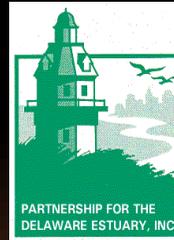
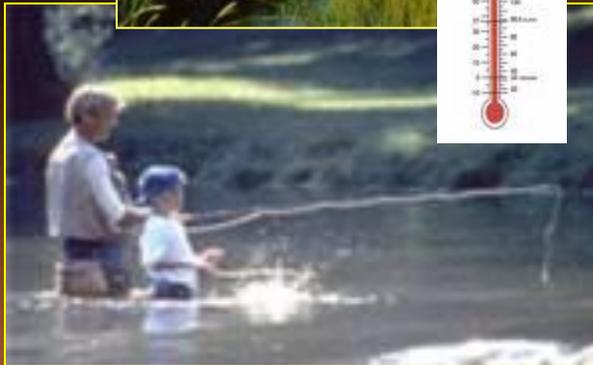
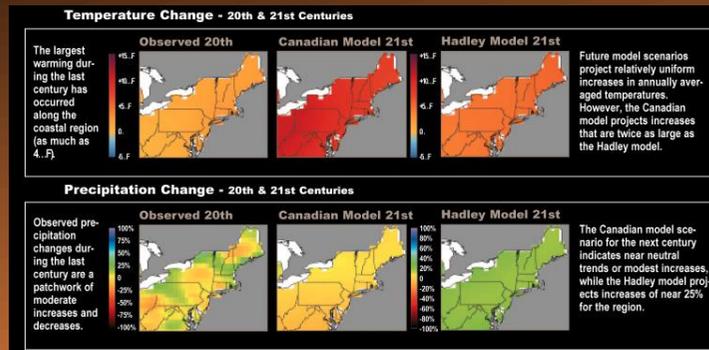


Importance of freshwater inflow for natural resources of the lower Delaware River Basin

