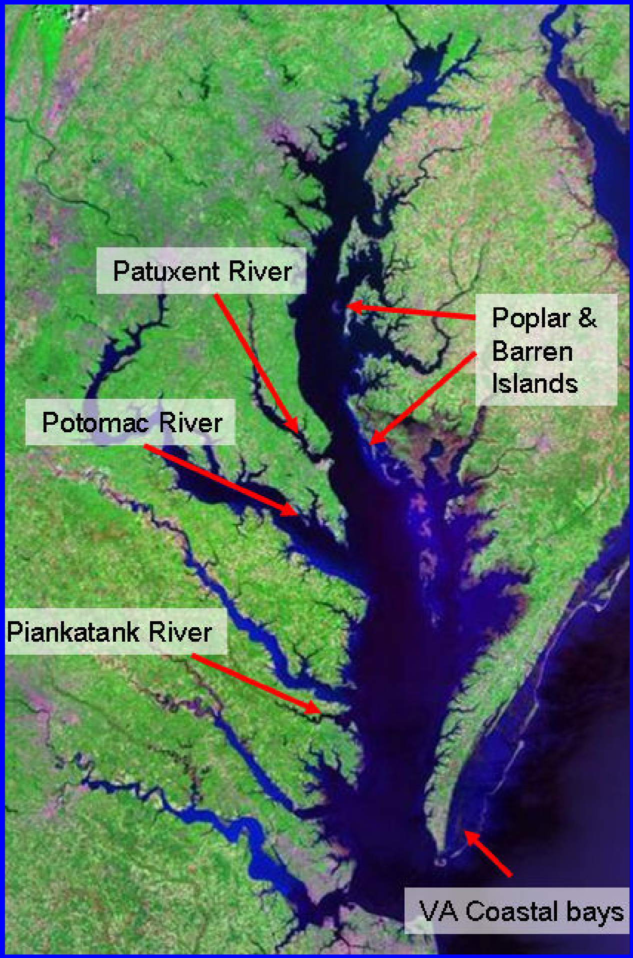


Large-scale Submerged Aquatic Vegetation Restoration in the Chesapeake Bay: 2003-2006

Dr. Deborah J. Shafer

Engineer Research and Development Center

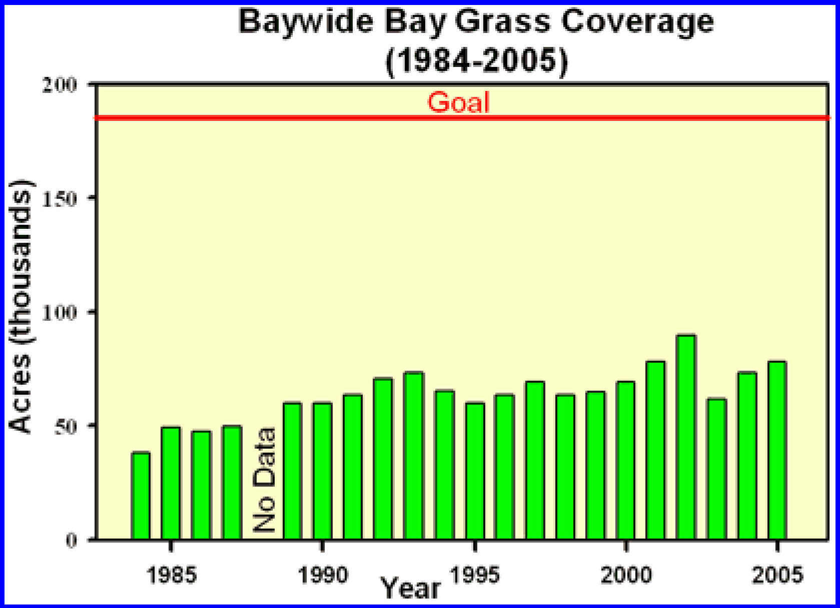
Why is SAV Restoration Important?

