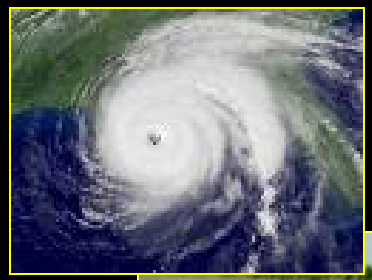
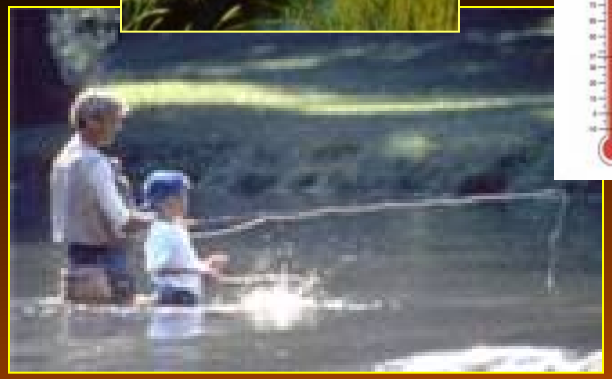
Enhancing and Harnessing Nature for Climate Resilience in the Delaware Estuary

Danielle Kreeger

Partnership for the Delaware Estuary

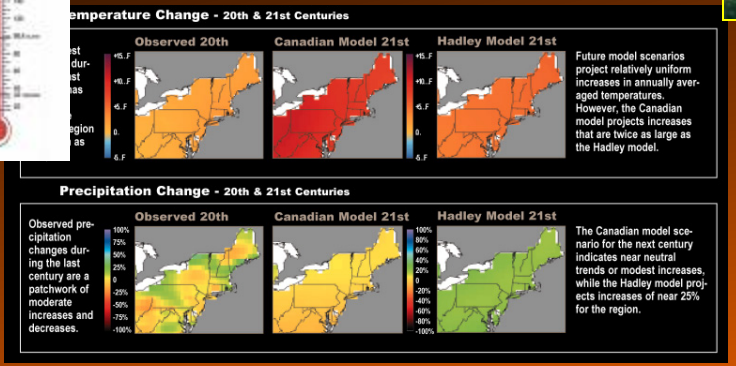


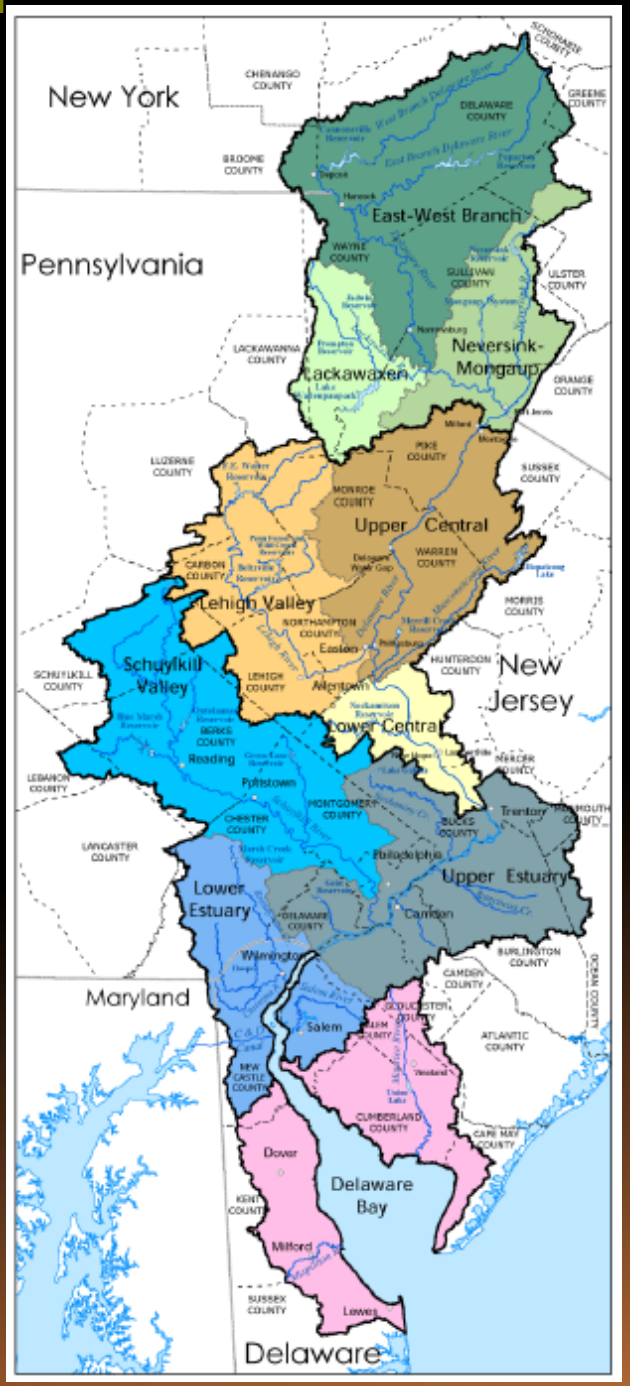


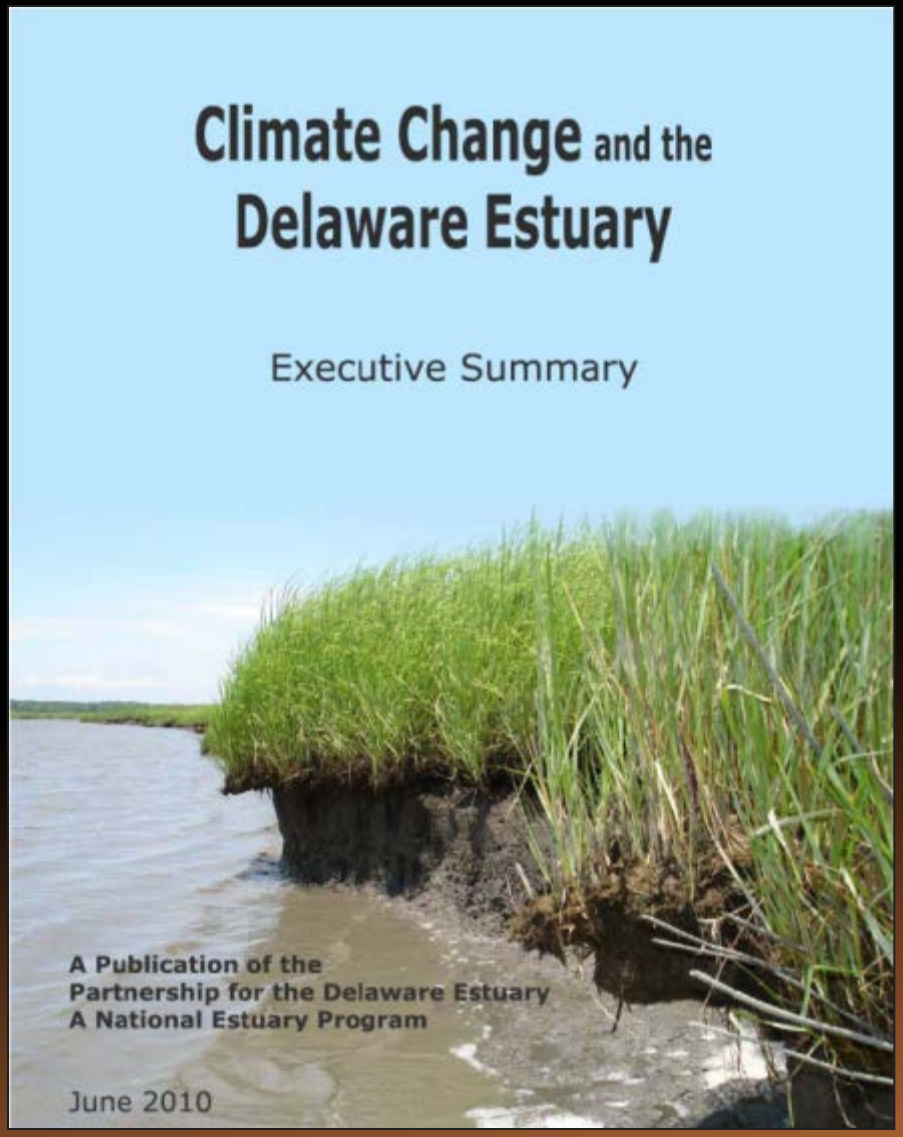
PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

AWRA

April 8, 2015

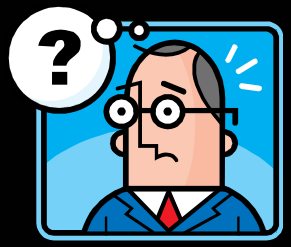




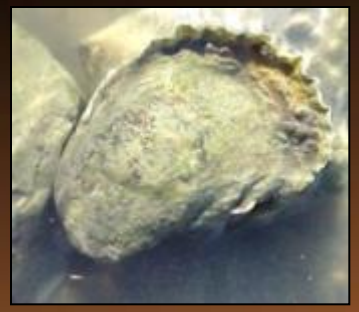


3 case studies

http://delawareestuary.org/climate-change



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?

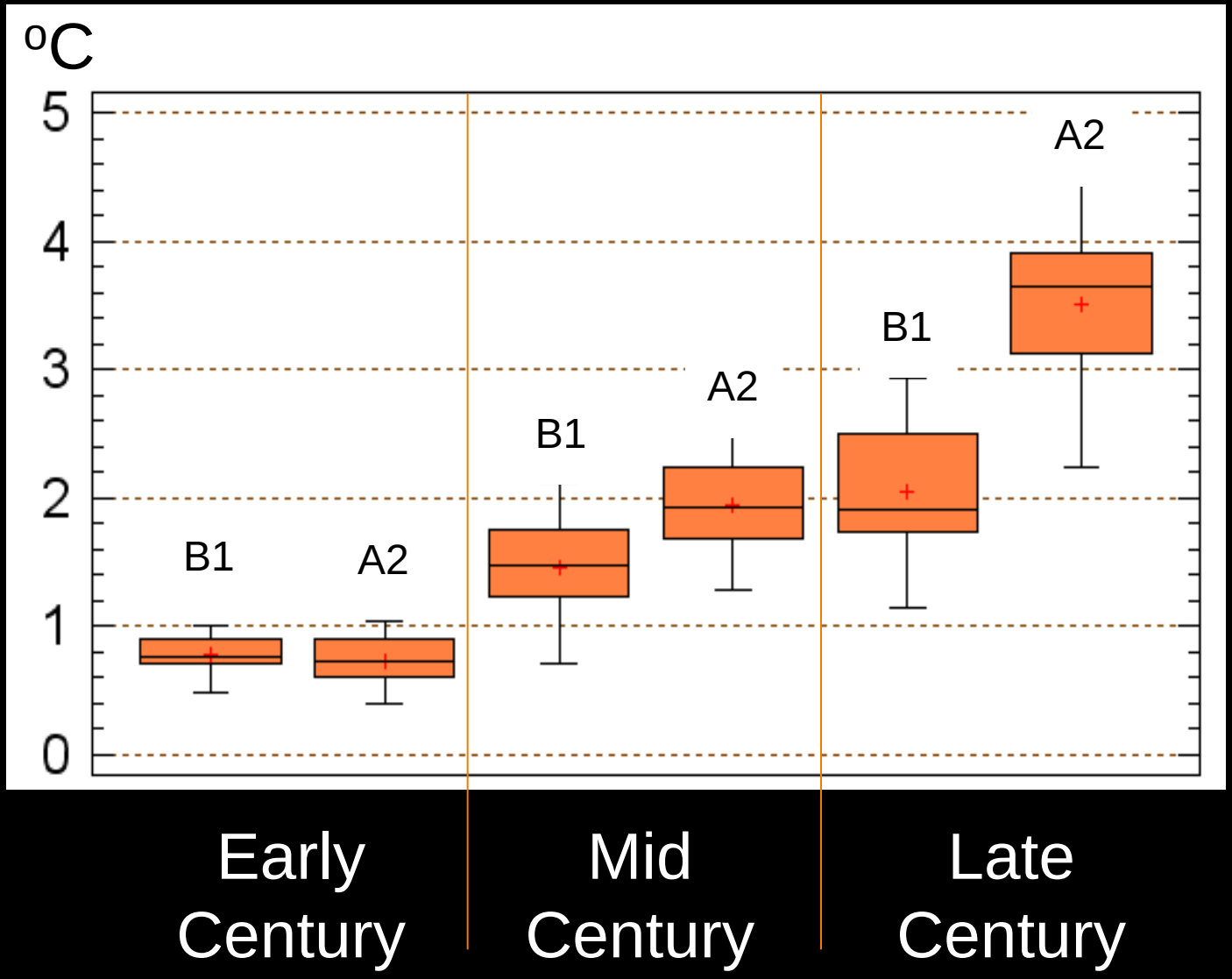
(since every dollar is precious)

How Will Climate Change?

Temperature

More in ummer than in winter

Locked in for next 30 years



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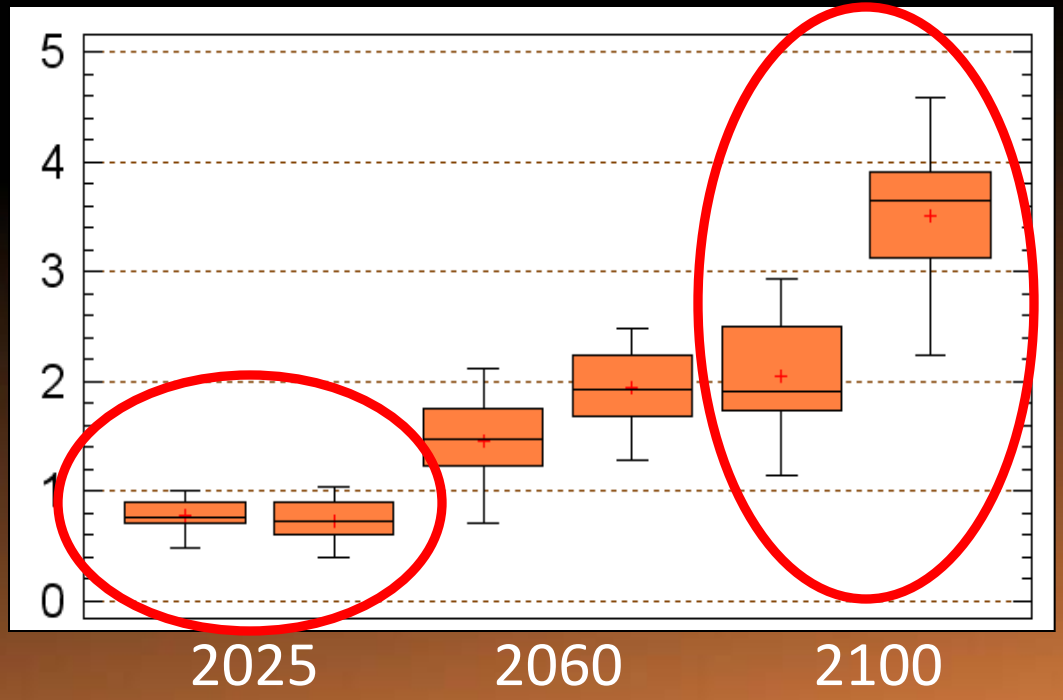
How Will Climate Change?

- ↑ Temperature
- ↓ Oxygen in Water



philly.com
anything & everything philly

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.

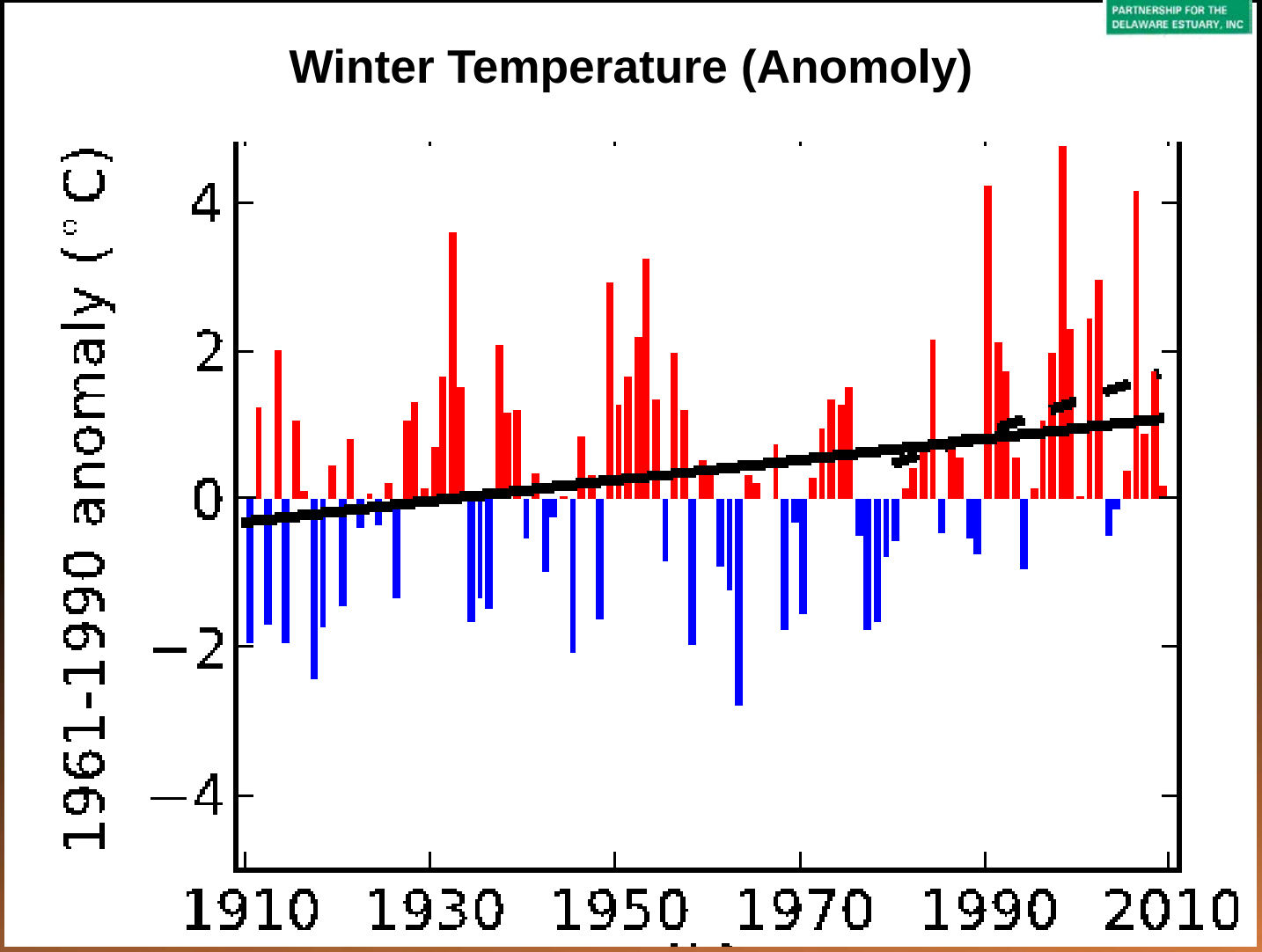
The kill was spotted around 6:30 a.m. Wednesday, when a 20-foot-wide floating patch of menhaden, also known as peanut bunker, was seen along the bayfront. Tides brought the dead fish onto the bay shore from Kimbles Beach in Middle Township to Villas in Lower Township. No other species appeared to be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

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



http://delawareestuary.org/technical-report-delaware-estuary-basin

Climate Momentum

Mitigation

Difference between a rise of 2 versus 4 ^{o}C =

difference between local versus mass extinction

Critically important for the grandkids

Adaptation

No amount of mitigation will stem 1 ^{o}C rise over the next 25 years – we must adapt

Critically important for us and the kids

http://www.spur.org/sites/default/files/featured_project_imgs/climate_adaptation.jpg

How Will Climate Change?

