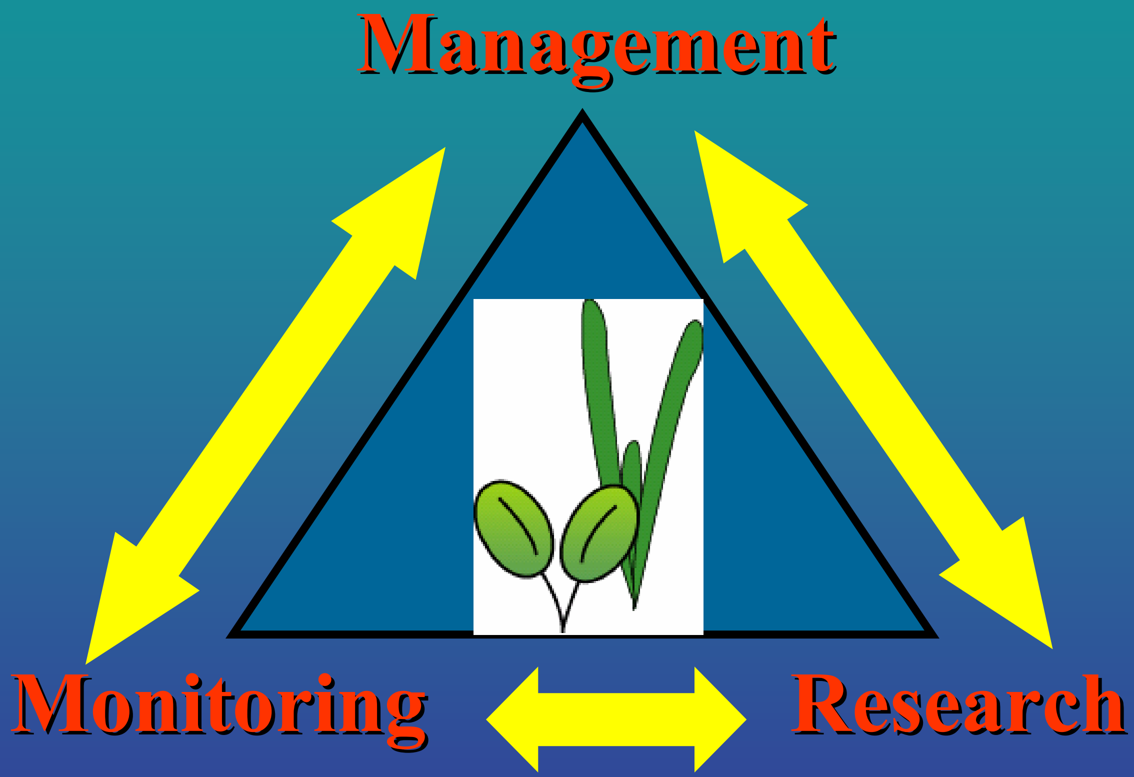
THE BENEFITS AND CHALLENGES OF INTEGRATING



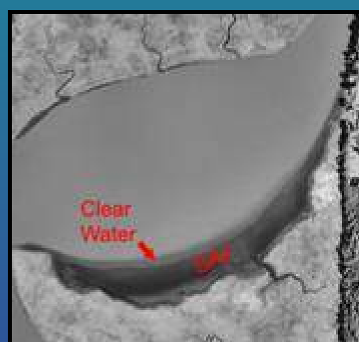
FOR

SUBMERGED AQUATIC VEGETATION CONSERVATION AND RESTORATION

Aquatic grass communities are important in Chesapeake Bay

Food for waterfowl

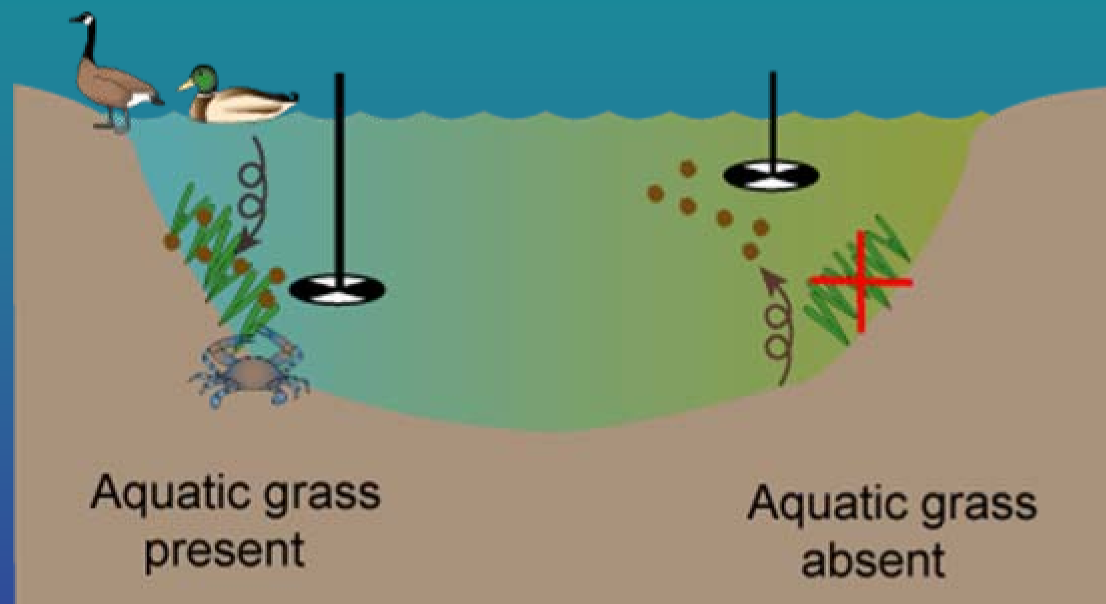
Increase water clarity



Habitat for blue crabs

Good water clarity

Poor water clarity



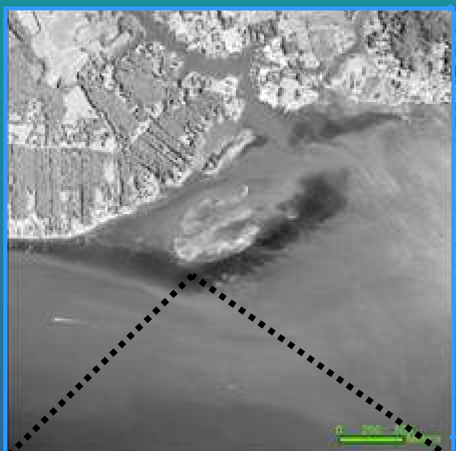
SAV as bioindicators

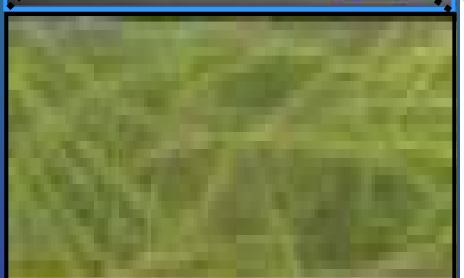
SAV make good bioindicators:
- Widespread distributions
- Responsive to perturbations (high light requirements)
- Integrative of environmental conditions
- Important ecological role

SAV= canary in Chesapeake Bay

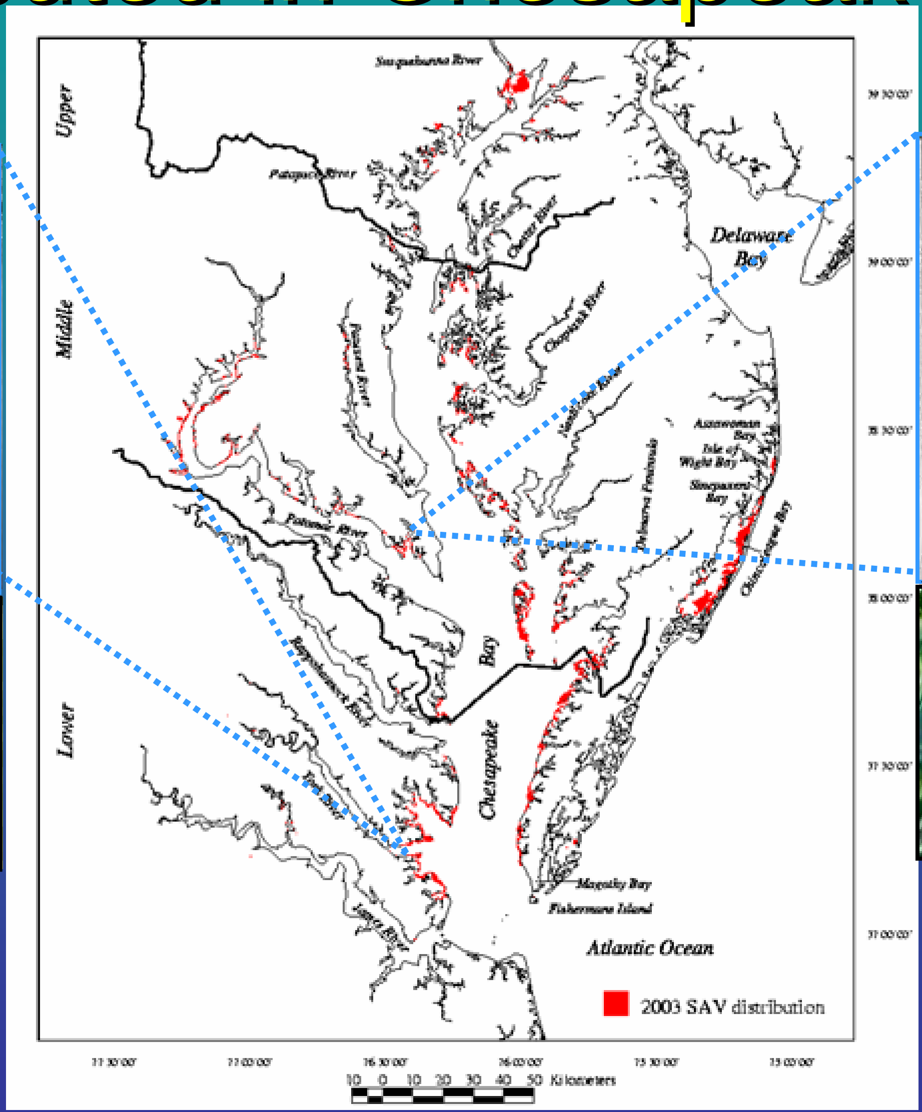
Aquatic grass communities - widely distributed in Chesapeake Bay

York River

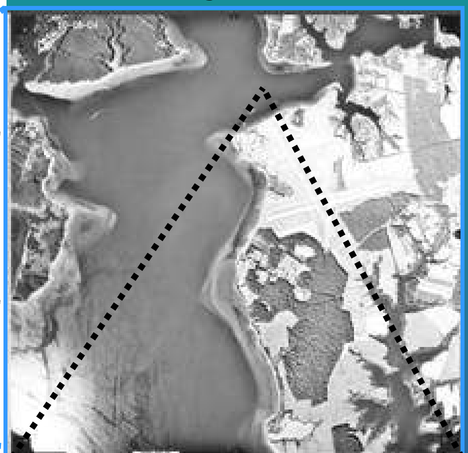


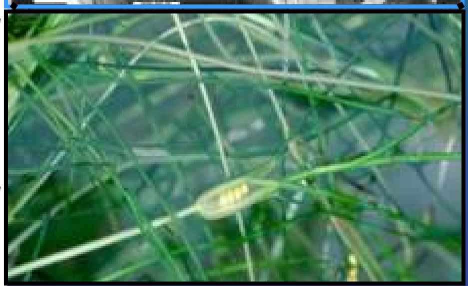


Zostera marina
'eelgrass'



St Mary's River

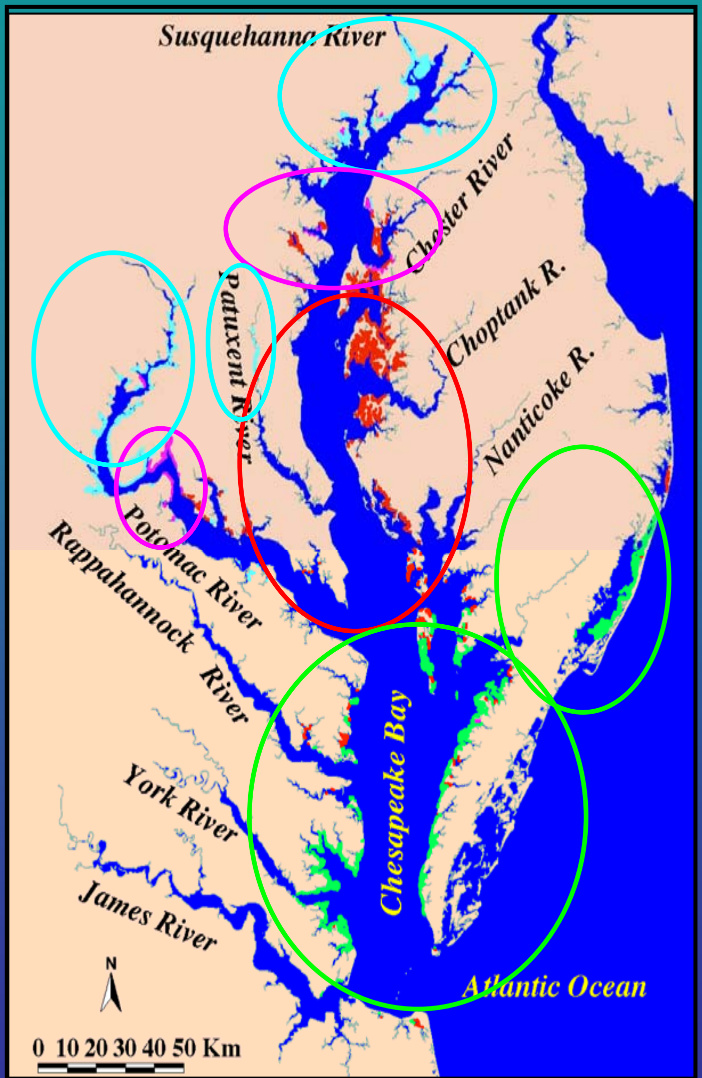




Ruppia maritima
'widgeongrass'

Sources: VIMS & Maryland DNR

Aquatic grass communities are determined by salinity regime

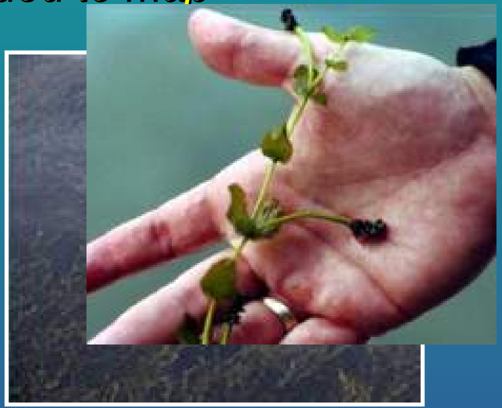


Moore, Wilcox, Orth (2000) Estuaries 23:115-227

Chesapeake Bay Communities

Names color coded to map

Freshwater

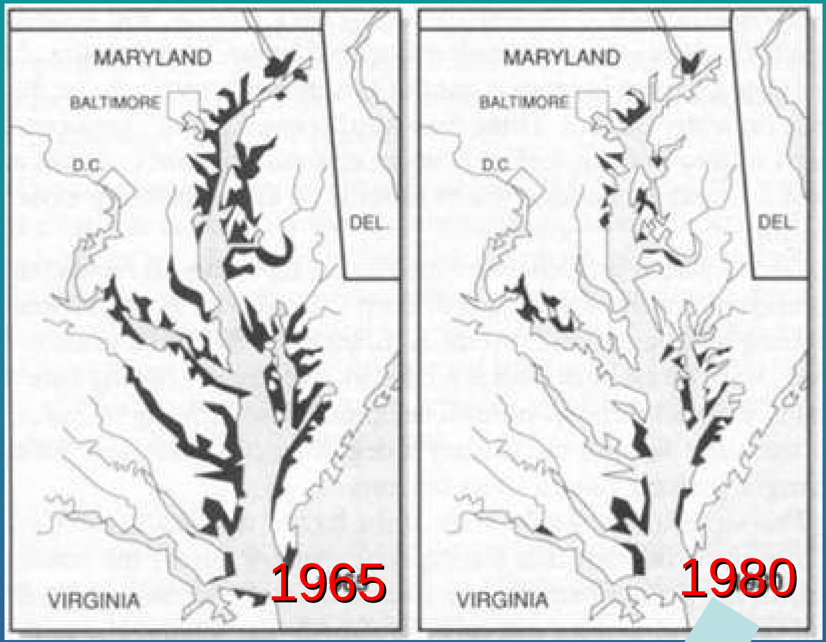


Potamogeton

Ruppia

Zostera

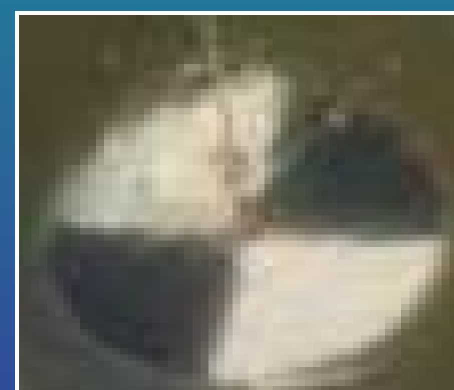
Chesapeake Bay: Bay wide seagrass loss



Restoration of aquatic grass communities of Chesapeake Bay:

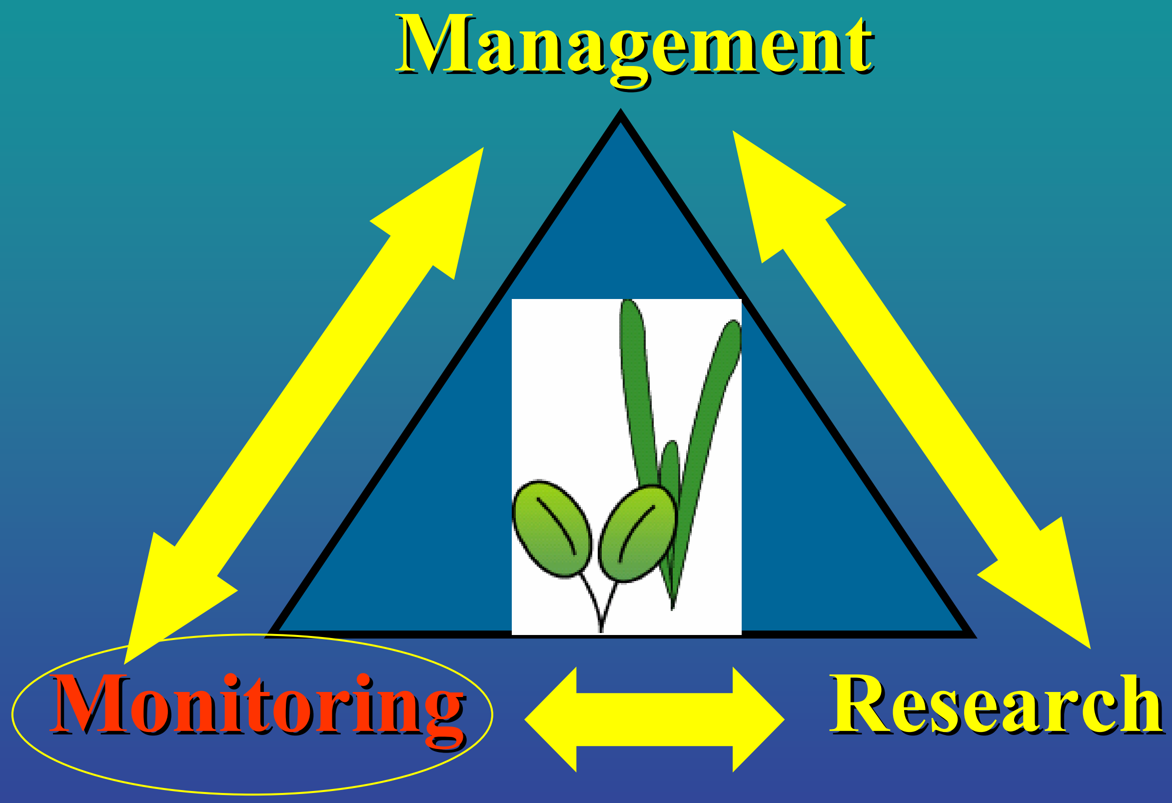
How should we proceed?