SAV performs many ecosystem functions:

- wave attenuation
- sediment stabilization
- water quality improvement
- primary production
- provide critical habitat structure

Widespread loss of SAV leads to diminished ecosystem functions --> economic impacts!

Chesapeake Bay Program SAV Goals



"Strategy to Accelerate the Protection and Restoration of Submerged Aquatic Vegetation in the Chesapeake Bay"
(Chesapeake Bay Program 2003)

Baywide Goal: 185,000 acres by 2010

Actions to increase SAV, including:

a) improving water quality,

b) promoting re-colonization, and

c) **planting 1,000 acres of SAV by December, 2008**.

How do we achieve goals?

- **Traditional approaches to SAV planting (e.g. hand-planting adult plants) are extremely labor-intensive and costly, with a variable track record of success**
- **Concerns: donor impacts, genetic diversity**
- **Significant investments in research and demonstrations must be made to improve our understanding of SAV restoration techniques**
- **Need guidance to select most appropriate methods for large-scale SAV restoration**

Federally Funded SAV Restoration Research Programs

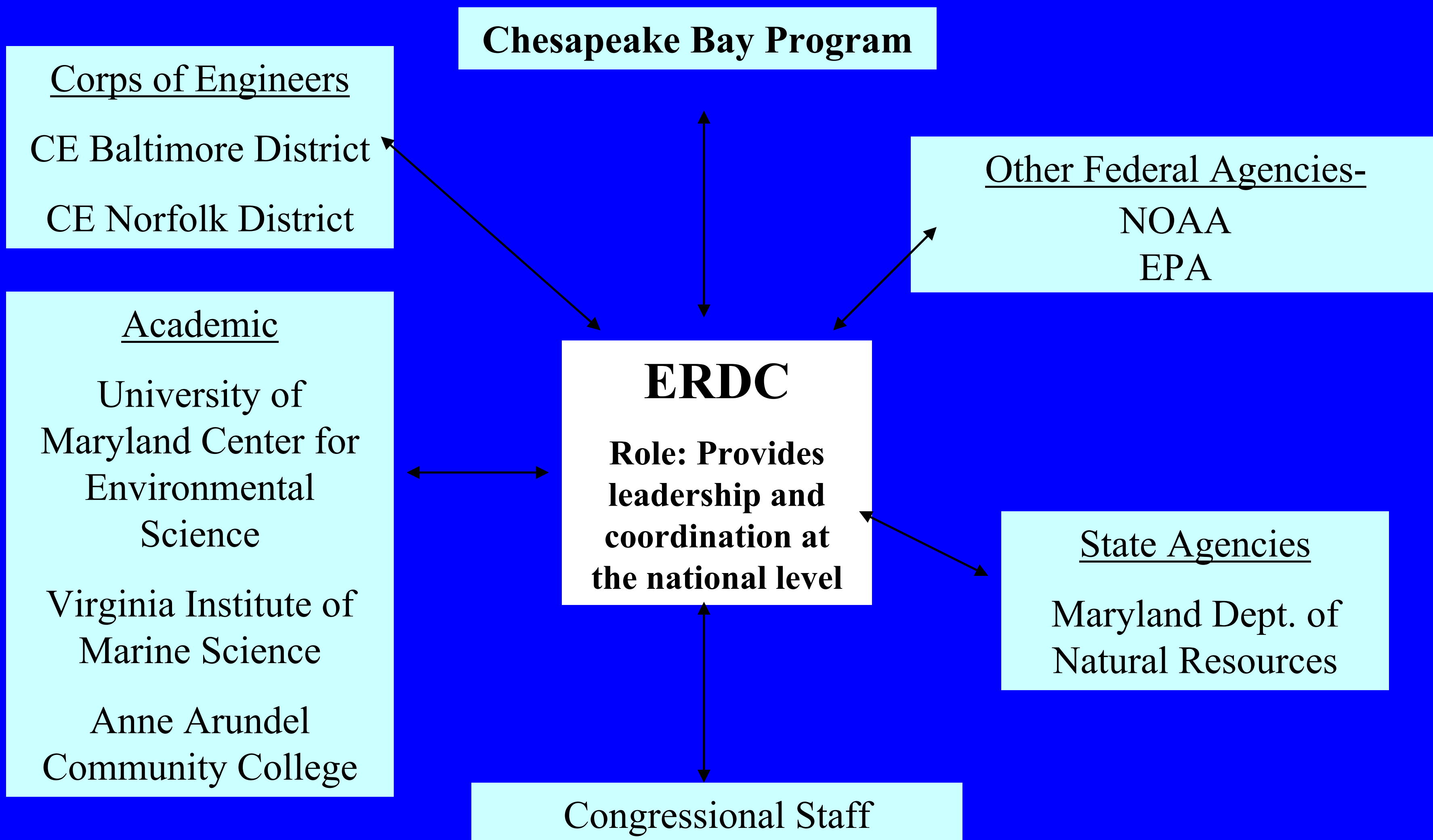
Previous SAV restoration efforts have largely been a series of small, un-coordinated projects that varied widely in their purpose, objectives, and methods used.