↑ Temperatures

↑ **Precipitation**

7-9 % increase

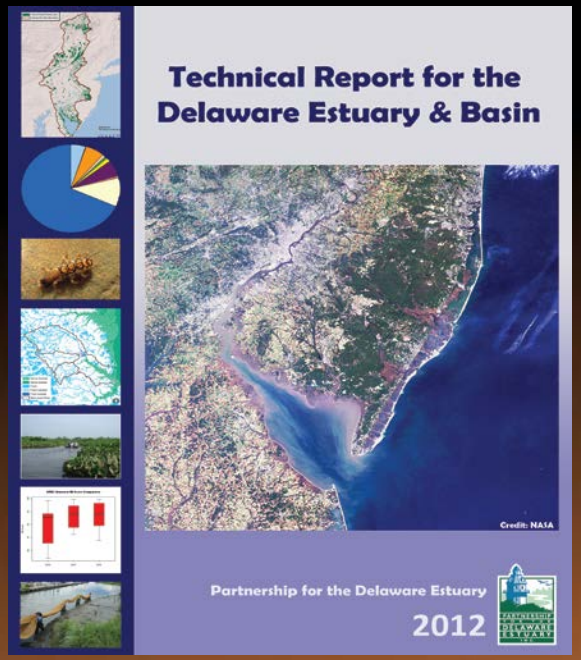
More in winter than in summer

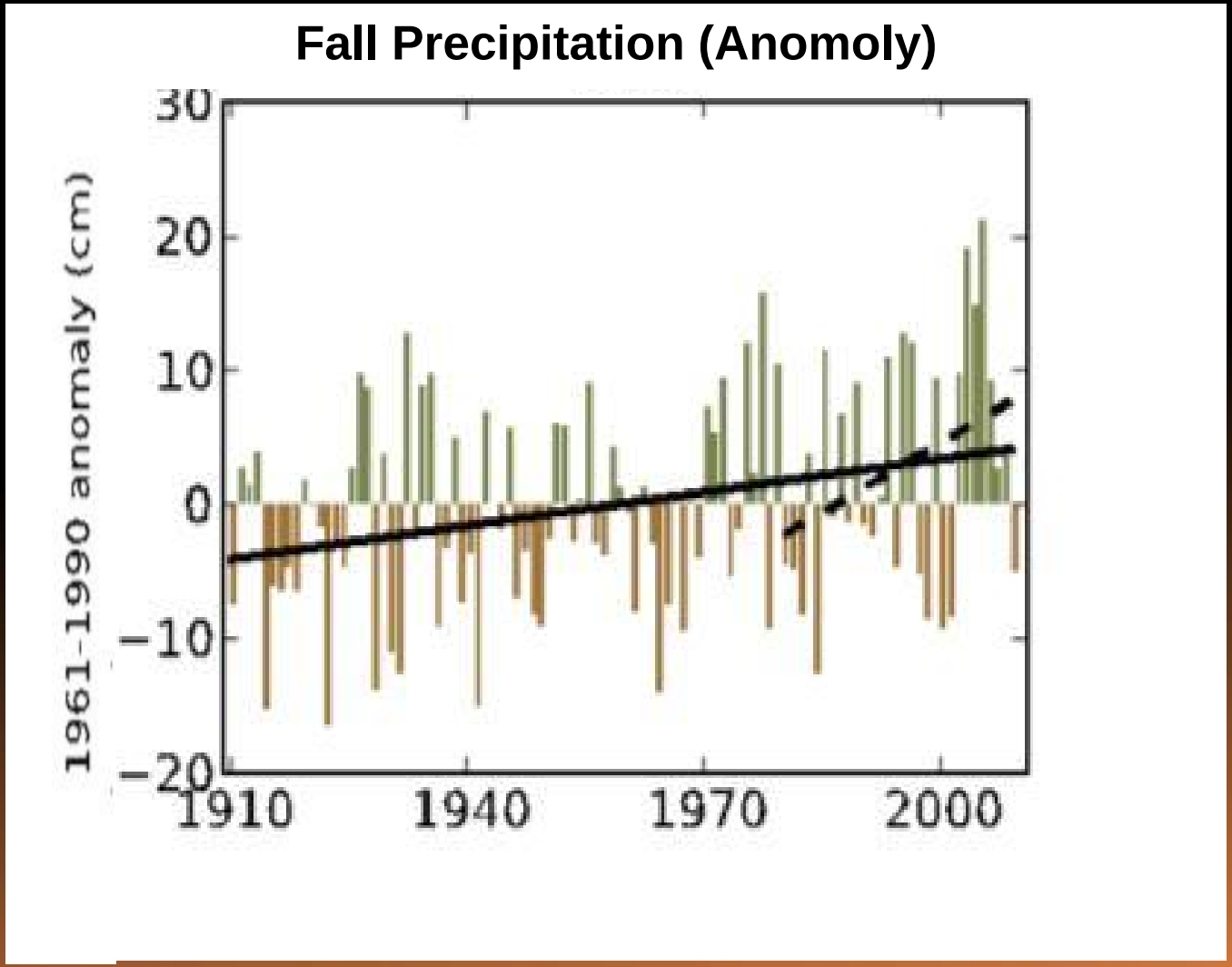
More heavy events

State of the Estuary 2012

Precip. has increased >10%

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

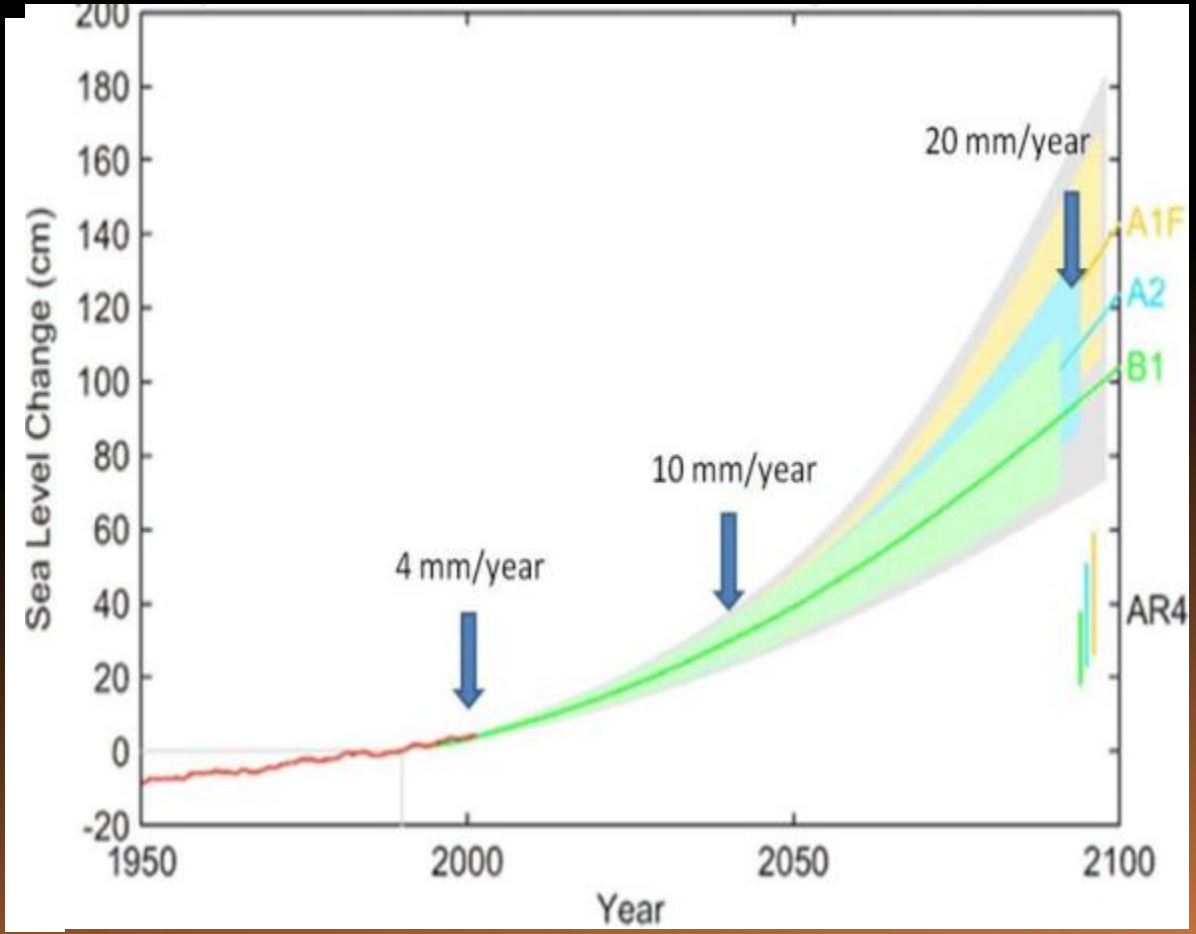




http://delawareestuary.org/technical-report-delaware-estuary-basin

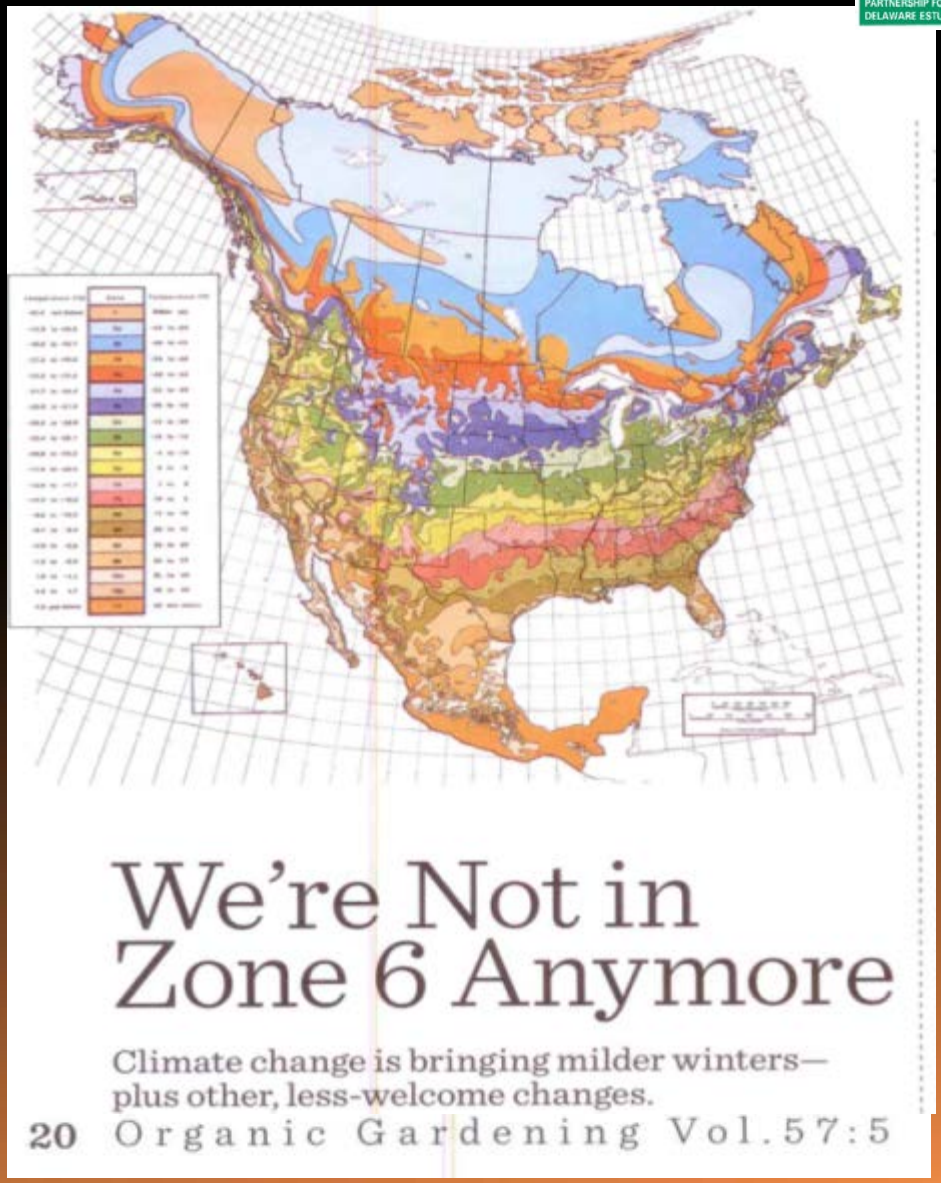
How Will Climate Change?

- ↑ Temperatures
- ↑ Precipitation
- ↑ **Sea Level**
  0.7 - 1.5 m by 2100
  local rates >> global
- ↑ **Salinity**



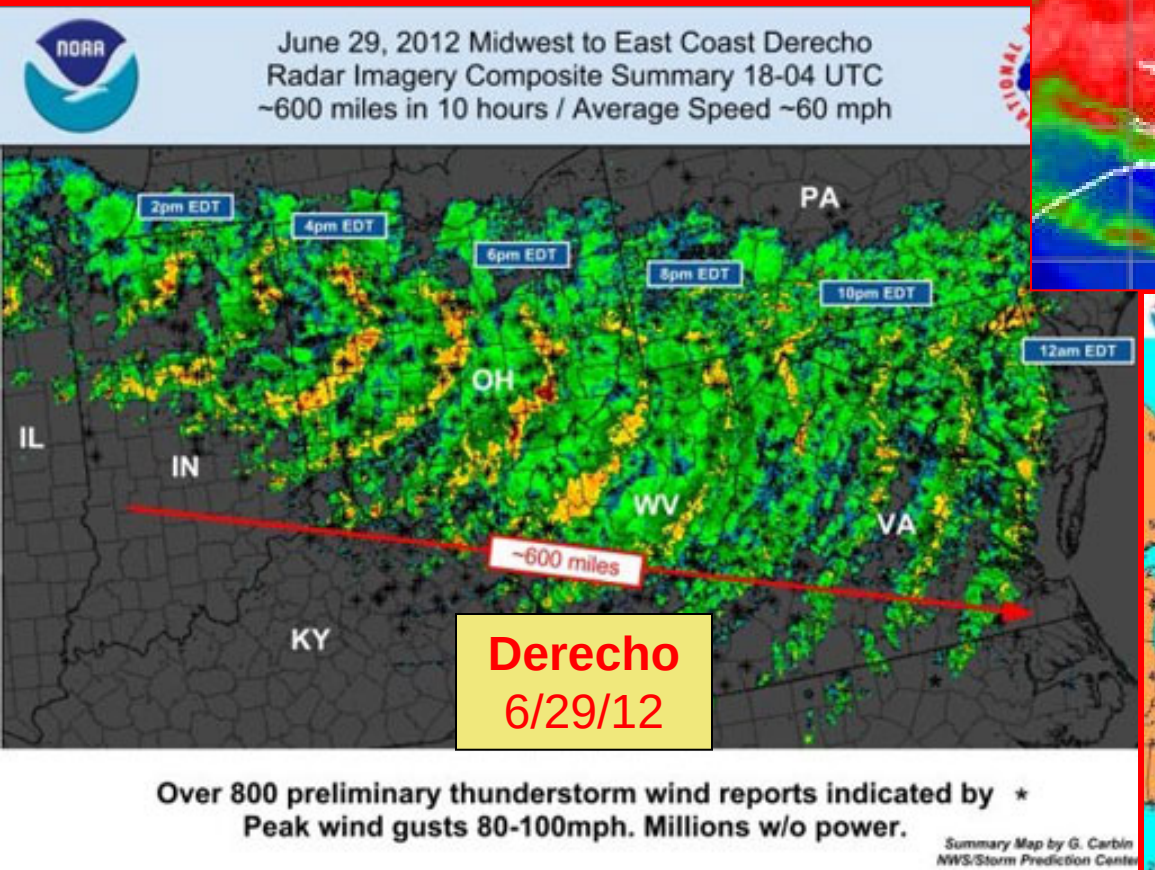
How Will Climate Change?

- ↑ Temperatures
- ↑ Precipitation
- ↑ Sea Level
- ↑ Salinity
- ↑ **Growing Season**

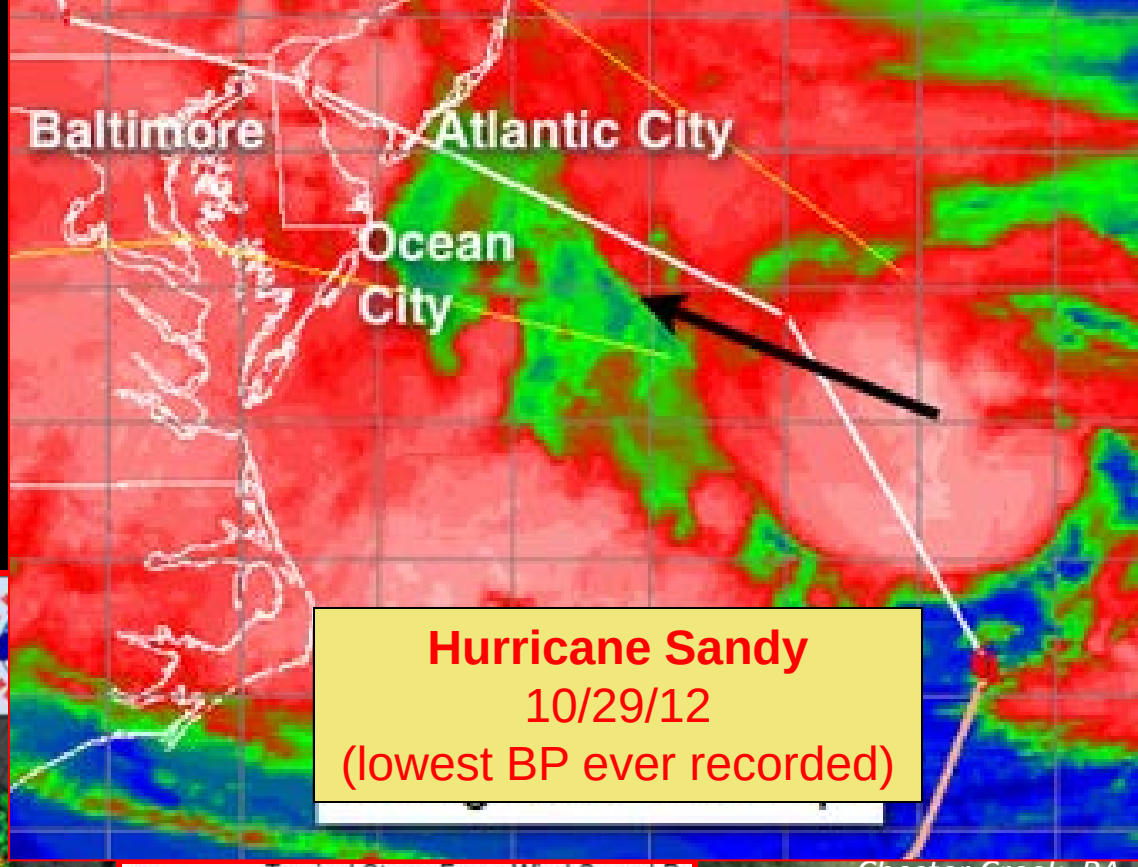


Emerging Threats

Frequent Bigger Storms
Heat Stress
Flooding (amid Droughts)



Derecho
6/29/12



Hurricane Sandy
10/29/12
(lowest BP ever recorded)

Hurricane
8/30/11

Storm
10/1/10

How Will Climate Change?

- ↑ Temperatures
- ↑ Precipitation
- ↑ Sea Level
- ↑ Salinity
- ↑ Growing
- ↑ **Storms**

Predictions > Vulnerability > Adaptation > Action

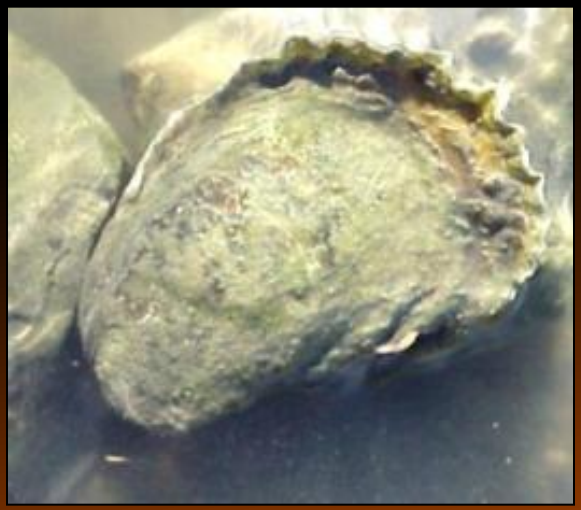
Drinking Water

Water Resource

Coastal Wetlands

Habitat Resource

Bivalve Shellfish



Living Resource

Drinking Water

>16 million people

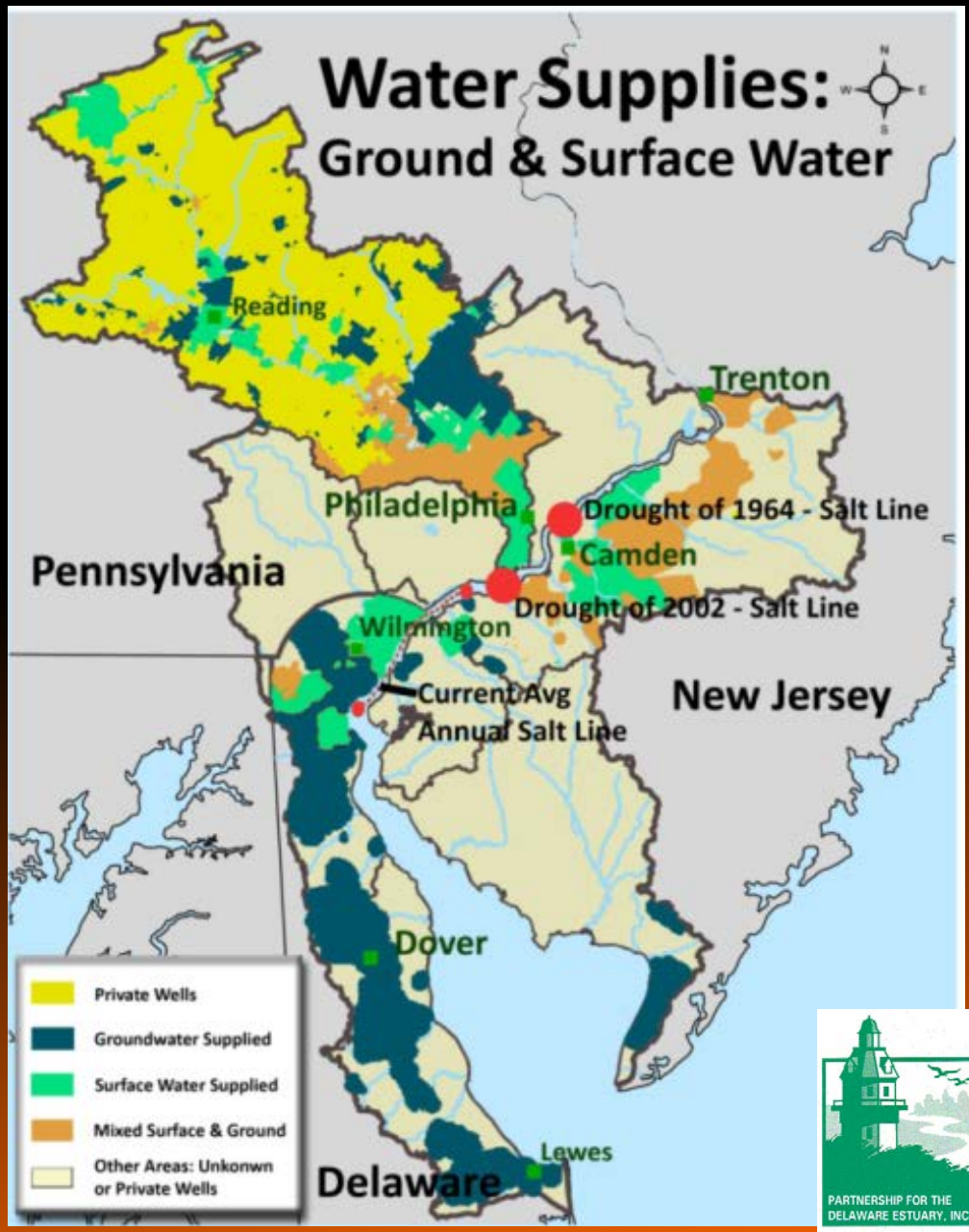
Philadelphia – 1.4 million

Population growth of 83% by 2100

95% used for power generation/industry

Increasing demands

e.g. shale drilling



Drinking Water – Vulnerability

Flooding / Storm Surge

Eroding Old Infrastructure

Saltwater Intrusion

Drought

Sea Level Rise

Drinking Water Threats

Degraded Source Water

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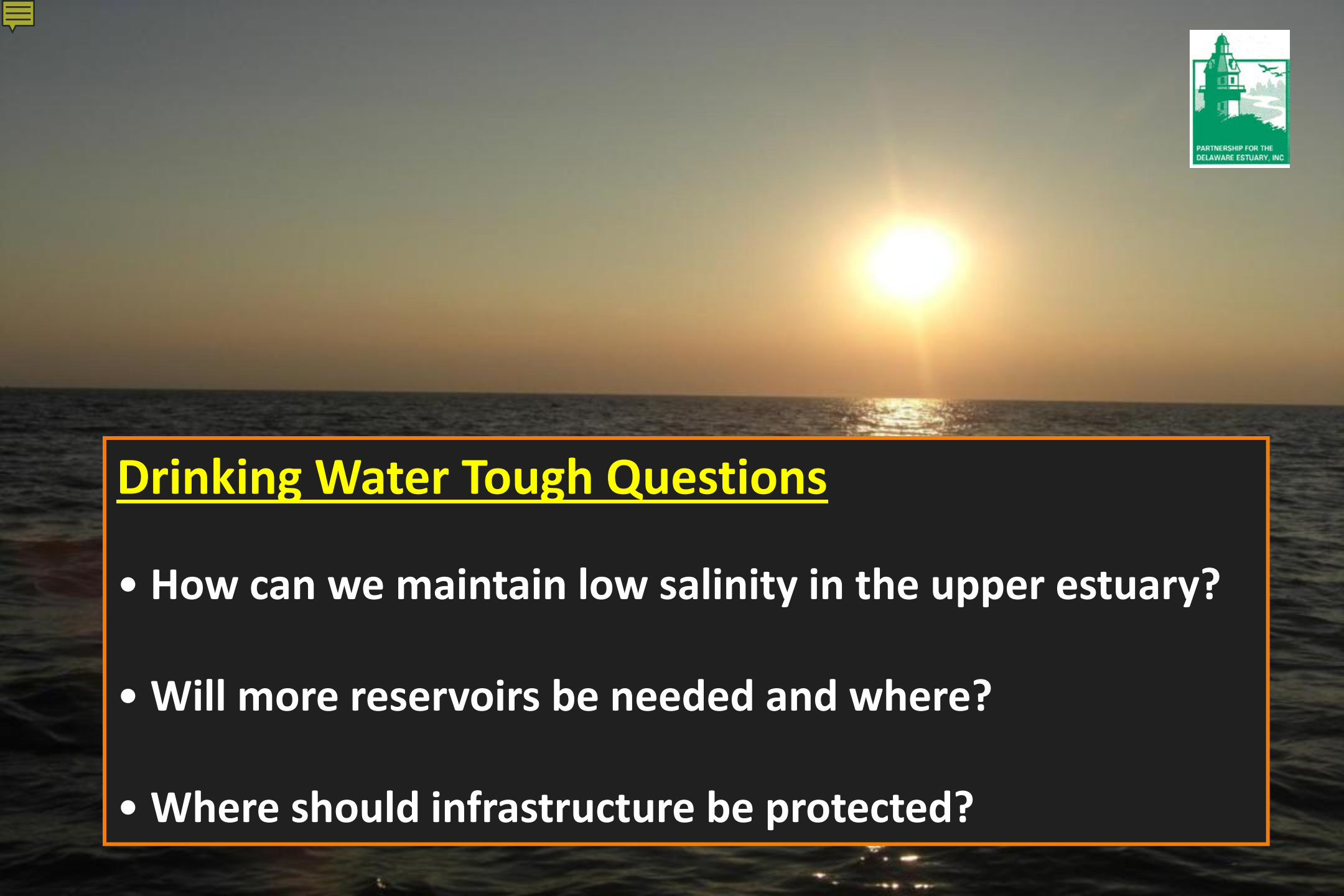
Drinking Water – Adaptation Options

- Infrastructure protection, upgrades
- New treatment & distribution system
- Storm water controls
- Source water protection
- Wastewater disinfection
- Increase 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?