Danielle Kreeger
Partnership for the Delaware Estuary



NCER
August 4, 2011



The Delaware River Basin

13,600 mi²

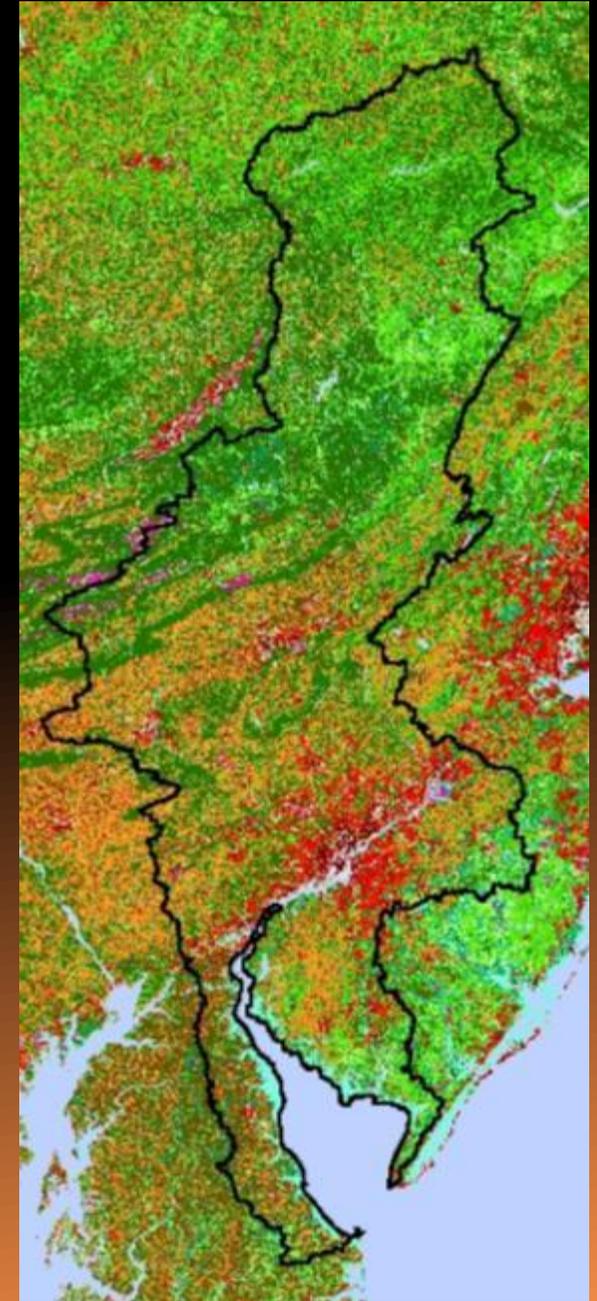
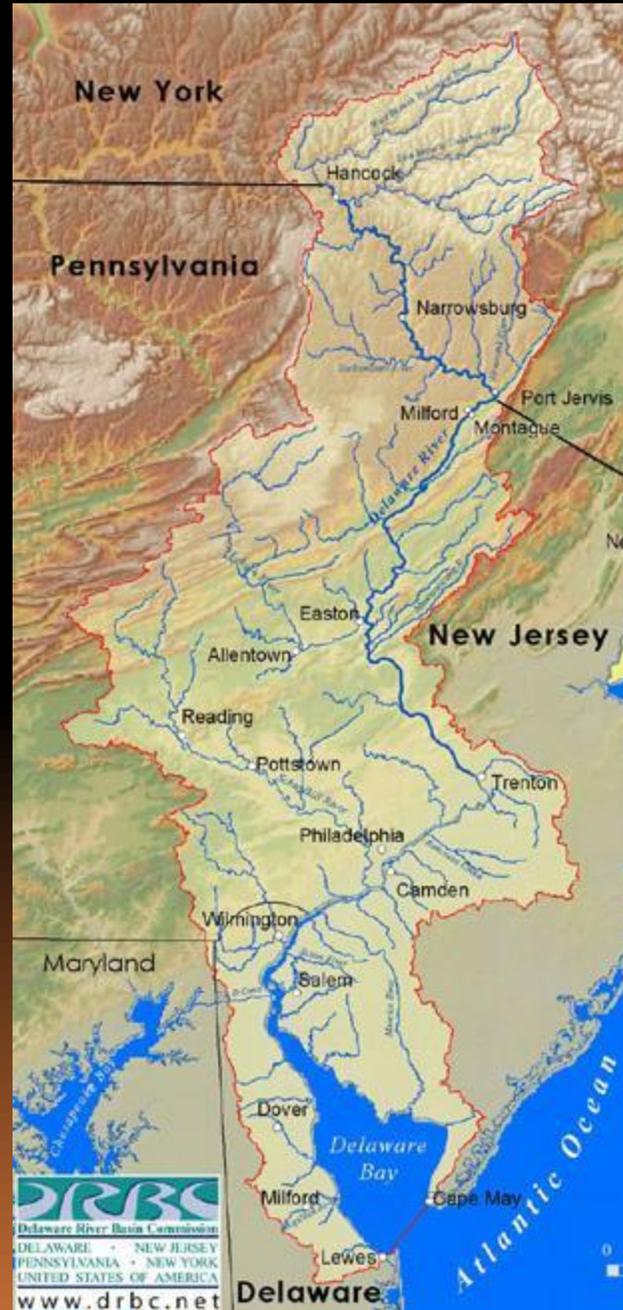
4 States

9 million people

Delaware River

60% of fw inflow (11,700 ft³/s)