This research program is the largest coordinated multi-agency effort to date to develop, evaluate, and refine protocols suitable for large-scale SAV restoration.

Funding: ERDC: General Investigations R&D (Congressional), $500K-1M/year since 2003

Similar levels of NOAA funding (NCBO: *Peter Bergstrom)*

SAV Program Coordination



New Directions in SAV Restoration

Moving away from a focus on planting adult plants towards development of an agricultural system

“crops of wild communities” ***Mark Fonseca***

Research Approach

Research Focus Areas:

I. **Large-Scale Planting Projects (NCBO and ERDC)**

II. **Applied Research** (ERDC)

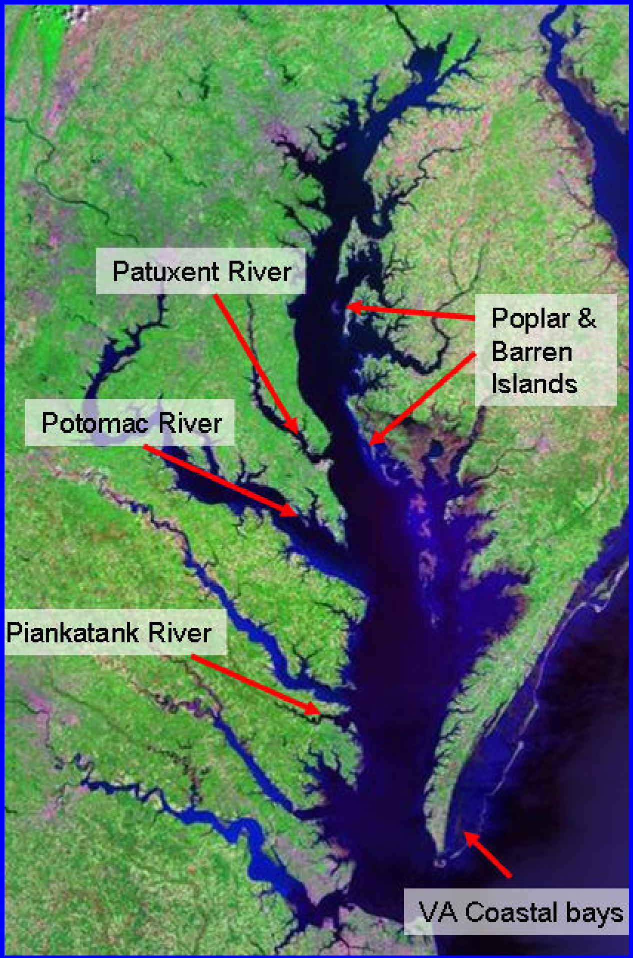
A. **SAV Production and Planting** (FY 03-FY08)

issues related to plant supply and propagation (ACTION 3.2 in CB SAV STRATEGY)

B. **Engineered SAV Habitats** (FY 05-FY08)

Wave energy thresholds for created and restored SAV beds—design criteria for wave attenuation structures

