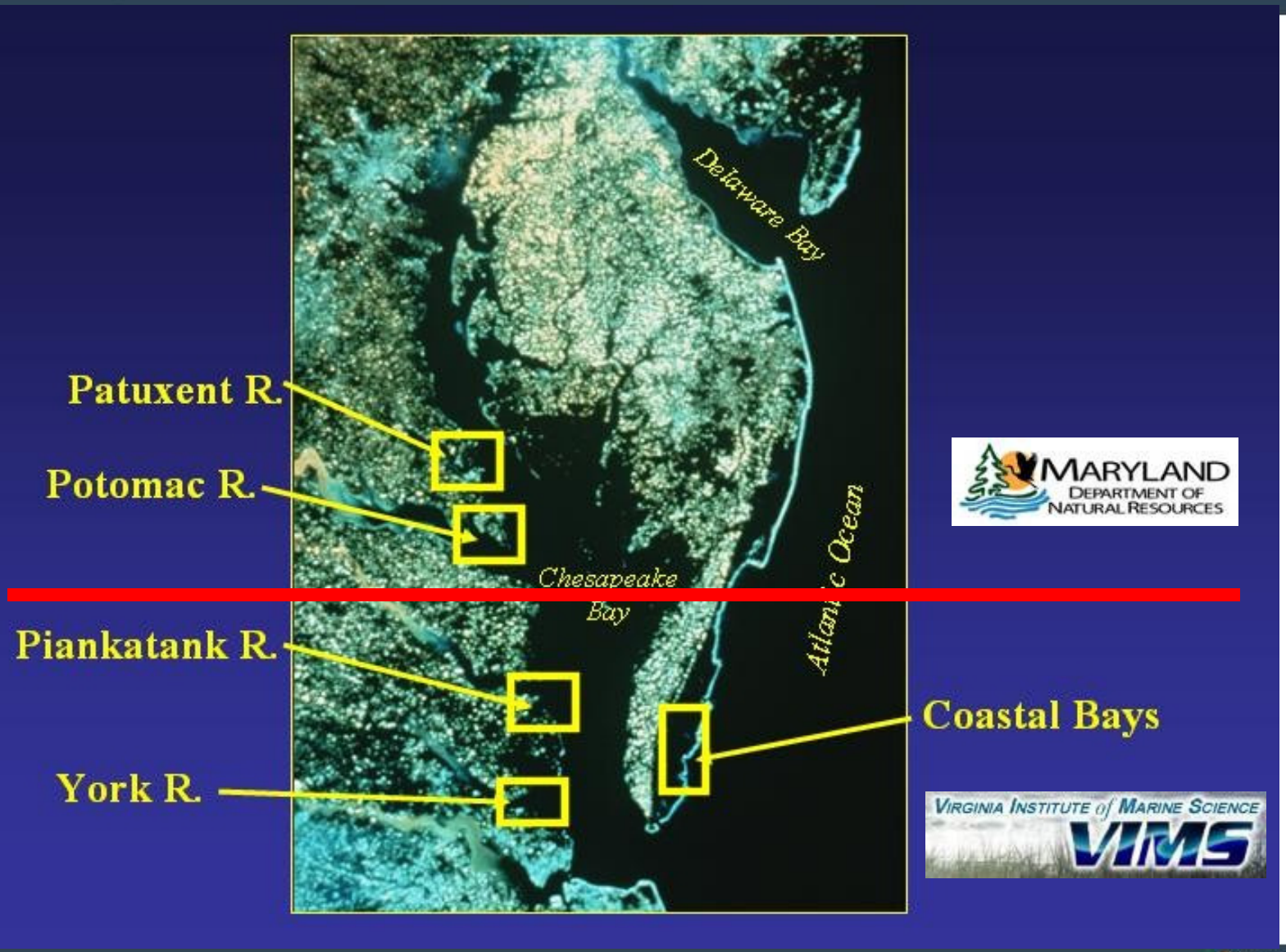


Seed Collection

Seed Dispersal – Technique 1

Seed Processing and Storage

Seed Dispersal – Technique 2

Fall Seed Broadcast

Seeds

Comparison of Dispersal Methods

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

	2003	2004	2005	2006			2007	2008
Collection								
Collection method	Manual	Mechanical	Mechanical	Manual	Mechanical	Total	Mechanical	Mechanical
No. of collection days	8	9	9	8	4	10	7	6
Z. marina yield (L)	22796	89918	204482	1451	2467	3918	54510	39179
Collection rate (L/day)	2849	9991	22720	181	617	392	7787	6530
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