Robert Orth(1), Peter Bergstrom(2), Walter Boynton(3), Tim Carruthers(3), William Dennison(3), Katia Englehardt(3), Dave Goshorn(4), Lee Karrh(4), Evamaria Koch(3), Scott Marion(1), Ken Moore(1), Laura Murray(3), Mike Naylor(4), Nancy Rybicki(5) and Dave Wilcox(1)



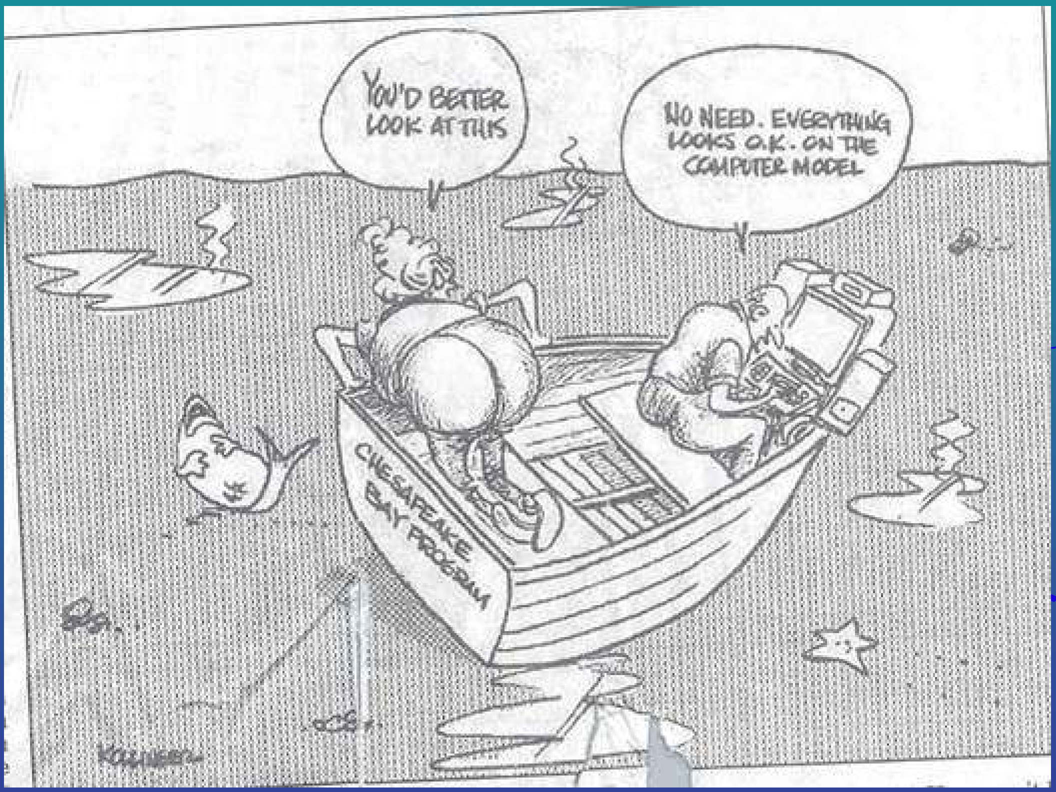
1 Virginia Institute of Marine Science VIMS
2 NOAA
3 University of Maryland Center for Environmental Science
4 Maryland Department of Natural Resources
5 USGS science for a changing world

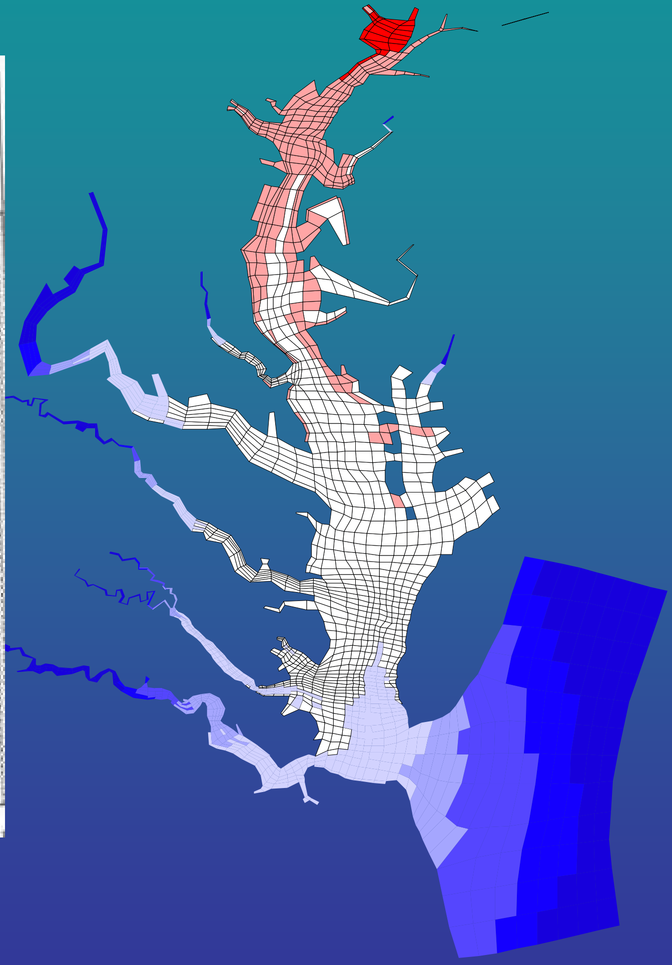
THE BENEFITS AND CHALLENGES OF INTEGRATING



FOR SUBMERGED AQUATIC VEGETATION CONSERVATION AND RESTORATION

Models are a powerful, but seductive tool for management

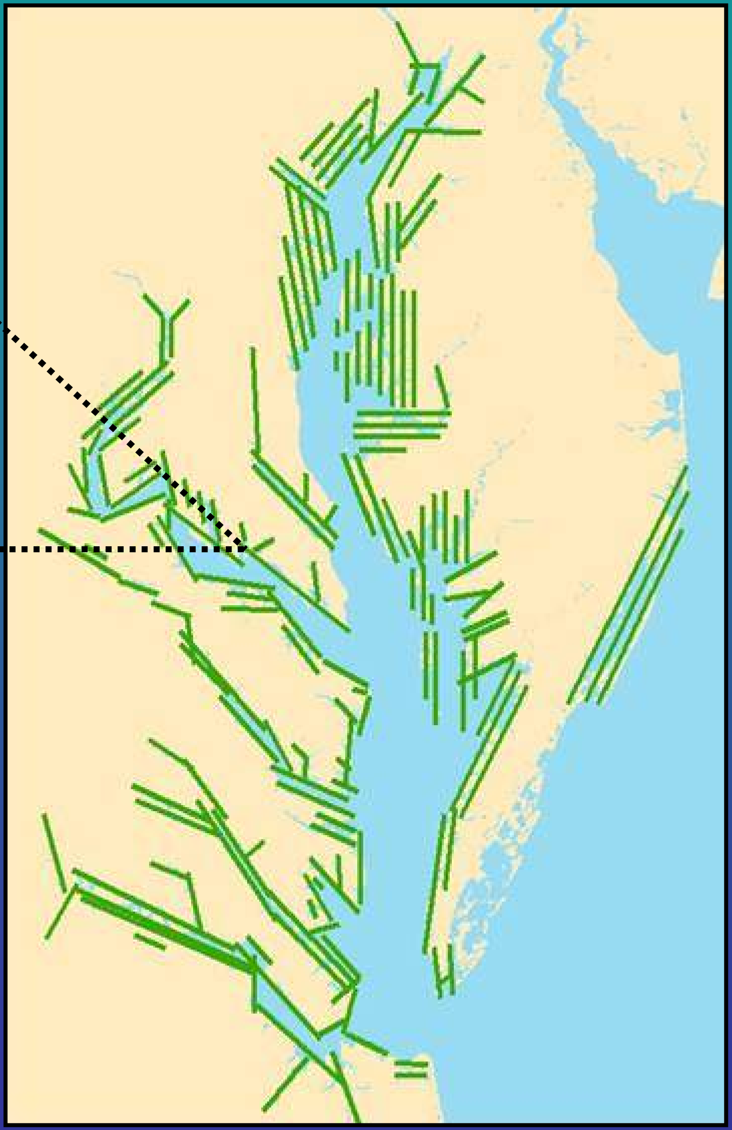




But monitoring...

Annual aquatic grass monitoring using aerial photography

Breton Bay



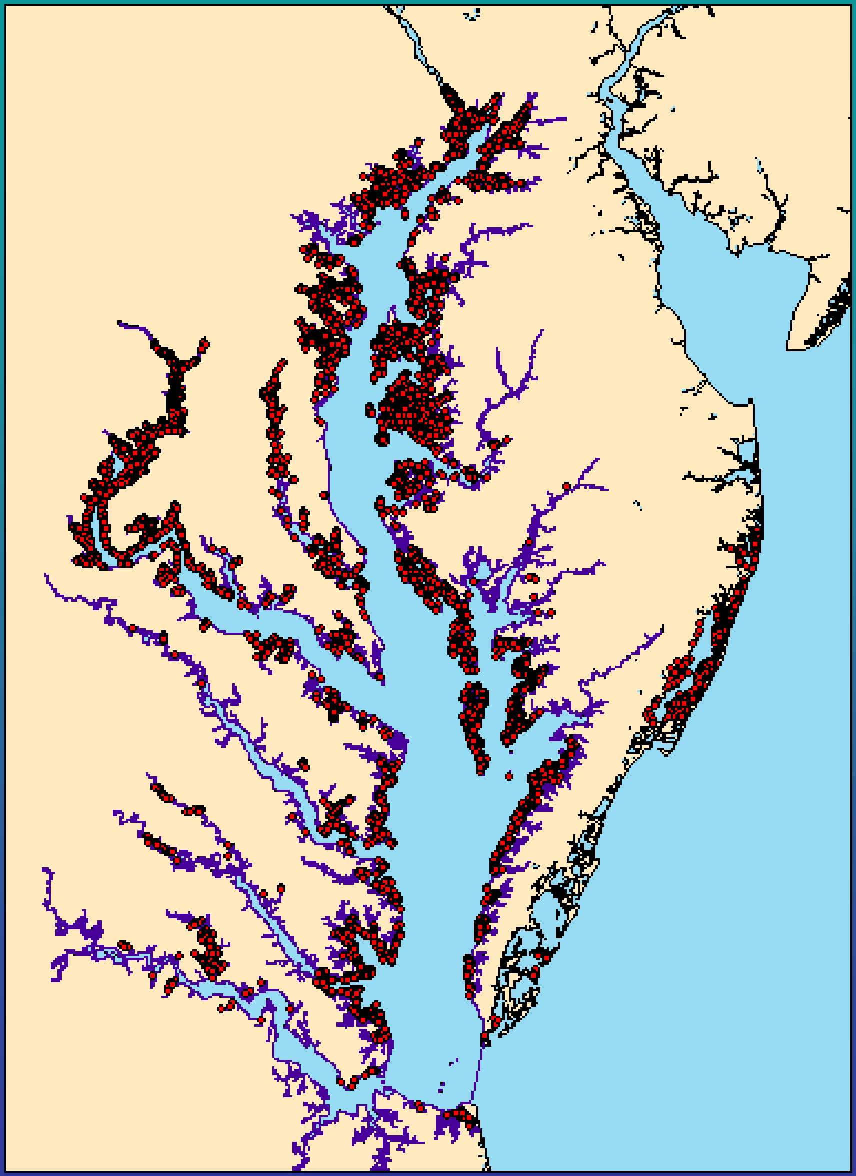
- Annual monitoring project (1978, 1984-present)
- 173 flight lines (2,340 mi)
- 2,033 B/W aerial photographs
- Scale 1:24,000
- Funding: EPA, NOAA, VA DEQ and CRM, MD DNR, ACE

SAV Species Observations

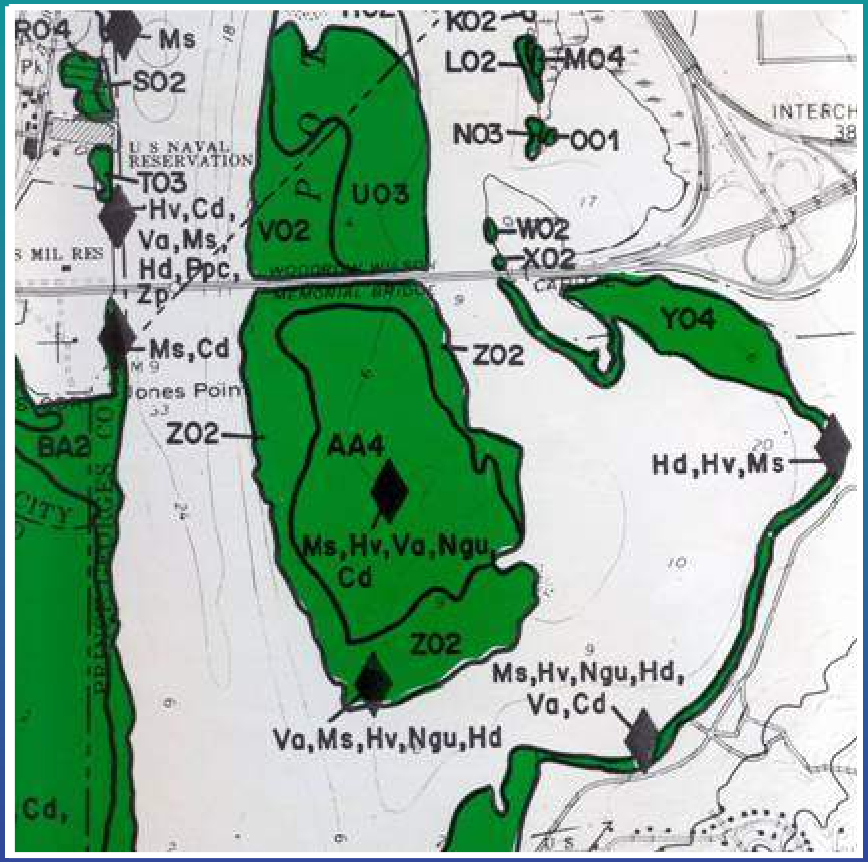
~1000 observations per year
Over 17,000 observations

Participants:

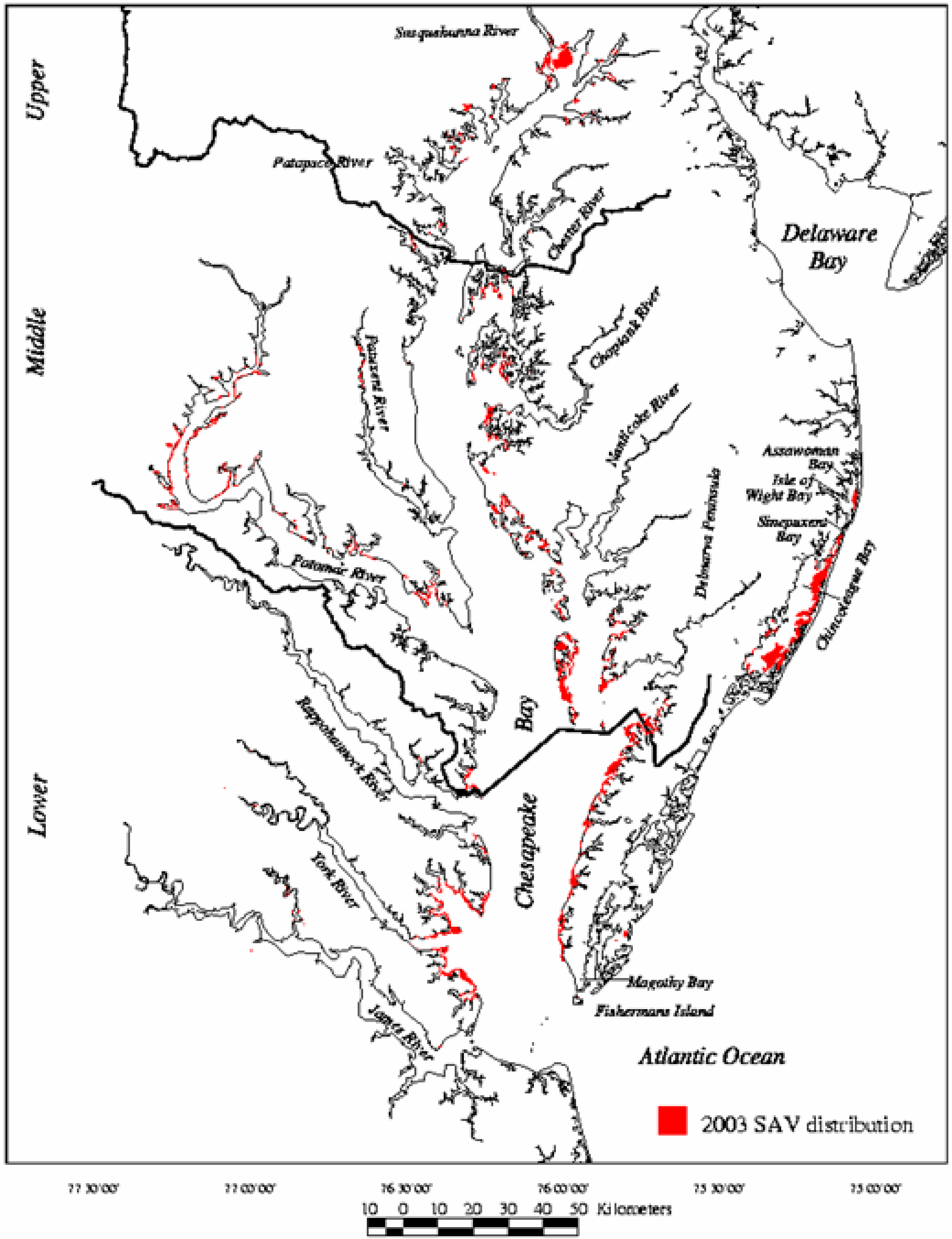
- Research programs
- Bay managers
- Charter boat captains
- "SAV Hunt"



Photographs are converted to maps by VIMS and ground truthed

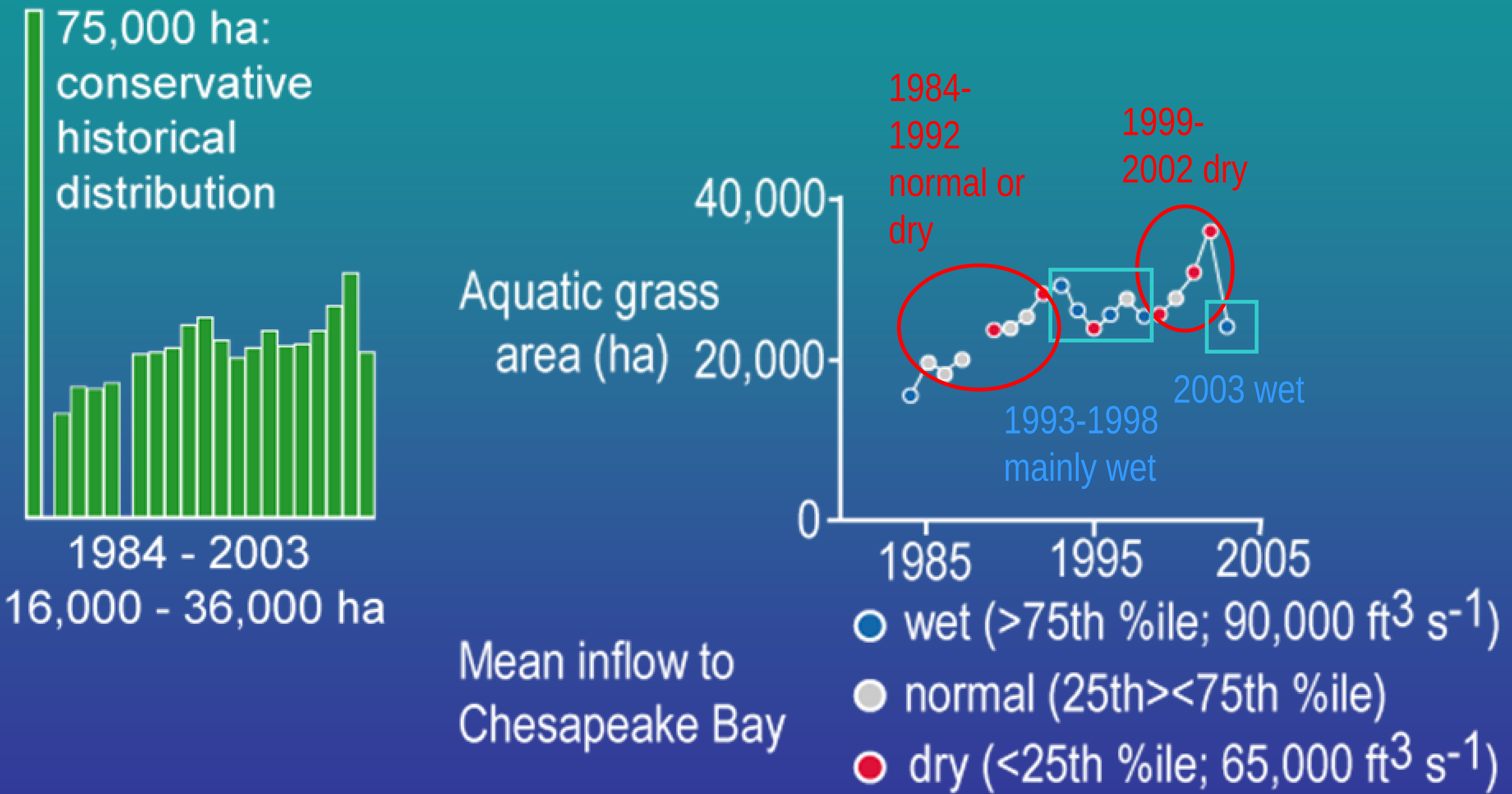


- Diamonds show ground truth sites, where species are recorded
- Density is also estimated from photographs

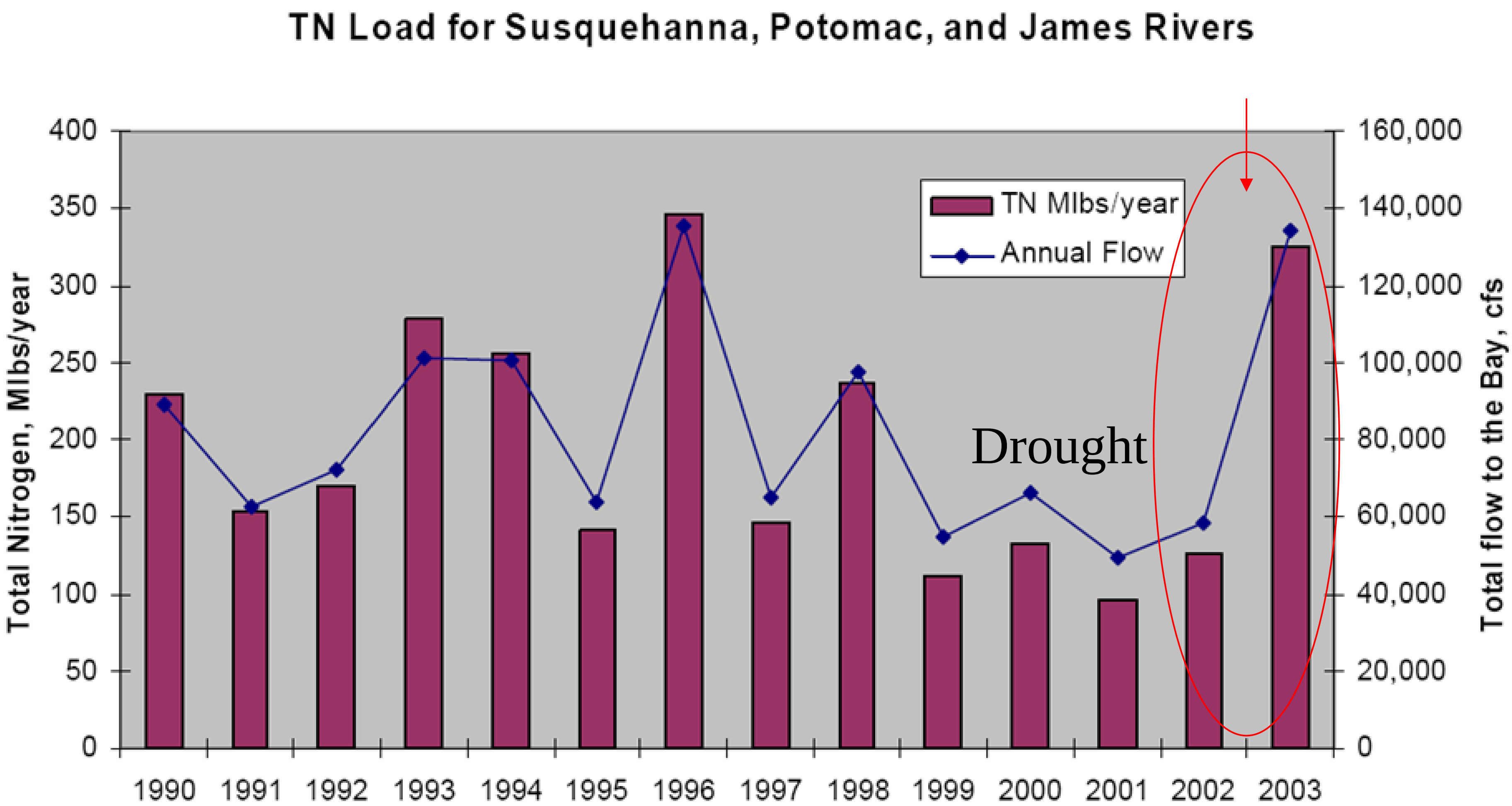


Upper
Middle
Lower
Susquehanna River
Patapsco River
Chester River
Choptank River
Nanticoke River
Patuxent River
Potomac River
Rappahannock River
York River
James River
Delaware Bay
Delmarva Peninsula
Assawoman Bay
Isle of Wight Bay
Sinepuxent Bay
Chincoteague Bay
Chesapeake Bay
Magothy Bay
Fishermans Island
Atlantic Ocean
2003 SAV distribution
10 0 10 20 30 40 50 Kilometers

Aquatic grass abundance is inversely related to freshwater flows



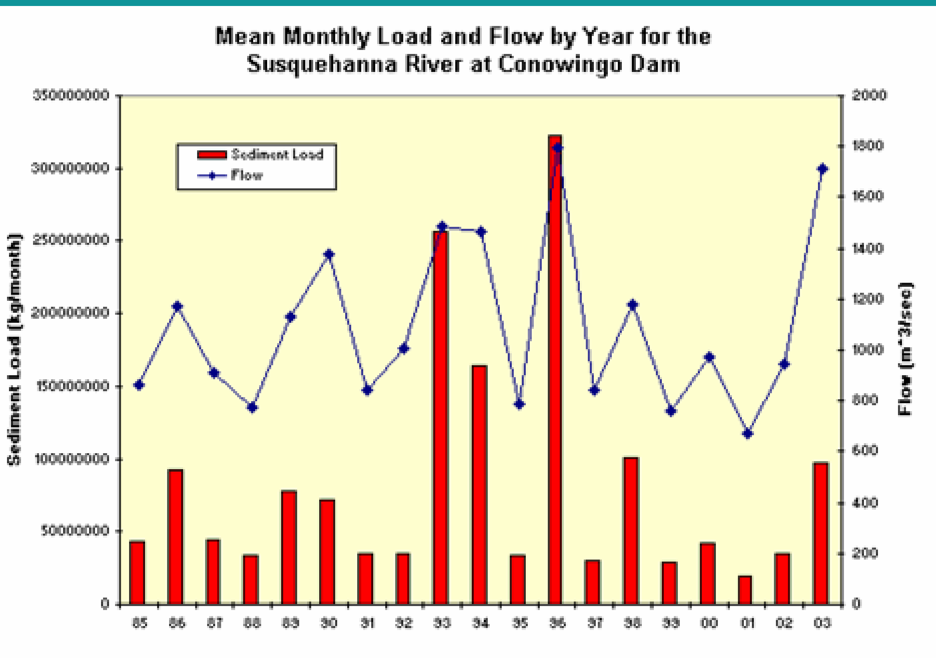
River flow affects nitrogen loads (and thus SAV area)

