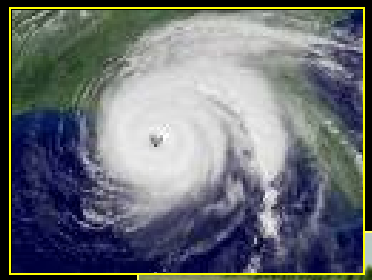
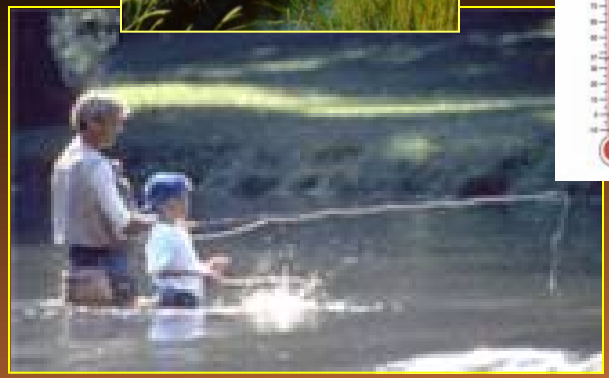
Enhancing and Harnessing Nature for Climate Resilience in the Delaware Estuary

Danielle Kreeger

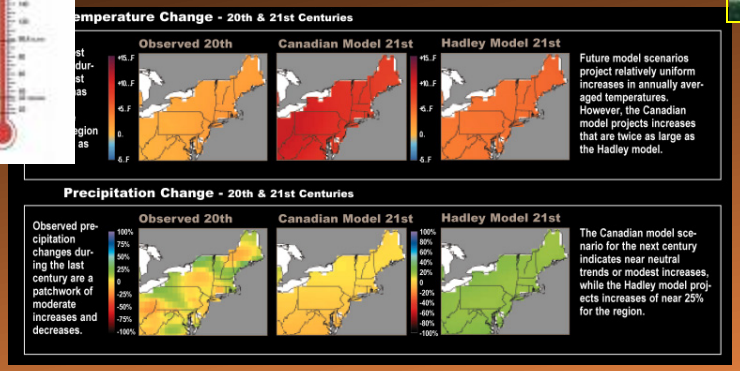
Partnership for the Delaware Estuary

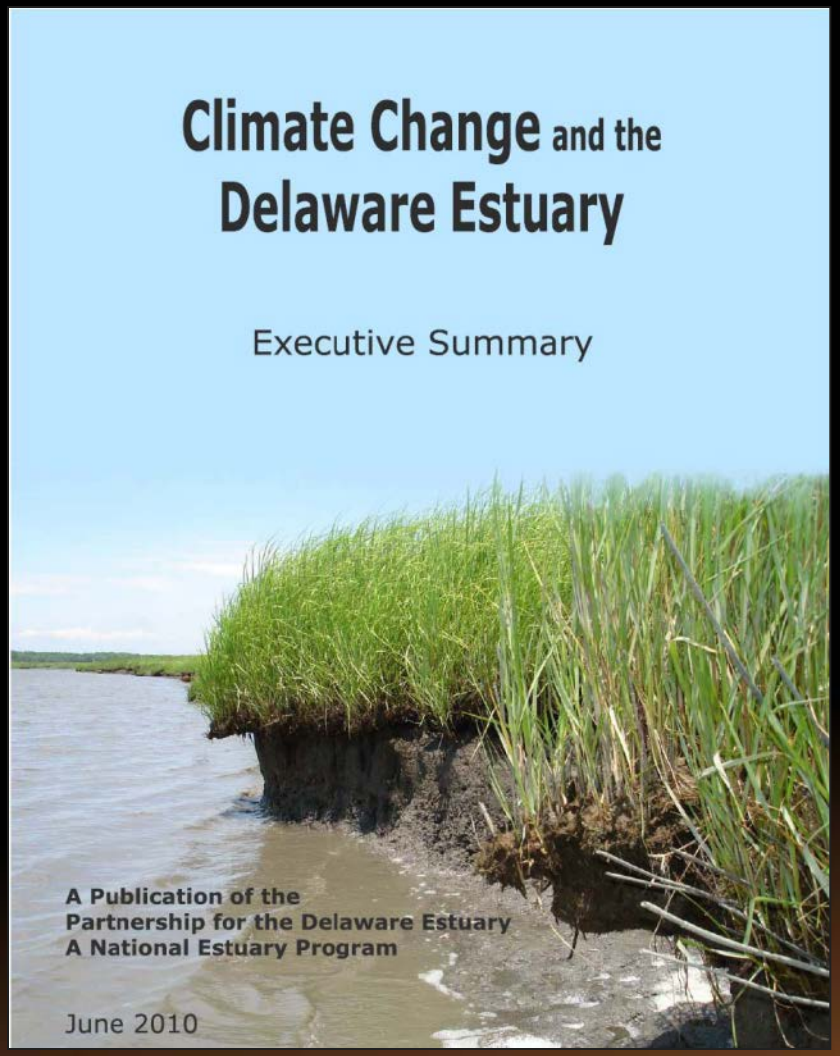


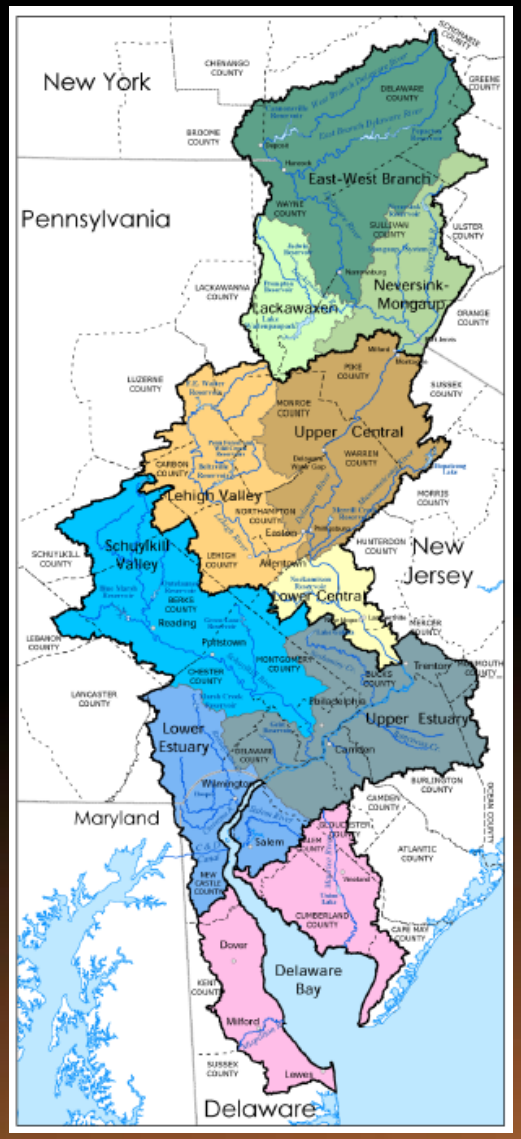


PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

SER Mid-Atlantic
March 29, 2013







3 case studies

CLIMATE READY ESTUARIES
EPA
PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

http://www.delawareestuary.org/science_projects_climate_ready_products.asp

Questions

How will climate change here?

How will changes impact resources?

What are our options for making these resources more resilient?

How do we prioritize tactics?

What if we don't take action?

(since every dollar is precious)

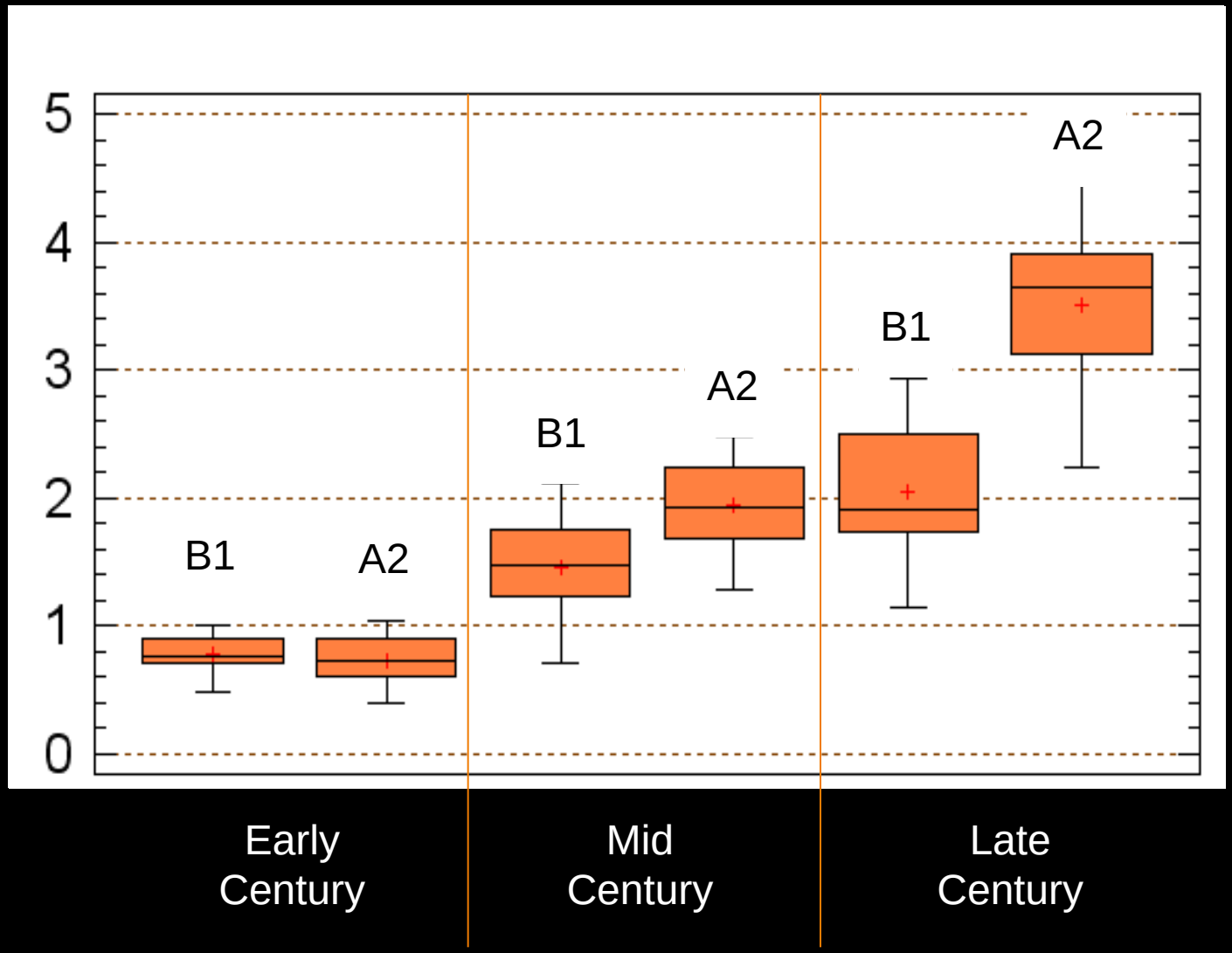
How Will Climate Change?

as per Dr. Ray Najjar

Temperatures

More in summer than in winter

Locked in for next 30 years



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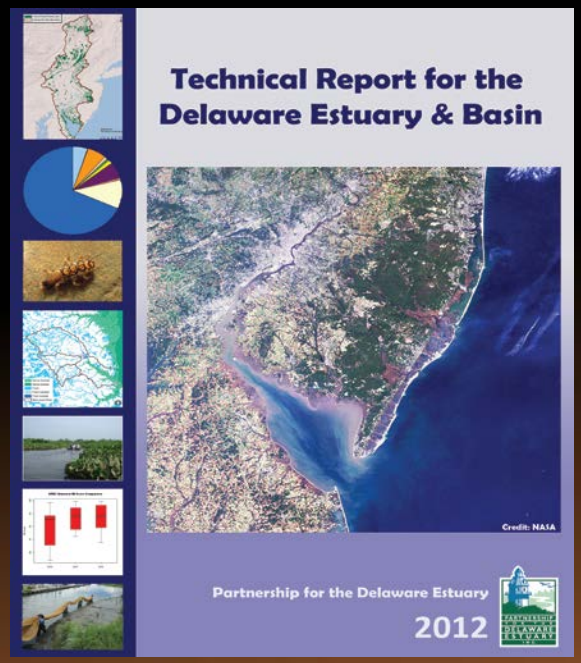
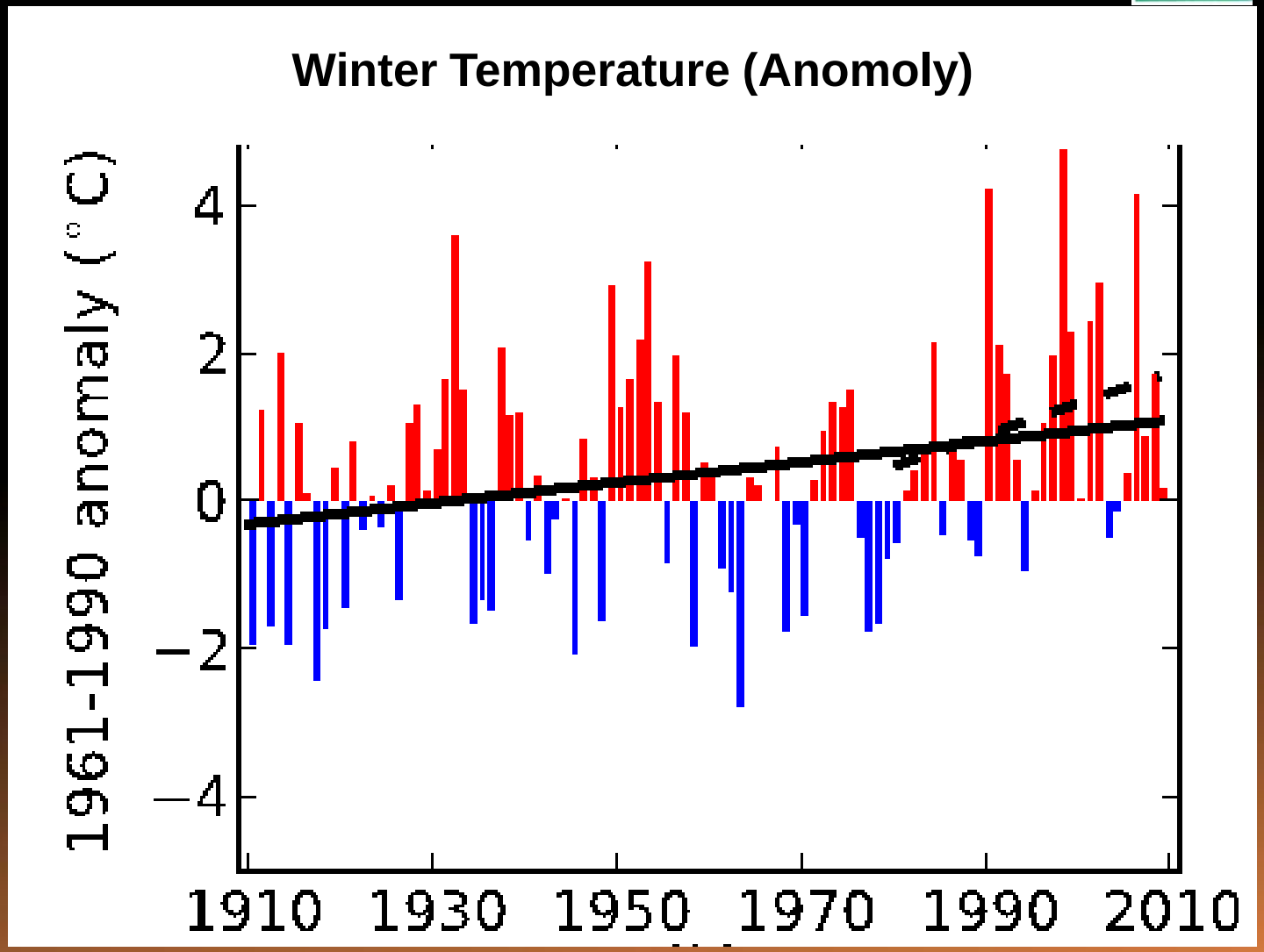
State of the Estuary 2012

Temp. has warmed by 1°C in the past century, mainly in past 30 yrs.





http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp

How Will Climate Change?

Temperatures

More in summer than in winter
Locked in for next 30 years

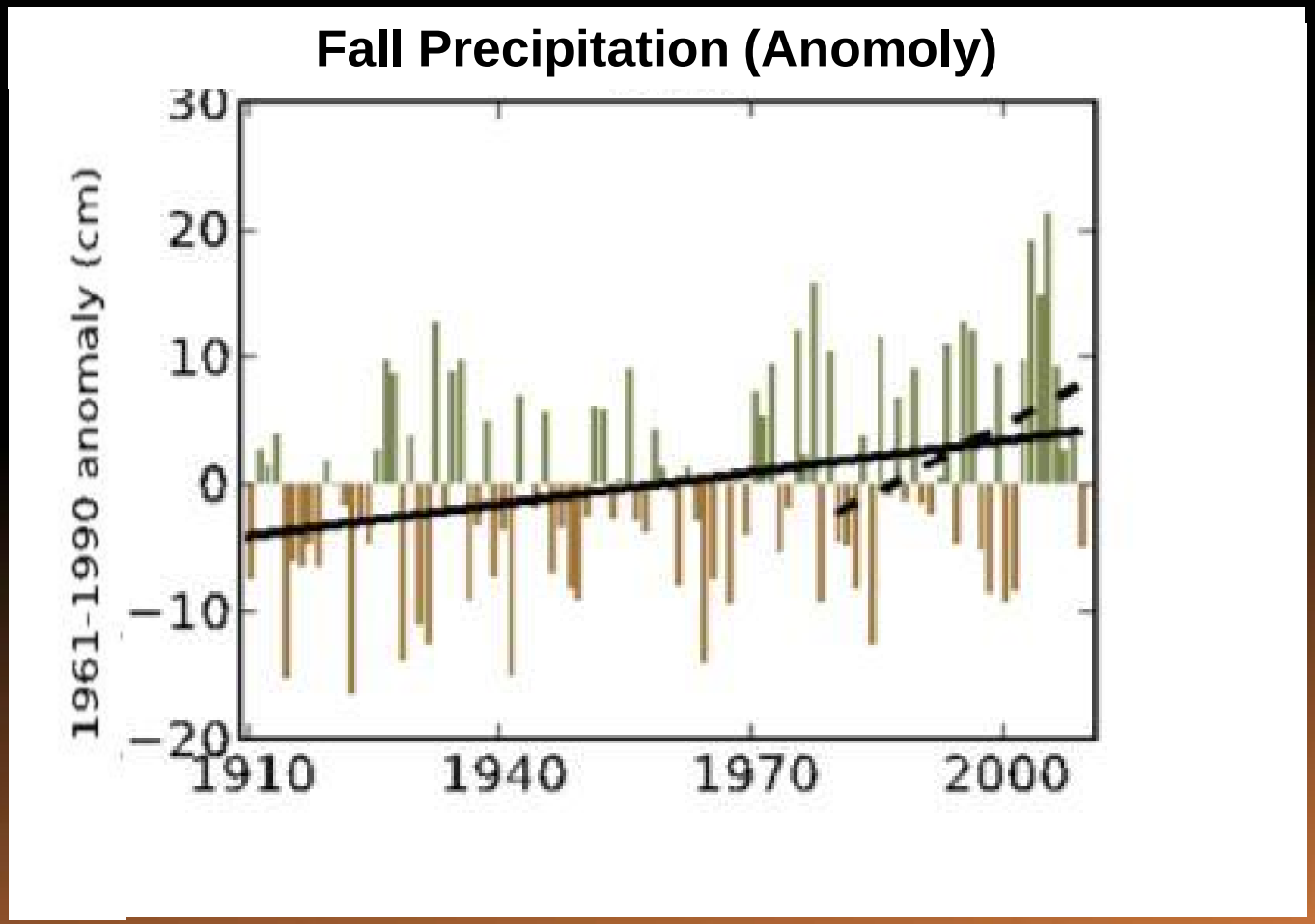
Precipitation

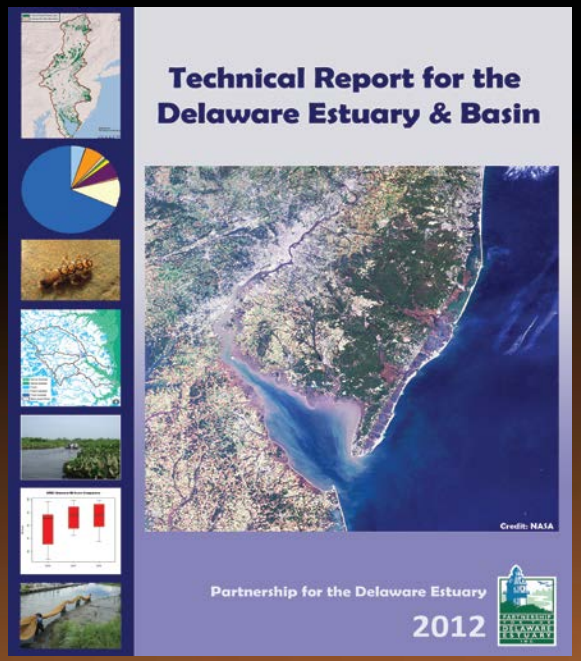
7-9 % increase
More in winter than in summer
More heavy events

State of the Estuary 2012

Precip. has increased >10%

Trend over past 30 years > 5 times trend over last 100 years





http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp

How Will Climate Change?

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Locked in for next 30 years

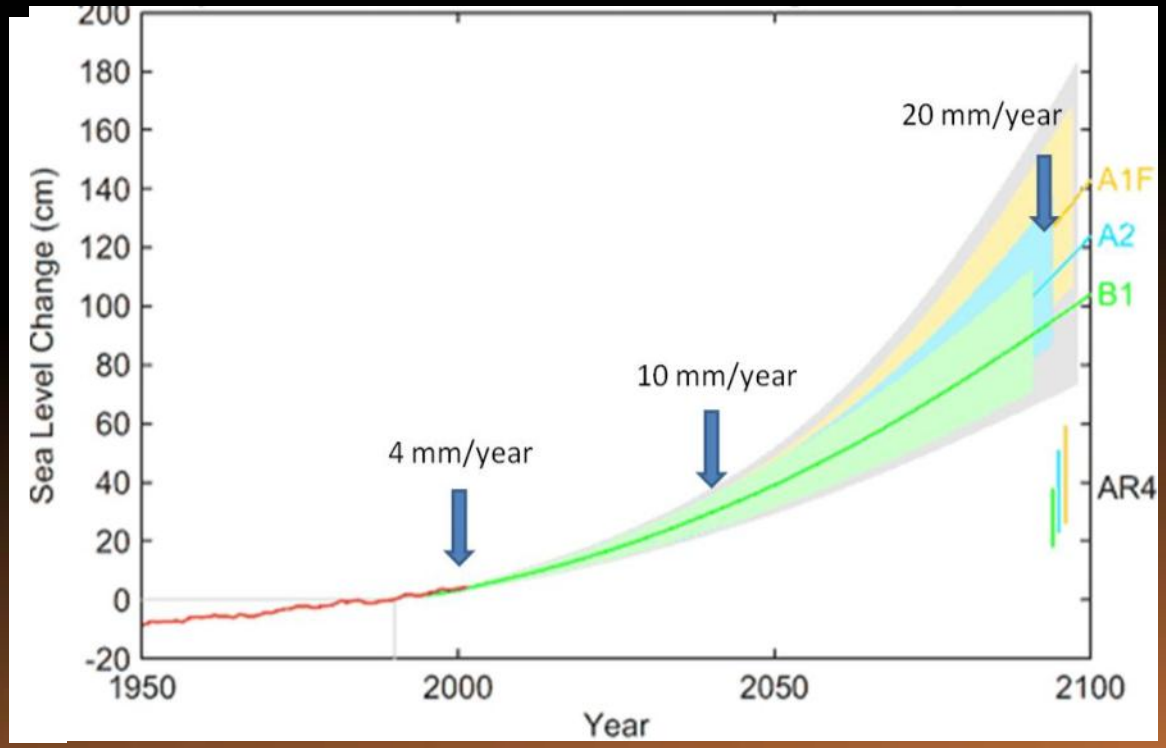
Precipitation

More in winter than in summer
More heavy events

Sea Level

0.6 - 1.5 m by 2100 (or more)
local rates >> global

Salinity



How Will Climate Change?

