Enhancing and Harnessing Nature for Climate Resilience in the Delaware Estuary

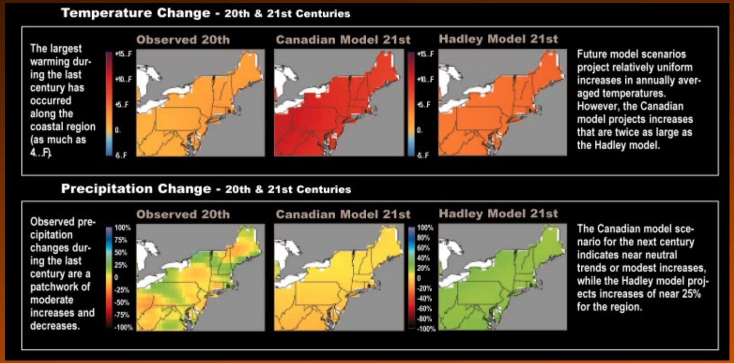
Danielle Kreeger

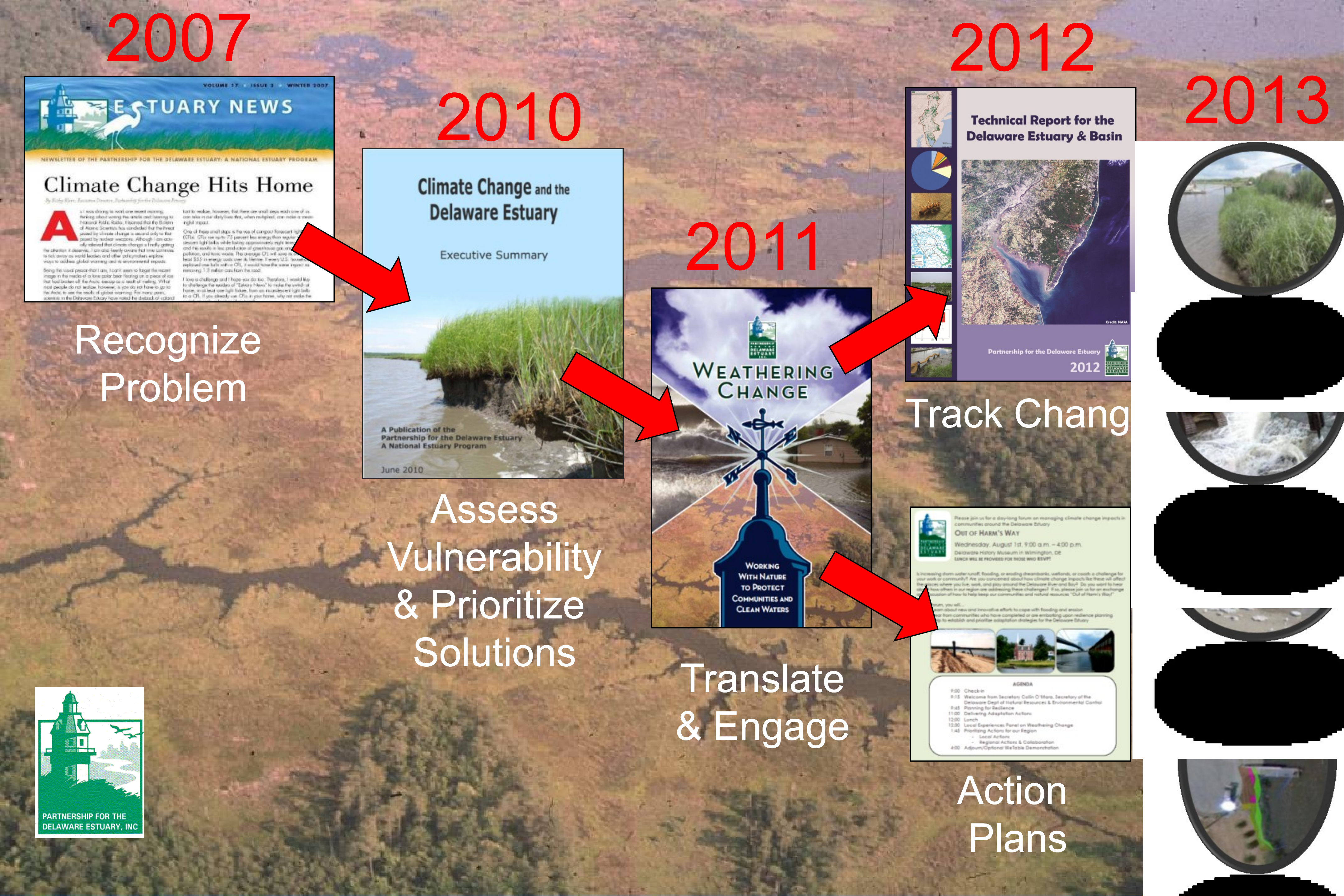
Partnership for the Delaware Estuary

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Presentation to 4CP Chester County Citizens for Climate Protection – West Chester, PA

September 5 2012




2007
ESTUARY NEWS
VOLUME 17 · ISSUE 3 · WINTER 2007
NEWSLETTER OF THE PARTNERSHIP FOR THE DELAWARE ESTUARY: A NATIONAL ESTUARY PROGRAM
Climate Change Hits Home
Recognize Problem
2010
Climate Change and the Delaware Estuary
Executive Summary
A Publication of the Partnership for the Delaware Estuary
A National Estuary Program
June 2010
Assess Vulnerability & Prioritize Solutions
2011
Weathering Change
Working With Nature to Protect Communities and Clean Waters
Translate & Engage
2012
Technical Report for the Delaware Estuary & Basin
Partnership for the Delaware Estuary
2012
Track Chang
Out of Harm's Way
AGENDA
Action Plans
2013
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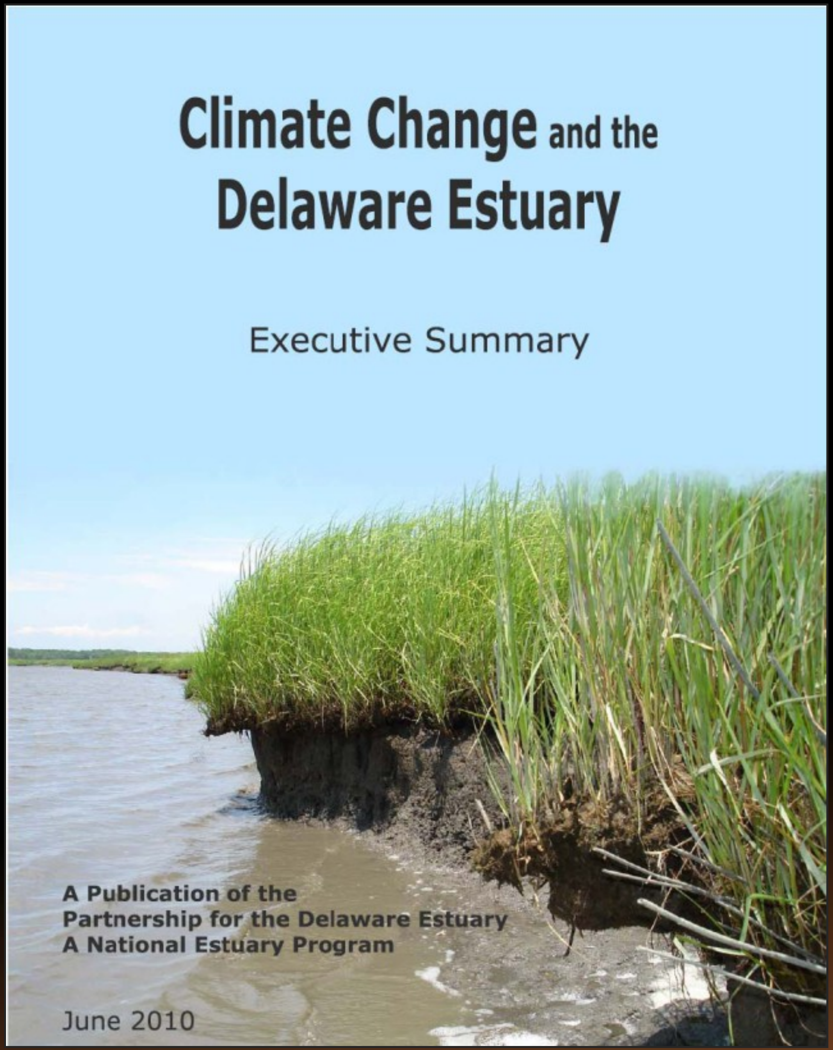
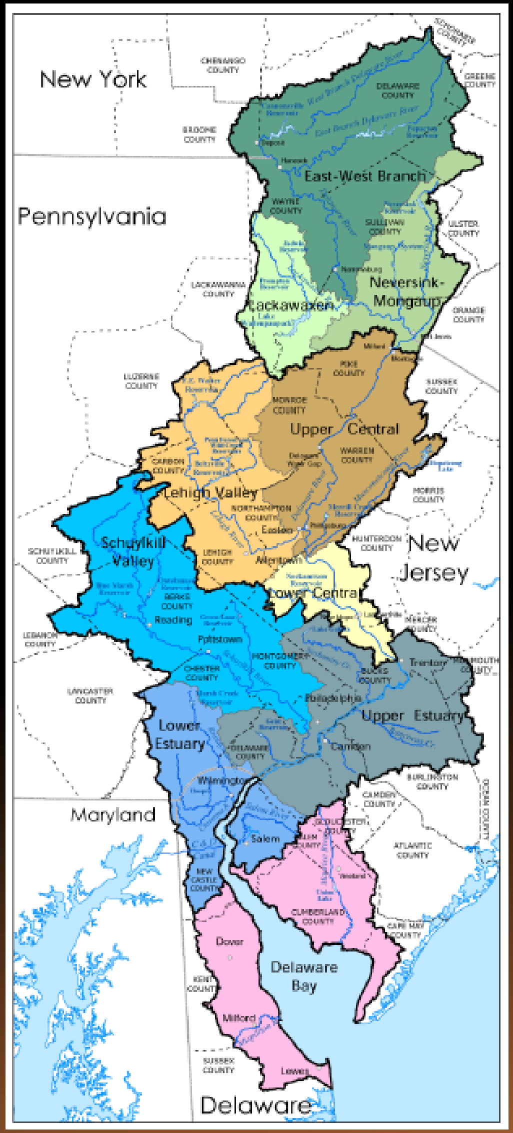
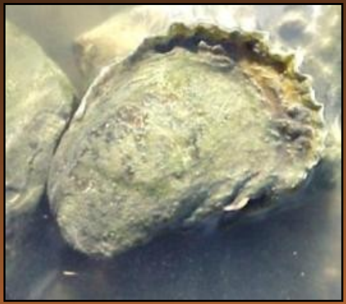




3 case studies



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CLIMATE READY ESTUARIES

EPA

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

Questions

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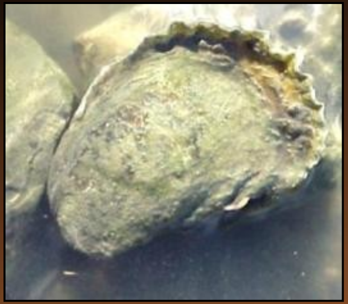


How will climate change here?

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)

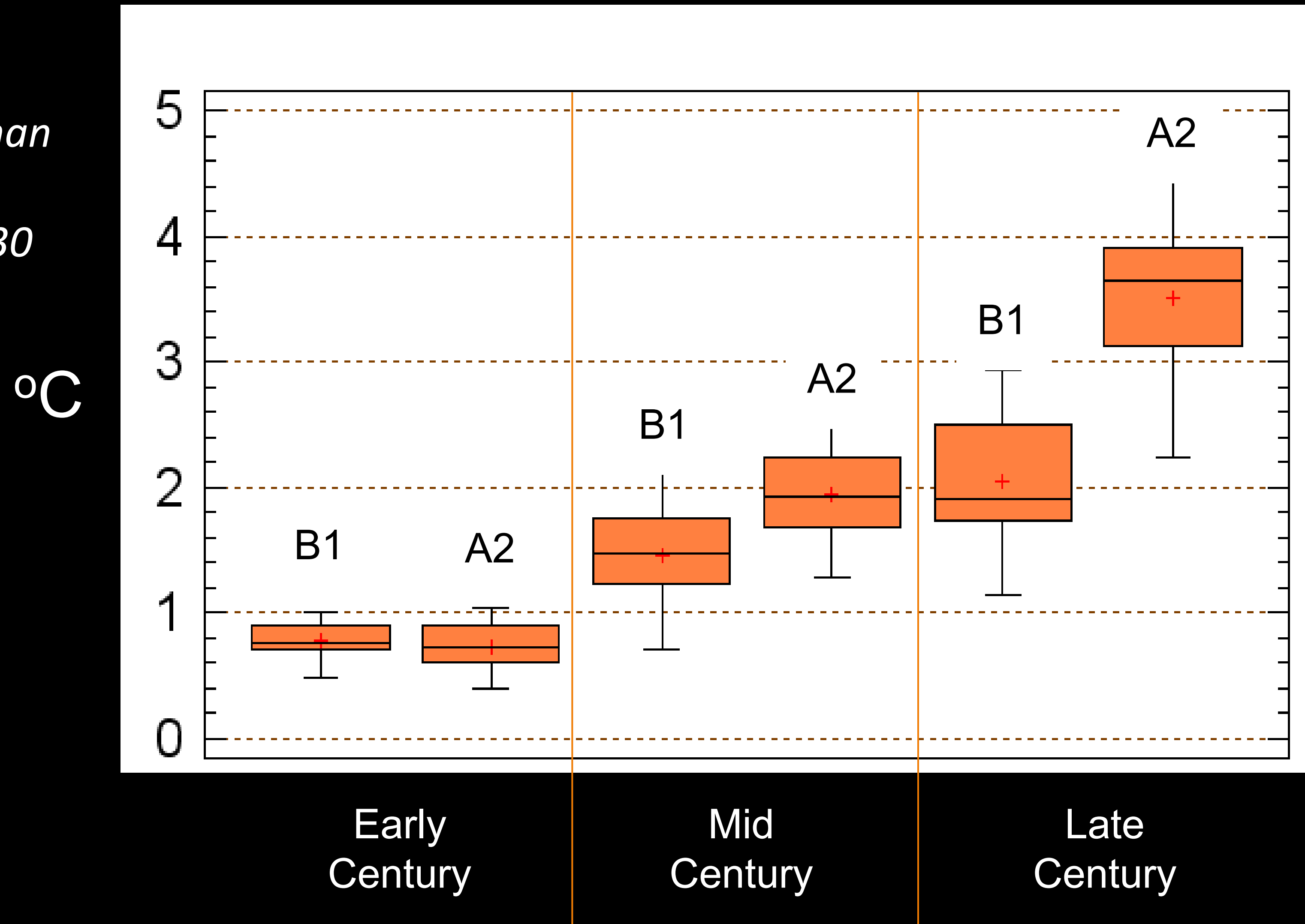
How Will Climate Change?

as per Dr. Ray Najjar

Temperatures

More in summer than in winter

Locked in for next 30 years



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How Will Climate Change?

as per Dr. Ray Najjar

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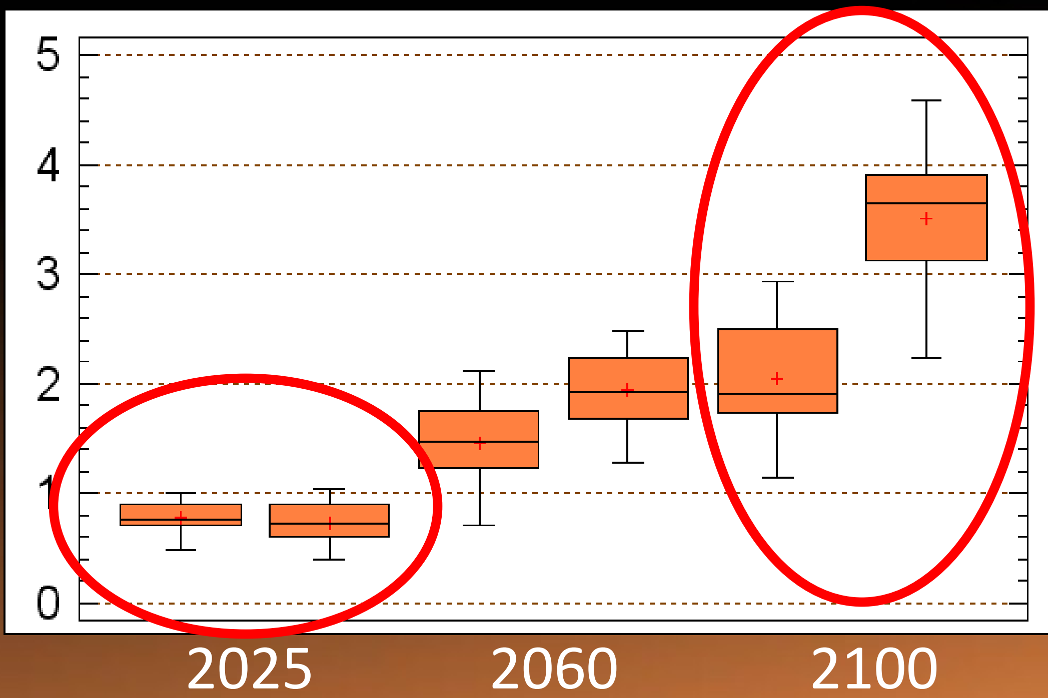

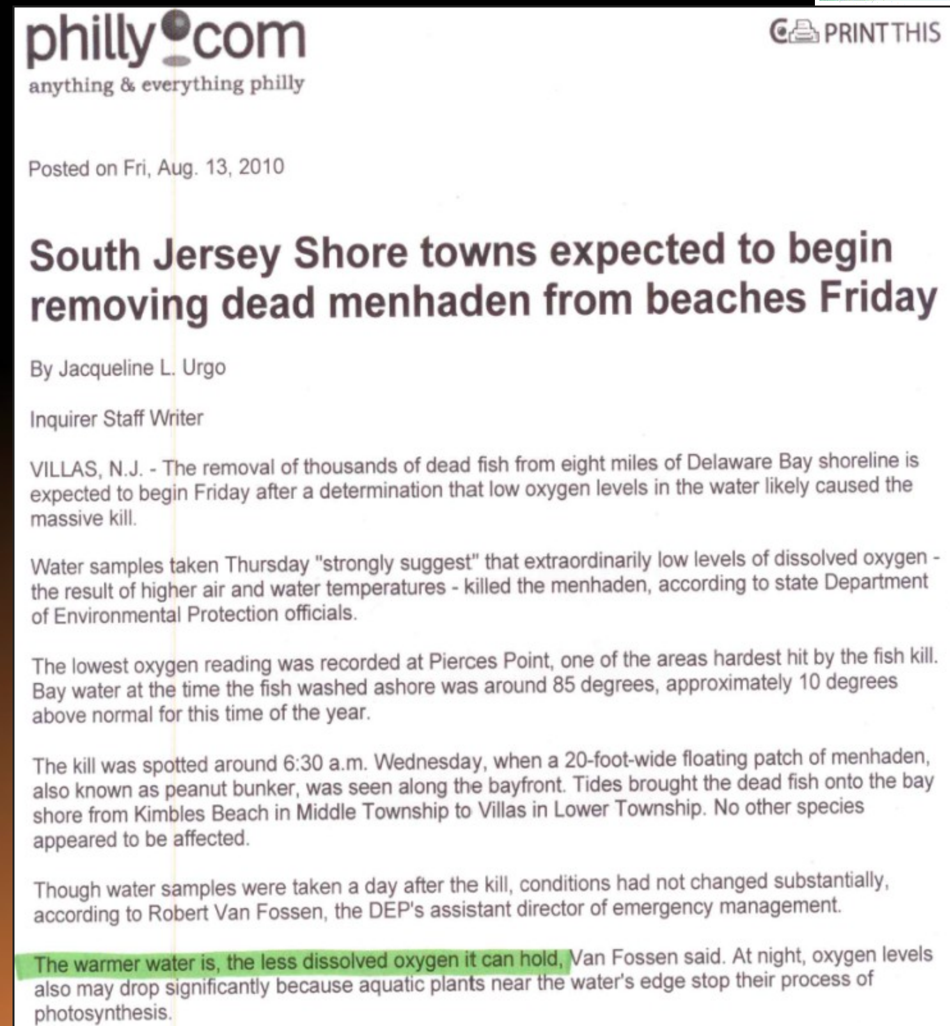

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PRINTTHIS

Posted on Fri, Aug. 13, 2010

South Jersey Shore towns expected to begin removing dead menhaden from beaches Friday

By Jacqueline L. Urgo

Inquirer Staff Writer

VILLAS, N.J. - The removal of thousands of dead fish from eight miles of Delaware Bay shoreline is expected to begin Friday after a determination that low oxygen levels in the water likely caused the massive kill.

Water samples taken Thursday "strongly suggest" that extraordinarily low levels of dissolved oxygen - the result of higher air and water temperatures - killed the menhaden, according to state Department of Environmental Protection officials.

The lowest oxygen reading was recorded at Pierces Point, one of the areas hardest hit by the fish kill. Bay water at the time the fish washed ashore was around 85 degrees, approximately 10 degrees above normal for this time of the year.

The kill was spotted around 6:30 a.m. Wednesday, when a 20-foot-wide floating patch of menhaden, also known as peanut bunker, was seen along the bayfront. Tides brought the dead fish onto the bay shore from Kimbles Beach in Middle Township to Villas in Lower Township. No other species appeared to be affected.

Though water samples were taken a day after the kill, conditions had not changed substantially, according to Robert Van Fossen, the DEP's assistant director of emergency management.

The warmer water is, the less dissolved oxygen it can hold, Van Fossen said. At night, oxygen levels also may drop significantly because aquatic plants near the water's edge stop their process of photosynthesis.

State of the Estuary 2012

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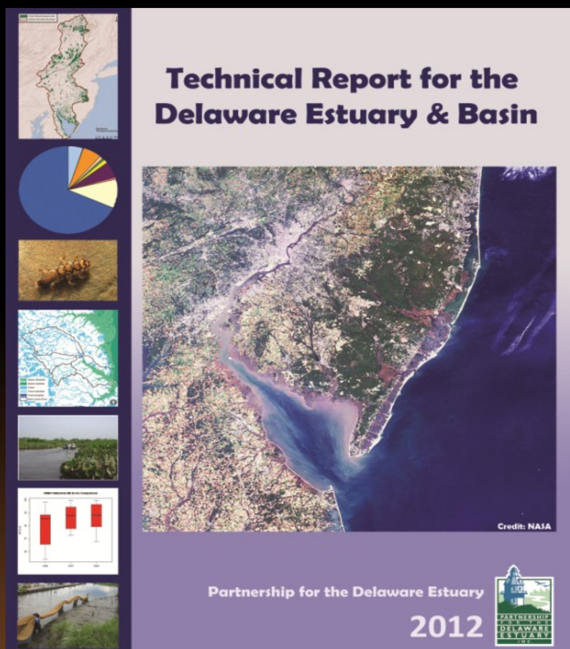
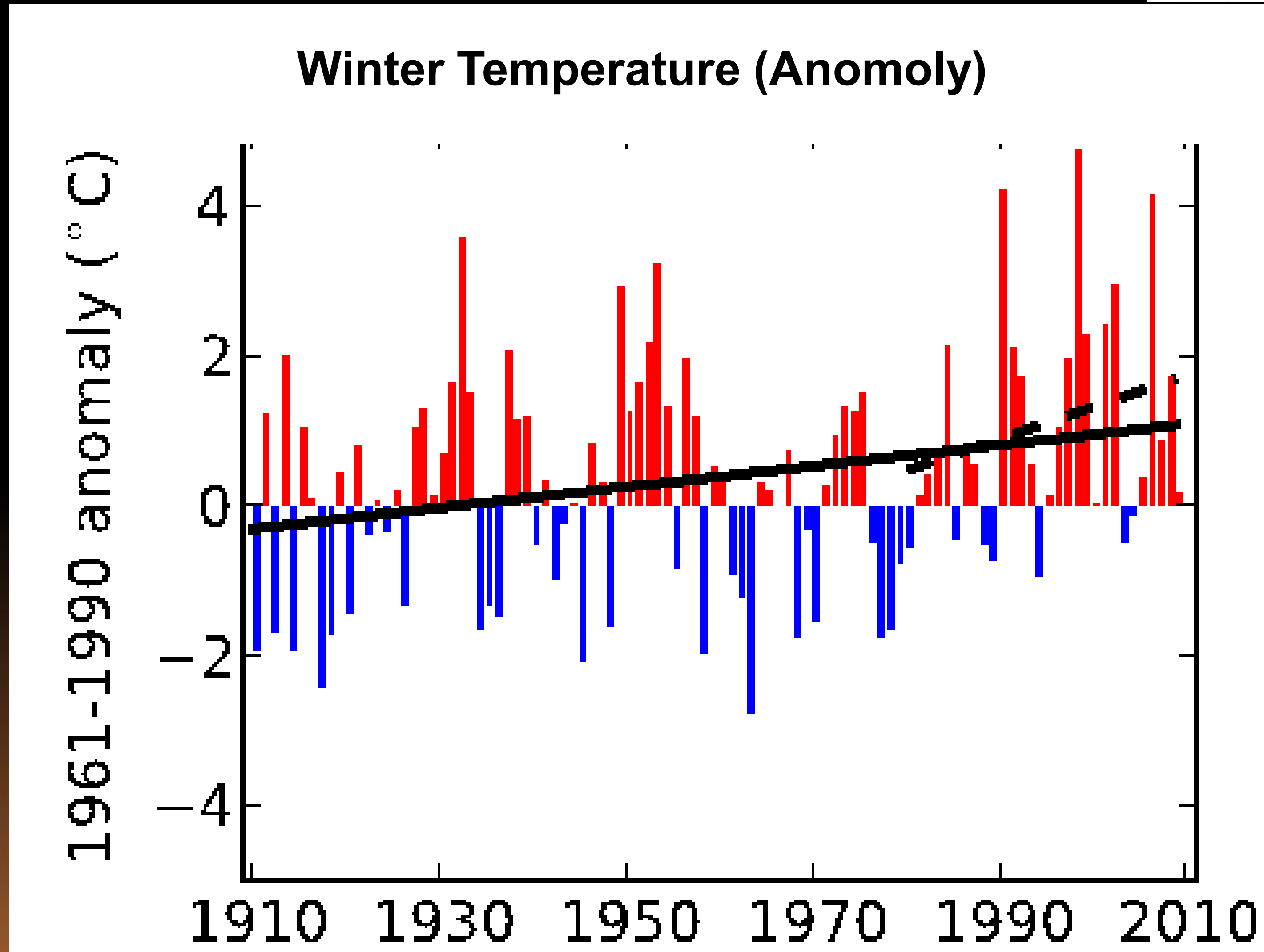
Temp. has warmed by 1°C in the past century, mainly in past 30 yrs.





http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp

Climate Momentum

<u>Mitigation</u> – critically important for the long-term (grandkids)

Difference between a rise of 2 versus 4 degrees centigrade translates into a difference between local versus mass extinction

<u>Adaptation</u> – critically important for the short-term (Kids)

No amount of mitigation will stem the 1 degree centigrade rise in temperatures expected over the next 25 years – we must adapt

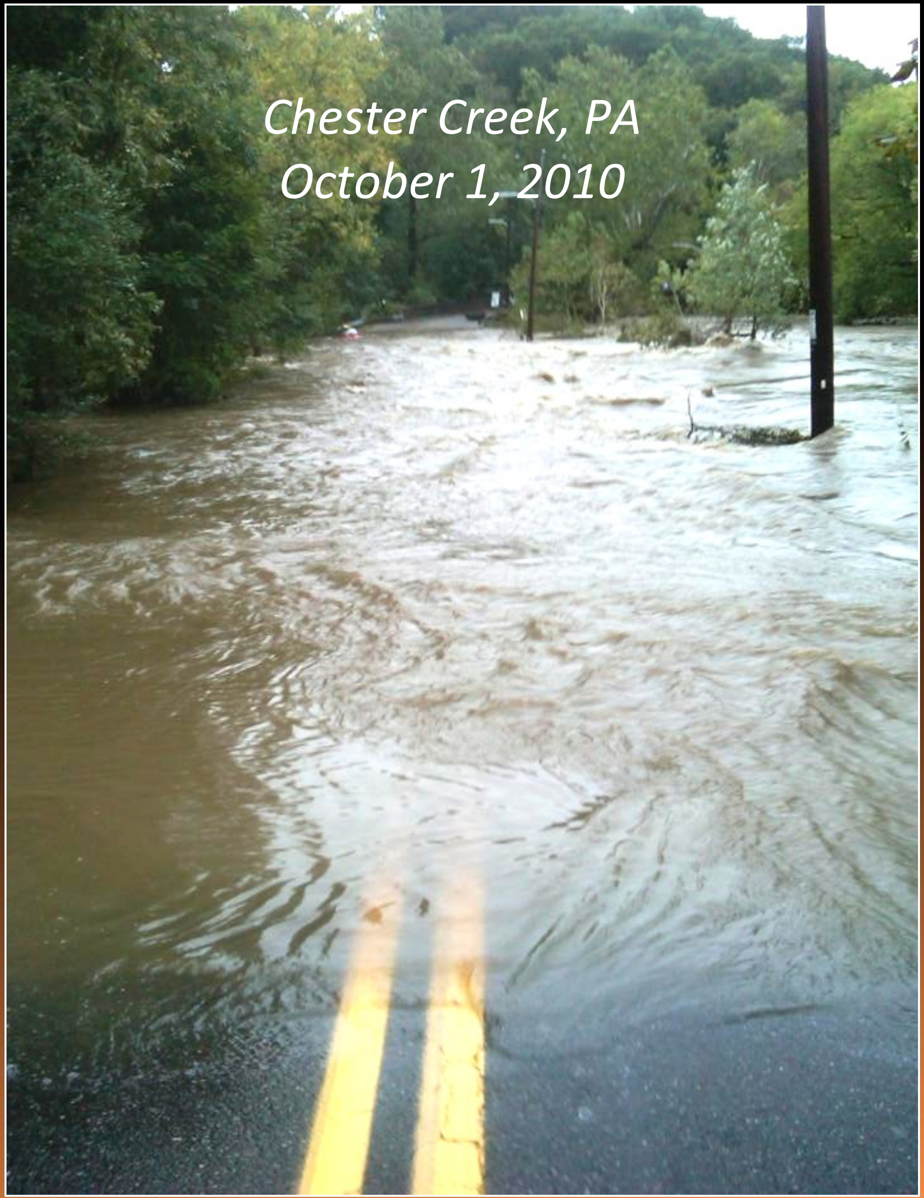
How Will Climate Change?