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

Fall Seed Broadcast

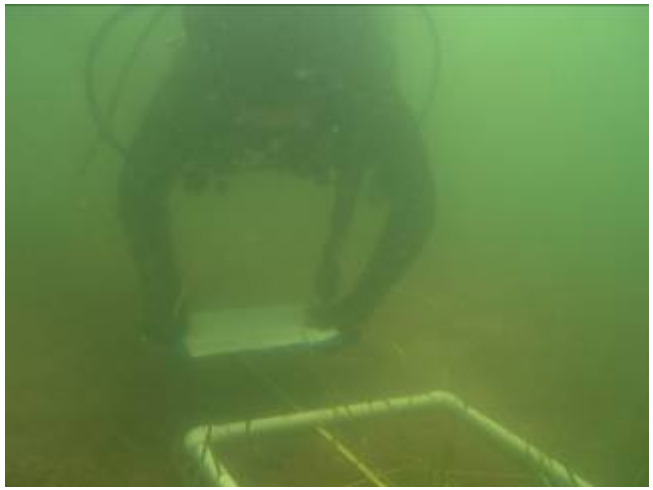
	Total Cost of Method	Total Number of Seeds	Cost per seed dispersed	Cost per Acre
2004	$125,616	374,500	$0.34	$67,085
2005	$153,294	1,802,500	$0.09	$17,009
2006	$110,056	349,500	$0.31	$62,979
2007	$142,718	540,000	$0.26	$52,859
2008	$117,708	961,567(800,000)	$0.12	$24,473
Mean	**$129,878**	**802,613**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

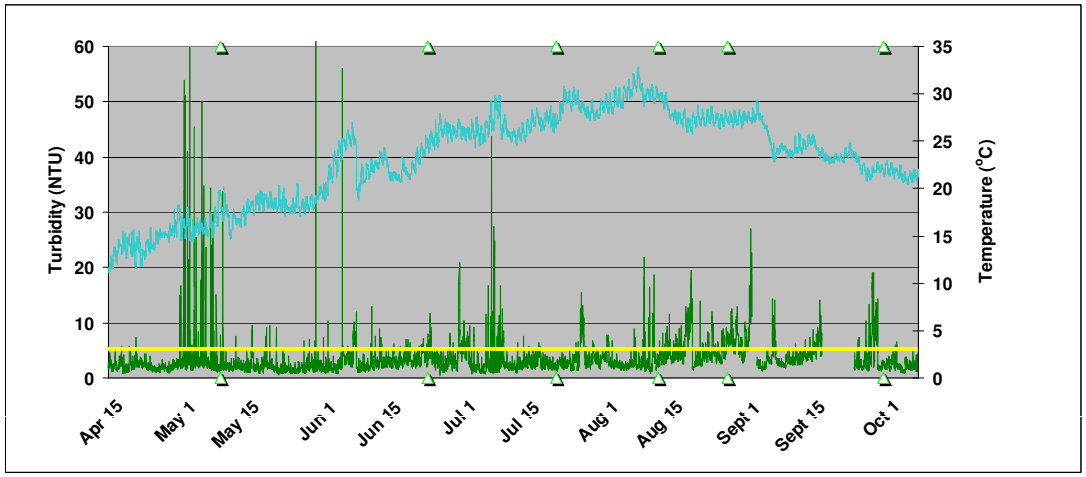
	Total Cost	Total Number of Seeds	Cost per seed dispersed	Cost per Acre
Grand Mean	**$77,804**	**969,744**	**$0.17**	**$32,365**