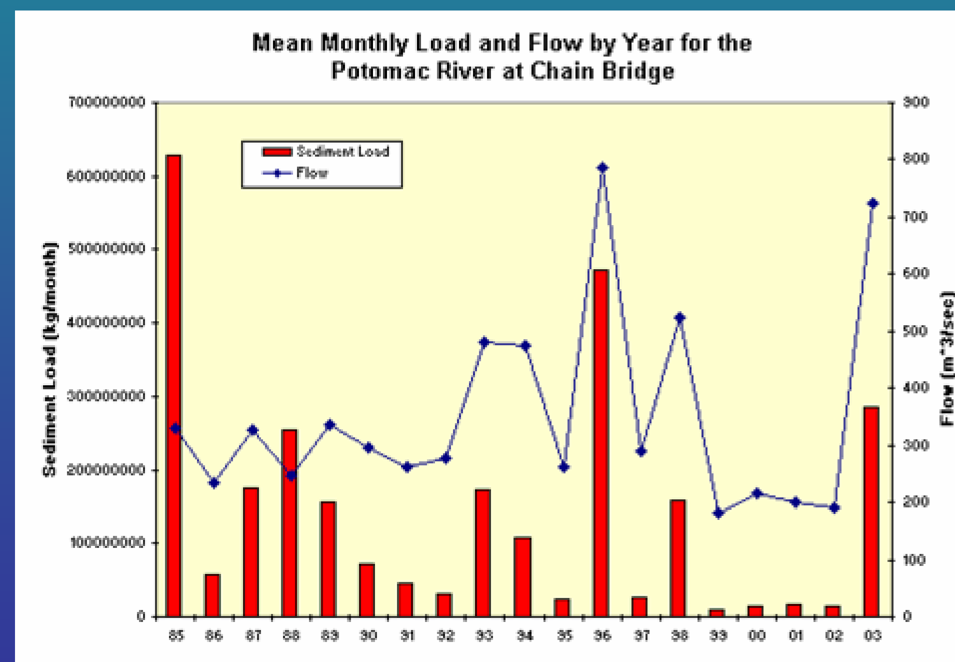


Sediment load also went up with flow, but was higher in 1996 than 2003

Source: USGS, CBP

Sediment load also responds to flow

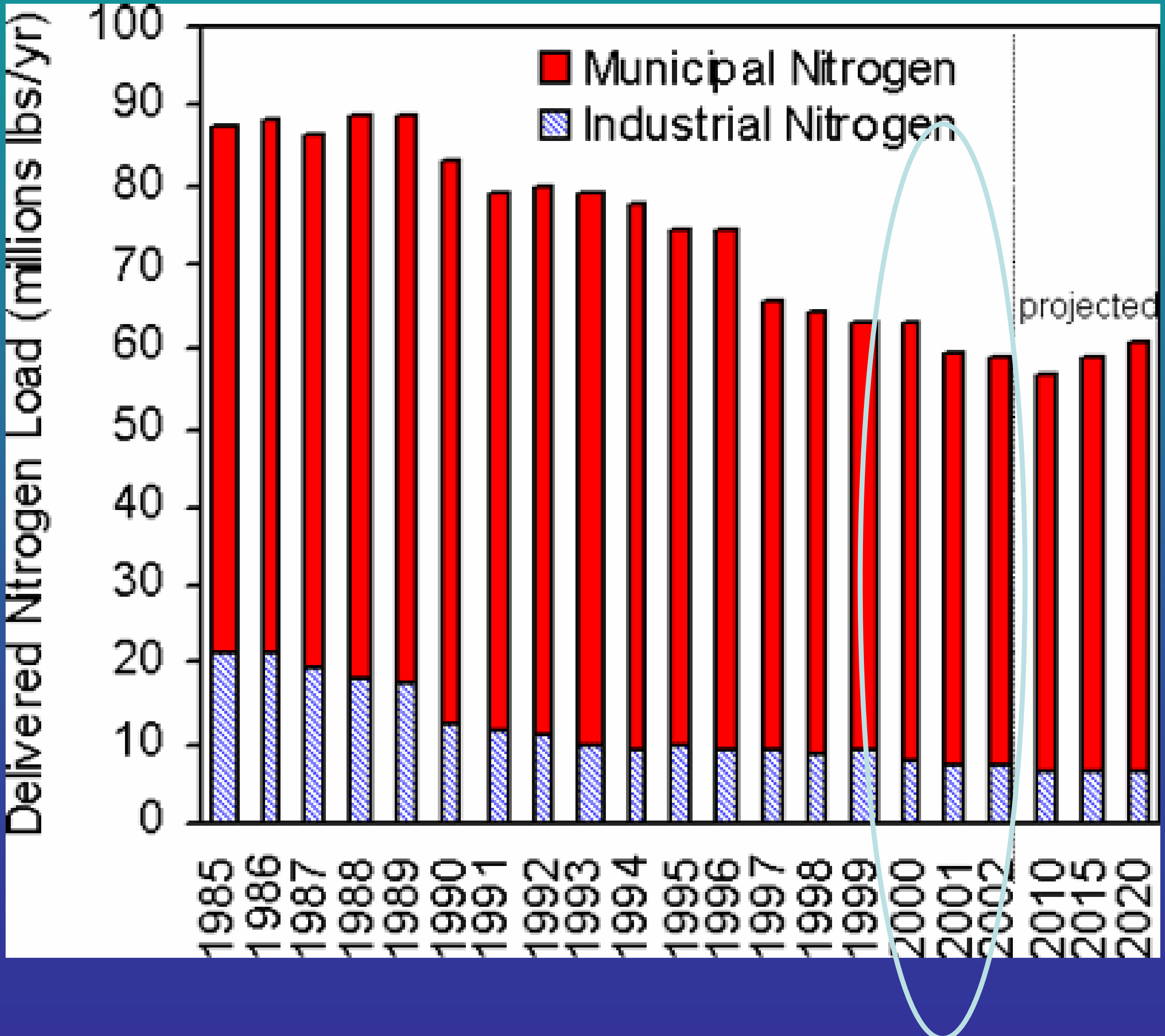




Source: MD DNR, CBP

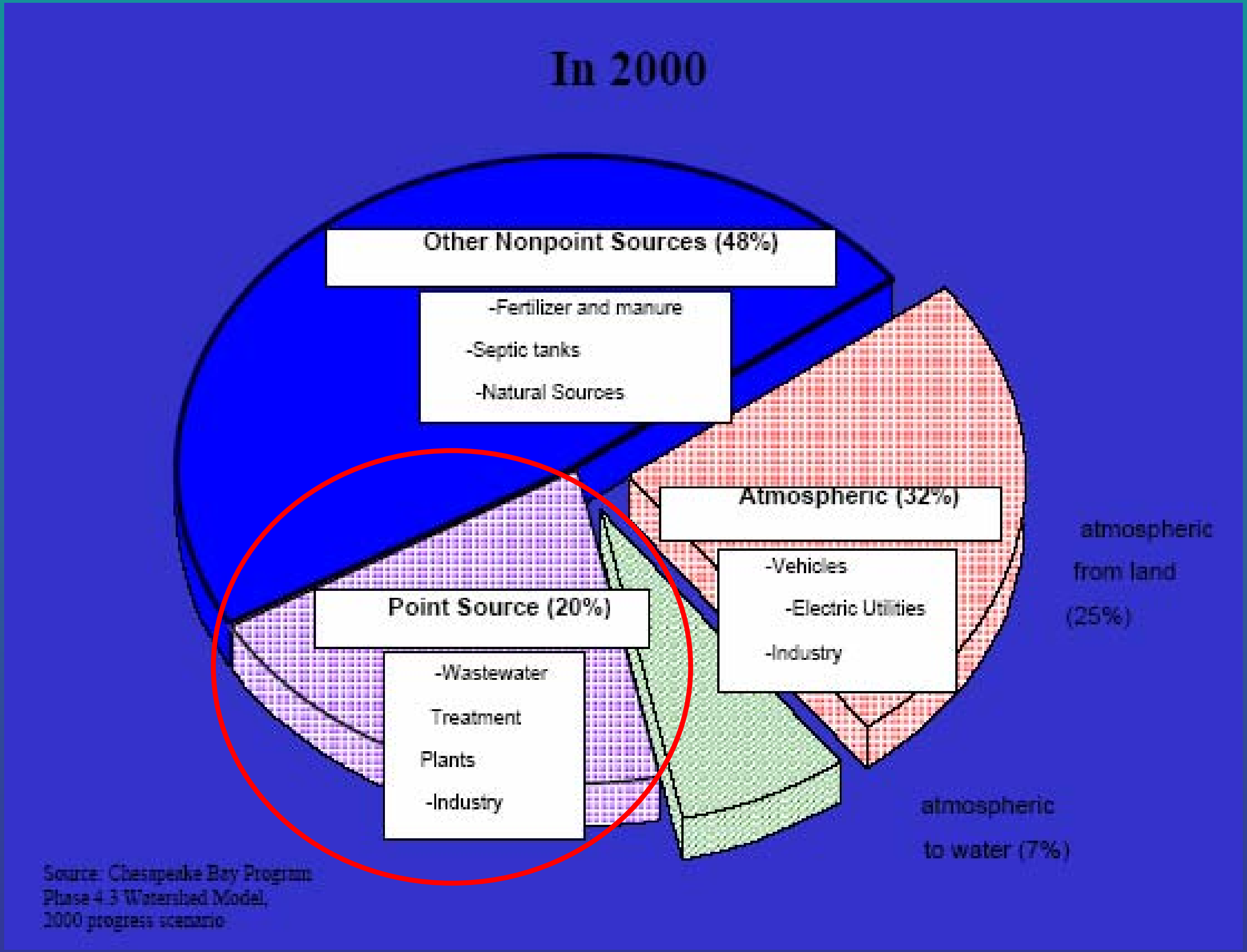
Why do changes in flow change N loads so much?

A: Point source nitrogen is going down...



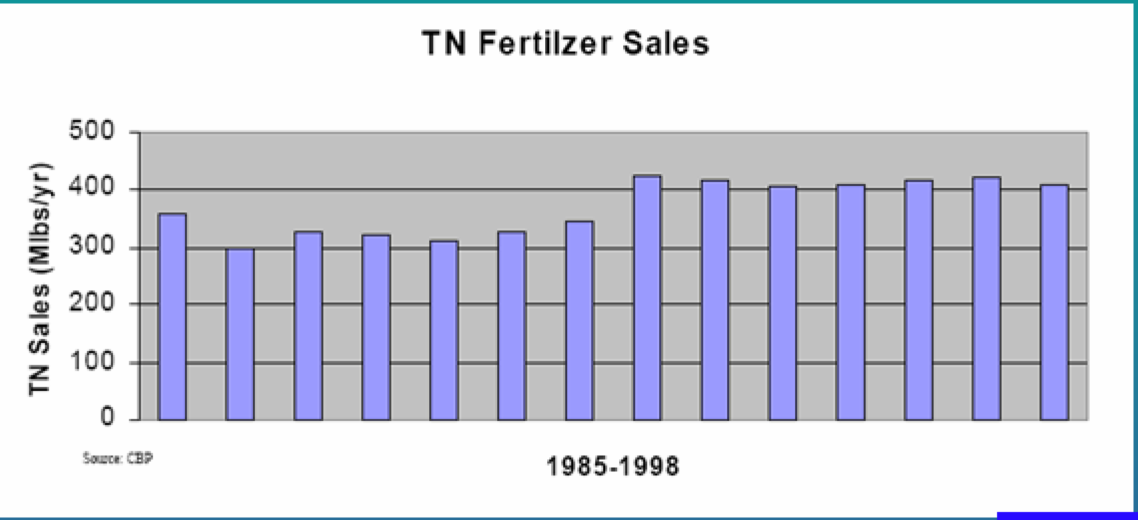
Source: CBP

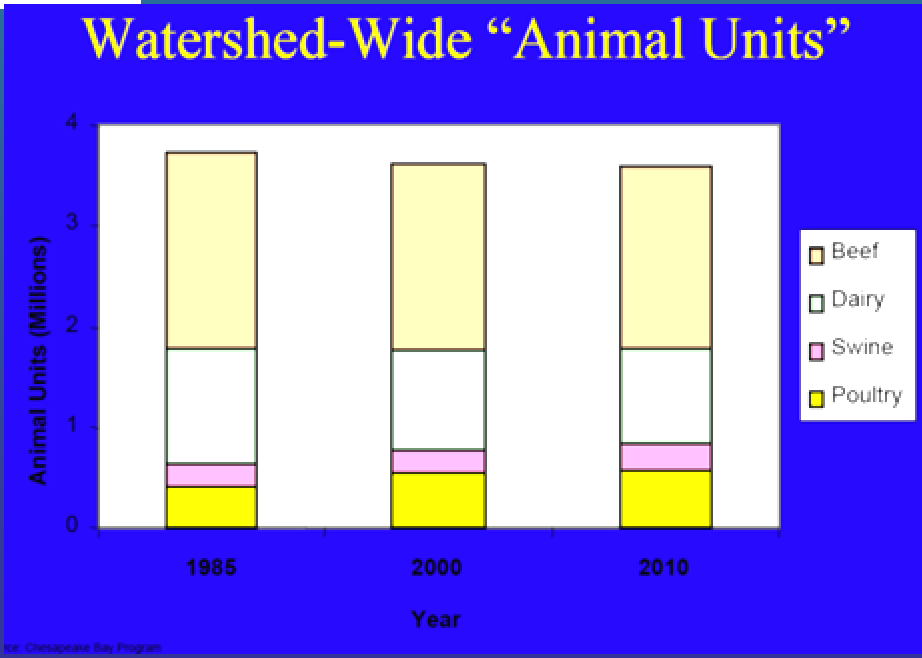
... but it's only 20% of the total inputs



Source: USGS, CBP

Diffuse N sources are more affected by rainfall, and *do not appear to be declining*





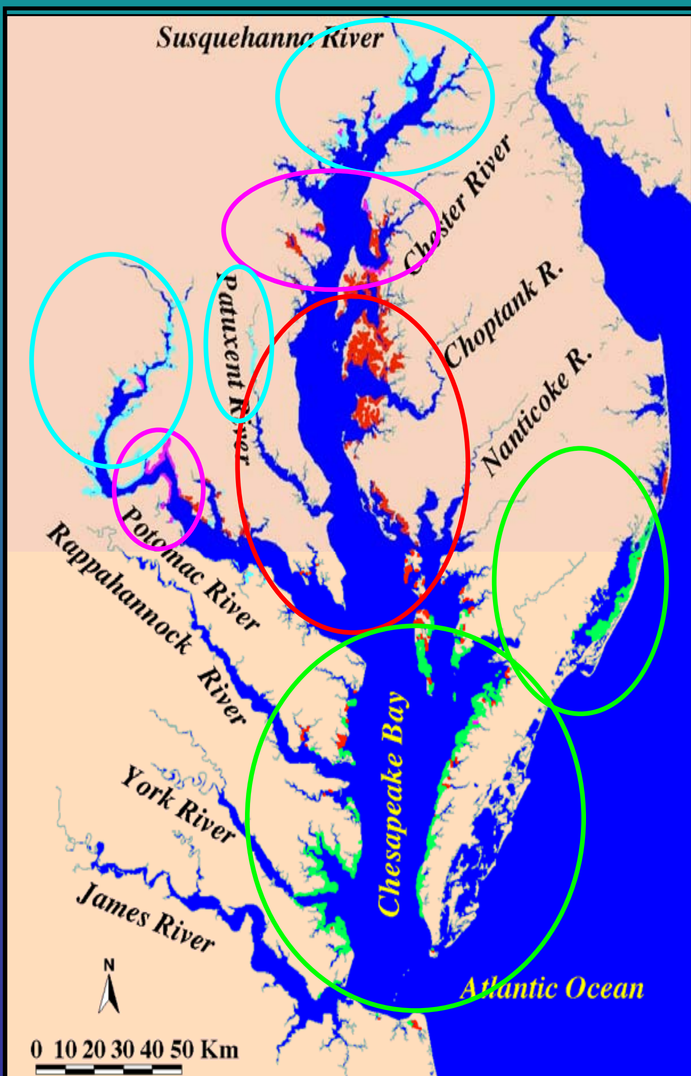
Tom Horton estimated that the manure produced by livestock in Lancaster County, PA, alone could meet the fertilizer needs for the whole watershed, but it would be too expensive to ship it.

Thus, we need to reduce diffuse N sources to improve aquatic grasses.

Source: USGS, CBP




Aquatic grass communities are determined by salinity regime



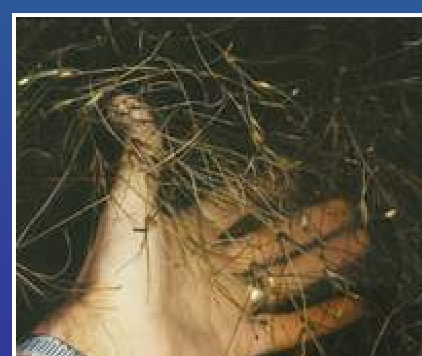
Moore, Wilcox, Orth (2000) Estuaries 23:115-227