Large-Scale SAV Seed Planting Projects 2003-2006



Location	Species	Recipient	Duration	Acres
Piankatank River, VA	***Z. marina***	VIMS	2003-2005	**40**
Potomac River, MD	***Z. marina***	MD DNR	2003-2006	**37.25**
Patuxent River, MD	***Z. marina***	MD DNR	2003-2005	**23.75**
Poplar Island, MD	*P. perfoliatus* *R. maritima*	AACC	2004	12
Barren Island, MD	*R. maritima*	AACC	2005	3
Various	Various	Various	2004-2005	16.5

Abbreviations: VIMS (Virginia Institute of Marine Science); MD DNR (Maryland Dept. of Natural Resources); UMCES (University of Maryland Center for Environmental Science; KCF (Keith Campbell Foundation); MPA (Maryland Port Authority); NAIB (National Aquarium in Baltimore); ACB (Alliance for the Chesapeake Bay).

Planting projects funded by NCBO, ERDC and others

Large-Scale Eelgrass Seed Planting Projects 2003-2006

I. Two methods of seed collection were compared:

(a) hand collection by divers, and
(b) use of a mechanical harvester

II. Two methods for dispersing eelgrass seeds were compared:

(a) immediate deployment of reproductive shoots in floating mesh bags in areas suitable for planting, and

(b) separation and storage after harvest and broadcast in the fall

Results

Total acres SAV planted = 133, average 33 acres/ yr

During the previous 21 years (1983-2003), approximately 189 acres of SAV were planted, an average rate of 9 acres/yr (Orth et al. 2006b).

● ~16,000,000 *Z. marina* seeds were dispersed at 3 sites (Piankatank, Potomac, and Patuxent Rivers)

● 101 acres planted at densities from 40,000-1,050,000 seeds/acre

● Barren Island, MD: > 130,000 *R. maritima* seeds dispersed -- 3 acres

● Poplar Island, MD: > 1,000,000 *R. maritima* and *P. perfoliatus* (522,720 seeds each) seeds dispersed -- 12 acres

Large-Scale SAV Seed Planting Projects 2003-2006:

Plant Establishment and Survival

● Eelgrass seedling establishment rates were very low (mean <1%) at all sites, range: 0-8.4 %

● Due to the large numbers of seeds distributed, even low rates of initial seedling establishment can result in large numbers of seedlings. (e.g. for seeds broadcast at mean density of 750,000 seeds/acre, an average seedling establishment rate of 0.57 % would yield > 4,200 seedlings/acre.

● Limited data suggest that eelgrass seedling establishment rates under ambient conditions in the field are also low (<10%) (Harrison 1993).

Research Approach

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Wave energy thresholds for created and restored SAV beds—design criteria for wave attenuation structures

An Agricultural Approach

● Seeds are the most cost effective method for the production of all major domesticated crop plants.

● Seeding offers the most cost effective approach for restoring large, genetically diverse, self-maintaining populations of underwater grasses.

PROBLEMS:

- Information on basic seed physiology lacking
- Protocols for the large-scale collection, storage, and dispersal of SAV seeds were unavailable

Manual SAV Seed Collection

Collect seeds retained in detached stems that accumulate as wrack

Pros: uses seed that would otherwise be unavailable

Cons: seed yields are lower, weather dependent

Collect reproductive shoots directly from actively growing beds

Pros: seed yields are higher, minimal impact to non-reproductive plant structures

Cons: removes seeds from reproductive pool

Mechanized SAV Seed Collection Methods

Comparison of 2 types of **mechanical equipment** for eelgrass seed harvest

Commercial harvester for nuisance aquatic vegetation

Pros: readily available

Cons: expensive, limited mobility

VIMS portable boat-mounted harvester

Pros: portable, easily attached to a small boat
Cons: not available commercially, specialized design

Seed Dispersal

Seeds can be dispersed immediately….