Project Summary

- 2003-2008
- 2 Rivers, 10 sites
- ~13 million eelgrass seeds
- 66 acres
- $0.17/seed (~$32,000/acre)

Monitoring





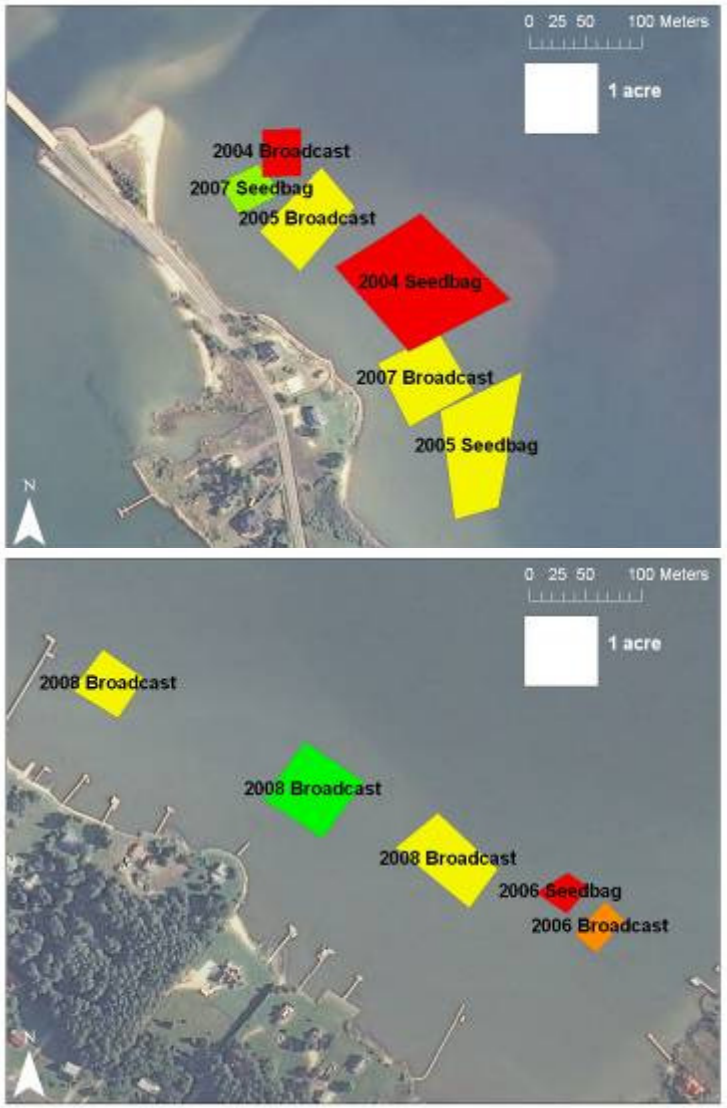
- Eelgrass monitoring: May, August, October
- Spatial & Temporal Habitat monitoring: April – October
- Compare by Seed dispersal method, Year & Site