⬆ Temperatures

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

⬆ Precipitation

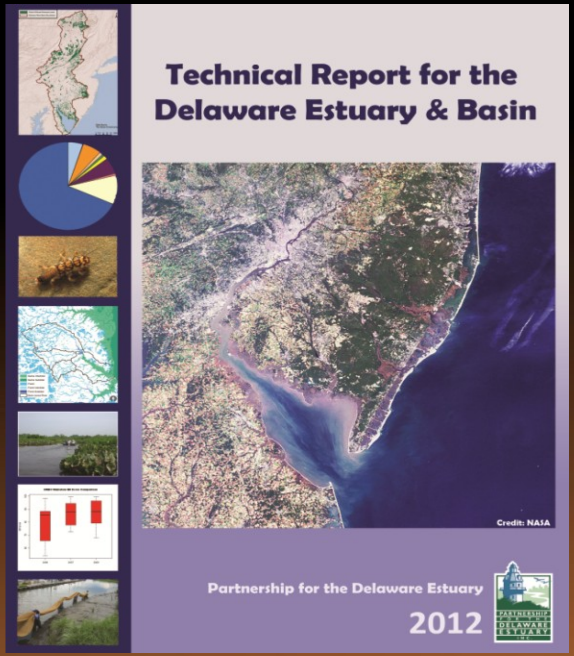
7-9 % increase
More in winter than in summer
More heavy events

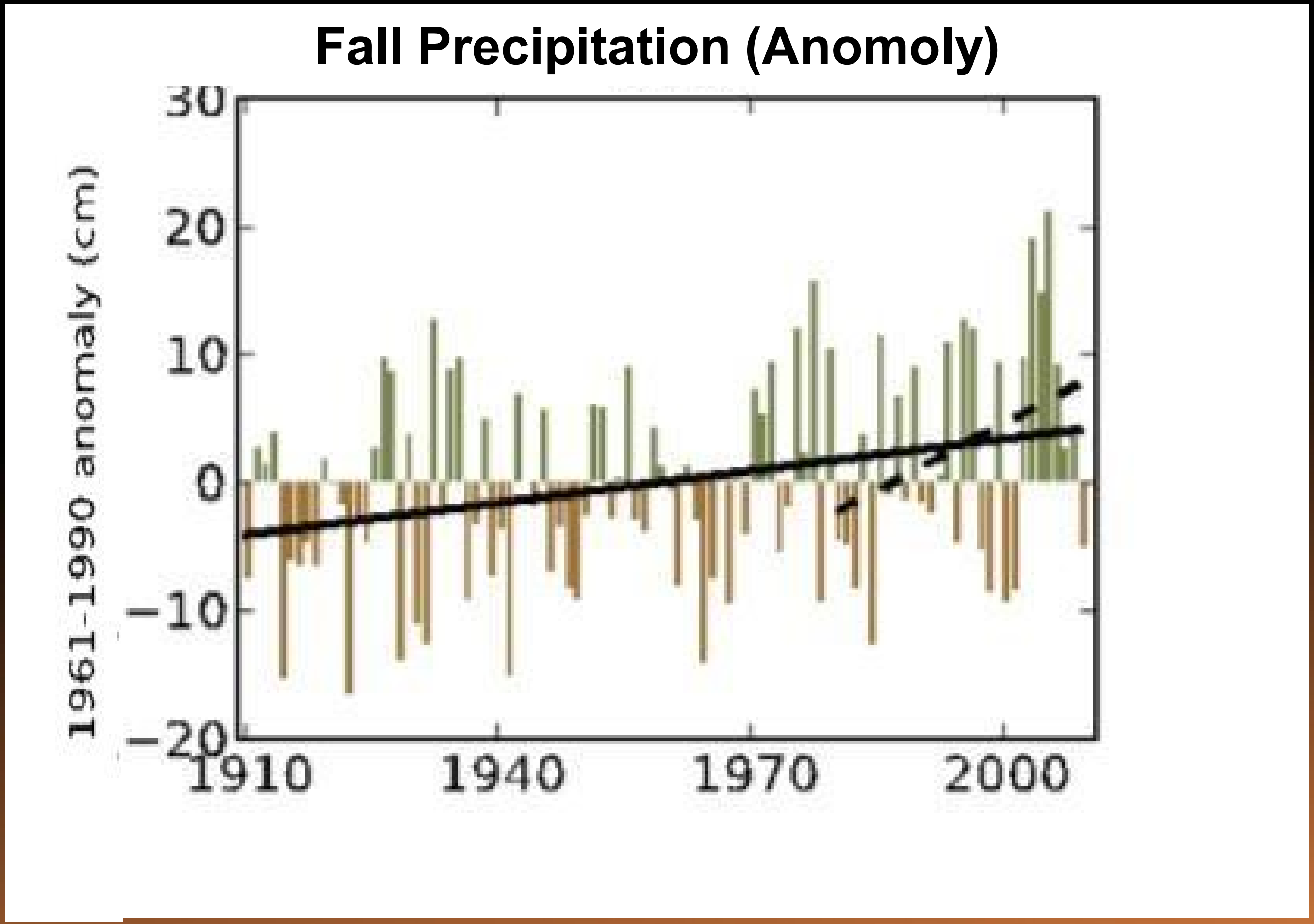


State of the Estuary 2012

Precip. has increased >10%

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





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How Will Climate Change?

↑ Temperatures

More in summer than in winter

Locked in for next 30 years

↑ Precipitation

More in winter than in summer

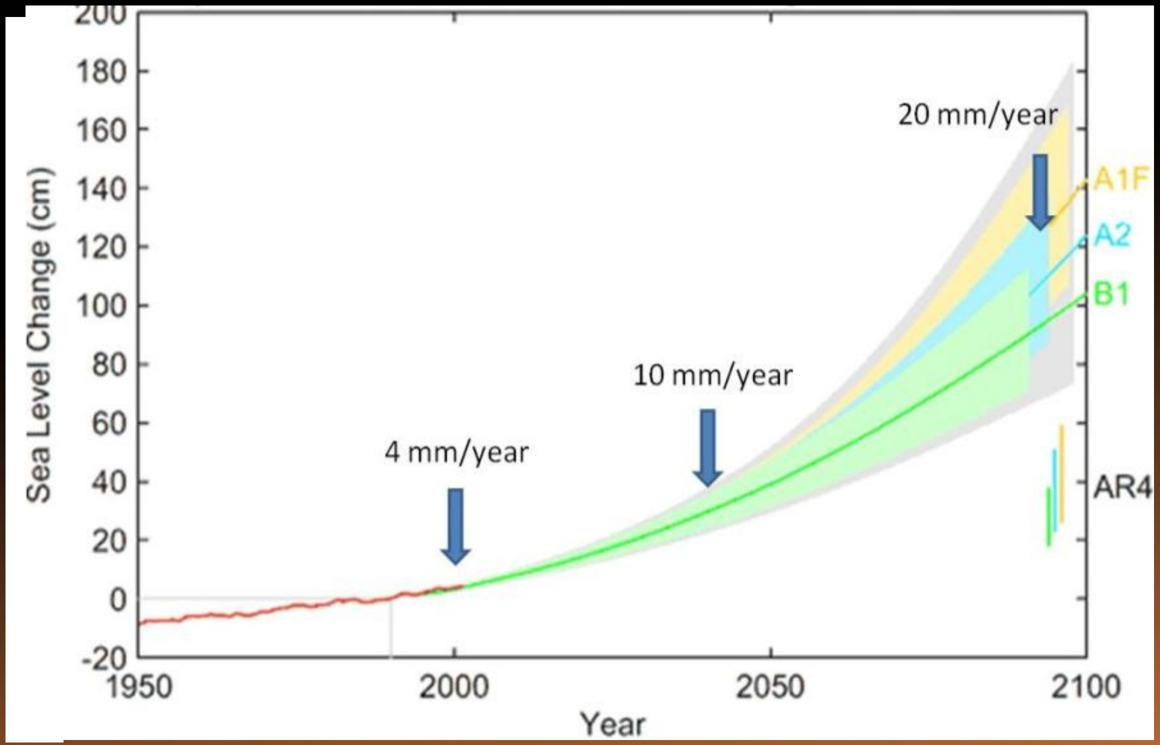
More heavy events

↑ Sea Level

0.6 - 1.5 m by 2100 (or more)

local rates >> global

↑ Salinity



How Will Climate Change?

Temperatures ↑

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

Precipitation ↑

More in winter than in summer
More heavy events

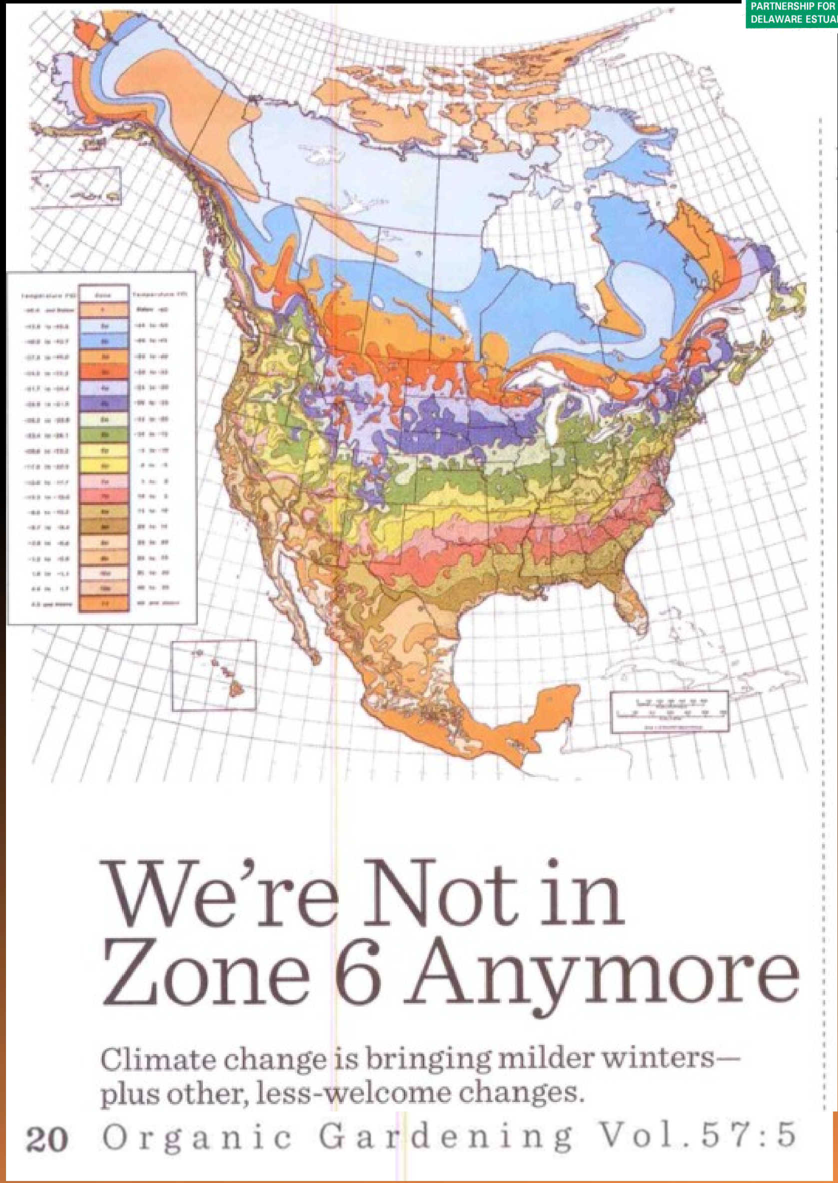
Sea Level ↑

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

Salinity ↑

Storms ? ↑

Growing Season ↑



Emerging Threats

- Heat Stress
- Saltwater and Sea Level Rise
- Flooding (amid Droughts)
- More Frequent, Larger Storms

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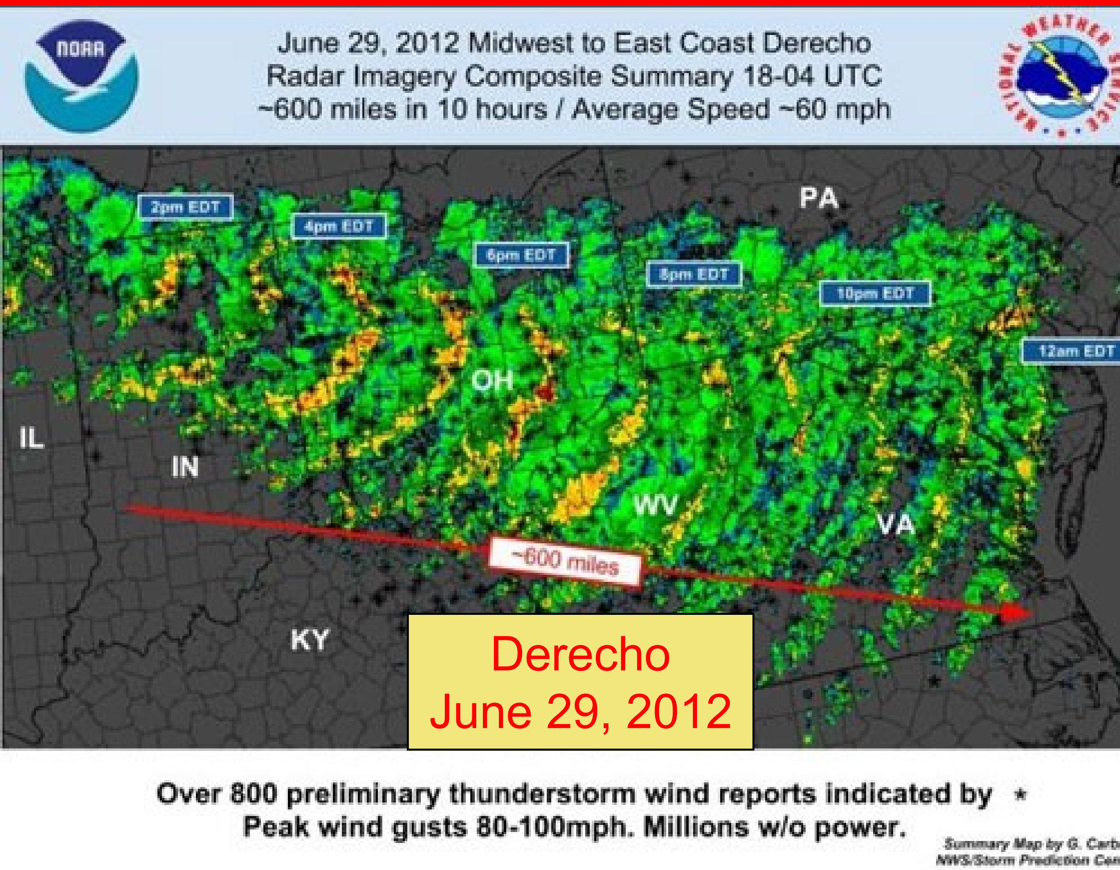
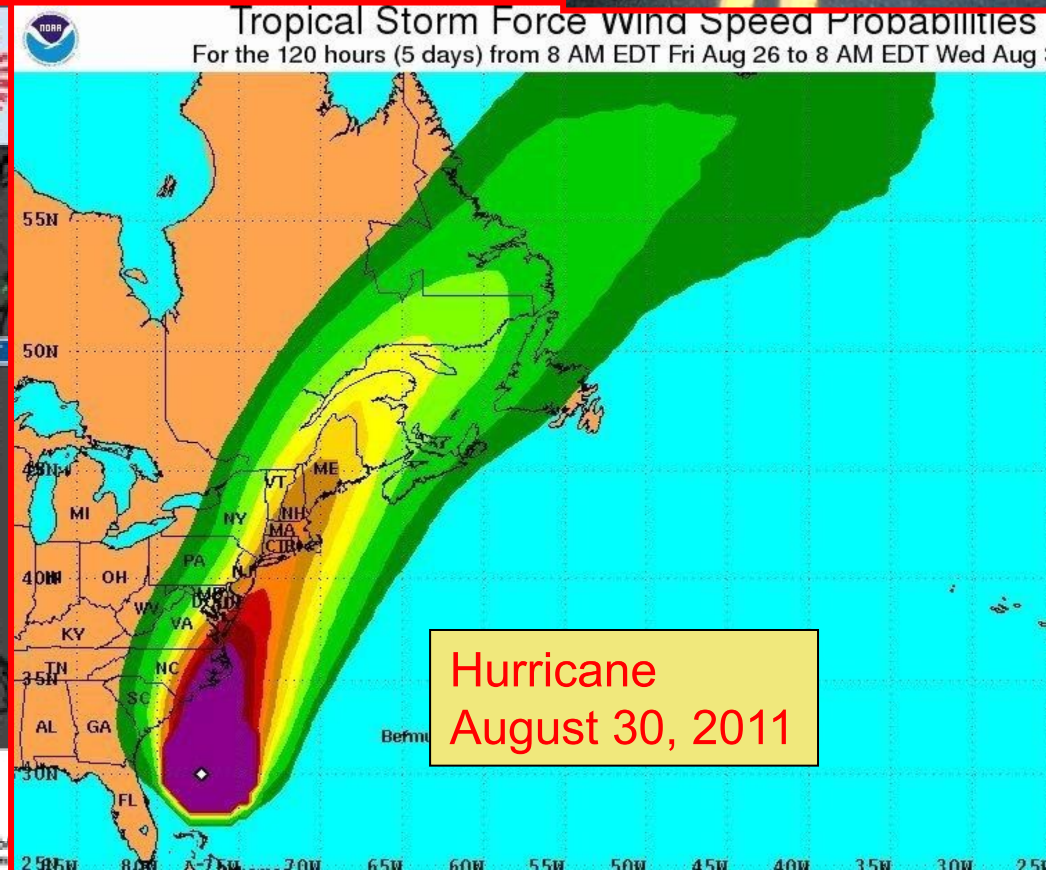
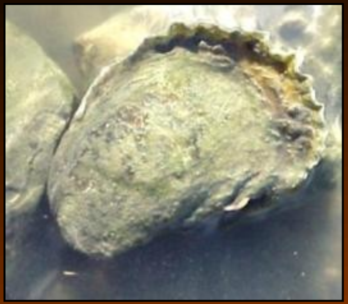


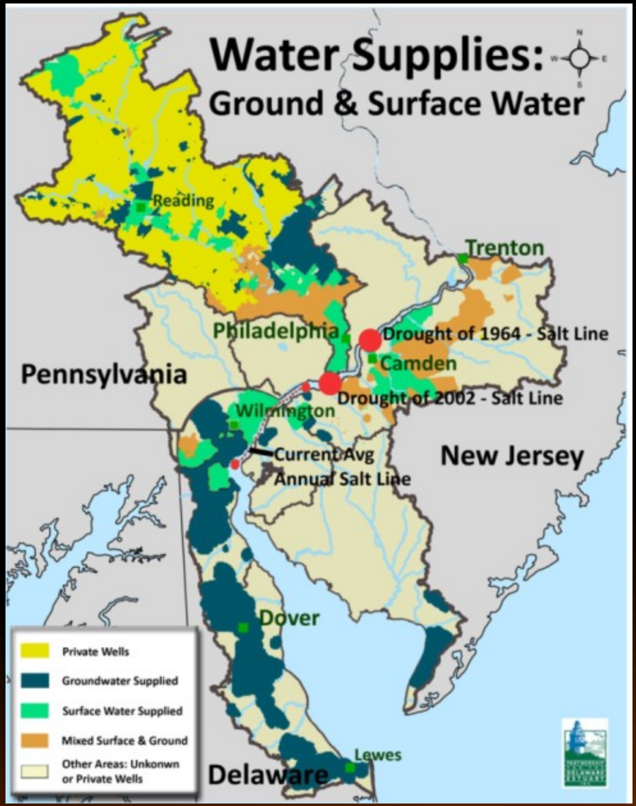


Predictions > Vulnerability > Adaptation > Action

Drinking Water



- >16 million people
- Philadelphia – 1.4 million
- New York City



- Anticipated population growth of 83% by 2100
- 95% used for power generation and industry
- Increasing demands for industry, e.g. shale drilling

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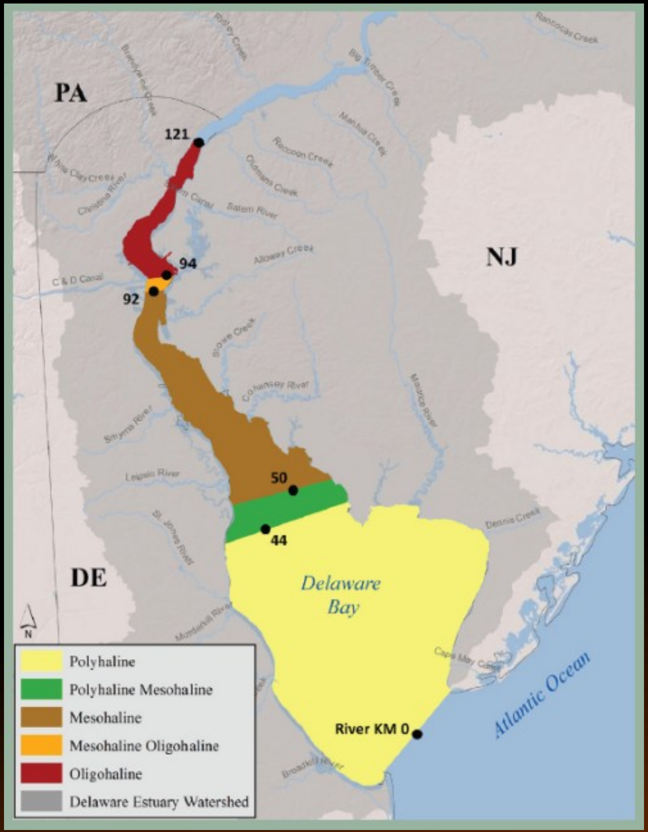
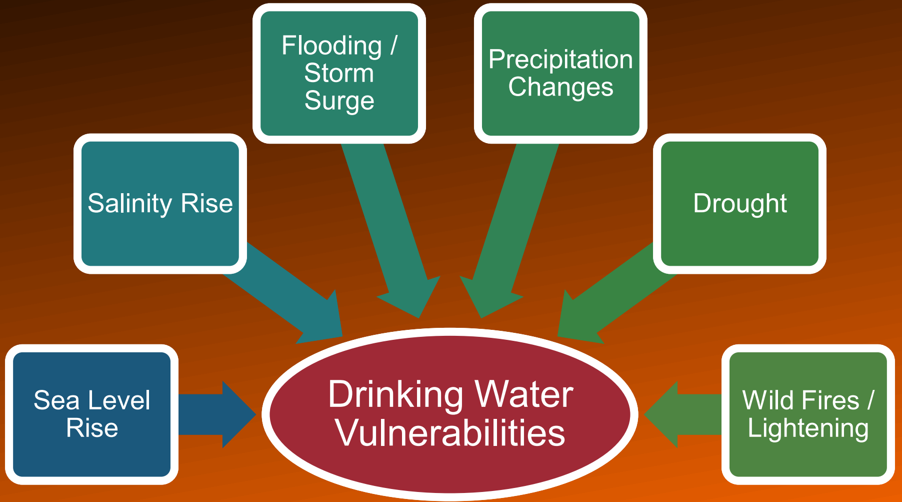
Drinking Water – Vulnerability

- Sea Level Rise
- Saltwater Intrusion
- Storms and Flooding
- Infrastructure Erosion
- Degraded Sourcewater





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Drinking Water – Adaptation Options

- Infrastructure protection and upgrades
- New treatment & distribution system
- Storm water control
- Source water protection
- Wastewater disinfection
- Protect river flow to offset saltwater

Drinking Water Tough Questions

- How can we maintain low salinity in the upper estuary?
- Will more reservoirs be needed and where?
- Where should infrastructure be protected?

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Coastal Wetlands

Abundant
Diverse

<u>Benefits:</u>

Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Capture

Tidal Wetlands

Tidal Wetlands – Why?

A Signature Trait of System

Near Contiguous Band
Diverse: *Freshwater Tidal Marshes*
Brackish Marshes
Salt Marshes

<u>Nature's Benefits</u>

Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Sequestration

Wetland Benefits (Ecosystem Services)

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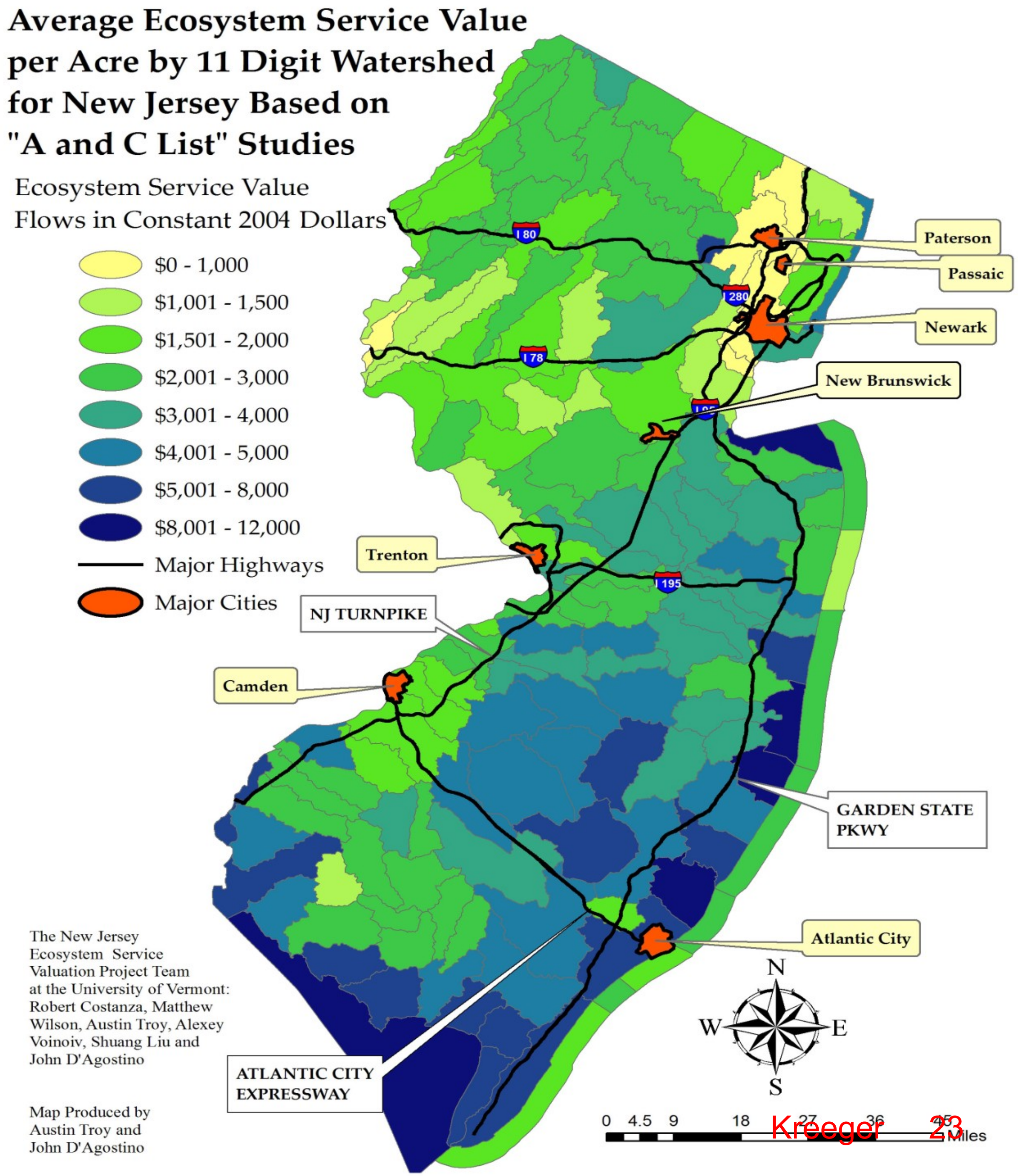
Millenium Ecosystem Assessment 1º Service	2º Service	3º Service	4º Service
Provisioning	Food	Fisheries Support	
	Livelihoods	ebrate production	
	Genetic Materials	Phragmites control research	
	Biochemical Products	Research in Antifungal Agents	Health
	Fiber and Fuel	Cellulose stock	
Regulating	Sequestration Health	Carbon	Carbon Caps, mitigation
	Sediment Stabilization	Erosion control	Meet TMDLs for sediment
	Storm Protection/ Wave Attenu Flood Protection	Lives 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__*

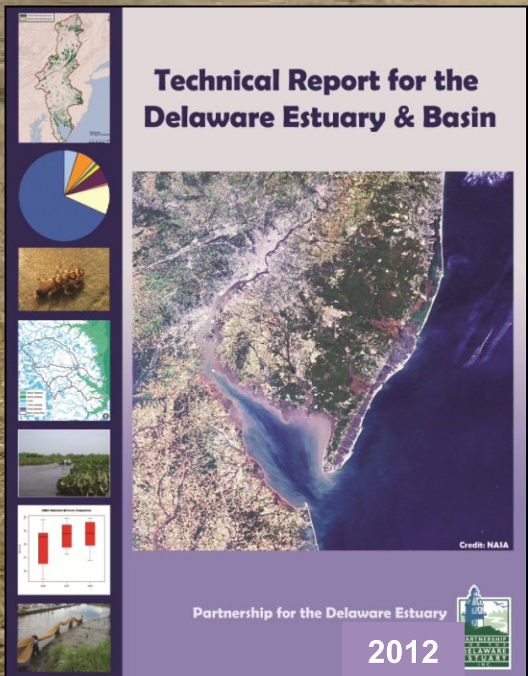
New Jersey Department of Environmental Protection

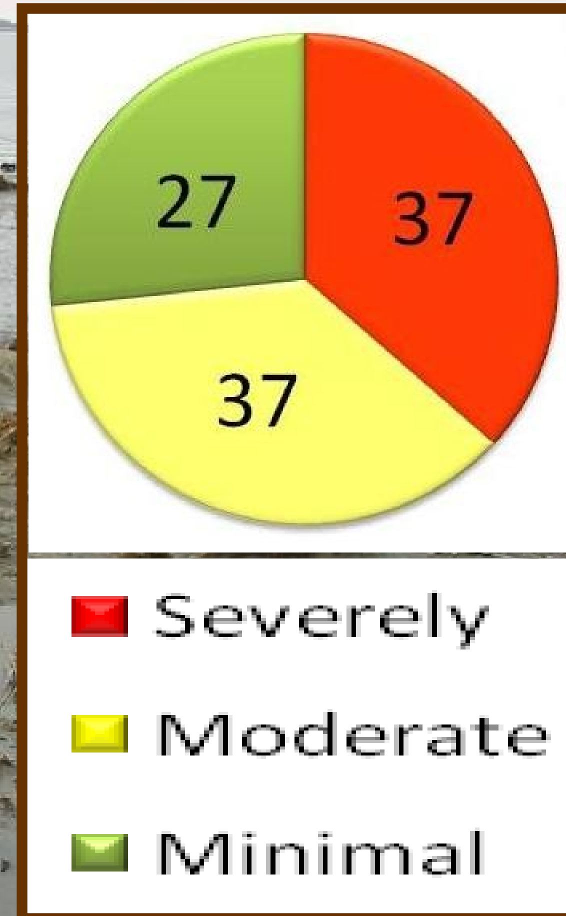


Slide from Bill Mates, NJDEP

2012 State of the Estuary Report

Rapid loss of acreage and degraded wetland health





Tidal Wetlands

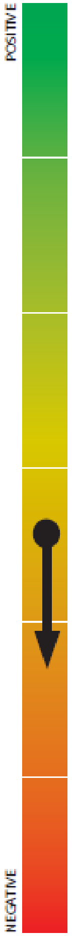
Acreage

- <50% left
- losses continue

Condition

- most are moderately or severely stressed
- degradation continues

Tidal Wetlands



INDICATOR DESCRIPTION: Coastal wetlands are one of the Delaware Estuary's most important and characteristic habitats, and they are a premier environmental indicator for the area's ecosystem. The Estuary has one of the largest freshwater tidal prisms in the world running from Trenton, New Jersey, to approximately Wilmington, Delaware. The gradual transition from fresh to salt water allows for abundant and rare freshwater tidal wetlands in the Upper Estuary, brackish marshes in the Middle Estuary, and salt marshes surrounding Delaware Bay. Together, these marshes form a nearly continuous perimeter fringing the tidal system. Tidal wetlands furnish essential spawning, foraging, and nesting habitat for fish, birds, and other wildlife. These wetlands are considered by many scientists to function like the ecosystem's "kidneys," absorbing contaminants, nutrients, and suspended sediments. Other scientists regard them as "fish factories" that are crucial to the success of important finfisheries. They also provide a first line of defense against storm surge and flooding. Acre for acre, tidal wetlands likely provide more ecosystem services than any other habitat type in the region.