Predictions > Vulnerability > Adaptation > Action

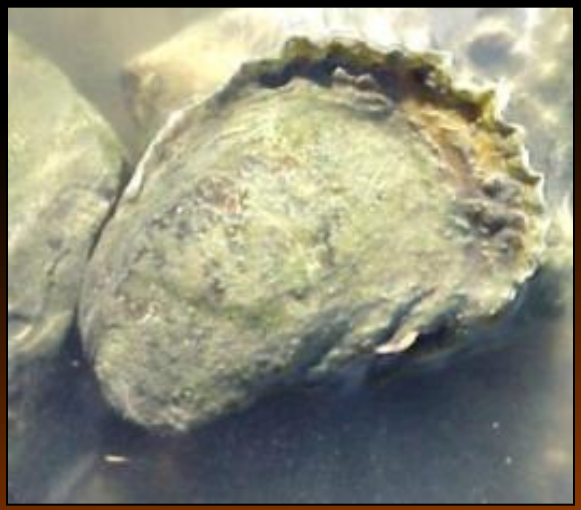
Drinking Water

Water Resource

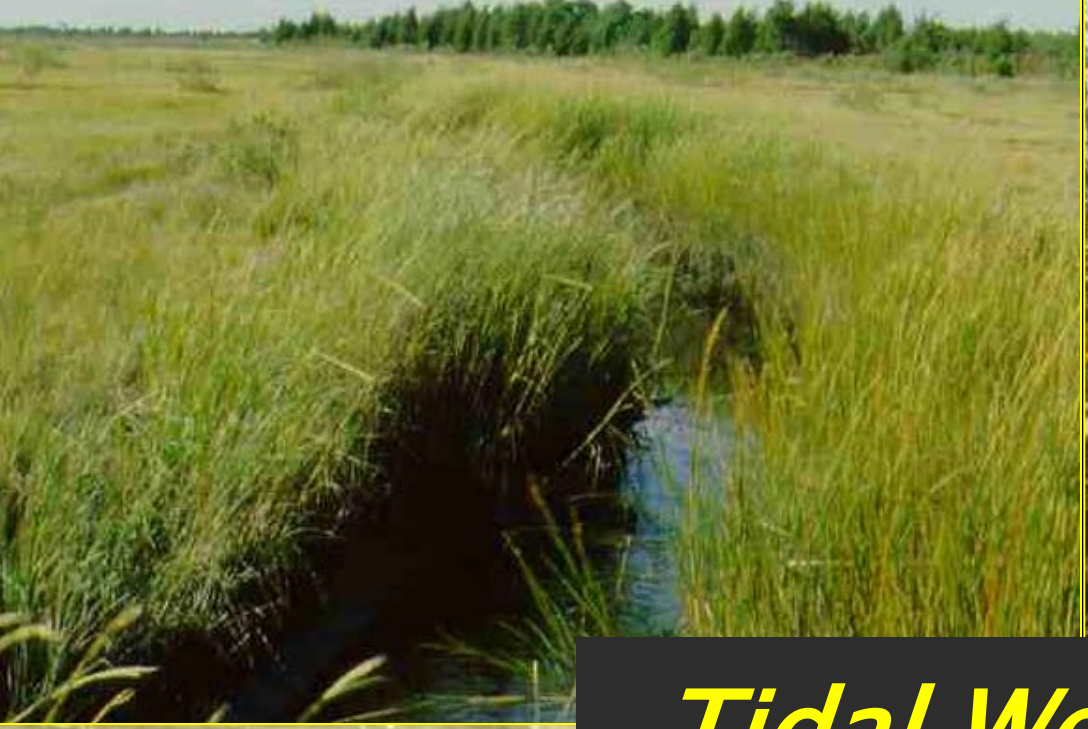
Coastal Wetlands

Habitat Resource

Bivalve Shellfish



Living Resource



Tidal Wetlands

Tidal Wetlands

A Signature Trait of System

Near Contiguous Band

Diverse: *Freshwater Tidal Marshes*
Brackish Marshes
Salt Marshes

Nature's Benefits

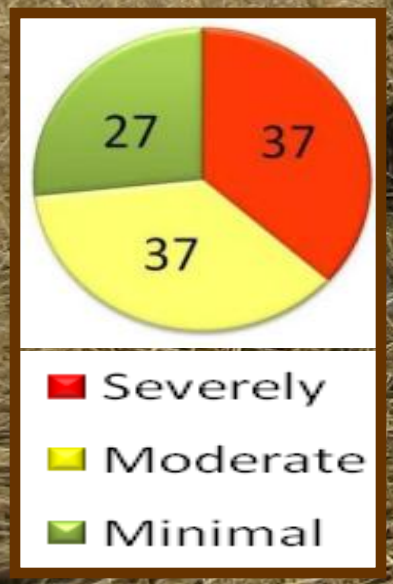
Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Sequestration

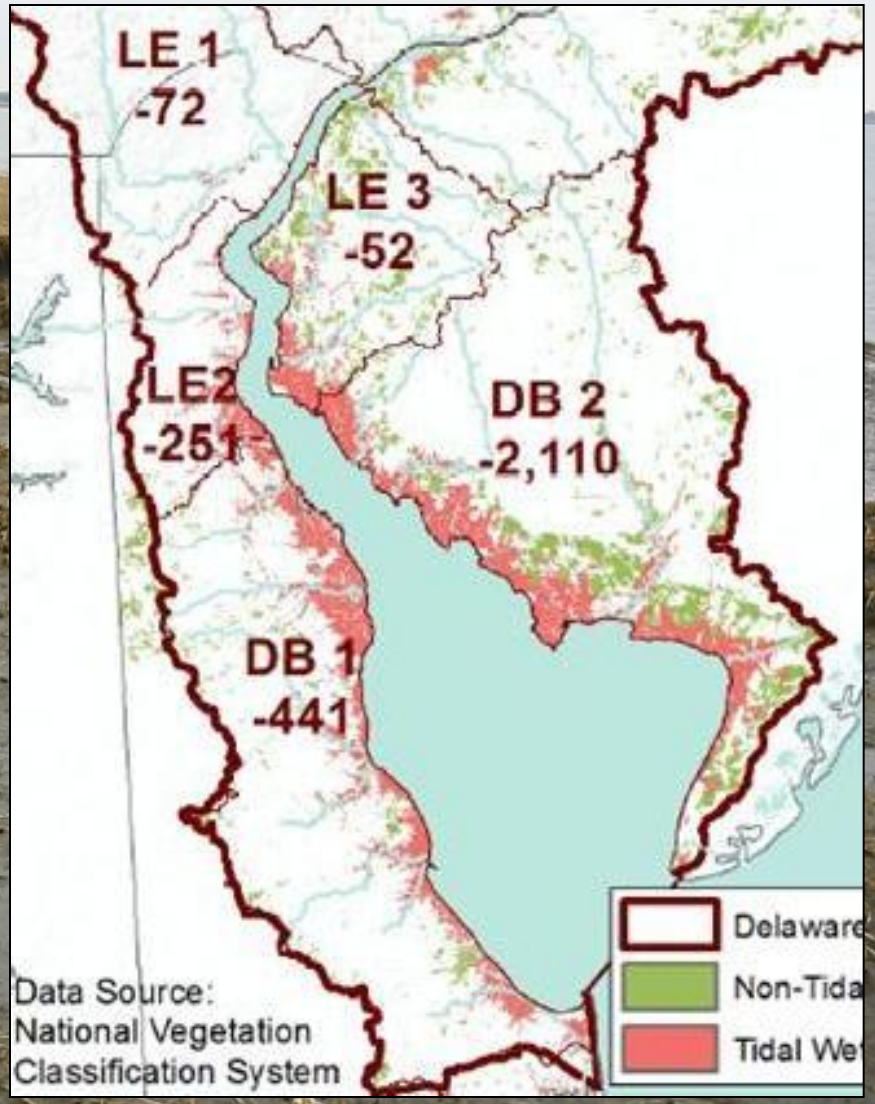
2012 State of the Estuary Report

Rapid loss of acreage and degraded wetland health

Losing an acre per day

Most are stressed





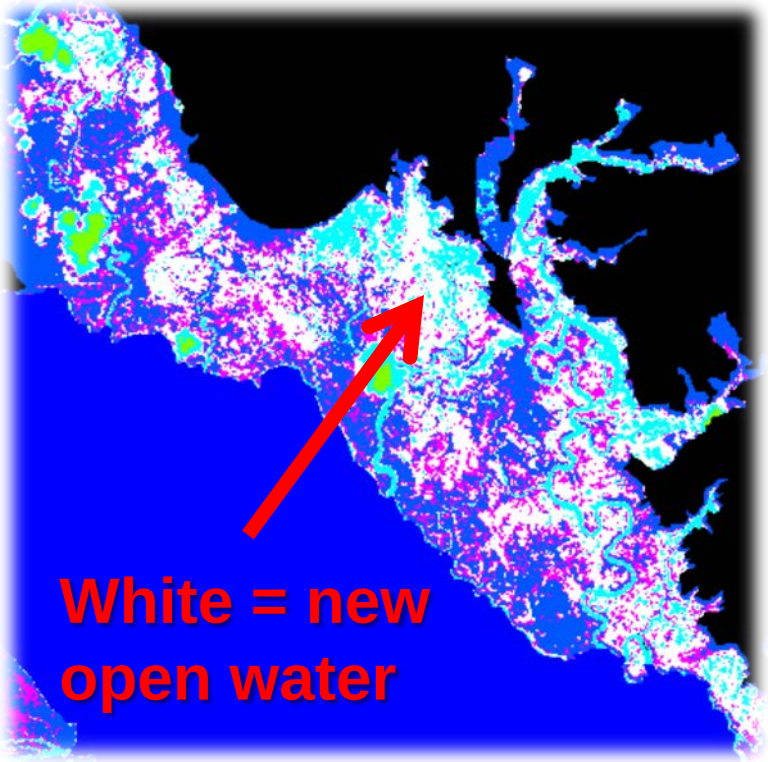
http://delawareestuary.org/technical-report-delaware-estuary-basin

Two Decline Patterns

MACWA
Mid-Atlantic Coastal Wetlands Assessment

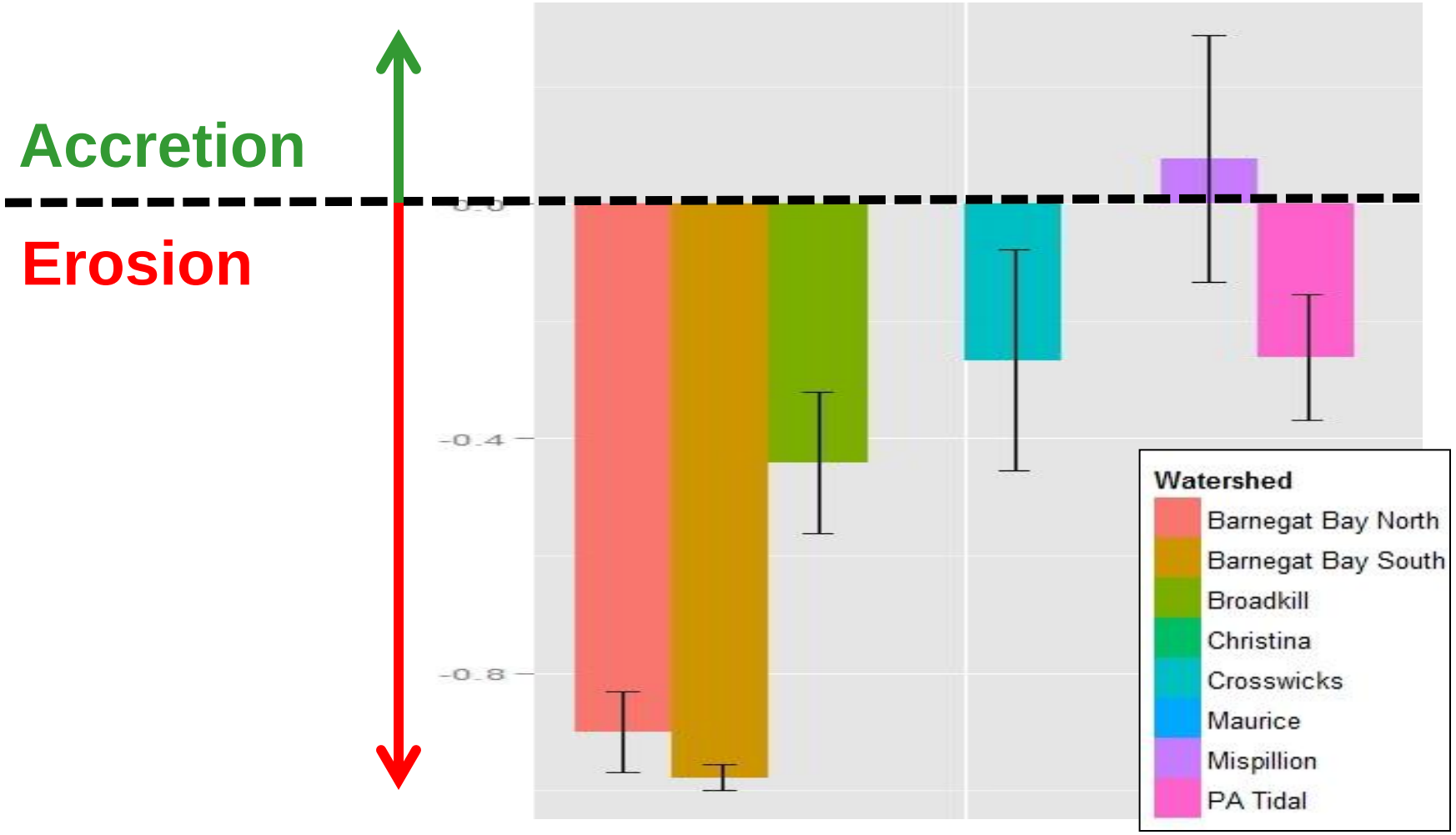
Edge Erosion (Horizontal)

Interior Drowning (Vertical)



Source: Riter and Kearney 2009

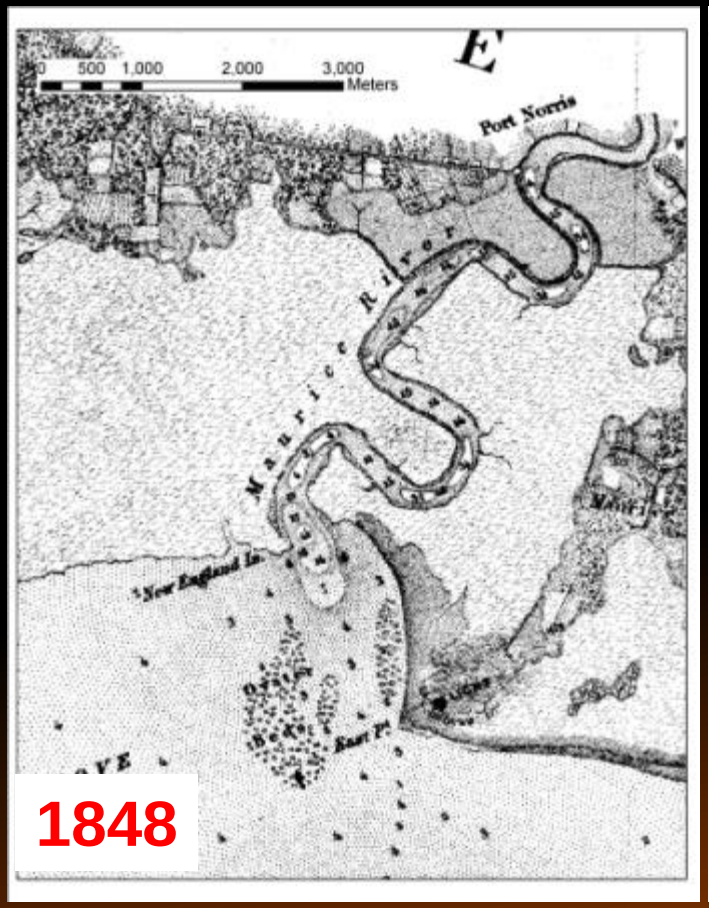
Erosion (Horizontal Loss)

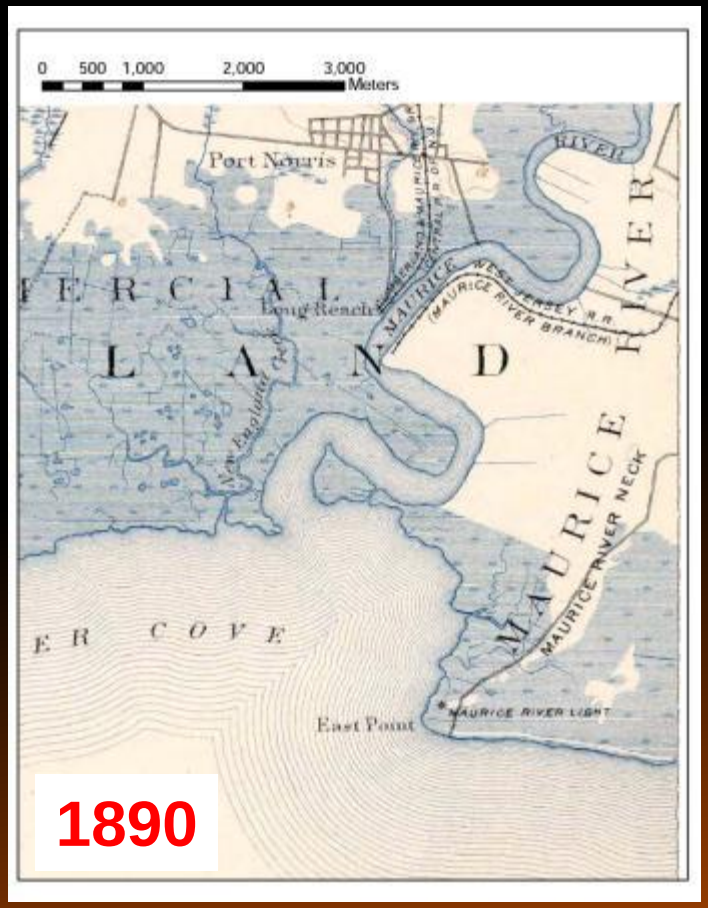


Source: MACWA 2014 Annual Report (draft)

Maurice River Mouth

Interior Drowning





Edge Retreat

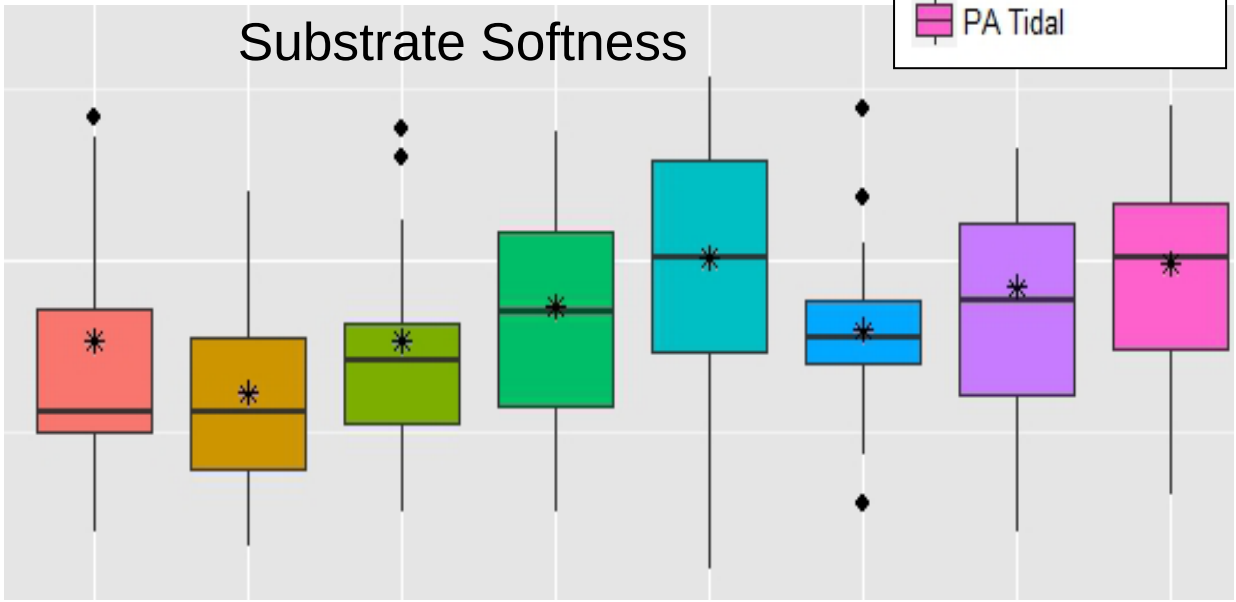
Courtesy, Jeff Gebert ACOE

Why are Wetlands Disappearing?