Seedling Establishment

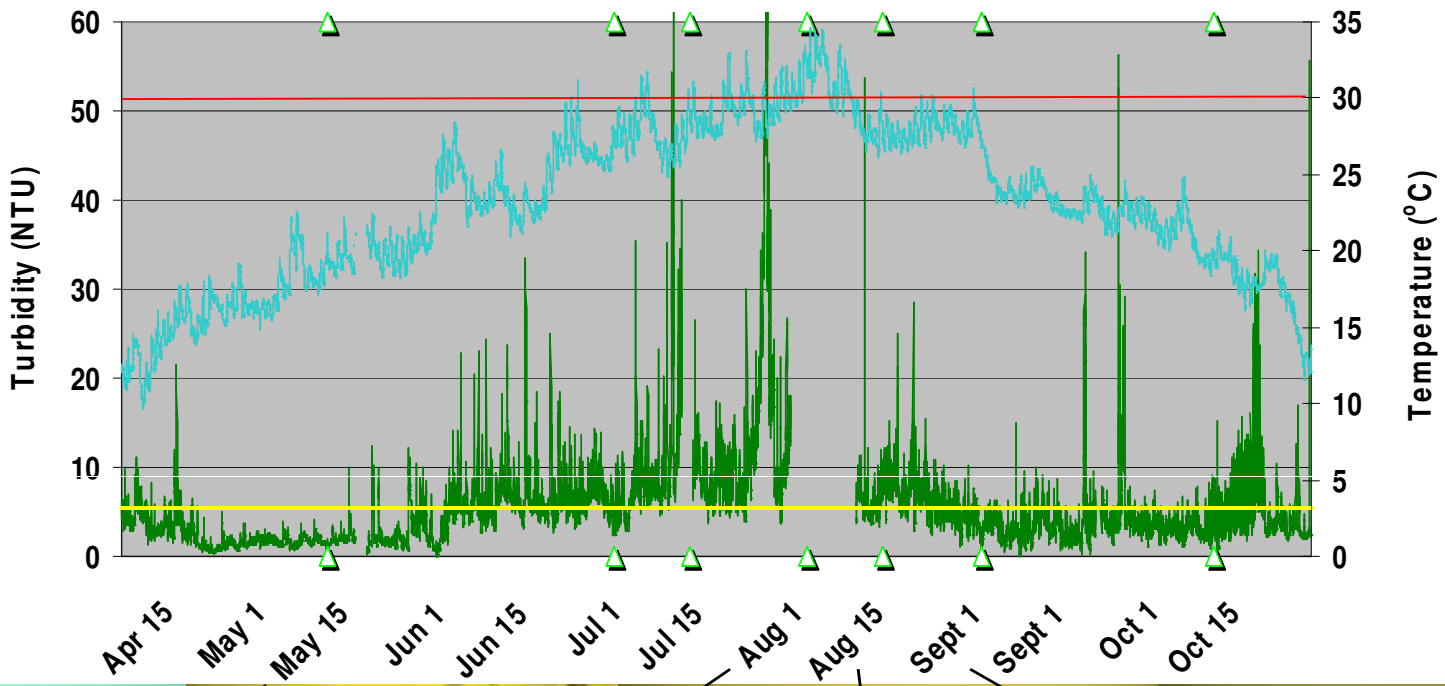
- % of seeds observed as seedlings
- Highly variable (0 – 8%)
- 80% of sites with observed seedlings