Drinking water for 16 million people



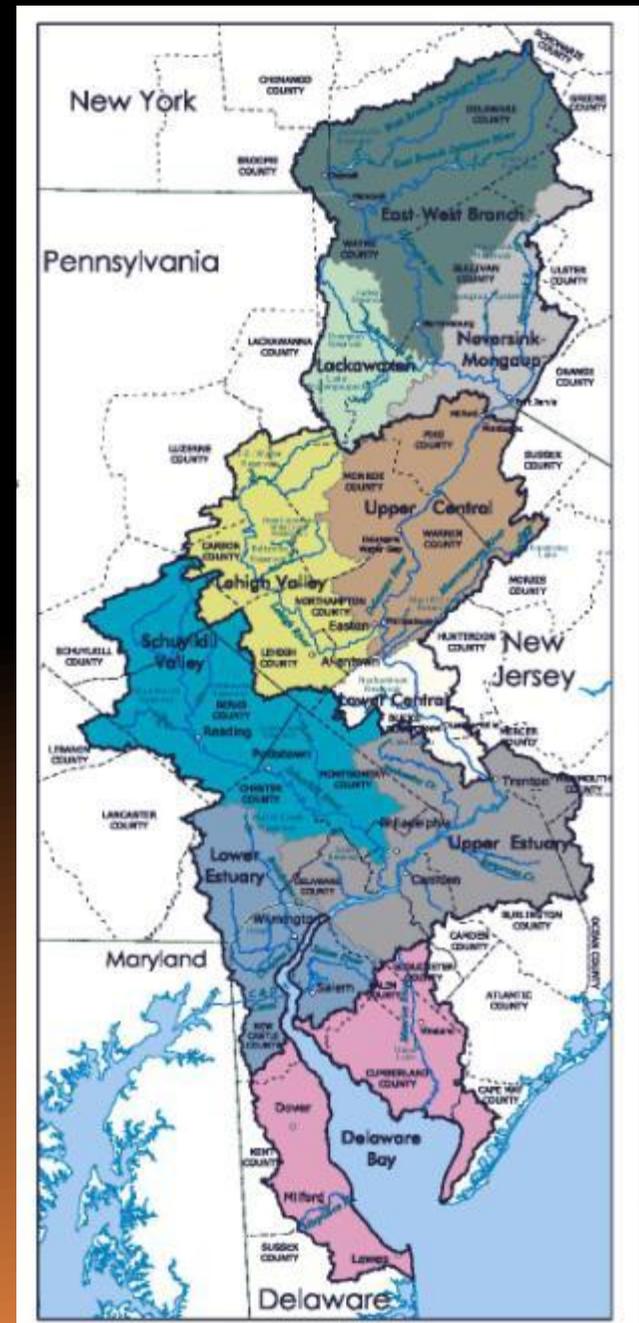
Delaware River Basin

Upper and Central Regions

- above Trenton
- pristine, wild and scenic
- longest undammed river in east

Lower and Bay Regions

- >90% of people
- legacy contaminants
- historic and modern development
- rich estuarine resources