MACWA
Mid-Atlantic Coastal Wetlands Assessment

Many Stressors, variable from place to place

- Sea Level Rise
- Hydrology alterations
- Sediment management
- Mosquito ditching
- Nutrient loadings
- Fill, Point sources
- Marine debris
- Development



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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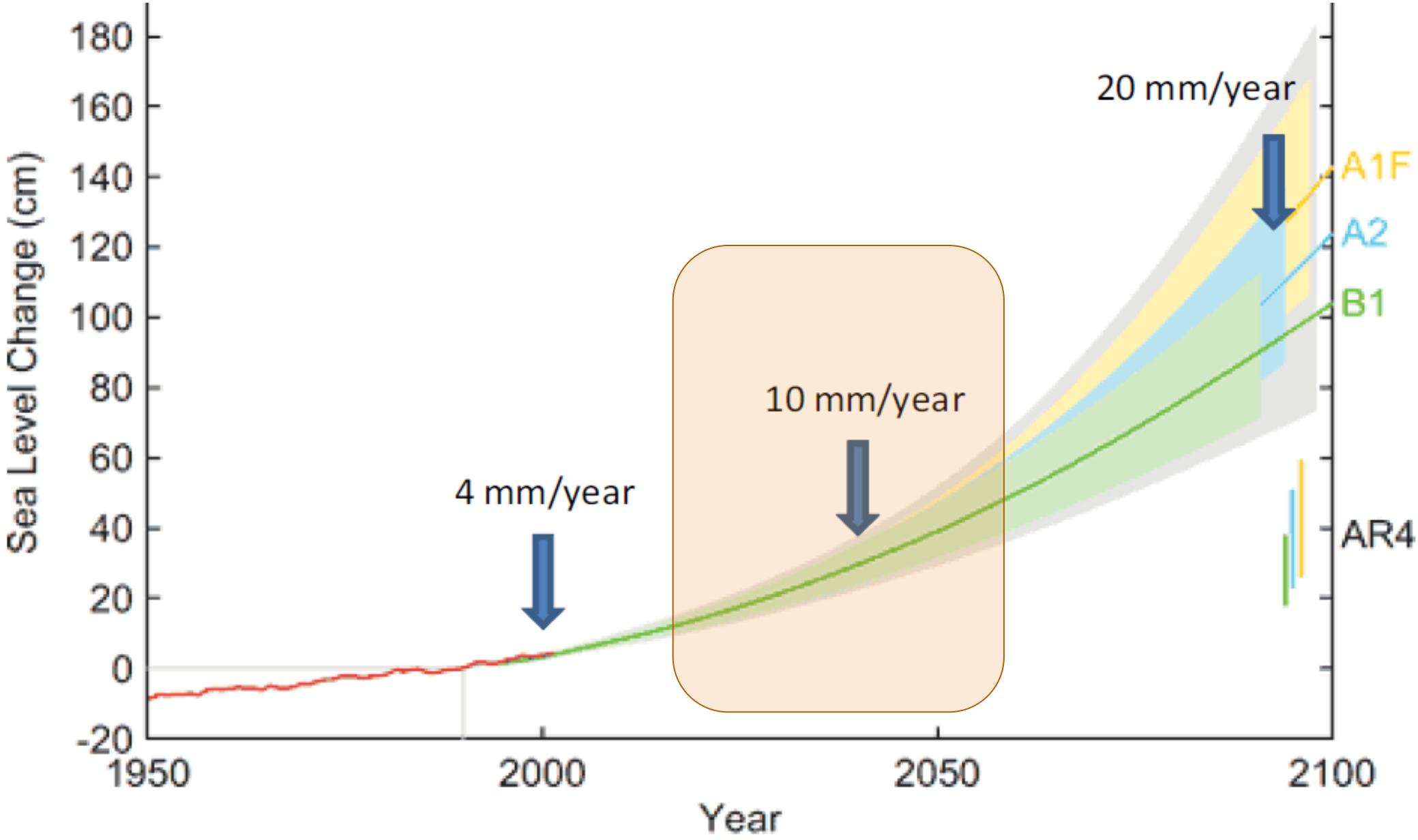
DK

Future Scenarios are Worrisome

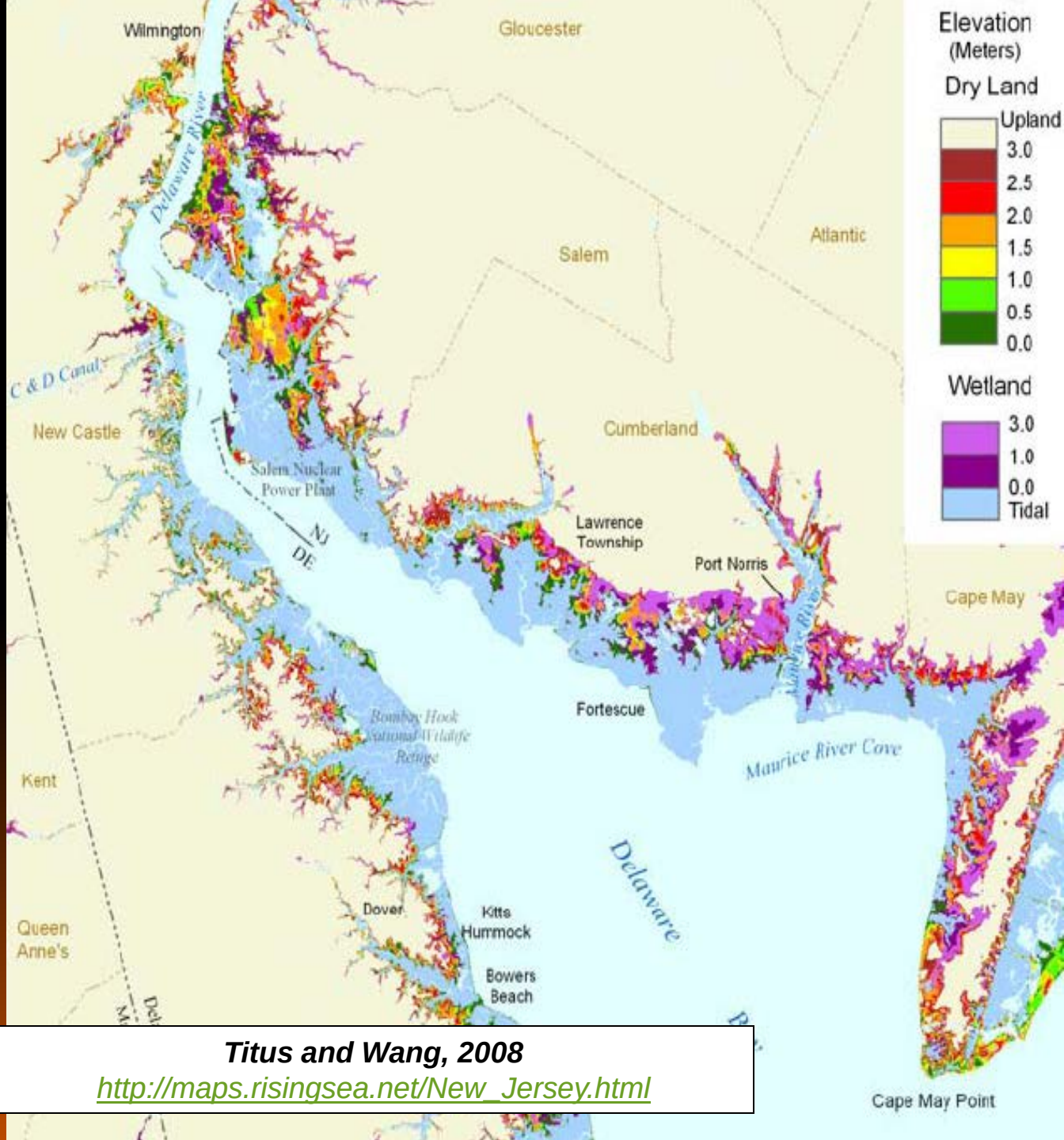


Tidal marshes need to move:

1) horizontally (landward)

and/or

2) vertically (to keep pace)



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

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Coastal Wetlands - Future

Massive 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

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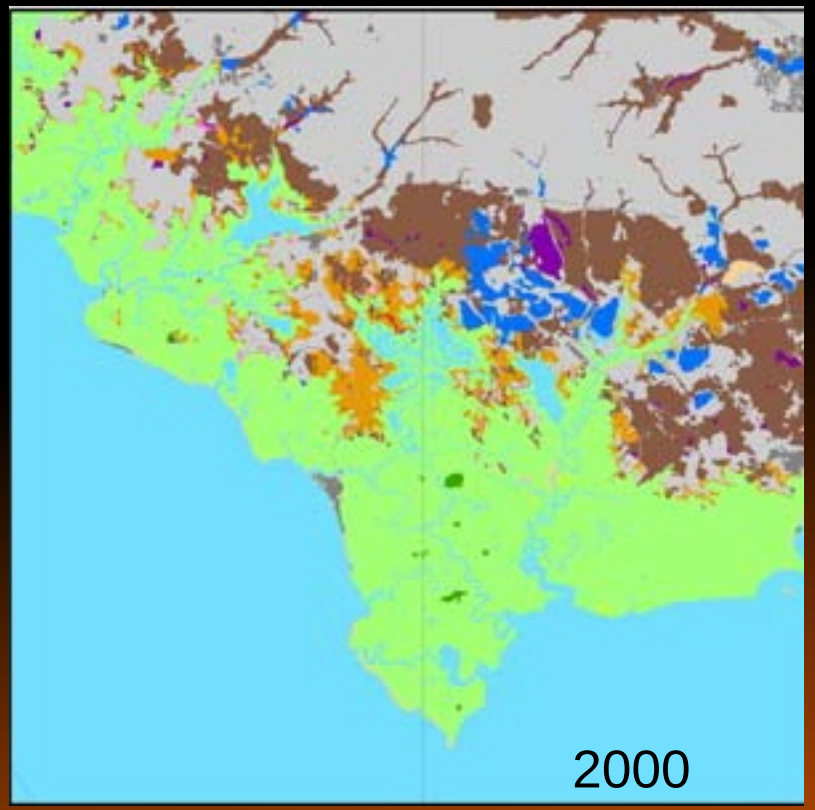
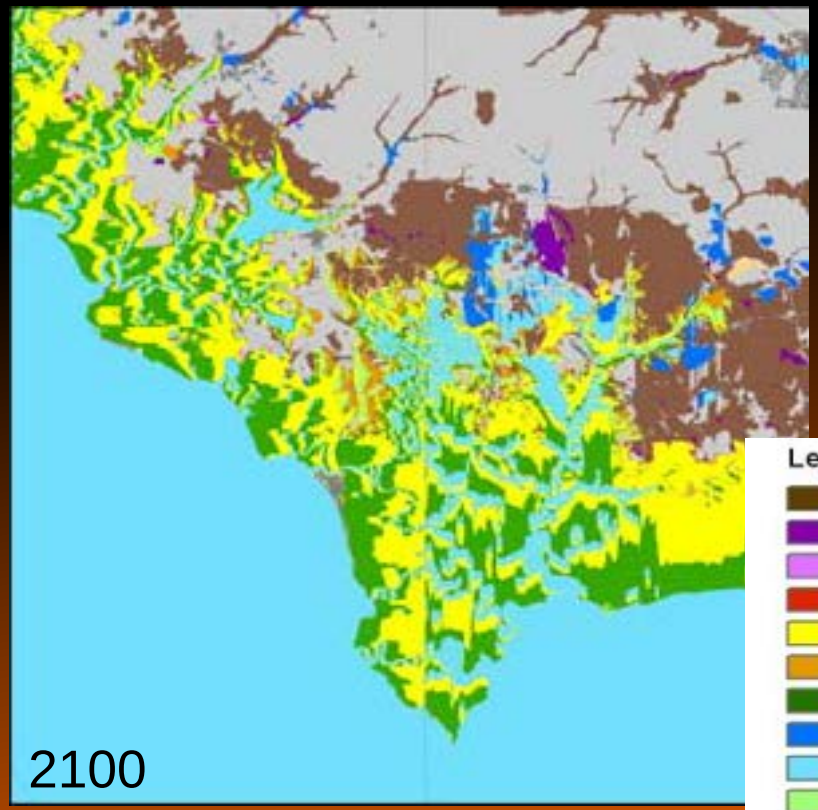
DK





Coastal Wetlands: a NEP Priority

Measurable Goals for the Delaware Estuary

Goal Statement: Healthy Habitats supporting healthy waters and communities.

From the CCMP (page 14):

- *Provide for the restoration of living resources of the Delaware Estuary and protect their habitats and ecological relationships for future generations.*

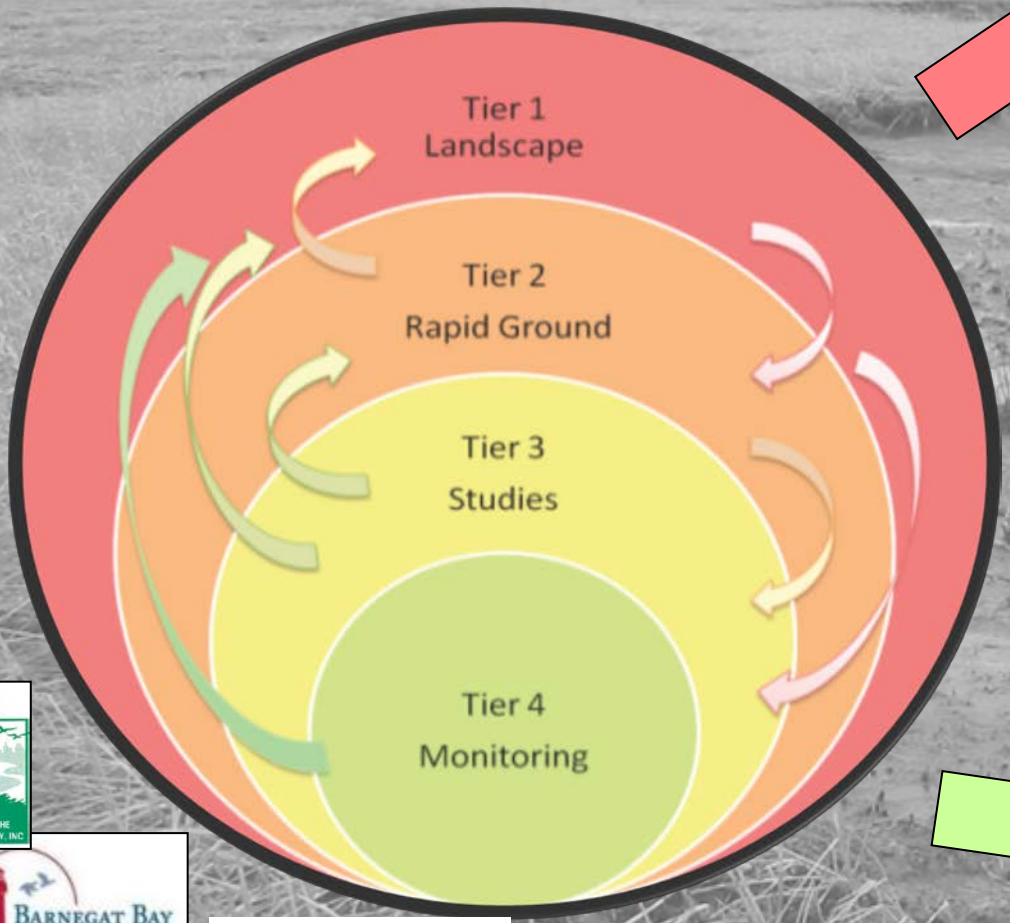
Healthy Habitats =	***Measure – short term***	***Measure – long term***	***Responsible Agencies:***	***Assumptions/ Needs:***
Functioning wetlands	• Get a robust tidal wetland monitoring program with a regional body for coordination and consistency of tracking wetland health in place by 2020 • Develop estuary-wide baseline for tidal wetland health by 2020 and goals to sustain tidal wetland health by 2022. • Identify and implement tactics to maintain high value tidal wetlands and limit acreage loss to 5% of 2006 acreage by 2025	• Take aggressive action to limit net acreage loss of tidal wetlands to 15% of 2006 acres by 2040 • Tidal wetland health TBD in 2022 based on short term actions • No net loss of non-tidal wetlands	PDE, EPA, States, USFWS, NOAA, USACE	*- Continuation of MACWA to track wetland acreage and health*

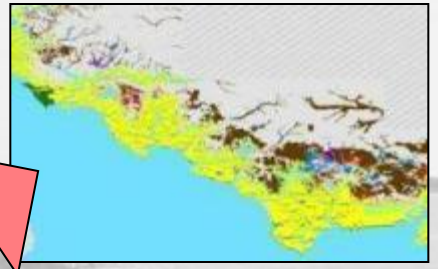
Coastal Wetlands – Adaptation Options

- Living shorelines
- Buffers
- Sediment mgt
- Structure setbacks
- River flow
- Monitoring !

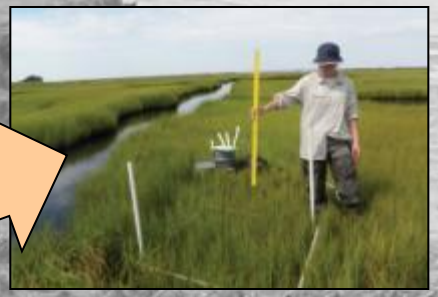
The Mid-Atlantic Coastal Wetland Assessment

Integrated monitoring of tidal wetlands for water quality, habitat management, and climate/restoration planning





Remote Sensing



Ground-Truthing

Intensive Studies

Station Monitoring

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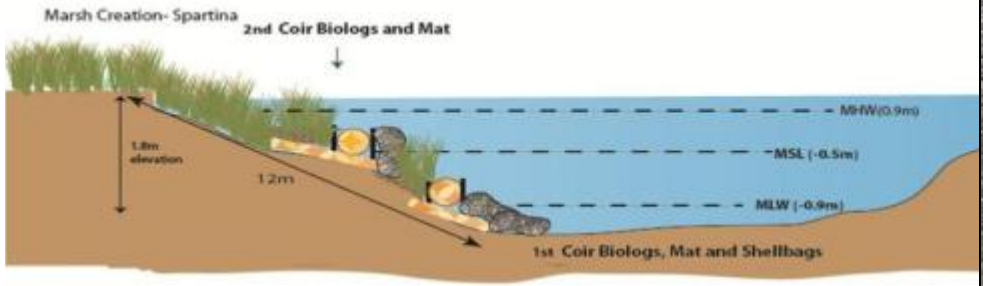
BARNEGAT BAY PARTNERSHIP

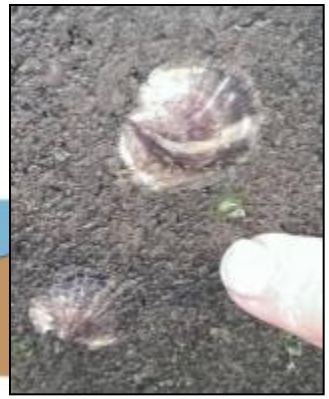
THE ACADEMY OF NATURAL SCIENCES of DREXEL UNIVERSITY

What tactics can be used to stem losses?