STATUS: A 1992 to 2001 land cover data comparison (for both tidal and non-tidal wetlands combined) showed wetland loss throughout the Estuary, except along the New Jersey side of Delaware Bay where extensive marsh restoration may have offset this trend (see map). During the preceding decade, a more in-depth analysis showed that Delaware's tidal marshes dropped by 12 percent and the proportion of marshes with degraded conditions almost doubled.

TRENDS: For over 300 years, the extent and integrity of tidal wetlands has been under assault across the Estuary. Perhaps 50 percent of the natural marshes have been lost to development, conversion, or degradation associated with human activities. Losses have been most severe in the urban corridor where perhaps only five percent of pre-settlement acreage of the nationally rare freshwater tidal marsh remains. Despite proactive laws protecting marshes, a growing awareness of their ecological value, and mounting restoration attention, marsh acreage and condition are still lost from human-caused impairments, land uses, and sea level rise.

ACTIONS AND NEEDS: Tidal wetlands are a hallmark feature of our watershed that suffer continued losses of both area and condition. Coordinated monitoring and assessment programs are urgently needed to regularly and carefully track tidal marsh extent and condition across the three Estuary states. A better scientific understanding is also needed of the factors that govern wetland well-being, such as sediment supply, water quality, and ecology. Studies of their ecosystem services and natural capital value would benefit land-use and regional-restoration planning.

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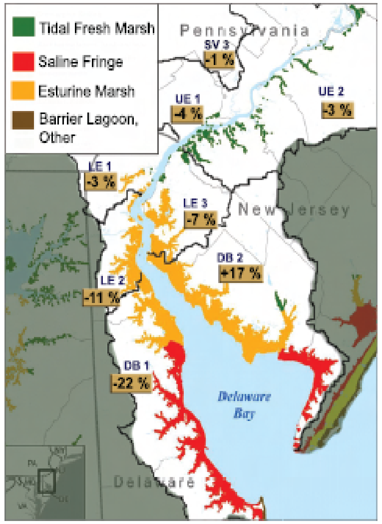
A coconut fiber log is deployed along the edge of a tidal marsh in Bivalve, New Jersey, in an effort to establish a "living-shoreline" reef that may soon protect against erosion.

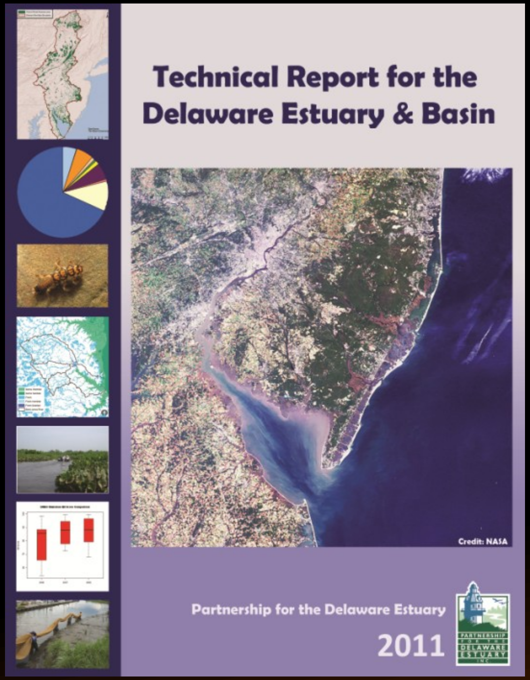
Relative Change in Wetland Acreage 1992-2001

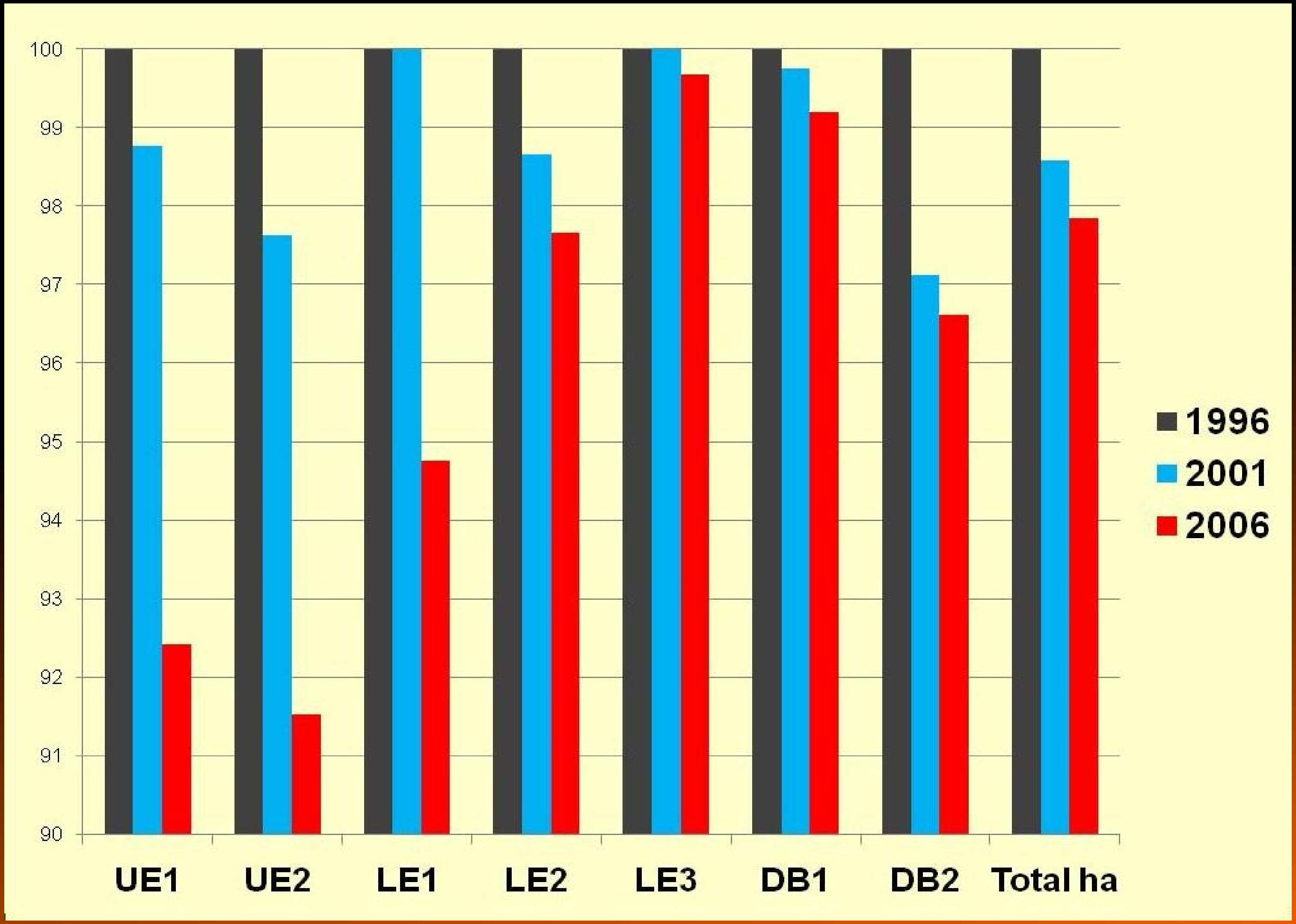


Please refer to the map on page 31 to view the full range of each region.

State of the Estuary Report 2012

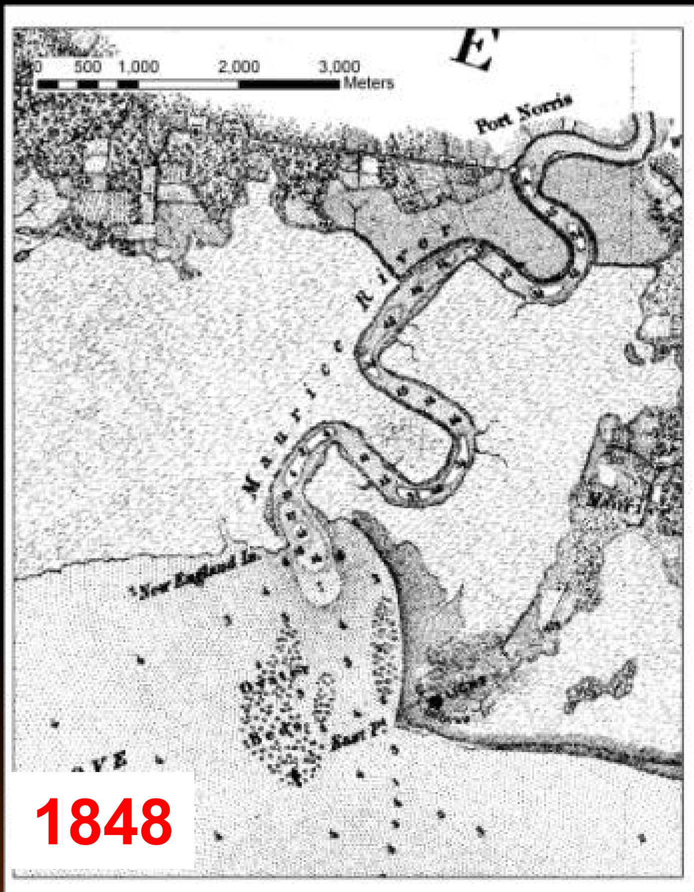
Percentage Loss of Emergent Tidal Marsh 1996-2006

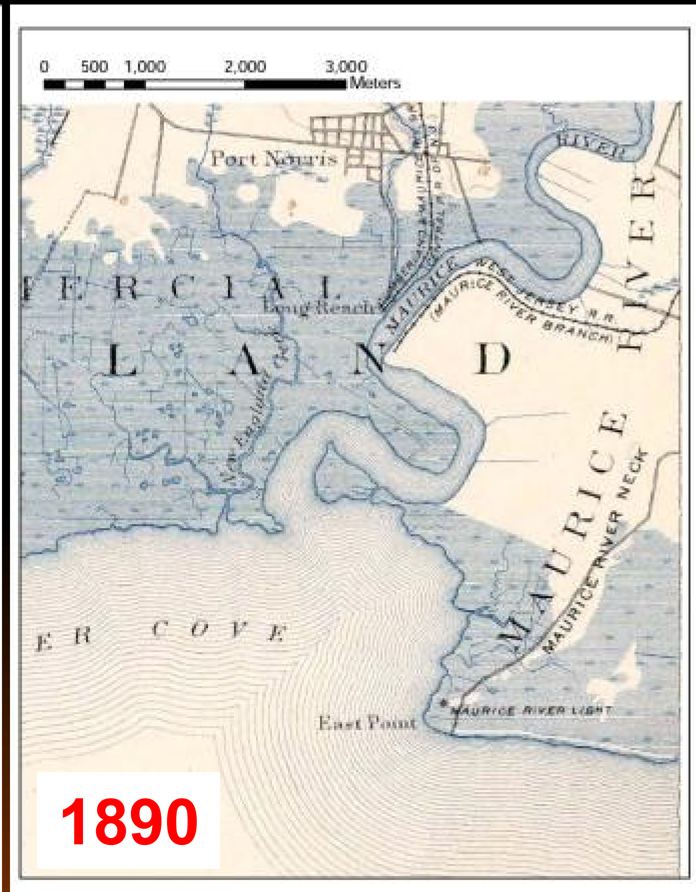




Maurice River Mouth

Interior Drowning

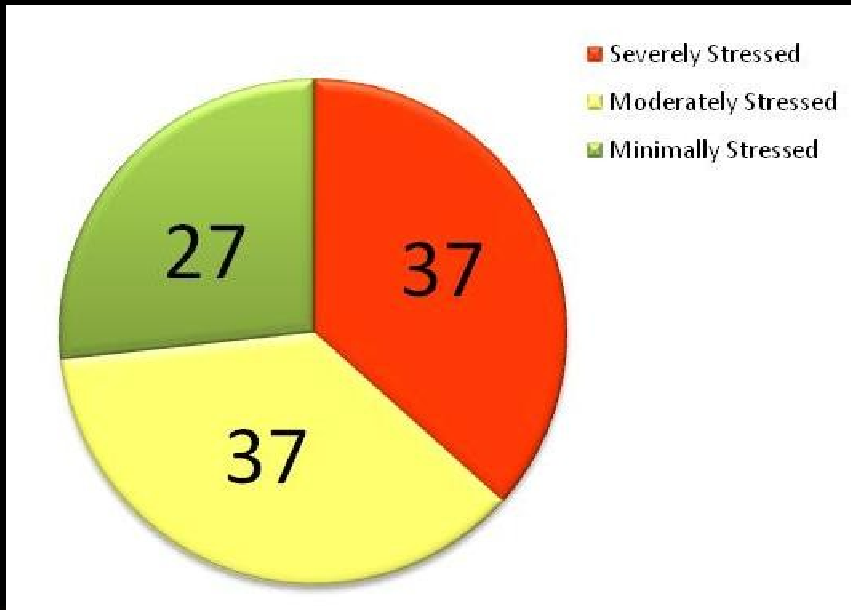




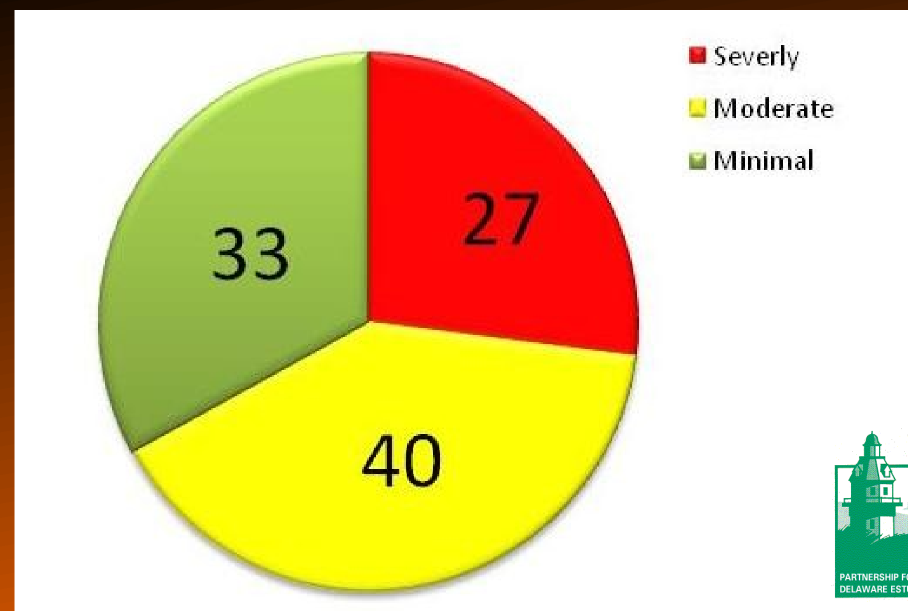
Edge Retreat

Courtesy, Jeff Gebert ACOE

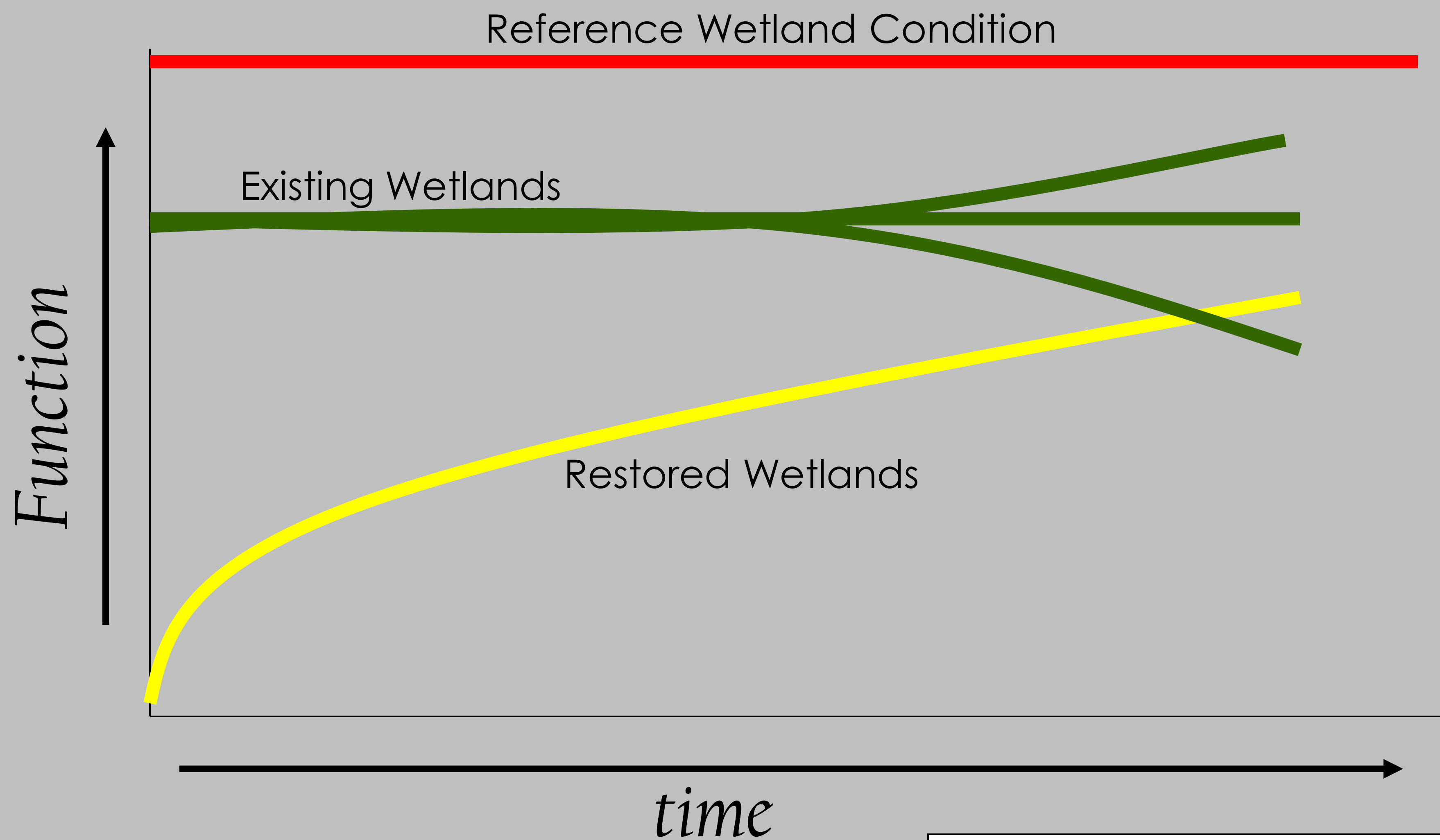
PA Tidal Wetlands – Condition Summary



Maurice Tidal Wetlands – Condition Summary

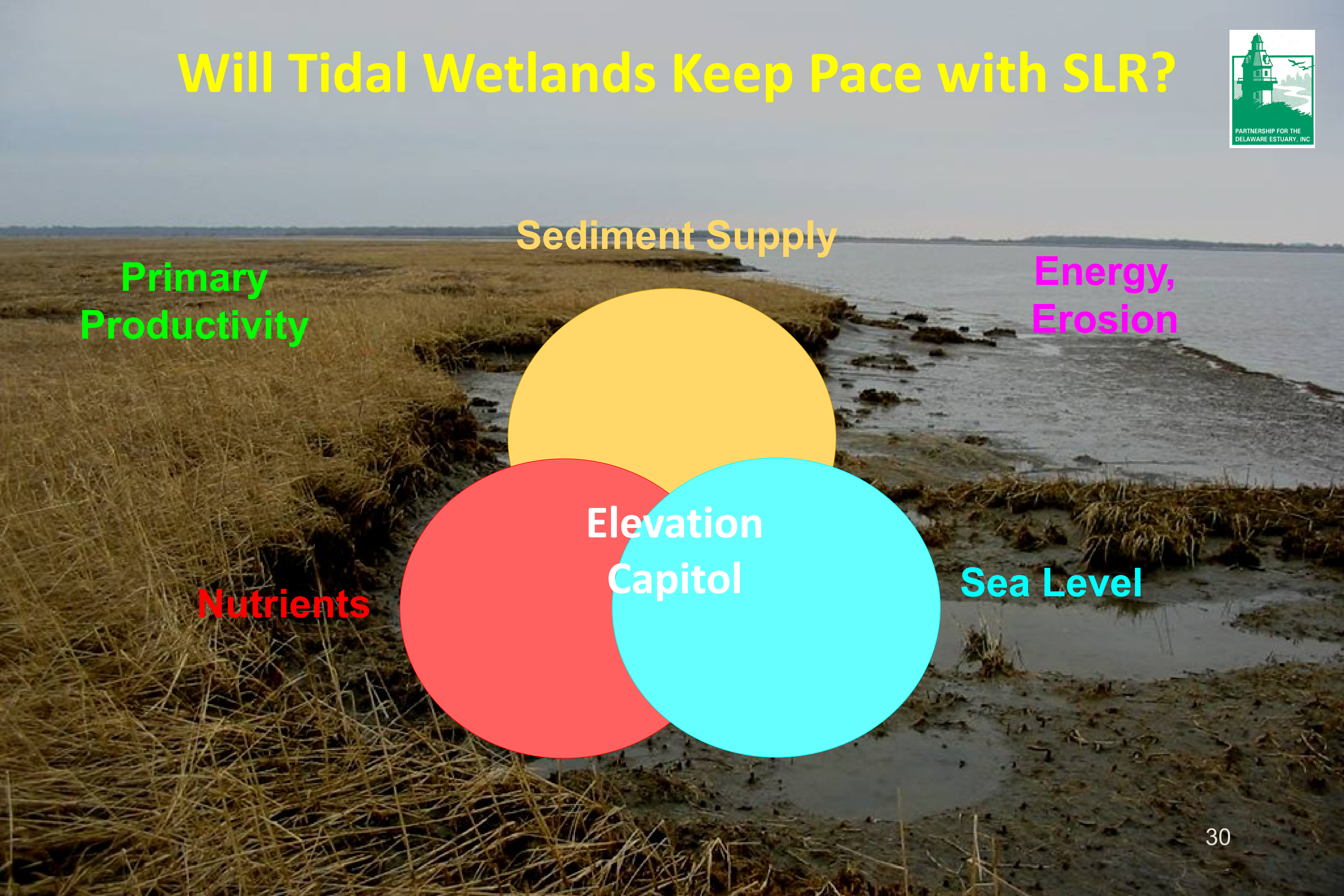


Changes in Health and Function

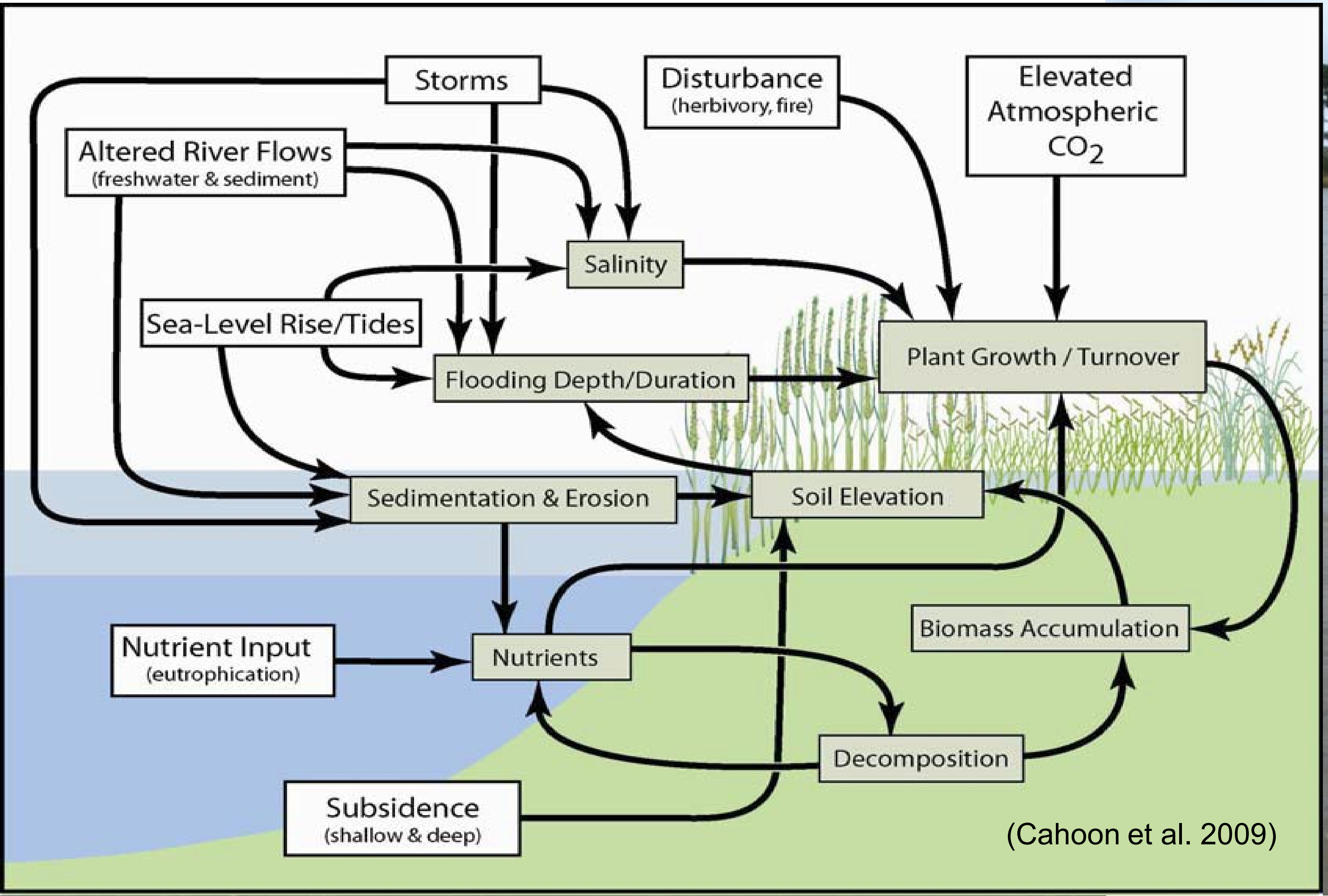


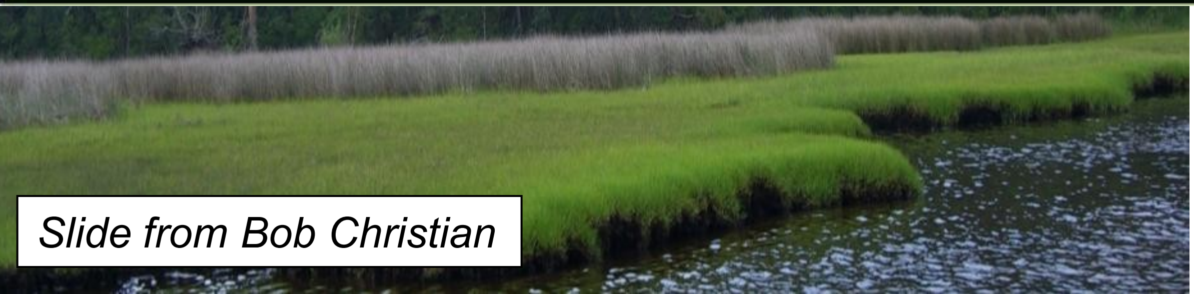
Slide from Amy Jacobs (DE DNREC)

Will Tidal Wetlands Keep Pace with SLR?