Chesapeake Bay Communities

Names color coded to map

Freshwater

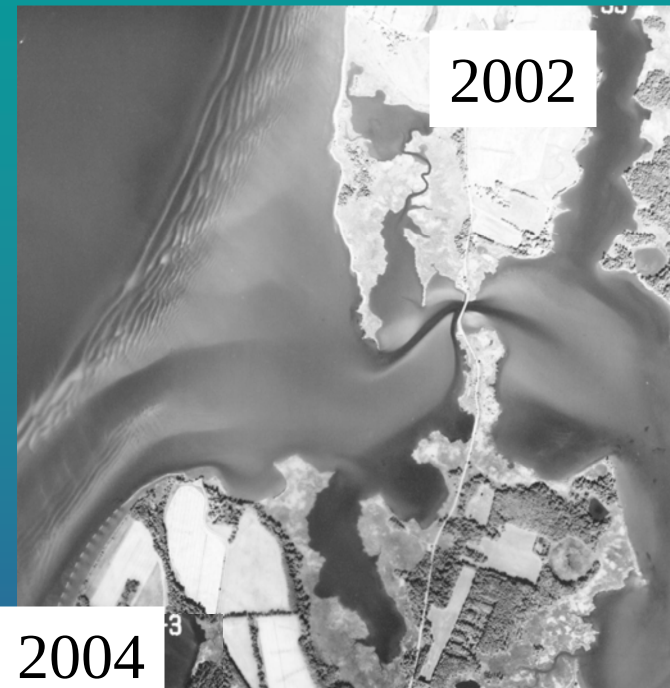
Potamogeton



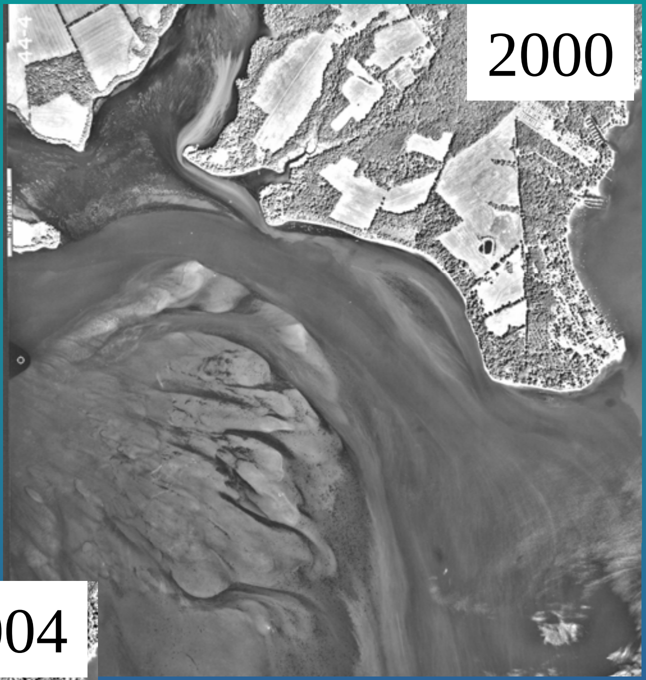
Ruppia

Zostera

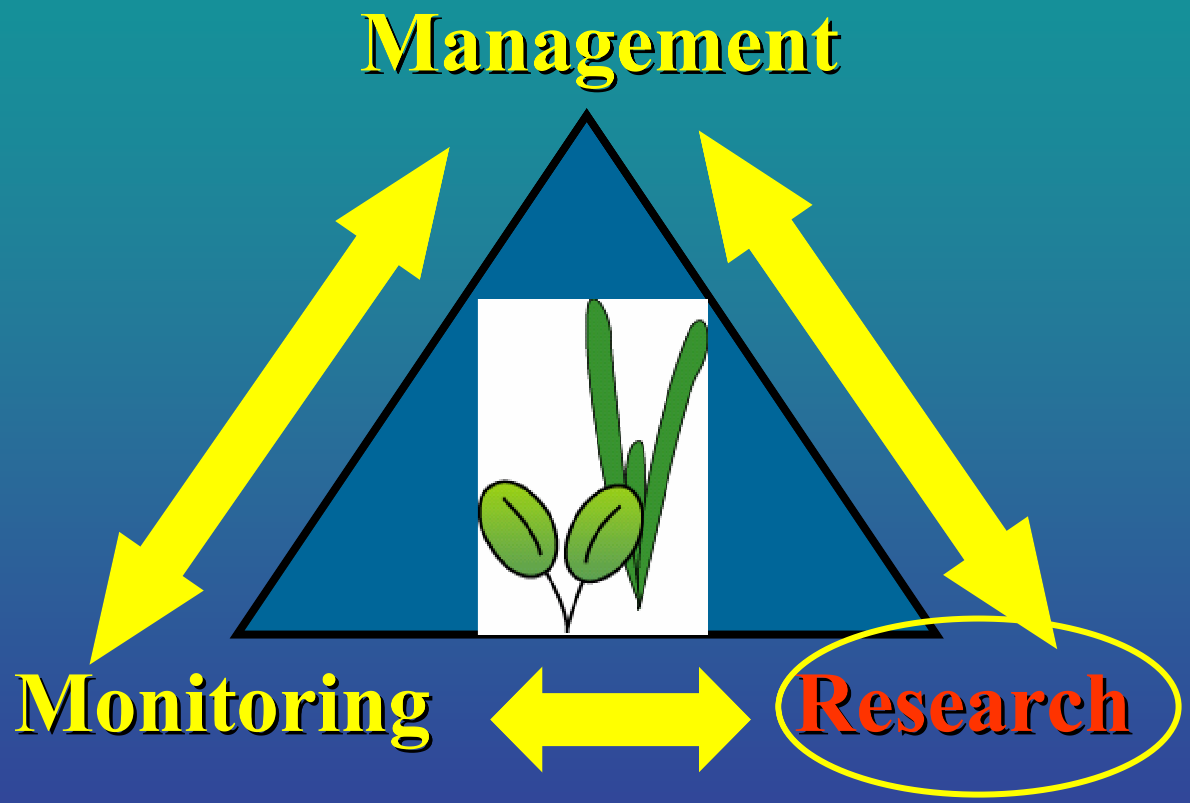
Eastern Neck Narrows



Havre de Grace



THE BENEFITS AND CHALLENGES OF INTEGRATING

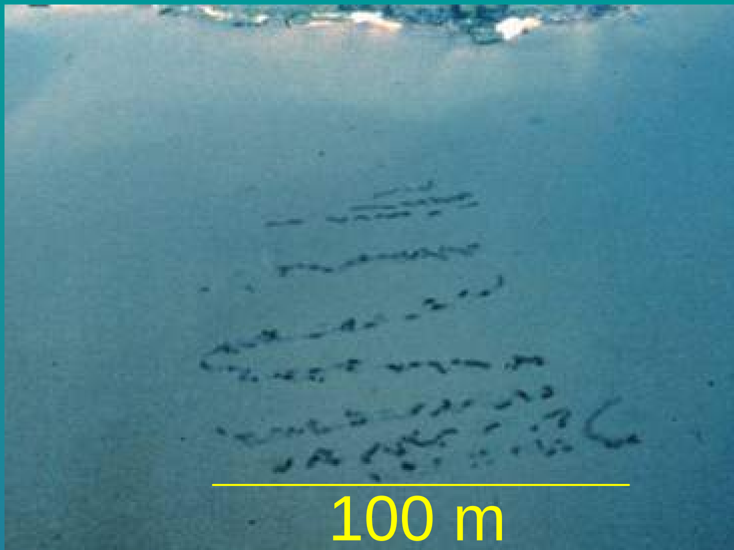


FOR SUBMERGED AQUATIC VEGETATION CONSERVATION AND RESTORATION

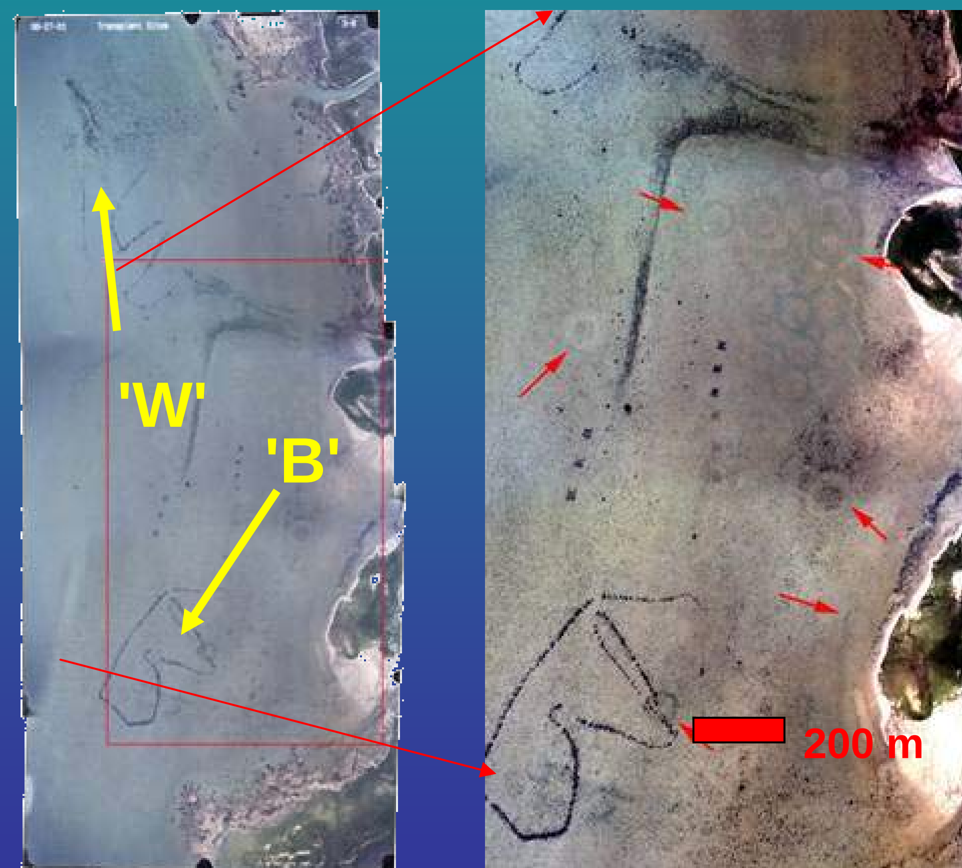
EMERGING ISSUES IN SEED ECOLOGY

Importance of seeds in establishing new beds versus maintaining existing beds (basic research)

Optimal time for use in restoration efforts with seed (spring, summer, fall) (applied research)



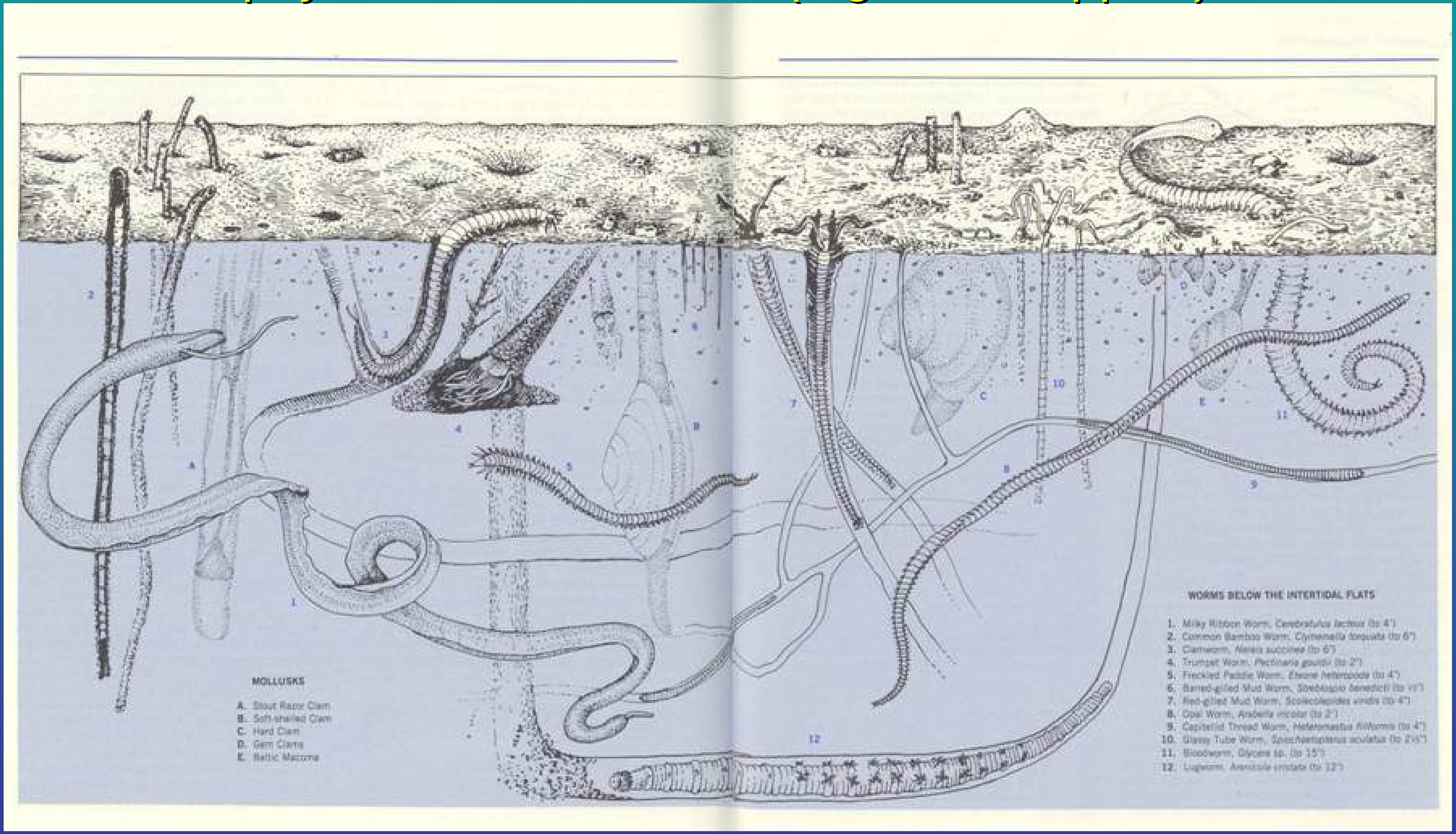
Dark bands are patches of seedlings from seeds broadcast onto bare sand substrate



Seeds on the sediment surface do not move far from where they settle

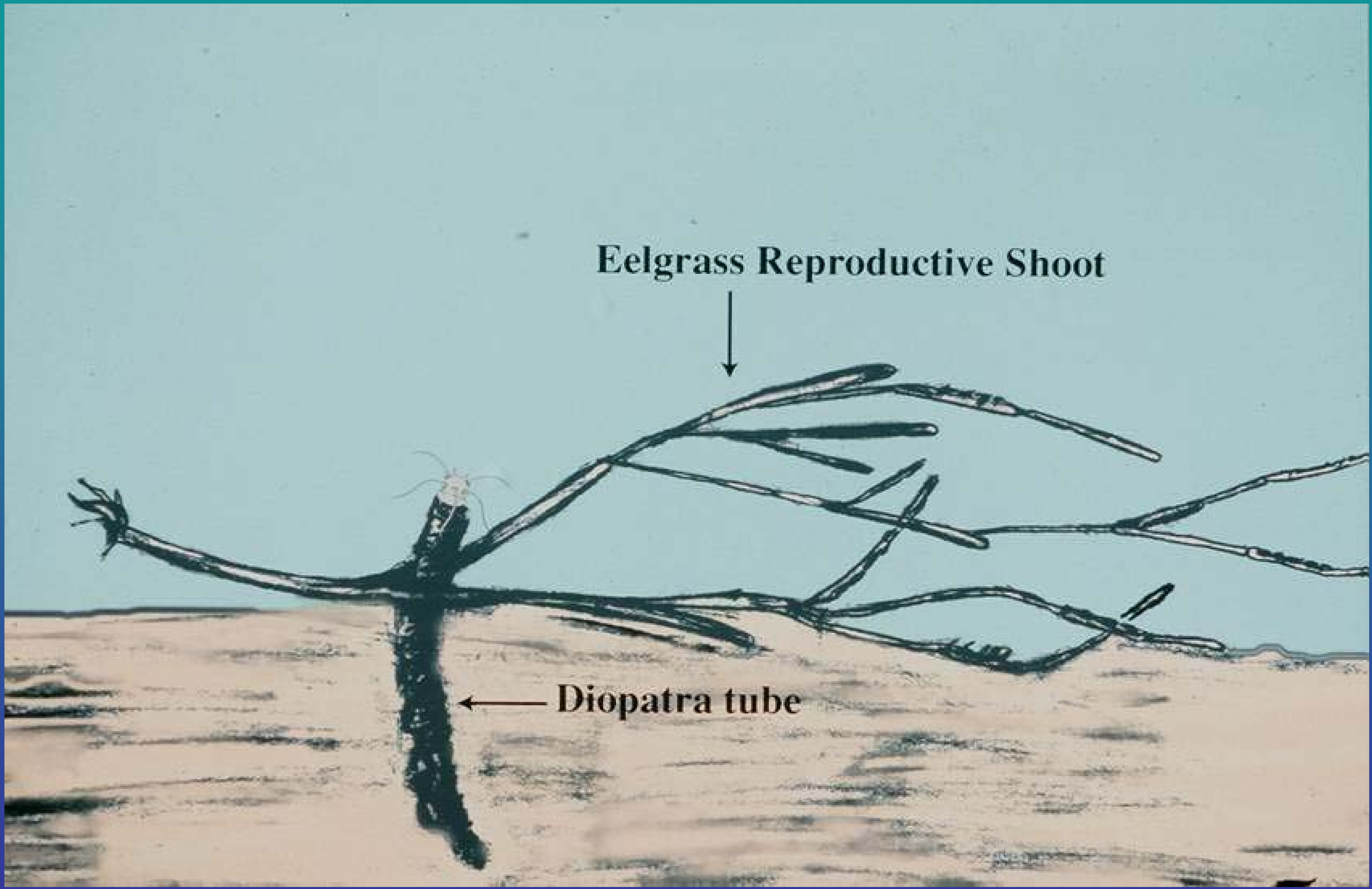
Orth, Moore and Luckenbach (1994) Ecology 75:1927-1939

Seeds retained where they settle because of topographic complexities of sediment surface due to bioturbation or physical discontinuities (e.g., sand ripples)



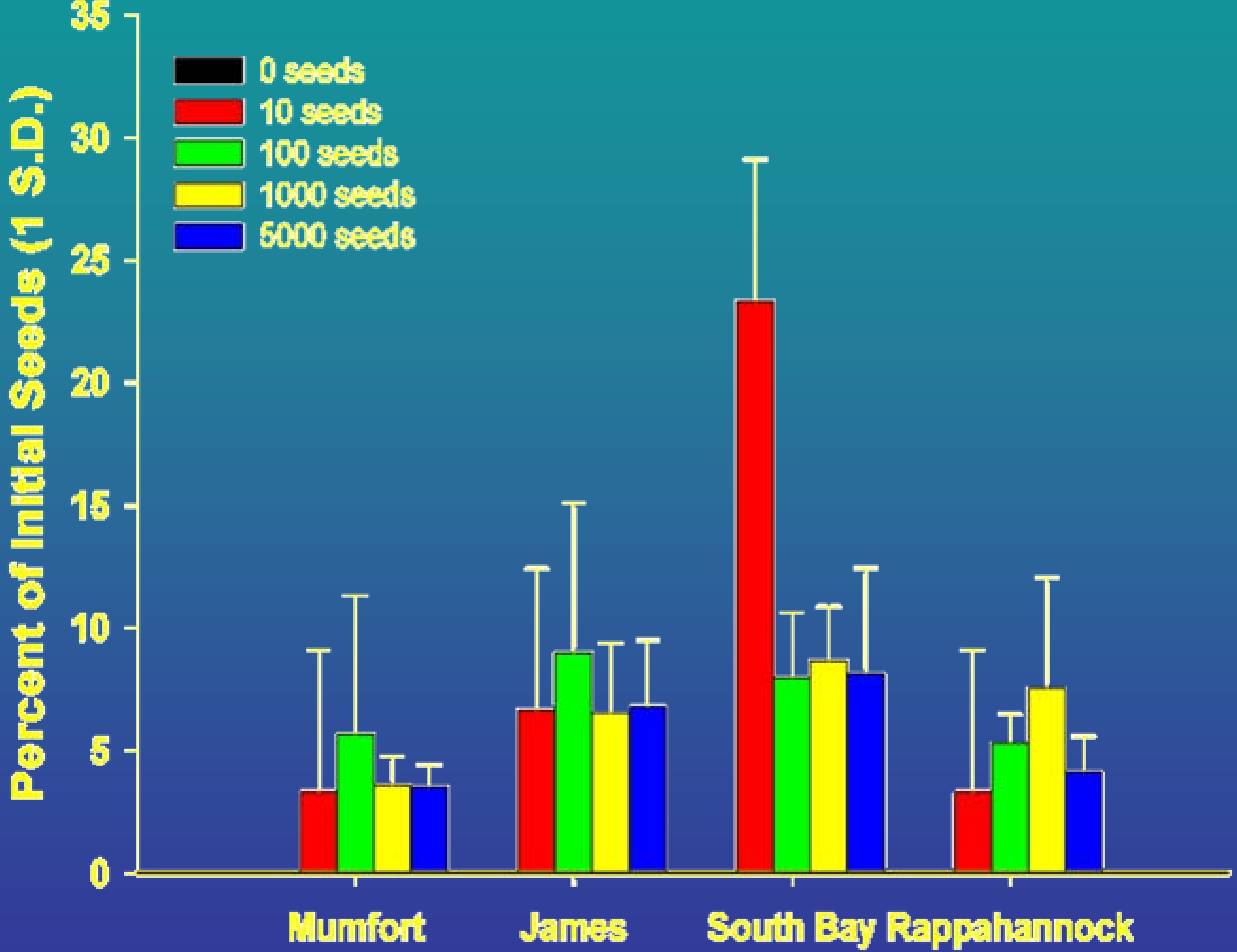
Luckenbach and Orth (1999) Aquatic Botany 62:235-247

Diopatra influences reproductive shoot dispersal by entraining then in tube caps



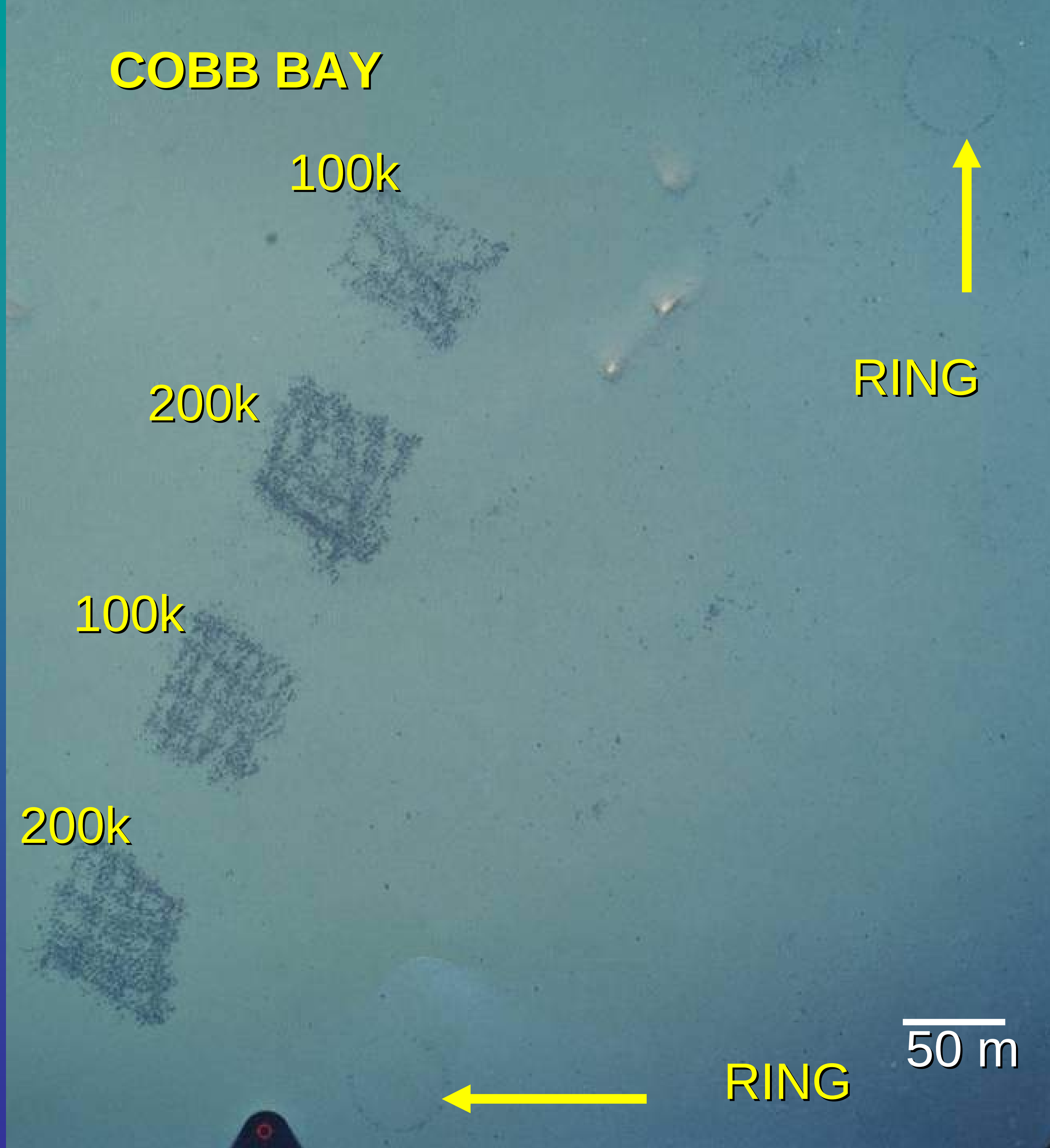
Harwell and Orth (2001) Aquatic Bot 70 1-7

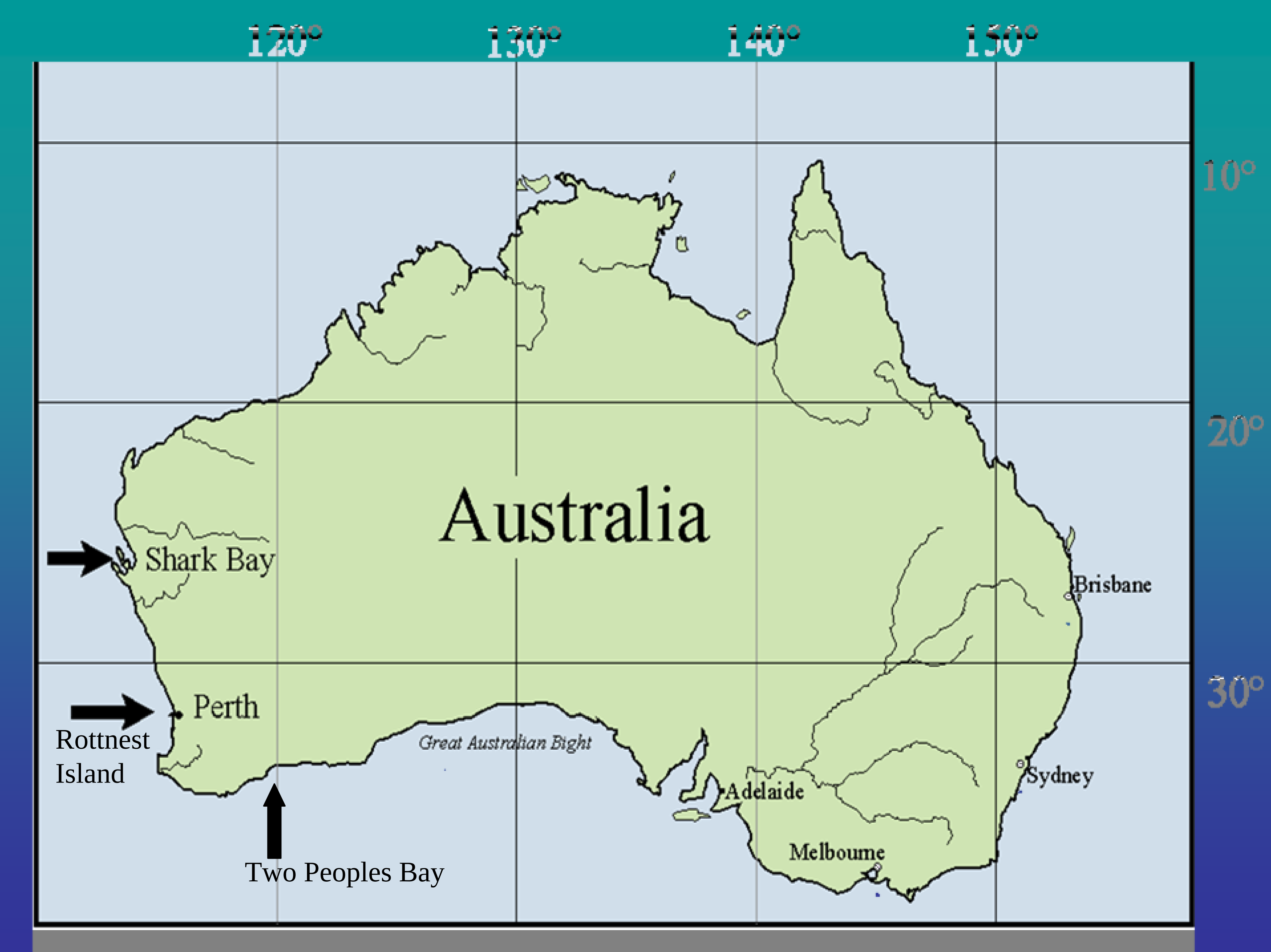
Seedling Abundance vs. Initial Seed Density