MACWA
Mid-Atlantic Coastal Wetlands Assessment

Many options now exist:





Performance monitoring can be linked to MACWA

April 2010


May 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC


June 2010
PARTNERSHIP FOR THE
DELAWARE ESTUARY, INC

June 2011

November 2012 (after Hurricane Sandy)

DelawareEstuary.org

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

Post-Sandy Lessons

Flooding and storm damage was lower adjacent to protective coastal wetlands and dunes

PDE-Rutgers Living Shoreline undamaged

Nearby destruction with hard infrastructure

The Delaware Estuary Living Shoreline Initiative

Since 2007:

Regional Planning

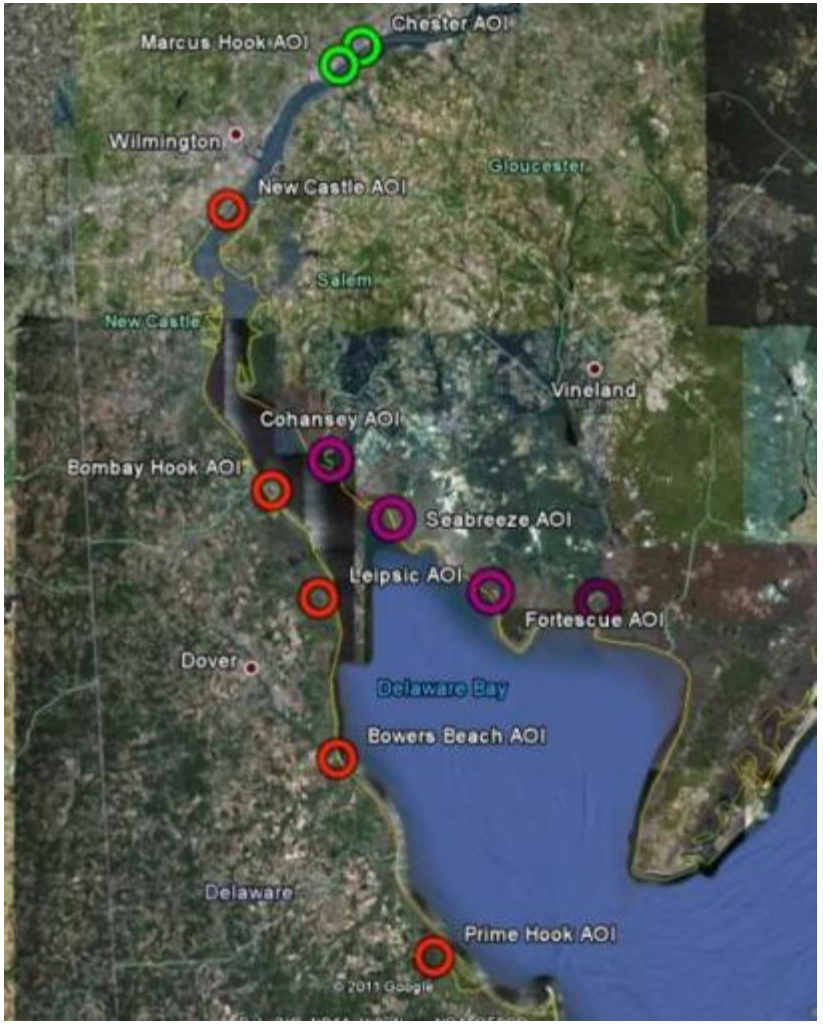
Tactics R&D

Demo Projects

Monitoring

Coordination

Outreach



DELSI - 2014


Money Island


Indian River Inlet

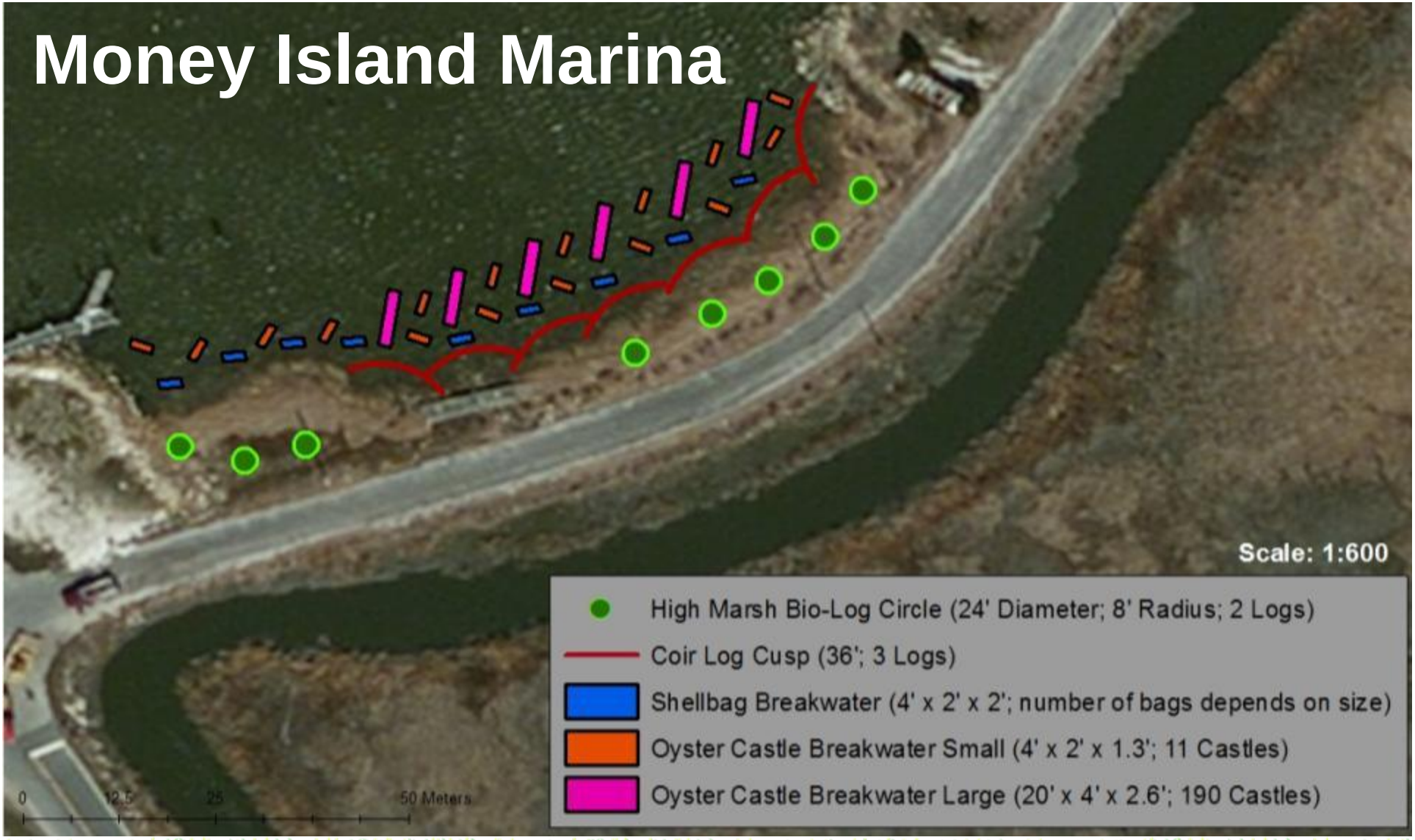

Lewes Canal


Mispillion Hybrid

The Delaware Estuary Living Shoreline Initiative

Mispillion Hybrid

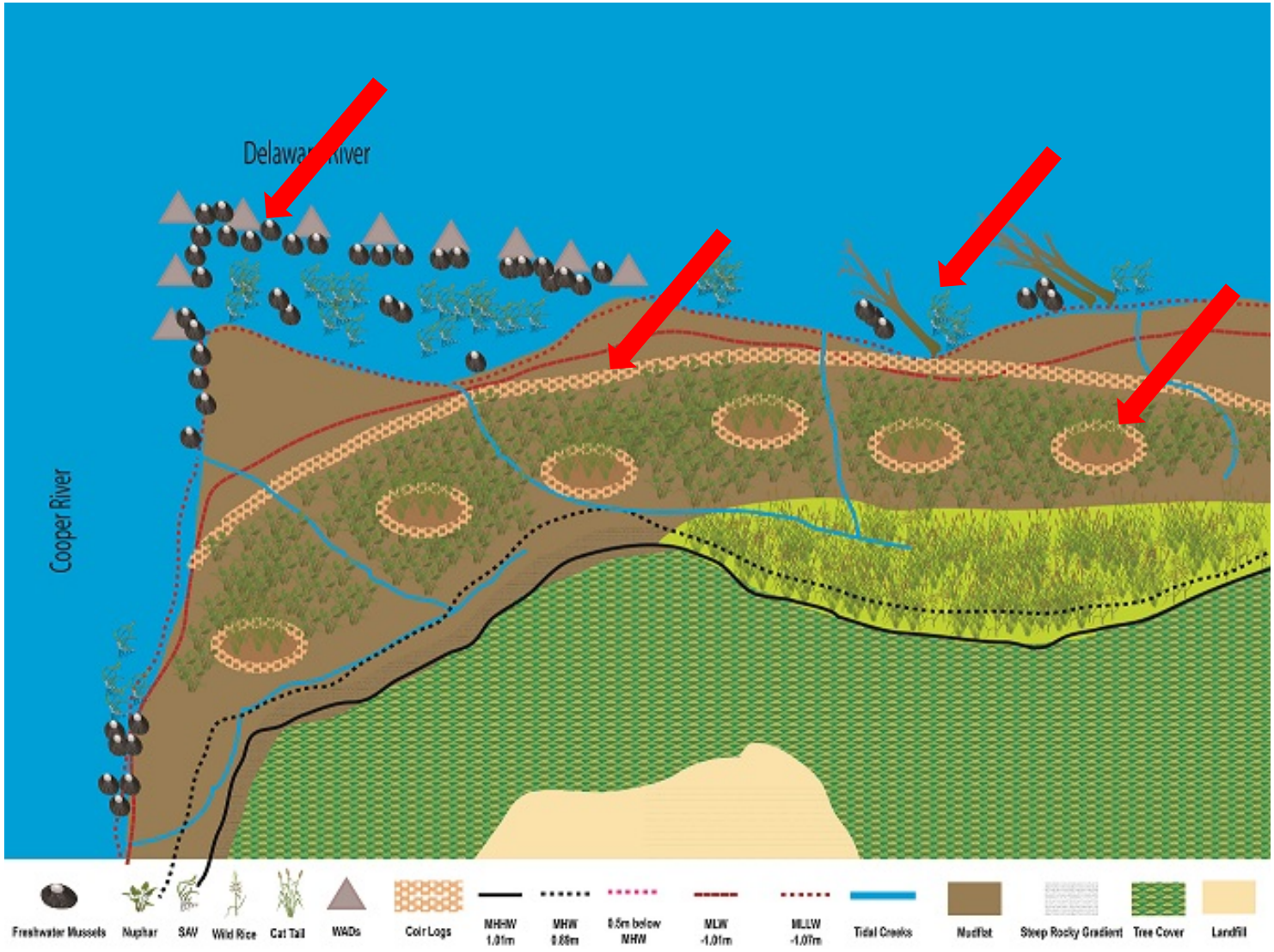
Next Gen Living Shorelines – 2015-2017



Next Gen Living Shorelines – 2015-2017

Camden

Habitat Mosaic Design



Coastal Wetlands – Adaptation Options

Wetland Tough Choices

- Where will they erode or drown?
- Where can we save them ?
- Where is strategic retreat the best option?

- **Protect river flow to offset saltwater**

Predictions > Vulnerability > Adaptation > Action

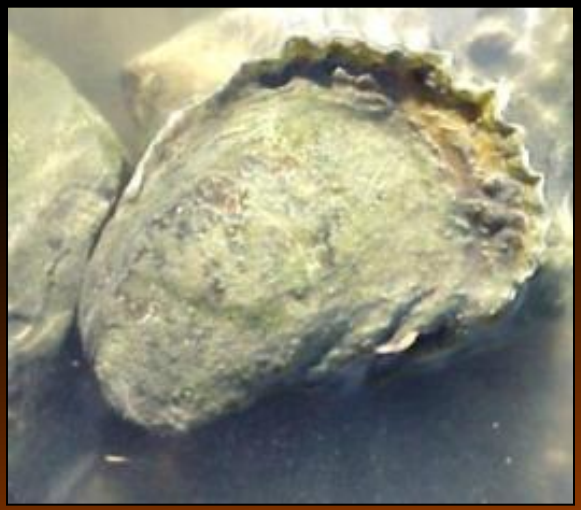
Drinking Water

Water Resource

Coastal Wetlands

Habitat Resource

Bivalve Shellfish

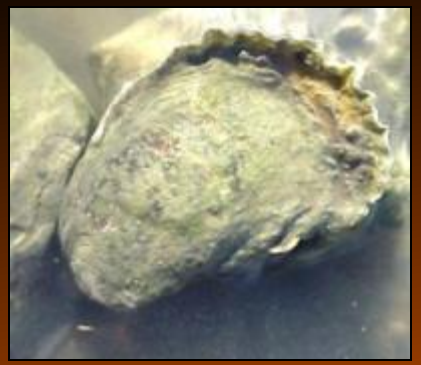


Living Resource

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

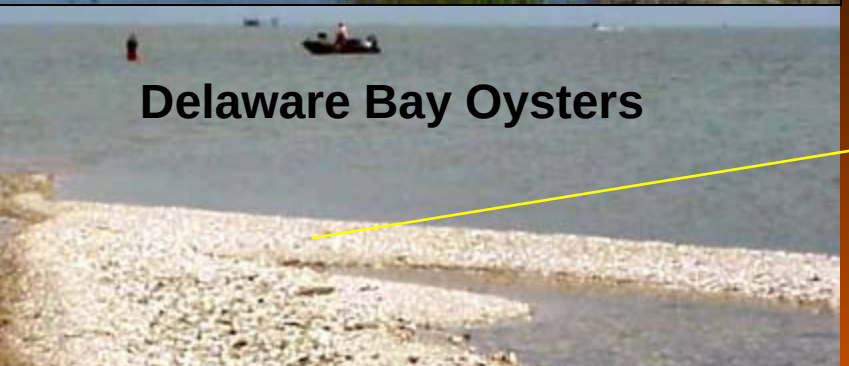
Delaware Freshwater Mussels

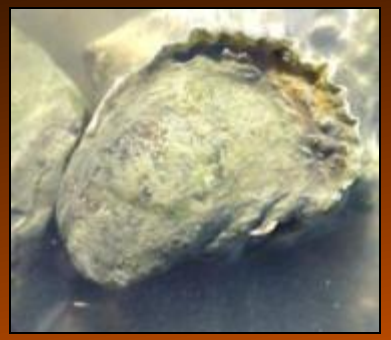
Elliptio complanata

Delaware Estuary Marsh mussels

Geukensia demissa

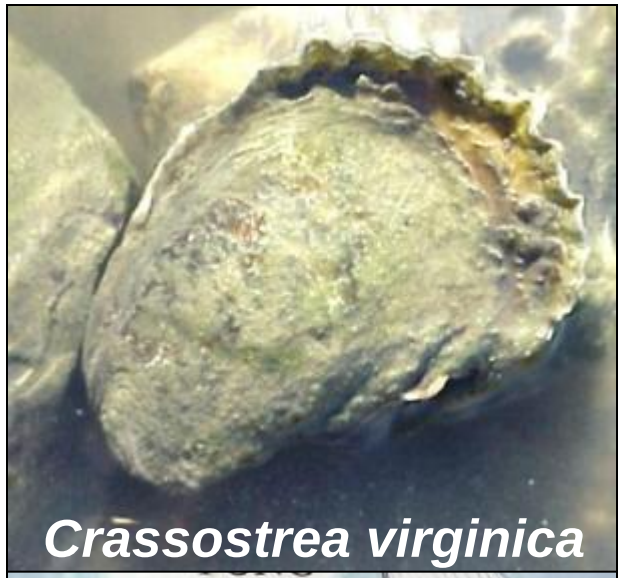
Delaware Bay Oysters



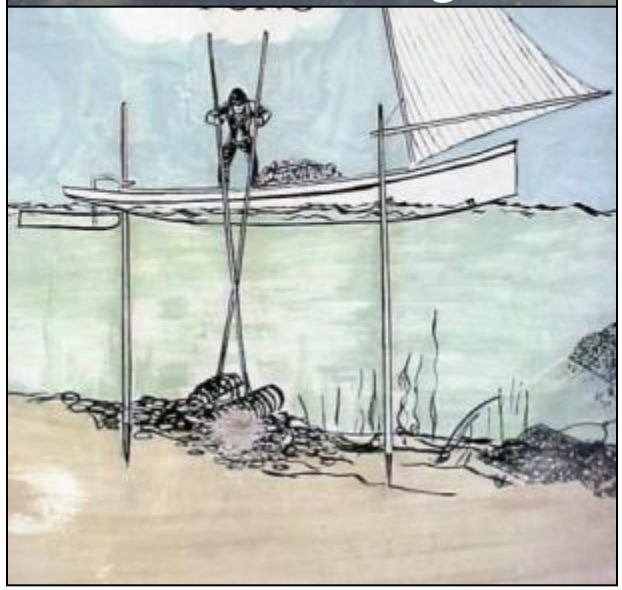


Crassostrea virginica

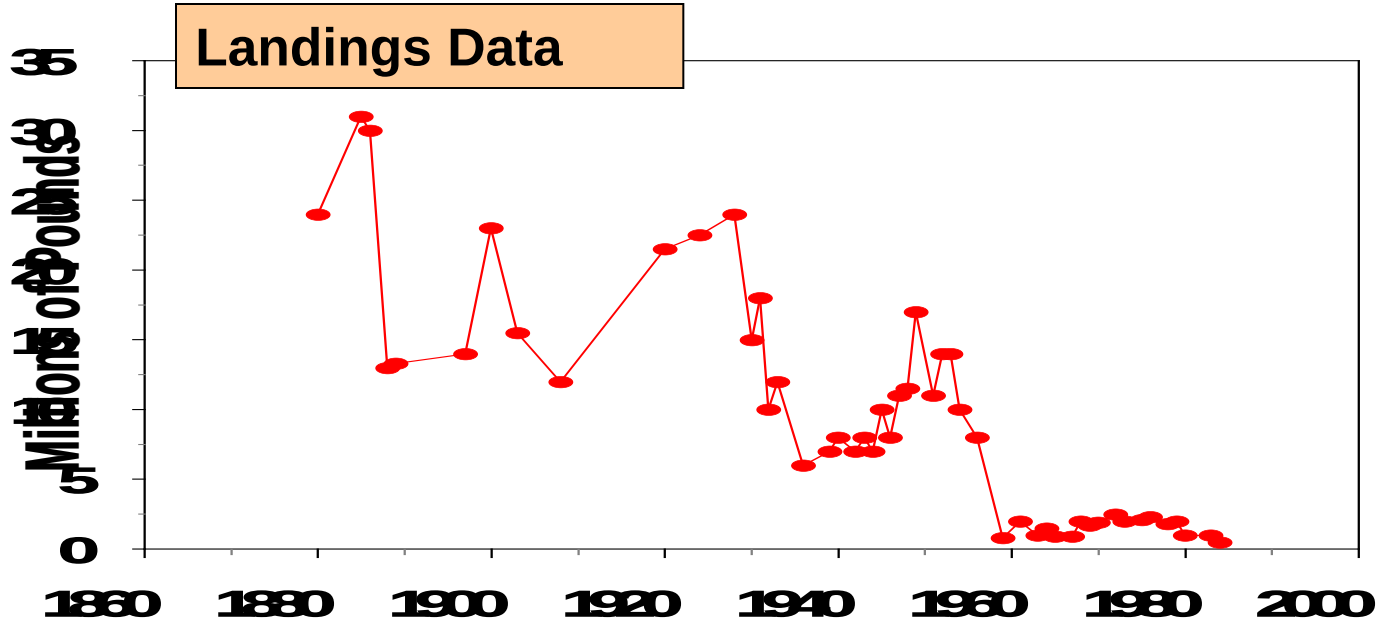
Oysters



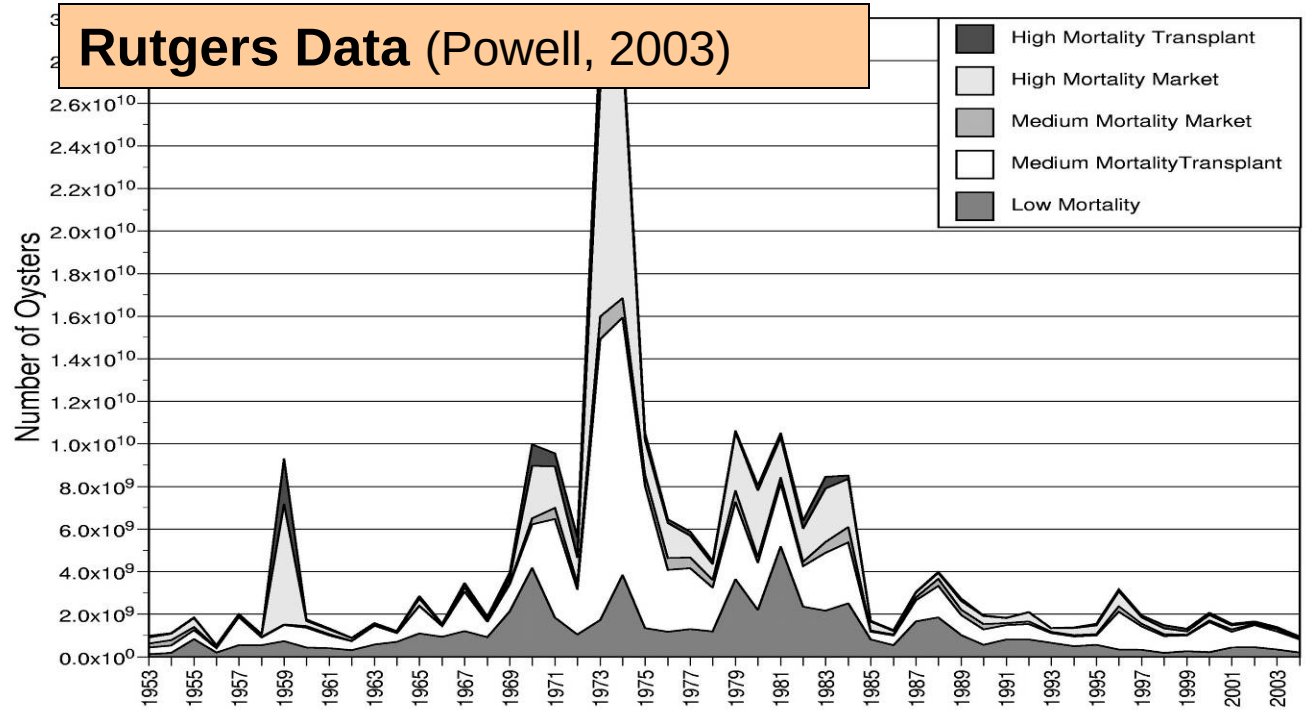
Crassostrea virginica



Landings Data



Rutgers Data (Powell, 2003)



Bivalves – Issues

Oysters
Crassostrea virginica

POSITIVE

DESCRIPTION: Eastern oysters are a nutritious f
and an important fishery in Delaware Bay. In 188
1,400 sailing vessels harvested approximately 1.5
bushels, or 22 million pounds of oysters. Today, h
deliver about 100,000 bushels with a dockside va
of $3 million to $5 million, but efforts are under w
boost those numbers. Oysters also provide impor
ecosystem services by creating reef habitats for fi
other organisms, filtering water, recycling nutrien
stabilizing sediments. However, these filter-feede
be sensitive to degraded water conditions. Like o
bivalve mollusks, oysters are world-renowned as
bioindicators of environmental conditions.

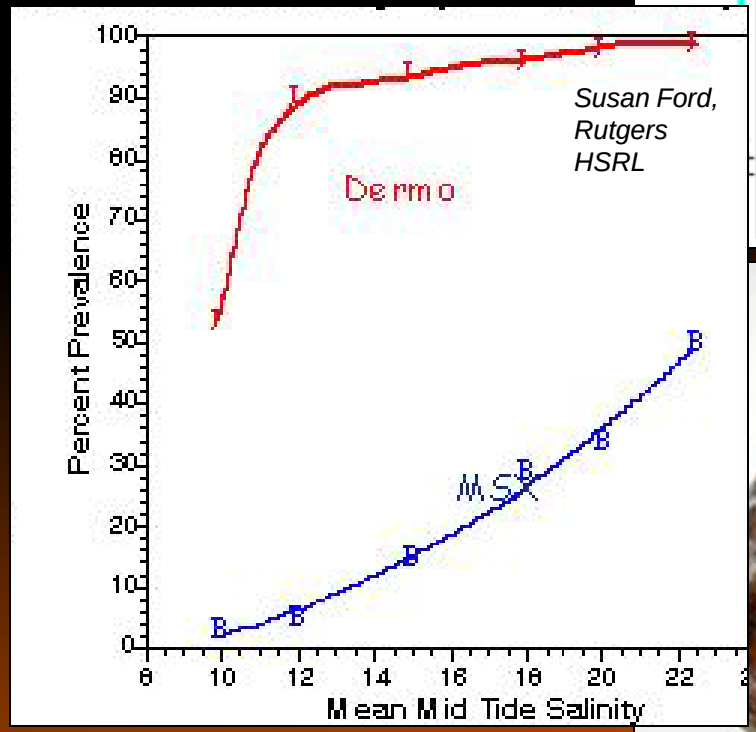
STATUS: Although only a fraction of their histori
today's oyster populations are carefully managed
maintain and increase abundance through the in
of harvest, oyster disease mortality, and recruitme
tunately, oysters in Delaware Bay have developed
resistance to MSX disease, which devastated the p
tion from 1957 to 1986. However, Dermo disease
been a persistent problem since 1990, especially
lower Bay's high-salinity waters. After an unprece
seven years of low "recruitment" by juvenile oyst
spat), 2007 marked a return to average levels.