Vertical movement of marshes

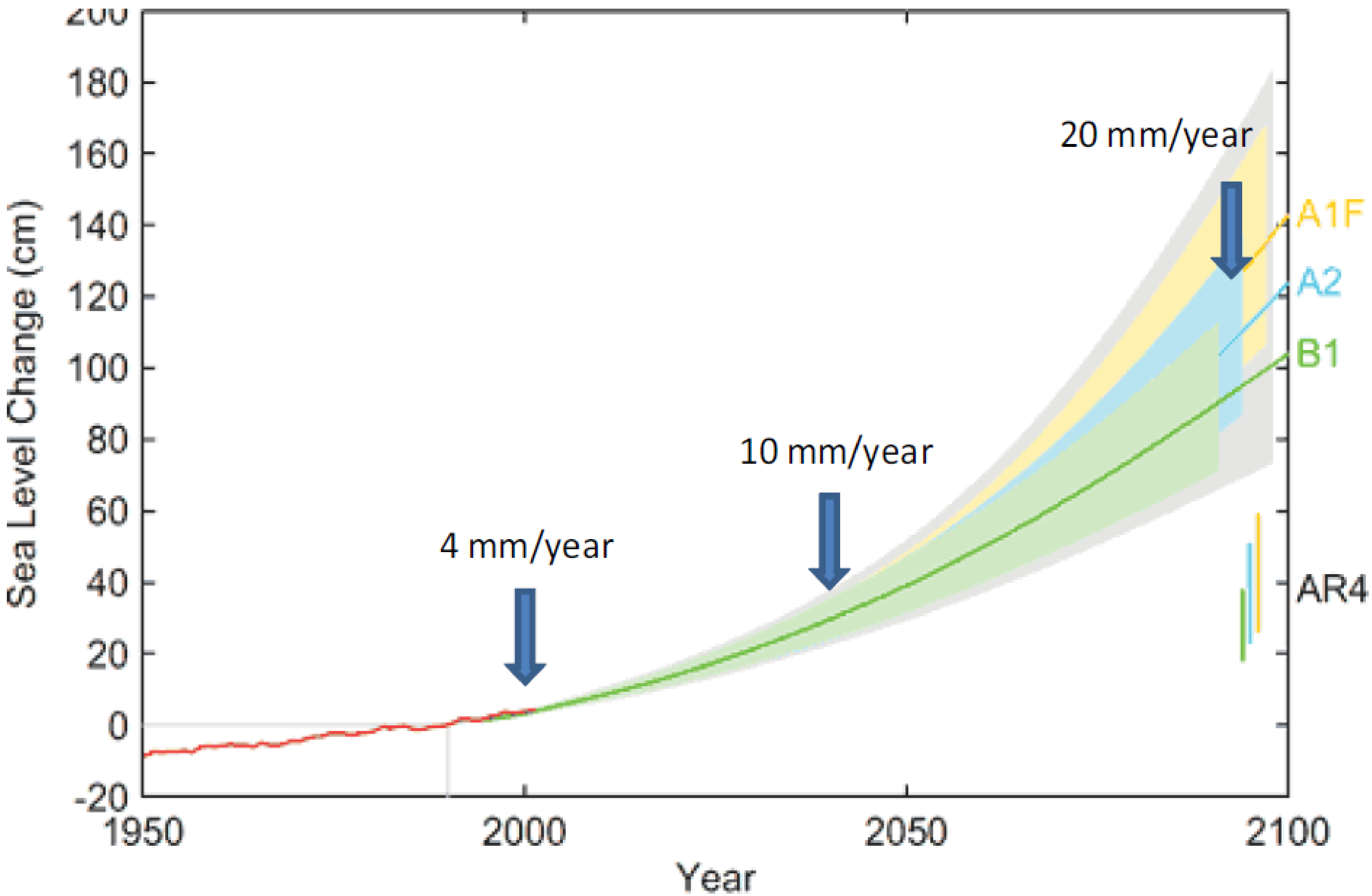




Slide from Bob Christian

- sedimentation
- bioaccretion

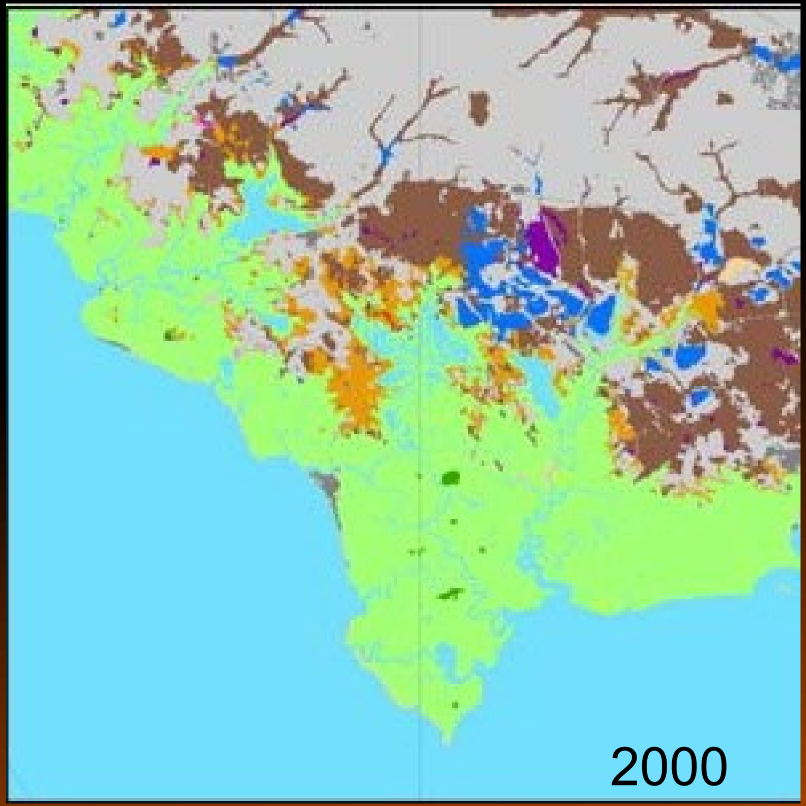
Most Salt Marshes Cannot Survive When Sea Levels Rise >1 cm Per Year

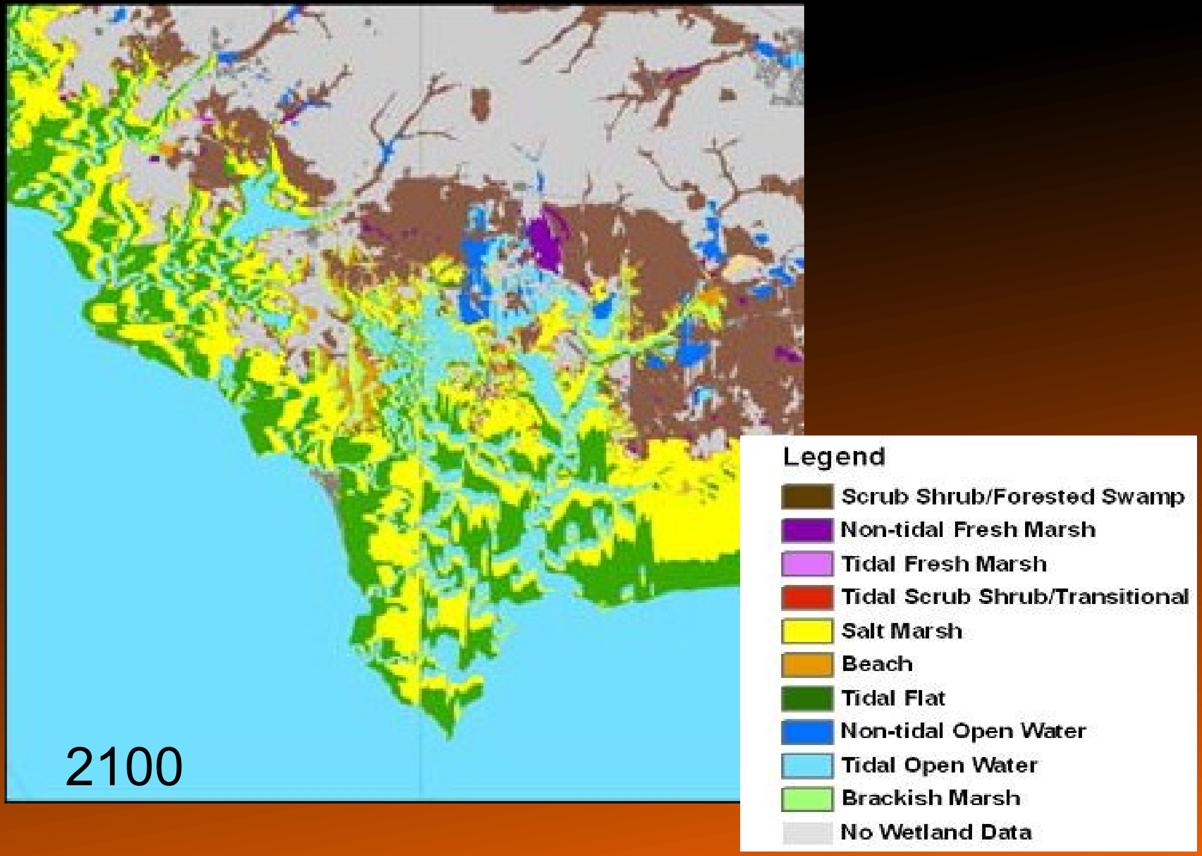


Coastal Wetlands - Future

>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





Tidal Wetlands Vulnerability Survey & Results

Table 3-3. Comparison of the effectiveness and feasibility of various potential adaptation options for addressing the main vulnerability of tidal freshwater we Table 3-3. Compa... tlands and brackish/saltwater wetlands exposed to changing sea level, salinity, precipitation/storms, and carbon dioxide levels by 2100 in the Delaware Estuary.

	Tidal Fresh	Tidal Salt/Brackish
Temperature Change		
Shifts in Community Species Composition	Med-High	Med-High
Desiccation of Marsh Sediments	Med-Low	Low
Change in Habitat Support	Med-Low	Med-Low
Productivity	Med-Low	Med-High
Invasive Species	Med-Low	Med-Low
Sea Level Rise		
Shifts in Community Species Composition	High	Highest
Ability of Accretion Rate to Equal RSLR Rate	Med-High	Highest
Ability for Landward Migration	High	Highest
Change of Marsh Area	High	Highest
Increased Tidal Range (Upper River)	Med-High	High
Ratio of shoreline edge to marsh area	Med-High	High
Rate of Channel Scour	Med-High	Med-High
Storm surge susceptibility	High	Highest
Seaward edge erosion	High	Highest
Salinity Range Increase		
Shifts in Community Species Composition	Highest	Med-High
Salt Water Intrusion to Fresh Water Habitats	Highest	Med-High
Salt exposure/stress event	High	Med-Low
Change in Habitat Support	Highest	Med-Low
Productivity	Med-High	Med-Low
Invasive Species	Med-Low	Med-Low
Precipitation & Storms		
Shifts in Community Species Composition	Med-High	Med-Low
Salt exposure/stress events	Med-High	Med-Low
Change in Habitat Support	Med-Low	Med-Low
Productivity	Med-Low	Med-Low
Desiccation, flooding or erosion	Med-High	Med-Low
Sediment supply	Med-High	Med-Low
Physical impacts by wind, waves and surge	Med-High	Med-High
Atmospheric Carbon Dioxide		
Shifts in Community Species Composition	Low	Low
Productivity	Low	Low

The Top Five....

Ranking	Vulnerability
1	Sea Level Rise Effects on Brackish/Saltwater Wetlands
2	Salinity Effects on Freshwater Tidal Wetlands
3	Sea Level Rise Effects on Freshwater Tidal Wetlands
4	Precipitation and Storm Effects on Freshwater Tidal Wetlands
5	Precipitation and Storm Effects on Brackish/Saltwater Wetlands

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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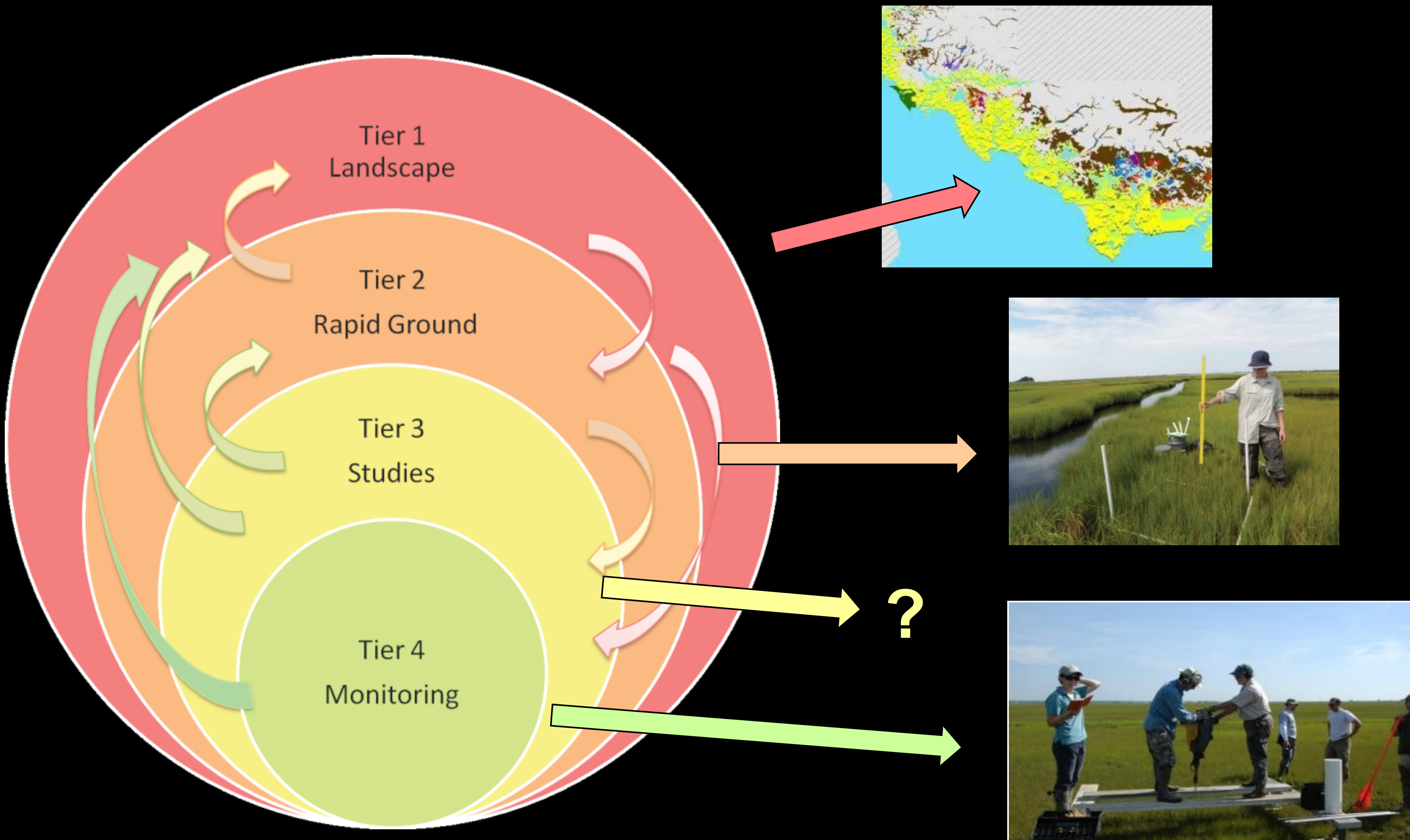
The Mid-Atlantic Coastal Wetland Assessment:

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



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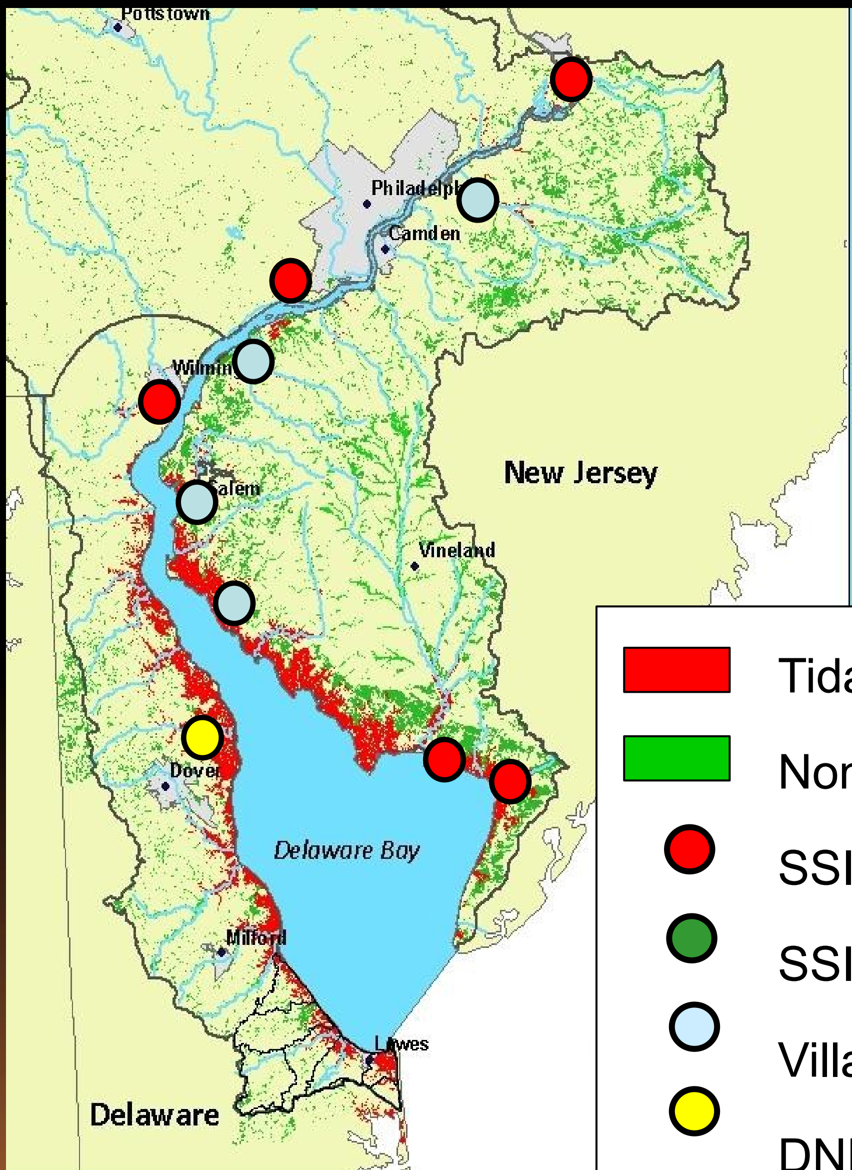
Site-Specific Intensive Monitoring (SSIM)



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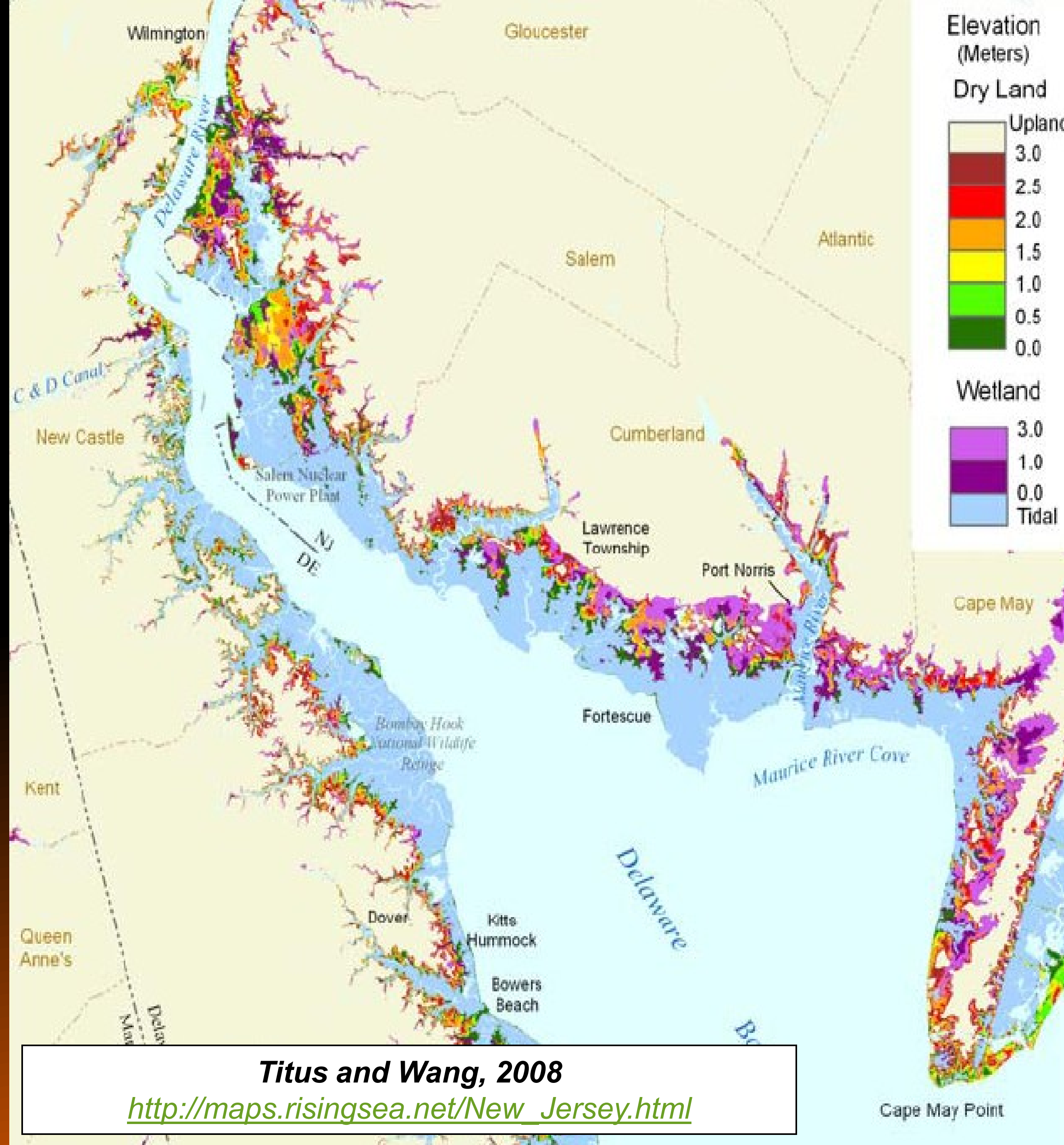
Tidal marshes need to move:

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

EXAMPLES

Living Shoreline R&D

Mussel Powered Living Shorelines for Salt Marsh Erosion Control


April 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC

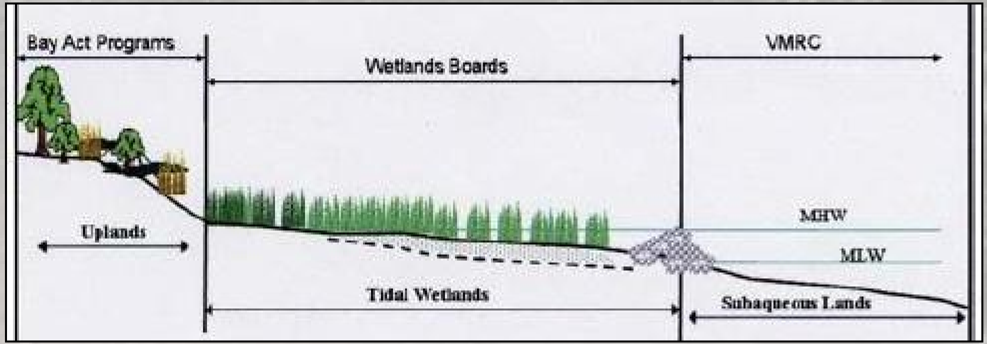
May 2010


June 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC


June 2011
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC


September 2011 (after hurricane)
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC

Living Shorelines – Many Options

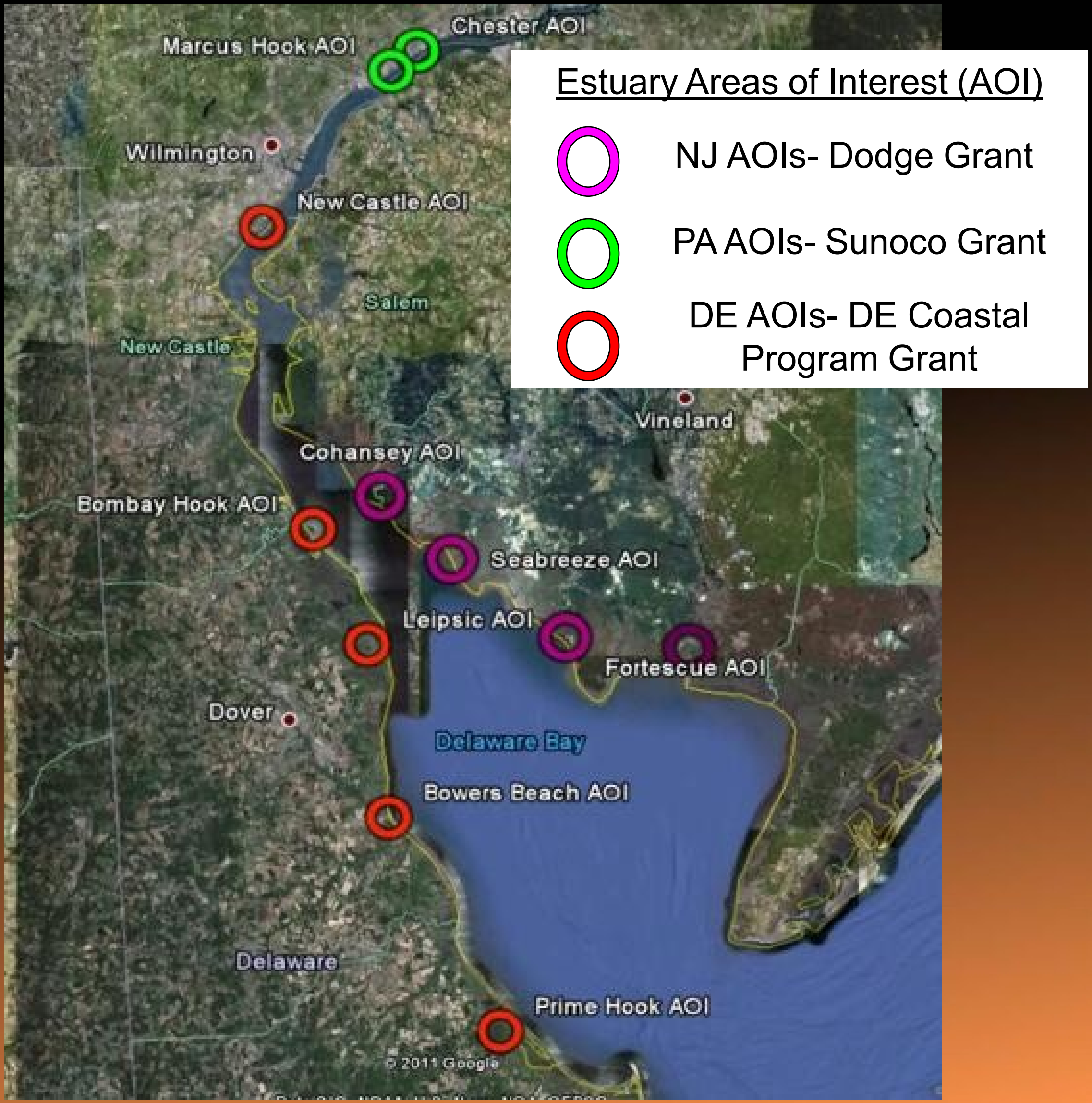


EXAMPLES

Living Shorelines Planning Project

DK

- Inventory of Types
- GIS Analysis in Areas of Interest
- Selection of Potential Project Sites
- Workshops



Potential Project Sites

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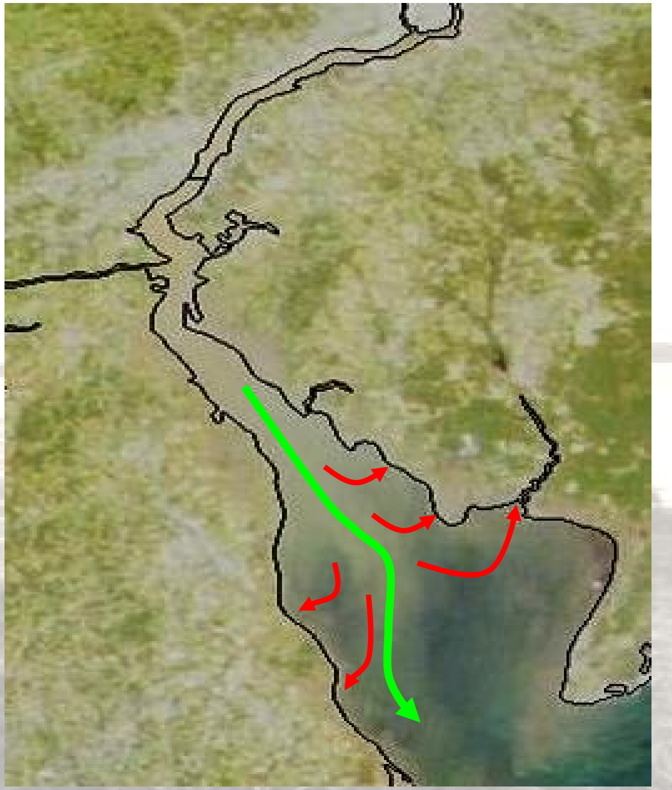
Beneficial Use

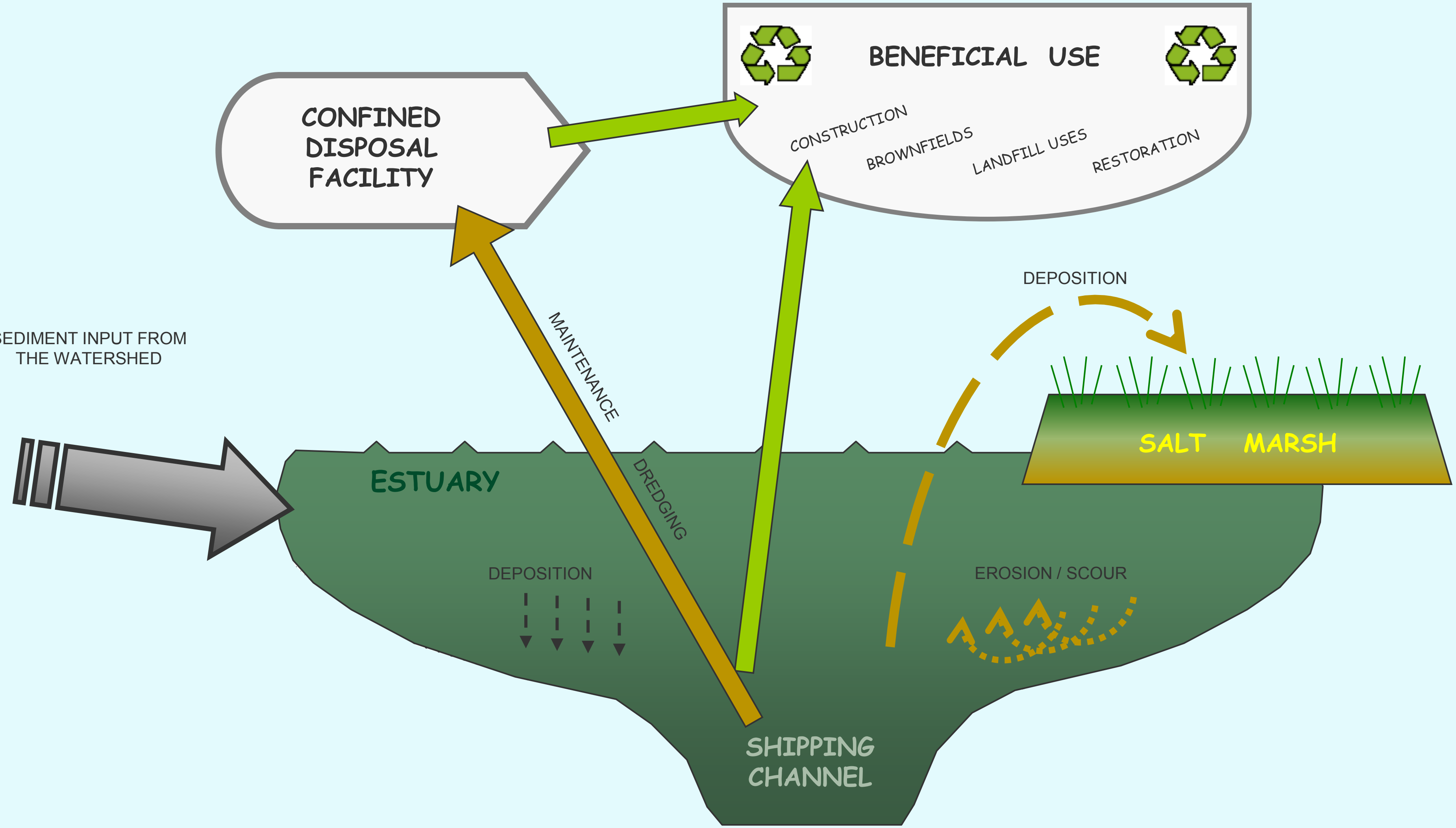
Why Needed?