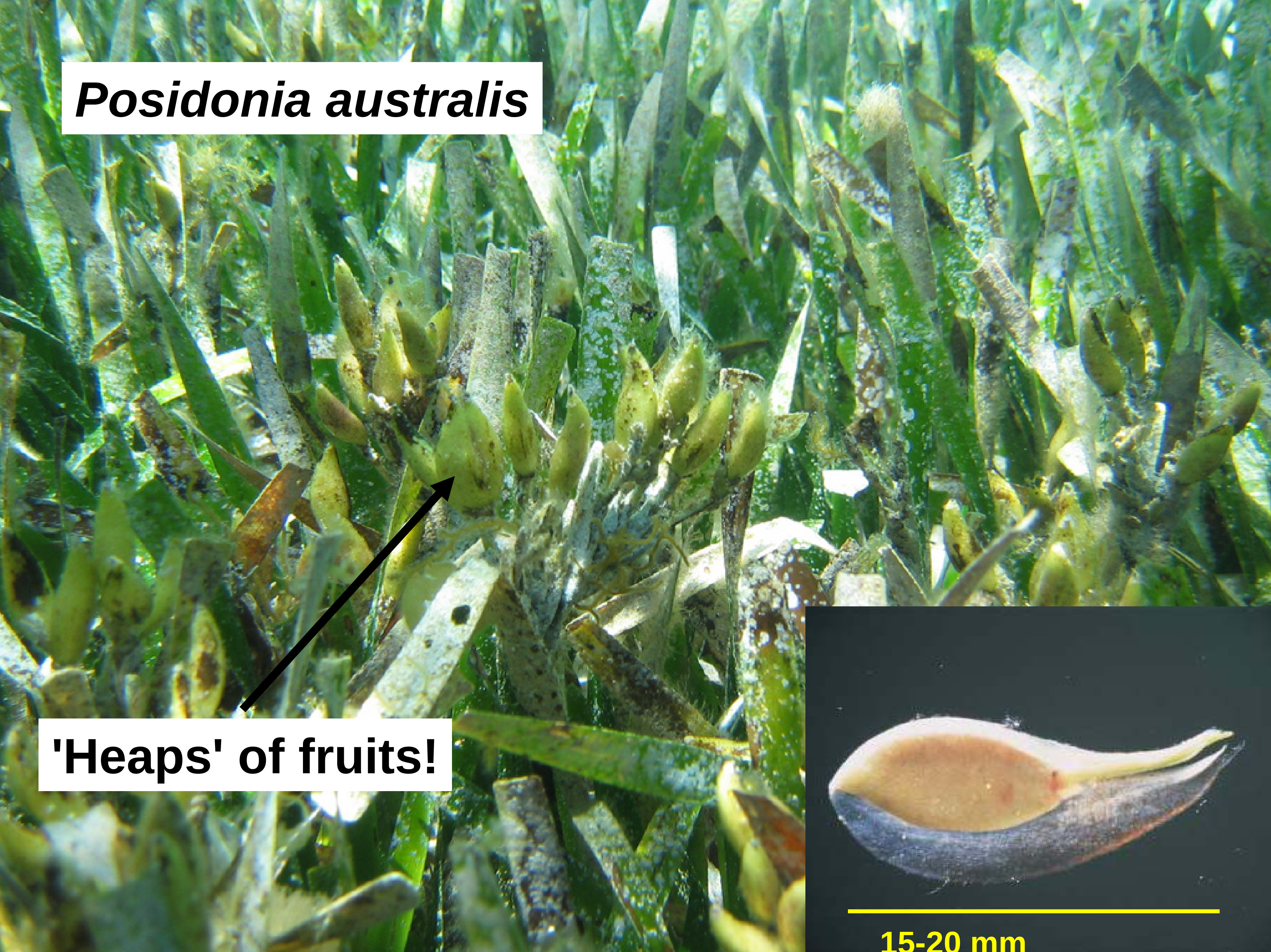


Orth, Fishman, Harwell and Marion (2003) Mar. Ecol. Prog. Ser. 250:71-79.

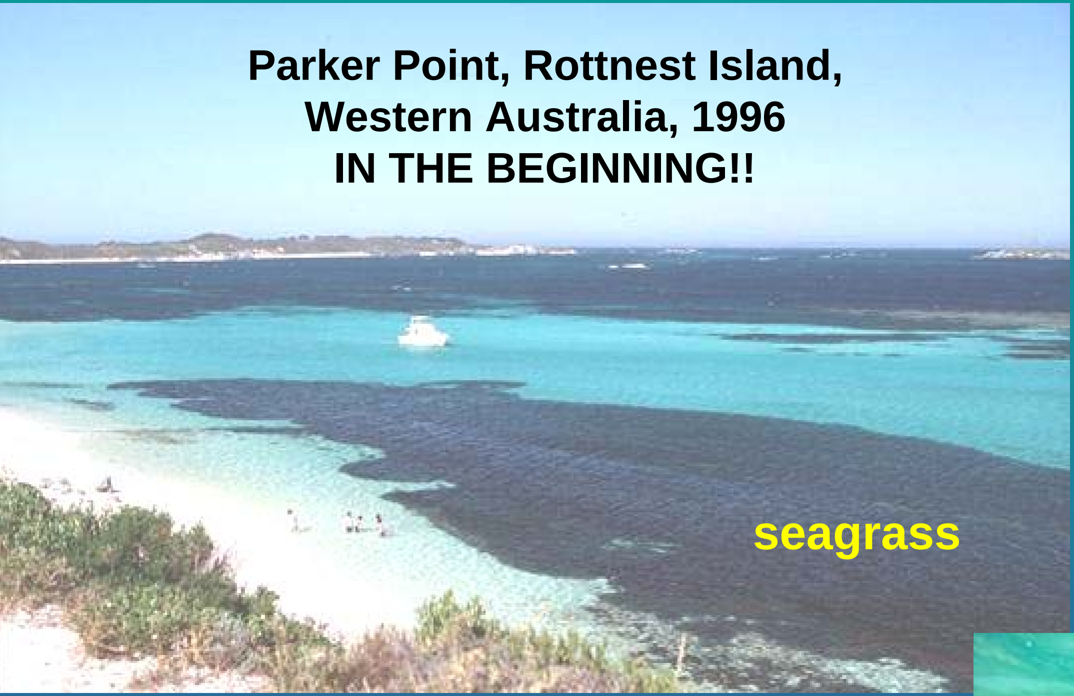
ACRE PLOTS PLANTED 2001




120°
130°
140°
150°
10°
20°
30°
Australia
Shark Bay
Perth
Rottnest
Island
Two Peoples Bay
Great Australian Bight
Adelaide
Melbourne
Sydney
Brisbane



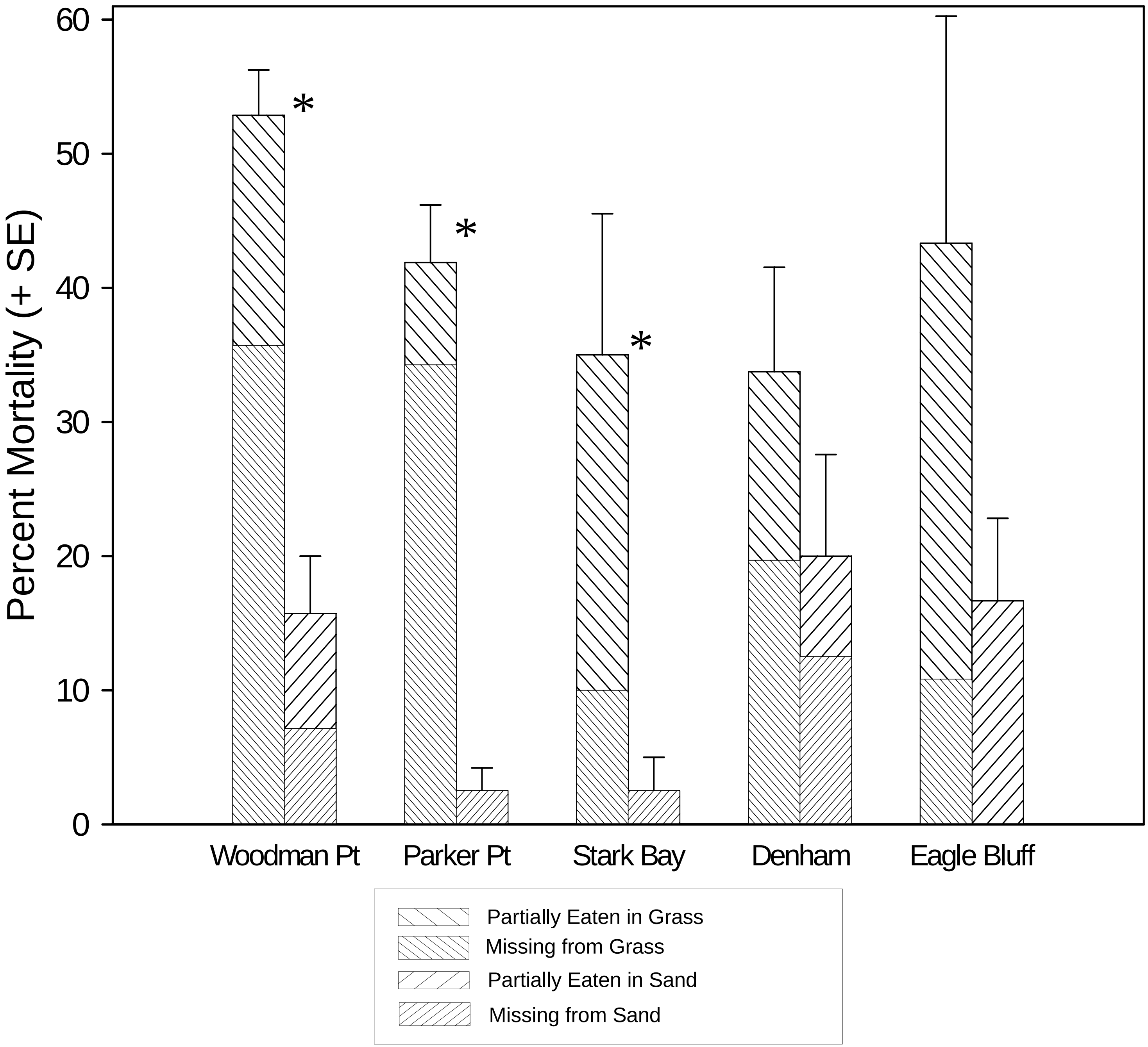
Posidonia australis
'Heaps' of fruits!
15-20 mm



Seedlings abundant in bare sand and *Halophila*, none in dense seagrass

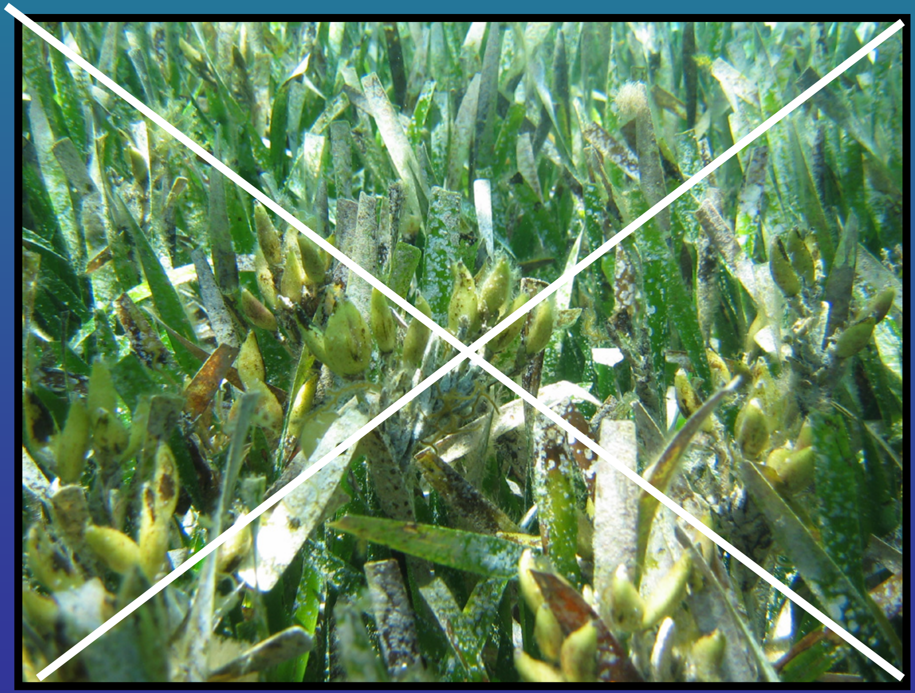
METHODS (Phase I)

- Tethered seeds
- 10 in sand and grass
- 24 hour test period
- Scored as completely or partially eaten
- Trials 3-8 days depending on location in Nov. & Dec. 2001



Orth *et al*. 2002.
MEPS 244:81-88

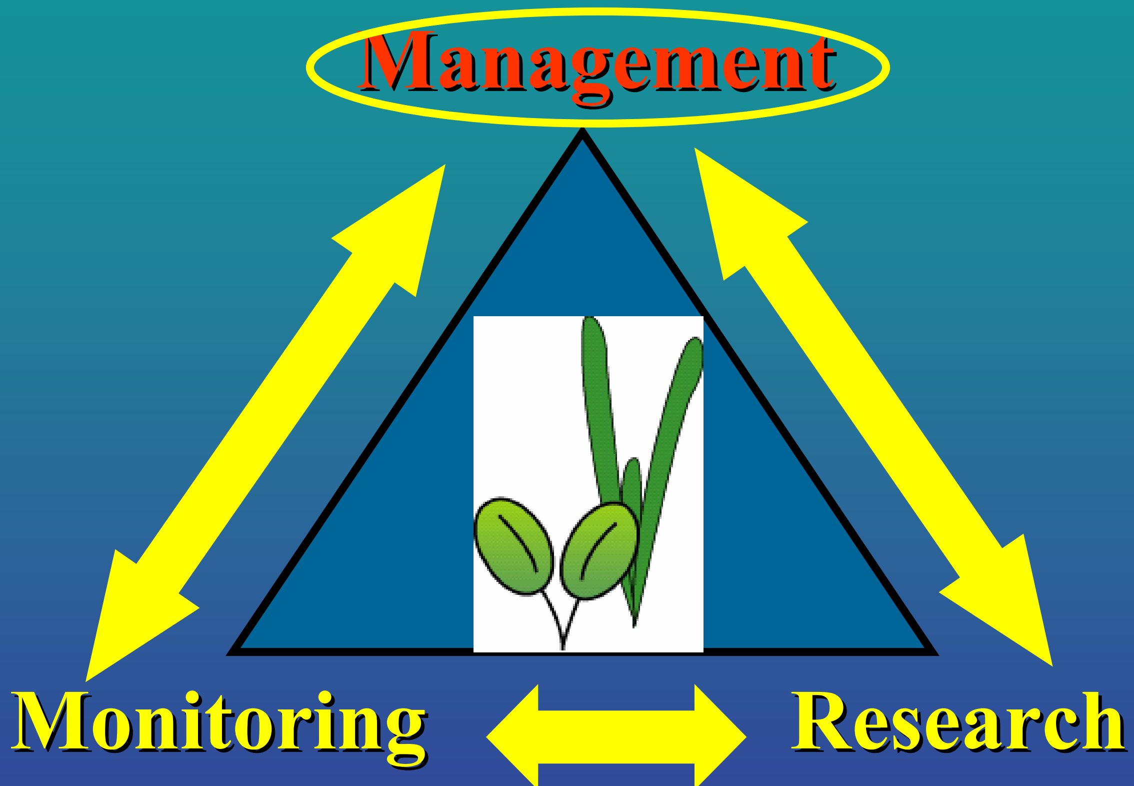

2
3
4



For a seed

STAY OUT OF THE GRASS

THE BENEFITS AND CHALLENGES OF INTEGRATING



FOR
SUBMERGED AQUATIC VEGETATION CONSERVATION AND RESTORATION

CHESAPEAKE BAY POLICIES FOR SEAGRASS RESTORATION AND CONSERVATION

- 1989 Management Policy - achieve net gain in seagrass distribution
- 1992 Bay Agreement - use seagrass as initial measure of progress in restoring living resources and water quality
- 1993 Bay Agreement - restore seagrass to historic levels and an interim goal of 114,000 acres

CHESAPEAKE BAY POLICIES FOR SEAGRASS RESTORATION AND CONSERVATION

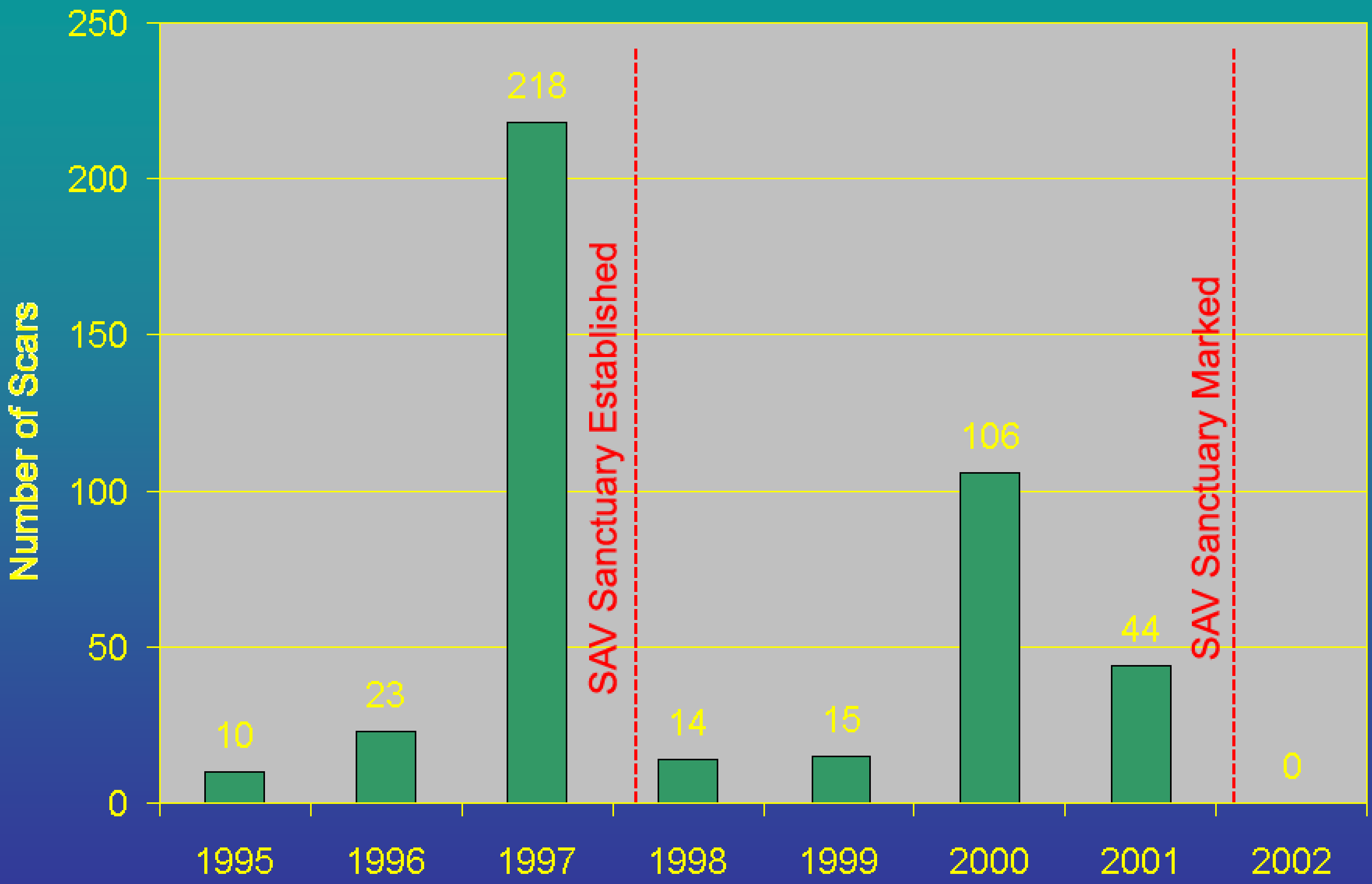
- 1997 Blue Crab Fisheries Management Plan - link fisheries management to both water and habitat (seagrass) quality
- 2000 Bay Agreement - develop specific plans to protect and restore seagrass
- 2002 Bay Agreement - new goal for restoring seagrass set at 186,000 acres
- 2003 - Strategy for the protection and restoration of SAV


Chincoteague Bay
SAV Sanctuary

CHINCOTEAGUE BAY SAV SANCTUARY

VMRC Reg 4VAC 20-1010-10 (1997 - no markers); amended by Reg 4VAC 20-70-120 (Dec. 1, 2001 - with marked boundaries) following meetings with staff, scientists, and watermen preventing clam and crab dredging in SAV protected area


SAV



Number of Scars
250
200
150
100
50
0
10
23
218
14
15
106
44
0
SAV Sanctuary Established
SAV Sanctuary Marked
1995
1996
1997
1998
1999
2000
2001
2002

Hydraulic Dredge Scars in Maryland

MARYLAND REGULATIONS

NR4-1006.1 - No clam dredging in areas delineated with SAV from a composite of 3 consecutive years of aerial photography (takes into account natural inter-annual variability)

Aquaculture versus critical habitats
Hard clam culture
Eelgrass

'Strategy to Accelerate Protection and Restoration of SAV in Chesapeake Bay'

By Dec. 2008, plant at least 1000 acres at multiple sites!!

Restoration of aquatic grass communities of Chesapeake Bay: How should we proceed?