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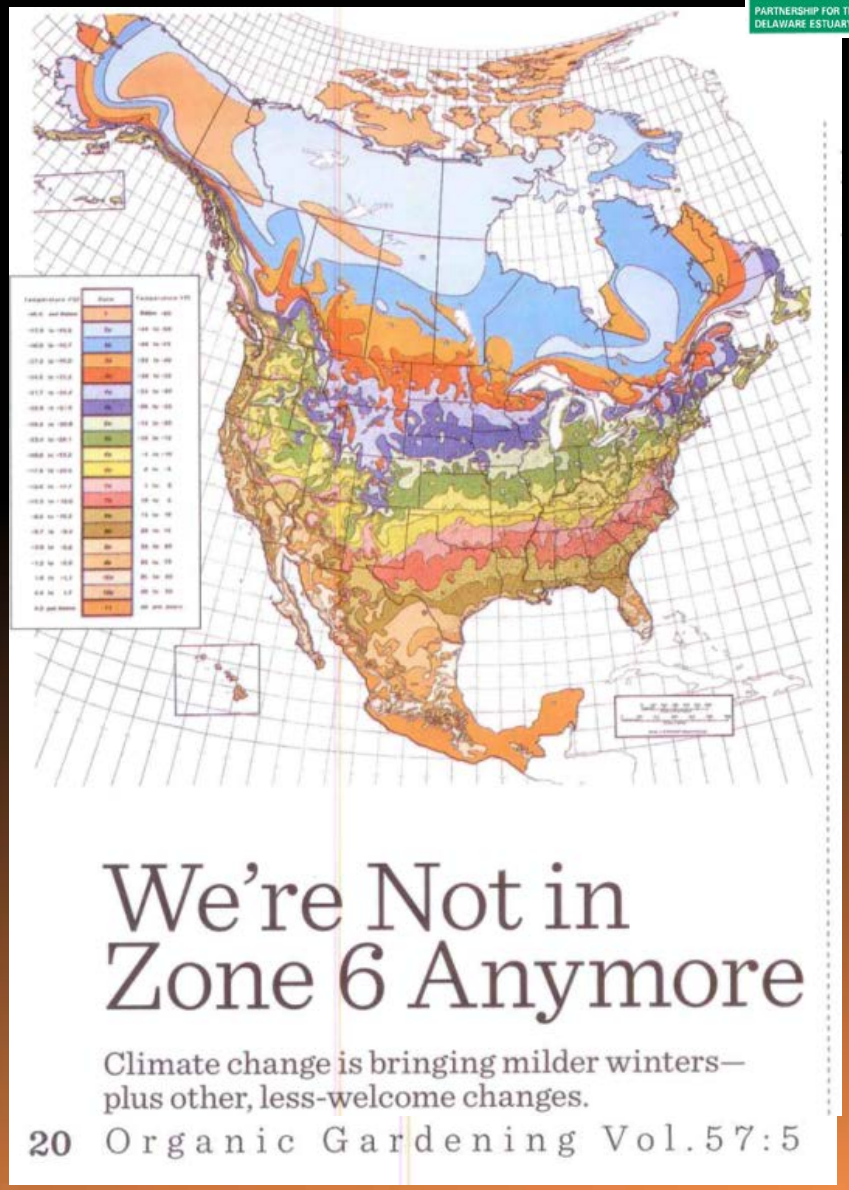
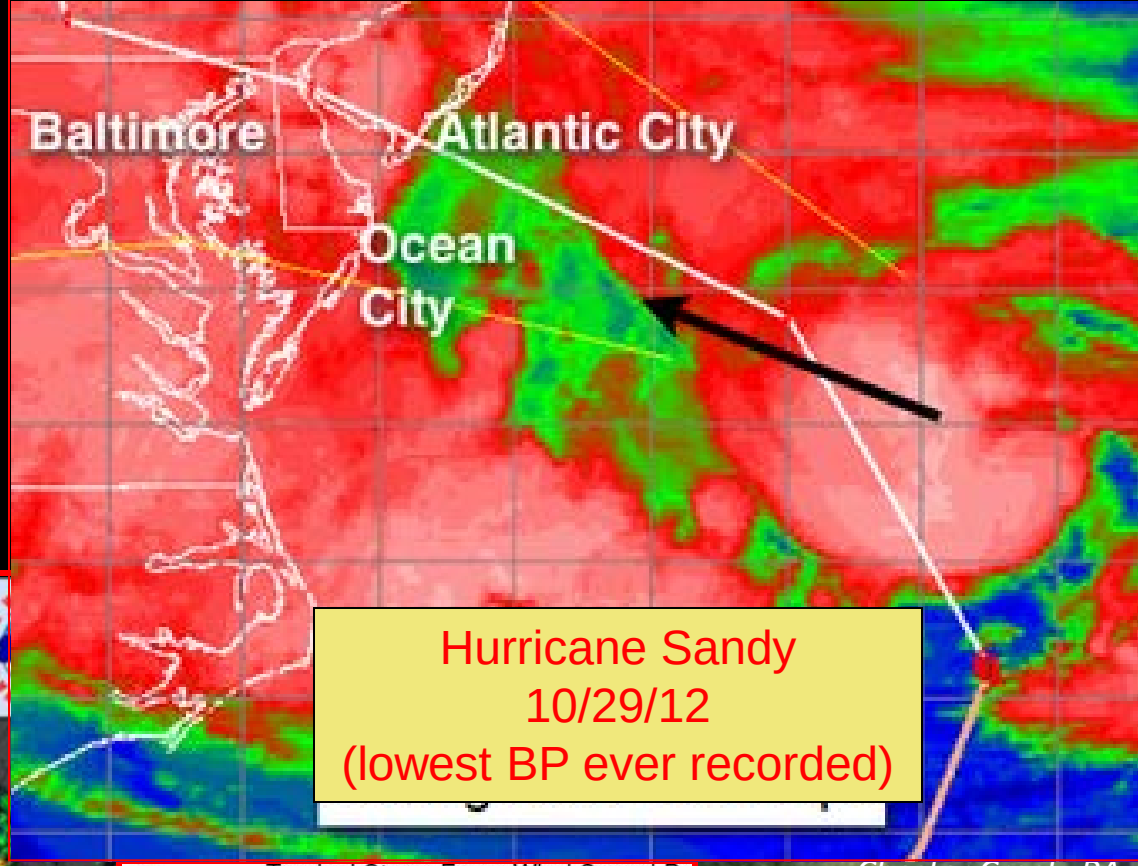
Salinity

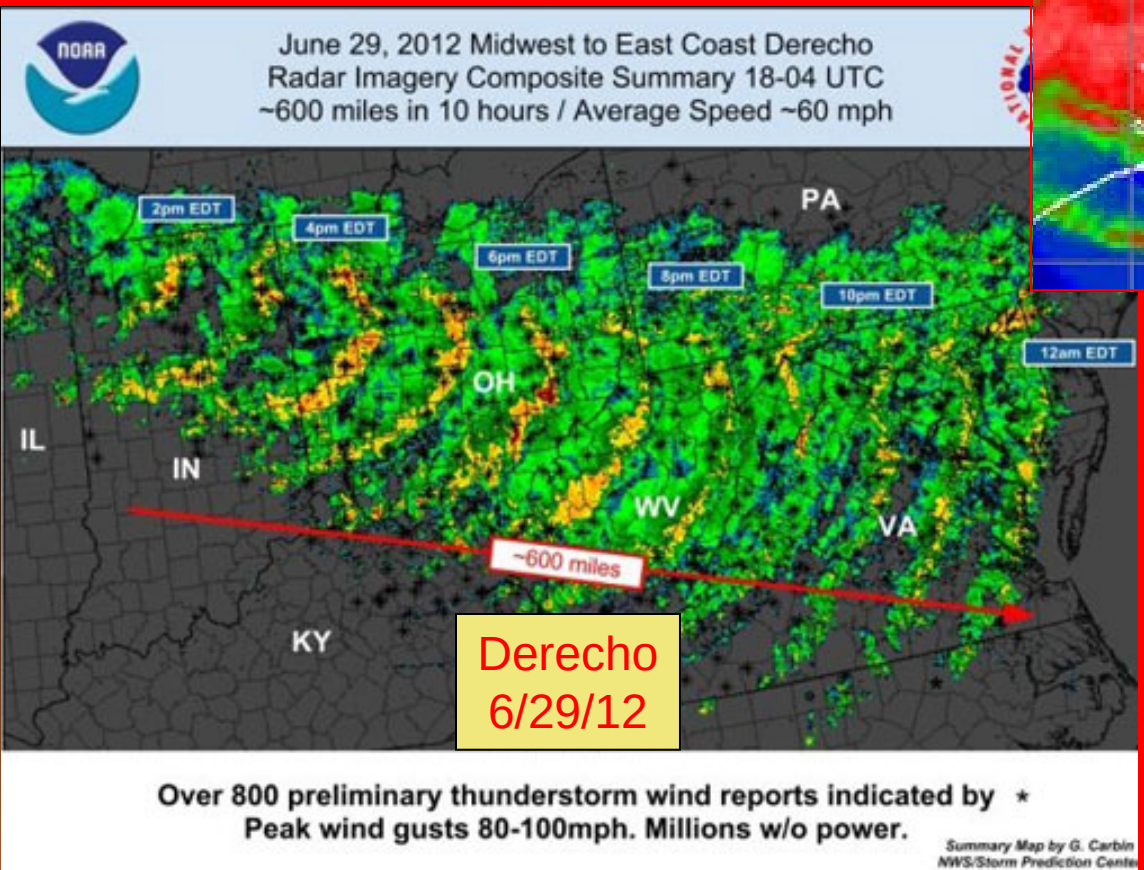
Growing Season



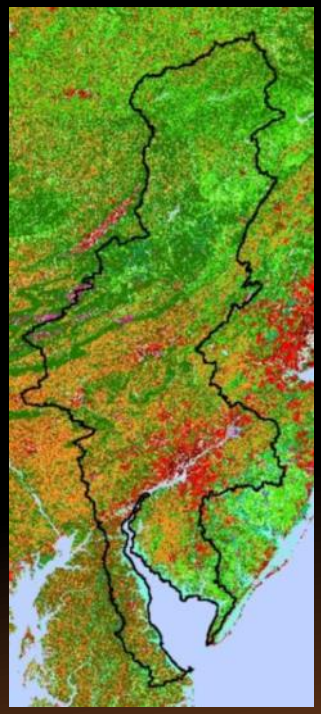
Emerging Threats

Frequent Bigger Storms
Heat Stress
Saltwater and Sea Level Rise
Flooding (amid Droughts)

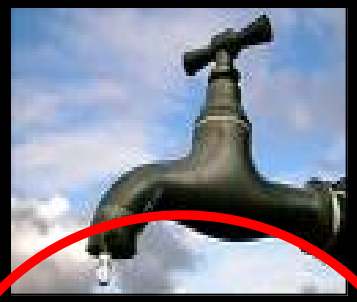




Predictions > Vulnerability > Adaptation > Action



Coastal Wetlands



Abundant
Diverse

<u>Benefits:</u>

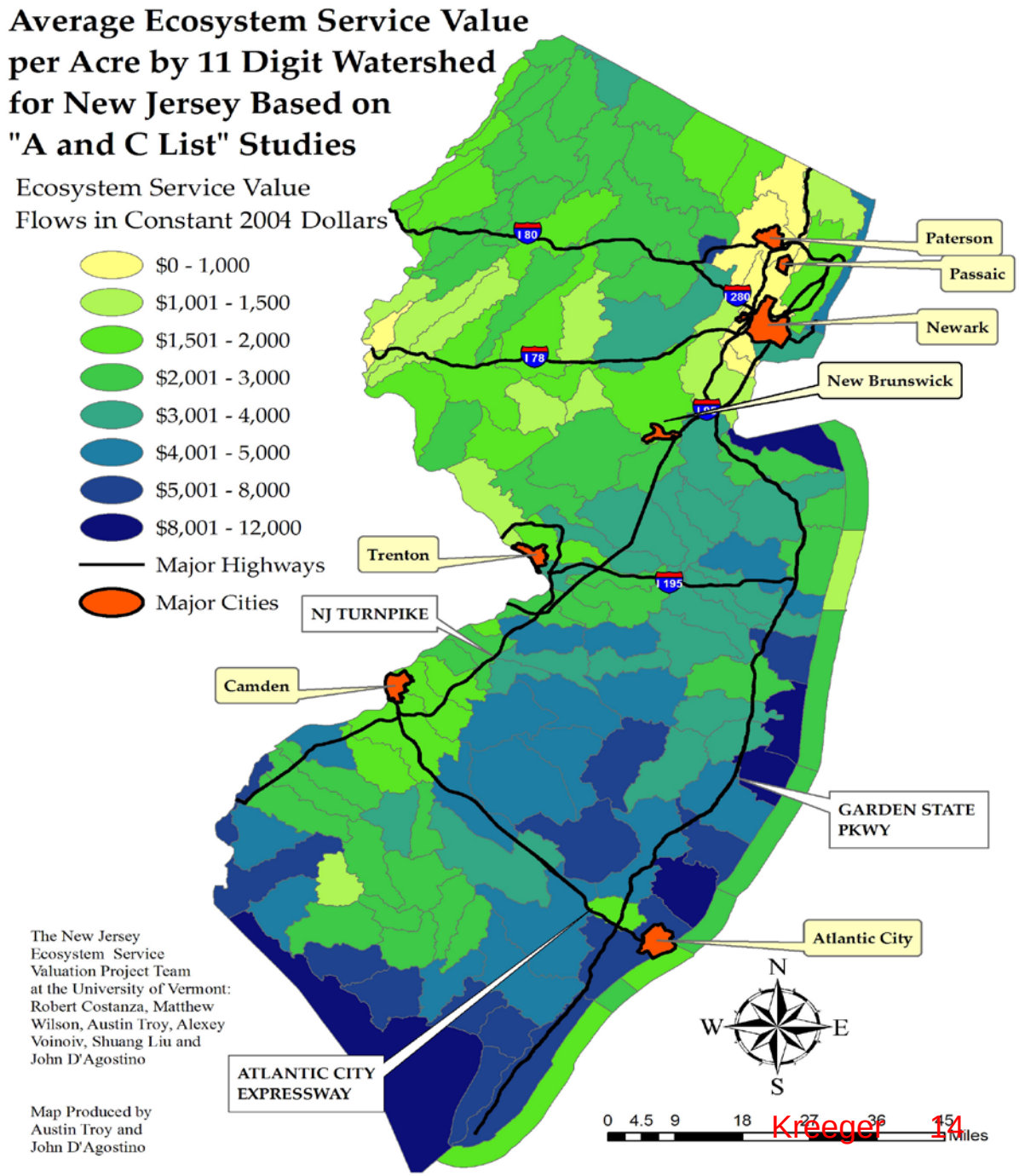
Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Capture

Wetland Benefits (Ecosystem Services)

Millenium Ecosystem Assessment 1° Service	2° Service	3° Service	4° Service
Provisioning	Food	Fisheries Support	
		Livelihoods ebrate production	
	Genetic Materials	Phragmites control research	
	Biochemical Products	Research in Antifungal Agents Health	
	Fiber and Fuel	Cellulose stock	
Regulating	Sequestration Health	Carbon	Carbon Caps, mitigation
	Sediment Stabilization	Erosion control	Meet TMDLs for sediment
	Storm Protection/ Wave Attenu Lives Flood Protection	Protect Property Values and infrastructure	
	Gas Regulation	Carbon Sequestration	
		Oxygen production	
	Water Quality Health	Sequestration, Filtering	TMDLs: Nutrients, Pollutants
Cultural/ Spiritual Human Well Being	Recreation	Bird watching, hunting, boating	
	Spiritual and Inspirational	Native American Uses Health	
	Educational	University reasearch & scho projects/trips	
	Aesthetic Value	Landscape pictures, paintings, open space	
Supporting	Habitat	Wildlife, shellfish, insects	
	Biodiversity	Maintain Plant Communities	
	Production	Primary Production	
	Water Cycling/Hydrologic Regim Health		
	Nutrient Cycling/Biogeochemical Processes	Maintain trophic cycles, soil building	

Valuation of New Jersey's Natural Capital and *Ecosystem Services*

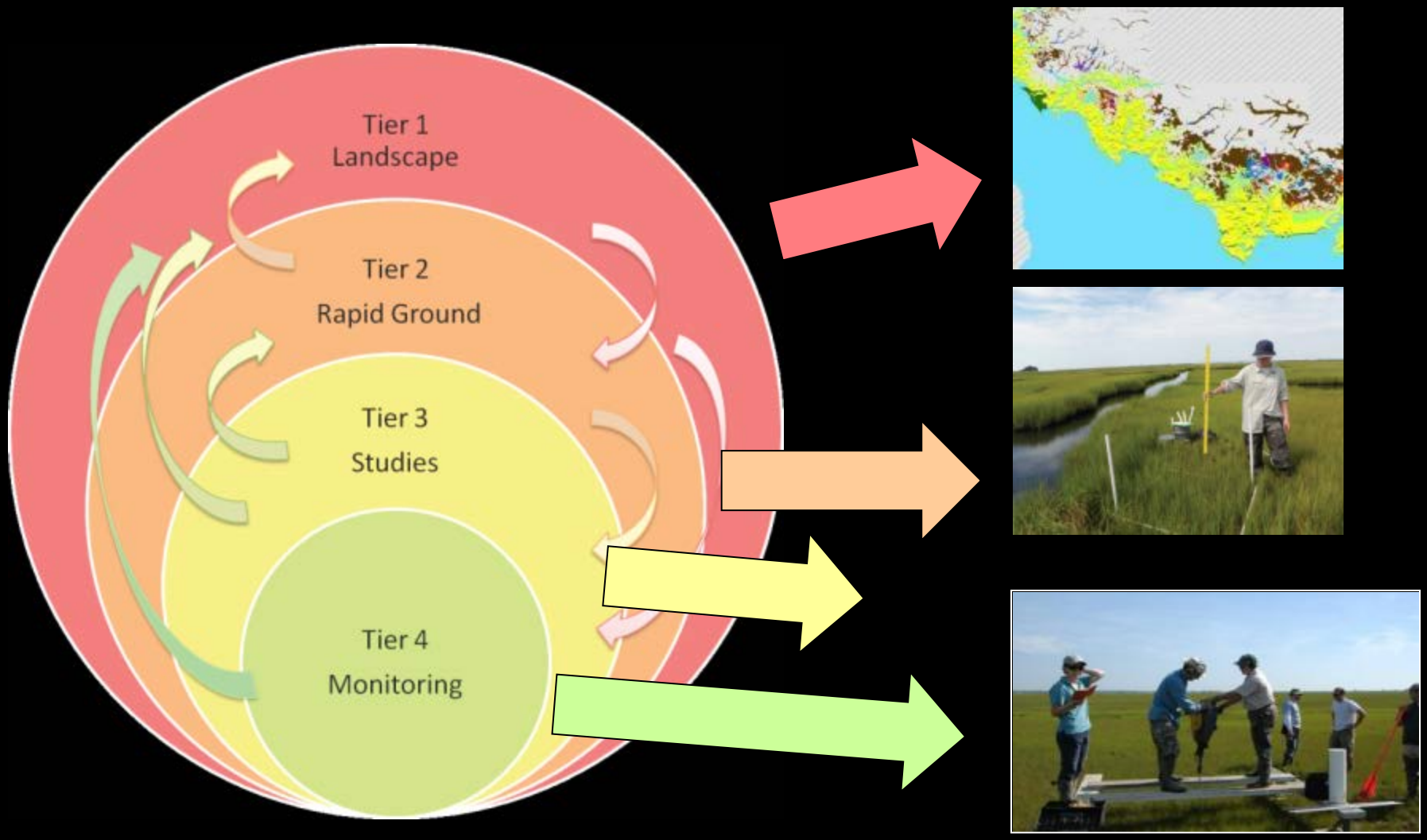
New Jersey Department of Environmental Protection



Slide from Bill Mates, NJDEP

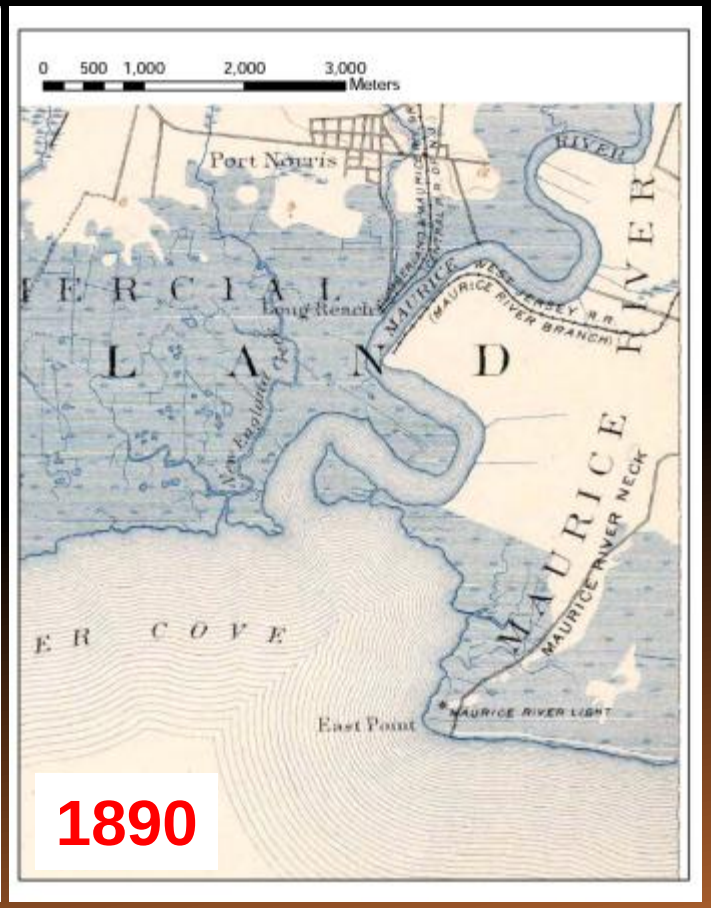
The Mid-Atlantic Coastal Wetland Assessment:

Integrated Monitoring of Tidal Wetlands for Water Quality and Habitat Management and Restoration Planning