TRENDS: Oyster abundance was not accurately
before the 1950s, but landings data suggest that
tions are a fraction of their historic size in the 19th
early 20th Centuries. Seed-bed data indicate that
abundance is 39 percent of the 1953 to 2007 long
average and 78 percent of the 1989 to 2007 short
average. While recruitment in 2007 was 54 percen
long-term average, it represents 135 percent of th
term average. In fact, populations in Upper Delaw
remain relatively robust. Therefore, it is likely the
population will continue to support commercial

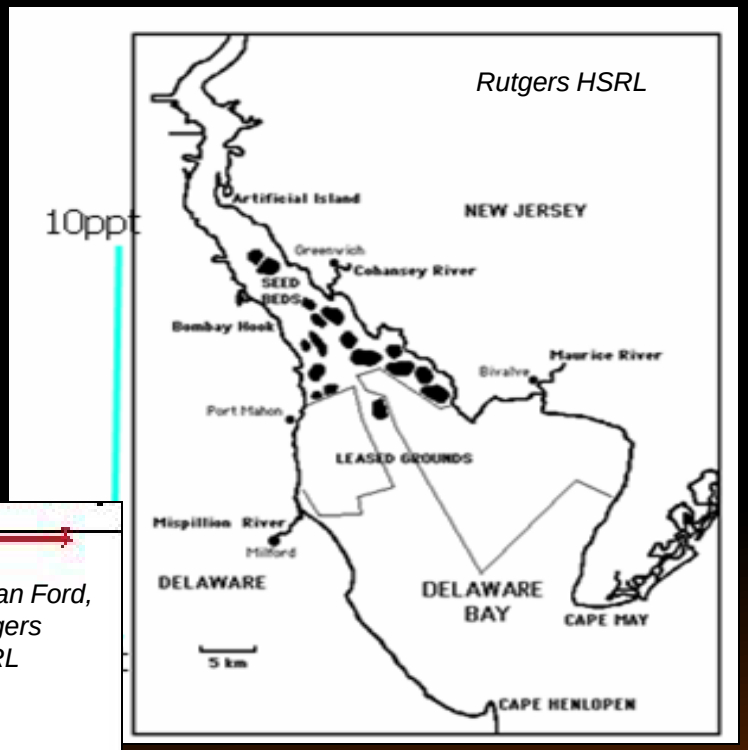
NEGATIVE

ACTIONS AND NEEDS: Oyster population healt

Oyster Disease and Salinity



Susan Ford, Rutgers HSRL



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

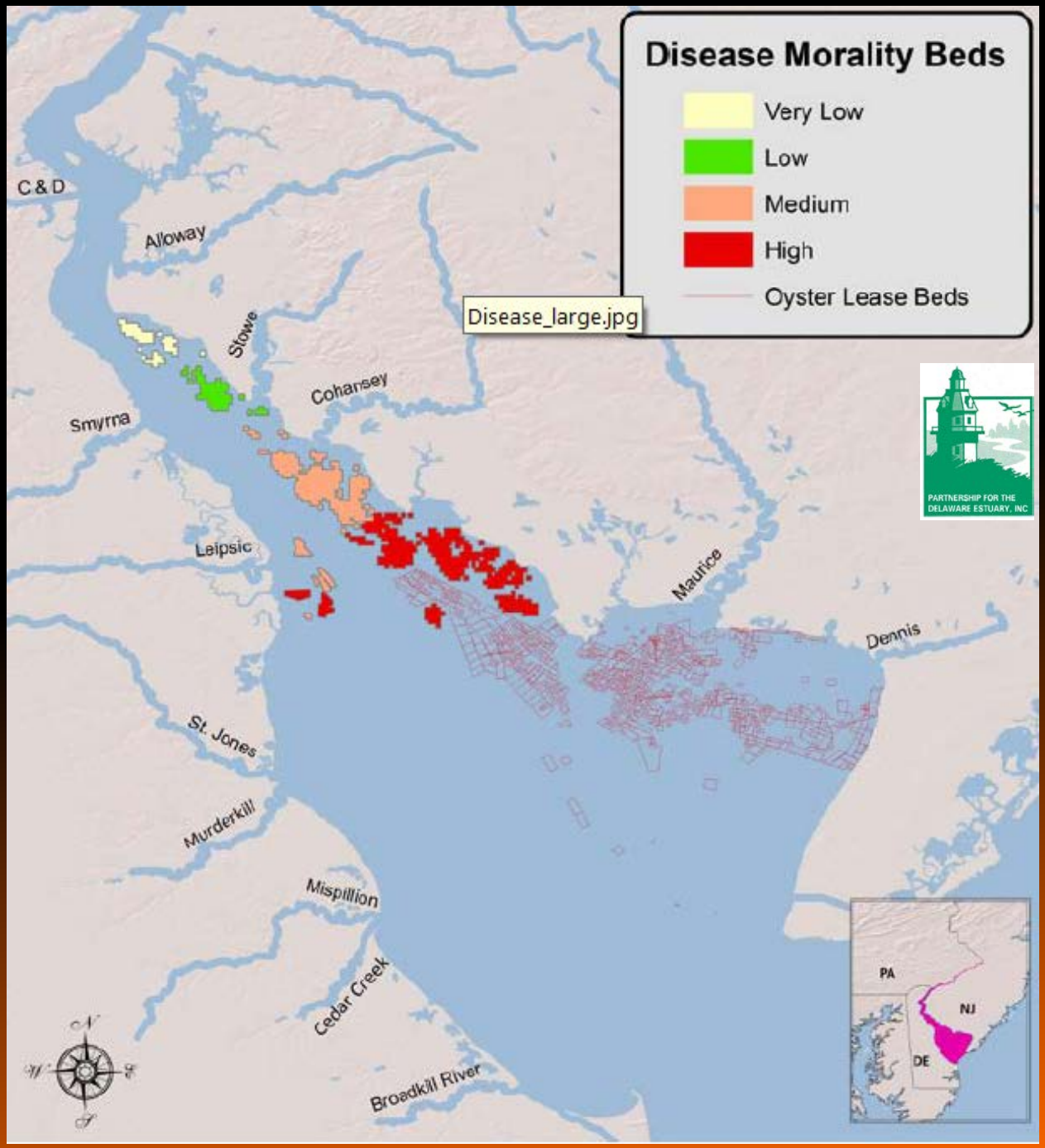
Oysters

Present Population:
~ 2 billion oysters

Commercial Fishery

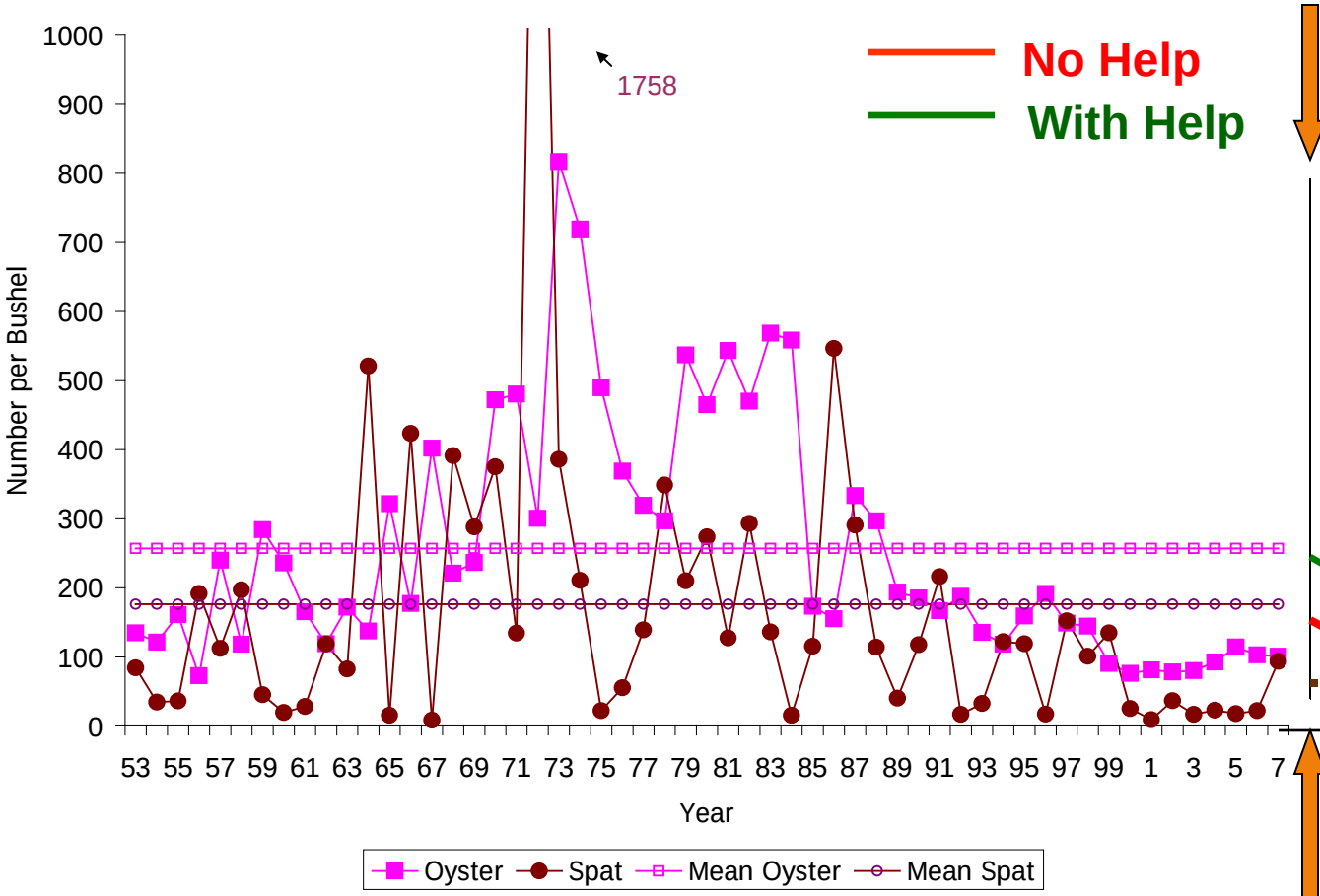
Challenges:

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



Bivalve Projections – Oysters

Can they be maintained until they might see better conditions?



Historical data from Rutgers Haskin Shellfish Laboratory

Ribbed Mussels in Salt Marshes

Bivalve Projections – Ribbed Mussels

Losing Marsh Habitat

Losing an acre per day

Freshwater Mussels

Highest Biodiversity is in North America

~300 species

Streams, rivers, lakes, tidal fresh

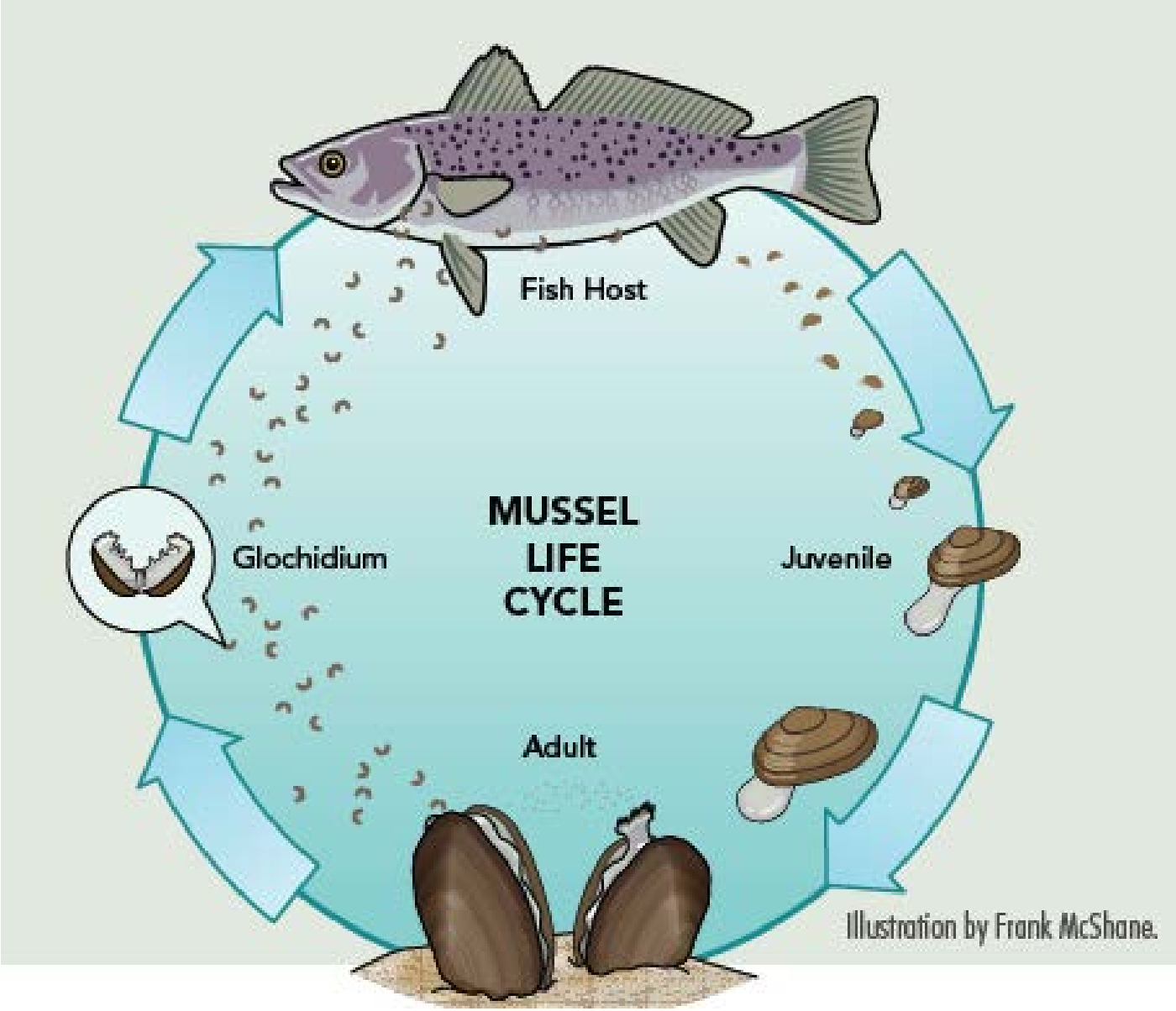
Freshwater Mussels

Elegant Life History

use fish
to reproduce

Long –Lived

30-100 years
like old growth
trees in streams



Source: PDE Mussel Guide: http://delawareestuary.org/freshwater-mussels

Freshwater Mussels of the Lower Delaware River

Ligumia nasuta

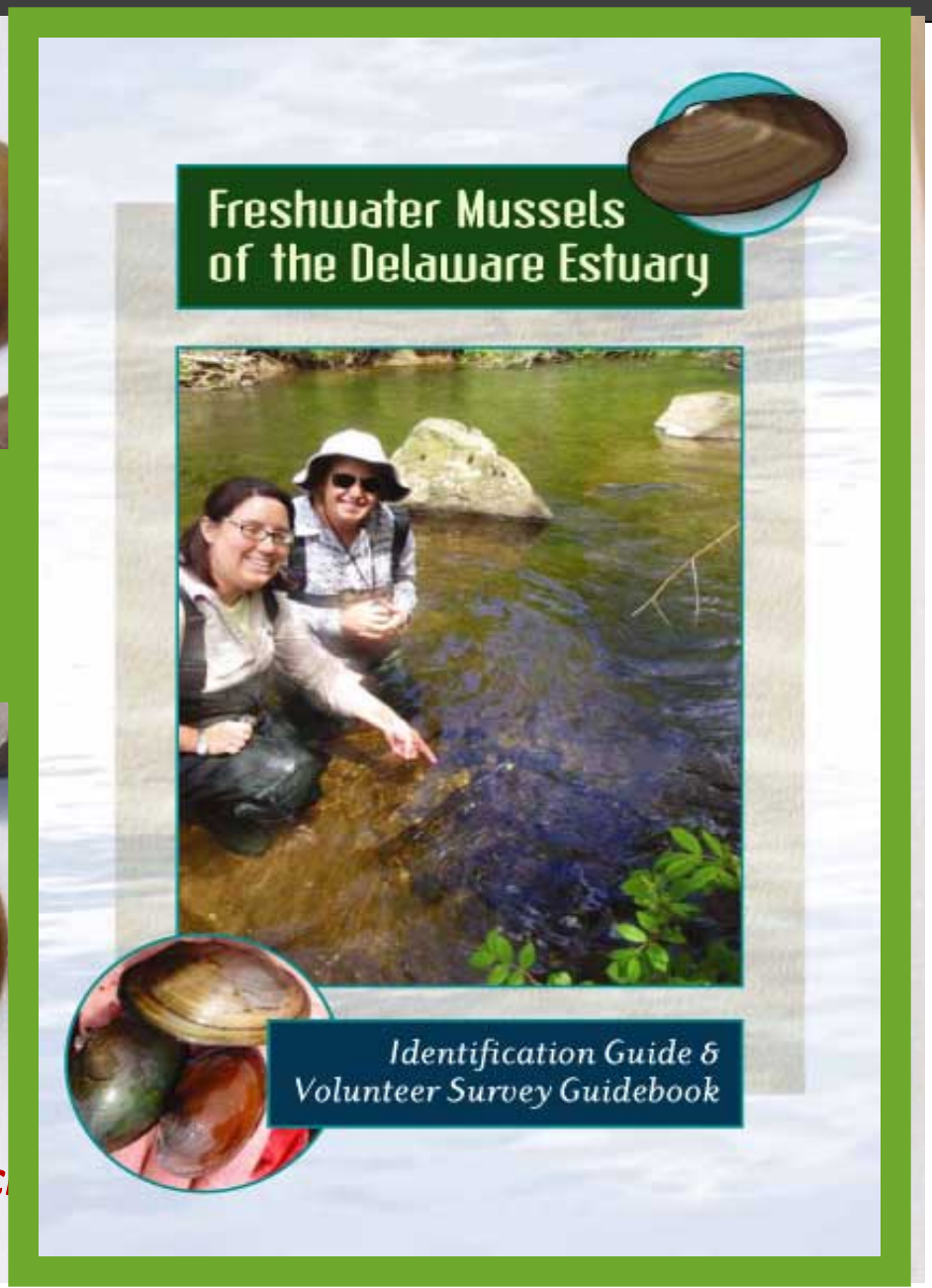
Downloadable Field Guide:

https://s3.amazonaws.com/delawareestuary/pdf/Restoration/Volunteer%20Guidebook.pdf