Seed Buoys (“Pickerell bags”) Pickerell et al 2005; 2006)

Pros: Mimics natural dispersal patterns, low cost, low tech, no expensive seed separation and storage required, avoids potential problems with seed mortality in storage, and well-suited to volunteer labor

Cons: very labor intensive over short duration, transport logistics, permitting for large deployments can be challenging

Seed Processing

The ability to harvest large volumes of plant reproductive material poses new logistical and technical challenges…

Seed Processing is a method of isolating the mature seeds from the stems and other less developed reproductive structures

Duration of seed release is a function of the stage of development at which seeds were harvested, water temperature, and the amount of material


Seed processing equipment. Left, large-scale outdoor seed processing tanks for *Z. marina* (Photo by VIMS)**. Right, wringer washing machine provides agitation to facilitate seed separation** (Photo by S. Ailstock)**.**

Seed Storage

If seeds are not to be dispersed immediately, they must be stored under conditions that maintain viability and prevent premature germination

Eelgrass seed storage facilities at VIMS.

Prior to the start of this research, there was little information available on the specific conditions for SAV seed storage

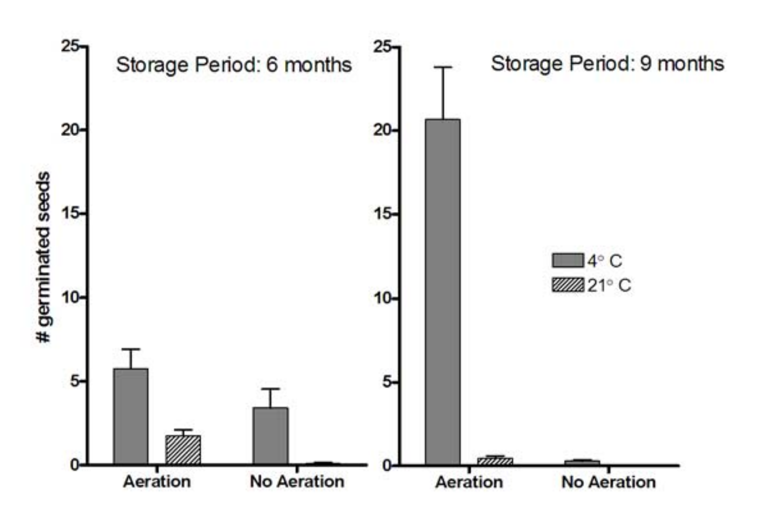
In some cases, high rates of seed mortality occurred during storage, but factors responsible for seed death were not well understood

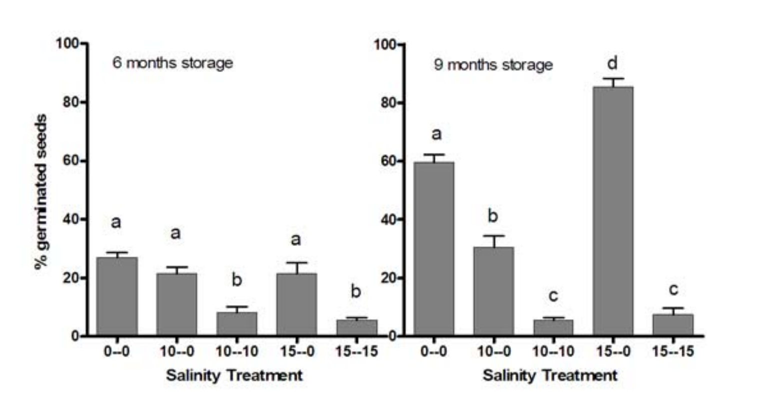
Determining the optimum conditions required for seed storage has been a critical research component!!