Maurice River Mouth

Interior Drowning

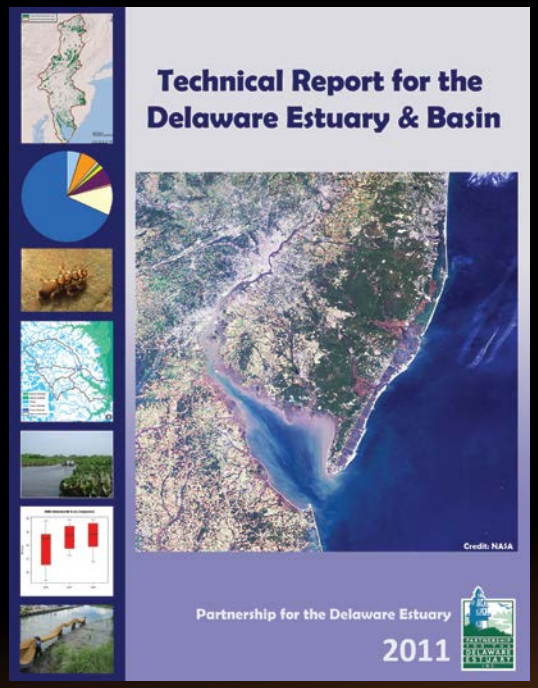


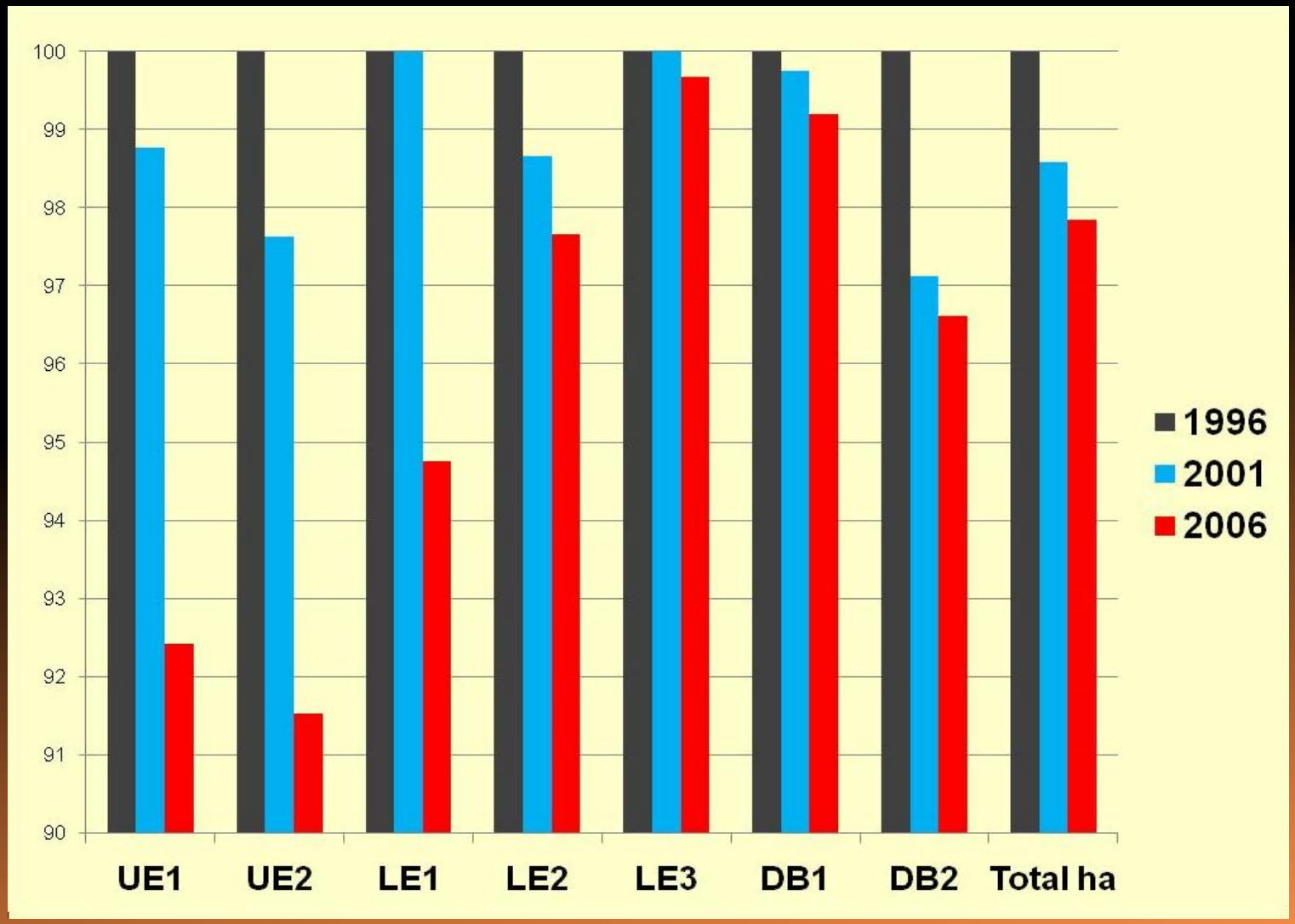
Edge Retreat

Courtesy, Jeff Gebert ACOE

State of the Estuary Report 2012

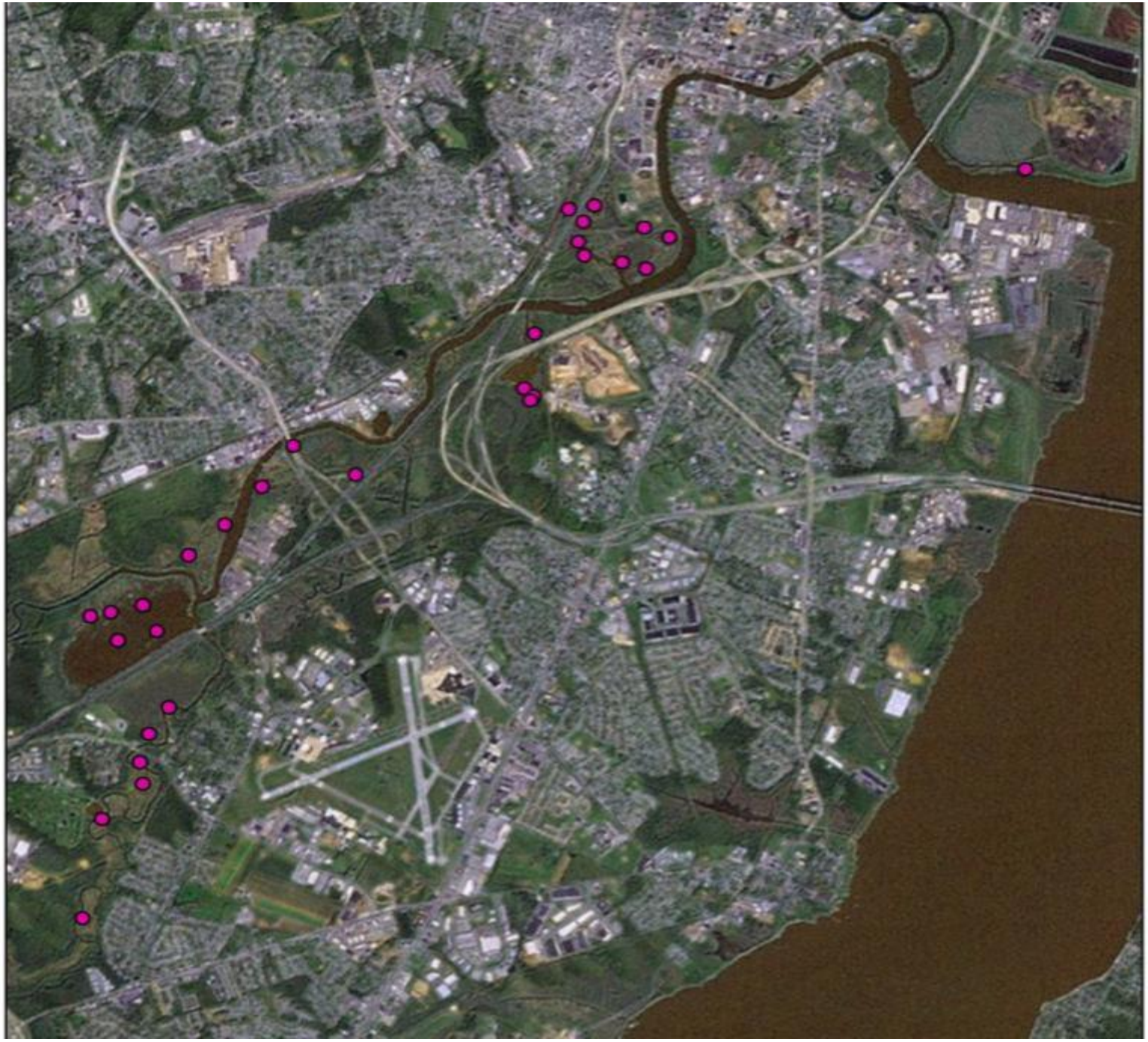
Percentage Loss of Emergent Tidal Marsh 1996-2006



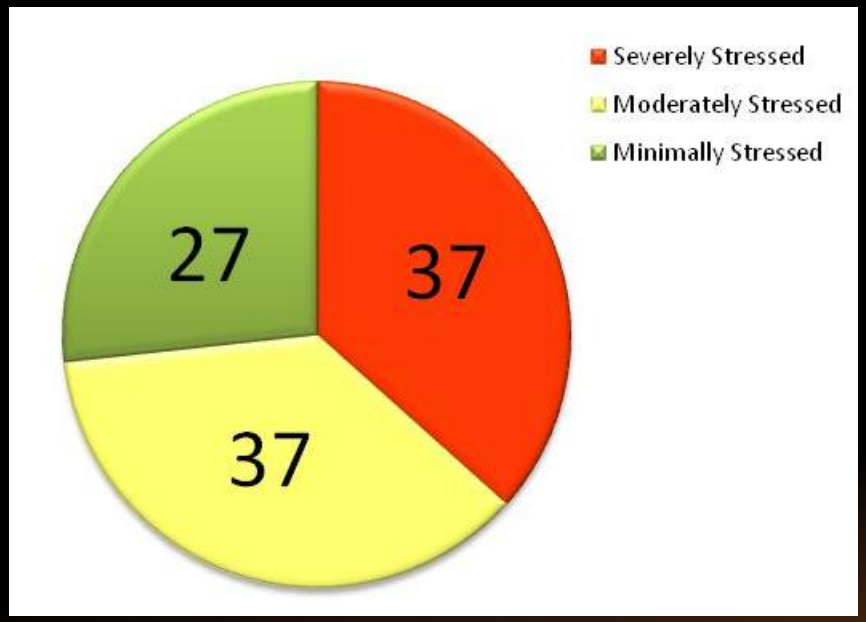


Christina Watershed Tidal Wetland RAM:

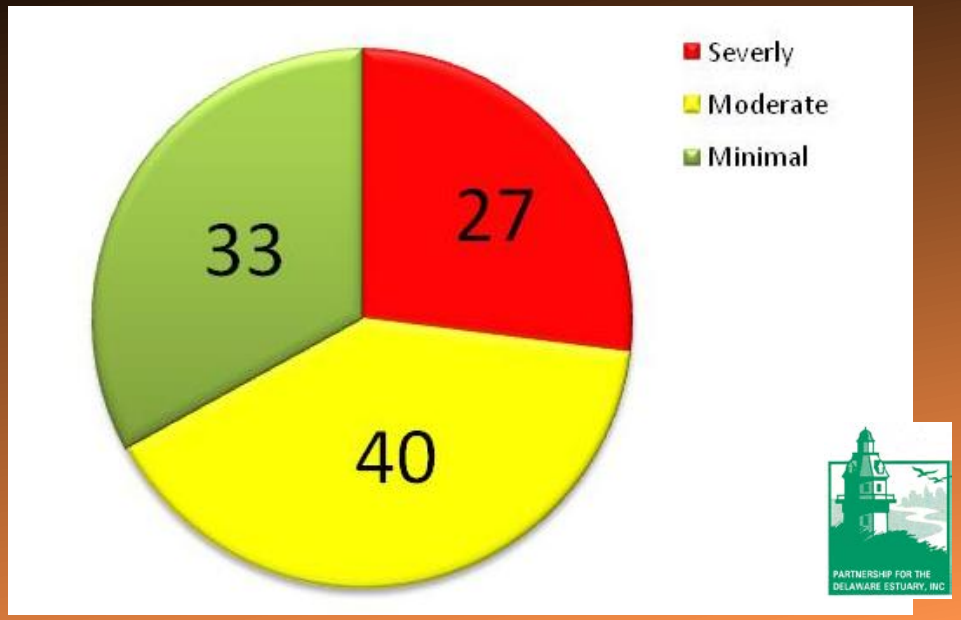
30 Sites in 2011



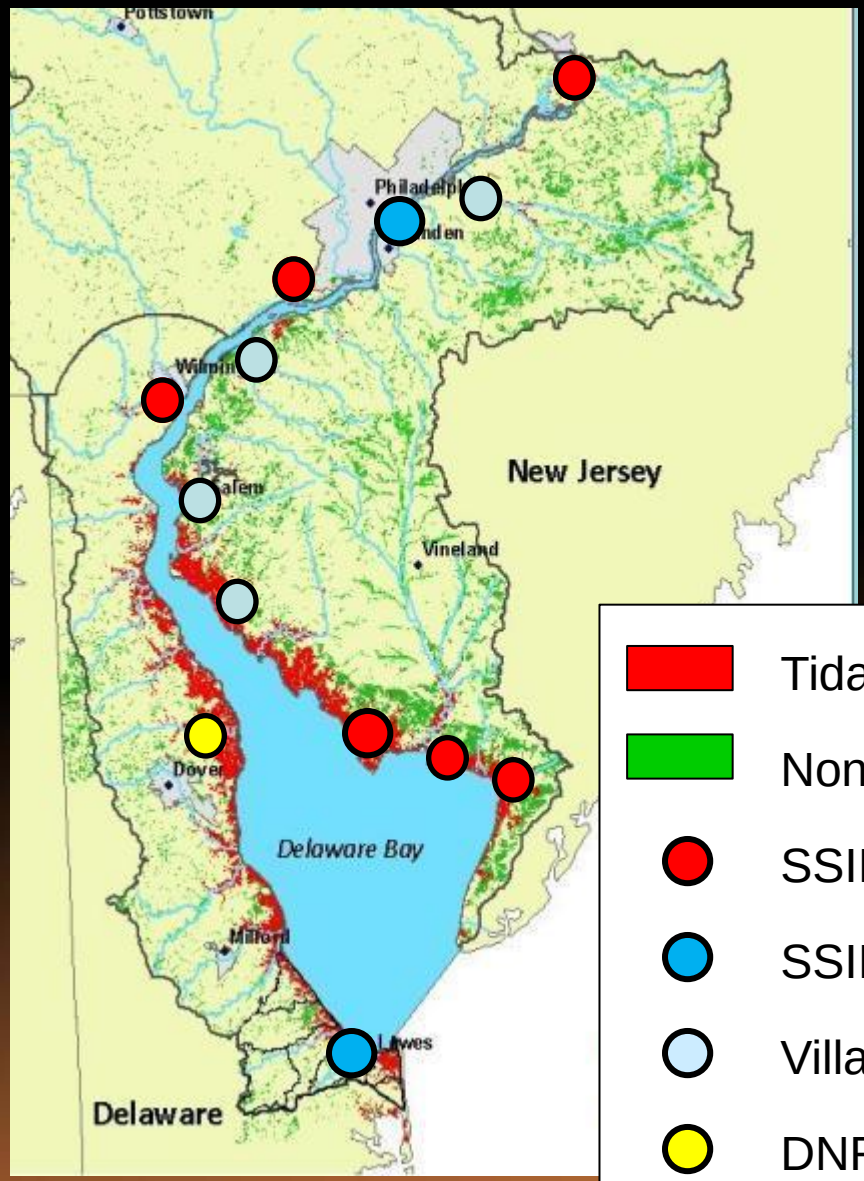
PA Tidal Wetlands – Condition Summary



Maurice Tidal Wetlands – Condition Summary



Site-Specific Intensive Monitoring (SSIM)



Tidal Wetlands

Non-Tidal Wetlands

SSIM Stations

SSIM Stations (Pending)

Villanova Stations

DNREC Station

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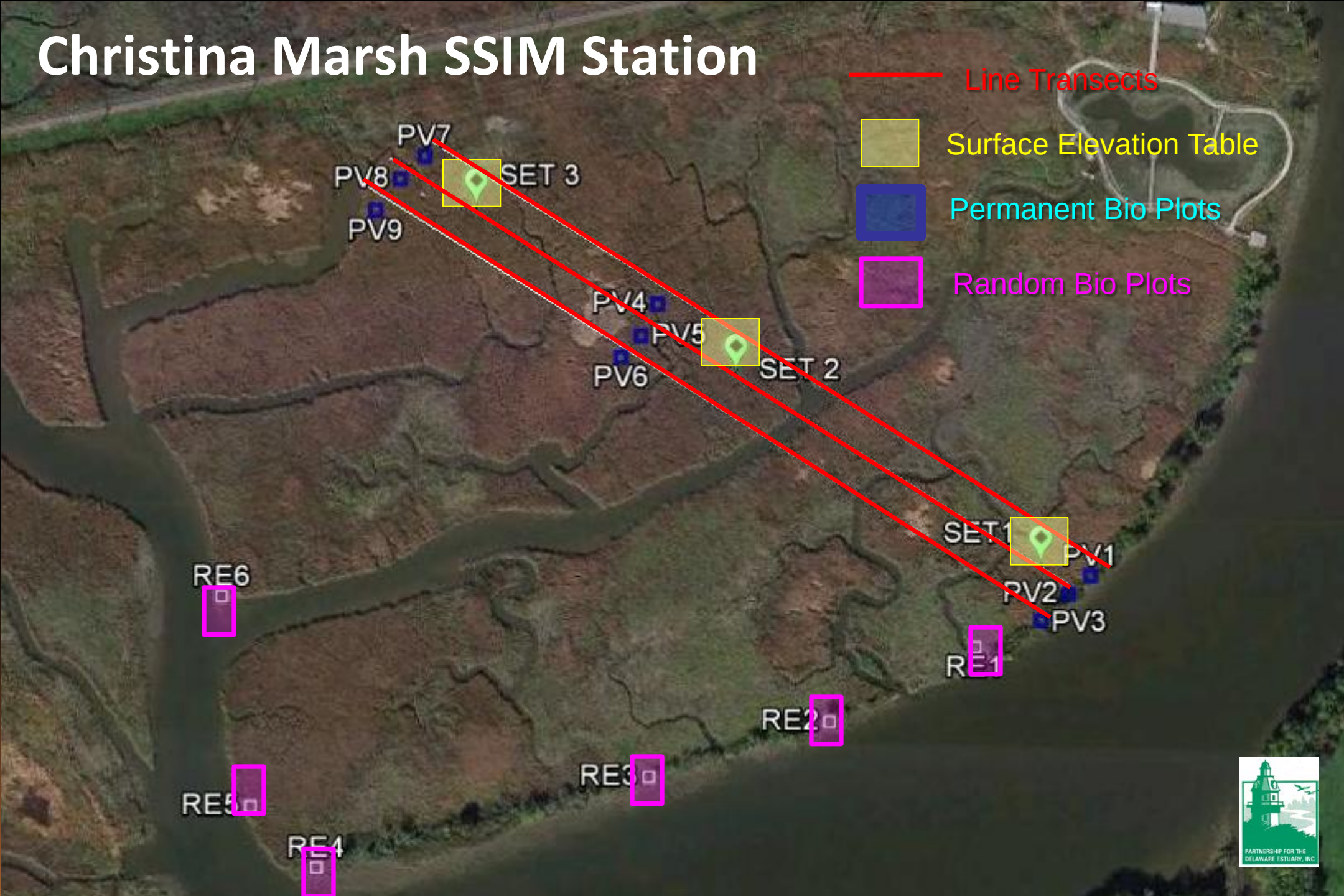
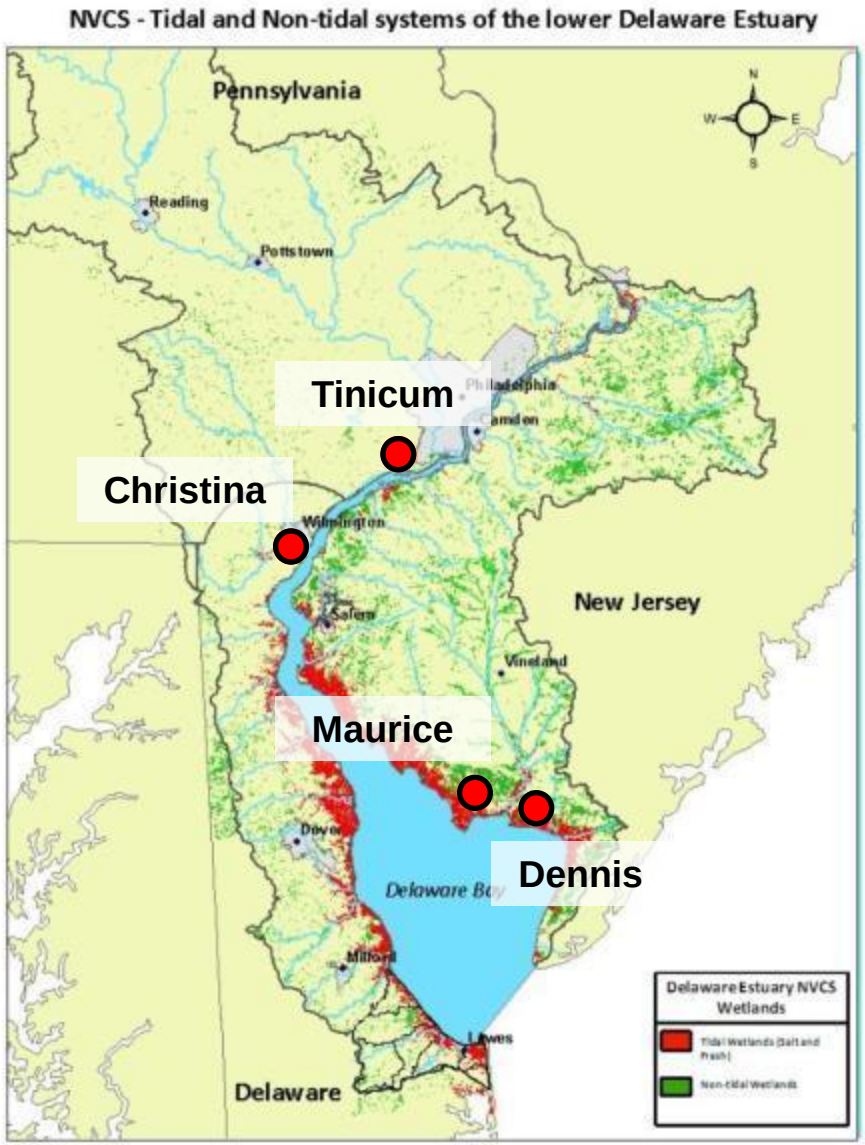
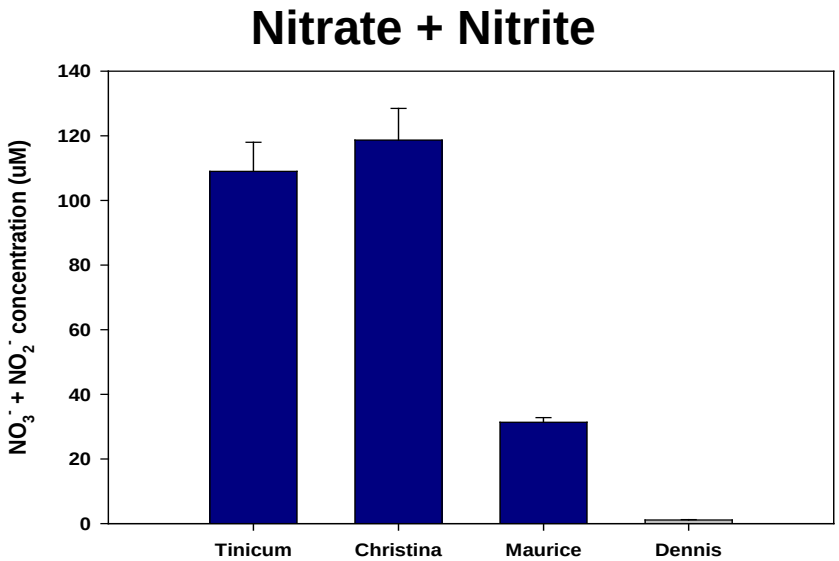
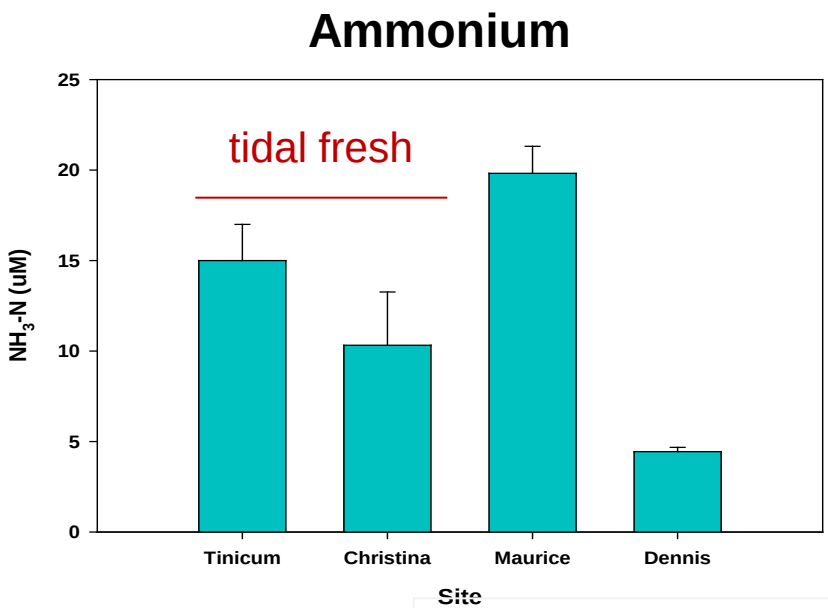
Christina Marsh SSIM Station