% Seedlings Observed

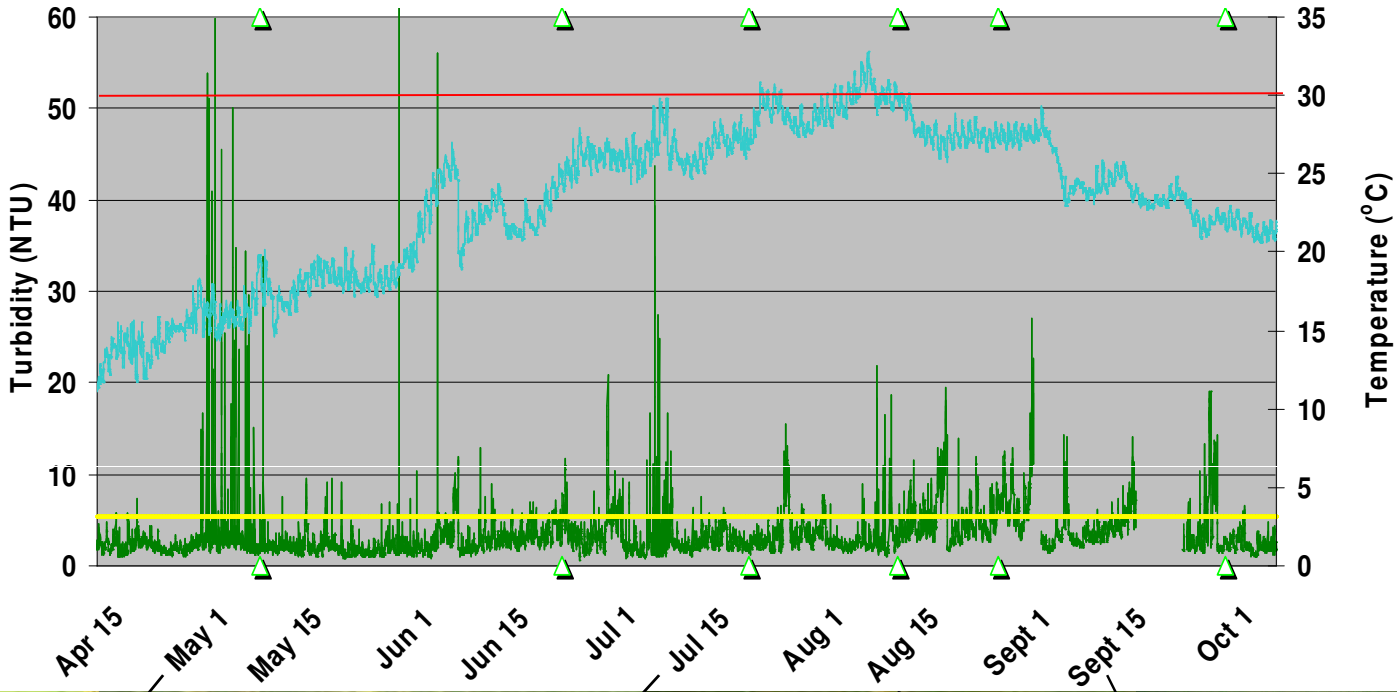
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 10