Seed Storage

Effects of storage period, storage temperature, aeration, and salinity on seed germination

P. perfoliatus





Aeration during storage is required

Longer storage increases seed germination

Cold storage increases germination rates

Regardless of the salinity at which they were stored, placing seeds in freshwater induced higher rates of germination

An Agricultural Approach to SAV Planting

Mechanized equipment for planting terrestrial crops has been available for more than a century

Development of mechanical equipment for planting underwater grasses is still in its infancy

An Agricultural Approach to SAV Planting

Mechanized equipment for planting adult plants and shoots
(Seagrass Recovery, Inc. Ruskin, FL)

JEB Wheel planter

Pros: can plant much more rapidly than by hand

Cons: plant survival lower than manual planting, not suitable in some sites (i.e. too shallow, too deep, bottom obstructions)

GIGA Planter

Pros: plants 4 x 5 ft sods with intact root, rhizomes, and sediments, good survival and expansion of sods, best suited for 'salvage' where damage to existing resources in unavoidable

Cons: not suitable in some sites (i.e. too shallow, too deep, bottom obstructions), limited by distance between donor site and planting site

An Agricultural Approach to SAV Planting

Seed Broadcasting

Eelgrass seed broadcasting has been shown to be effective because seeds are rapidly incorporated into the sediments and generally do not move far from where they settle (Orth et al. 1994).

Photo by VIMS

Manual Seed Broadcasting

Pros: low tech, low cost

Cons: slow, even seed distribution difficult to achieve

Photo by MDDNR

Mechanized Seed Broadcasting

Pros: capable of evenly dispersing seeds at suitable densities (100,000 - 300,000 seeds/acre) at the rate of 10 minutes/acre.

Cons: ??

An Agricultural Approach to SAV Planting

Subsurface Seeding

Concerns with low seed germination rates and possible seed predation effects led to investigation of various means to distribute seeds just below the sediment surface

A mechanical planter capable of injecting seeds suspended in a gel matrix 1-2 cm below the sediment surface was designed and constructed by scientists at the University of Rhode Island (URI, Traber et al. 2003)

An alternative design that does not require a gel matrix for seed delivery was also designed and tested by VIMS

Alternatives to Seeds

Over-wintering propagules (e.g. buds and tubers) can provide an alternative to seeds for restoration of some mesohaline SAV species

P. perfoliatus buds

S. pectinata tubers

Current research is investigating:

1) natural propagule production and viability,
2) artificially induced propagule production,
3) the effects of salinity and cold storage on propagule viability
4) propagule planting methods

Research Approach

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Engineered SAV Habitats:
Effects of Breakwaters on SAV Colonization

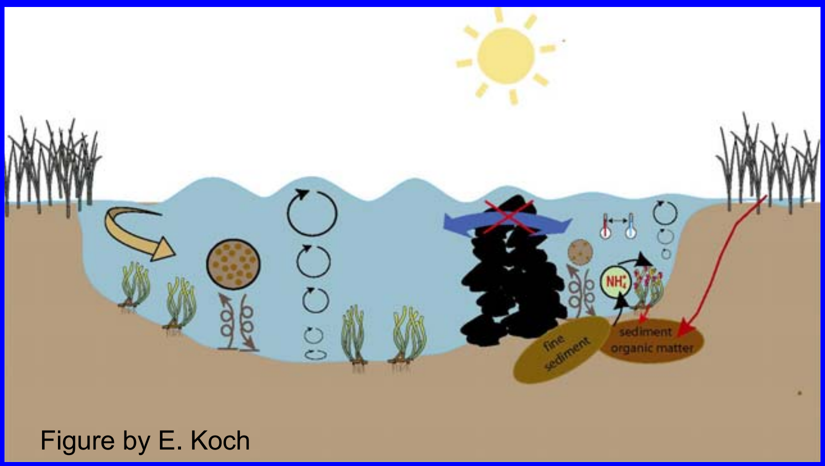


Figure by E. Koch

Breakwaters are built to attenuate wave energy and minimize shoreline erosion

In high energy areas: Potential to improve SAV habitat by:
1) reducing wave energy and improving water quality via reduced sediment resuspension, and

2) reducing sediment movement, thereby allowing seagrasses to become dense and well-established.