Tidal Creek Nutrients



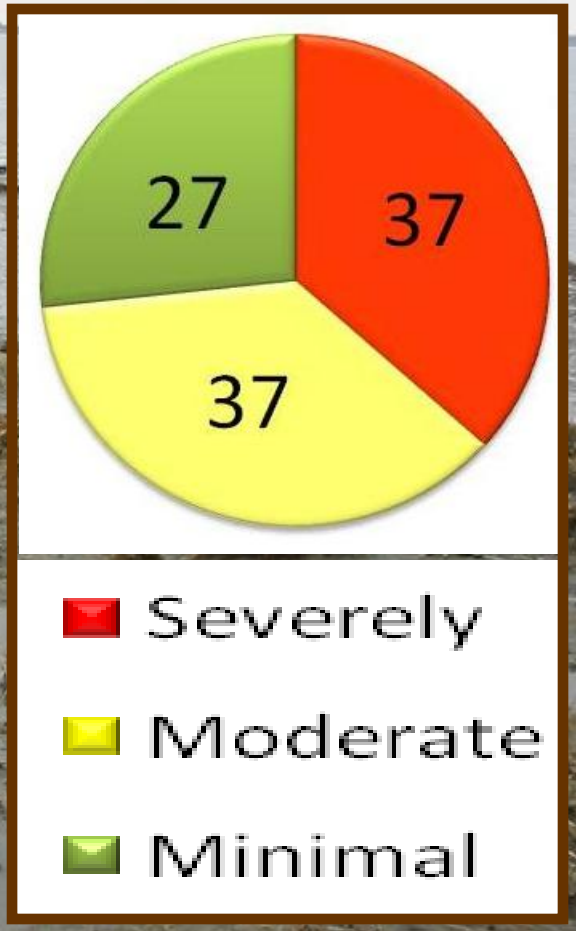




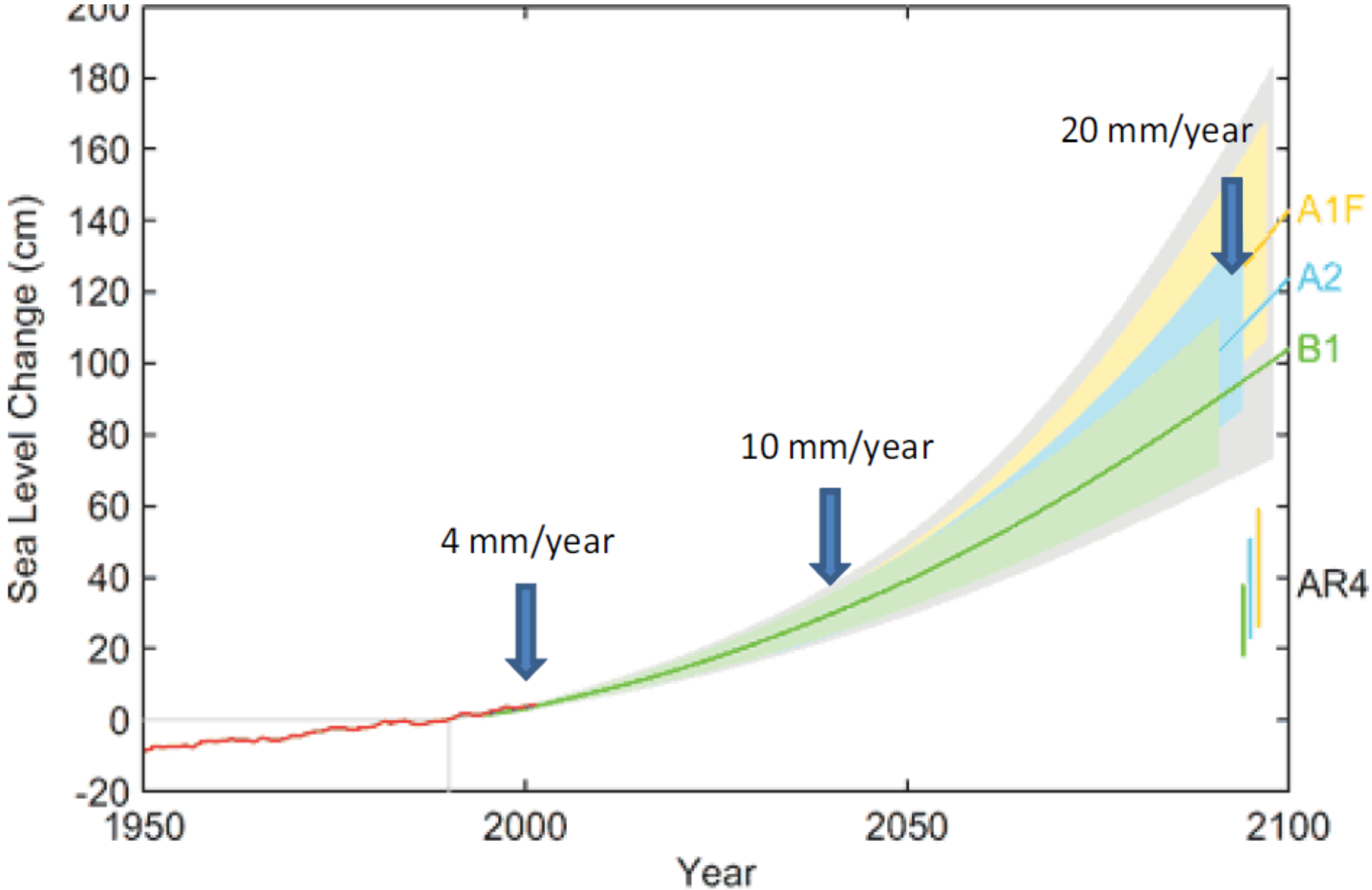
Slide credit: Dr. Tracy Quirk

2012 State of the Estuary Report

Rapid loss of acreage and degraded wetland health



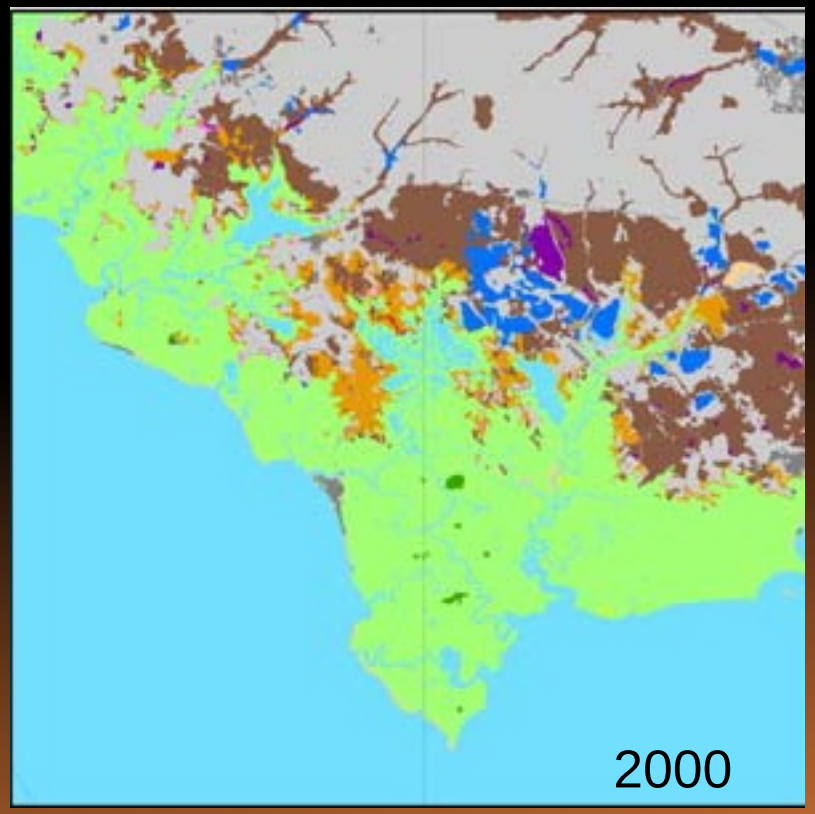
Most Salt Marshes Cannot Survive When Sea Levels Rise >1 cm Per Year

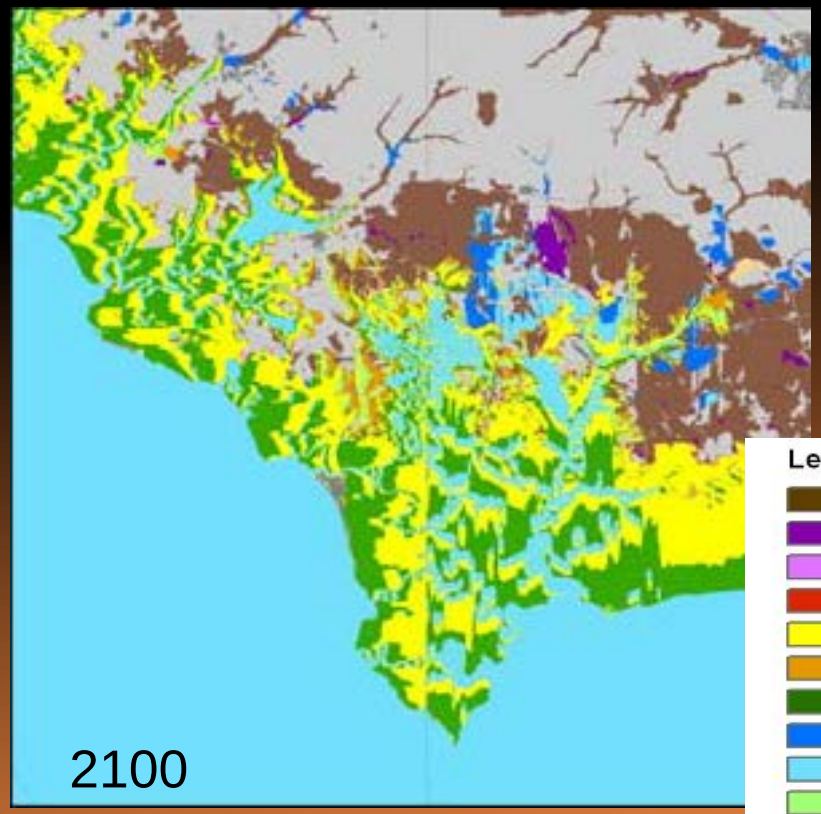


Coastal Wetlands - Future

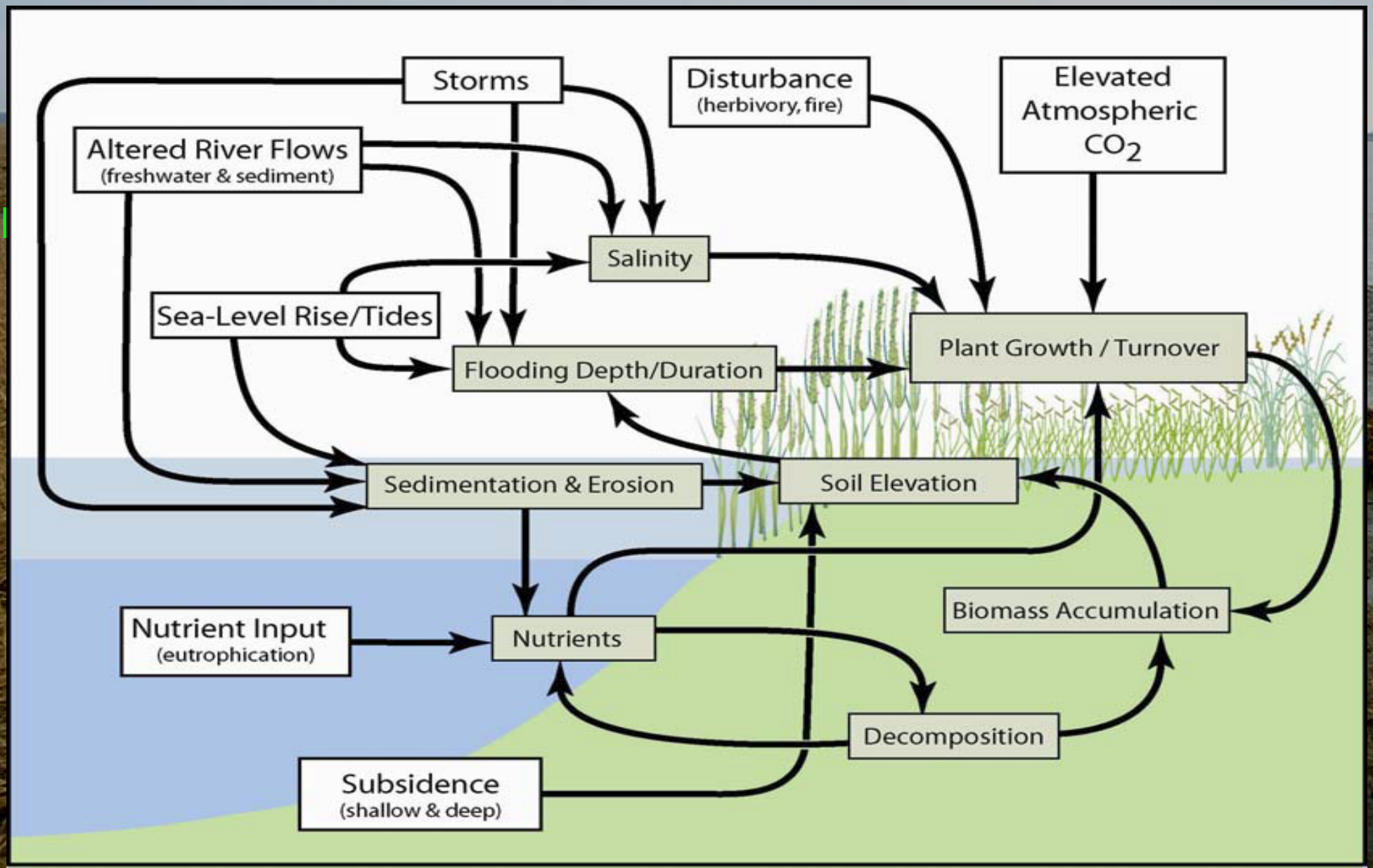
>25% Loss of tidal wetlands

- Conversion of >40,000 acres Uplands to Wetlands
- Conversion of >100,000 acres Wetlands to Water
- Loss of Benefits >> Acreage Losses





Will Tidal Wetlands Keep Pace with SLR?



Coastal Wetland Vulnerability

Freshwater Tidal Marshes

- Salinity Rise
- Barriers to Landward Migration
- Tidal Range

Salt Marshes

- Sea Level Rise
- Storms and Wind Wave Erosion
- Barriers to Landward Migration

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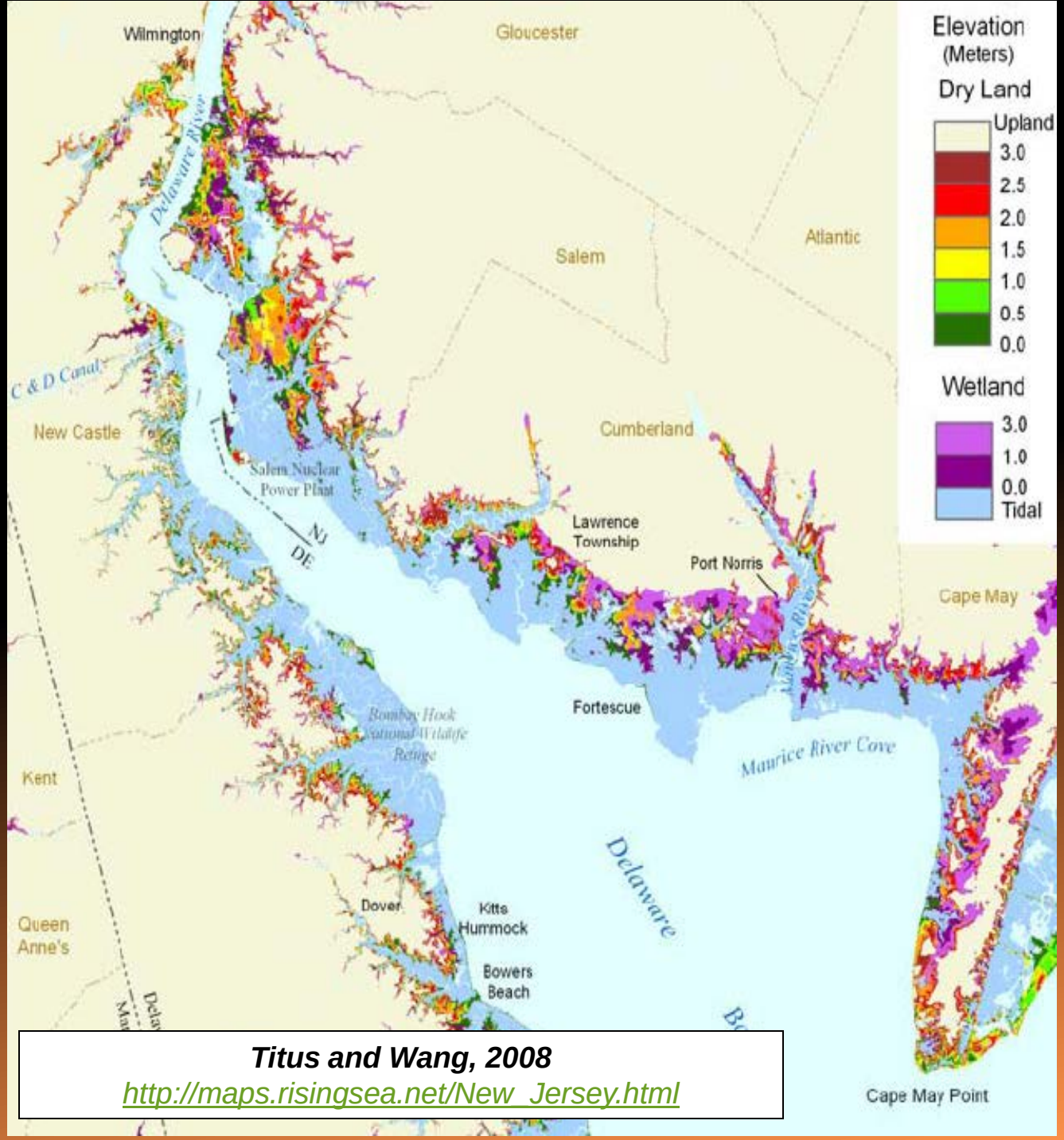
To promote tidal marshes, help them move:

1) <u>horizontally</u>
(landward)

and/or

2) <u>vertically</u>
(to keep pace)



Titus and Wang, 2008
http://maps.risingsea.net/New_Jersey.html

Coastal Wetlands – Adaptation Options

- Living shorelines
- Buffers
- Sediment management
- Structure Setbacks
- Strategic Retreat
- Protect river flow to offset saltwater

Wetland Tough Choices

- Where will they be converted to open water?
- Where can we save them ?
- Where is strategic retreat the best option?

Living Shorelines

- Control Erosion
- Enhance Ecological Conditions
- Not Natural

Living Shoreline R&D

Mussel Powered Living Shorelines for Salt Marsh Erosion Control

April 2010


May 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC


June 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC


June 2011
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC

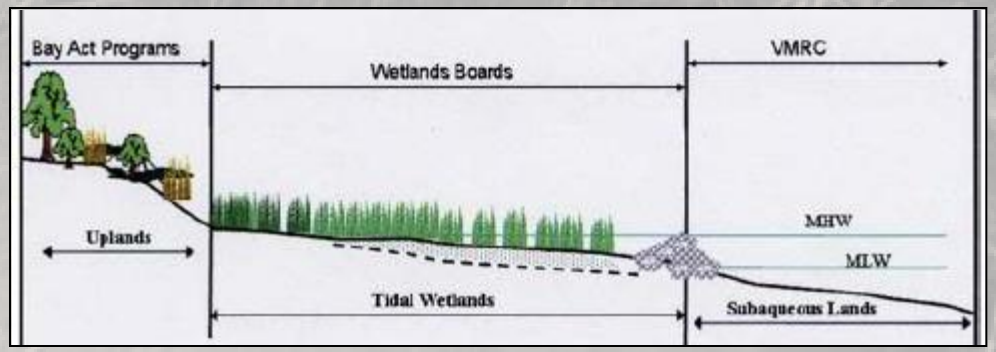
September 2011 (after Hurricane Irene)

November 2012 (after Hurricane Sandy)

DelawareEstuary.org

- Practitioners Guide
- Outreach Products
- Potential Project Inventory (DE, NJ)