Robert Orth(1), Peter Bergstrom(2), Walter Boynton(3), Tim Carruthers(3), William Dennison(3), Katia Englehardt(3), Dave Goshorn(4), Lee Karrh(4), Evamaria Koch(3), Scott Marion(1), Ken Moore(1), Laura Murray(3), Mike Naylor(4), Nancy Rybicki(5) and Dave Wilcox(1)

1 Virginia Institute of Marine Science VIMS
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4 Maryland Department of Natural Resources
5 USGS science for a changing world

A variety of techniques are used for restoration of aquatic grass

Adult shoot transplants

Seed dispersal

All are labor intensive; tedious; have potential donor bed impacts; and only plant small areas

Long term survival of eelgrass planted in the York River at VIMS

1984

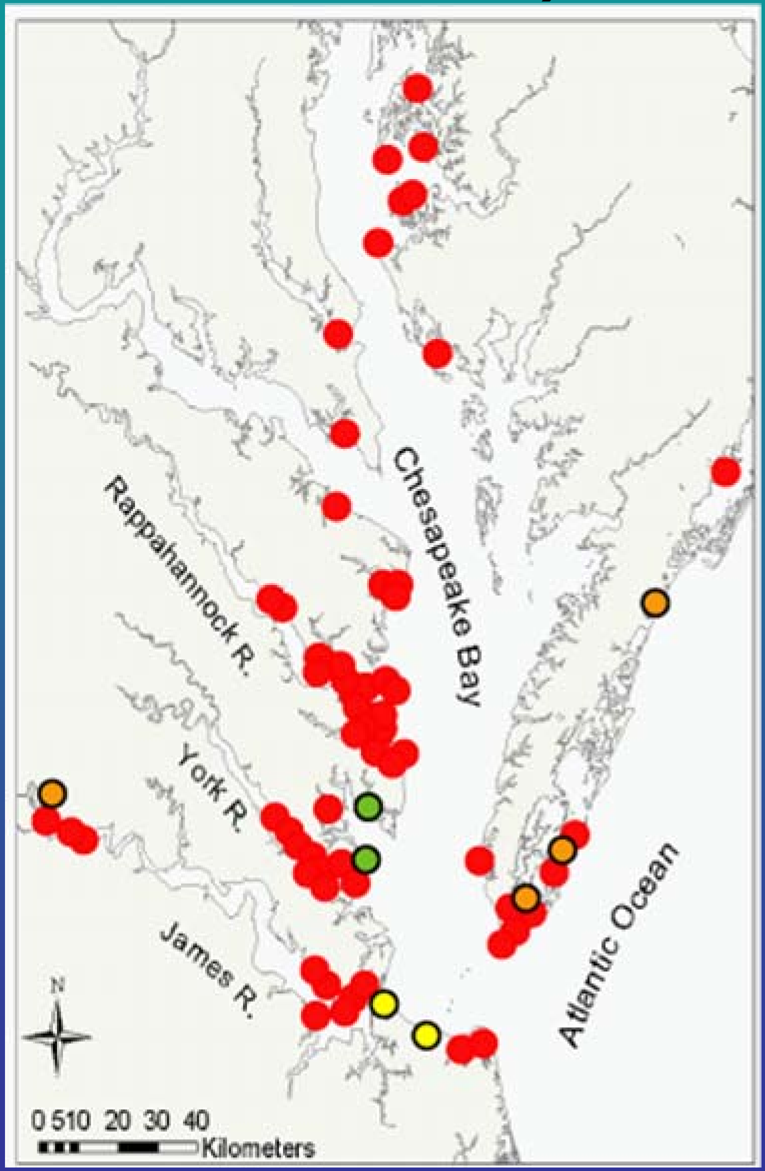
1985

1987

1988

1990-2004

However, less than 10% of transplant sites (adult or seed) have long term survival



VIMS Transplant Sites 1979-2004

- Transplants died
- Survival 1-5 years
- Survival 5-10 years
- Survival >10 years

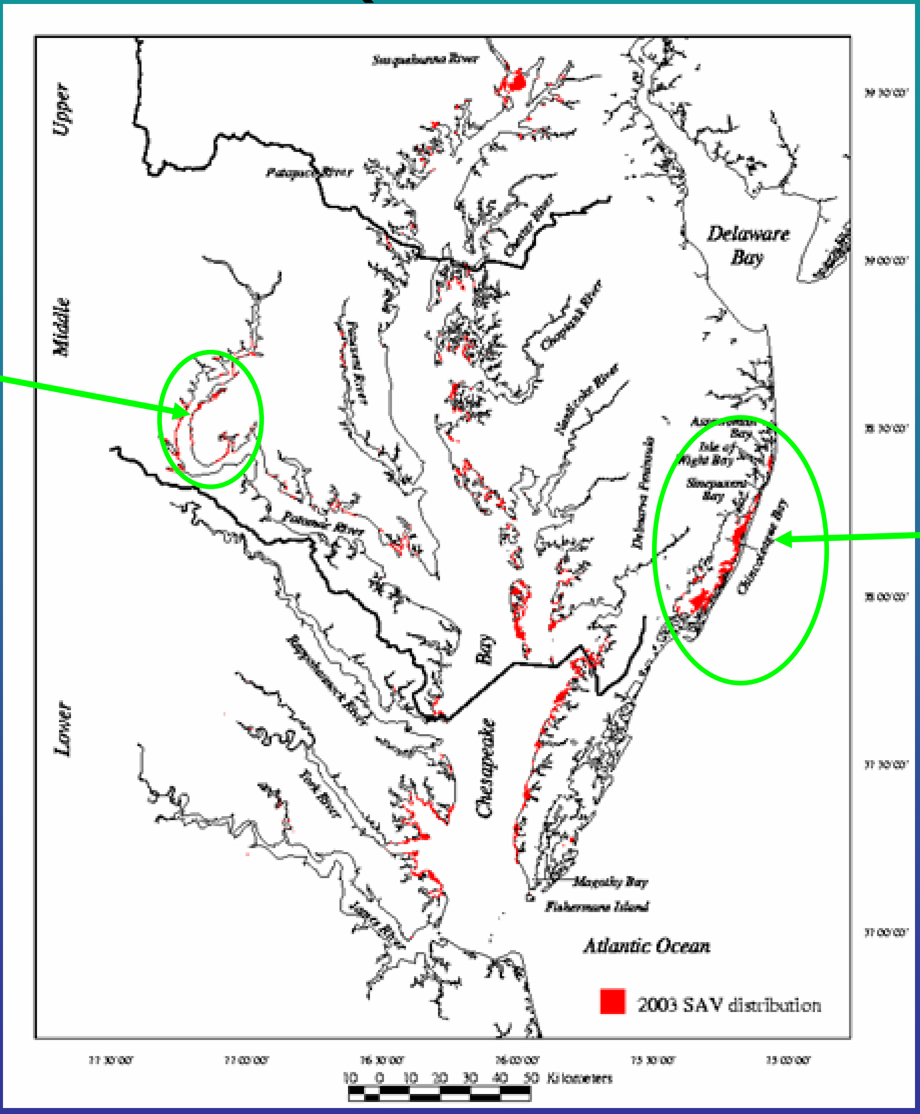
How is nature doing relative to our efforts?

Humans

Nature

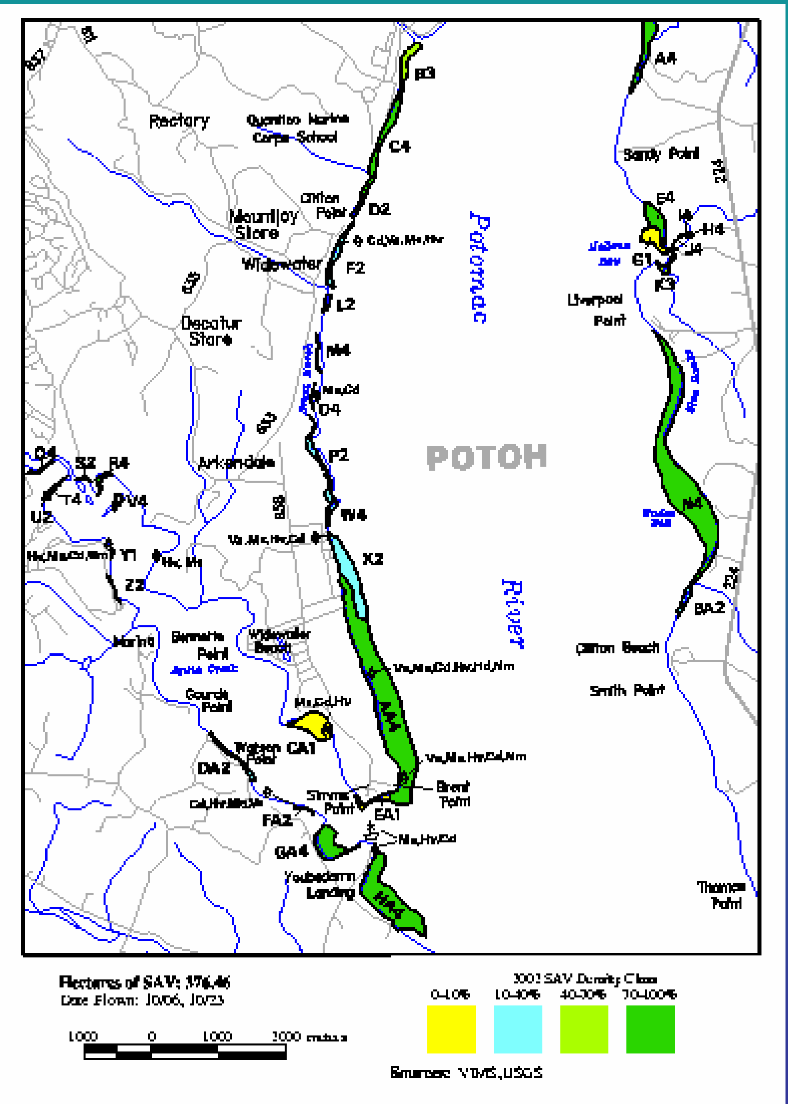
Nature is doing pretty well in some areas (natural recovery)

Middle Potomac River

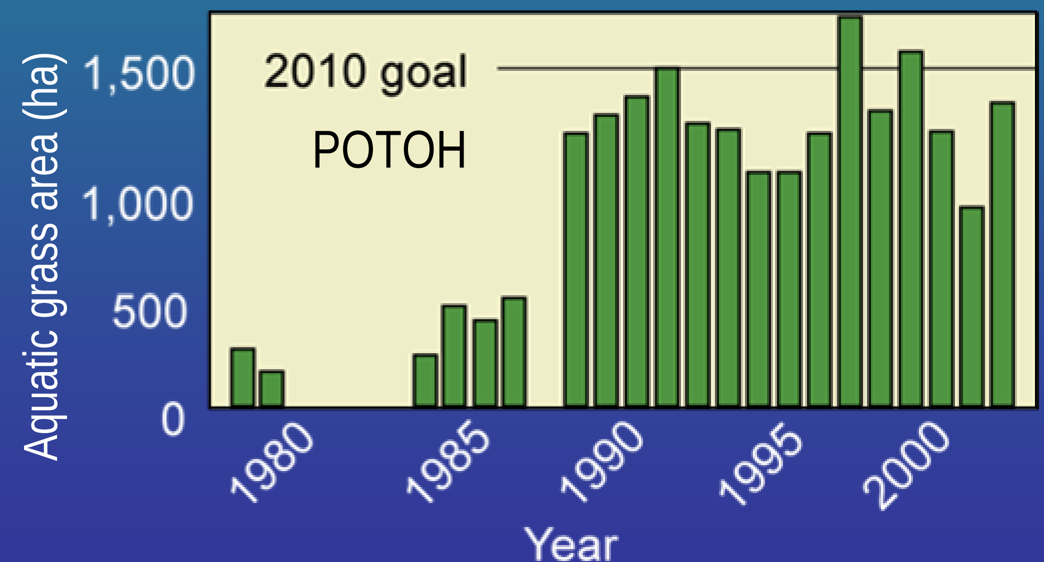


MD Coastal Bays

Natural recovery of freshwater community in the middle Potomac; 1982-2003

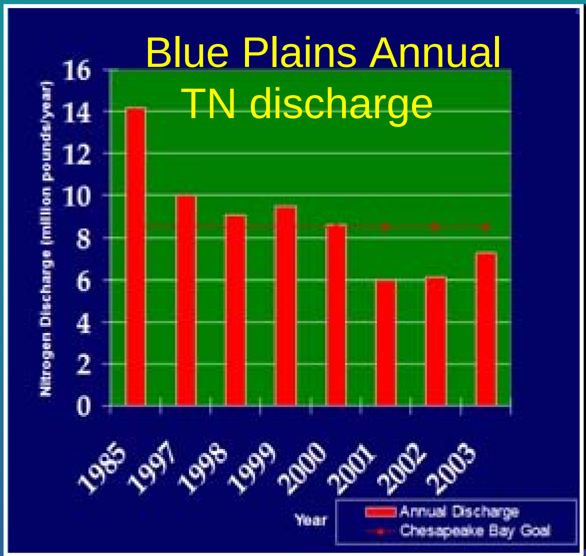


- Initial recruitment of exotic *Hydrilla*
- Native species slowly increased from propagules upriver - *Hydrilla* remains
- During this period, nitrogen in the middle Potomac declined (next slide)

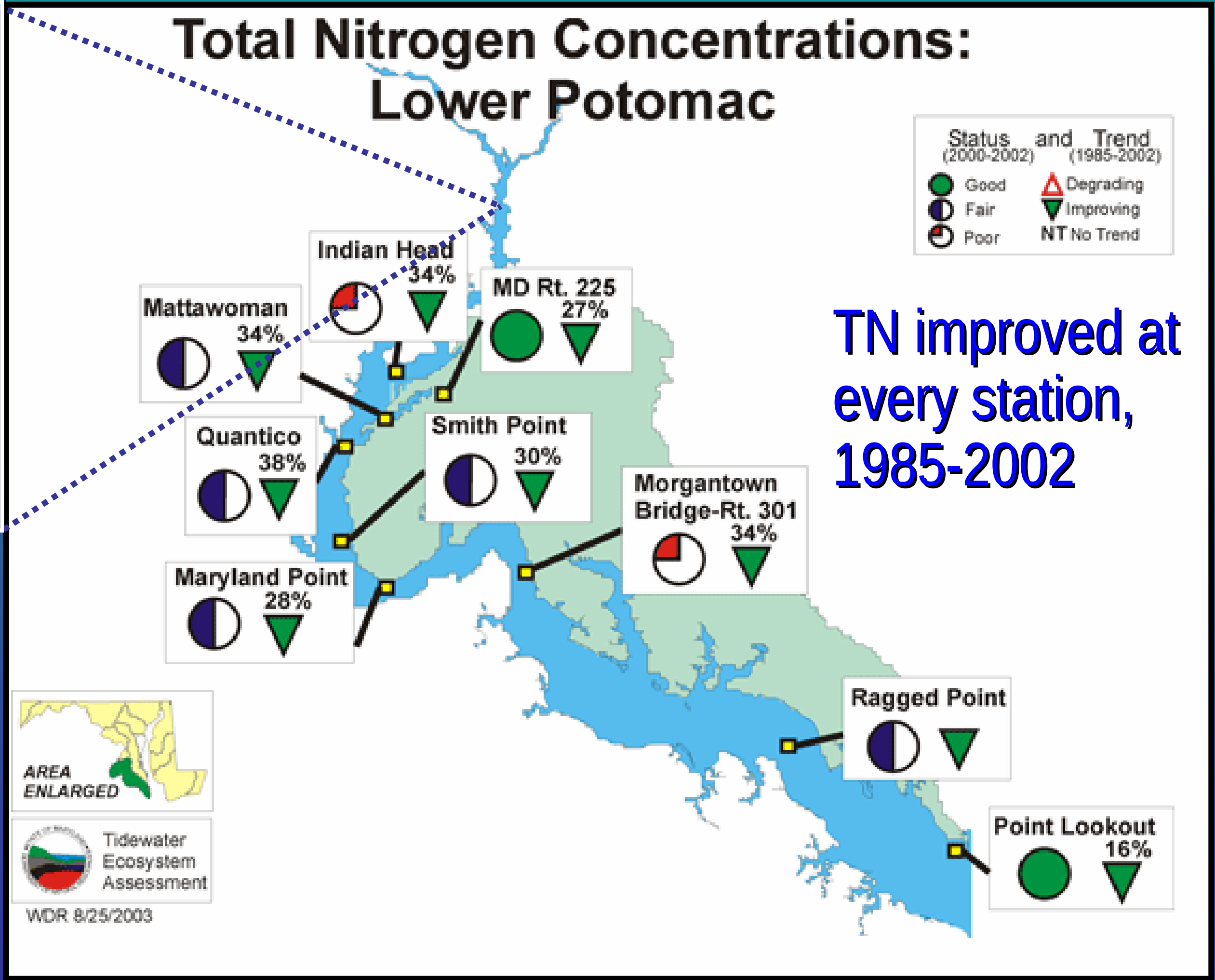


Source: VIMS

Middle Potomac had improving water quality (nitrogen) during this natural recovery



49% reduction in TN discharge from Blue Plains WWTP; 1985-2003

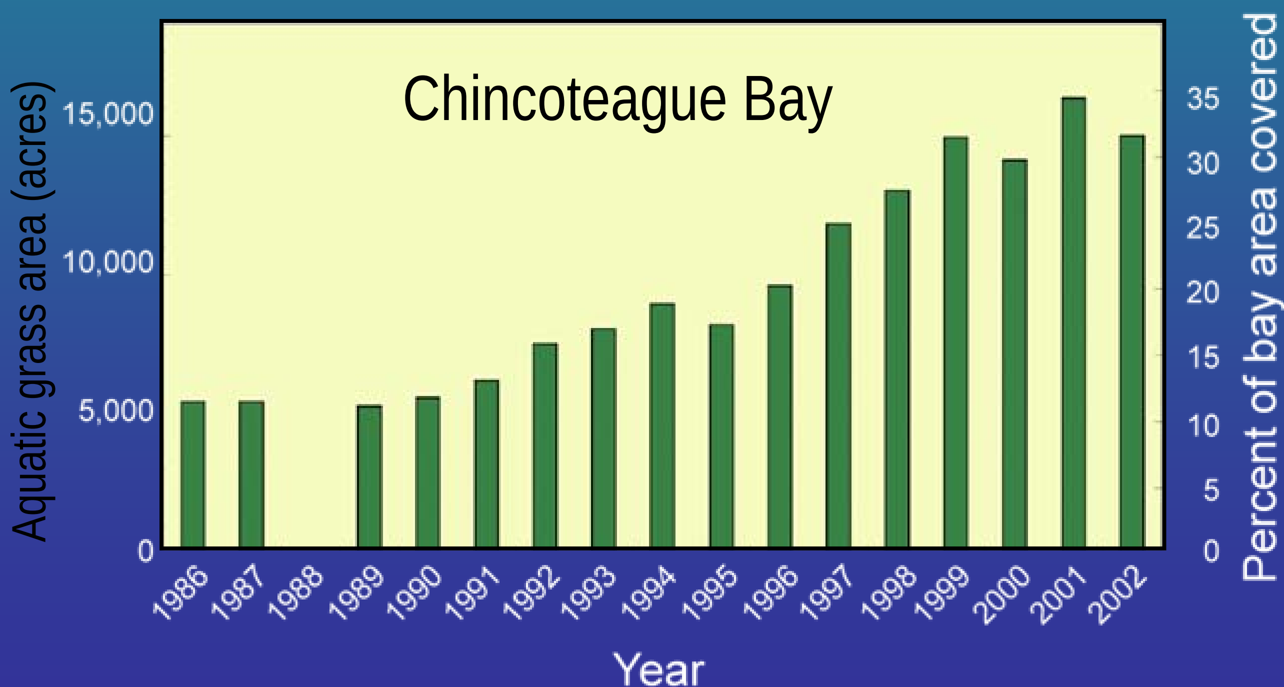


TN improved at every station, 1985-2002

Sources: MD DNR, MWCOG

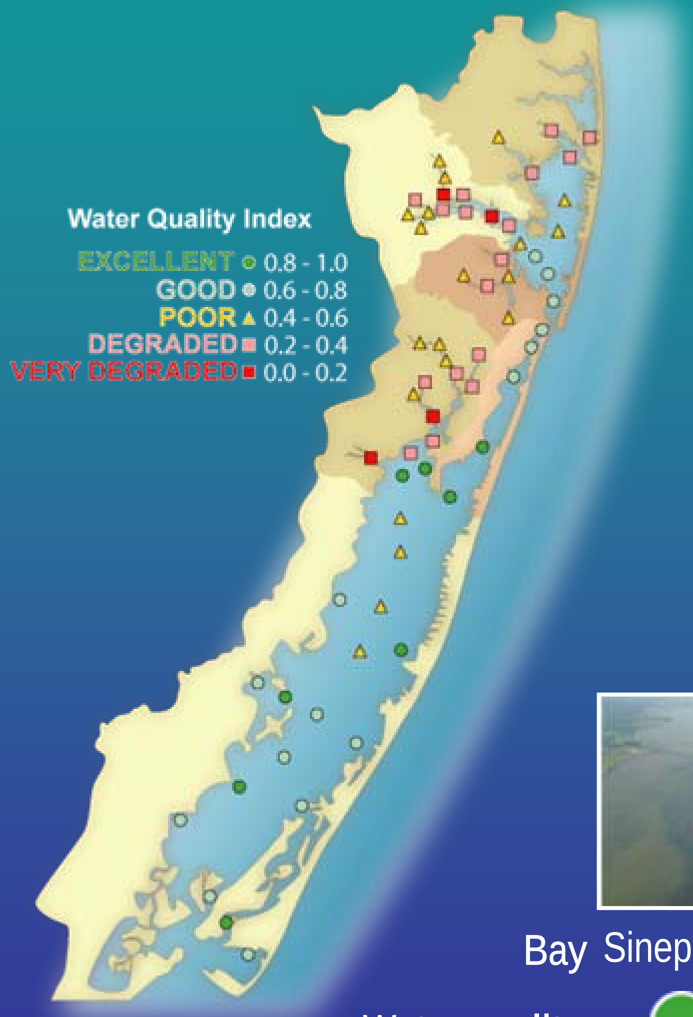
Natural recovery of *Zostera* community in MD Coastal Bays; 1986-2003

- Aquatic grass died in 1930s; wasting disease
- *600 acres per year returned without planting (1986-2003)*



Source: State of Maryland Coastal Bays 2004

MD Coastal Bays had good water quality where this natural recovery occurred



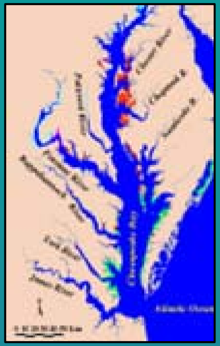
- Areas of regrowth in Chincoteague had good water quality 2001-2003
- Among MD Coastal Bays, grass cover highly related to water quality (see below)

Source: State of Maryland Coastal Bays 2004

Bay	Sinepuxent	Chincoteague	Assawoman	Isle of Wight	Newport	St Martin
Water quality	●	○	■	▲	■	■
Aquatic grass area (% of Bay)	36	32	8	5	4	<1

Conclusions

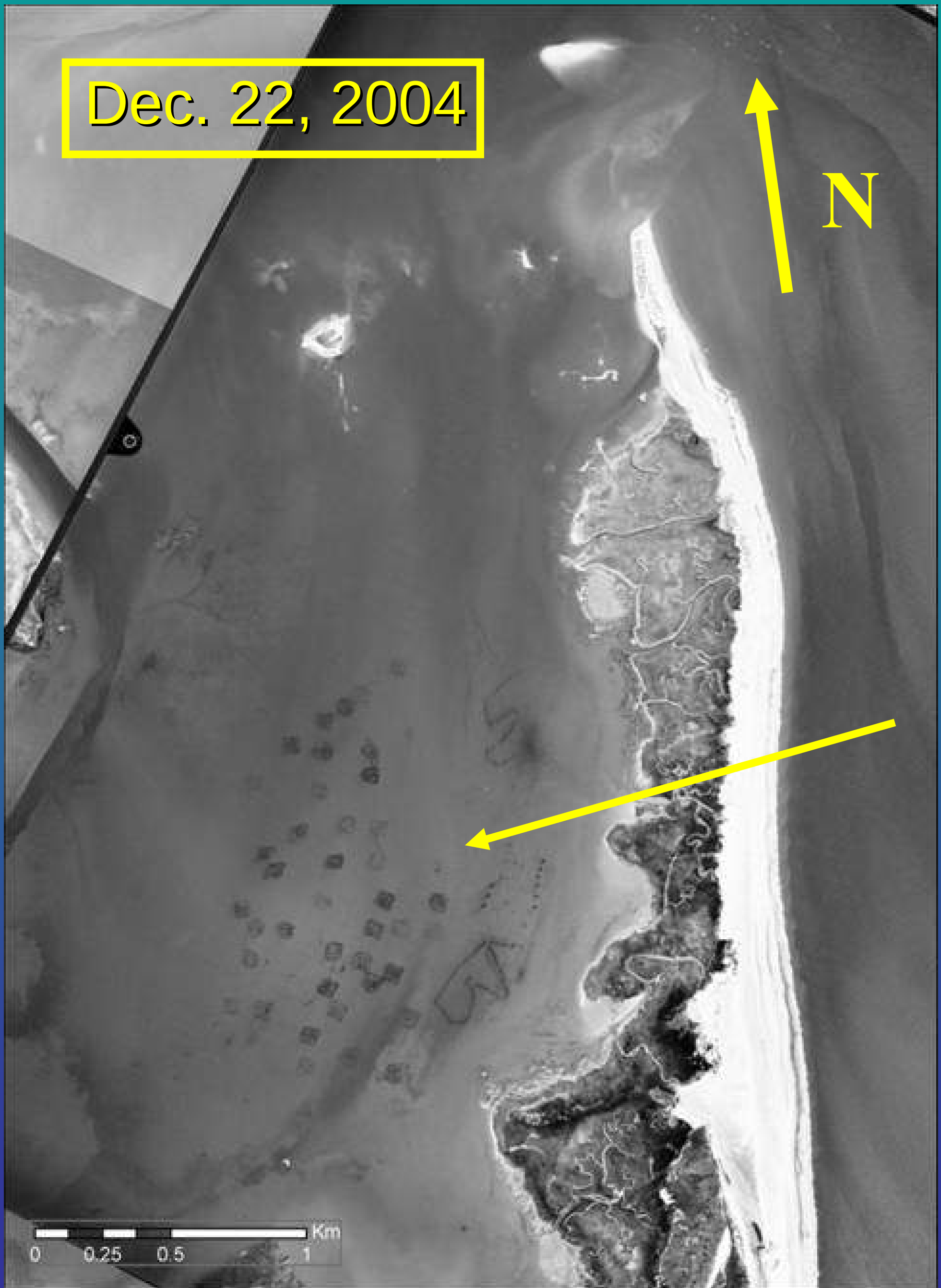
- Aquatic grass communities widespread in Chesapeake Bay; variable and greatly reduced from historical distribution