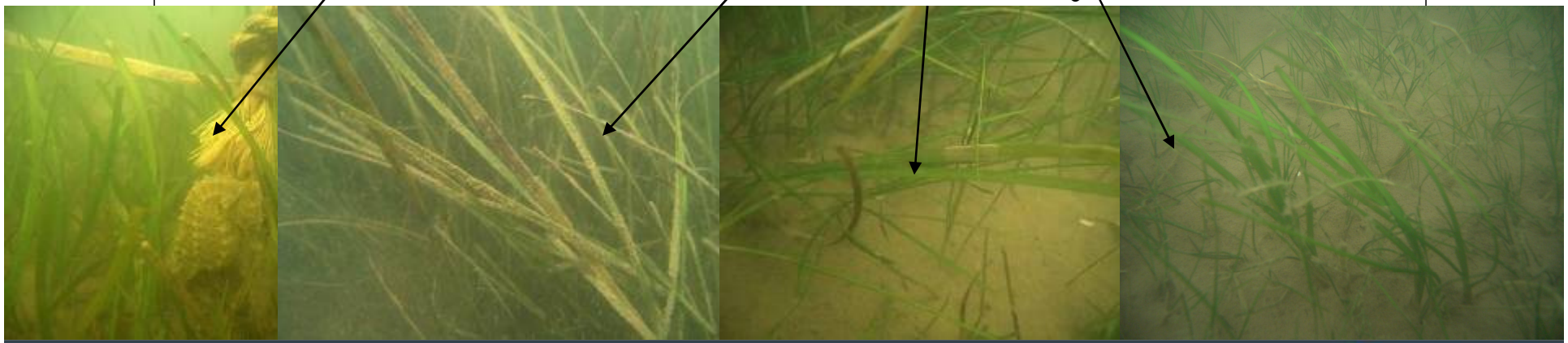


Patuxent River - 2006



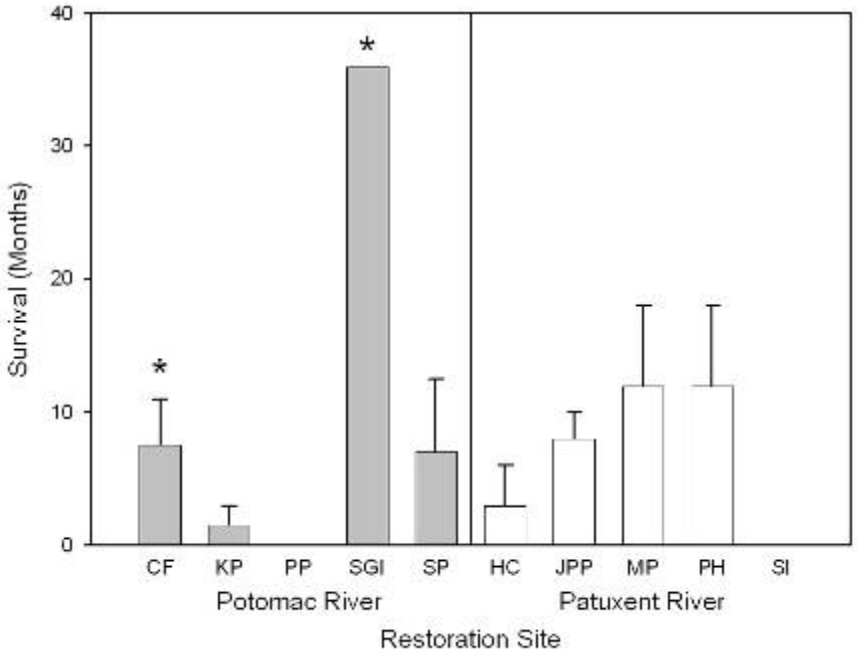
Potomac River -2006





Eelgrass Survival

- 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

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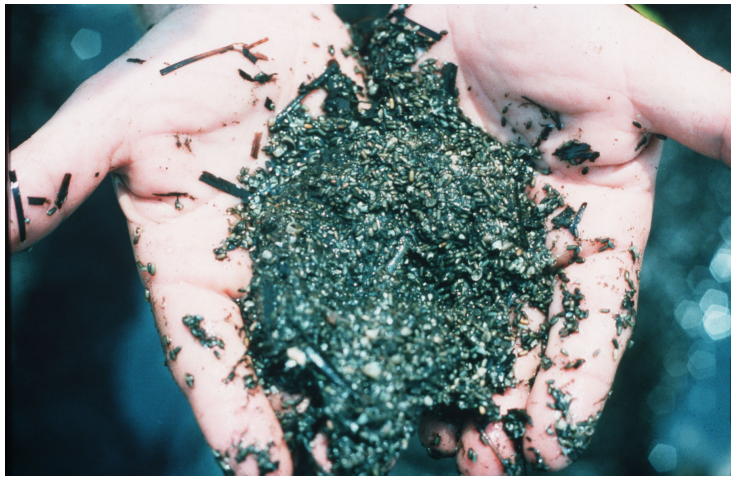

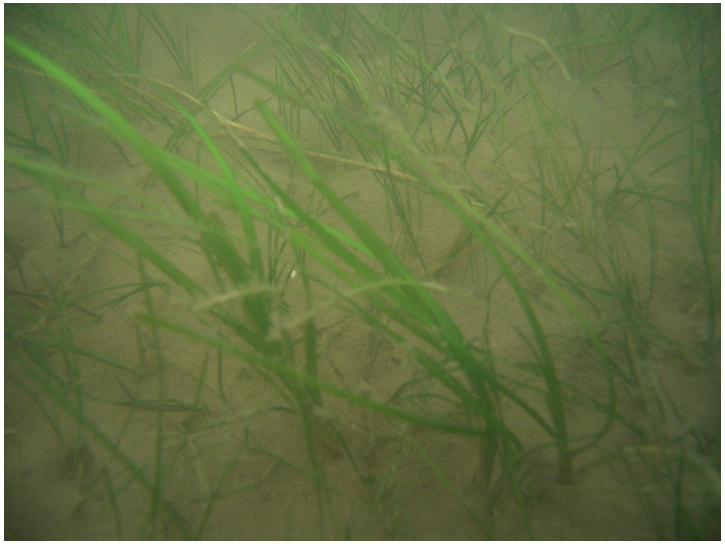

Challenges

- 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?

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