Living Shorelines – Many Options

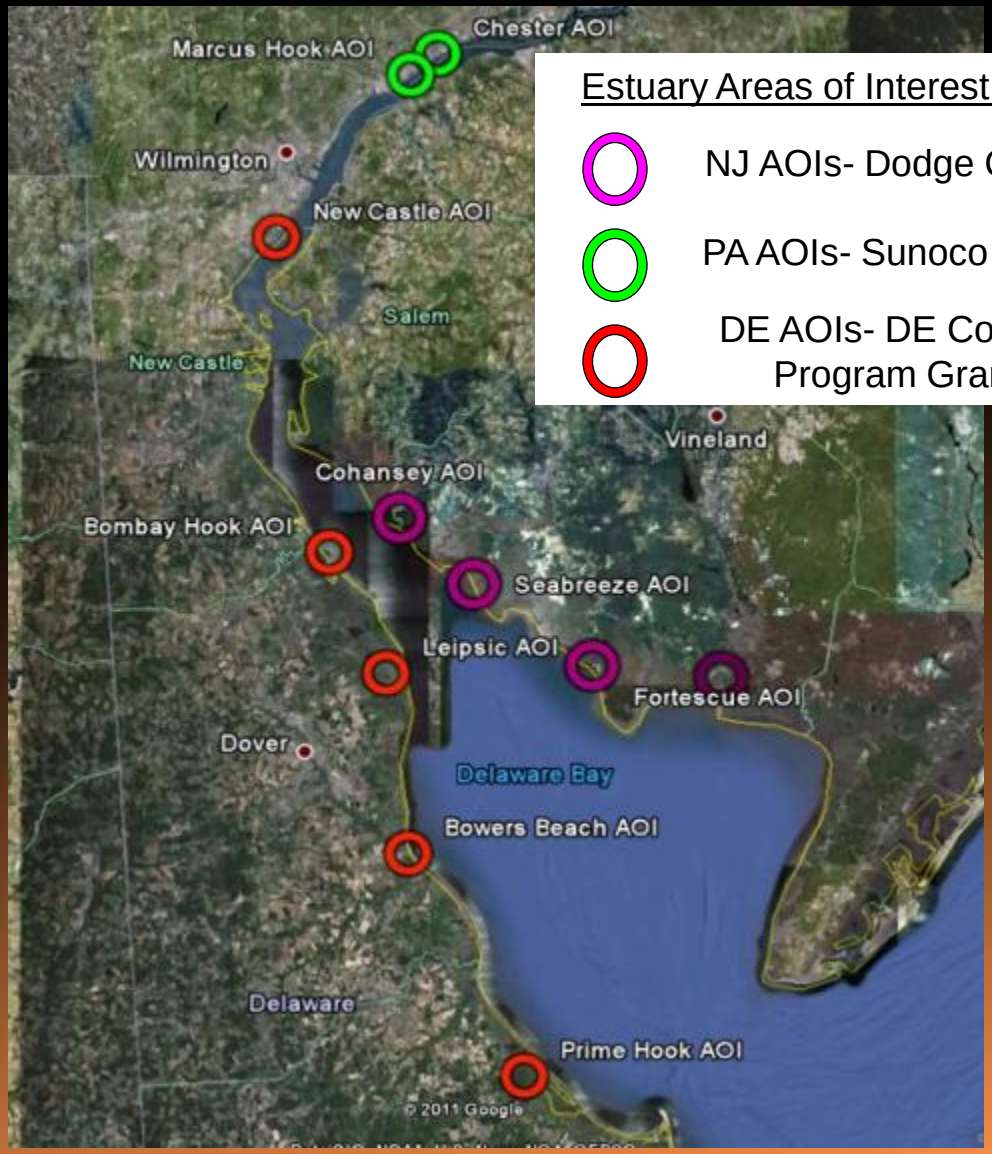


EXAMPLES

Living Shorelines Planning Project

DK

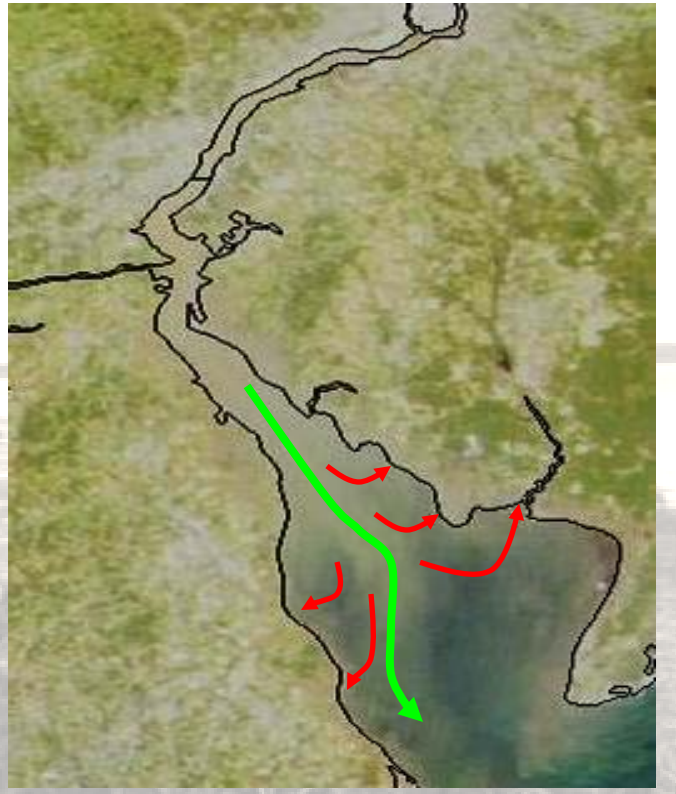
- ☐Inventory of Types
- ☐GIS Analysis in Areas of Interest
- ☐Selection of Potential Project Sites
- ☐Workshops
- ☐Proposals for Pilots



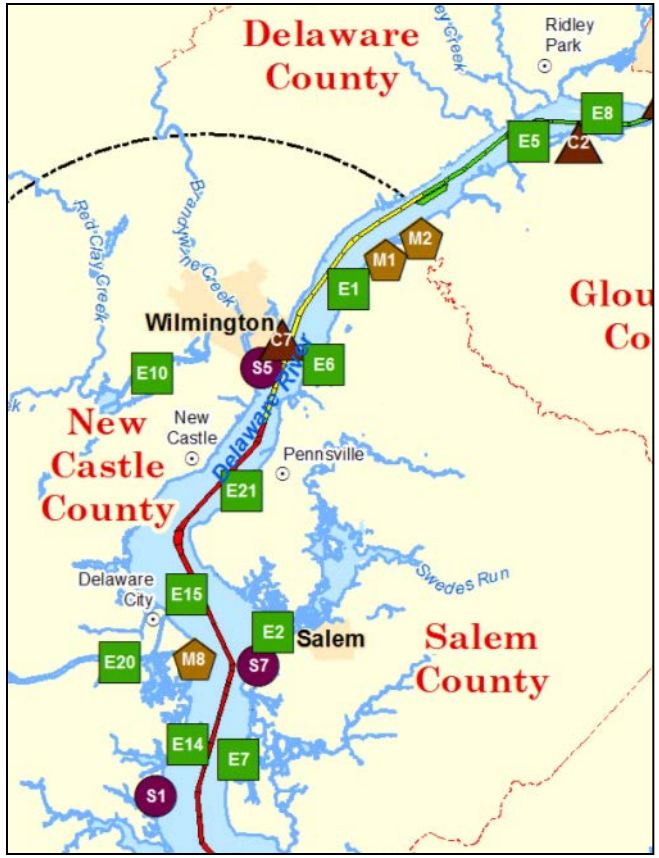
Potential Project Sites

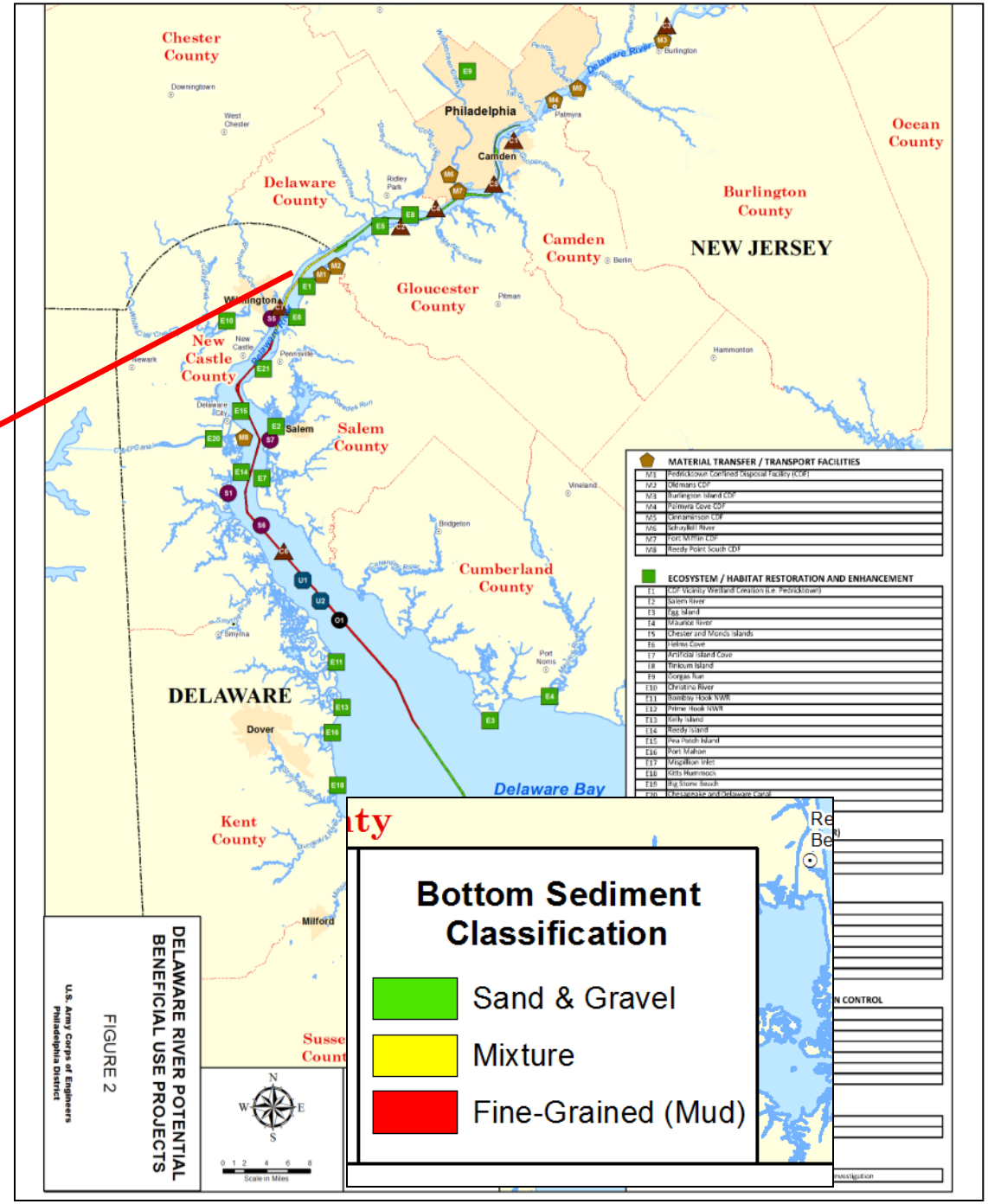
Beneficial Use

- Marshes need sediments
- More sediment is removed from the system by dredging than enters via rivers
- Sediment deficits > marsh drowning
- River sediments might follow main channel to sea rather than enter marshes
- Waves from ships exacerbate erosion
- Both *passive* sediment trapping (e.g. living shorelines) and *active* sediment placement can help replace lost elevation due to these factors



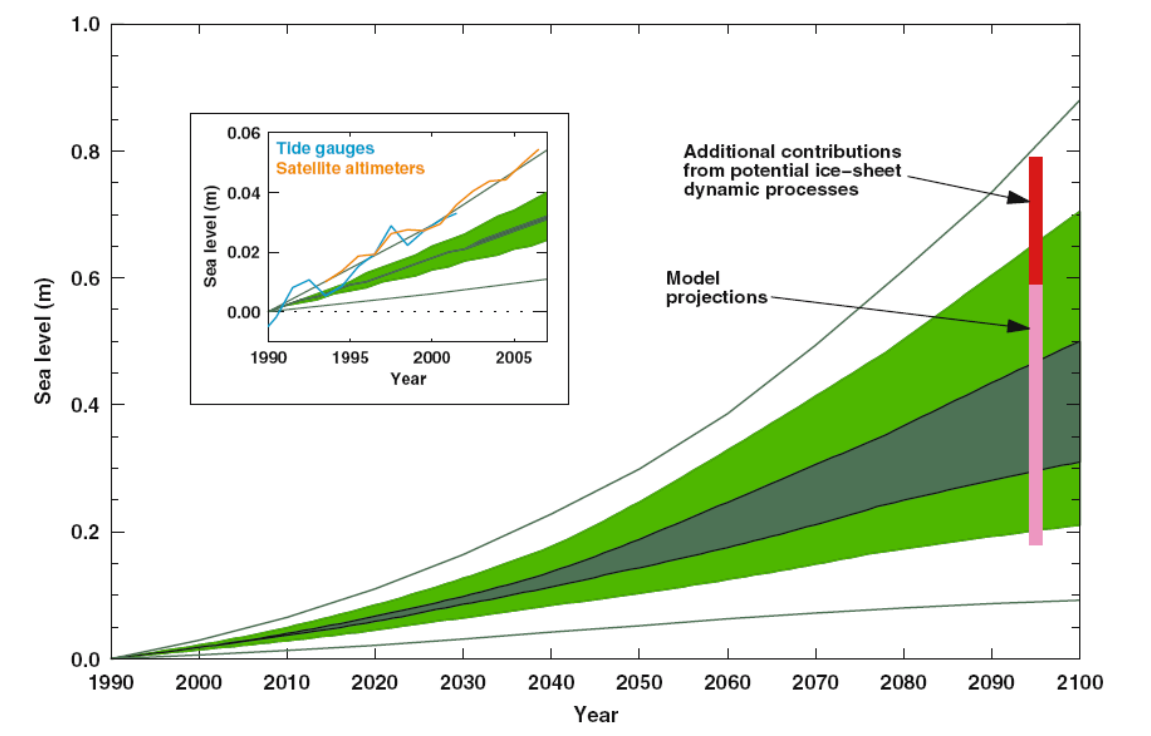
Potential Dredged Material Utilization Projects

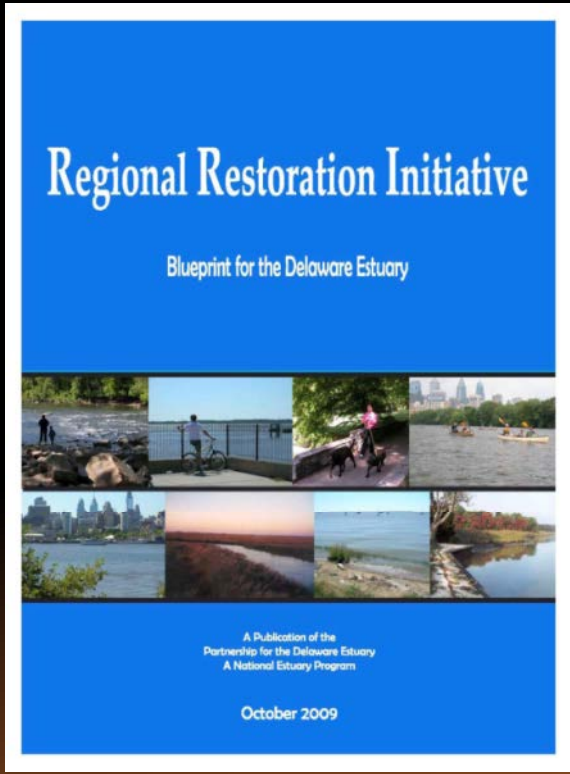




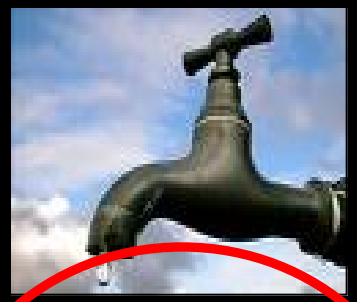
J.B. Smith, ACOE 2011

Restoration for the Future = Climate Adaptation





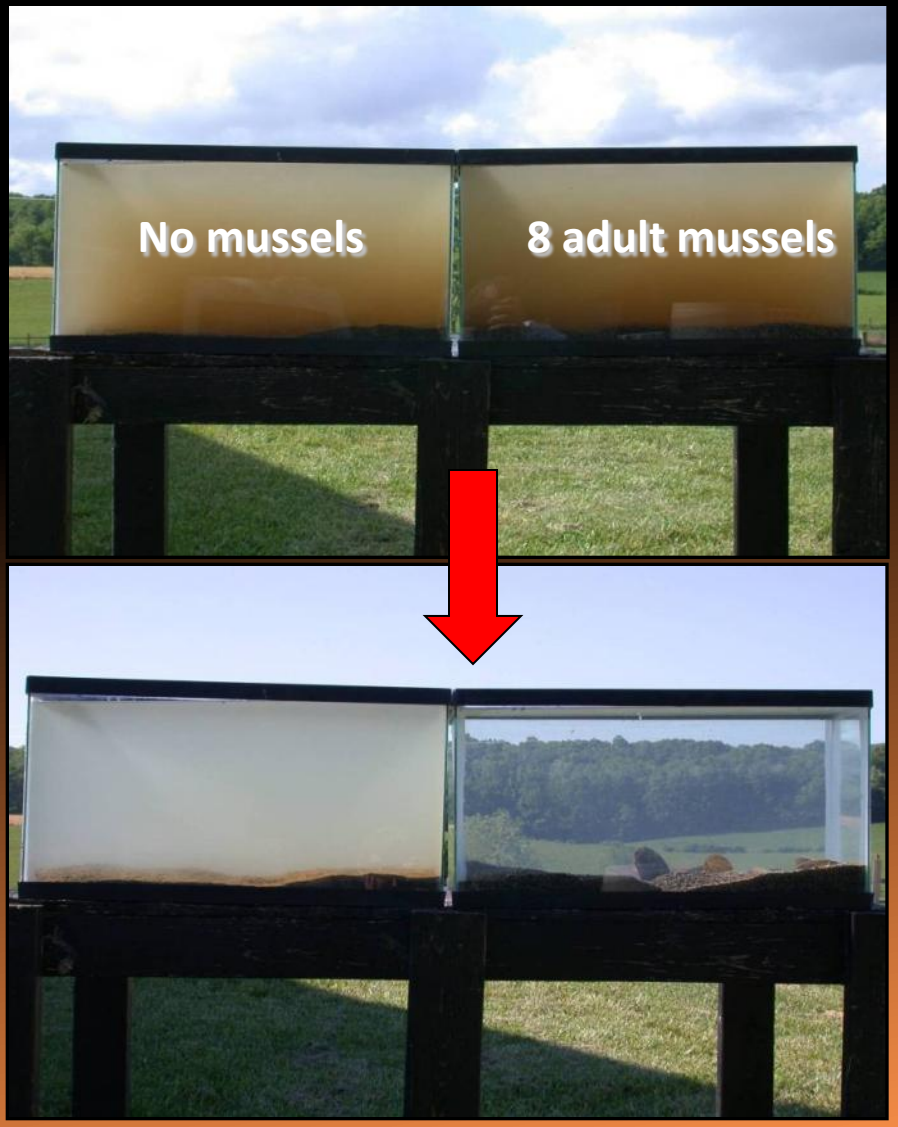
Bivalve Shellfish (oysters, mussels, clams)



60 Species
Diverse

<u>Benefits:</u>

Stabilize Erosion
Water Quality
Fish and Wildlife
Commercial Fishery



Slides from Dick Neves, VA Tech

Bivalves of the Delaware

Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea

Rangia cuneata

Mya arenaria

Mytilus edulis

Ensis directus

Mercenaria mercenaria

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Nature's Benefits

Bivalve Shellfish are "Ecosystem Engineers"

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Mussel Beds

CTUIR Freshwater Mussel Project

Oyster Reefs

Kreeger

Ecosystem Services - Why are they Important?