- Marshes need sediments
- More sediment is removed from the system by dredging than is replaced via river inputs
- Sediment deficits can lead to marsh drowning
- River sediments might follow main channel to sea rather than disperse over pre-deepening "delta"
- Large 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



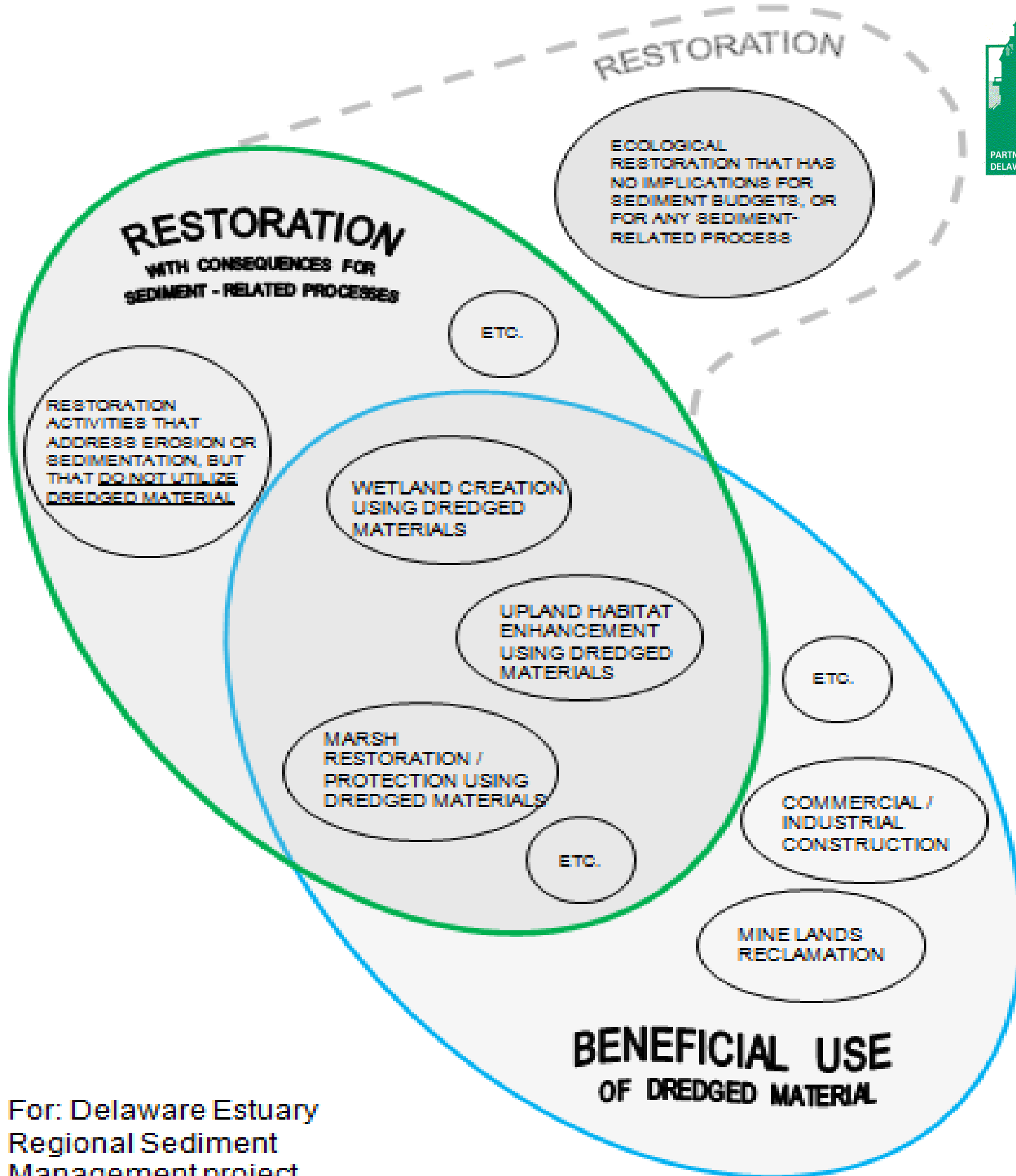
EXAMPLES

Restoration and Beneficial Use



Slide from Burke 2010

Relationship Between Restoration and Beneficial Use

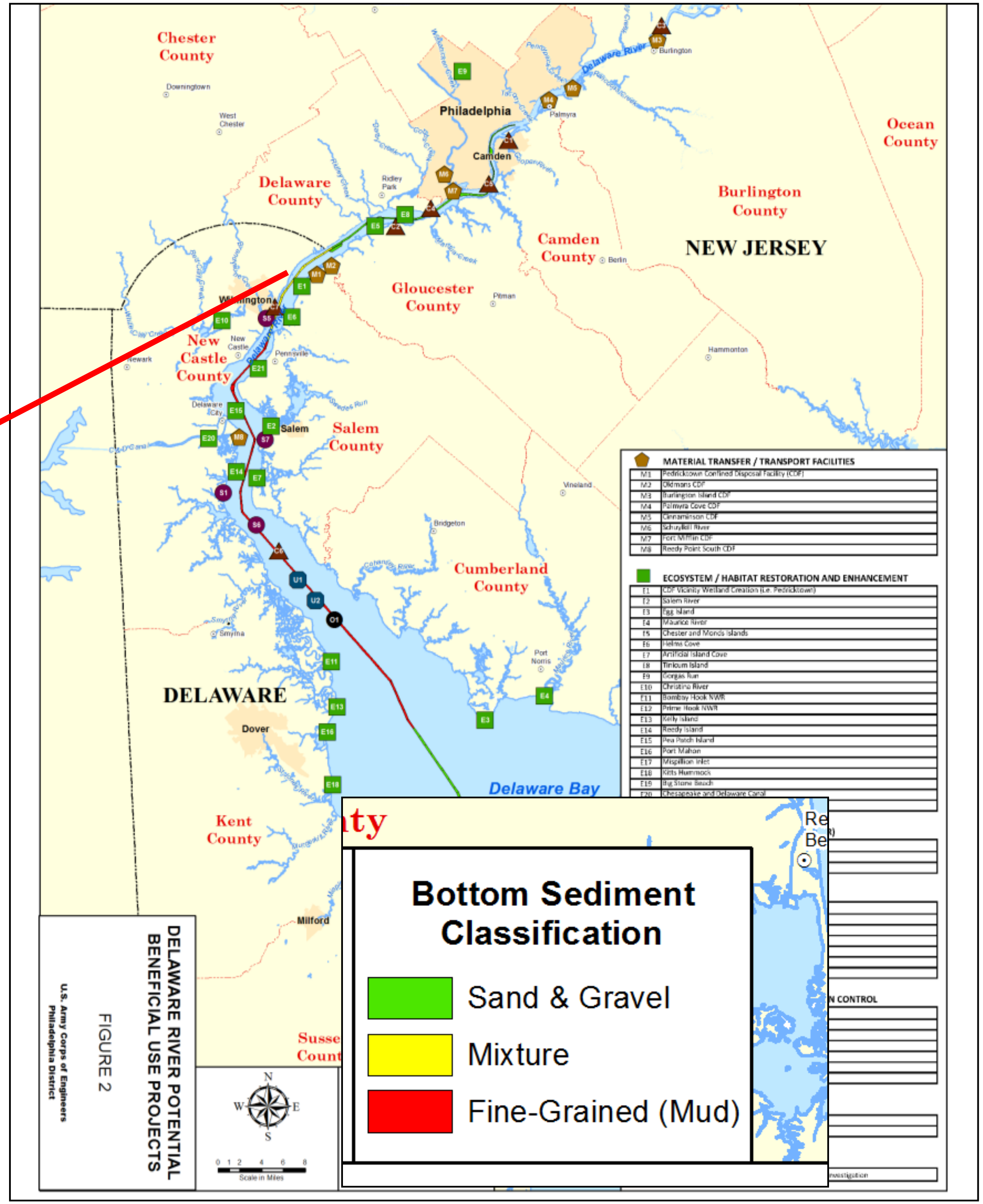


For: Delaware Estuary Regional Sediment Management project

Contact: David Burke PADEP 484-250-5822 daburke@state.pa.us

Burke 2011

Potential Dredged Material Utilization Projects

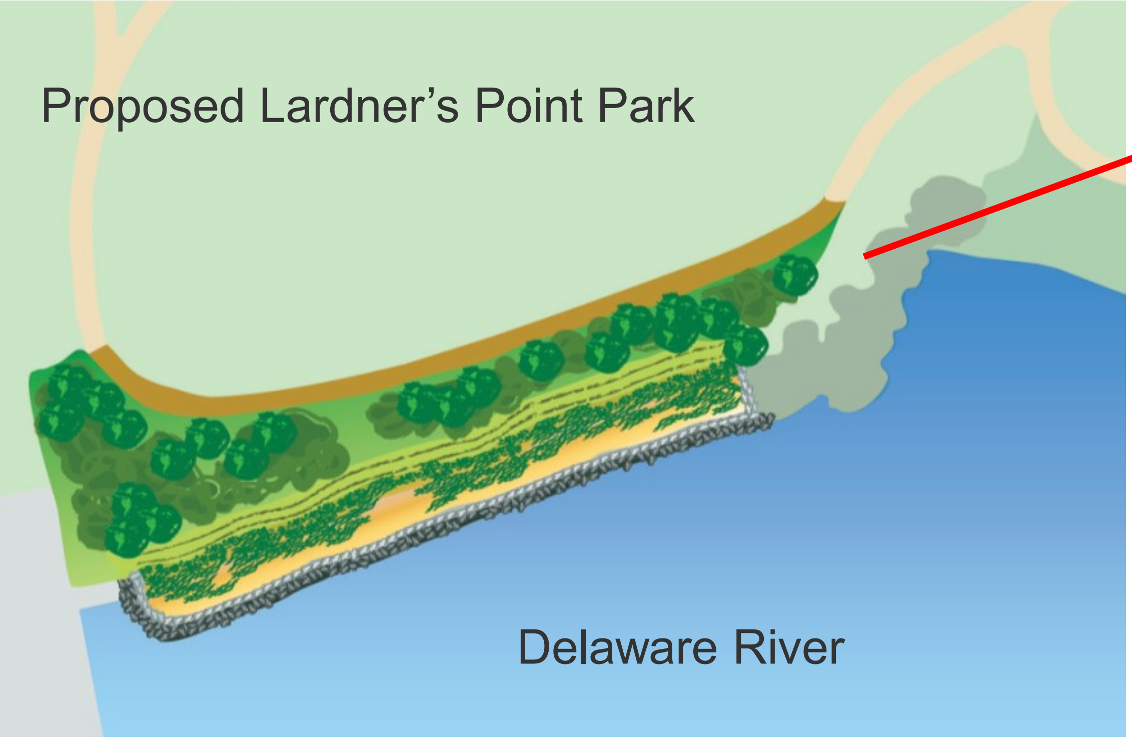


J.B. Smith, ACOE 2011

Urban Waterfront Application Example

Many Other Potential Sites:

- Philadelphia
- Camden
- Wilmington
- Chester



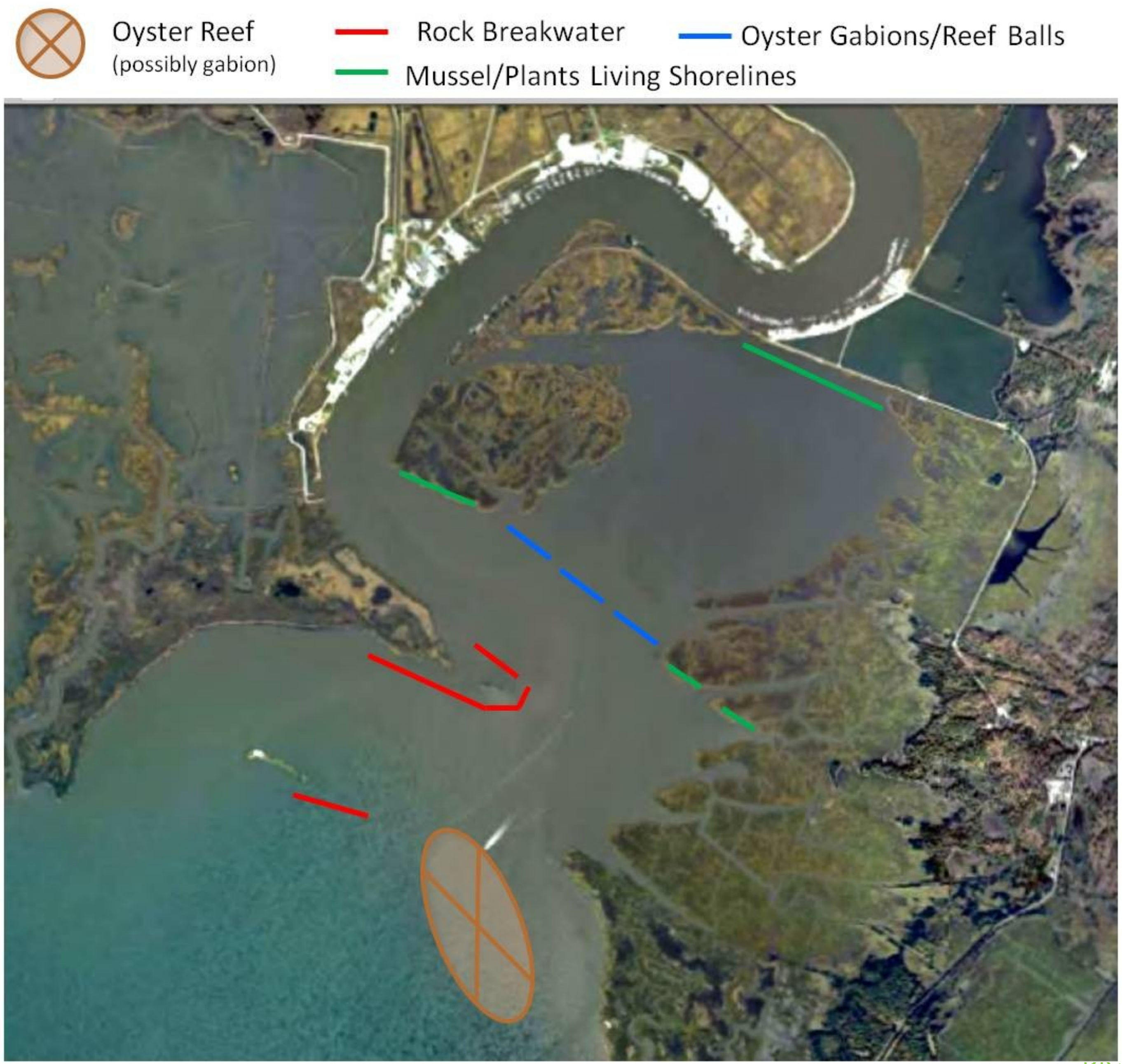
Biohabitats 2011

Potential Big Hybrid Project

Would Include:

- Rock Breakwaters
- Oyster Reefs
- Sediment Placement
- Interidal Living Shorelines
- Marsh Restoration

Maurice River Mouth Stabilization – Conceptual Ideas (Kreeger 4/14/11)



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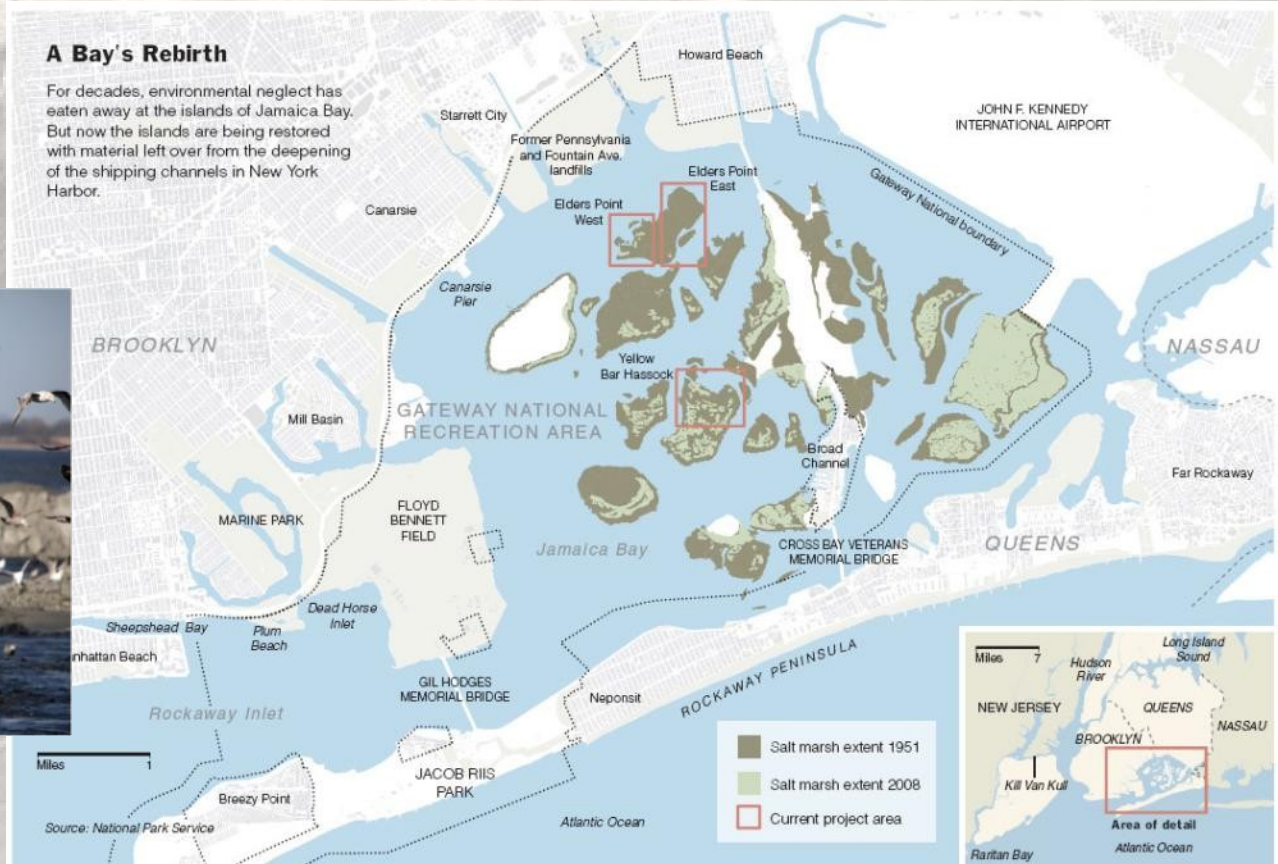
Beneficial Use

Jamaica Bay, NYC

From New York Harbor's Depths, Muck to Restore Islands in Jamaica Bay
[New York Times]

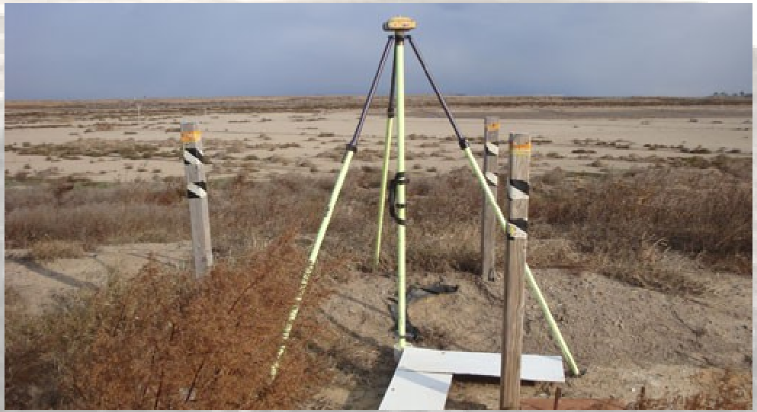


EXAMPLES

Beneficial Use

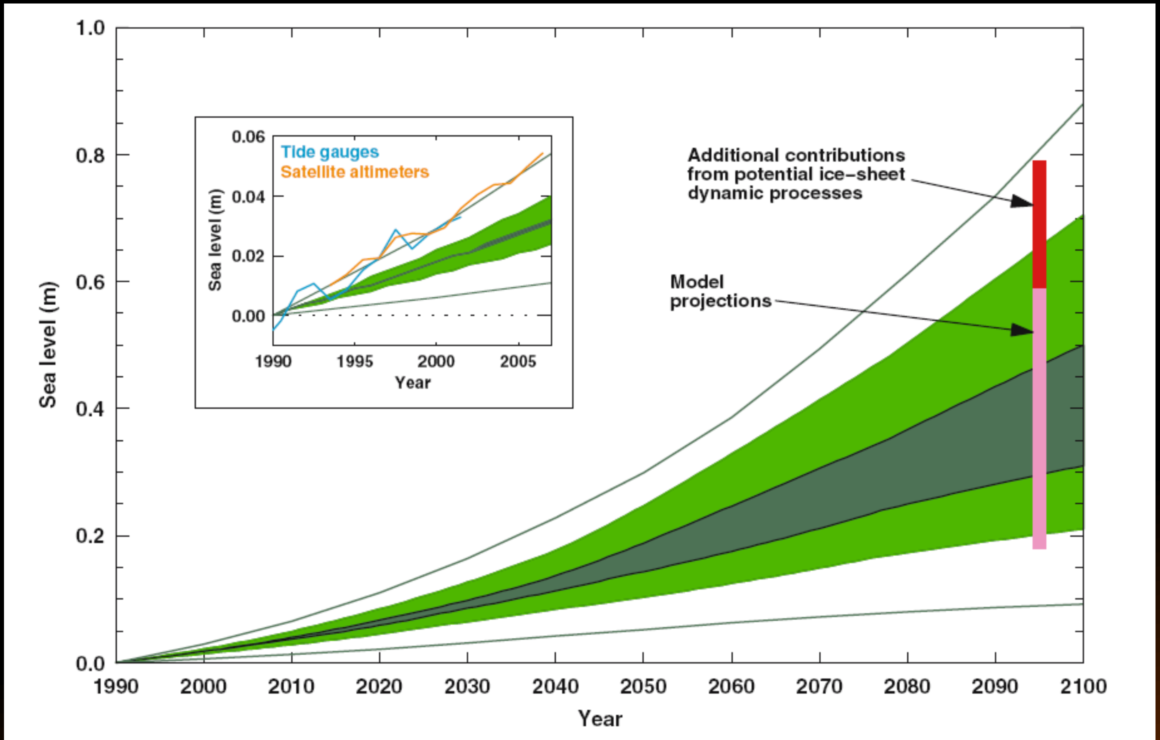
Poplar Island, Chesapeake

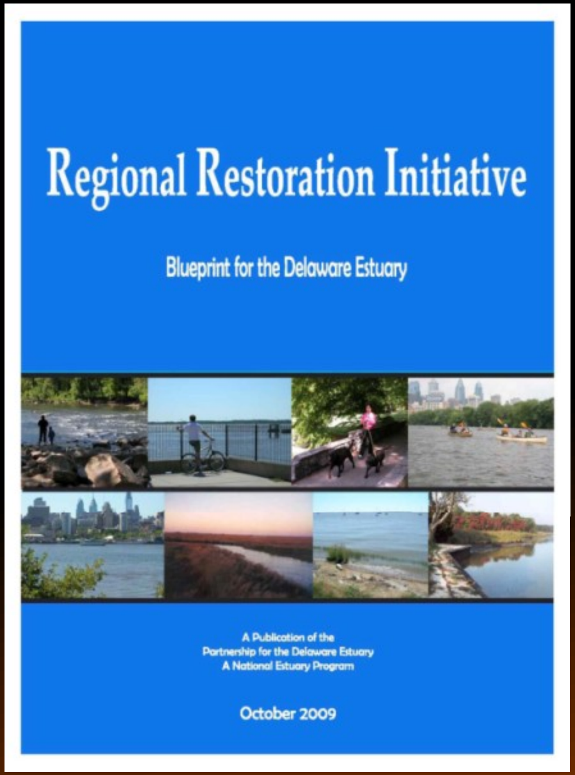
m New York Harbor’s Depths, Muck to Restore Islands in Jamaica Bay
[New York Times]



EXAMPLES

Restoration for the Future = Climate Adaptation





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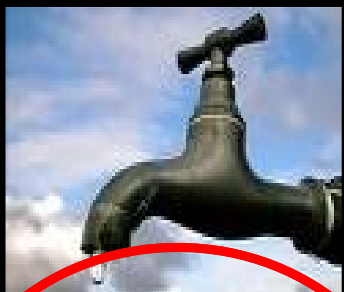
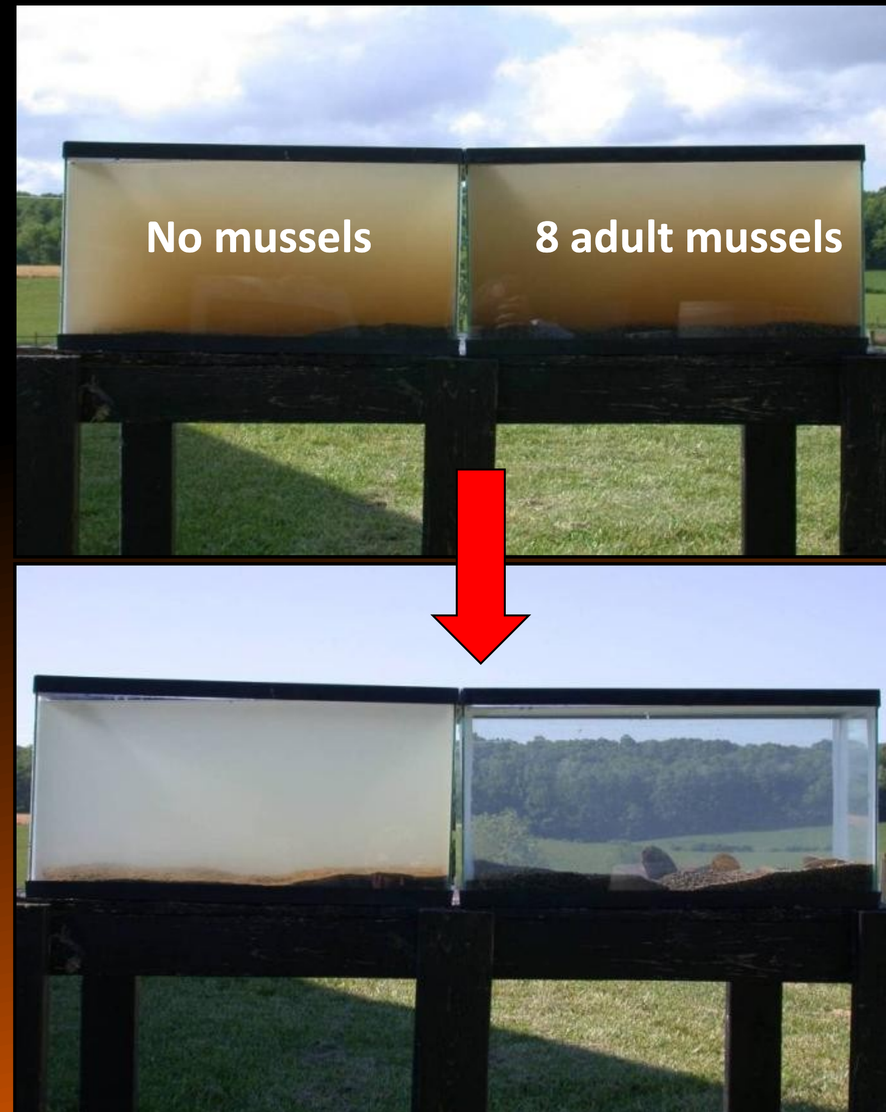
Bivalve Shellfish (oysters, mussels, clams)



60 Species
Diverse

Benefits:

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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Freshwater Mussels of the Delaware

Freshwater Mussels of the Delaware

What are they?

Status and Trends?

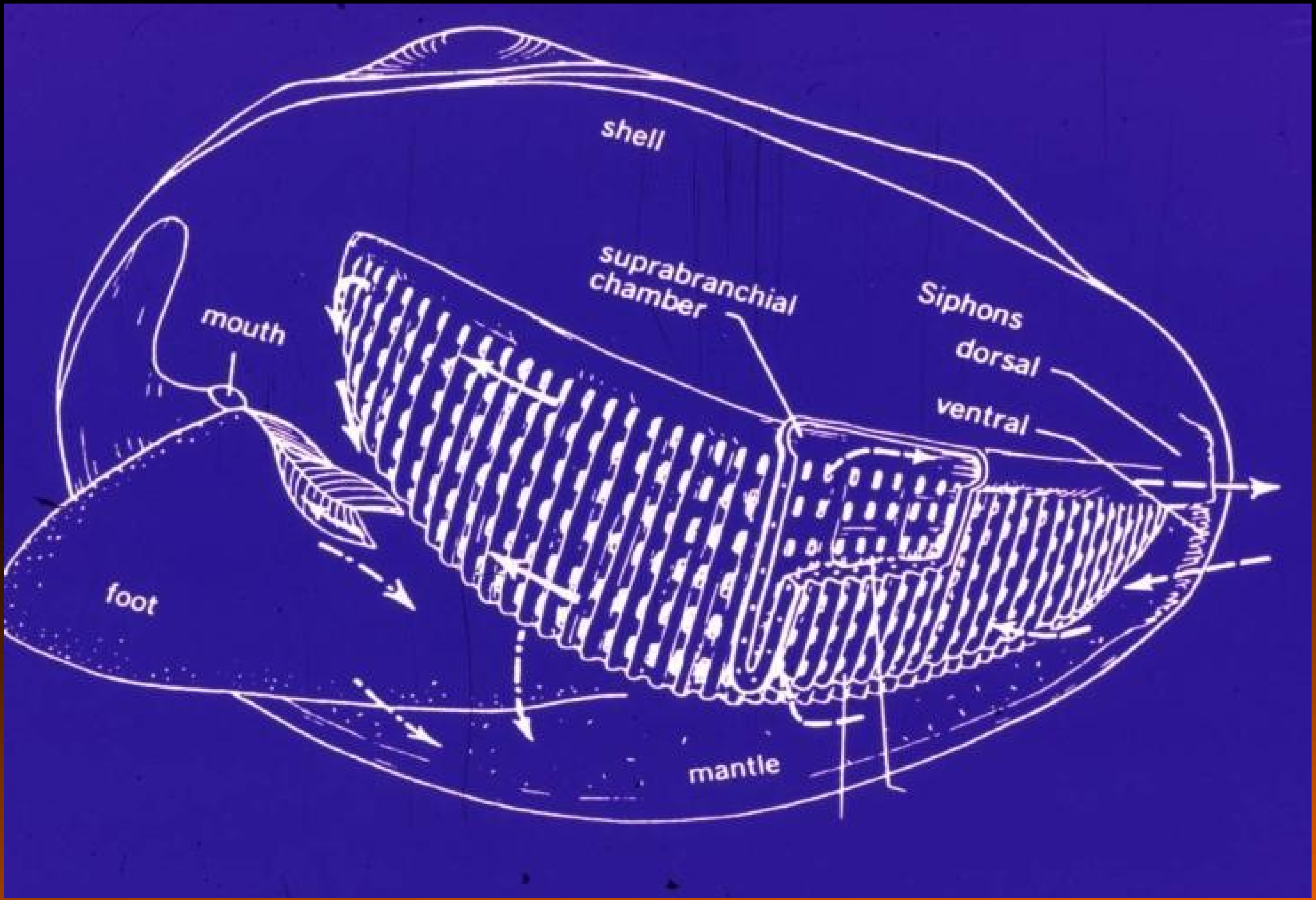
Why are they Important?

What are we doing?