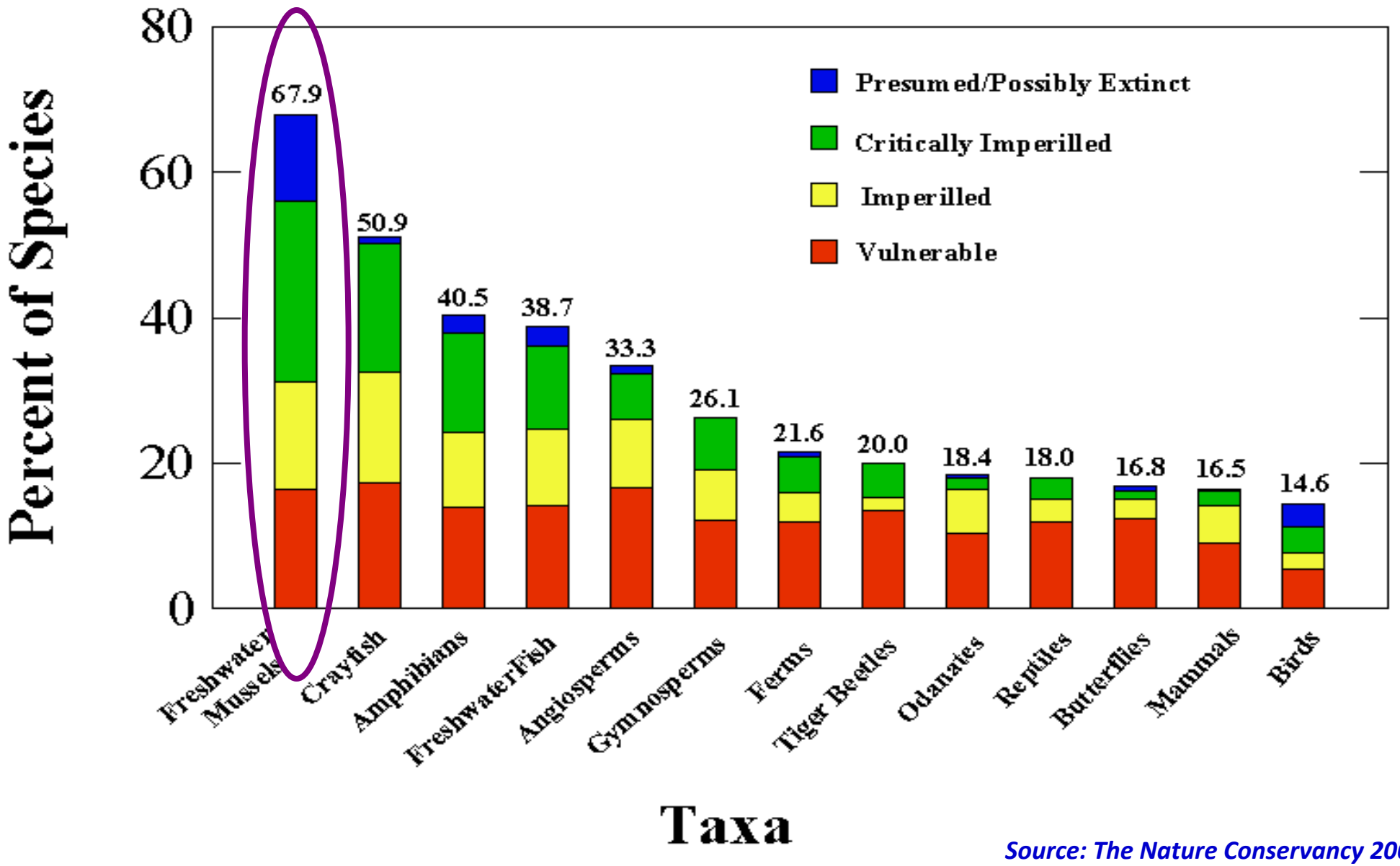
Lampsilis cariosa

Strophitus undulata

Leptodea oc



Conservation Status of United States Taxa



Source: The Nature Conservancy 2007

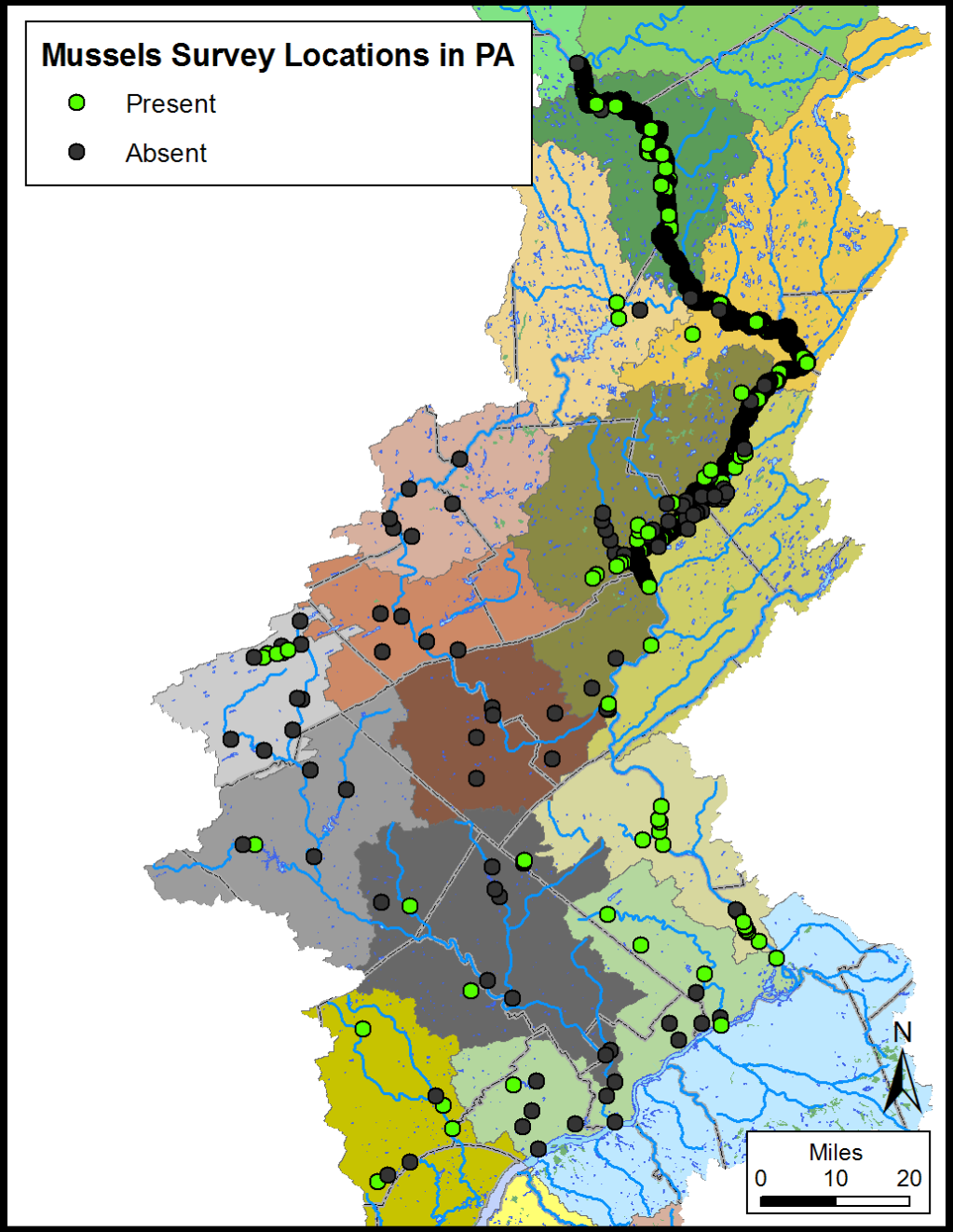
Delaware River Basin

Patchy, Impaired

Rare

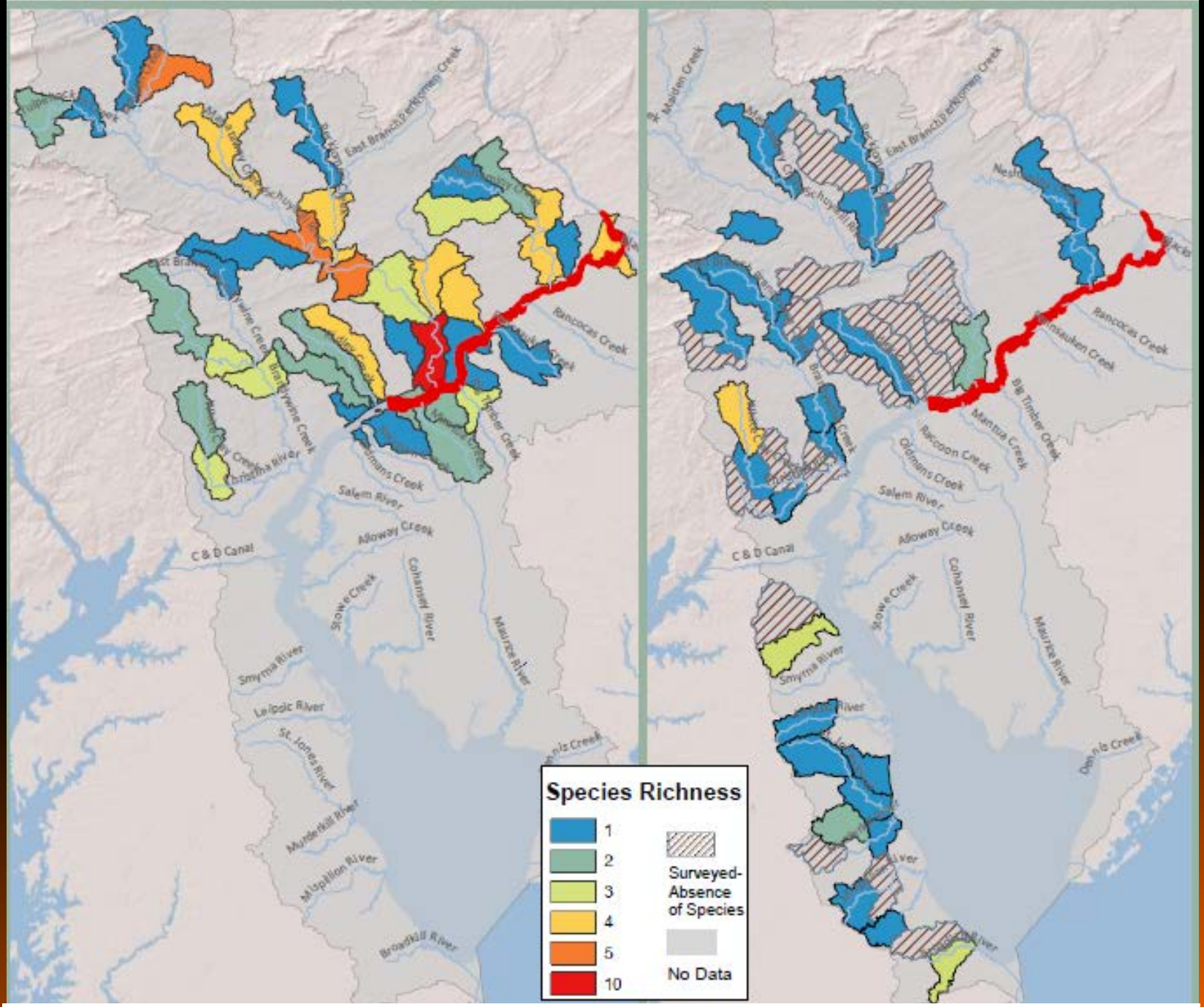
Extirpated

		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


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

1919

Since 1996



Source: Technical Report for the Delaware Estuary and River Basin, PDE, 2012

Culprits

Water Quality

Stormwater

Unstable Bottoms

Reduced Riparian Canopy

Loss of Fish Hosts

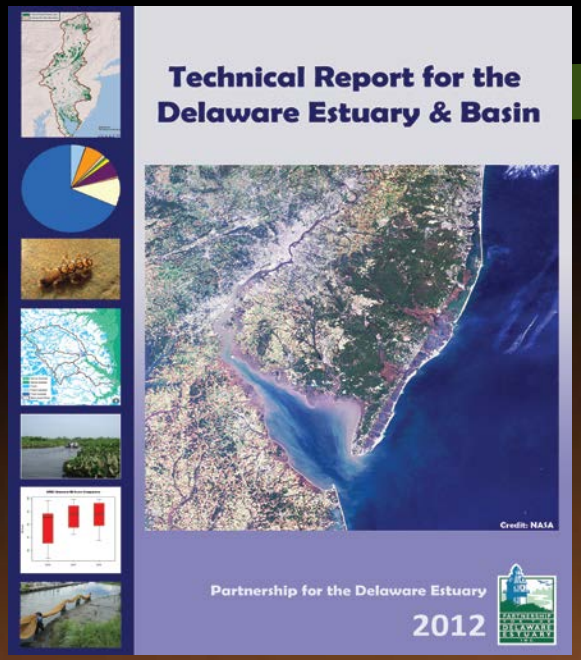
Habitat Degradation

Photo by D. Kreeger

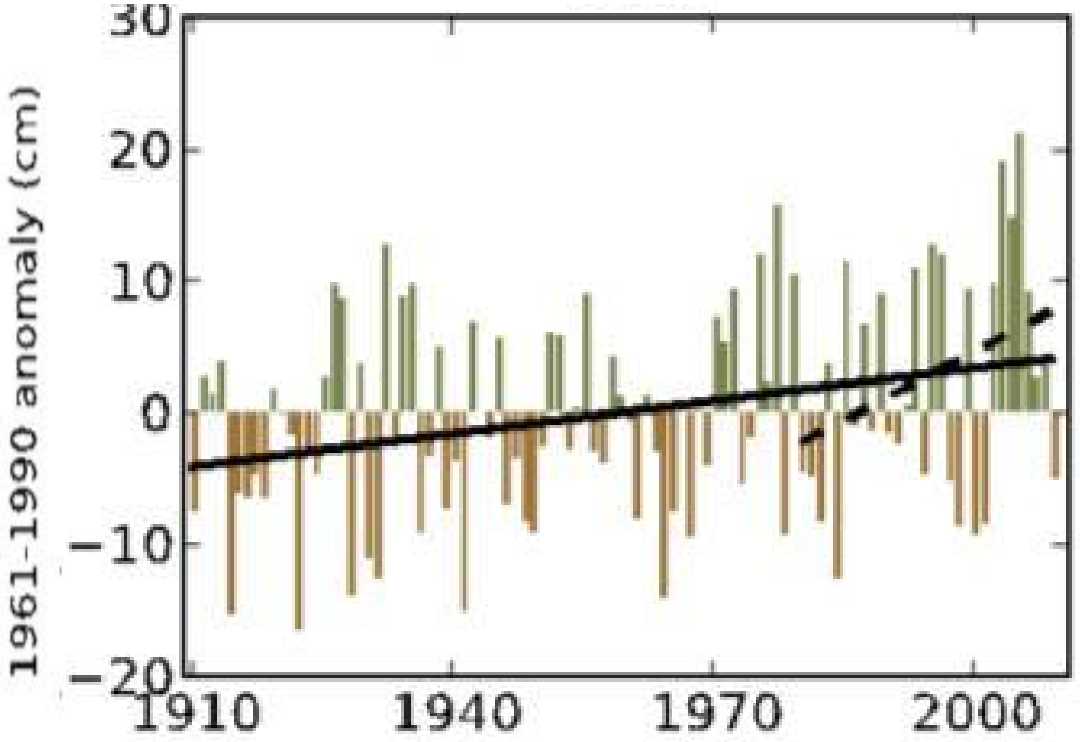
Freshwater Mussel – Future Challenges

Kreeger

↑ Precipitation
↑ Flooding
↑ Temperature
↑ Salinity



Fall Precipitation (Anomoly)



Source: Technical Report for the Delaware Estuary and River Basin, PDE, 2012

Bivalve Projections – FW Mussels

Shifting Species Ranges, But No Dispersal

Kreeger

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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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

Why Care ?

Nature's Benefits

Bivalve Shellfish are "Ecosystem Engineers"

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Mussel Beds

CTUIR Freshwater Mussel Project

Oyster Reefs

Kreeger

Ecosystem Services

Benefits to People
And the Environment

1. Structural Ecology

↑ Habitat Complexity

Stabilize Bottoms

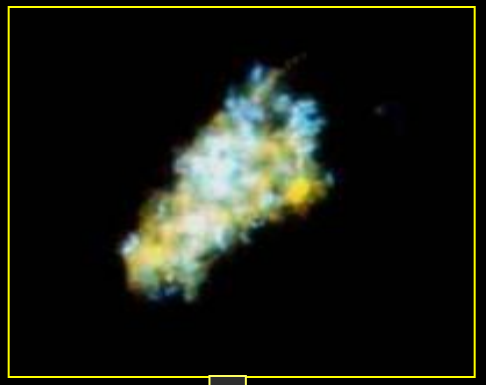
2. Functional Ecology

↓ Suspended Particulates

↓ Particulate N, P

↑ Light reaching bottom

↑ Sediment Enrichment



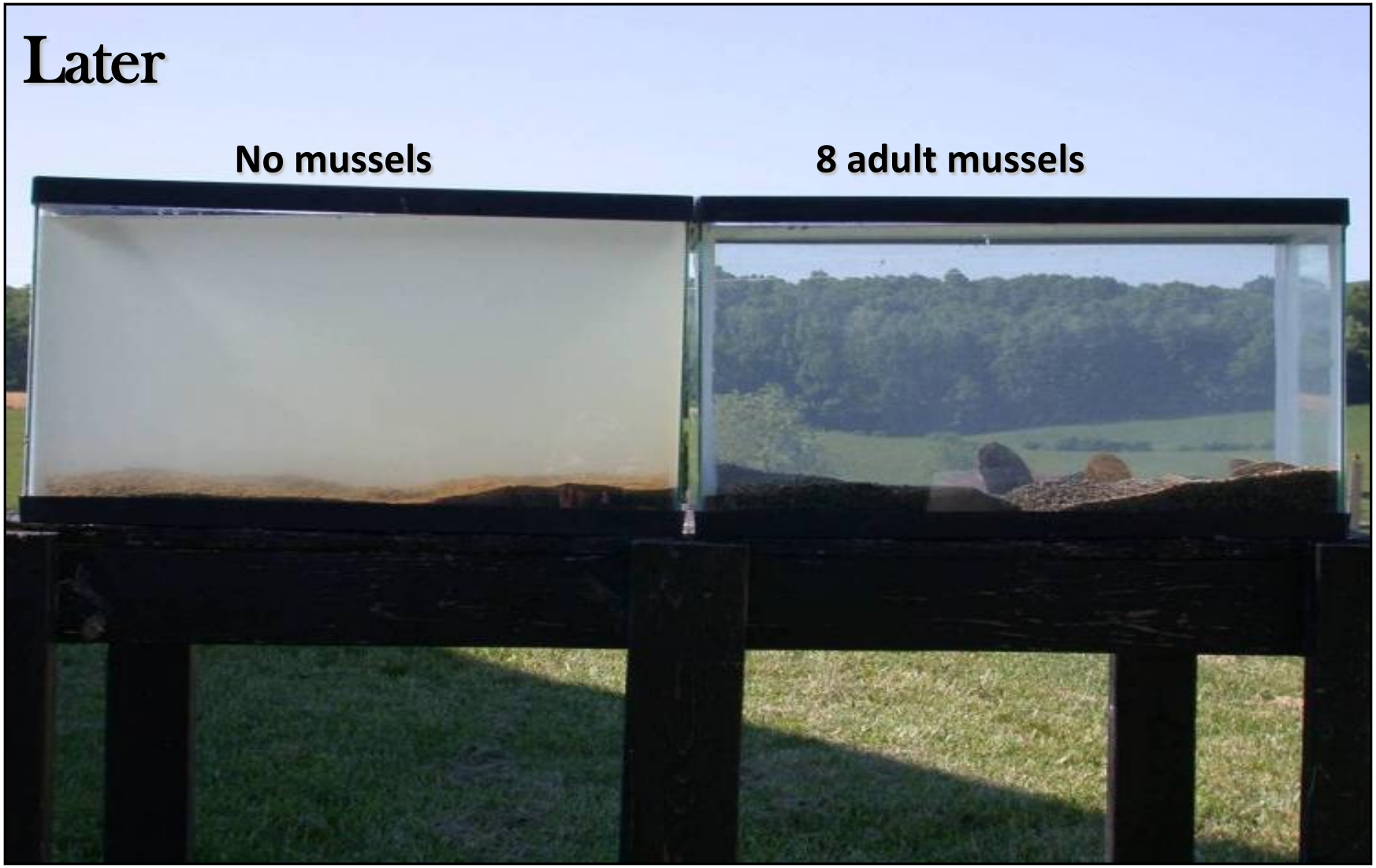
Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

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

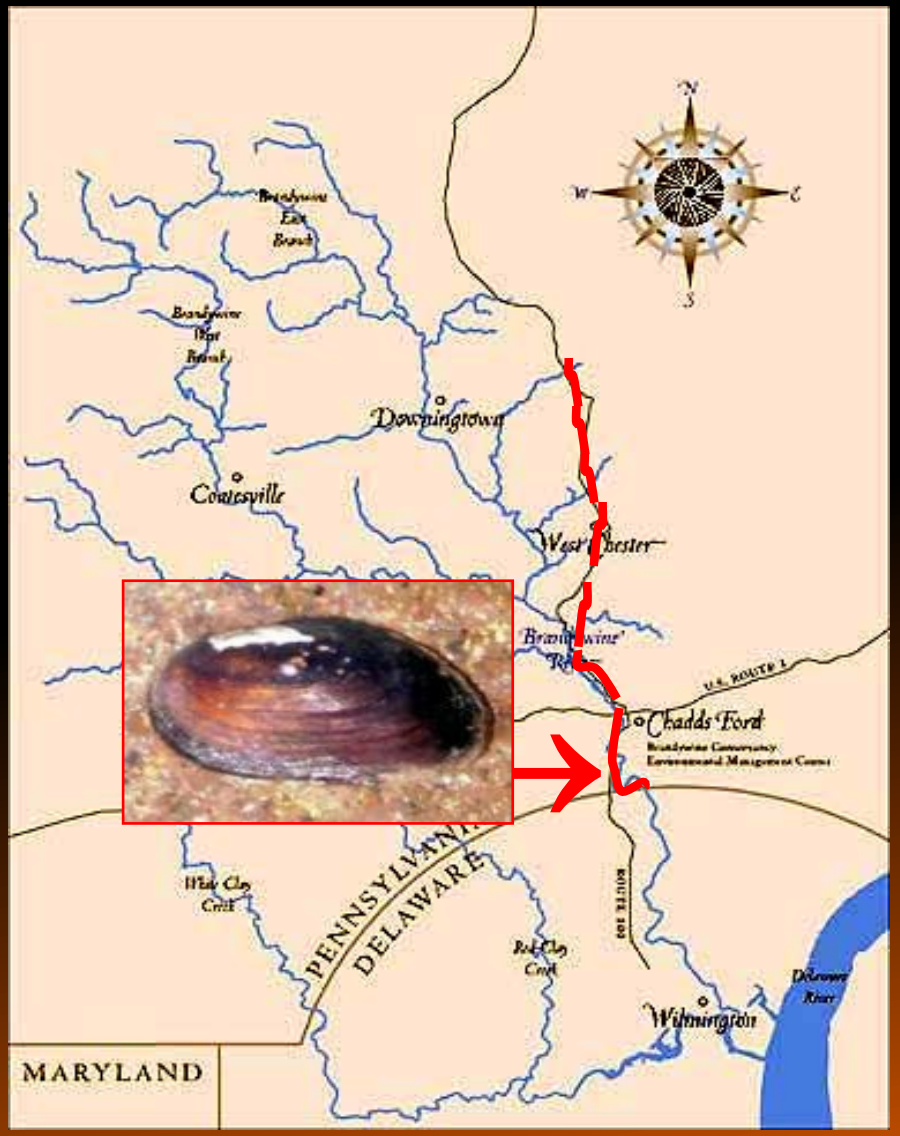
Example 1:

Brandywine River

~500,000 *Elliptio complanata* in 6-mile reach

Filter >25 metric tons dry suspended solids per year

Estimated Removal = 7.1 %



Map from The Brandywine River Conservancy

Data from Kreeger, 2006

Example 2:

Tidal Delaware River

2008-2009 Discoveries

Millions of mussels

6 species, two that were believed locally extinct


Health & Science

Surprising survivors

IMPORTANCE

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 Rate (gal day^{-1})	TSS Filtration (kg DW day^{-1})
Site 1	4,230	23,163	74,210	0.875	5.55	411,867	7.8
Site 2	18,648	477,389	992,074			5,506,008	104.2
Site 3	13,983	256,560	241,151			1,338,387	25.3
Site 4	35,525	1,662,570	586,163			3,253,202	61.6
Total	**72,386**	**2,419,682**	**1,893,597**			**10,509,464**	**198.9**