1. Structure

↑ Habitat Complexity

Bind Bottom

Stabilize Shorelines

↑ Bottom Turbulence

2. Function

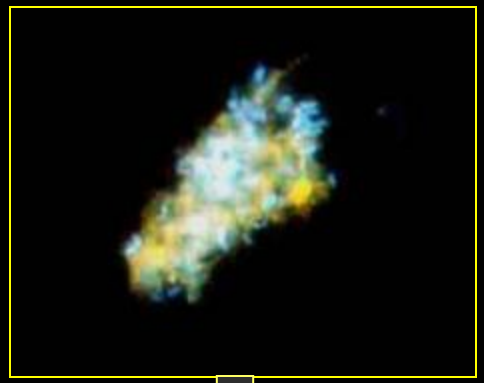
↓ Suspended Particulates

↓ Particulate N, P

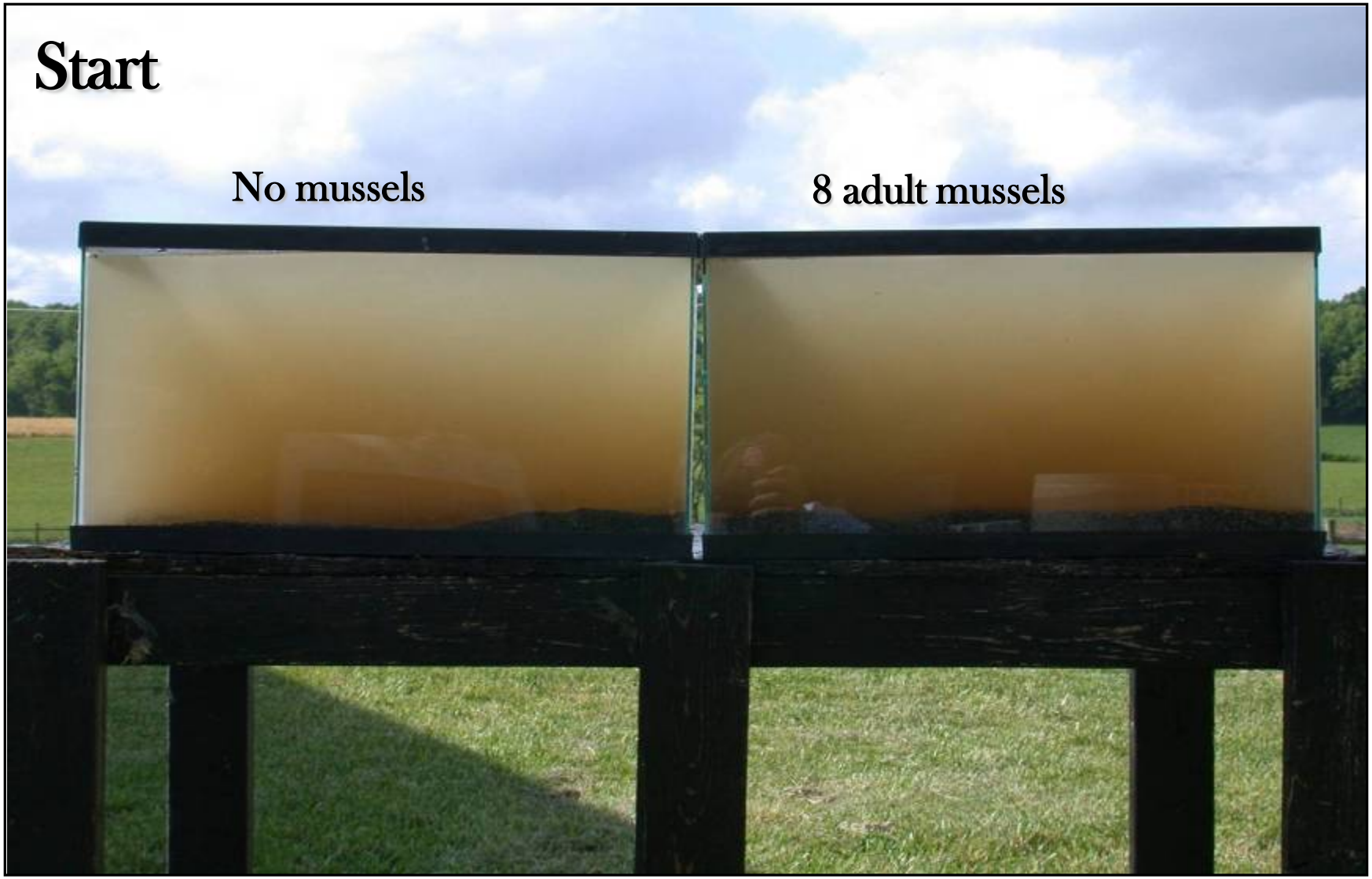
↑ Light reaching bottom

↑ Sediment Enrichment

↑ Dissolved Nutrients

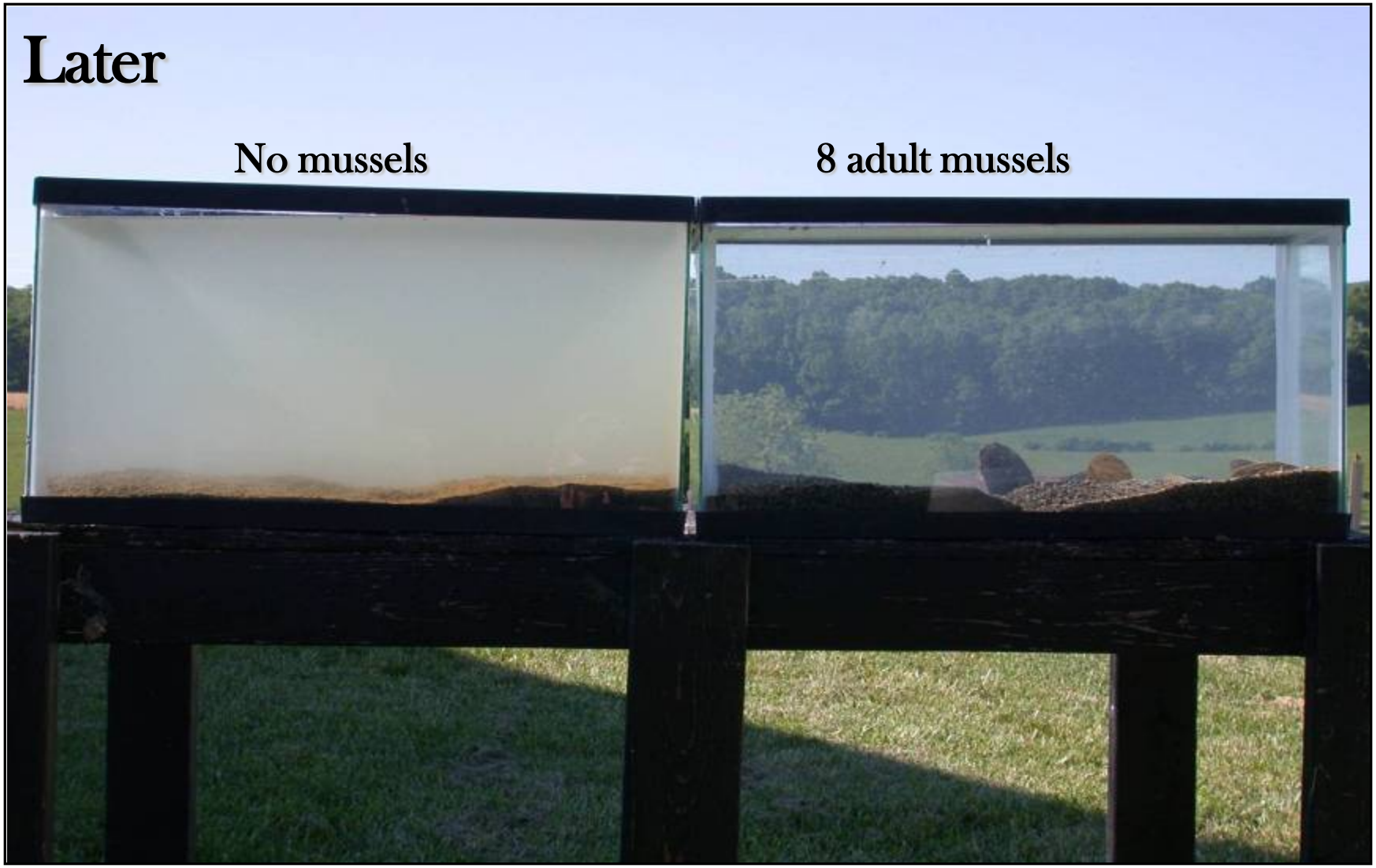


Biofiltration Potential



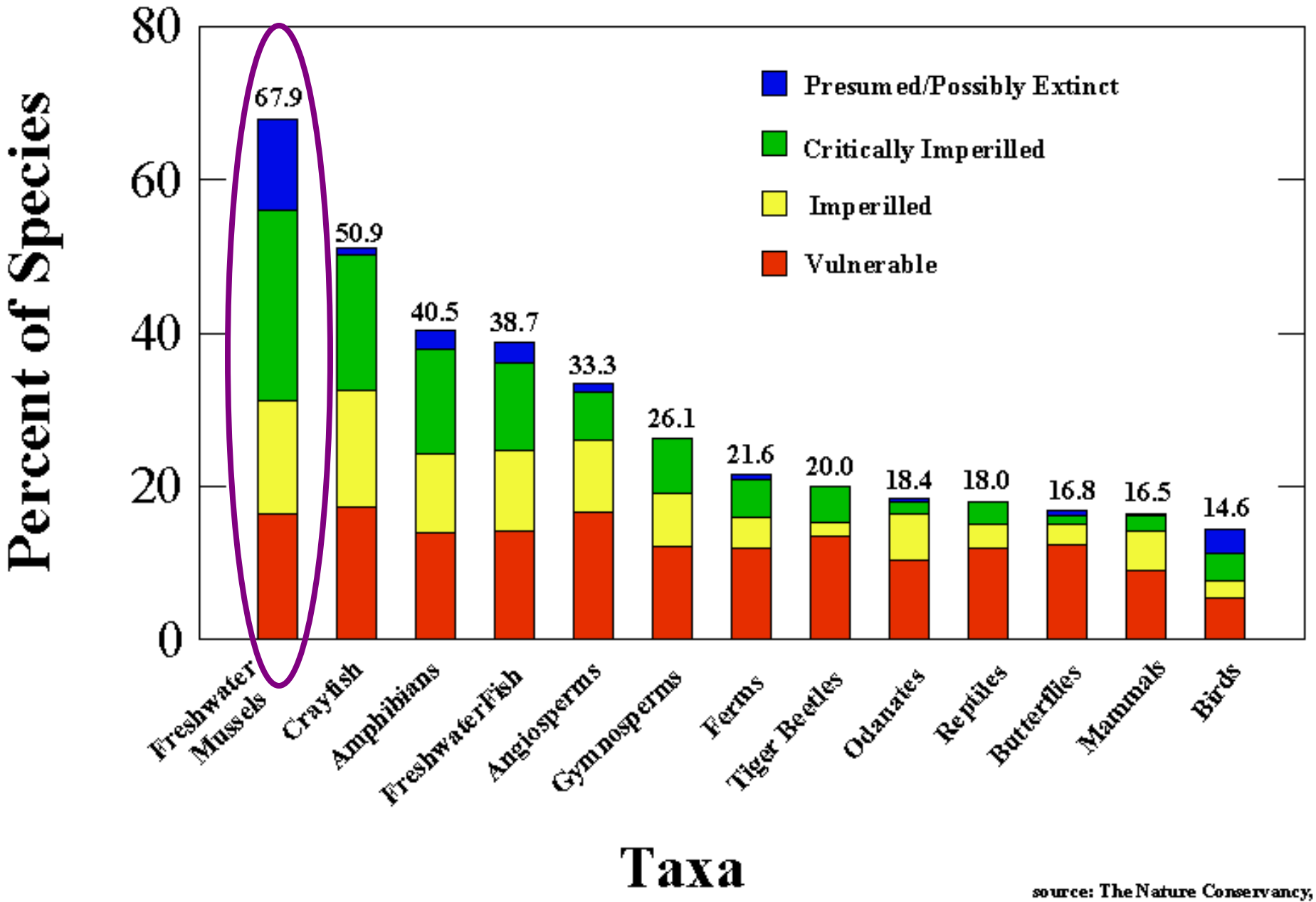
Slide from Dick Neves, VA Tech

Biofiltration Potential



Slide from Dick Neves, VA Tech

Conservation Status of United States Taxa



source: The Nature Conservancy, 1997

Delaware River Basin

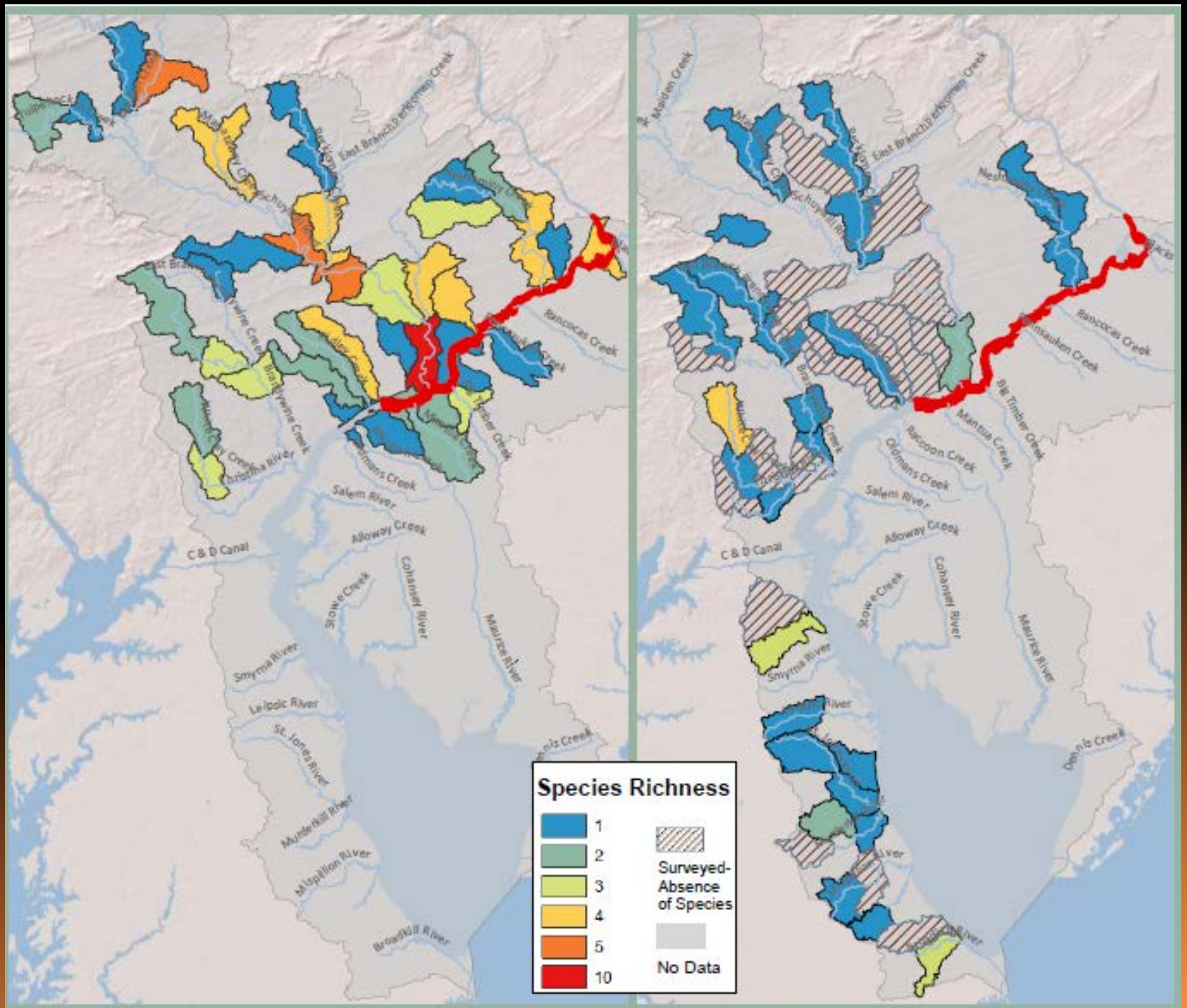
Patchy, Impaired

Rare

Extirpated

		State Conservation Status		
Scientific Name	**Scientific Name**	**DE**	**NJ**	**PA**
ALASMIDONTA HETERODON	DWARF WEDGEMUSSEL	Endangered	Endangered	Critically Imperiled
ALASMIDONTA UNDULATA	TRIANGLE FLOATER	Extirpated ?	Threatened	Vulnerable
ALASMIDONTA VARICOSA	BROOK FLOATER	Endangered	Endangered	Imperiled
ANODONTA IMPLICATA	ALEWIFE FLOATER	Extremely Rare	no data	Extirpated ?
ELLIPTIO COMPLANATA	EASTERN ELLIPTIO	common	common	Secure
LAMPSILIS CARIOSA	YELLOW LAMPMUSSEL	Endangered	Threatened	Vulnerable
LAMPSILIS RADIATA	EASTERN LAMPMUSSEL	Endangered	Threatened	Imperiled
LASMIGONA SUBVIRIDIS	GREEN FLOATER	no data	Endangered	Imperiled
LEPTODEA OCHRACEA	TIDEWATER MUCKET	Endangered	Threatened	Extirpated ?
LIGUMIA NASUTA	EASTERN PONDMUSSEL	Endangered	Threatened	Critically Imperiled
MARGARITIFERA MARGARITIFERA	EASTERN PEARLSHELL	no data	no data	Imperiled
PYGANODON CATARACTA	EASTERN FLOATER	no data	no data	Vulnerable
STROPHITUS UNDULATUS	SQUAWFOOT	Extremely Rare	Species of Concern	Apparently Secure

1919



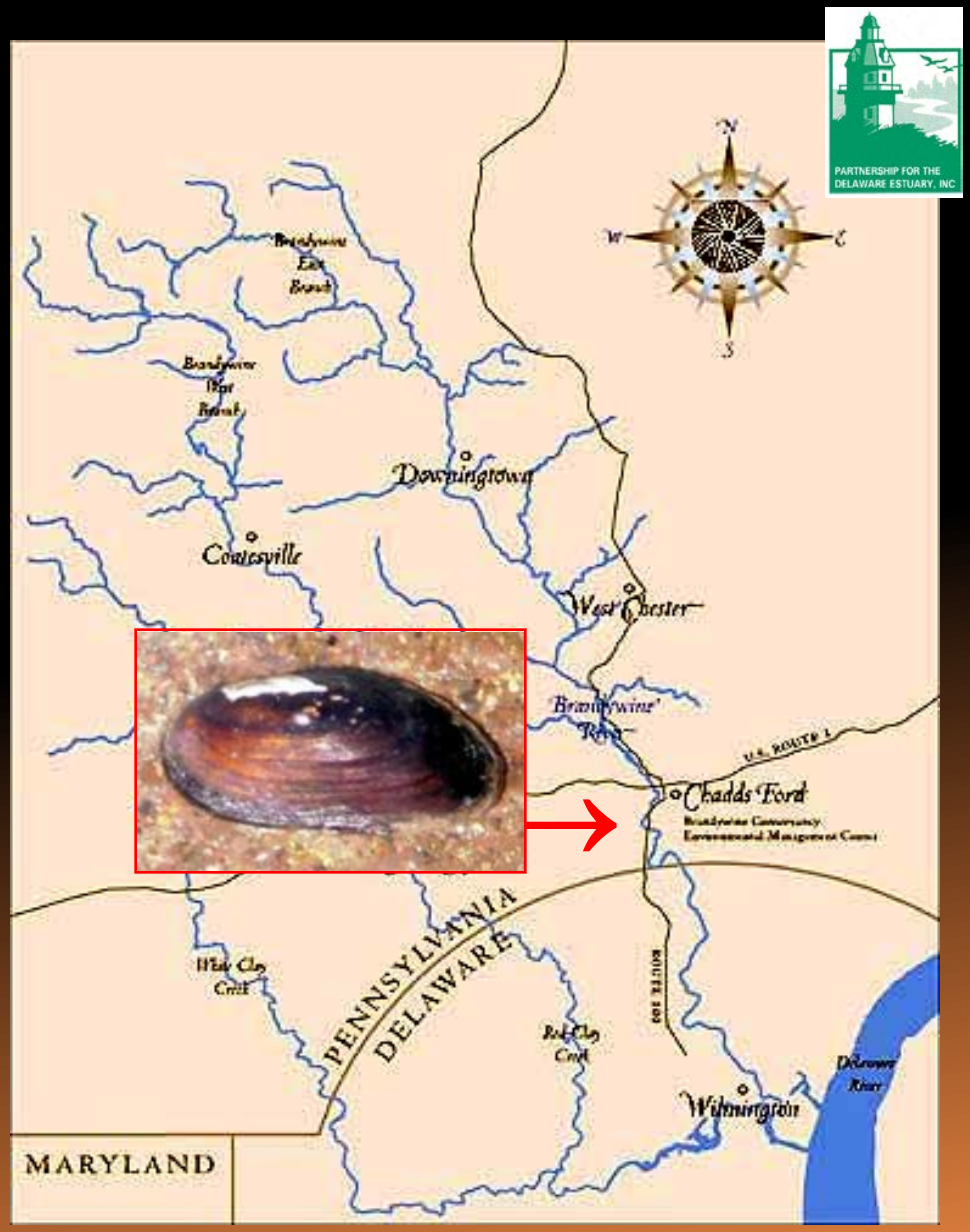
Since 1996

Kreeger

One Mussel Bed in a 6 mile reach of the Brandywine River

Filters >25 metric tons dry suspended solids per year

Estimated Removal = 7.1 %



Map from The Brandywine River Conservancy

Data from Kreeger, 2006

Water Processing Estimate

4.3 Billion *Elliptio* *(DK estimate)*

2.9 Million Kilos Dry Tissue Weight *(DK)*

= 9.8 Billion Liters per Hour

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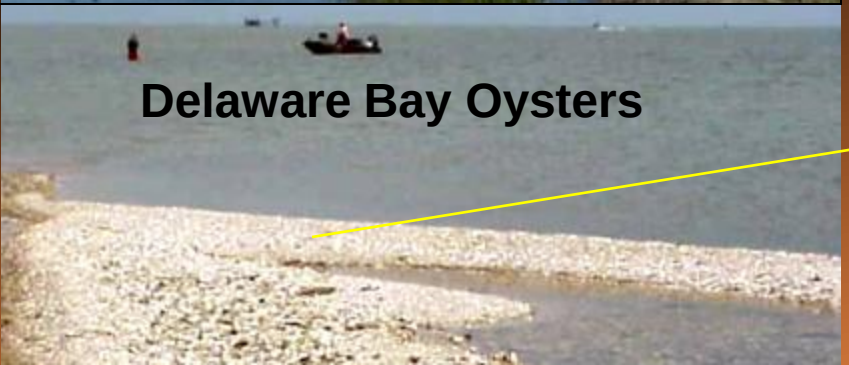
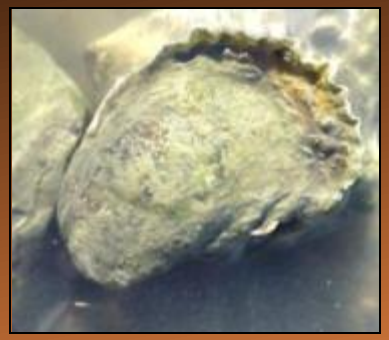
Kreeger

Elliptio complanata

Geukensia demissa





Crassostrea virginica

Kreeger

Ribbed Mussels in Salt Marshes

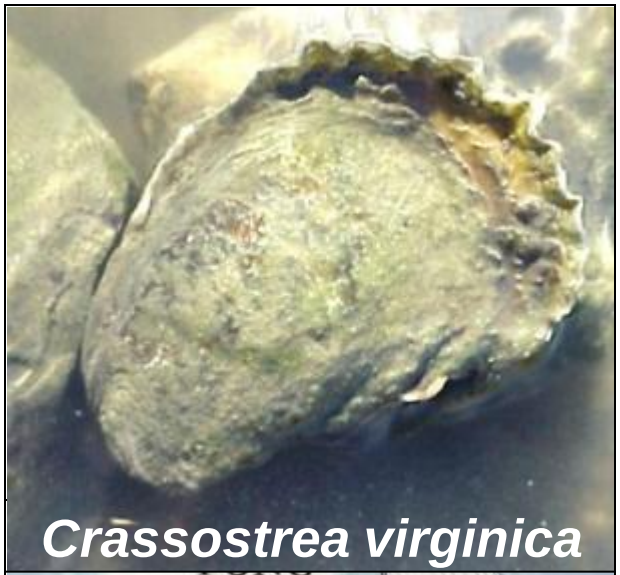
Kreeger

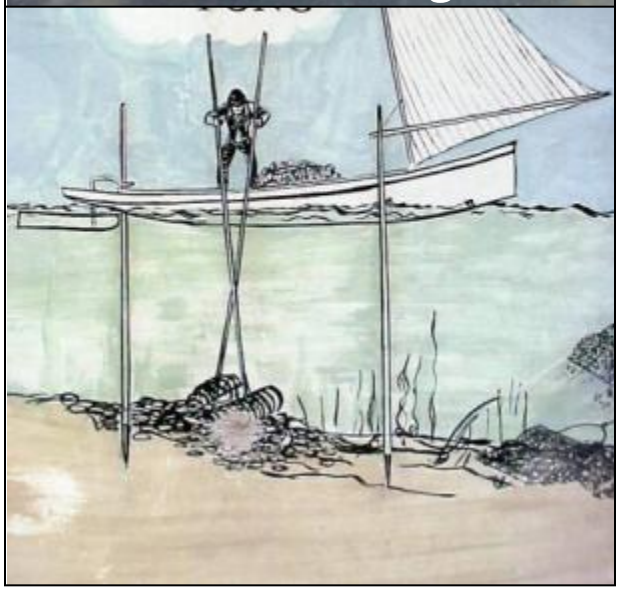
Ribbed Mussels in Salt Marshes

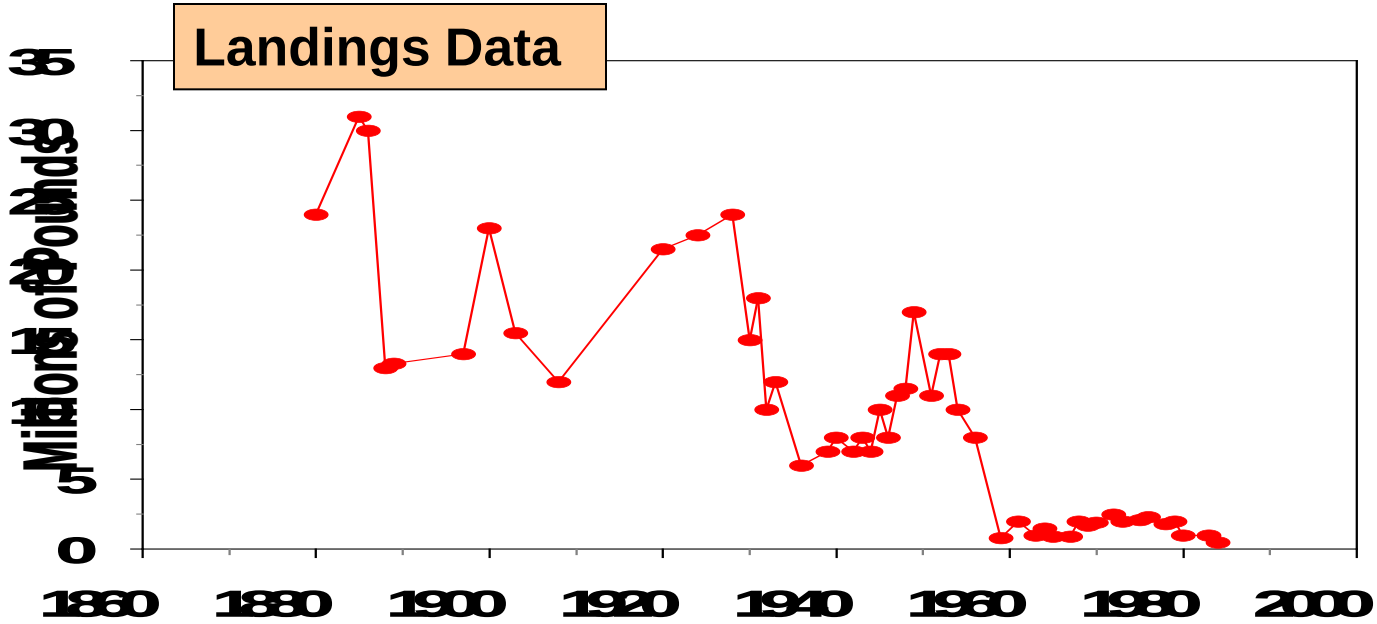
208,000 per hectare on average
10.5 Billion *Geukensia*
Clearance Rate = 5.1 L h-1 g-1 *(DK data)*
11.7 Million Kilos Dry Tissue Weight *(DK)*