Freshwater Mussels of the Delaware

What are they?

typical bivalve physiology and morphology



... but, Atypical Reproduction

Freshwater Mussel Larvae Require Fish Hosts

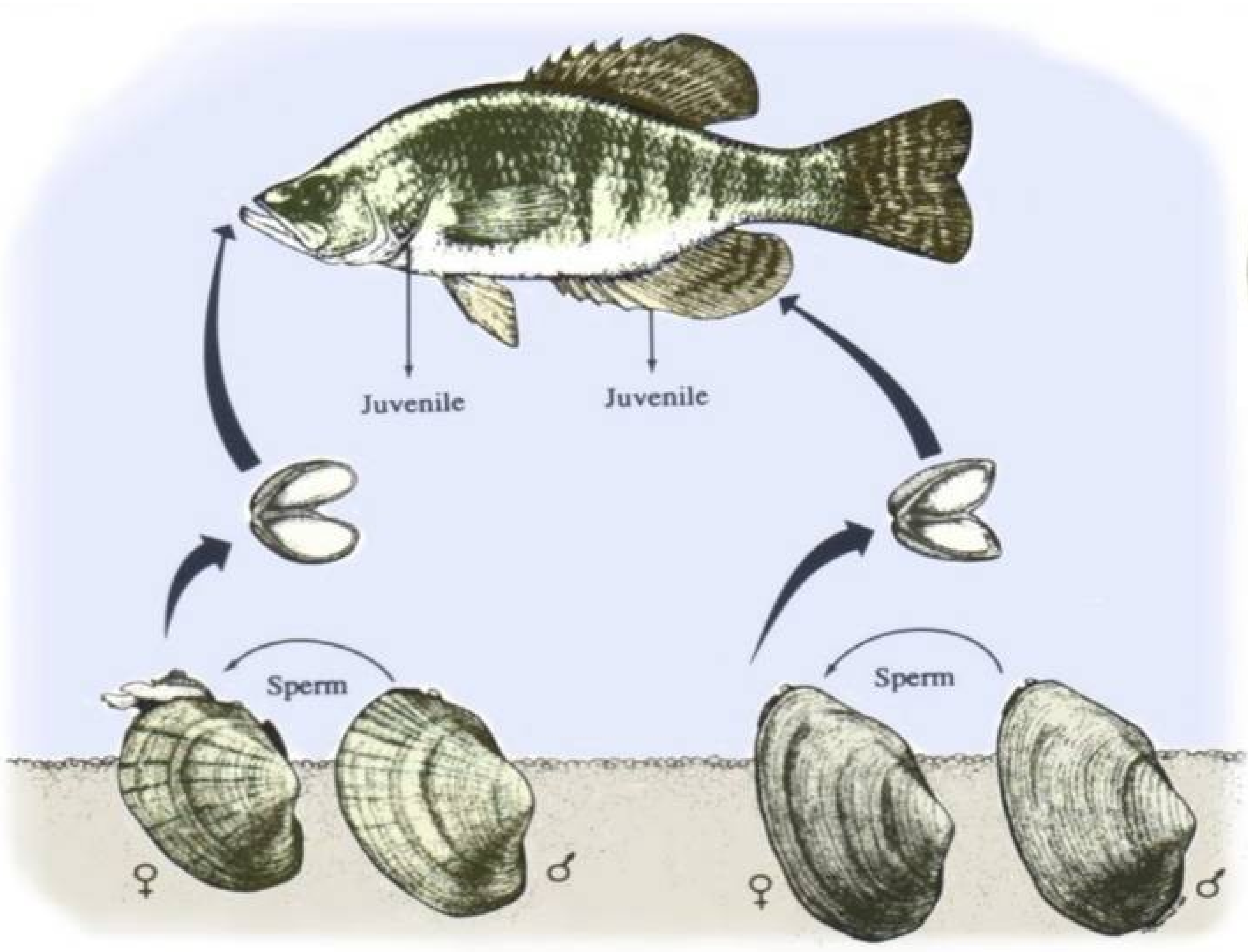
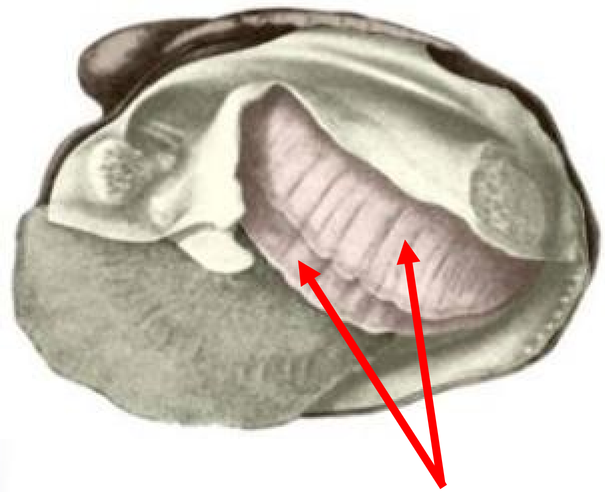


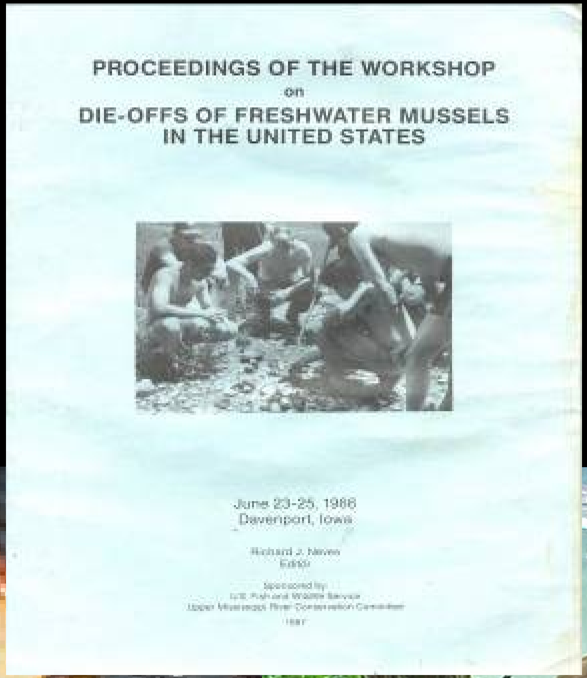
Figure from Cummings and Mayer (1992).



Larvae are brooded in the ctenidia

Most mussels depend on particular fish species

Status and Trends – A Taxa in Decline



PROCEEDINGS OF THE WORKSHOP

on

DIE-OFFS OF FRESHWATER MUSSELS IN THE UNITED STATES

June 23-25, 1986

Davenport, Iowa

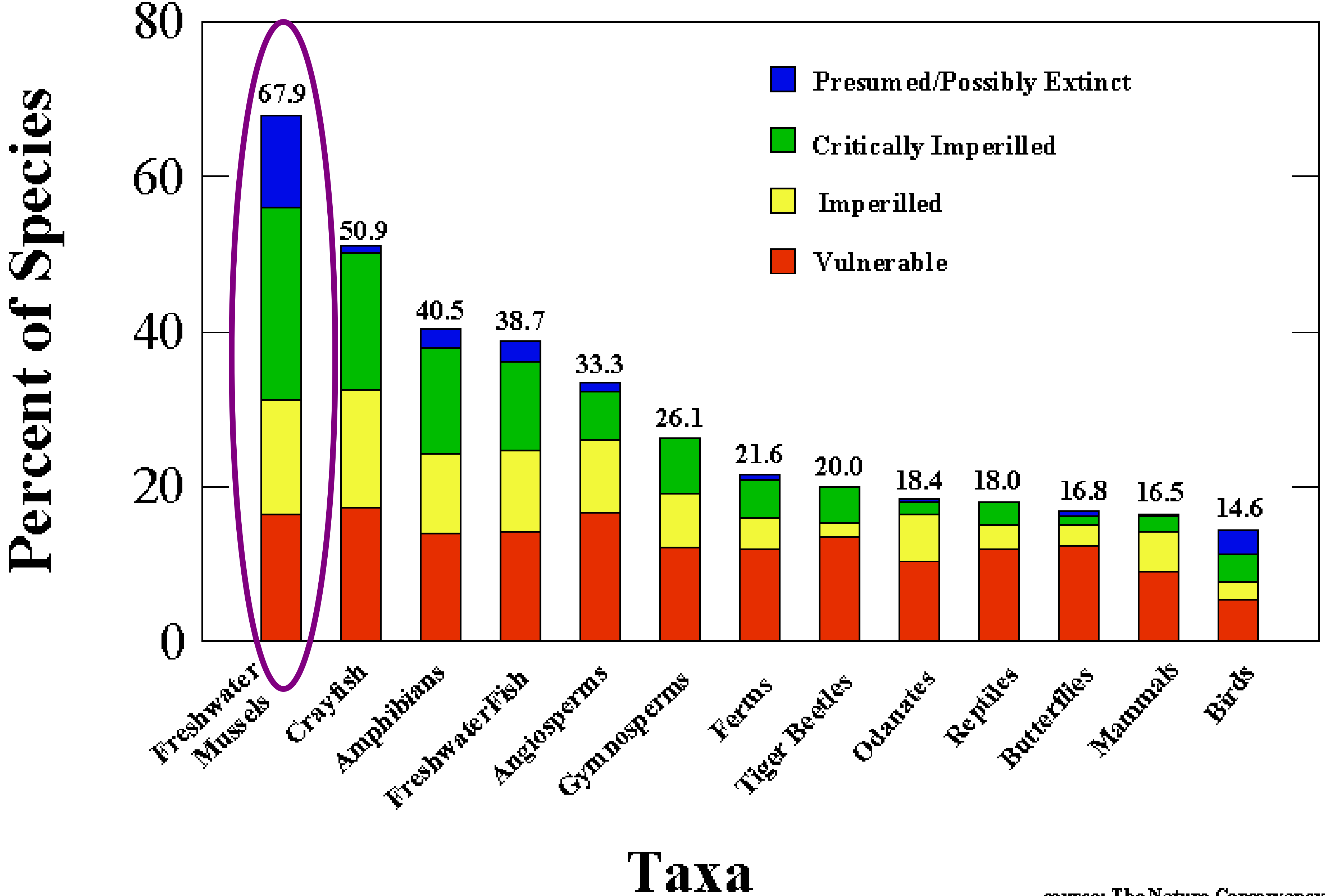
Richard J. Neves

Editor

Biodiversity

Population Biomass

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

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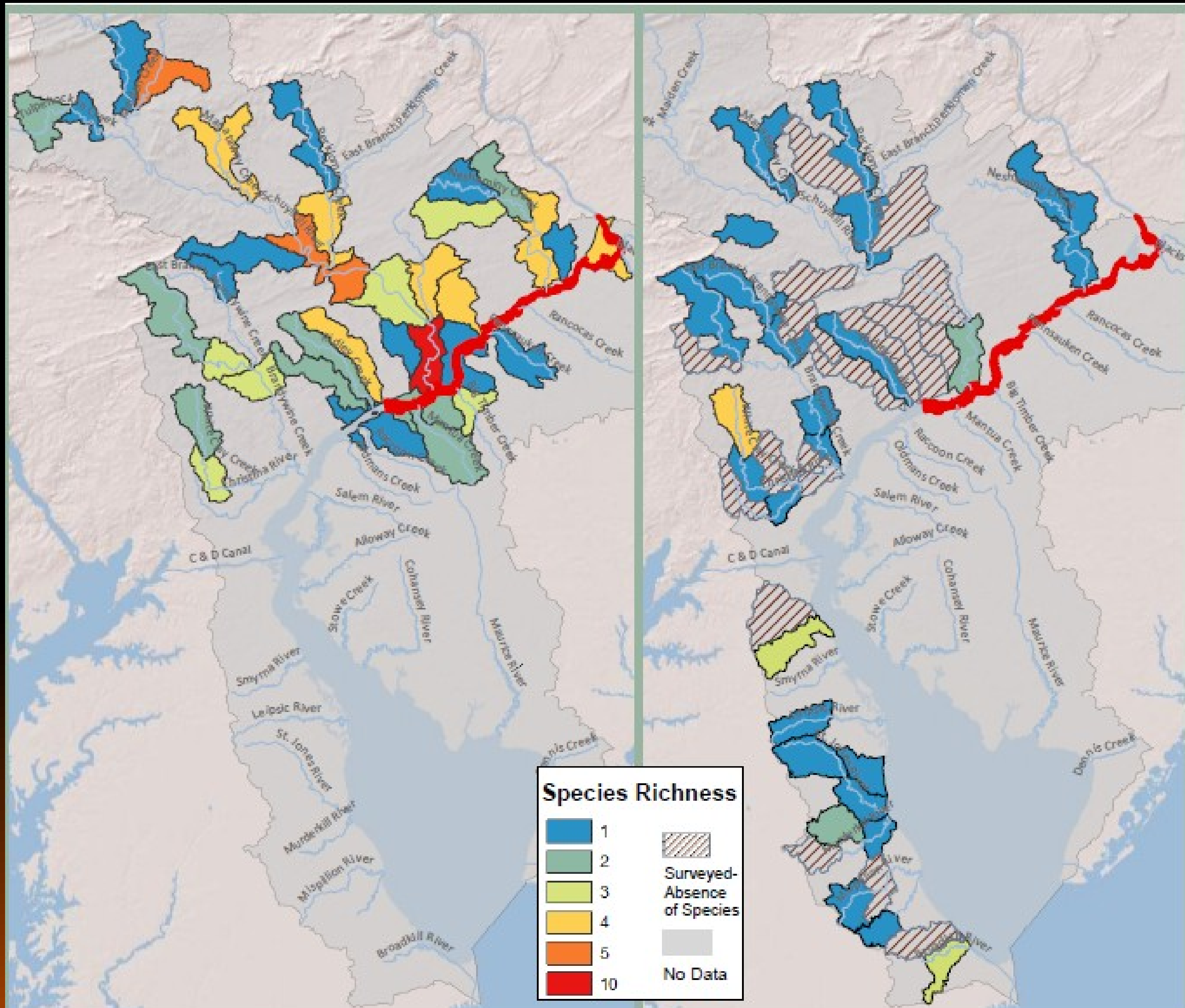
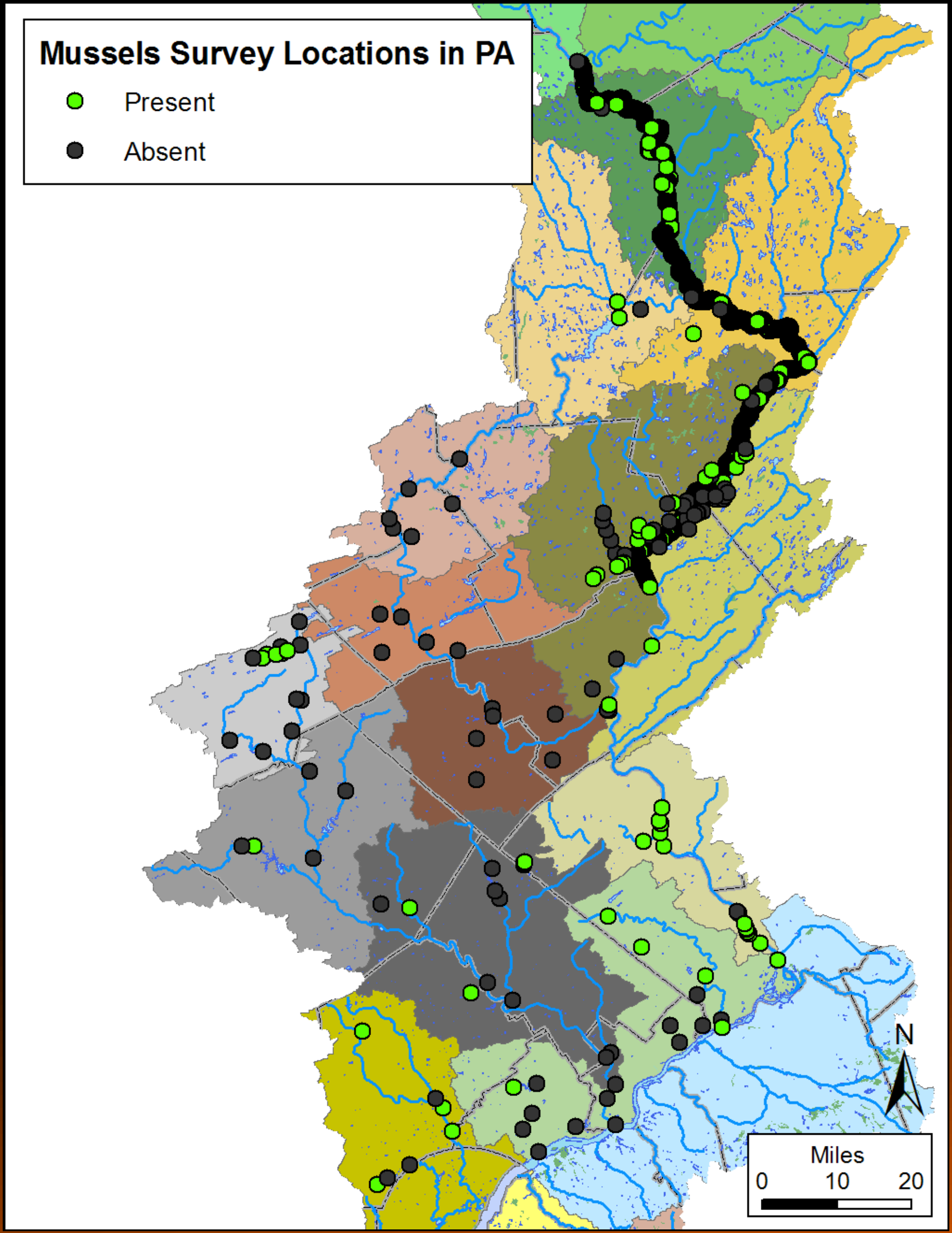
1919

Since 1996



Kreeger


Mussels Survey Locations in PA
Present
Absent
N
Miles
0
10
20

Kreeger

Culprits

Water Quality

Habitat Loss and Degradation

Photo by D. Kreeger

Exotic Species

Ecological Magic - 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

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Nature's Benefits

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Bivalve Shellfish are "Ecosystem Engineers"

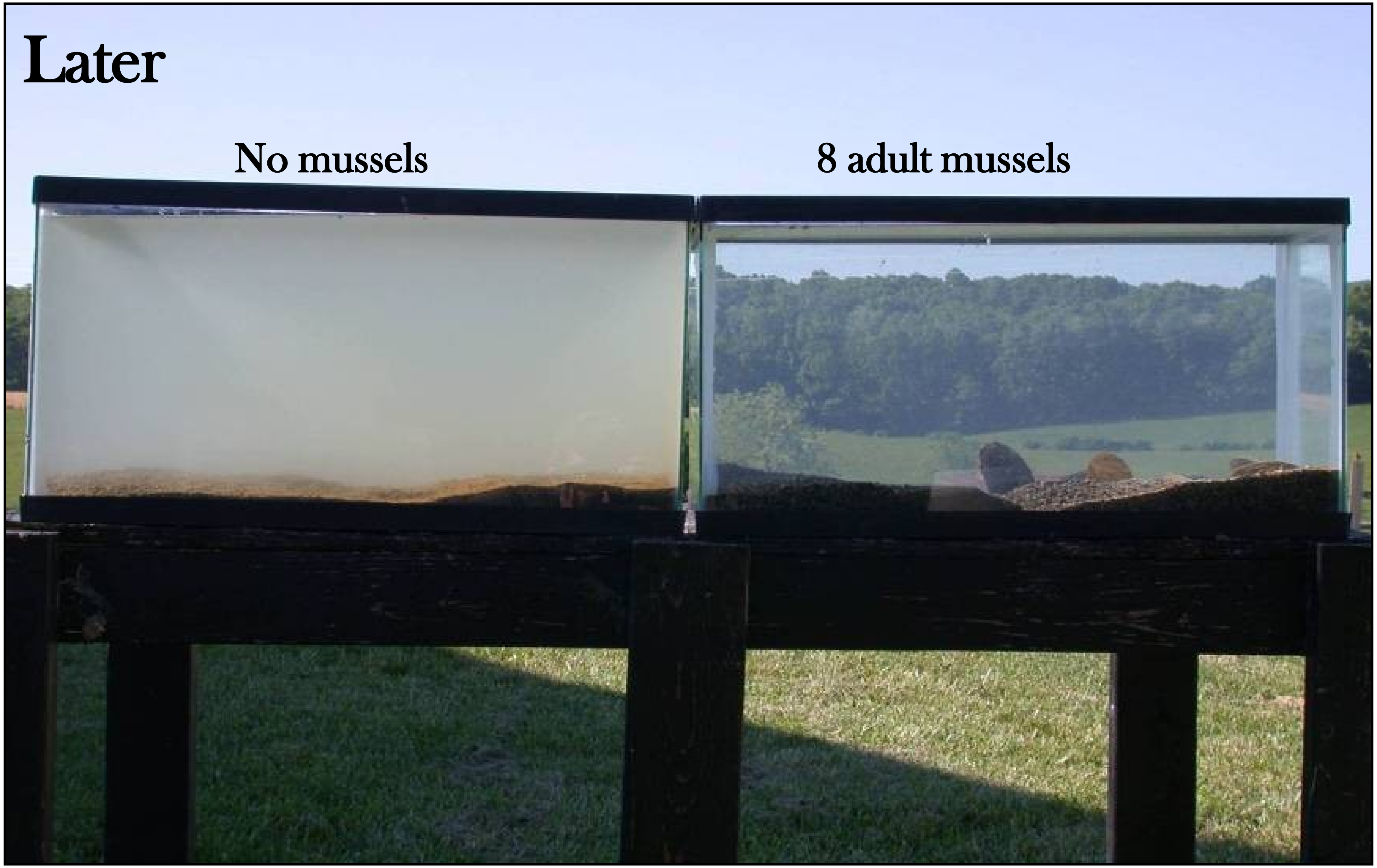
Mussels Are Habitat INITIATIVE Restoring Our Nation's Water Quality

Biofiltration Potential

Slide from Dick Neves, VA Tech

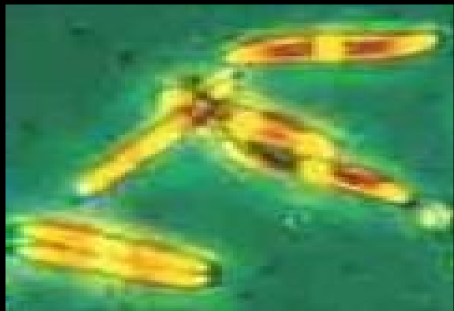
Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

Biofiltration Potential



Slide from Dick Neves, VA Tech

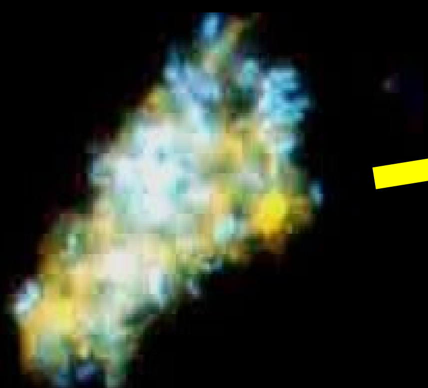
Natural Diets and Particle Type Selection



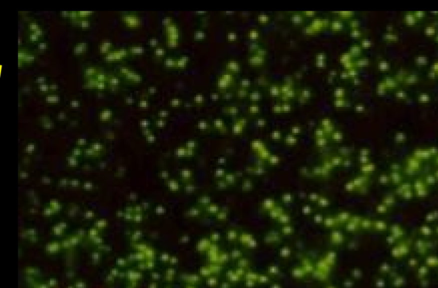
Pennate Diatoms

Phytoplankton

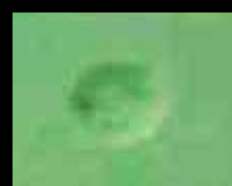
Centric Diatoms



Detritus Complex



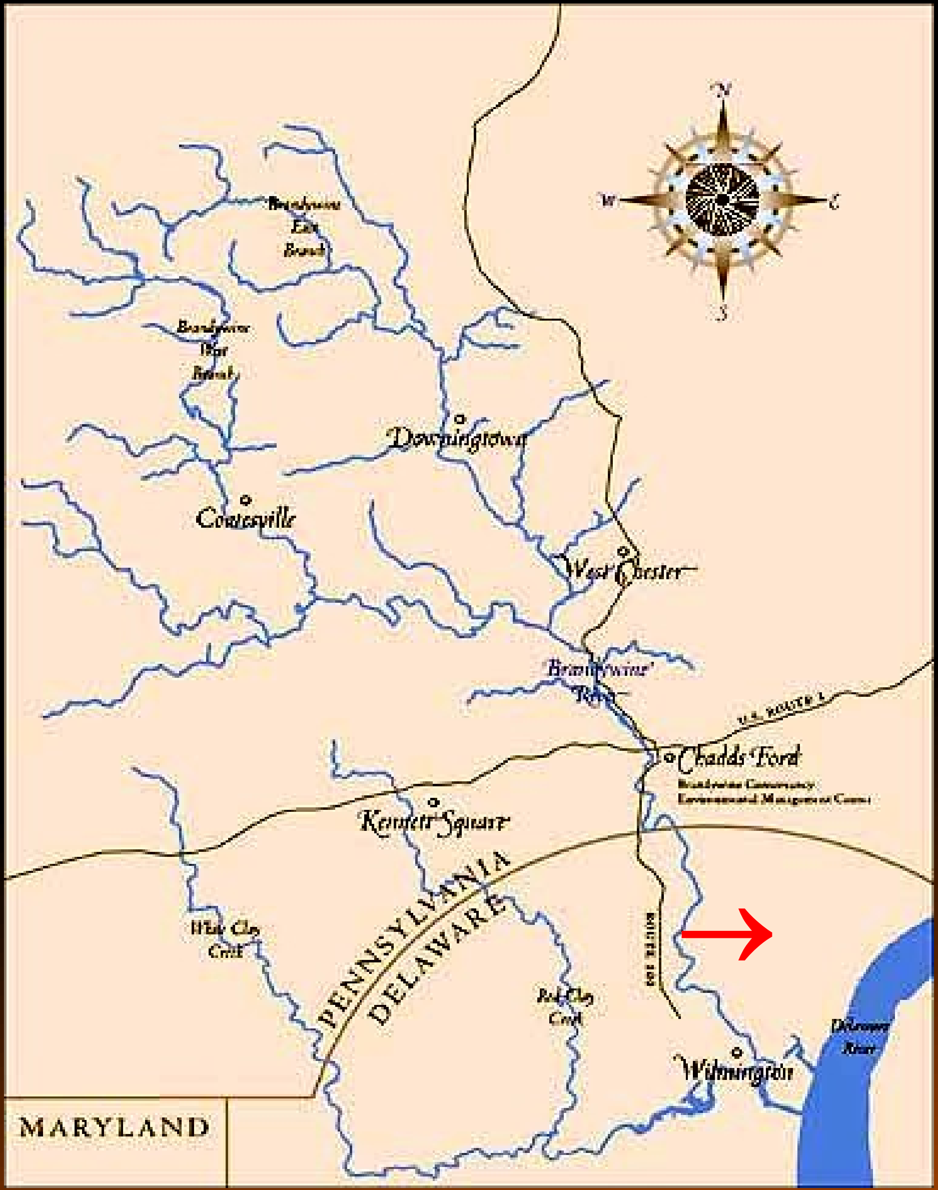
Bacteria



Heterotrophic Protists

Brandywine River

Studied 2000 - present



Map from The Brandywine River Conservancy

Elliptio complanata

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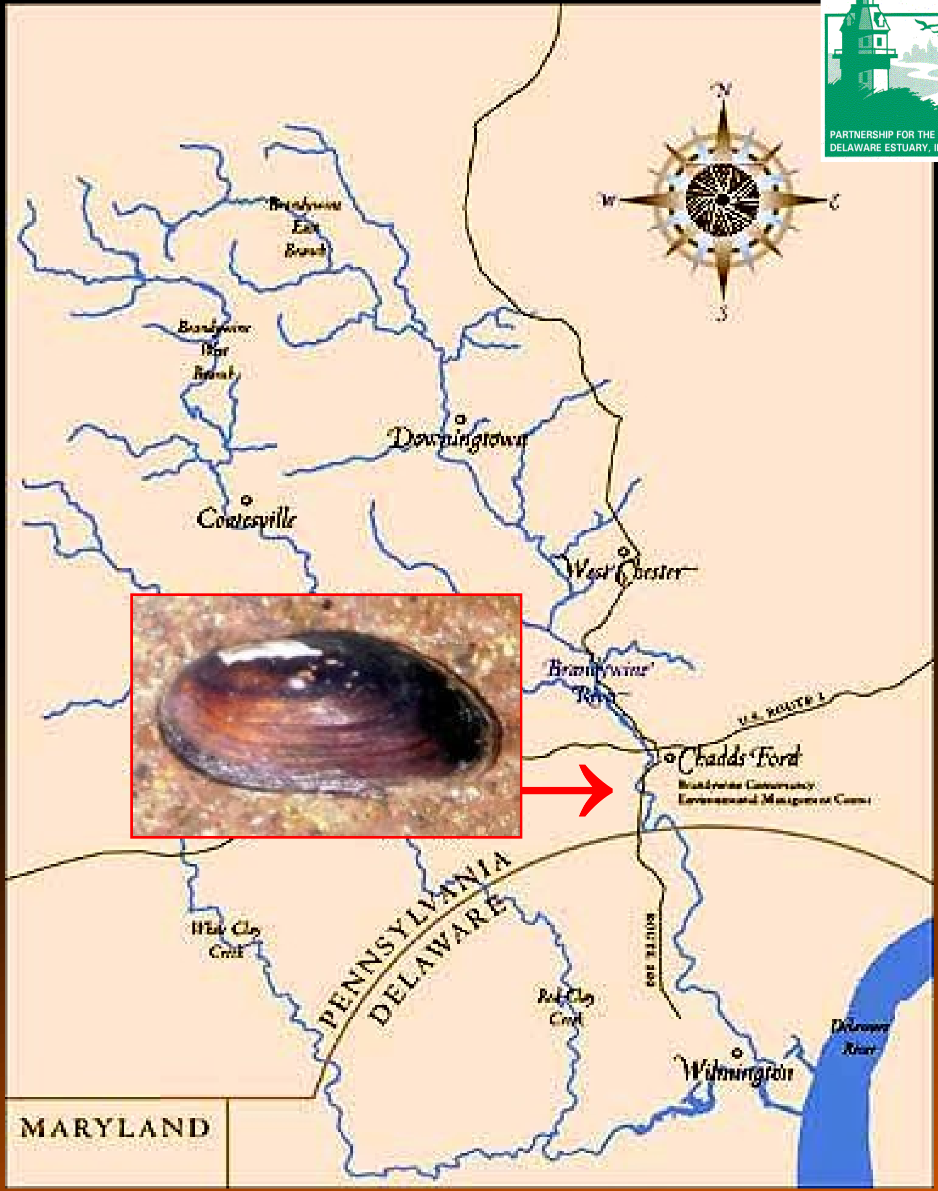
One Mussel Bed in a 6 mile reach of the Brandywine River