- Seed and shoot transplanting can work, but <10% long term success

- Natural recovery has occurred where there is good water quality

- Where good water quality occurs, targeted local restoration efforts are valuable



1 acre eelgrass plots located behind Wreck Island (PLANTED WITH SEEDS IN 2001 AND 2002)

Scale - 1:24,000


seeds
VIMS
V6 150
V25

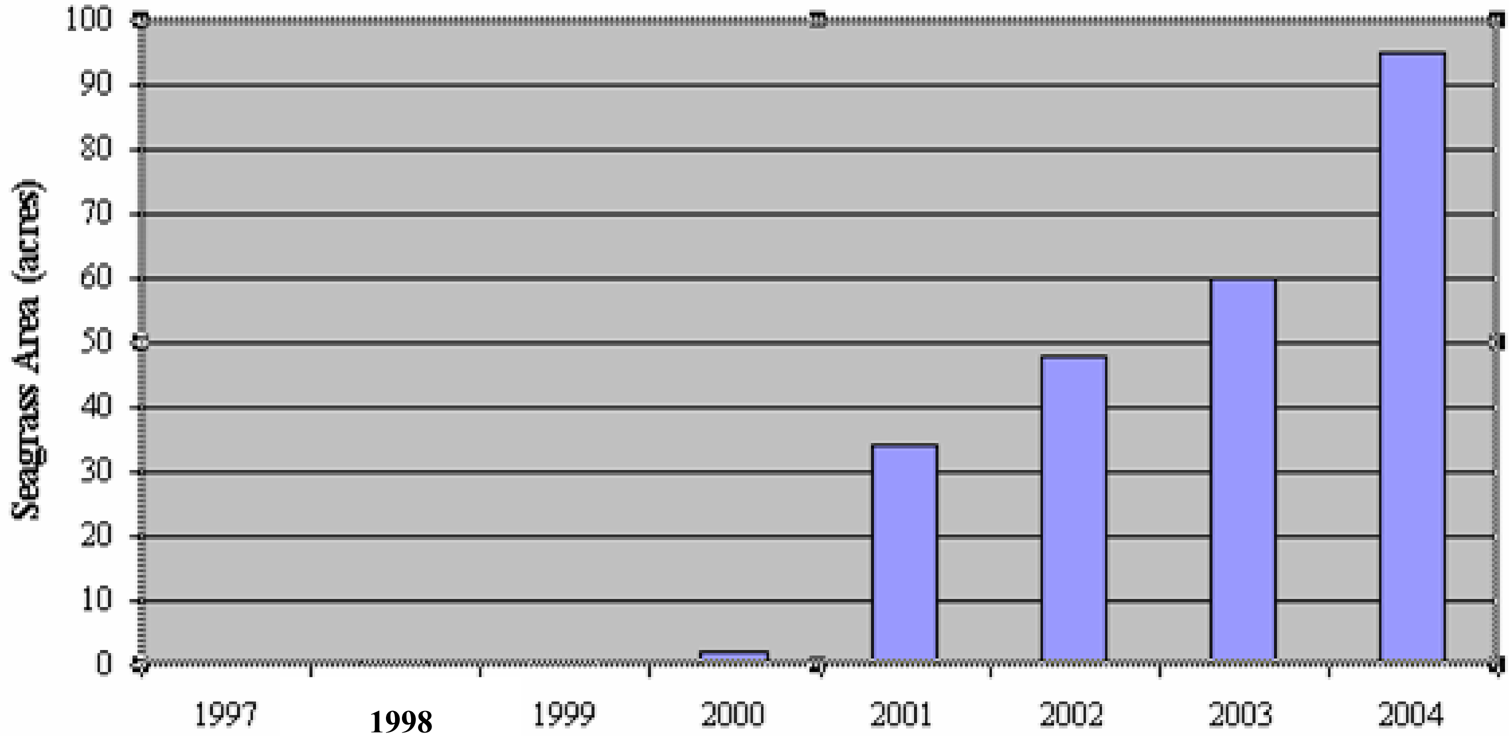
2003

100 m

'Dots' are small eelgrass patches from seeds produced by plants in the 'B' and not observed in 2003 photo

~100% SAV cover derived from small test plots

Seagrass Planted in the Seaside Coastal Bays



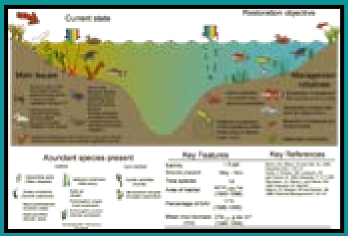
Restoration of aquatic grass communities of Chesapeake Bay: How should we proceed?

Robert Orth(1), Peter Bergstrom(2), Walter Boynton(3), Tim Carruthers(3), William Dennison(3), Katia Englehardt(3), Dave Goshorn(4), Lee Karrh(4), Evamaria Koch(3), Scott Marion(1), Ken Moore(1), Laura Murray(3), Mike Naylor(4), Nancy Rybicki(5) and Dave Wilcox(1)

1 Virginia Institute of Marine Science VIMS
2 NOAA
3 University of Maryland Center for Environmental Science
4 Maryland Department of Natural Resources
5 USGS science for a changing world

Recommendations

- Need better understanding of the four aquatic grass communities, their variability and recovery

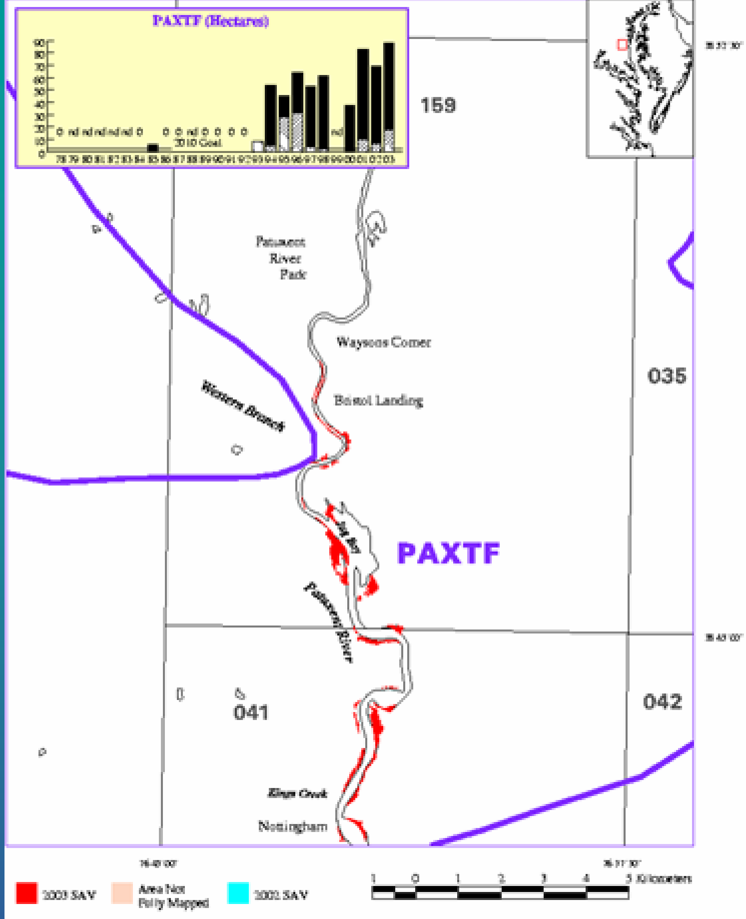


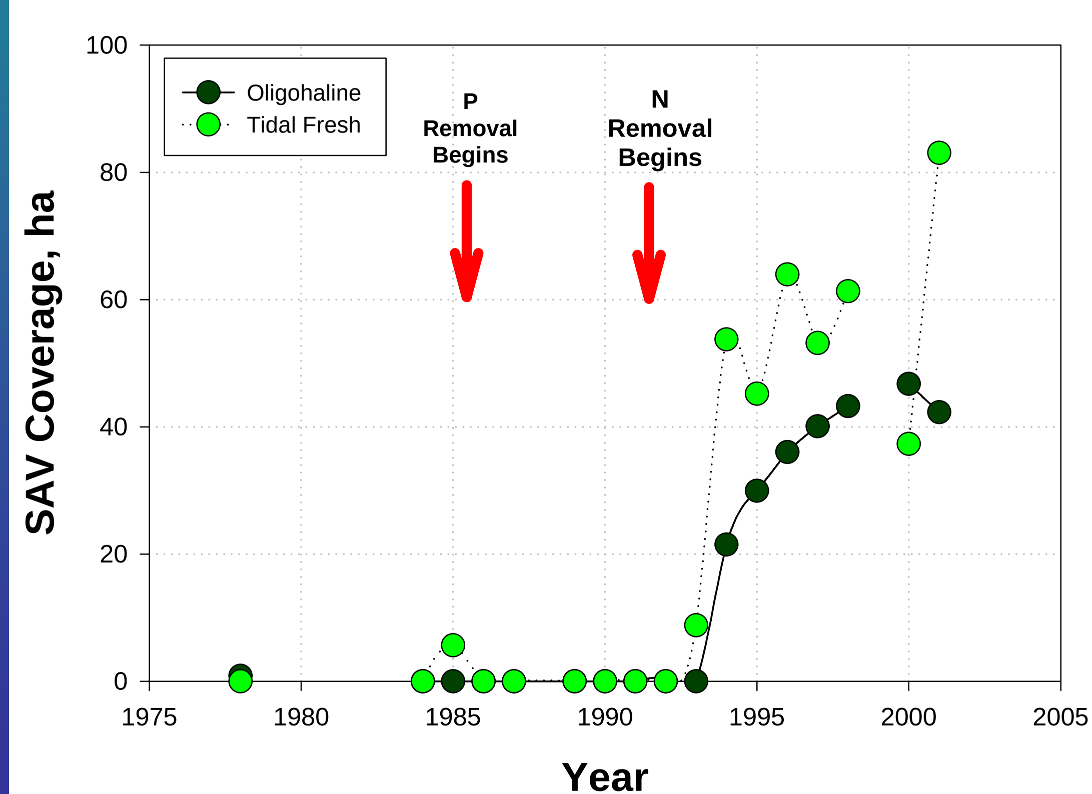
- Due to limited long term survival, restoration projects must include long term monitoring, and improved site and technique targeting

- Continue annual aquatic grass mapping to quantify natural recovery events

- Returning aquatic grasses to Chesapeake Bay will require **improved water quality**

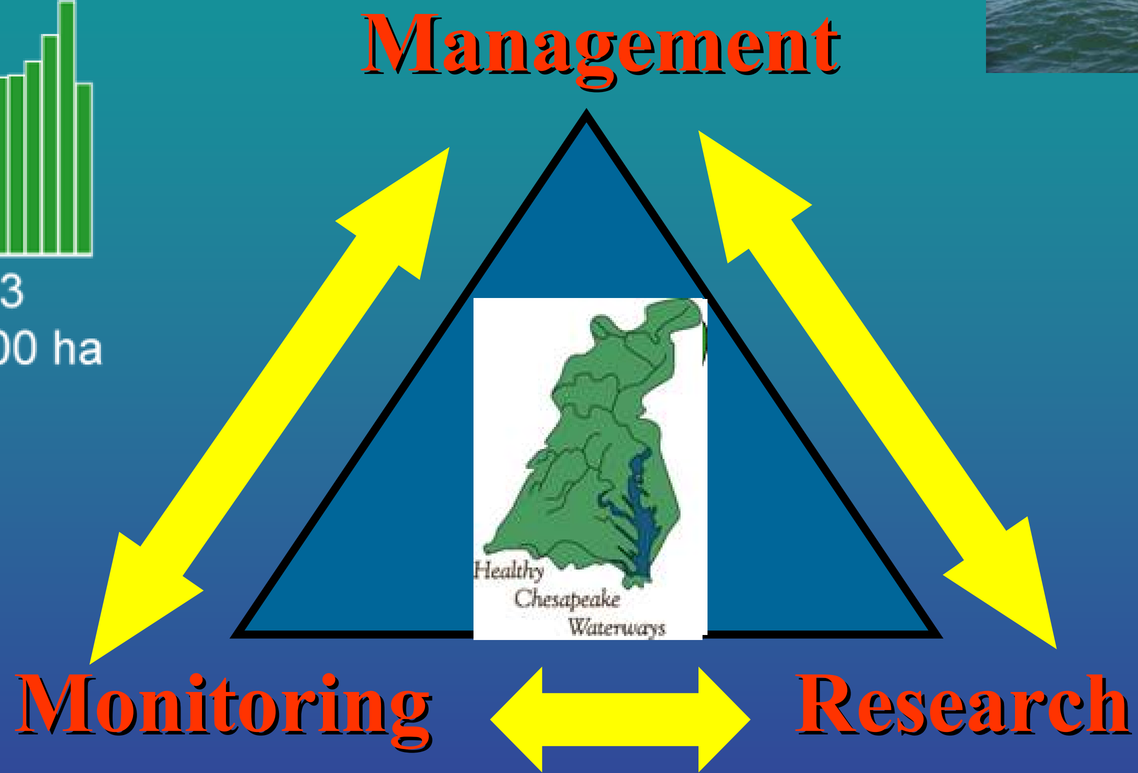
SAV recovery in tidal freshwater region of the Patuxent River






75,000 ha:
conservative
historical
distribution
1984 - 2003
16,000 - 36,000 ha


SAV


Management
Healthy
Chesapeake
Waterways
Monitoring
Research

Acknowledgments

- Chesapeake Bay Program for making aquatic grasses a priority since 1976
- Funding agencies for **aerial survey**: EPA, NOAA, VA DEQ and CRM, MD DNR, USACE
- Funding agencies for **aquatic grass restoration**: NOAA (NMFS, VA & MD CZM and Sea Grant), KCF, VMRC, DoD (USACE, Legacy, USAEC, APG), EPA, NFWF, CBT, CBF, NAIB, MPA, USGS, MD DNR, VIMS Hopewell WWTP

Virginia Institute of Marine Science VIMS

NOAA

University of Maryland Center for Environmental Science

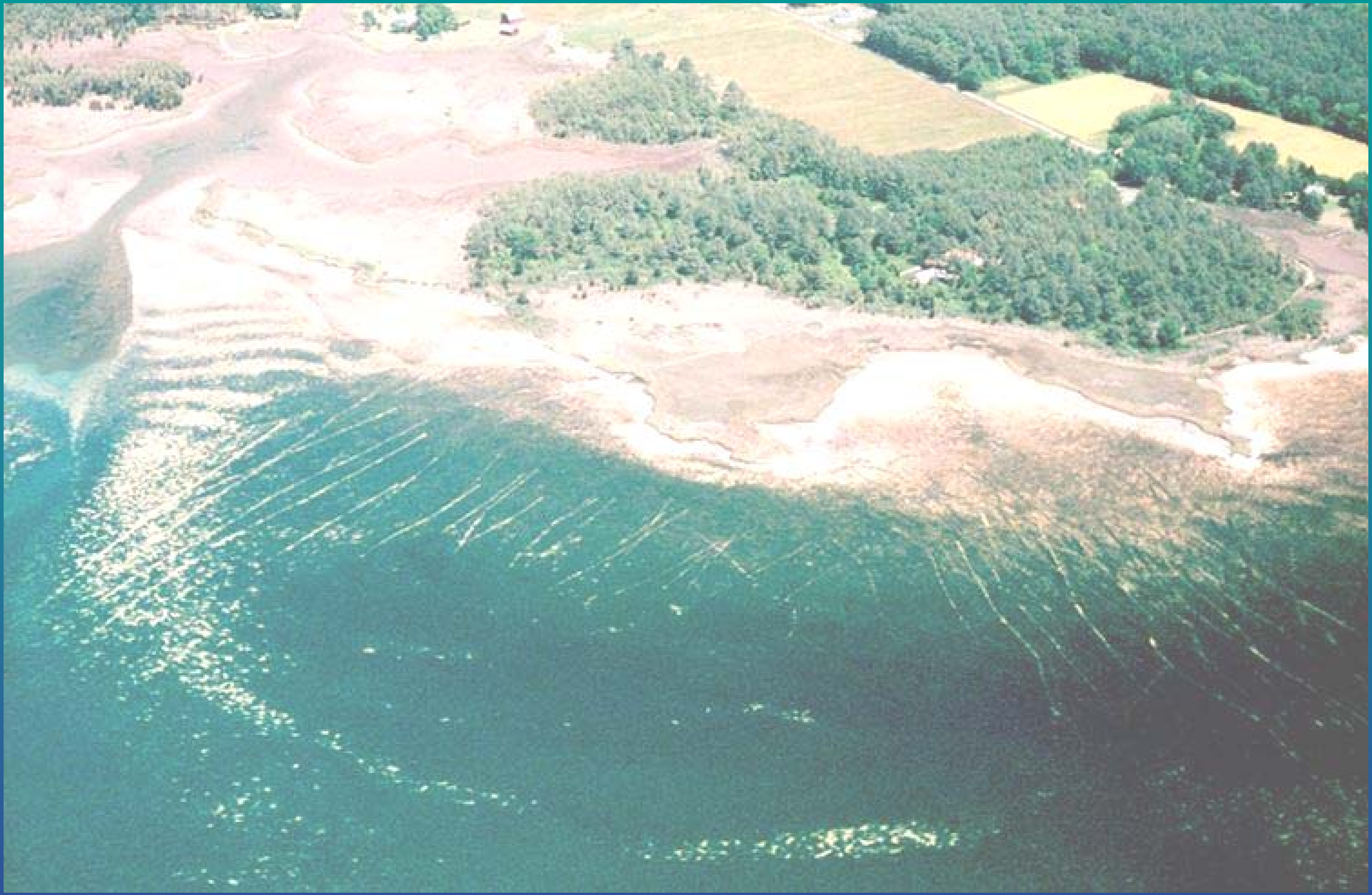
Maryland Department of Natural Resources