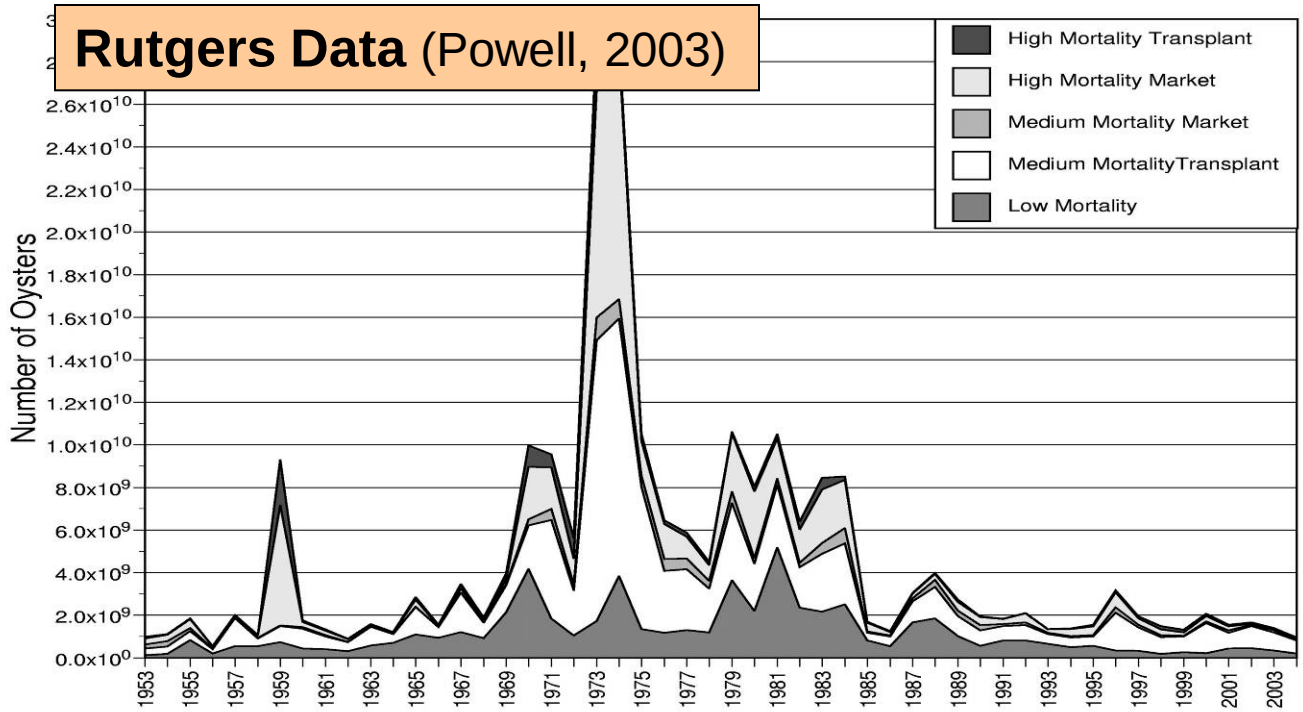
= 59.0 Billion Liters per Hour

Oysters


Crassostrea virginica




Landings Data
Millions of Pounds
0
5
10
15
20
25
30
35
1860
1880
1900
1920
1940
1960
1980
2000


Rutgers Data (Powell, 2003)
High Mortality Transplant
High Mortality Market
Medium Mortality Market
Medium MortalityTransplant
Low Mortality
Number of Oysters
0.0x10^0
2.0x10^9
4.0x10^9
6.0x10^9
8.0x10^9
1.0x10^10
1.2x10^10
1.4x10^10
1.6x10^10
1.8x10^10
2.0x10^10
2.2x10^10
2.4x10^10
2.6x10^10
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

Oysters on Seed Bed Reefs

2.0 Billion *Crassostrea* *(Powell, 2003 data)*
Mean size = 0.87 g dry tissue weight *(DK data)*
Clearance Rate = 6.5 L h-1 g-1*(Newell et al 2005)*
= 11.2 Billion Liters per Hour

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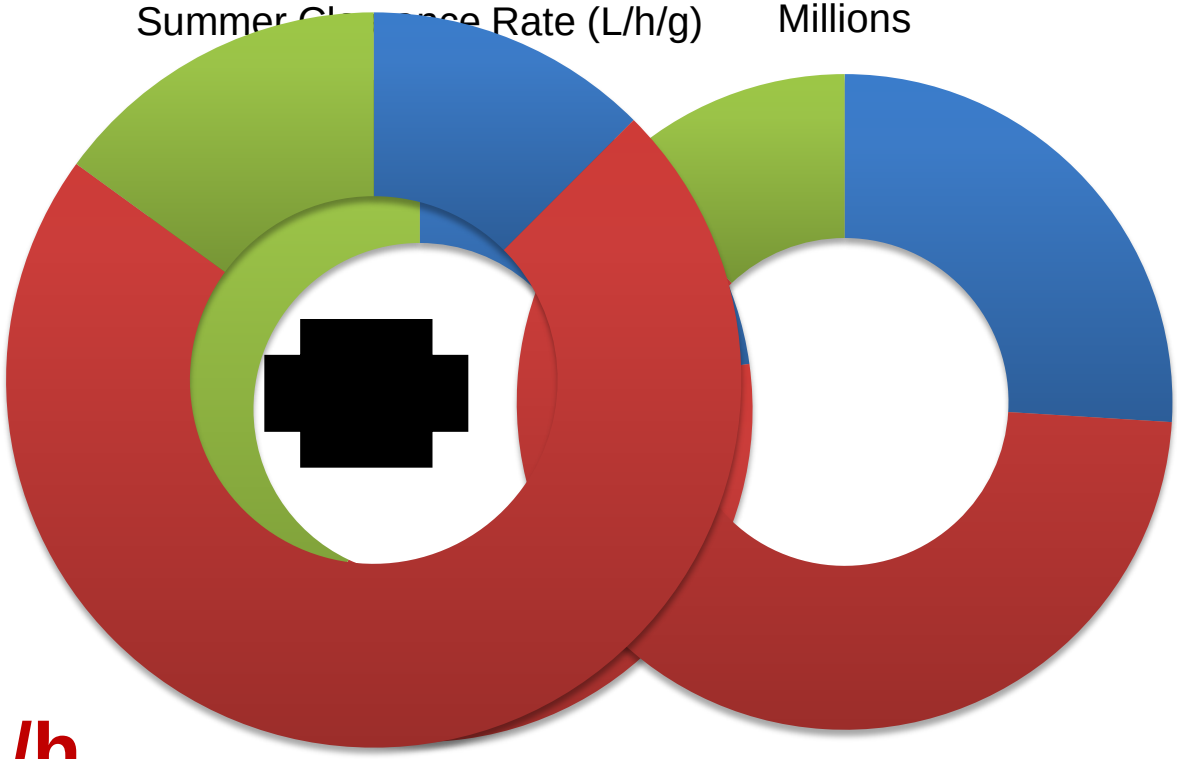
Kreeger

Population-level Water Processing

Water Processing per Unit Biomass

Population Abundance



= 80 Billion L/h

Freshwater Mussel

Marsh Mussel

Oyster

Bio-filtration

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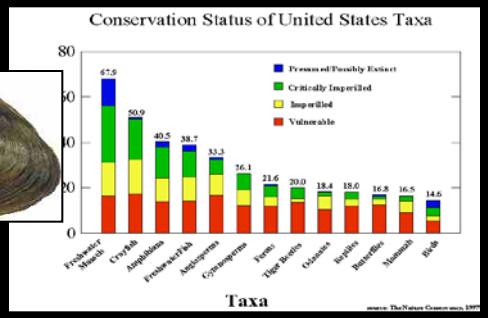
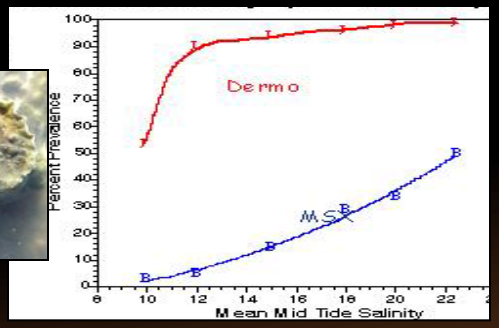
Considerations

- Total filtration capacity for one fw mussel species (~10 billion L/hr) is >250X freshwater inflow from the Delaware River and other tributaries (not total volume)
- Total filtration capacity of oysters and ribbed mussels in Delaware Bay (~70 billion L/hr) is ~8% of tidal volume per day (100% in 11.5 days)
- Water processing potential is estimated based on current abundances
- We need to estimate carrying capacity for current future bivalves and not just look at the past

Climate Impacts Vary by Species and Location



Freshwater Mussels: imperiled, complicated live history, cannot tolerate salinity

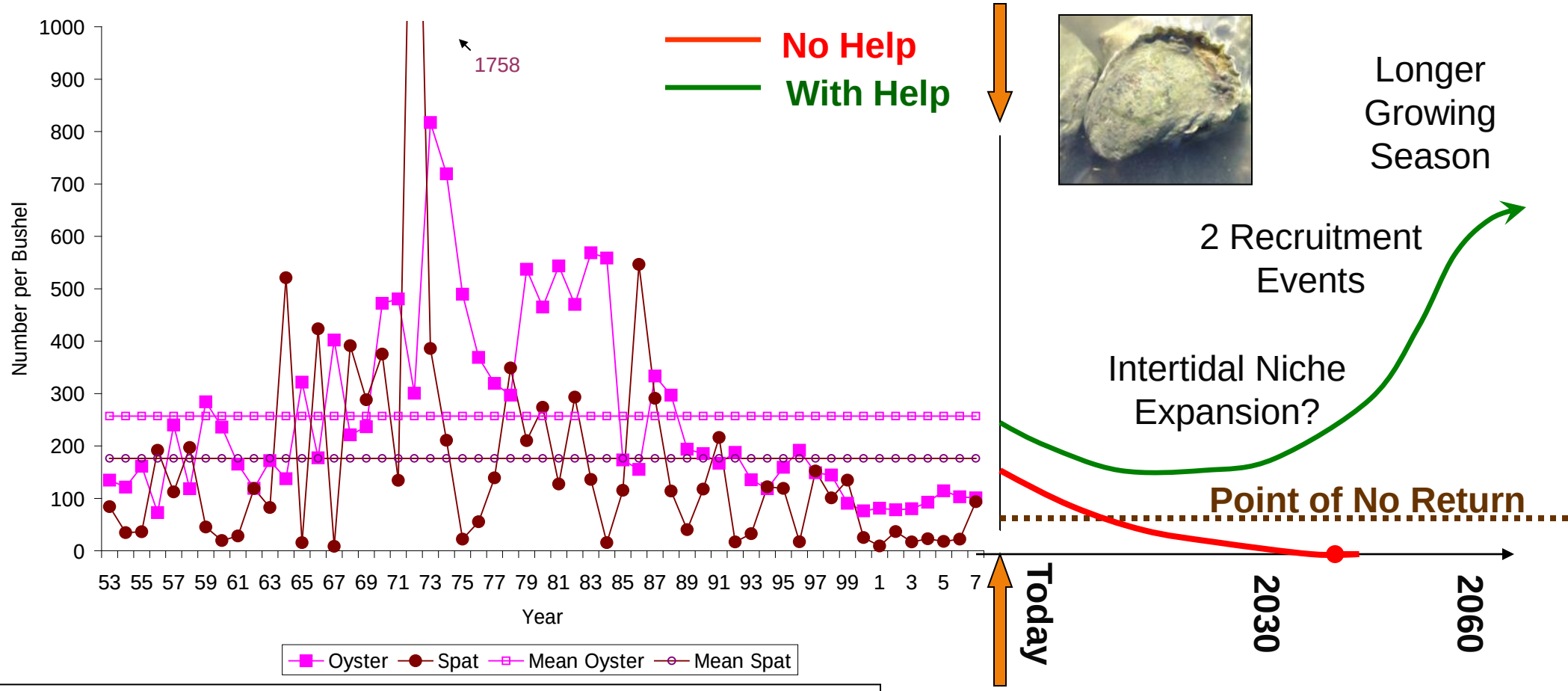


Oysters: disease and salinity

Ribbed Mussels: losing marsh habitat

Bivalve Projections – Oysters

Can they be maintained until they might see better conditions?



Historical data from Rutgers Haskin Shellfish Laboratory

Bivalve Projections – Ribbed Mussels

Losing Marsh Habitat

Bivalve Projections – FW Mussels

Shifting Species Ranges, But No Dispersal

Patchy, Impaired

Elliptio complanata

Rare

Strophitus undulatus

Extirpated

Alasmidonta heterodon

		State Conservation Status		
Scientific Name	**Scientific Name**	**DE**	**NJ**	**PA**
ALASMIDONTA HETERODON	DWARF WEDGEMUSSEL	Endangered	Endangered	Critically Imperiled
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LIGUMIA NASUTA	EASTERN PONDMUSSEL	Endangered	Threatened	Critically Imperiled
MARGARITIFERA MARGARITIFERA	EASTERN PEARLSHELL	no data	no data	Imperiled
PYGANODON CATARACTA	EASTERN FLOATER	no data	no data	Vulnerable
STROPHITUS UNDULATUS	SQUAWFOOT	Extremely Rare	Species of Concern	Apparently Secure

Options for Making Shellfish More Resilient

Water Quality &
Flow Management

What Actions Are Recommended for Shellfish?

	Combined Scores - Impact +Conf		
	FWM	FWT	SW
Monitor/Research Vulnerability Impacts	Highest	Highest	Med-High
Hatchery Propagation and Restocking of Populations	Med	Med-High	Med-Low
Transplants of Broodstock to Expand Ranges	Med	Med	Med-High
Metapopulation Expansion for Common Species	Med	Med-Low	
Restoration of Extirpated Rare Species	Low	Low	
Dam Removals to Assist Dispersal on Fish Hosts	Med-High		
Assisted Migration (of southern species) to Fill Open Niches	Low	Low	
In-streamand/or Riparian Habitat Enhancements	Highest	Med-High	
Water Quality Management	Med	Med-High	
Water Quantity (Flow) Management	Med	Med	
Shellplanting on Seed Beds (Oysters)			Highest
Shellplanting or Living Shorelines Along Marshes/Tributaries			Med-High

1	Plant Shell for Oysters
2	Propagate all Bivalves and Seed New Reefs/Beds
3	Restore Riparian Buffers for Freshwater Mussels
4	Manage Water Flow to Minimize Effects of Flooding on Freshwater Mussels and Salinity on Oysters and Freshwater Tidal Bivalves
5	Maintain Water Quality for all Bivalves

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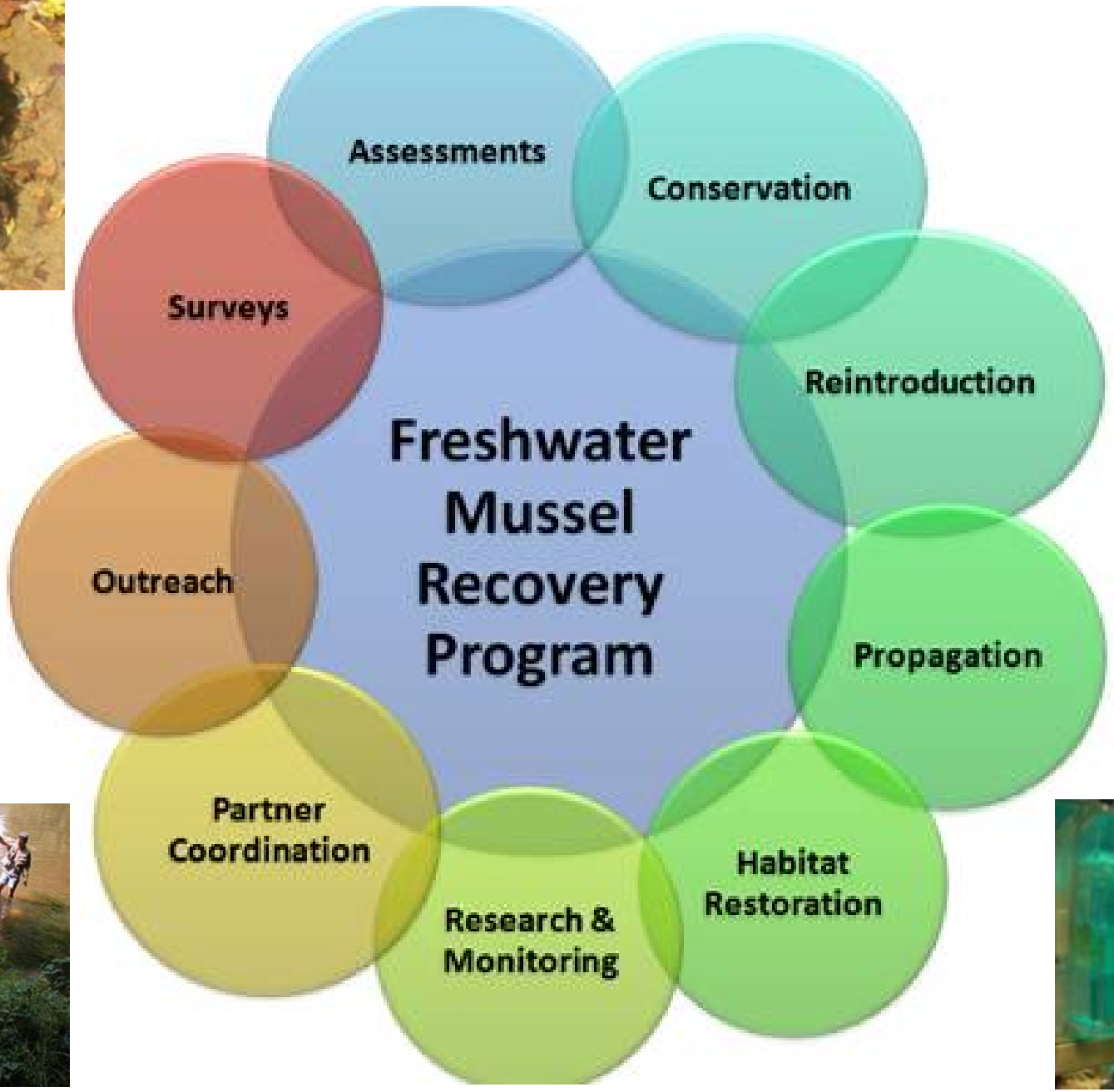

http://www.delawareestuary.org/science_projects_mussel_restoration.asp

Surveys

- Determine current mussel population status
- Identify sources for restoration
- Areas with Mussels: Prioritize for Conservation
- Areas without Mussels: Prioritize for Restoration

Main Line Health

Health & Science

SECTION D

MONDAY, JANUARY 17, 2011 B The Philadelphia Inquirer WWW.PHILLY.COM

Surprising survivors

In an urban stretch of the Delaware River, a researcher found imperiled species of freshwater mussels, valuable as aquatic vacuum cleaners.

DAVID M WARREN / Staff Photographer

Tidewater mucket shells — a species of mussels — found along the Delaware River in 1893, displayed at the Academy of Natural Sciences.

By Sandy Bauers
INQUIRER STAFF WRITER

If not for the heat of a summer day, one of the major biological finds in the Delaware River in recent years might not have occurred.

It was June, and researchers were scouring the banks and shallows of the river between Trenton and Philadelphia for evidence of freshwater mussels, important water-filtering organisms that are becoming increasingly hard to find in the region's streams.

Danielle Kreeger, science director of the nonprofit Partnership for the Delaware Estuary, had spotted shells along the banks during a wetlands project, and she wanted to see if live mussels were in the river nearby.

So far, no luck.

But Kreeger, who was out on the river in a boat, got hot. Putting on her mask and snorkel, she slipped into the river and swam through the murky water toward the bottom.

Suddenly, she saw them. The riverbed was studded with mussels. They weren't the edible kind, but it was better still — a seven-species mother lode including two species thought to be locally extinct. One, the tidewater mucket, hasn't been seen in this area for more than half a century. The discovery bodes well for the mussels and the river itself.

"I stayed underwater for quite a while,

See MUSSELS on D2

Partnership for the Delaware Estuary.

Researcher Danielle Kreeger unexpectedly found seven species of mussels — two thought to be locally extinct — in the river.

The newfound mussel species include (from left) creeper; yellow lampmussel; and elliptio.

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Stream Suitability Tests

- Ensure recipient streams can support mussels
- Monitor fitness of caged mussels
- Compare candidate restoration streams
- Strategic restoration

Reintroduction

- Restock mussels in former range
- Reproductive adults
- Juvenile “seed”
- Track performance with electronic tags
- Inexpensive

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Propagation

- Fastest and clearest way to boost stocks
- Technical challenges largely resolved
- Difficult to fund, more expensive

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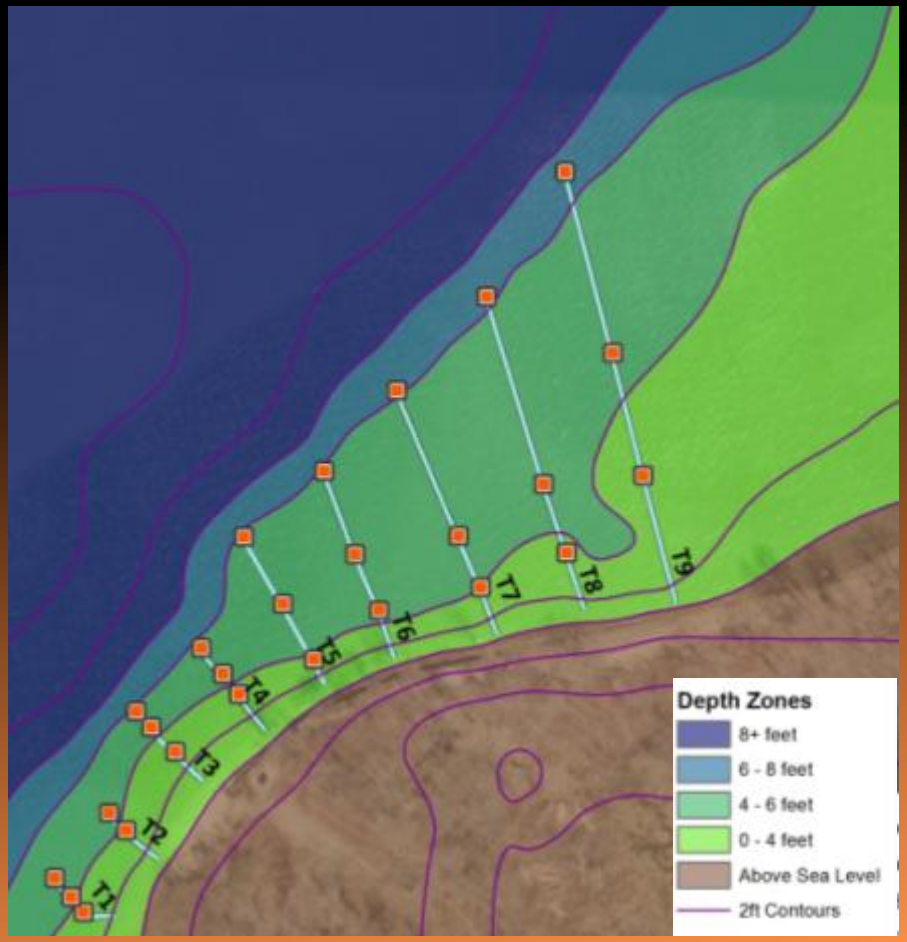
Tidal Delaware River - Quantitative Surveys

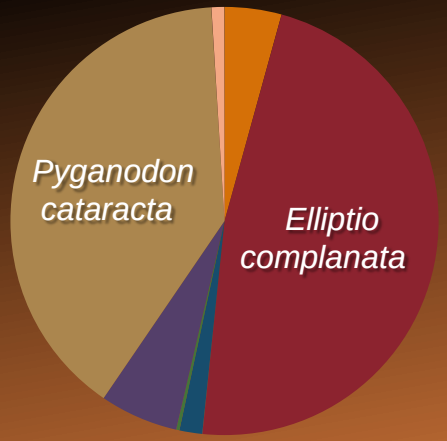
Make case for restoration via ecosystem services

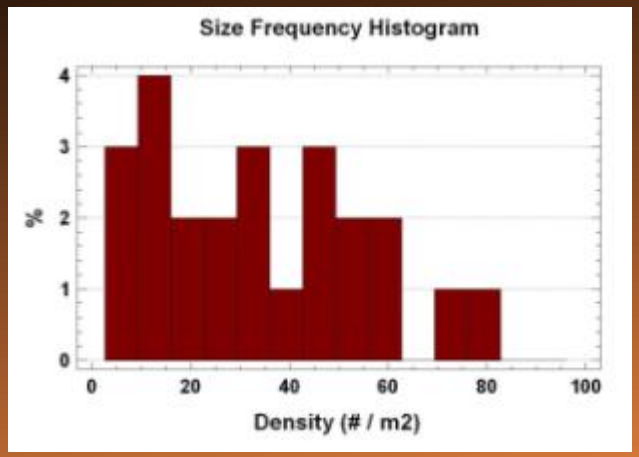
Identify habitat needs to guide restoration designs