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

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Kreeger

Elliptio complanata

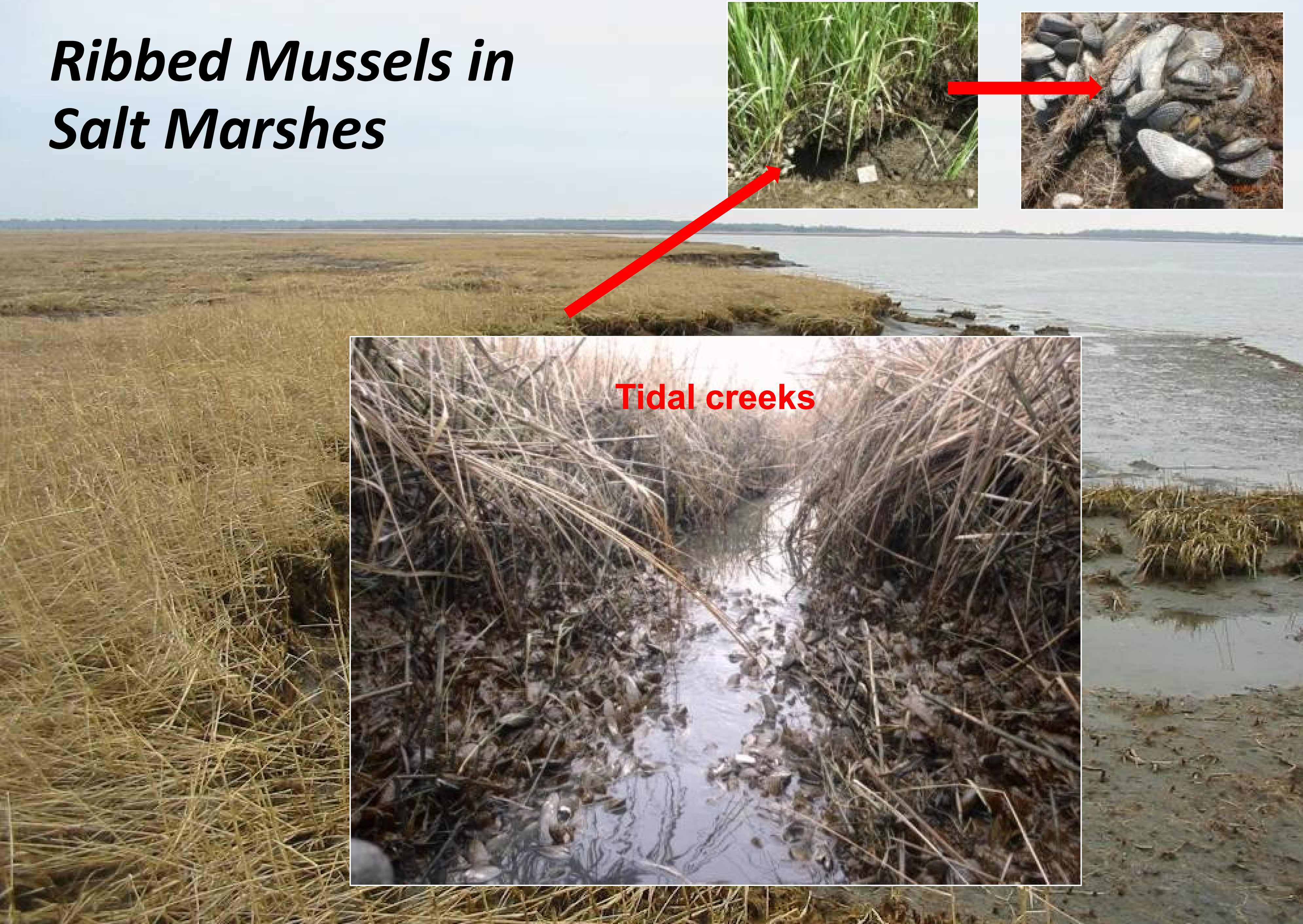
Geukensia demissa

Crassostrea virginica

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Kreeger

Ribbed Mussels in Salt Marshes



PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Kreeger

Ribbed Mussels in Salt Marshes

208,000 per hectare on average

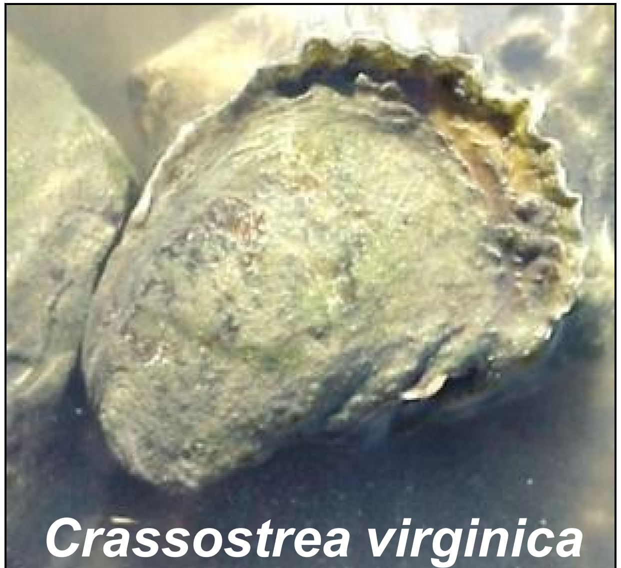
10.5 Billion *Geukensia*

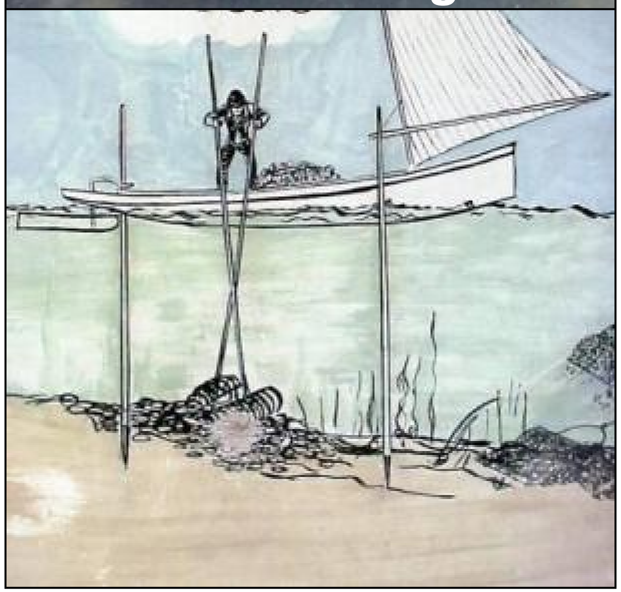
Clearance Rate = 5.1 L h-1 g-1 *(DK data)*

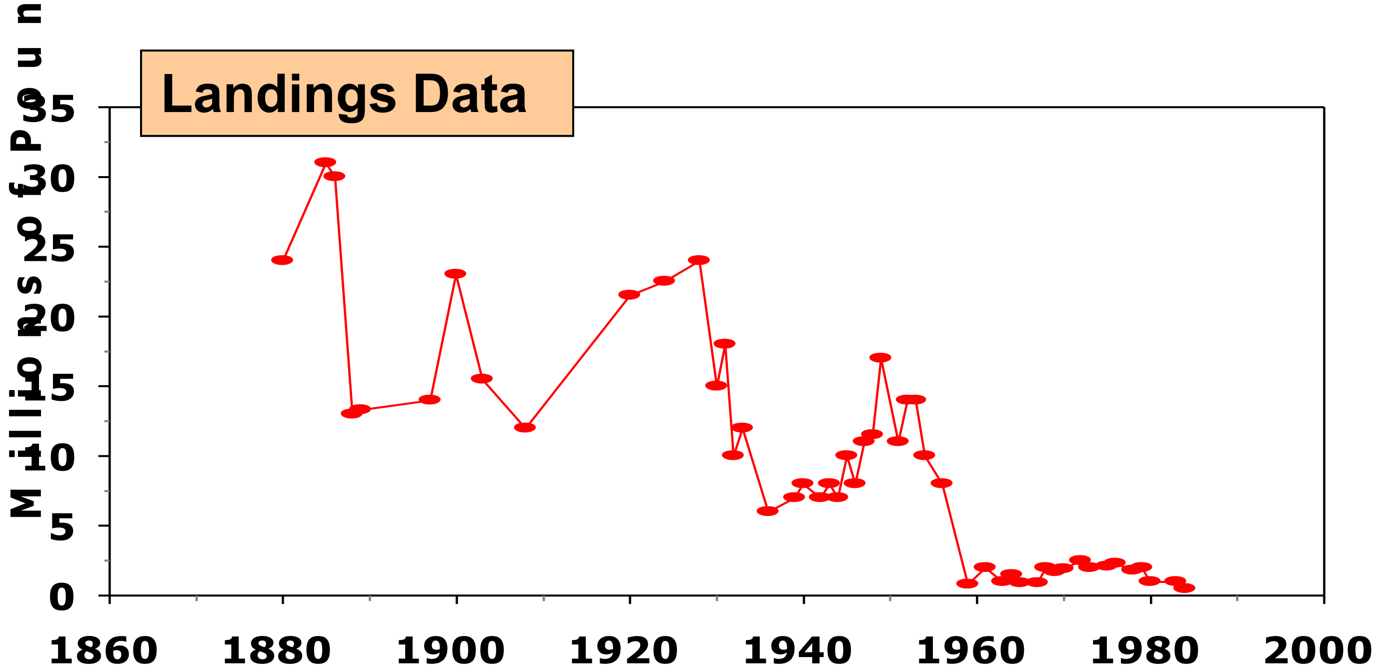
11.7 Million Kilos Dry Tissue Weight *(DK)*

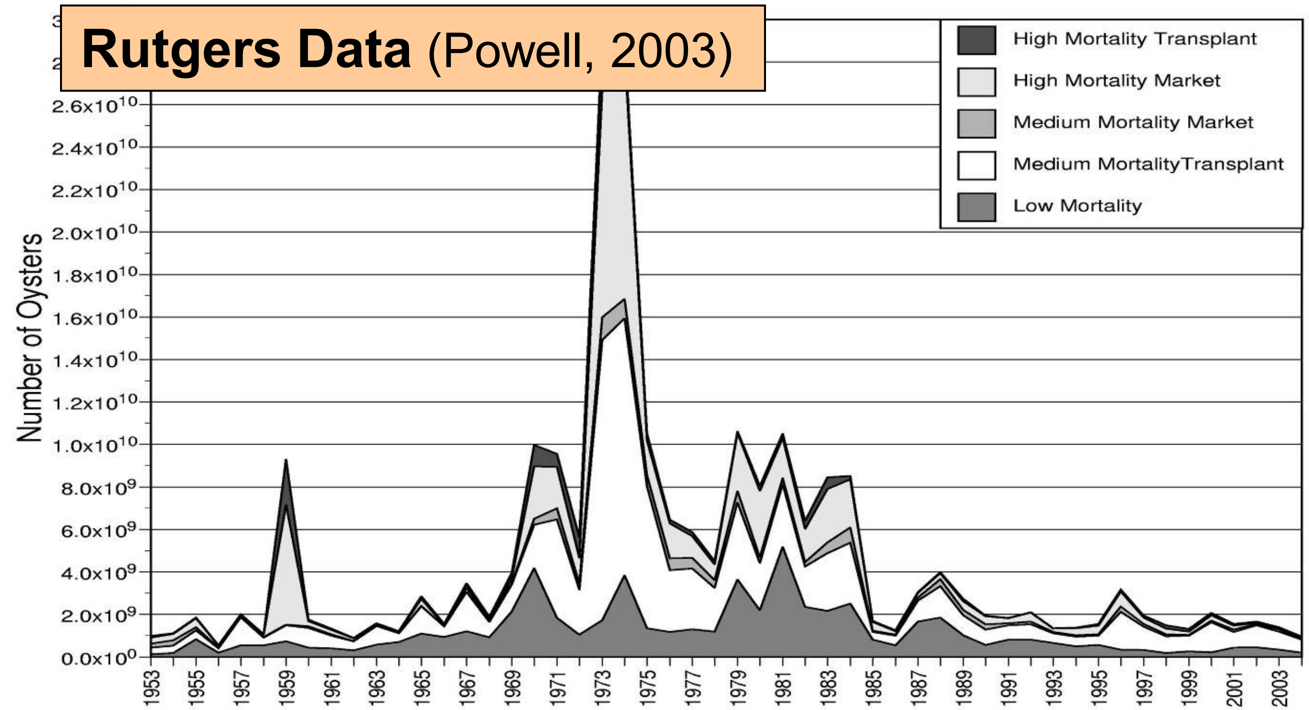
= 59.0 Billion Liters per Hour

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
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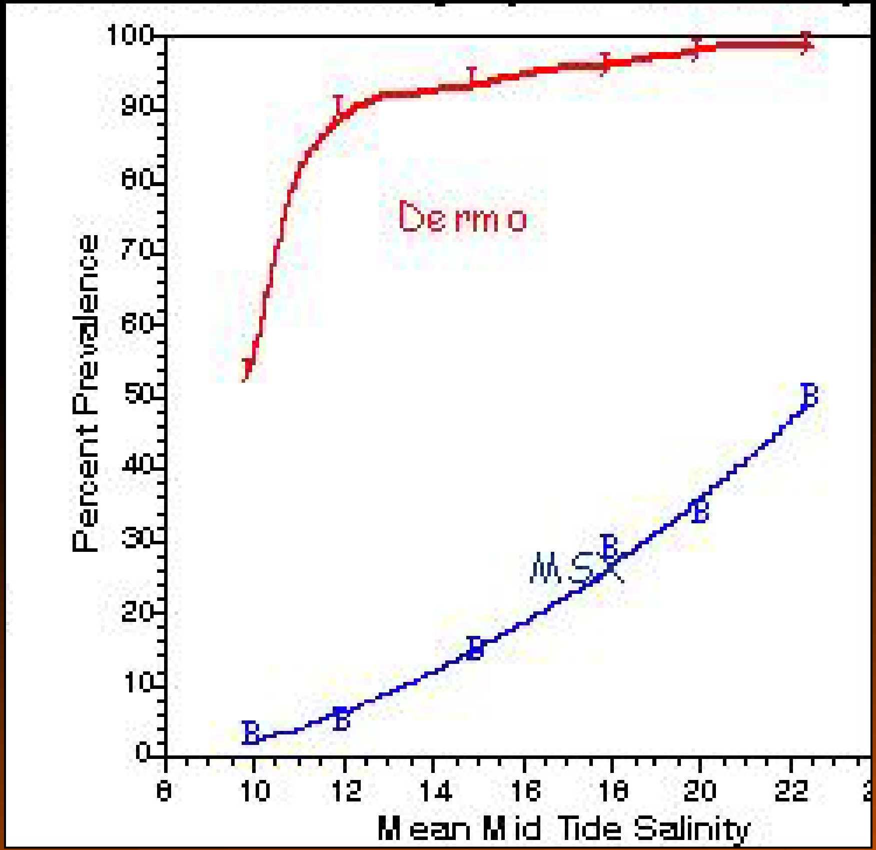
2001
2003

Bivalves – Issues

Oyster Disease and Salinity




www.livingclassrooms.org/lbo/dermo/oyster2.jpg

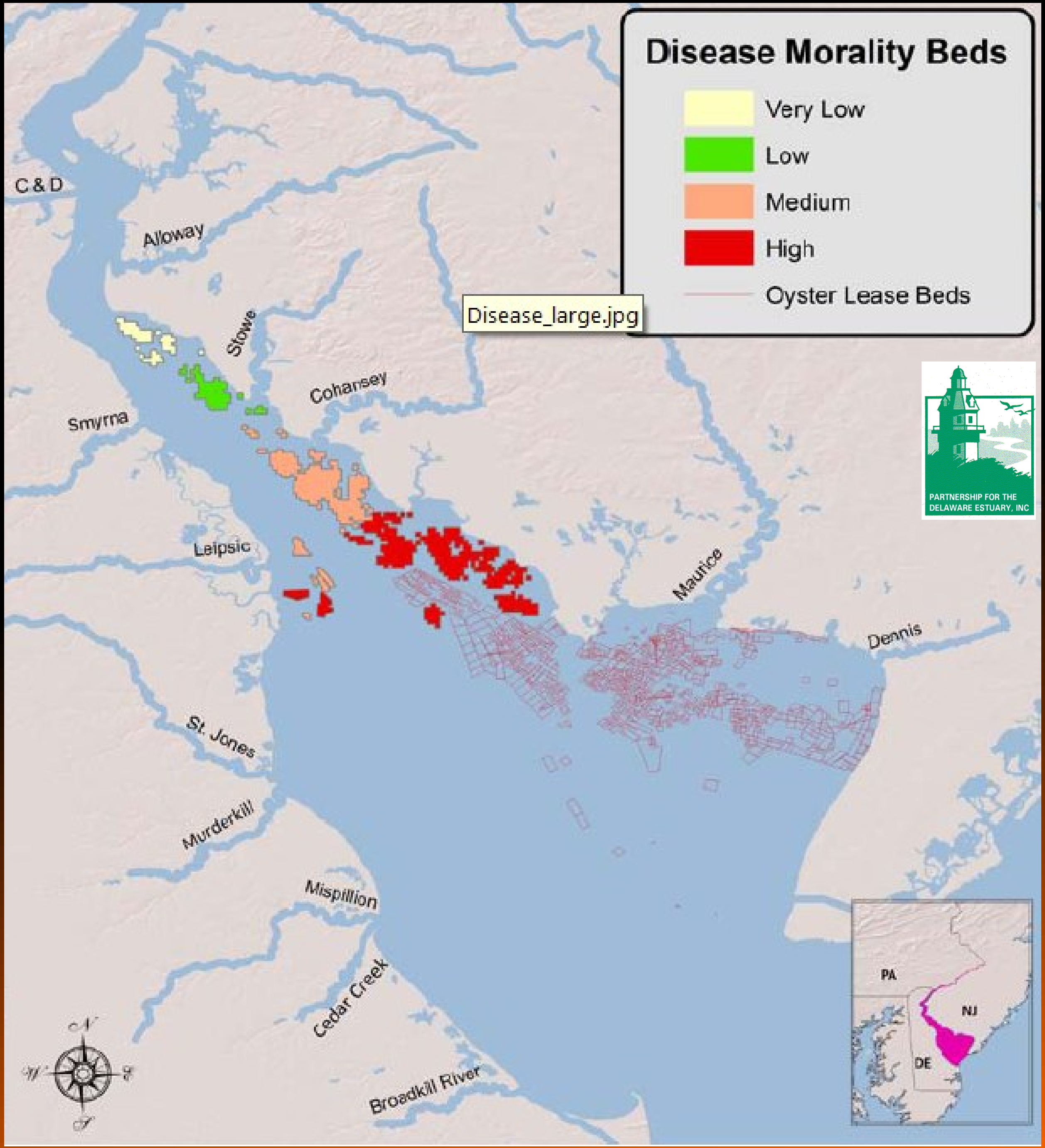
Oysters

Present Population:
~ 2 billion oysters

PDE Supports Oyster Restoration

<u>Challenges</u>:

- Disease
- Industry Tradeoffs
- Human Health Mgt
- Climate Change
  - ↑ salinity
  - ↓ suitable bottom



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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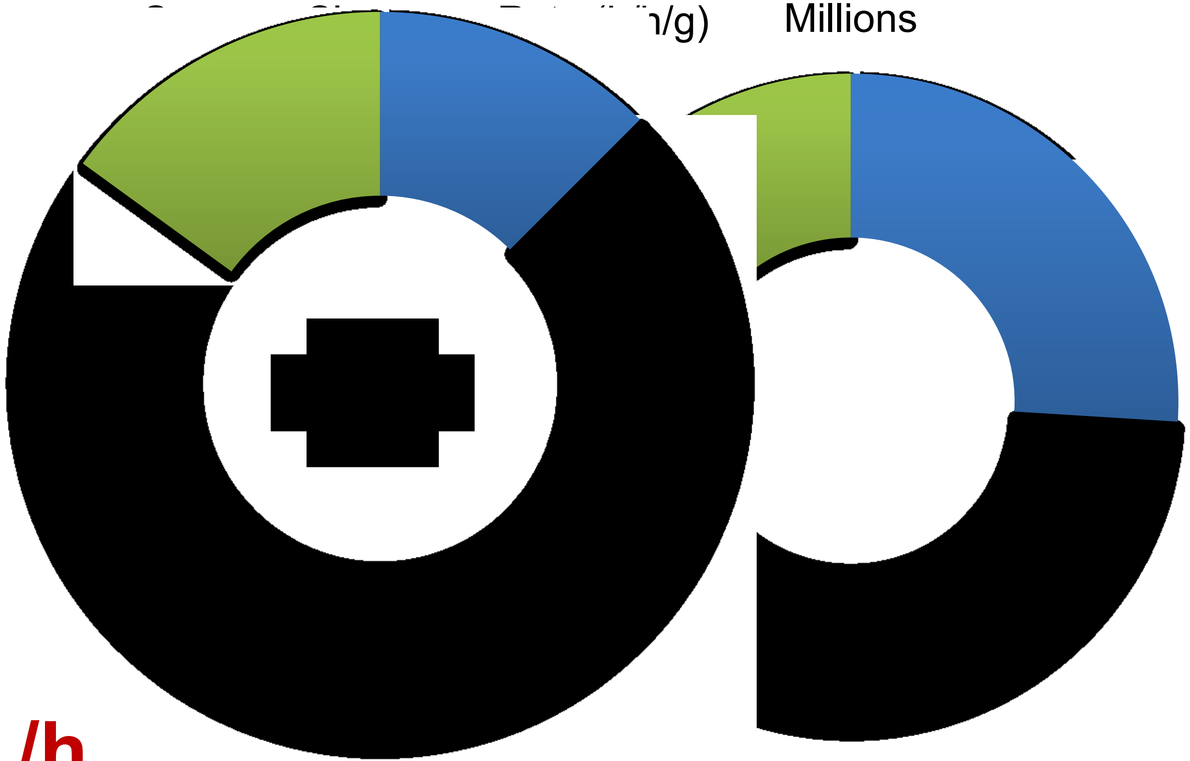
Kreeger

Population-level Water Processing



= 80 Billion L/h

Freshwater Mussel

Marsh Mussel

Oyster

Bio-filtration

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

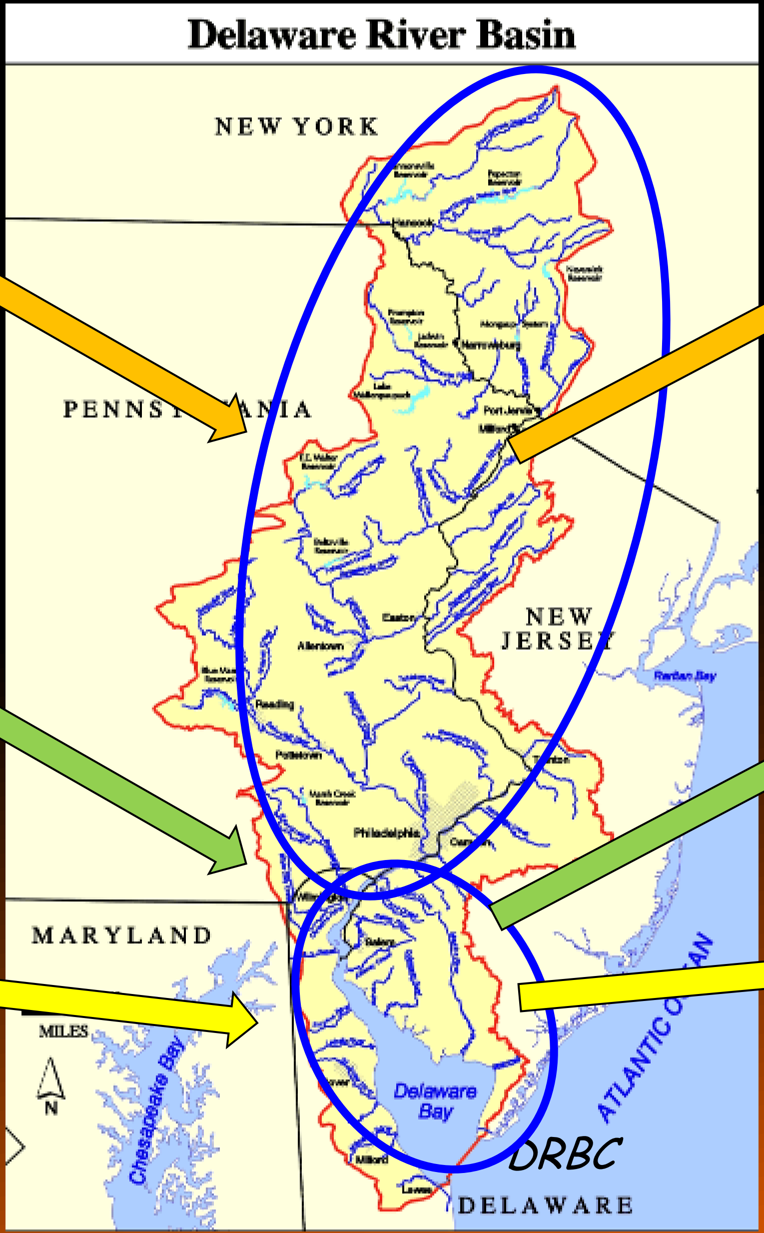
- We need to estimate carrying capacity for current future bivalves and not just look at the past

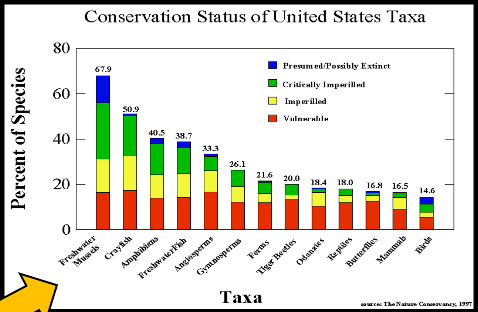
Shellfish Vulnerability

Freshwater Mussels

Marine Mussels

Oysters





Imperiled

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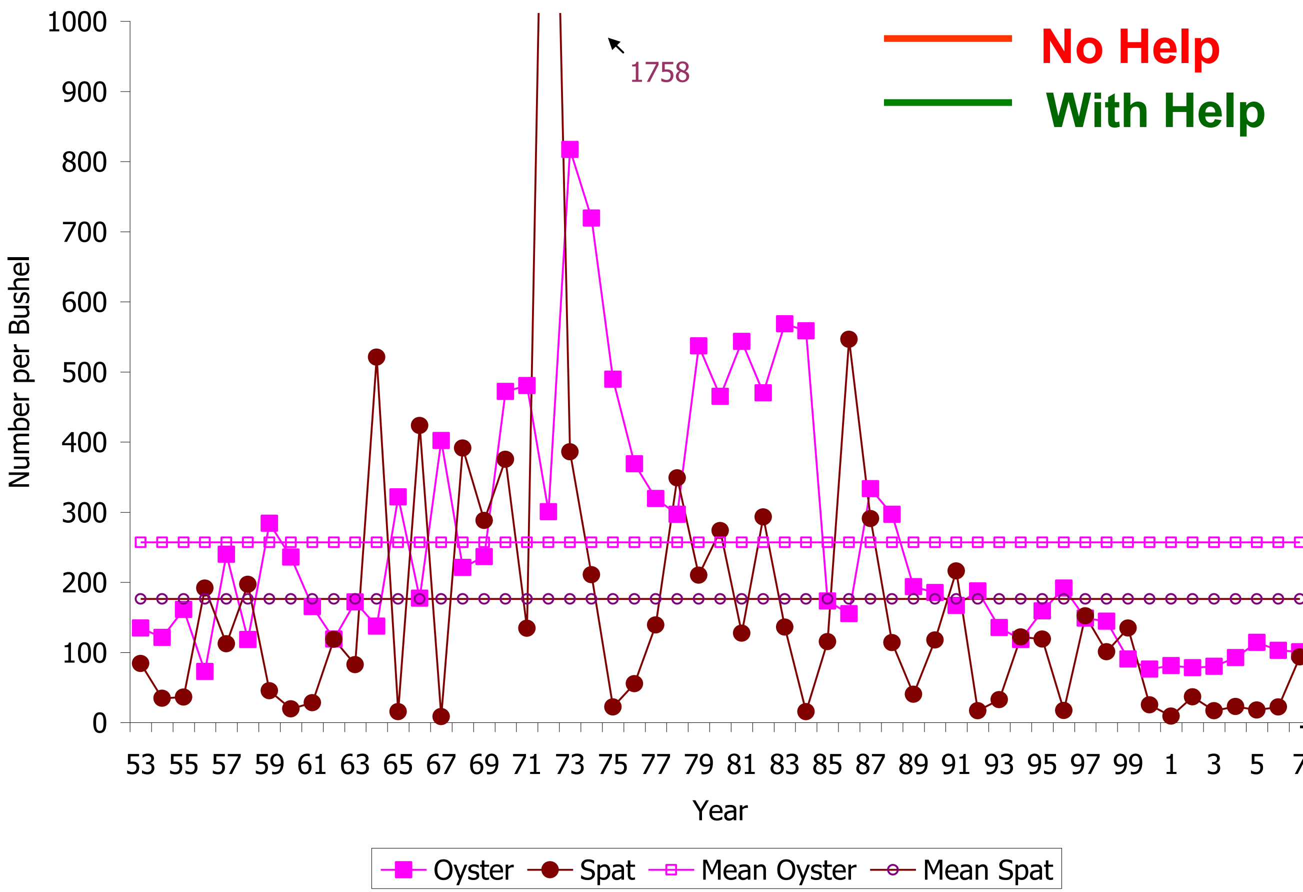
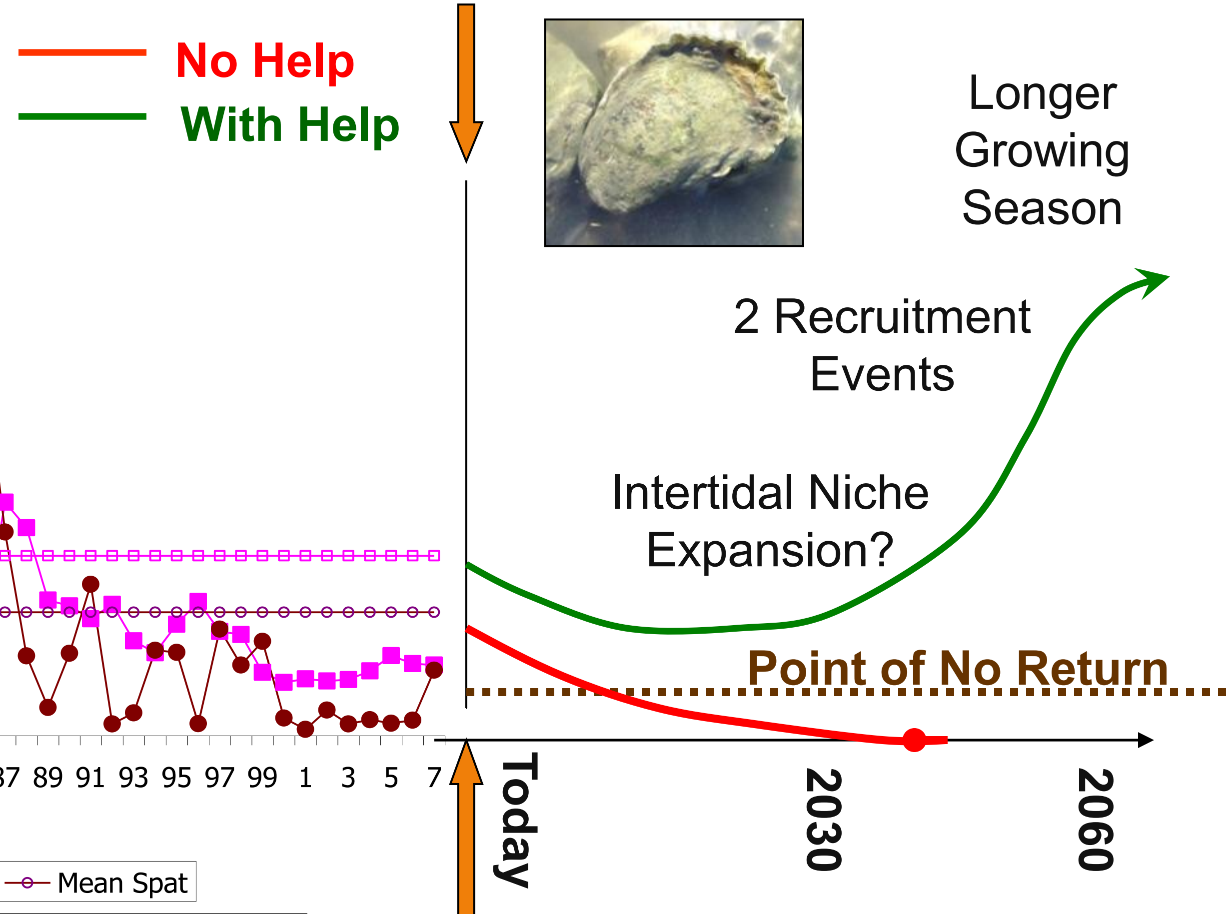
Losing Habitat

Salt water

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**
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**

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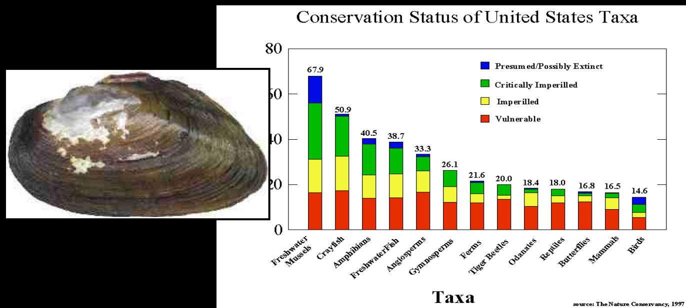
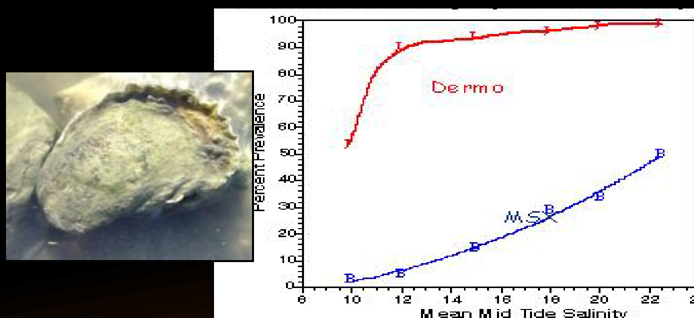
Impacts Depend on Species and Location