Engineered SAV Habitats:
Effects of Breakwaters on SAV Colonization

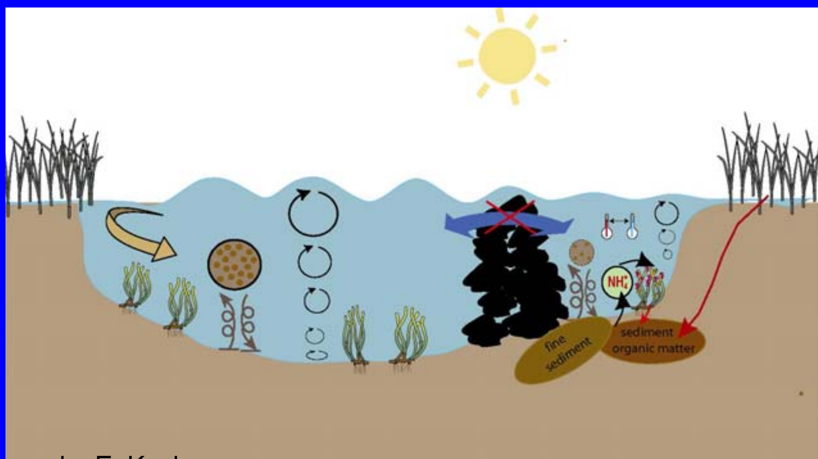


Figure by E. Koch

In moderate energy areas: Potential to degrade SAV habitat by:

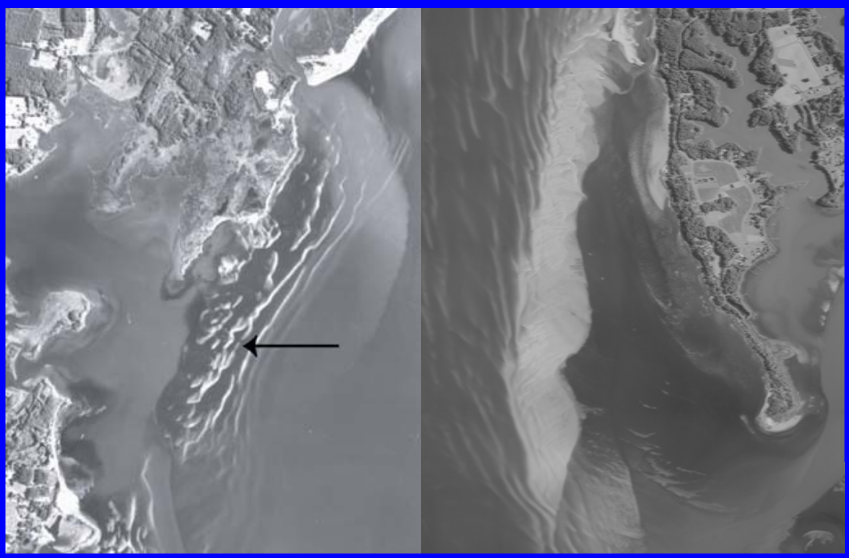
1) accumulate fine/organic particles behind the structure which are readily resuspended by small waves --> increased turbidity

2) Fine/organic sediments release more nutrients, fueling epiphyte growth

3) Waters inside restrictive breakwaters can get warmer than those offshore, leading to elimination of certain species

Engineered SAV Habitats:

Comparative Effects of Breakwaters and Sandbars on SAV Colonization



Some of the healthiest SAV beds in Chesapeake Bay are found shoreward of sand bars, a natural wave-reducing structure.

Why do SAV flourish in sand bar protected areas but not in breakwater protected areas?

Ongoing research suggests that some wave exposure is necessary in order to keep fine and organic sediments at a low level that allows SAV growth.

This information could then be used in the engineering of seagrass habitats for large-scale restoration projects.

Future Research

(Initiated in 2008)

Suitability of Breakwaters for SAV Habitat and Large-scale Restoration

Evaluation of SAV bed health, *sediment grain size characteristics and sedimentation rates at various breakwater configurations* throughout the Bay

Results can be used to make recommendations for the construction of SAV-friendly breakwater structures

Future Research

Refining SAV Site Section Models
Are we selecting the right sites for planting?