Site 2

- Six species
- Richness = 3.4 species m^{-2}
- Density:
  range = 0 – 80 mussels m^{-2}
  mean = 30.1 mussels m^{-2}
- Co-dominants
  Pyganodon cataracta and *Elliptio complanata*

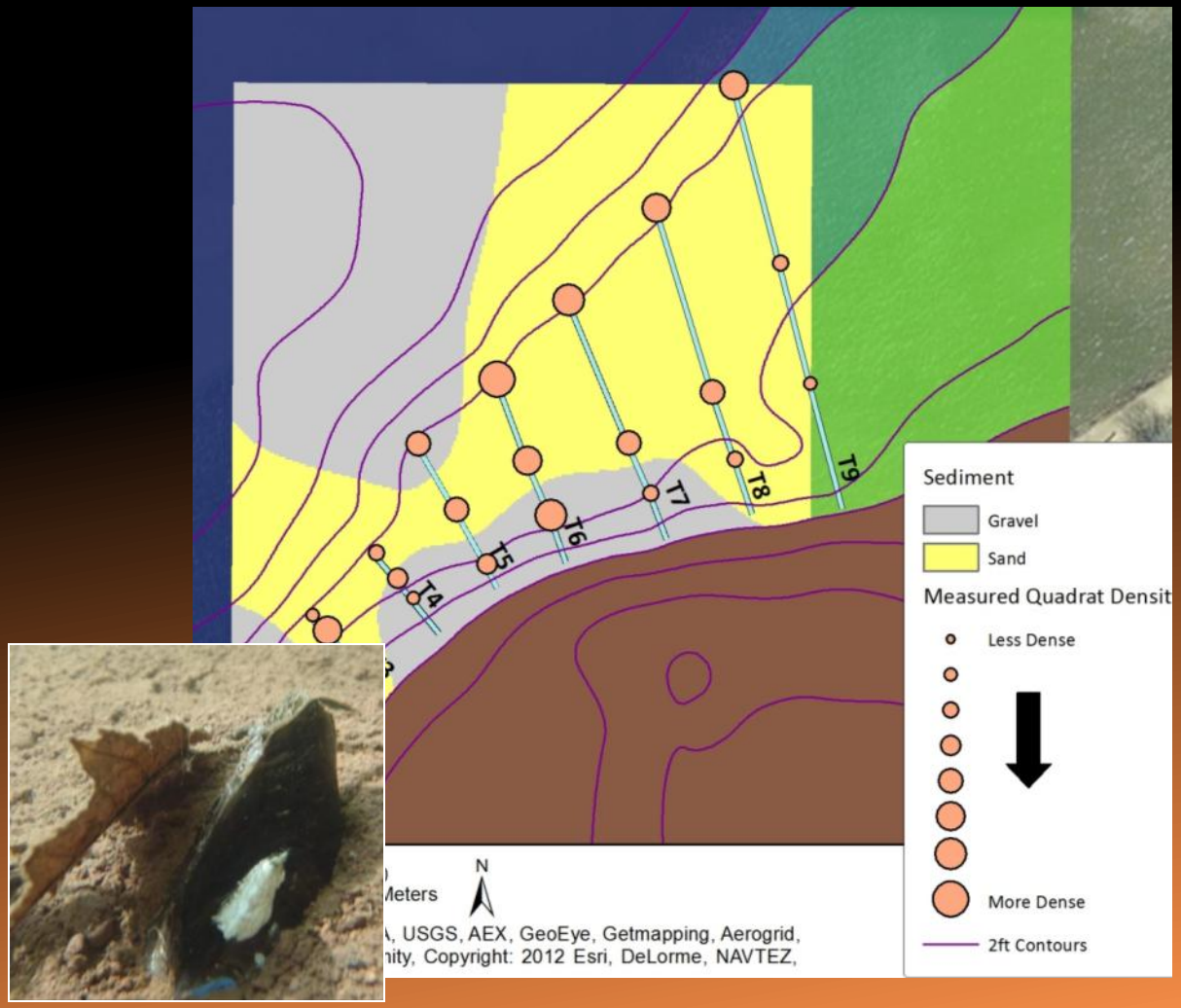






Planned: Mussel Habitat Engineering

- Substrate Needs ID'd
- Incorporate mussel habitat into freshwater tidal living shorelines ?
- Promotes bed stability plus water quality



Physiologically-Based Water Filtration Estimate

Location	Area (m^2)	Number	Tissue Weight (g)	Clearance Rate (L hr^{-1} g DTW^{-1})	Clearance Rate (gal day^{-1} g DTW^{-1})	Bed Clearance (gal day^{-1})	TSS Filtration (metric tons DW day^{-1})
Site 1	4,230	23,163	74,210	0.875	5.55	411,867	0.54
Site 2	9,504	287,230	726,001			4,029,306	5.32
Site 3	13,983	256,560	241,151			1,338,387	1.77
Site 4	10,658	115,458	104,226			578,456	0.76
Total	**38,375**	**682,412**	**1,145,589**			**6,358,016**	**8.40**

>6 million gallons per day

Observations

- Potential filtration of 6.3 mgd for these 4 beds is:
  - 2.5% of freshwater inflow from the Delaware River
  - 1.6% of drinking water withdrawals for Philadelphia
- More beds exist, especially in New Jersey
- More mussels live deeper
- Sites with low bed stability had few or no mussels; therefore:,

Habitat restoration to increase benthic carrying capacity for mussels could yield measureable water quality benefits (returns on investment)

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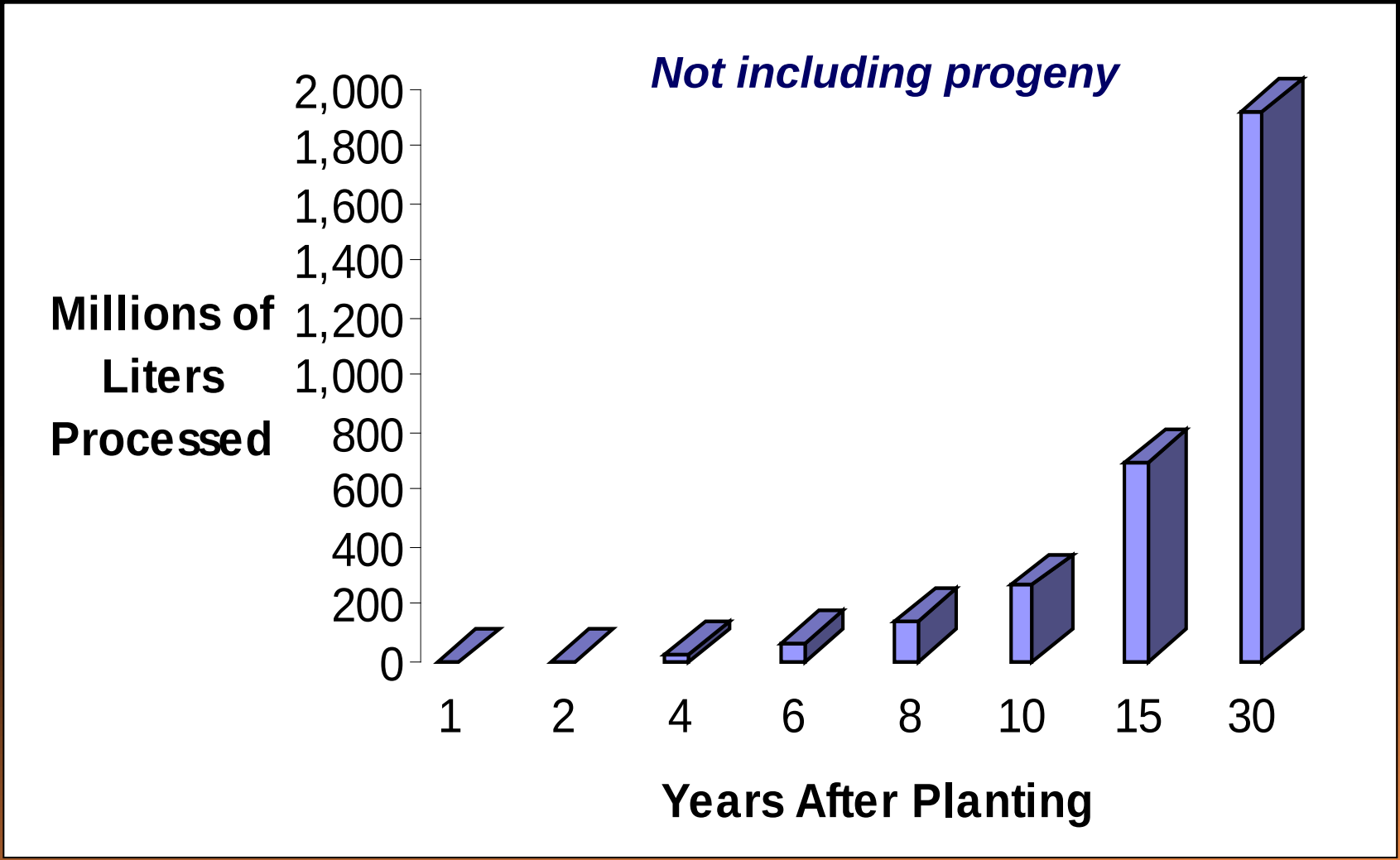
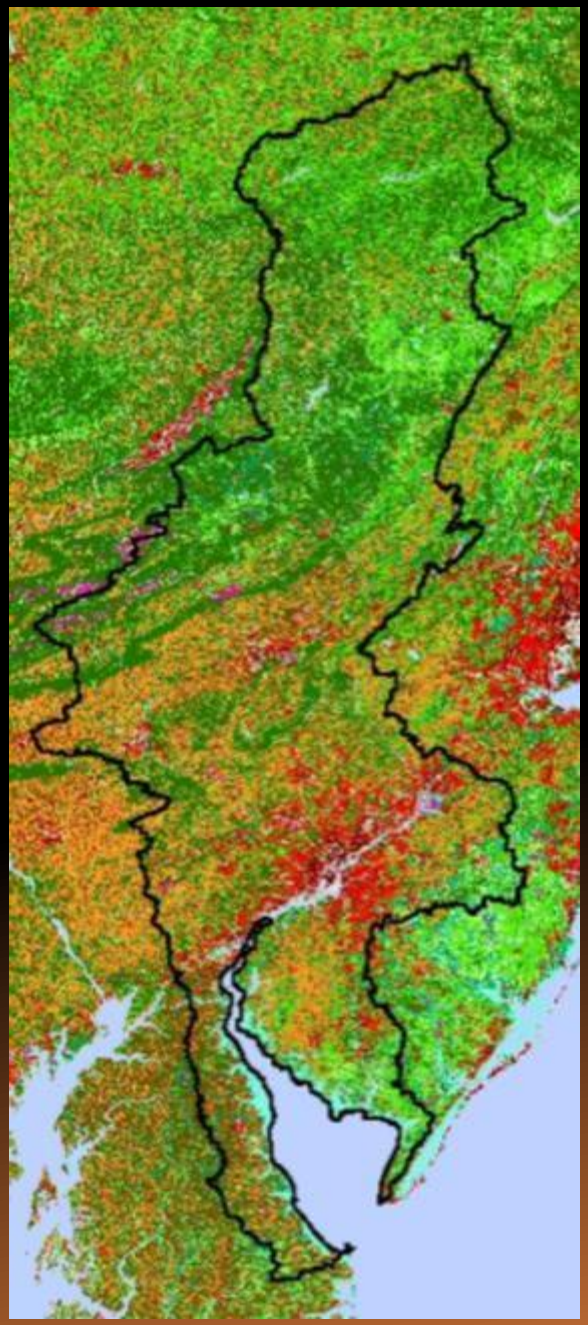
Freshwater Mussel Recovery Program

Goals Based on Ecosystem Services





Desired Watershed Condition:

A diverse and robust assemblage of native bivalves living in abundance in all available tidal and non-tidal ecological niches and providing maximum possible natural benefits.

Kreeger





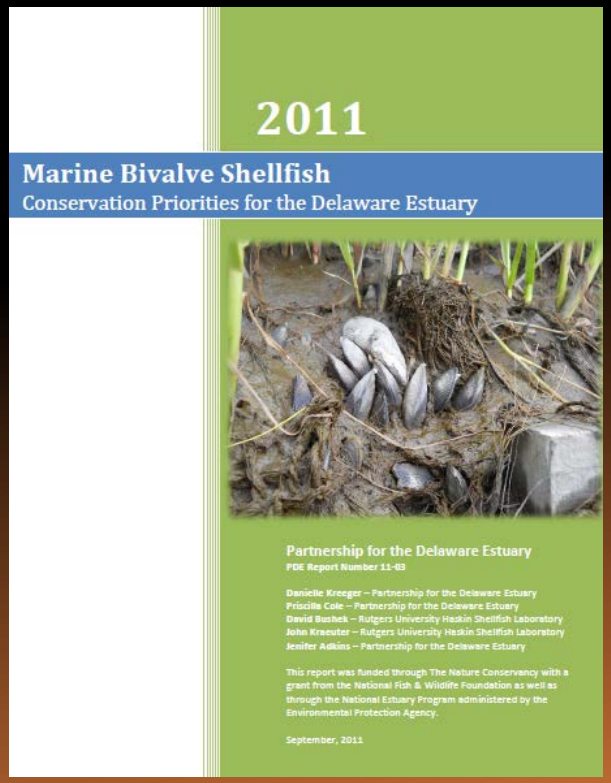


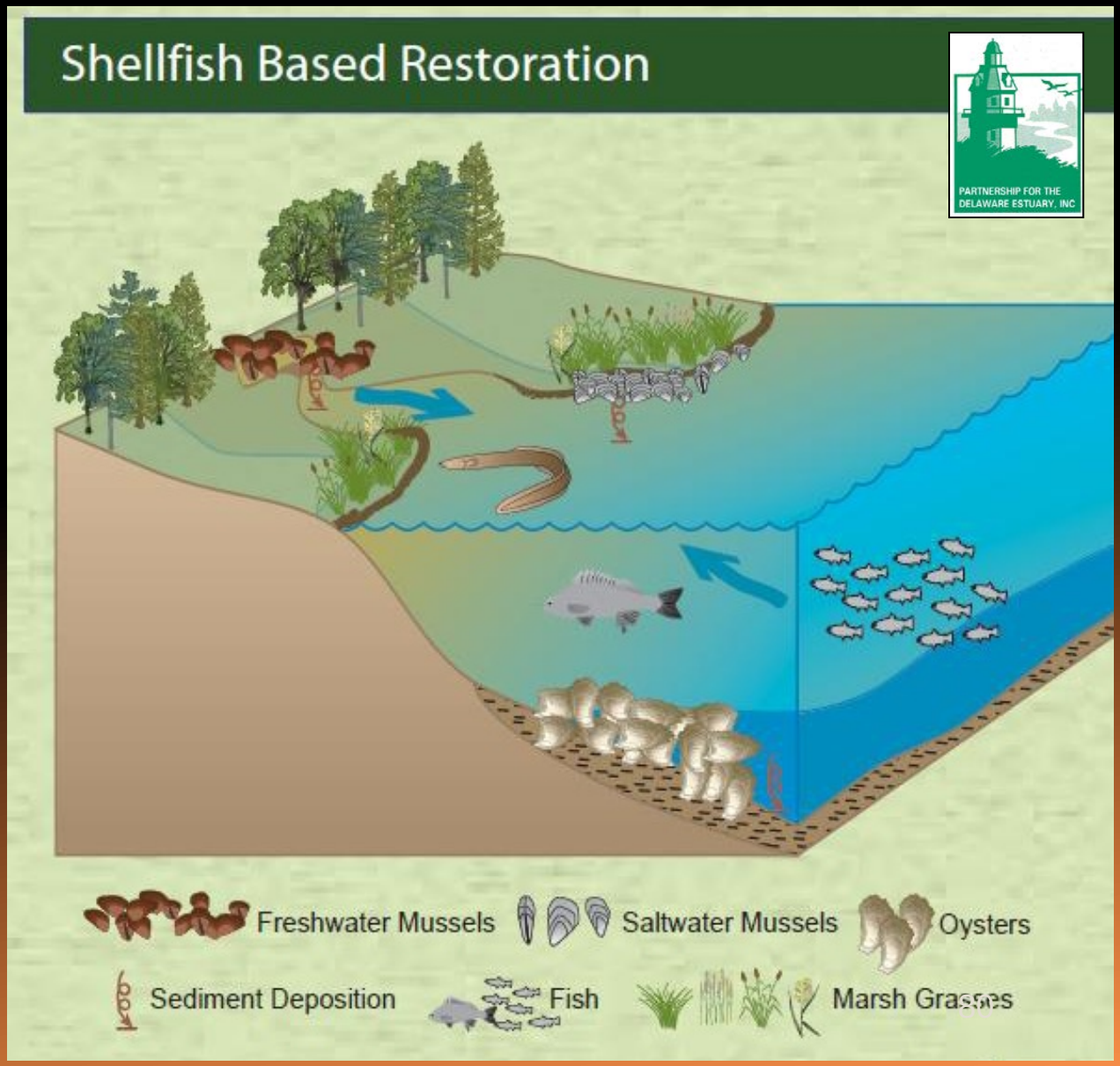


Restoration for the Future = Climate Adaptation

Headwaters to Sea

1. Non-tidal
2. Intertidal
3. Subtidal

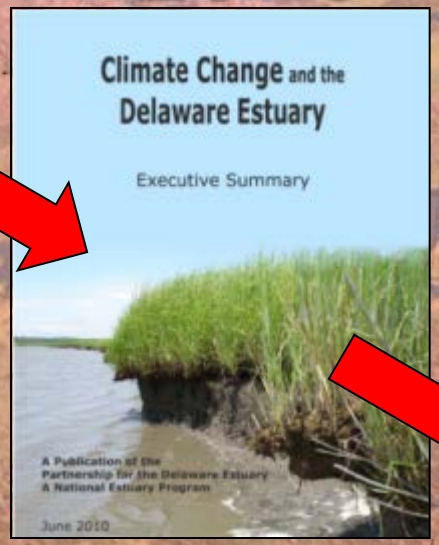




2007

Recognize Problem

2010



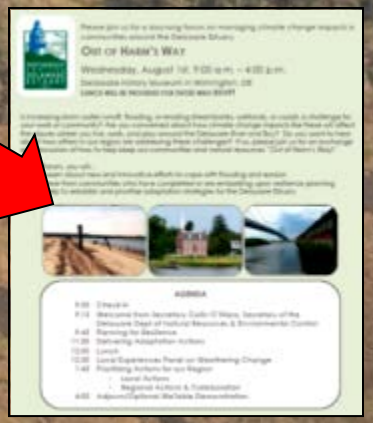
Assess Vulnerability & Prioritize Solutions

2011

Translate & Engage

2012

Track Change



Action Plans

2013

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Climate Change + Other Changes

- Marcellus Shale
- Dredging
- Withdrawals
- Land Use Change
- Development
- Emerging Pollutants
- Ecological Flows
- Spills

Added Complexity

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11/27/2004

Take Home Messages

- Not all changes to natural resources will be damaging, but there will be many ***more losers than winners***
- ***Need a Paradigm Shift***: Plan and "restore" for the future rather than the past, dynamic rather than static conditions
- Adaptation requires ***investment*** to protect lives, livelihoods
- Proactive investment today will ***save money*** in the long term due to compounding of ecosystem services
- Adaptation actions are underway but constrained by funding

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Investment in Delaware Valley Lags

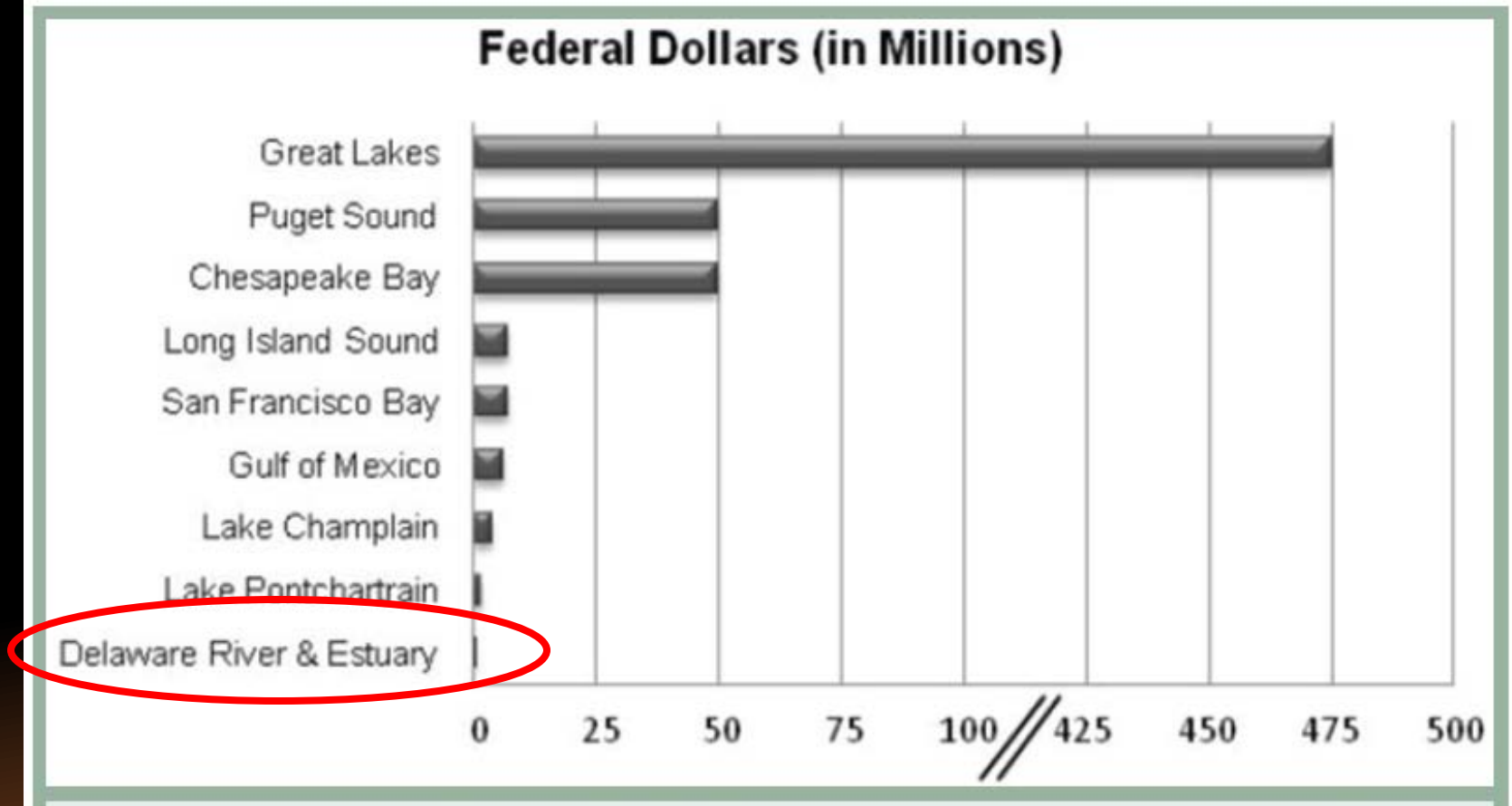

Fig. 8.8. Comparison of US EPA federal spending in FY2010 on environmental management and restoration in nine major water bodies in the United States (from Strackbein and Dawson 2011)

Despite Tough Times,…

<u>High Potential</u> for Beneficial Outcomes from Natural Infrastructure Investment

http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp

CLIMATE READY ESTUARIES

EPA

Delaware Estuary Pilot

www.DelawareEstuary.org