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



Oysters: disease and salinity

Ribbed Mussels: losing marsh habitat

Options for Making Shellfish More Resilient

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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-stream and/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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Shellplanting of 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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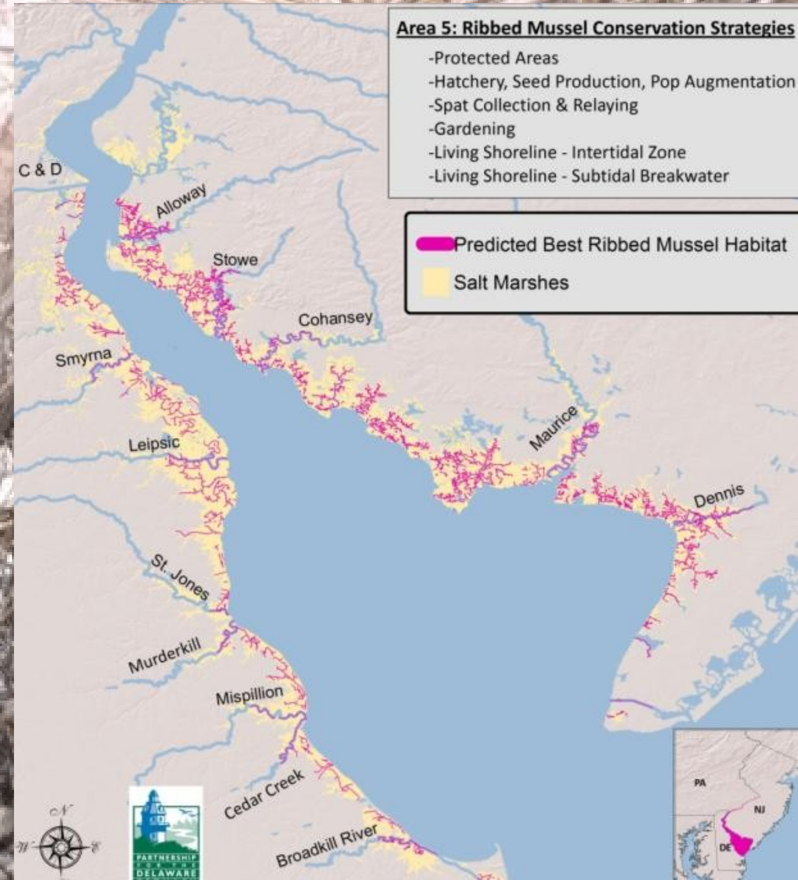
Kreeger

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

Freshwater Mussels

Elliptio complanata

4.3 Billion *Elliptio* *(DK estimate)*
2.9 Million Kilos Dry Tissue Weight *(DK)*

= 9.8 Billion Liters per Hour

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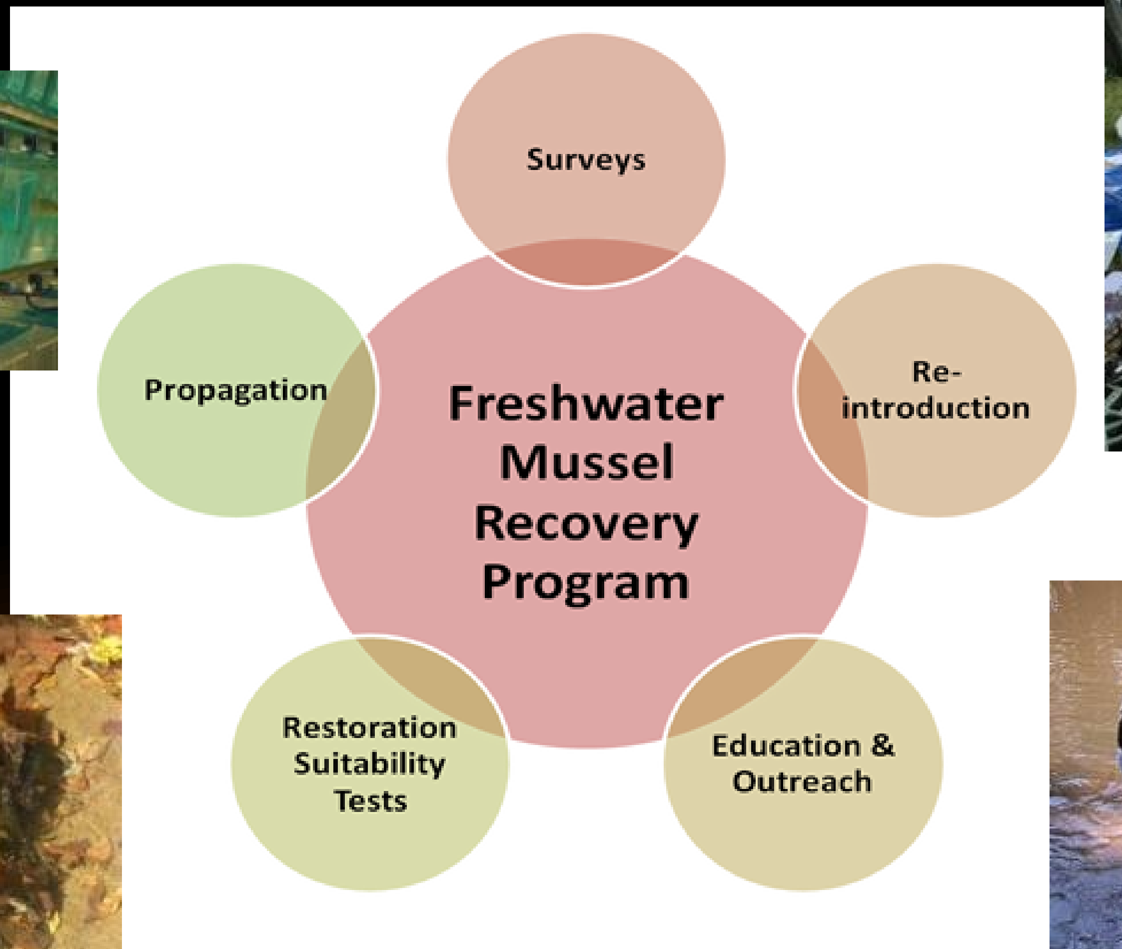
Kreeger

Freshwater Mussel Recovery Program



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

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Surveys to Fill Data Gaps

PDE, ANSP, PWD

Main Line Health

Health & Science

MONDAY, JANUARY 17, 2011 · The Philadelphia Inquirer

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.

Propagation and Reintroduction

USFWS & Cheyney Hatcheries

Fish Infestation

Fish from USGS, Academy of Natural Sciences

Larval Transformation Into Juveniles

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Propagation and Reintroduction

Propagated Juveniles

Photos, R. Neves, VA Tech

Reintroduction of Tagged Mussels

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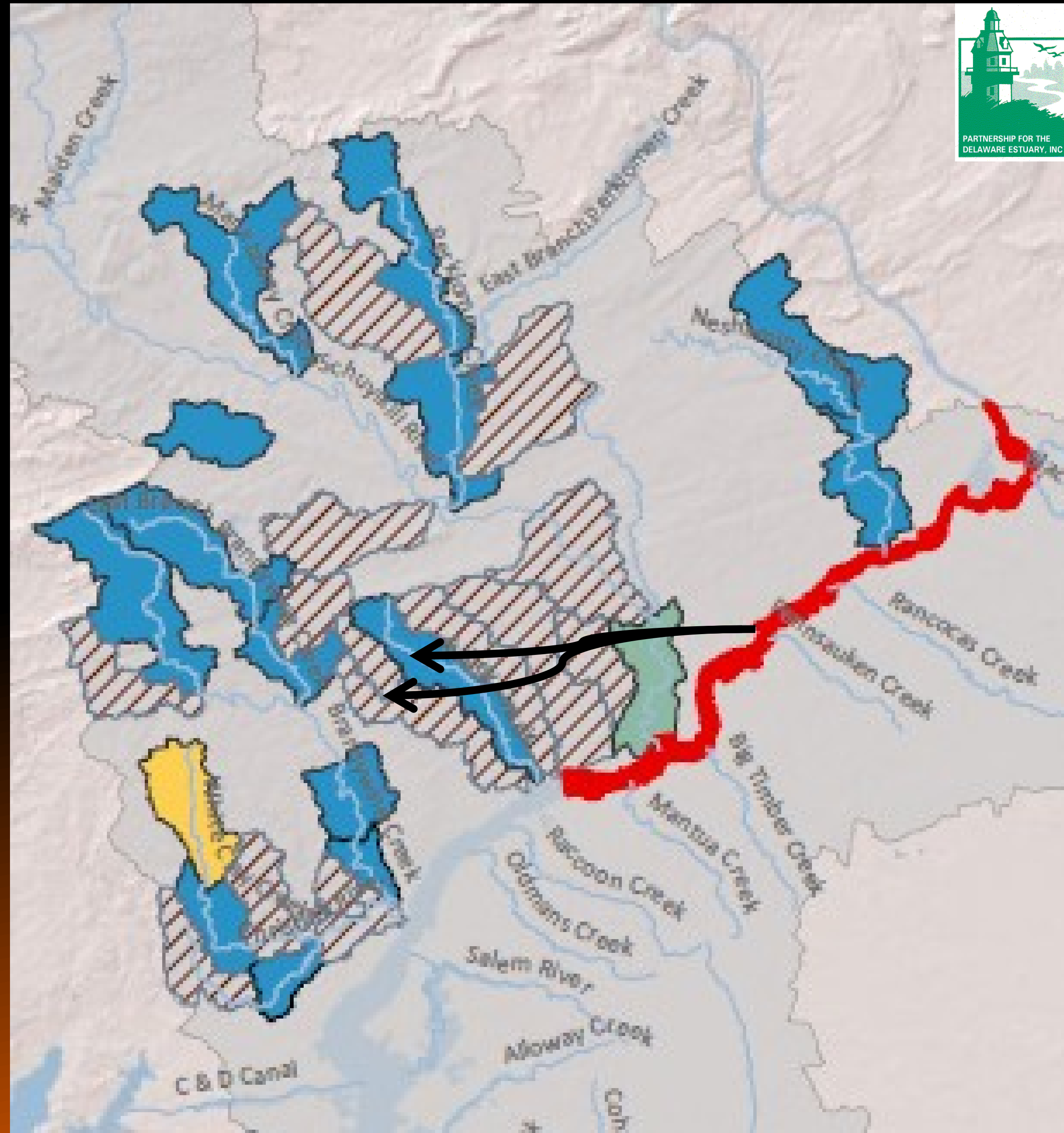
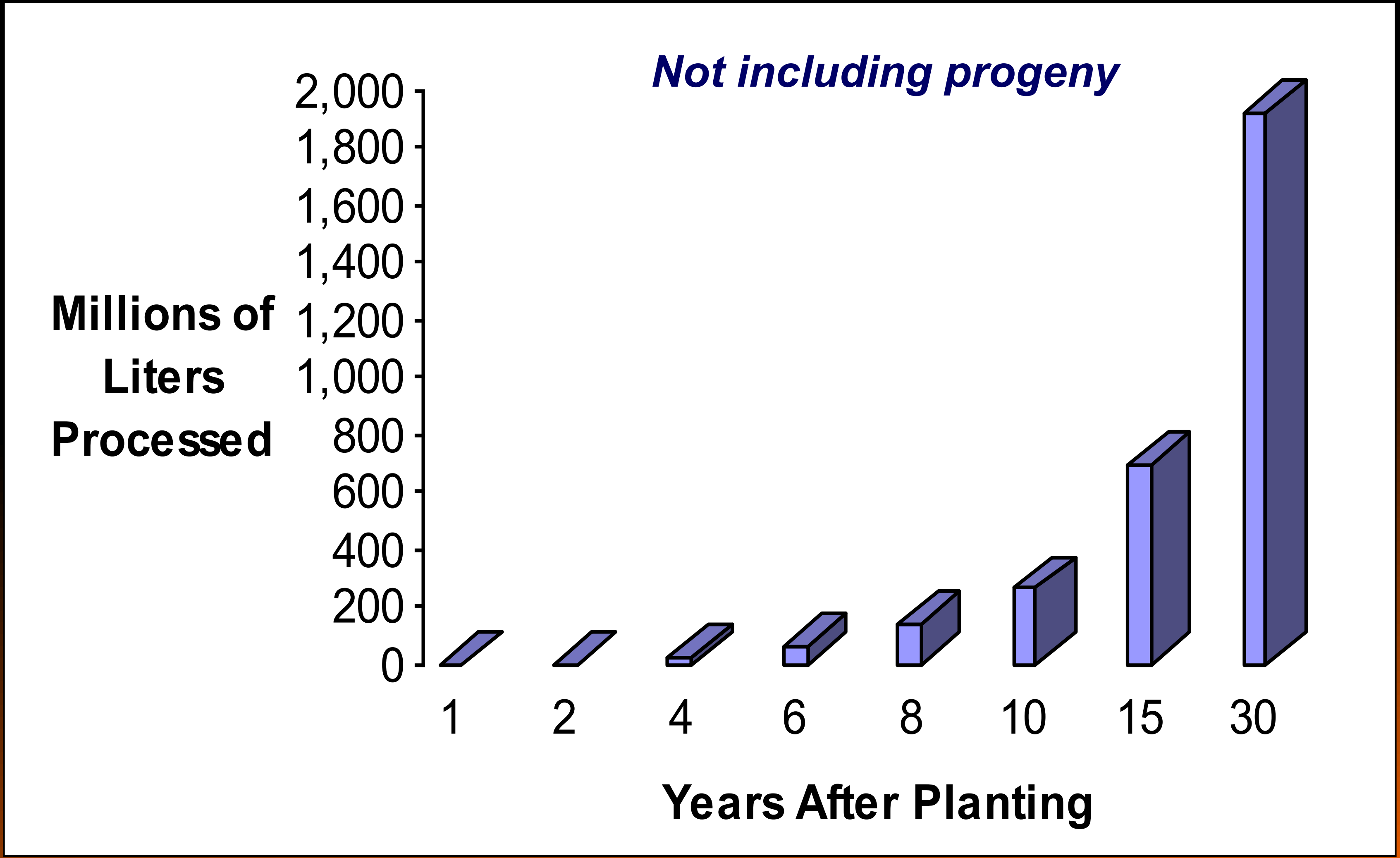
Pyganodon cataracta

Elliptio complanata



Freshwater Mussel Recovery Program

Goals Based on Ecosystem Services



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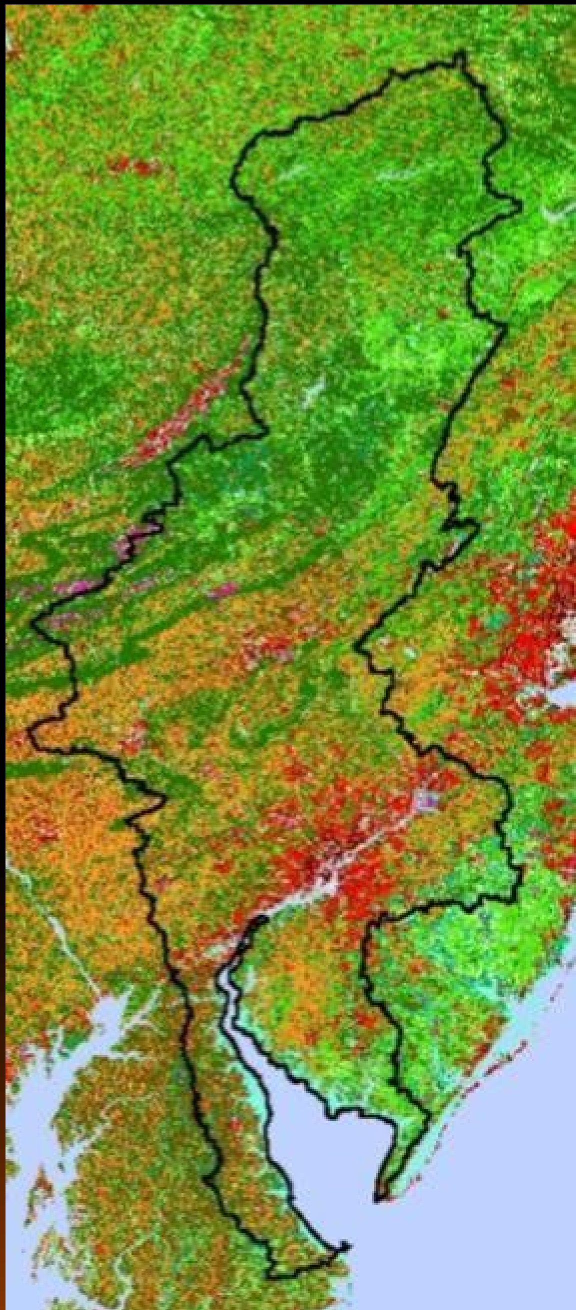
Kreeger



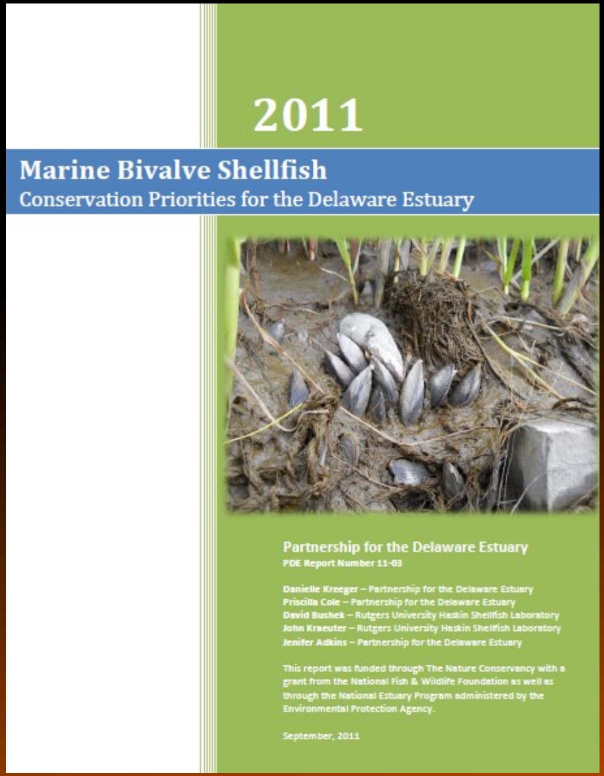
Desired Watershed Condition:

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.

Restoration for the Future = Climate Adaptation

Headwaters to Sea

1. Non-tidal
2. Intertidal
3. Subtidal


2011

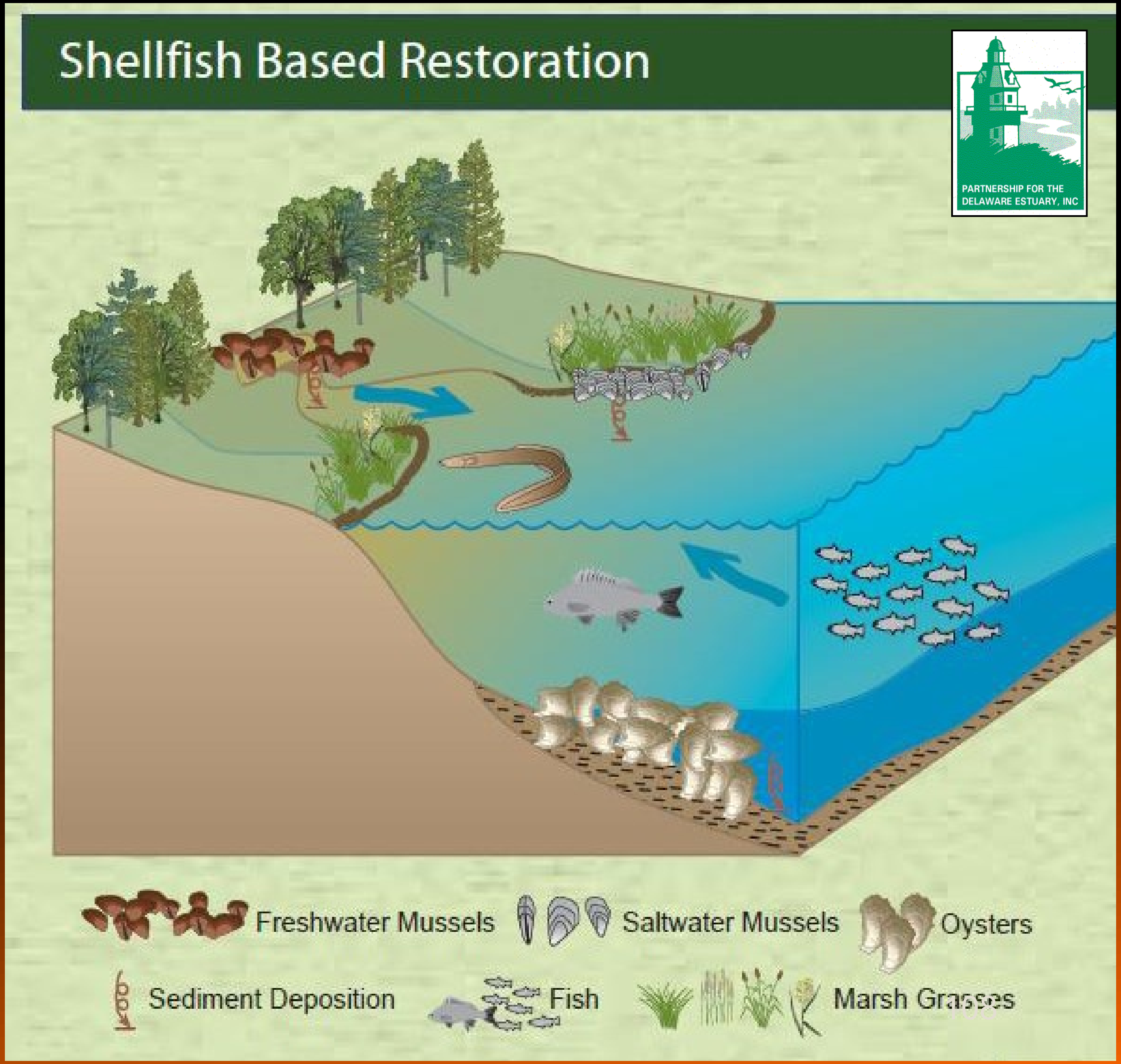
Marine Bivalve Shellfish
Conservation Priorities for the Delaware Estuary

Partnership for the Delaware Estuary
PDE Report Number 11-03

Danielle Kreeger – Partnership for the Delaware Estuary
Priscilla Cole – Partnership for the Delaware Estuary
David Bushek – Rutgers University Haskin Shellfish Laboratory
John Kraeuter – Rutgers University Haskin Shellfish Laboratory
Jenifer Adkins – Partnership for the Delaware Estuary

This report was funded through The Nature Conservancy with a grant from the National Fish & Wildlife Foundation as well as through the National Estuary Program administered by the Environmental Protection Agency.

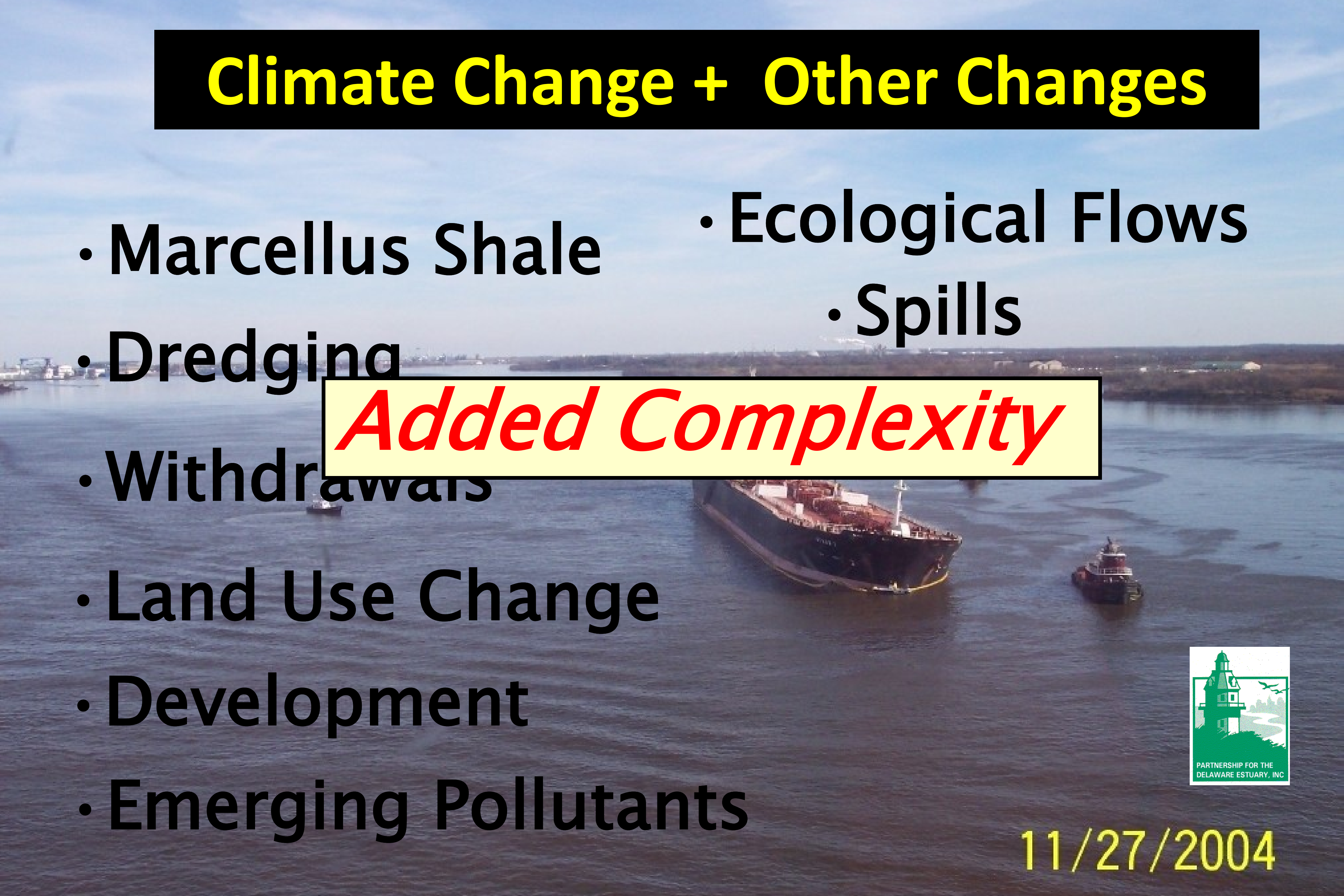
September, 2011



Climate Change + Other Changes

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

Added Complexity



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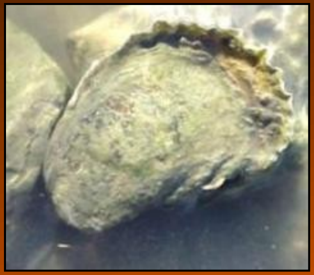
Take Home Messages

- 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

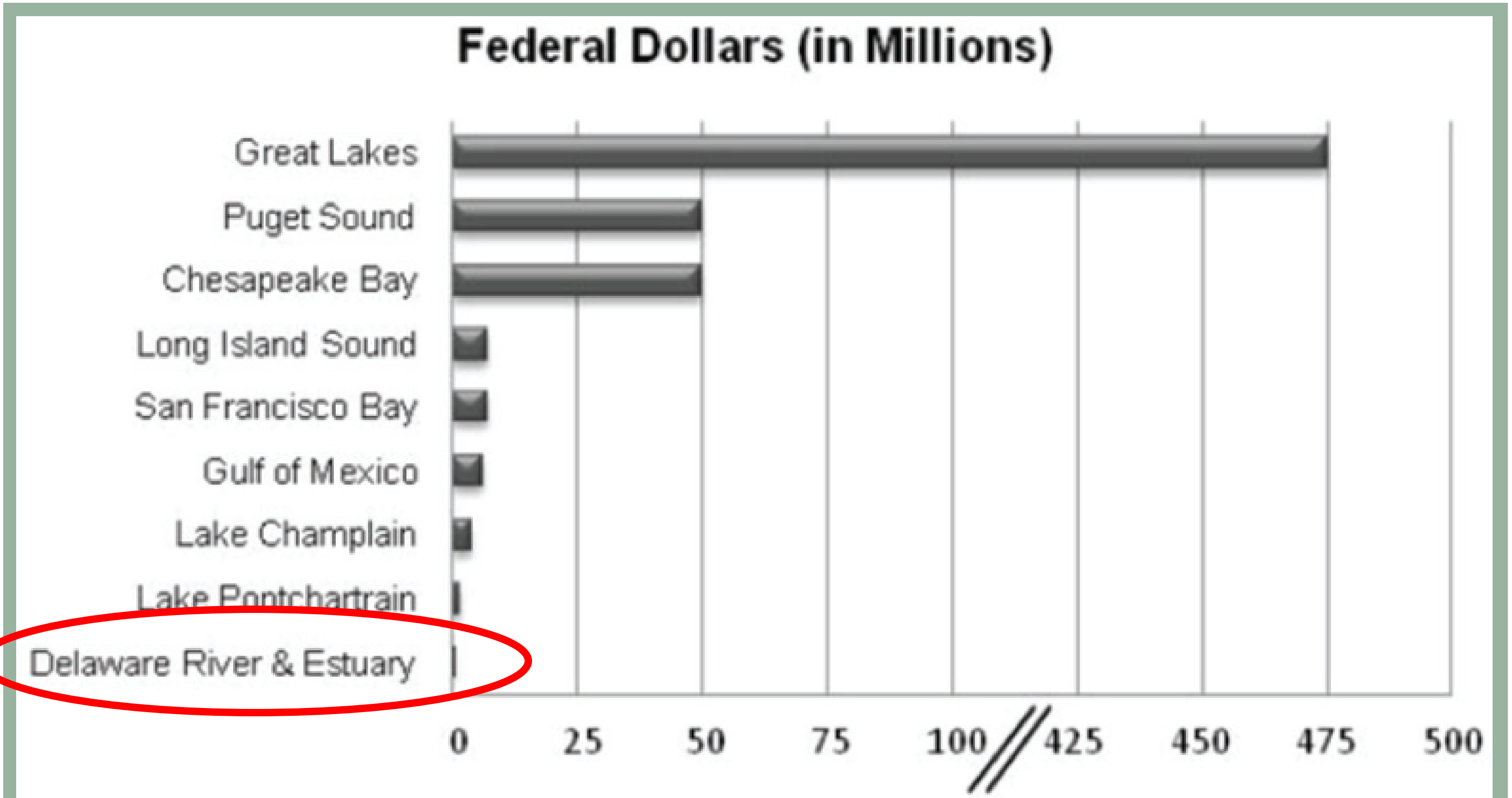

Fig. 8.8. Comparison of US EPA federal spending in FY2010 on environmental management and restoration in nine major water bodies in the United States (from Strackbein and Dawson 2011)

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