● SAV habitat requirements currently used in the site selection process were developed primarily for established populations of plants

(Batiuk et al. 1992, Dennison et al. 1993, Kemp et al. 2004)

● These criteria may be either too lax or incomplete for establishment of new SAV beds

● Establishment of new beds either from seeds or transplants is likely to require water quality conditions that exceed those of existing established beds (Fonseca et al. 1998).

Factors Affecting
Seed and Seedling Dispersal and Establishment

Most SAV research has focused on adult stages.

Factors affecting seed dispersal and early seedling establishment remain poorly understood

Ongoing Research

Factors Affecting Seed and Seedling Dispersal and Establishment

Evaluation of *in situ* light, salinity, nutrient, and temperature habitat criteria for mesohaline SAV seedling establishment

(Initiated in 2008 Anne Arundel Community College, MDDNR)

Factors Affecting Seed and Seedling Dispersal and Establishment

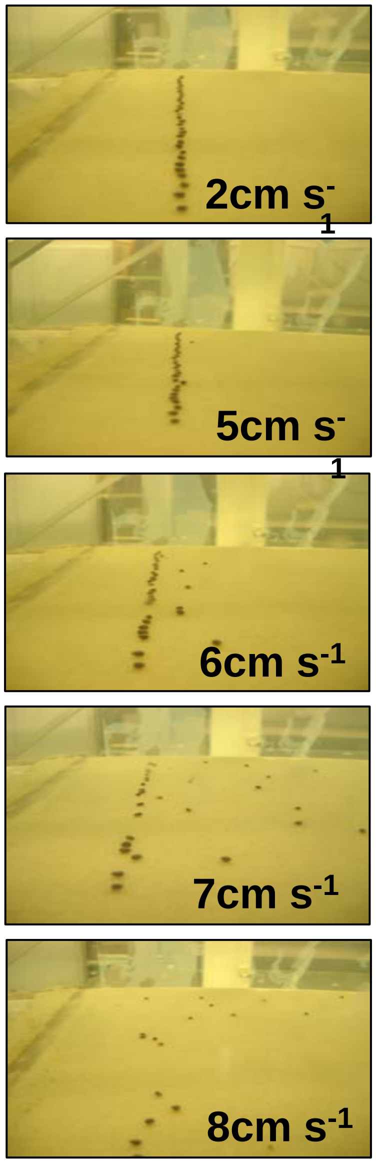


Photo by D. Booth

Ongoing research is investigating the effects of waves, currents, and sediment grain size on seed and seedling dispersal

Preliminary Results:

- Seeds move at very low current velocities, as would be found within established SAV beds
- Seed movement varies by species, depending on seed morphology
- Seed movement also varies with sediment grain size

Products: Technical Notes Series

TITLE
Restoration Potential of *Ruppia maritima* and *Potamogeton perfoliatus* by Seed in the Mid-Chesapeake Bay
Buoy Deployed Seeding: A New Low-Cost Technique for Restoration of Submerged Aquatic Vegetation From Seed
Applications and Limitations of Micro-propagation for the Production of Underwater Grasses
Protocols for Large-Scale Collection, Processing, and Storage of Seeds of Mesohaline Submerged Aquatic Plant Species
Reproductive ecology of the freshwater macrophyte *Valisneria americana*
Waves in seagrass systems: a review and technical recommendations.

http://www.wes.army.mil/el/sav/

Additional Products:

- Special issue of *Restoration Ecology in 2010*

- Dedicated session

  Restore America's Estuaries conference

  Providence, RI Fall 2008

Tech Transfer:

These techniques have also been applied to a Section 206 restoration project in North Carolina. POC: Chuck Wilson, Wilmington District

Benefits

State-of-the-art technical standards and guidance for planning, implementing, and monitoring submerged aquatic vegetation restoration projects will:

- Provide resource managers with tools to meet targeted SAV restoration goals
- Contribute to improved success rates and predictability for SAV restoration projects
- Provide practical guidance on selection of appropriate methods for SAV restoration
- Improve coordination between Corps and other stakeholders involved in SAV restoration