Values updated from: PDE Report 13-02. http://delawareestuary.org/node/203

=72.6 metric tons dry TSS per year

DRB Water Processing Estimate

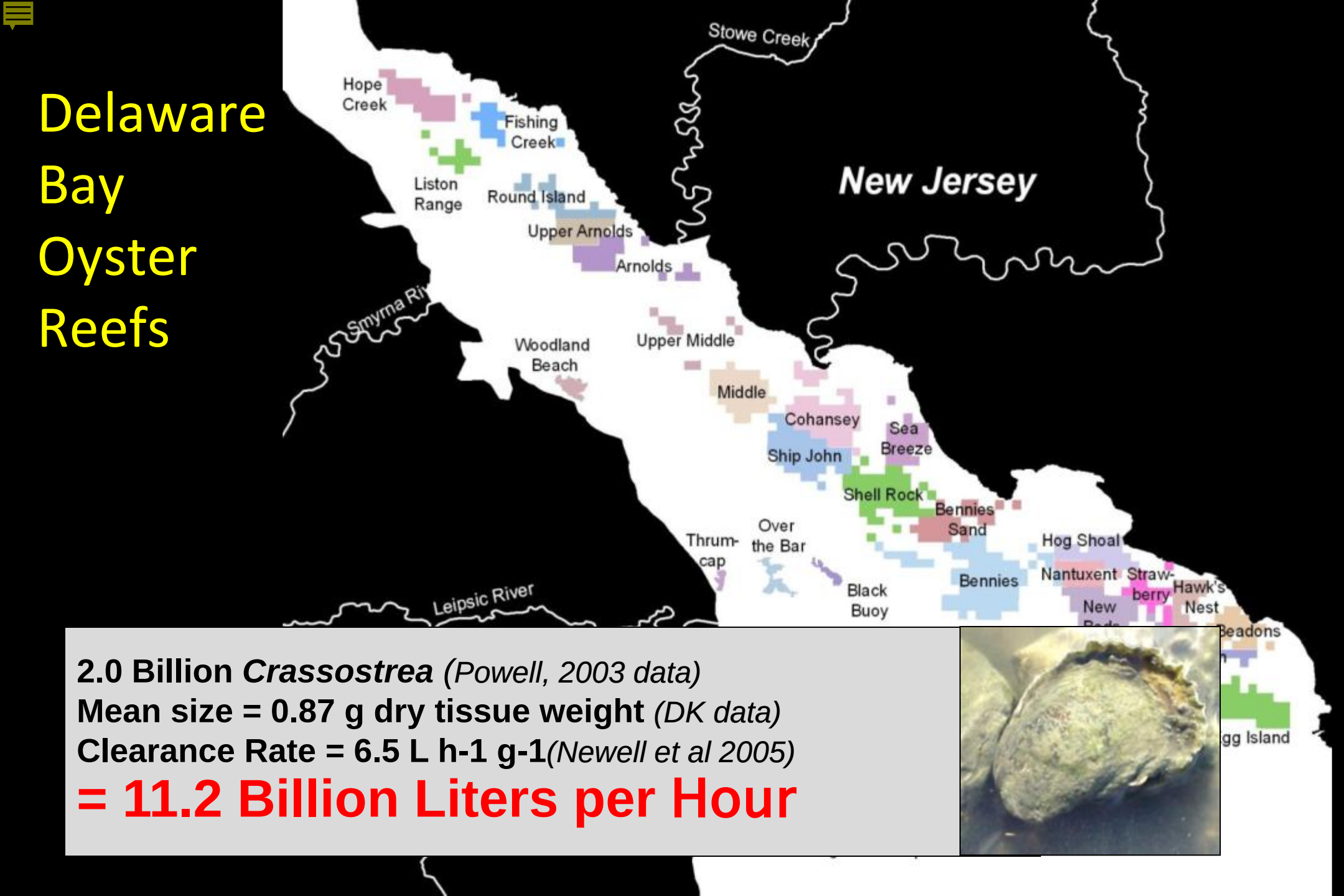

Elliptio complanata

4.3 Billion *Elliptio*

2.9 Million kg Dry Tissue Weight

= 9.8 Billion Liters per Hour

Delaware Bay Oyster 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

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)*

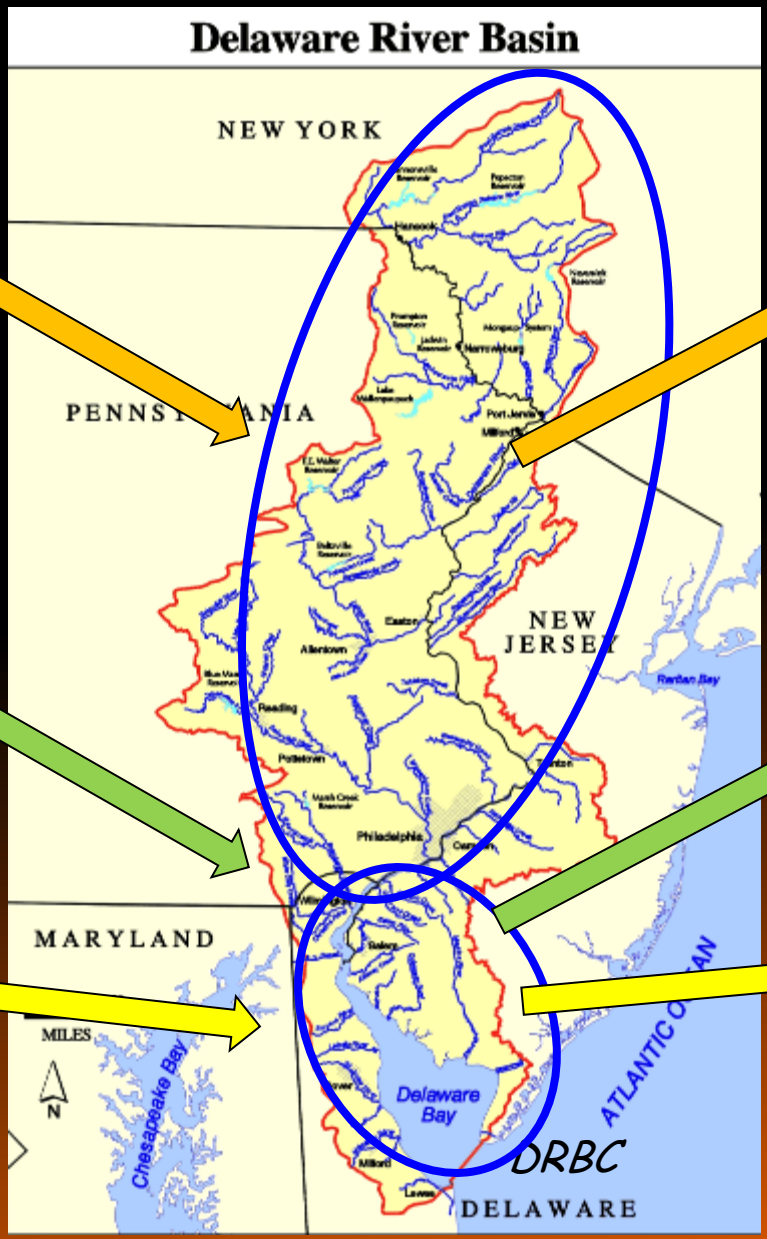
= 59.0 Billion Liters per Hour

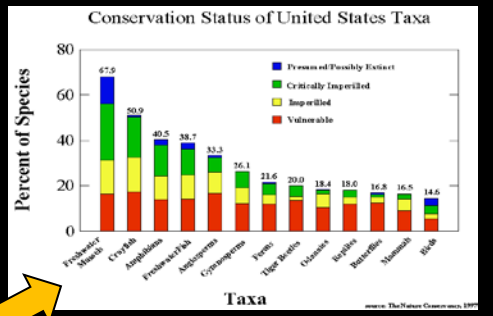
Shellfish Vulnerability

Freshwater Mussels

Marine Mussels

Oysters





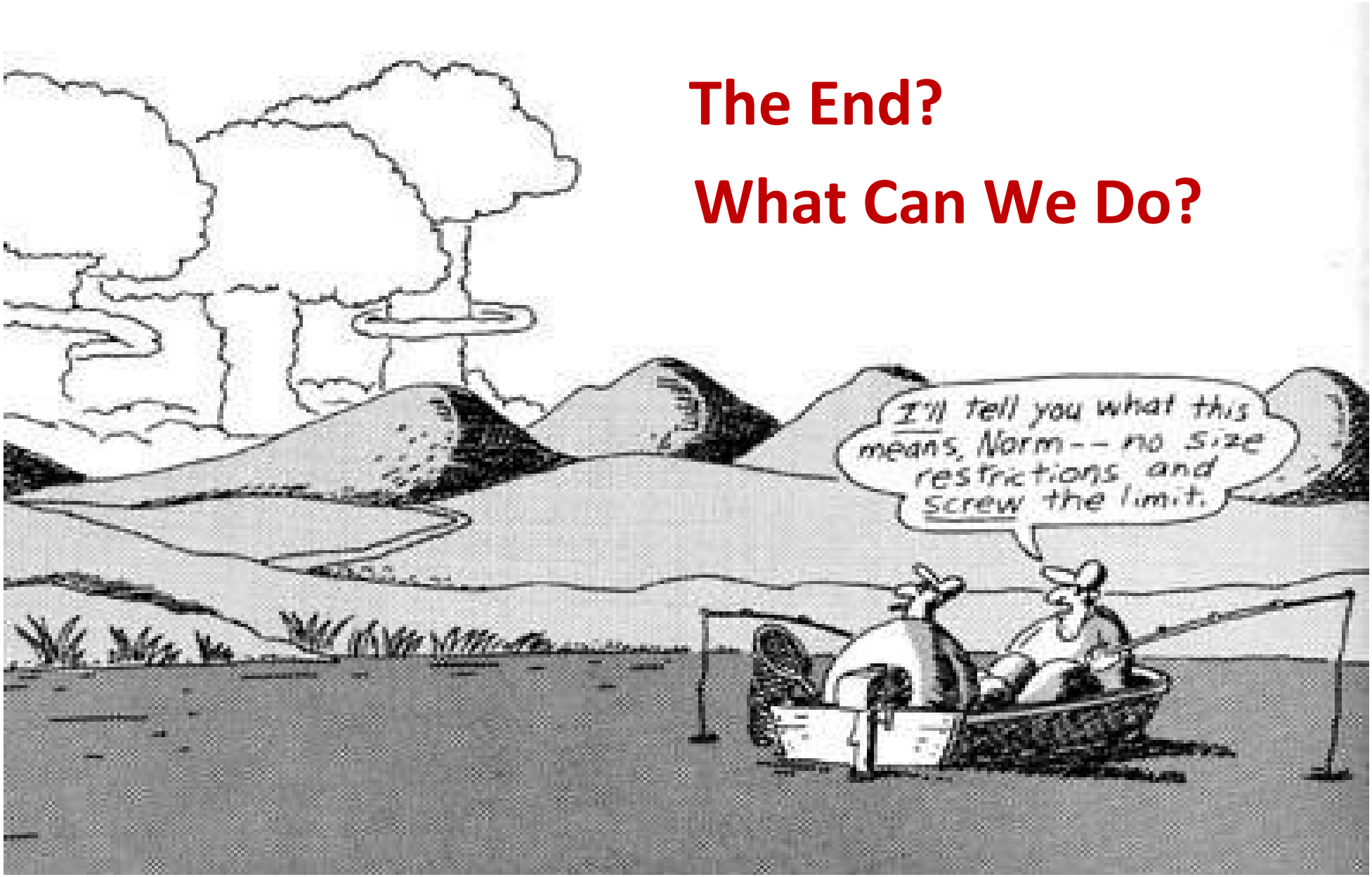
Imperiled

Losing Habitat

Salt water

The End?

What Can We Do?

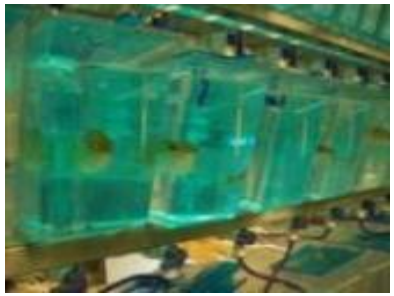


The Far Side by Gary Larson

Tactics and Solutions Exist

Water Quality & Flow Management

FWM Strategy Activity Areas

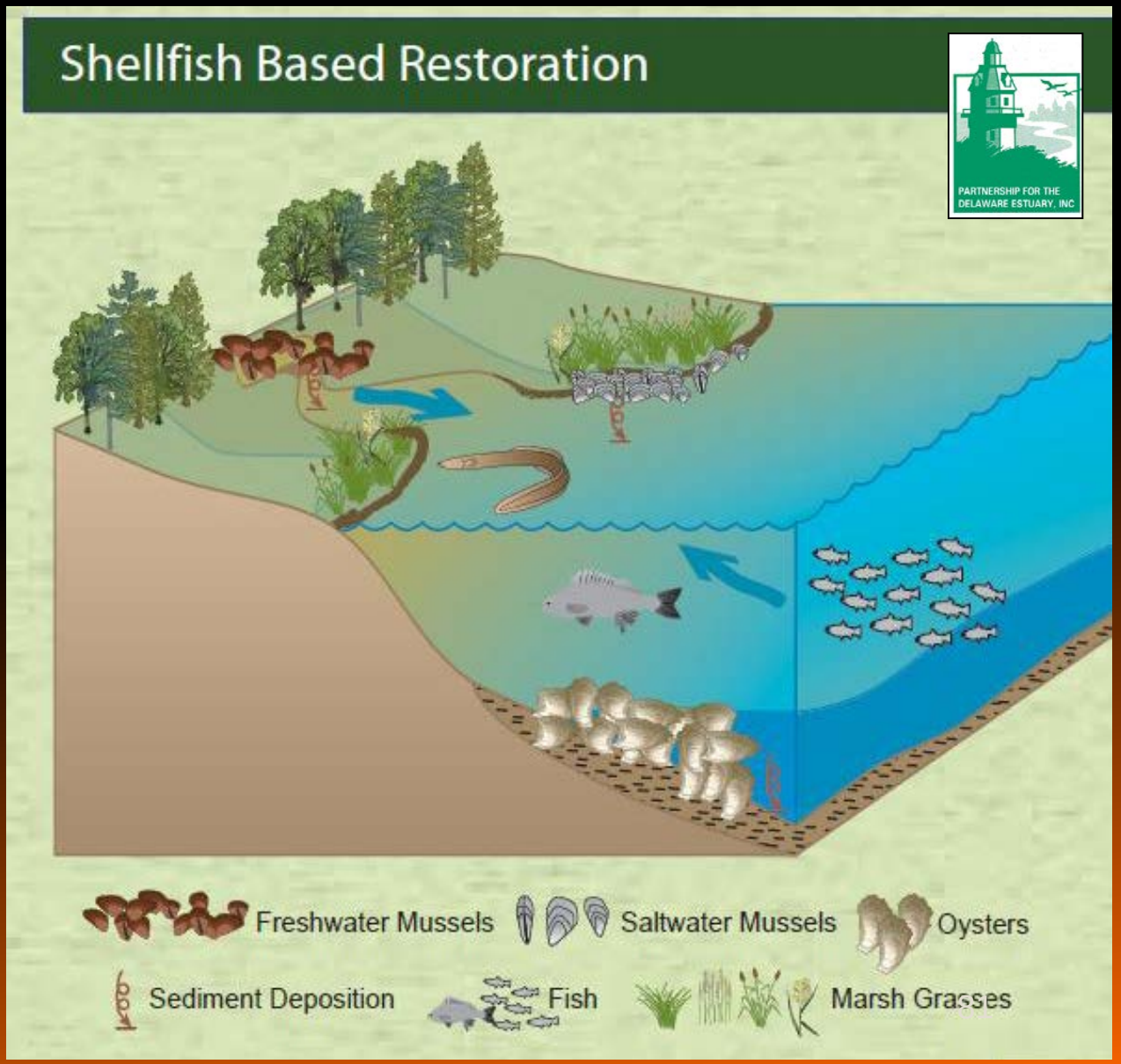


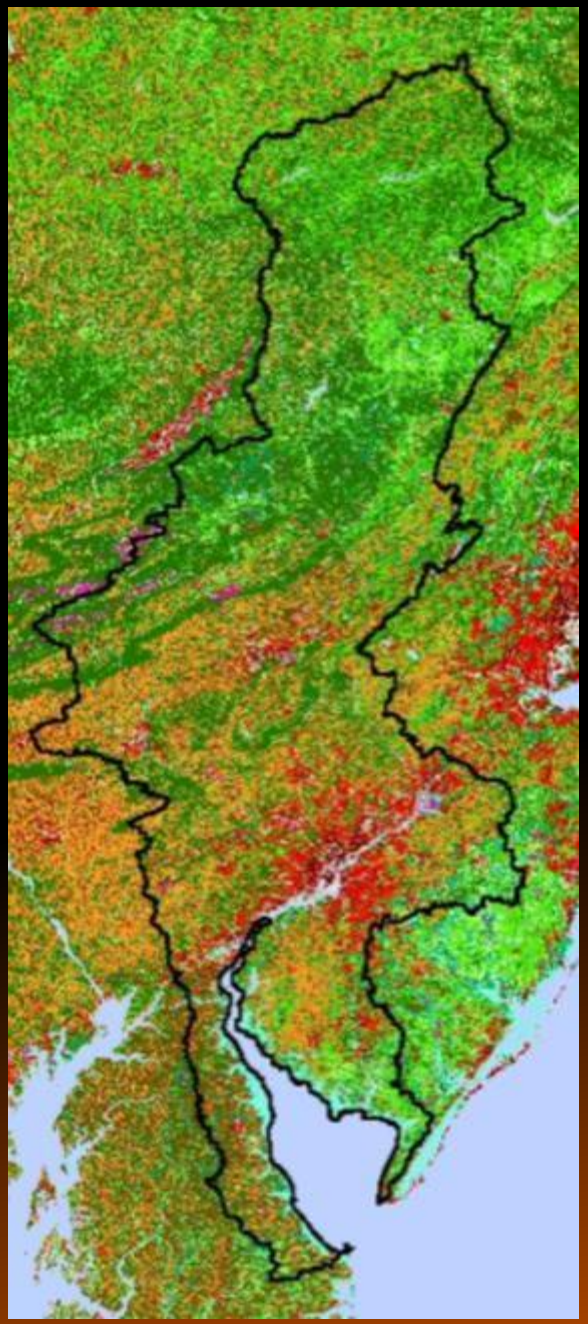
http://delawareestuary.org/node/202

Restoration for the Future = Climate Adaptation

Headwaters to Sea

1. Non-tidal
2. Intertidal
3. Subtidal





Desired Watershed Condition:

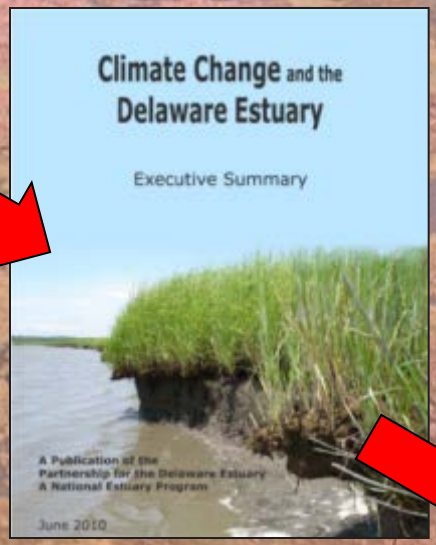
A diverse and robust assemblage of native bivalves living in abundance in all available tidal and non-tidal ecological niches and providing maximum possible benefits and climate resilience.

Kreeger

2007

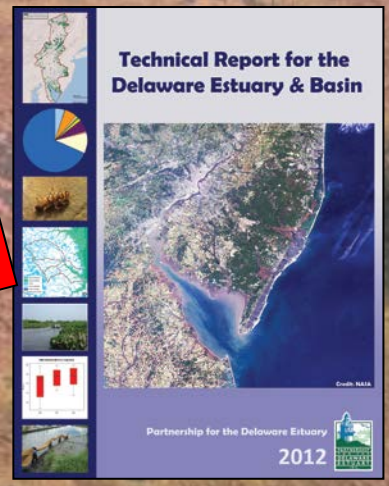
Recognize Problem

2010



Assess Vulnerability & Prioritize Solutions

2012



Track Change

Actions

Nature's Benefits: Clean Water, Climate Resilience

Other Issues

e.g., species disconnects

Website slides are from the Delaware Shorebird Project and the Horseshoe Crab Conservation Network

Climate Change + Other Changes

- Gas Drilling
- Dredging
- Withd
- Land Use Change
- Development
- Emerging Pollutants
- Ecological Flows
- Spills

Added Complexity

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

11/27/2004

Investment in Delaware Valley Lags

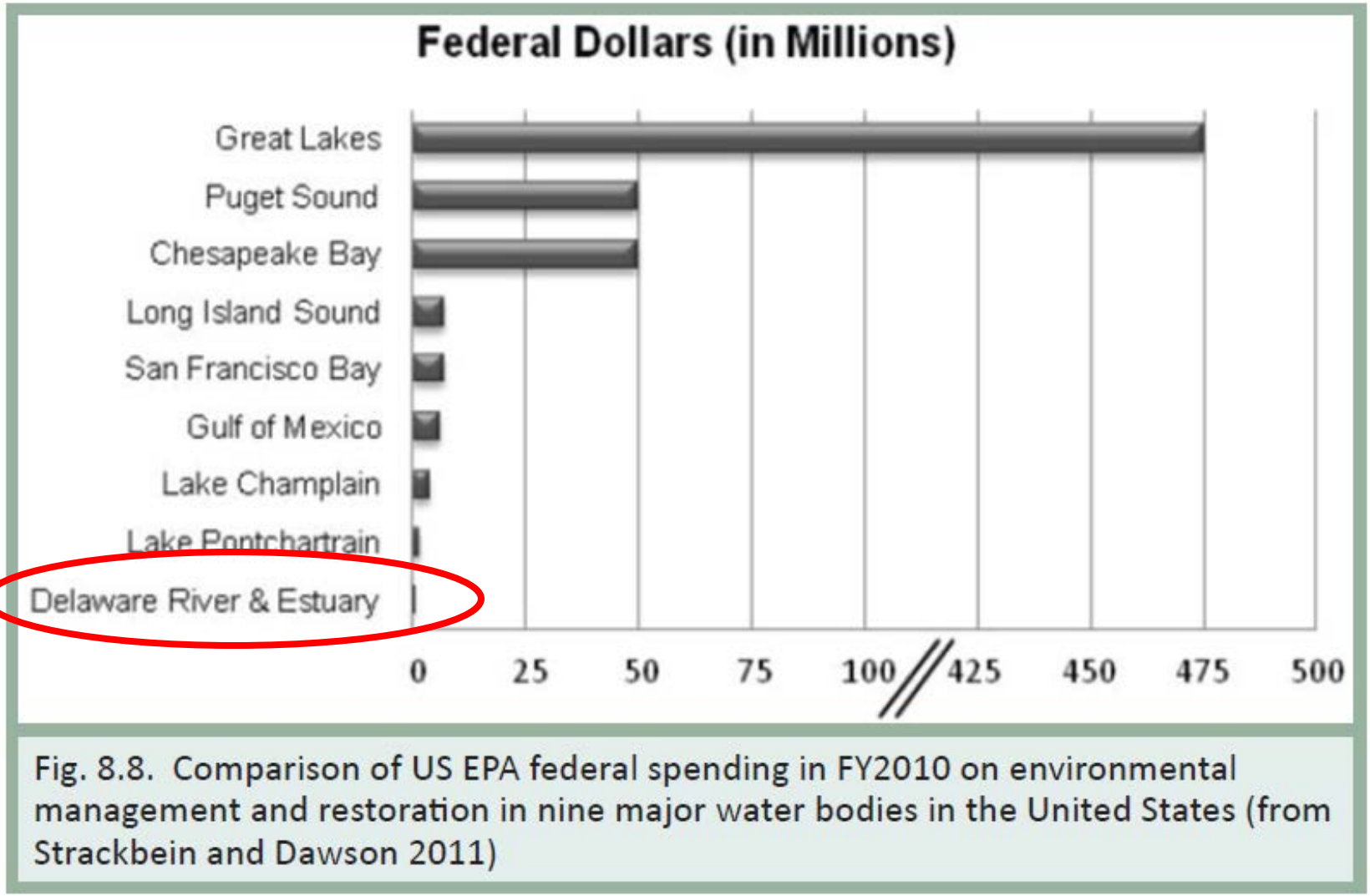


Fig. 8.8. Comparison of US EPA federal spending in FY2010 on environmental management and restoration in nine major water bodies in the United States (from Strackbein and Dawson 2011)

Natural Infrastructure

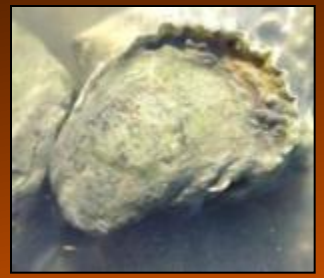
= High ROI

http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp

Take Home Messages

- Not all changes will be bad, but many ***more losers than winners***
- ***Need a Paradigm Shift***: "restore" for the future rather than the past, and expect dynamic rather than static conditions
- Adaptation requires ***investment*** to protect lives and livelihoods
- Proactive investment today will ***save money*** in the long term due to compounding of ecosystem services
- Adaptation is underway but hampered by funding, especially here






for more Info:

http://www.delawareestuary.org/Science_Programs