USGS science for a changing world

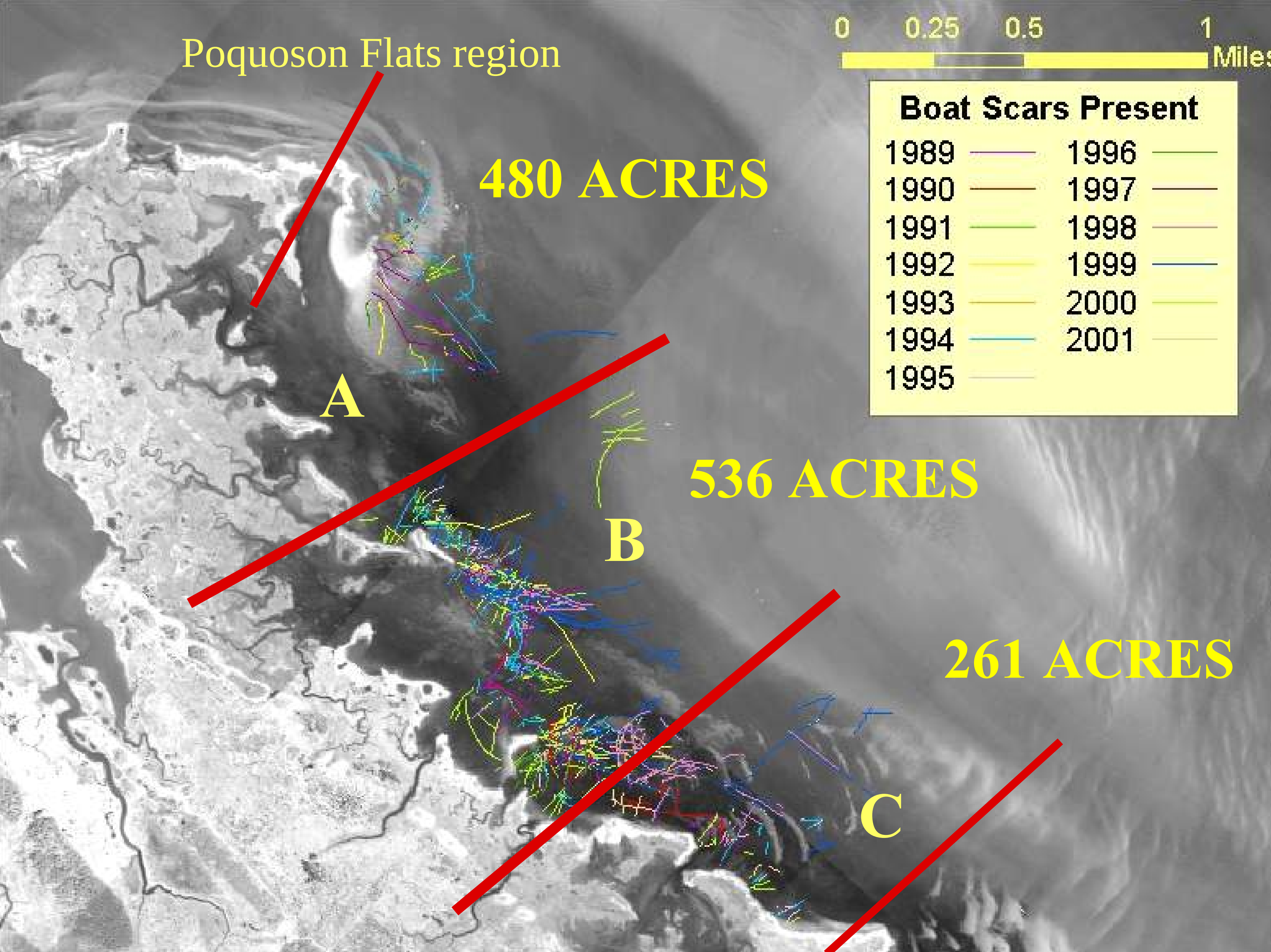
EELGRASS

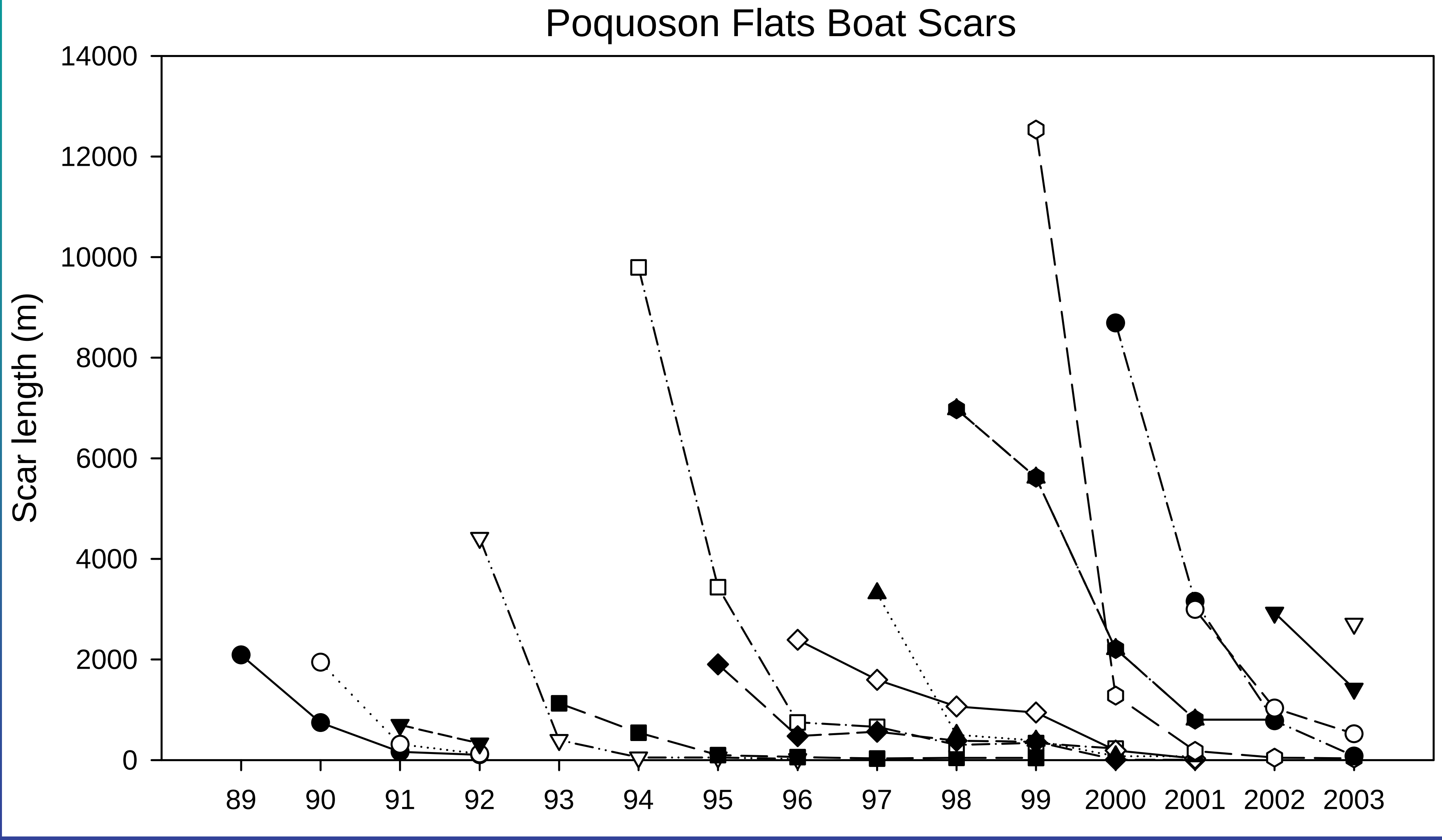
SAV Habitat Requirements

Salinity	Kd	TSS mg/l	Chl µg/l	DIN mg/l	DIP mg/l	PLW	PLL
Tidal Fresh (<0.5 ppt)	< 2	< 15	< 15	---	< 0.02	> 13%	> 9%
Oligohaline (0.5-5 ppt)	< 2	< 15	< 15	---	< 0.02	> 13 %	> 9%
Mesohaline (5-18 ppt)	< 1.5	< 15	< 15	< 0.15	< 0.01	> 22%	> 15%
Polyhaline (>18 ppt)	< 1.5	< 15	< 15	< 0.15	< 0.02	> 22%	> 15%

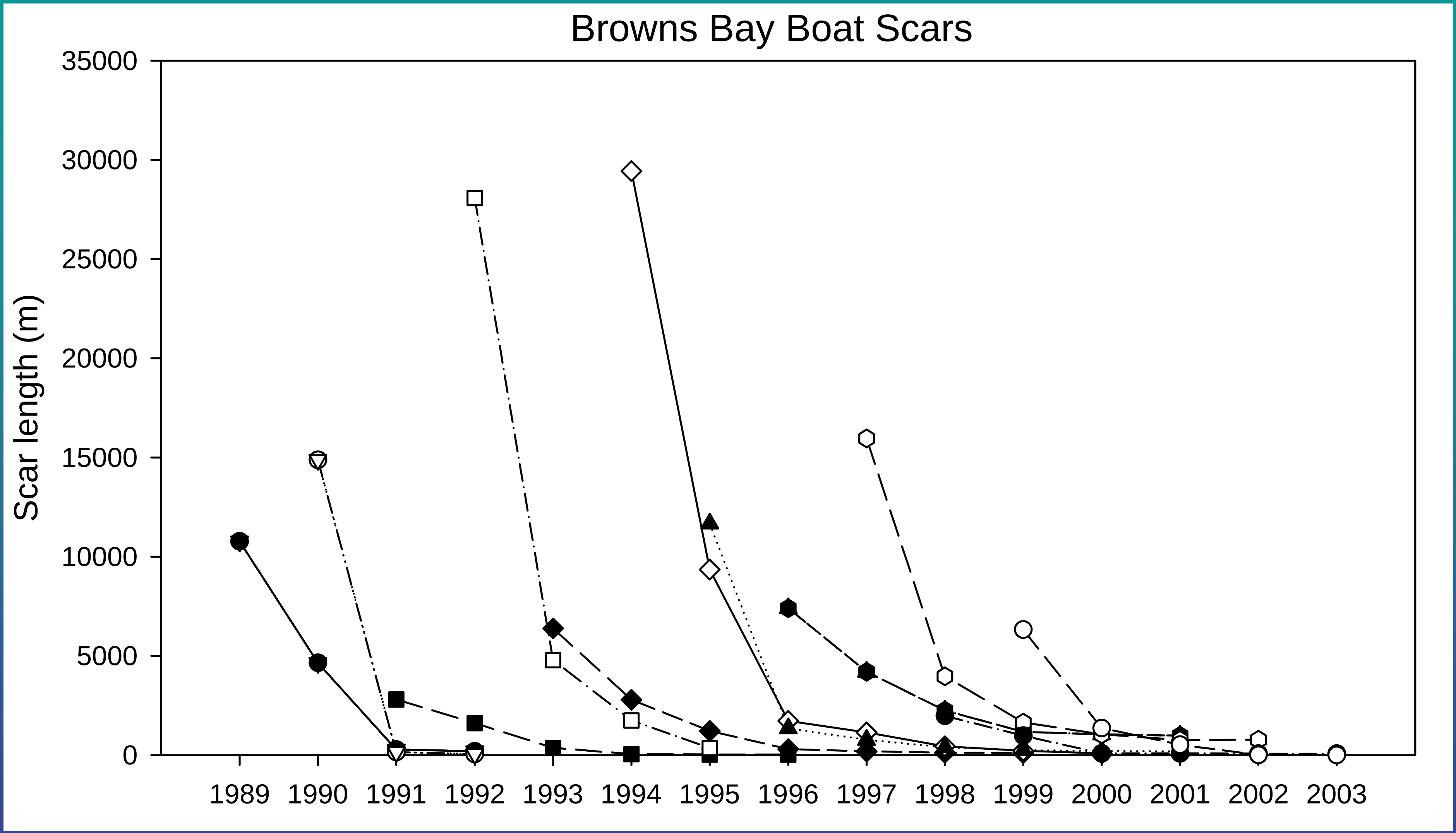


PROPELLER SCARRING


Poquoson Flats region
0 0.25 0.5 1 Miles
Boat Scars Present
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
480 ACRES
A
536 ACRES
B
261 ACRES
C

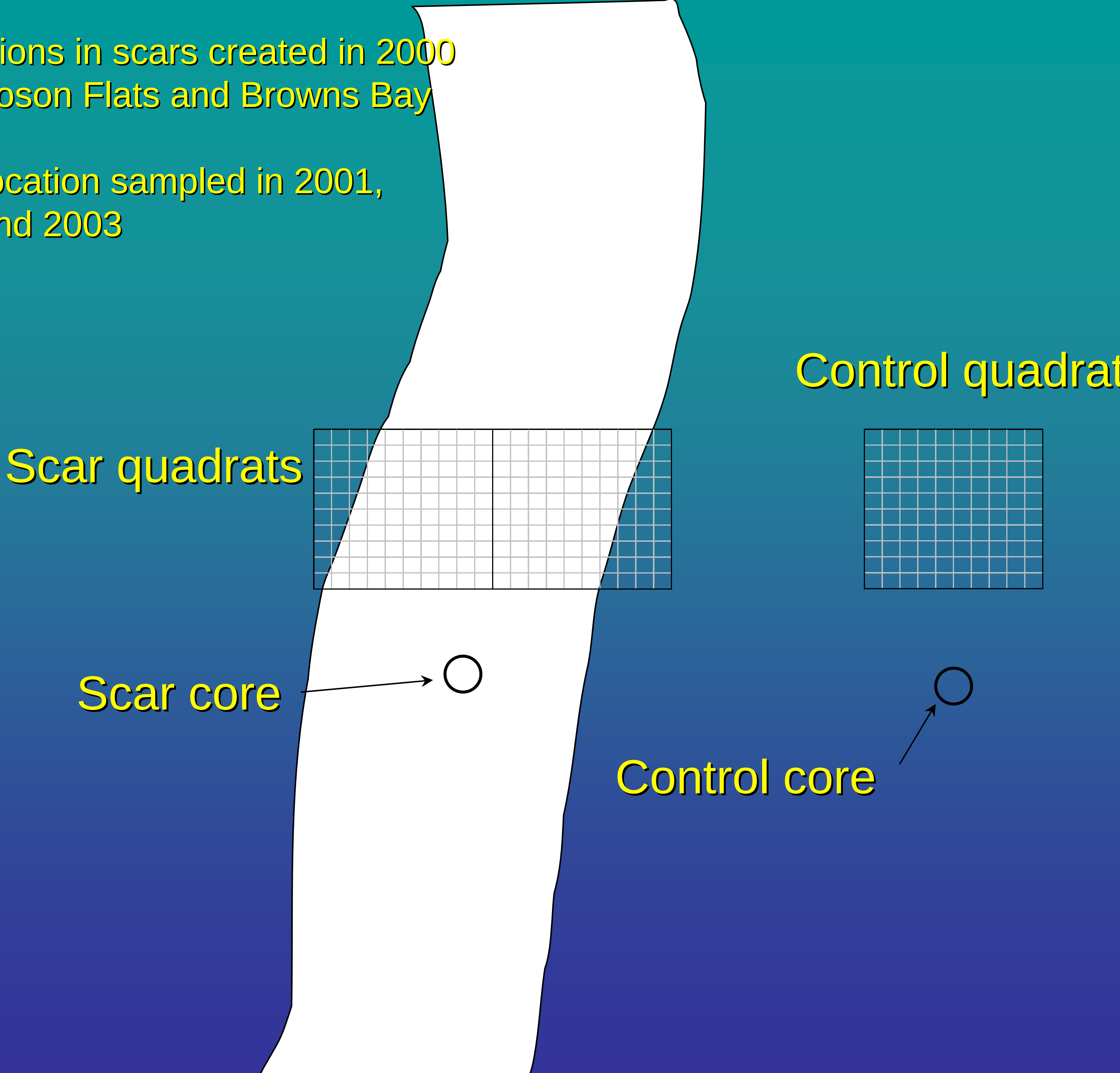


Poquoson Flats Boat Scars
Scar length (m)
14000
12000
10000
8000
6000
4000
2000
0
89
90
91
92
93
94
95
96
97
98
99
2000
2001
2002
2003


Browns Bay Boat Scars
Scar length (m)
35000
30000
25000
20000
15000
10000
5000
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

20 locations in scars created in 2000 in Poquoson Flats and Browns Bay

Same location sampled in 2001, 2002, and 2003



PF #11

2001

b	r	r	b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	b	z
r	b	b	z	-	-	-	-	-	-	-	-	-	-	-	-	-	z	z	z
b	r	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	z	-
b	b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	b	b	-	b
-	r	r	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	b	b
b	-	r	b	r	-	-	-	-	-	-	-	-	-	-	-	z	-	z	r
b	b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	b
r	-	z	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	z	b
z	z	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	z	b	b
z	-	-	-	-	-	-	-	-	-	-	-	-	-	-	b	r	z	b	b

r	b	z	r	b	z	z	z	z	z
r	b	z	r	b	z	b	z	z	z
b	b	b	z	b	z	b	b	b	z
b	b	z	b	z	b	b	b	b	z
b	b	z	z	z	b	b	z	b	z
b	z	b	b	z	z	z	b	b	z
b	z	z	b	z	r	z	b	b	z
b	r	b	r	z	b	z	b	b	z
r	b	-	z	b	z	b	b	z	b
r	r	b	z	r	r	z	z	z	b

2002

b	b	z	b	b	b	r	r	r	r	n	r	b	b	z	z	z	b	r	b
r	r	b	b	b	b	r	r	r	b	n	r	b	b	z	z	z	b	b	b
r	r	r	b	b	b	r	b	b	b	n	n	r	z	z	z	b	z	b	r
b	r	b	b	r	r	r	b	b	b	n	n	r	n	z	n	z	b	r	r
b	b	r	b	r	b	r	r	r	b	n	n	r	r	z	z	z	n	z	b
b	b	r	r	r	r	r	r	b	b	r	r	r	r	z	z	z	n	n	b
b	b	r	r	r	b	r	r	r	r	r	z	b	r	z	z	z	r	z	z
b	b	r	r	r	r	r	r	r	r	r	b	r	r	n	z	z	n	b	b
r	r	r	r	r	r	r	r	r	r	r	b	r	n	z	z	b	z	n	b
r	r	r	r	r	r	r	r	r	r	r	r	r	r	z	b	b	b	b	b

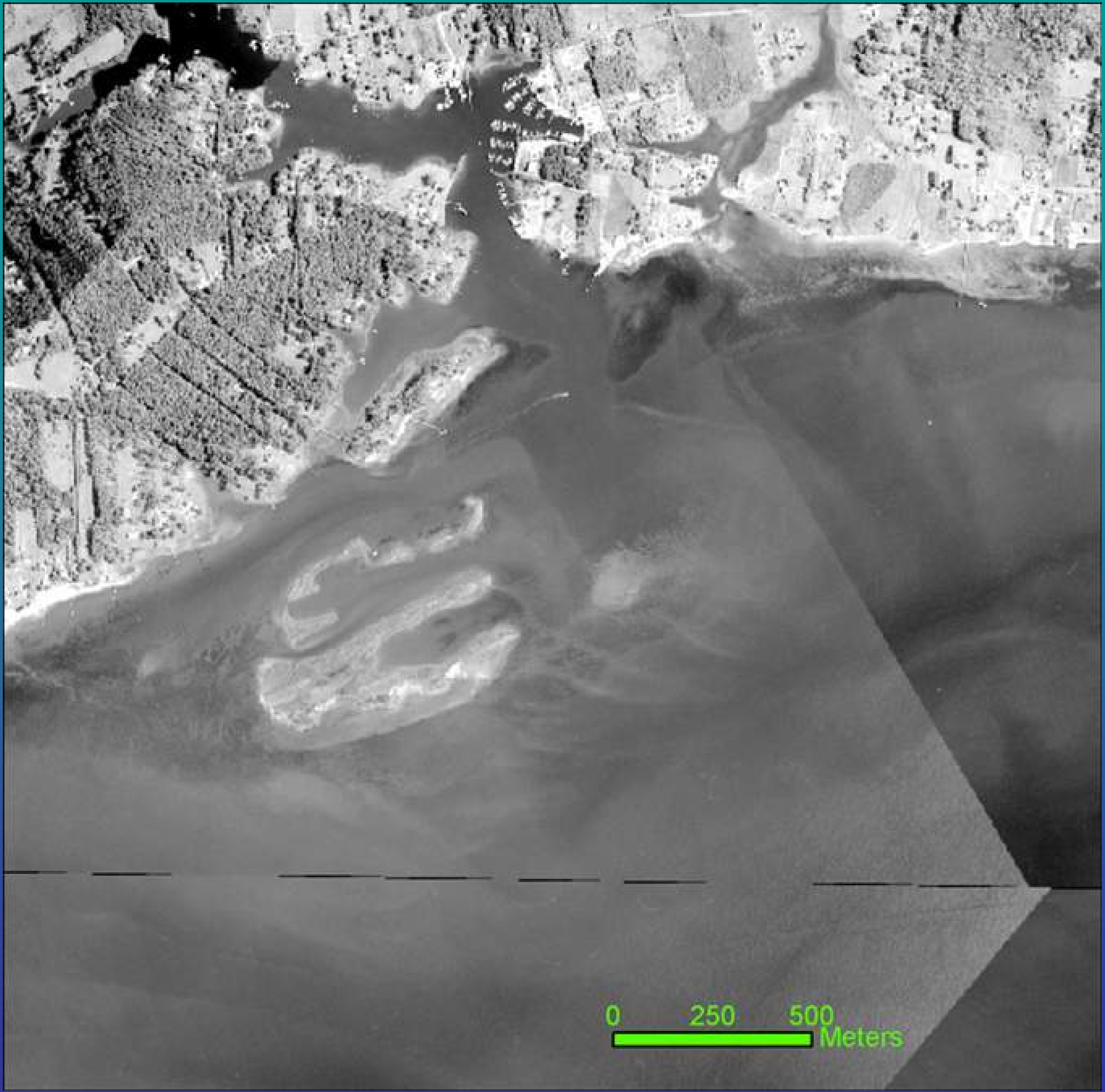
b	b	b	b	b	b	b	r	r	b
b	b	b	b	b	b	b	r	r	b
b	b	b	b	b	b	b	b	b	b
b	b	b	b	b	b	b	b	b	b
r	r	r	b	b	b	b	b	b	b
r	r	r	b	b	b	b	b	b	b
r	r	b	b	b	b	b	b	b	b
b	r	b	r	r	r	r	b	b	b
b	r	r	r	r	r	r	r	r	r
b	r	r	r	r	r	b	r	r	b

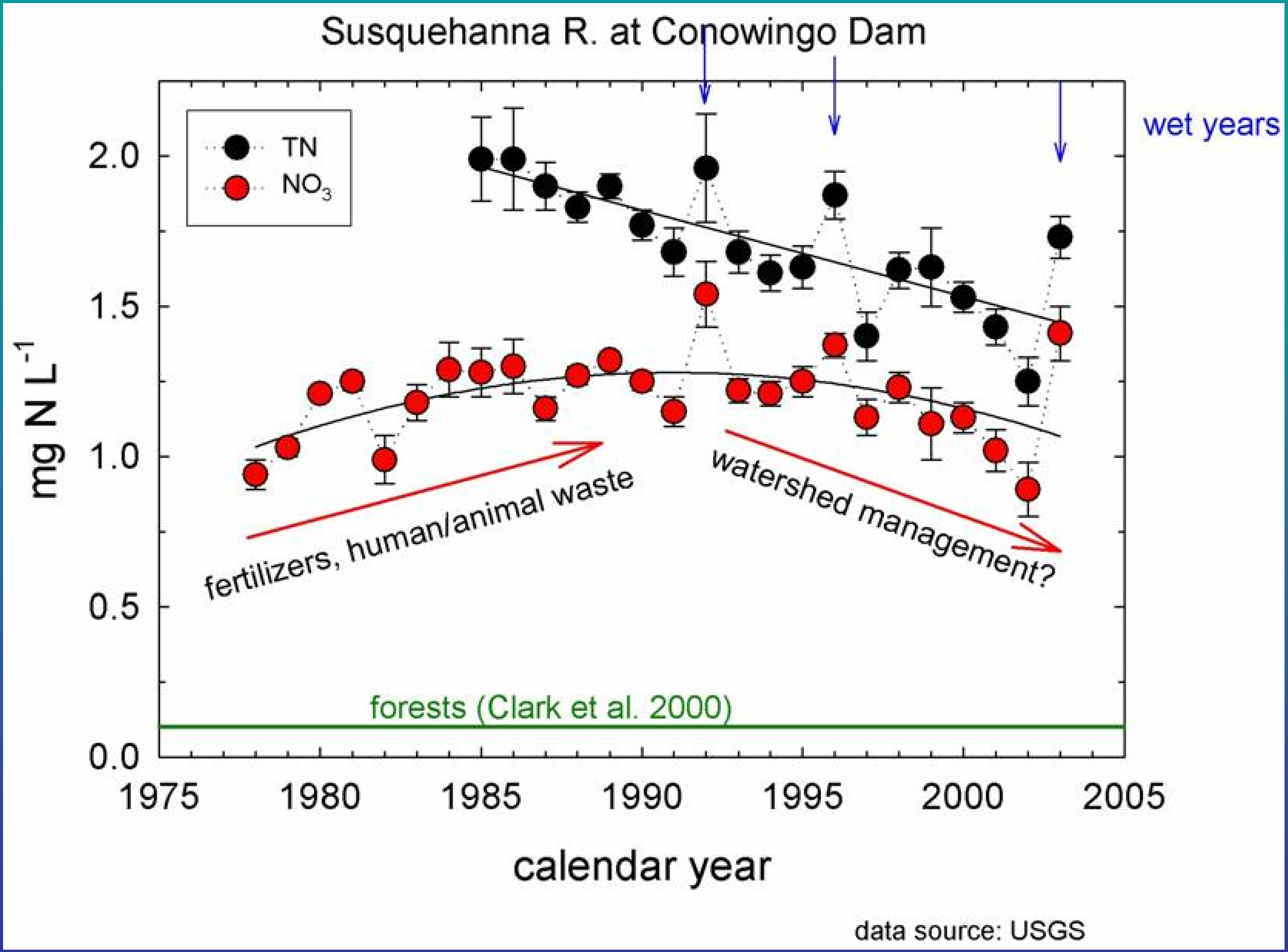
2003

b	b	b	b	b	b	b	b	b	b	r	r	r	b	b	b	z	z	z	z
b	b	b	b	b	b	b	b	r	b	r	b	b	b	z	z	z	z	b	b
b	b	b	b	b	b	b	b	n	n	n	r	b	r	z	z	z	z	b	b
b	b	b	b	b	b	b	b	b	b	n	n	r	z	z	z	z	z	b	b
b	b	b	b	b	b	b	b	b	z	n	n	r	z	z	z	z	z	b	b
b	b	b	b	b	b	b	b	b	b	n	n	r	r	z	z	z	z	b	b
b	b	b	b	r	r	r	r	b	b	n	n	z	b	b	z	z	z	b	b
b	b	b	b	r	r	r	b	b	b	n	n	z	b	b	b	z	z	b	b
b	b	b	r	r	r	r	r	b	z	n	n	z	z	b	z	b	b	b	b
b	b	r	r	r	r	r	r	z	z	n	z	z	z	z	z	b	b	b	b

r	r	r	r	r	r	r	b	b	b
r	r	r	r	r	r	r	r	r	b
b	r	n	r	r	r	r	n	r	r
n	r	n	r	r	r	r	n	r	r
n	r	r	r	r	r	r	n	r	r
r	r	r	r	b	r	r	n	r	r
r	r	r	r	r	r	r	r	r	r
r	r	r	r	r	r	r	r	r	z
r	r	r	b	b	r	b	r	z	z
r	r	r	r	r	r	b	b	b	b


0 250 500
Meters


0 250 500
Meters



Susquehanna R. at Conowingo Dam
wet years
TN
NO3
mg N L-1
2.0
1.5
1.0
0.5
0.0
fertilizers, human/animal waste
watershed management?
forests (Clark et al. 2000)
1975
1980
1985
1990
1995
2000
2005
calendar year
data source: USGS