Flow Management - Upper Basin

Flooding

- 3 of 6 floods of record in last 10 years

Coldwater Trout Fishery

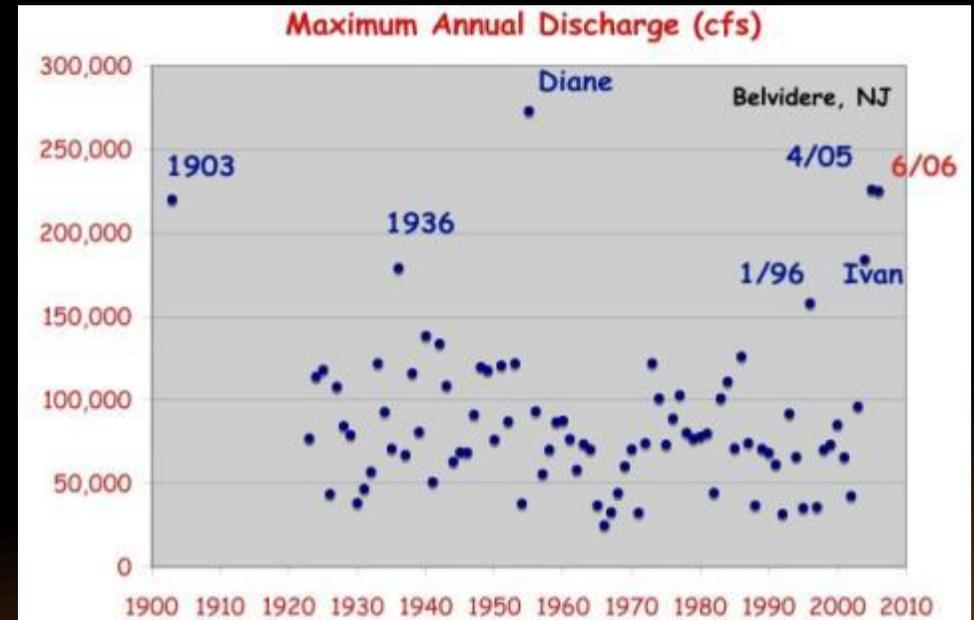
- important recreational resource

Endangered Species Protection

- dwarf wedgemussels

Flow Managed at Trenton

- Delaware River Basin Commission
- Protects ecological flows for upper basin natural resources



<http://www.ct.gov/dep/cwp/view.asp?A=2723&Q=325902>

Flow Management - Lower Basin **

Salinity Maintenance

- largest freshwater tidal prism in world
- broad salinity gradient & fw/sw mixing zone



Drinking Water

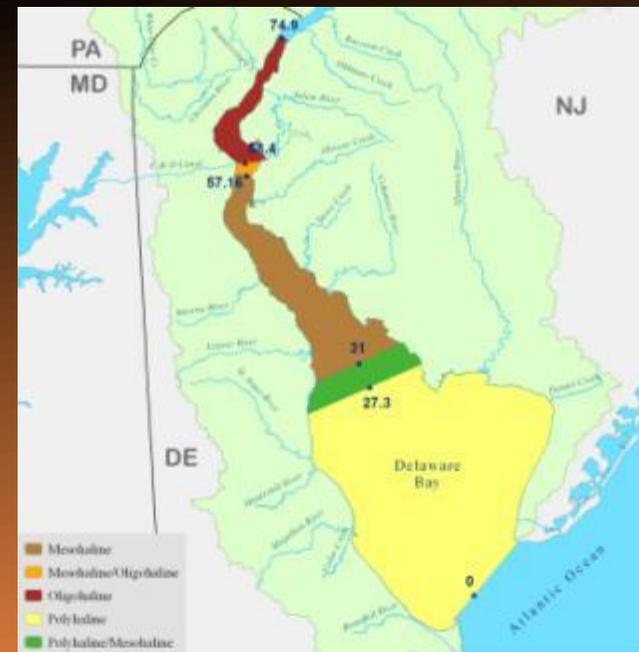
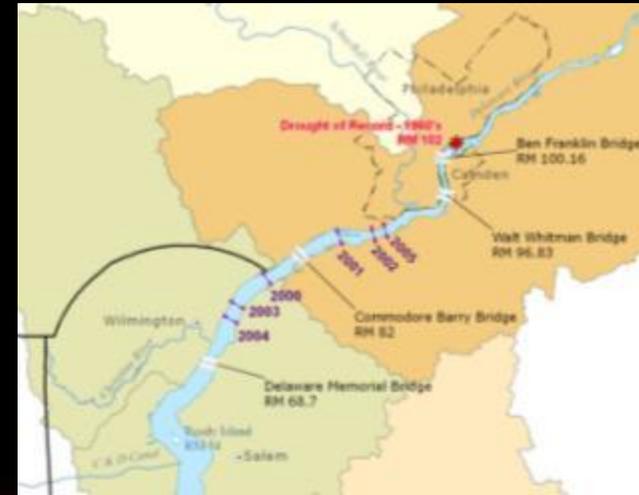
- Philadelphia intakes in fw tidal zone

Rare Freshwater Mussels



Freshwater Tidal Wetlands

Oysters



Climate Change and the Delaware Estuary

Executive Summary

[http://www.delawareestuary.org/
science_projects_climate_ready_products.asp](http://www.delawareestuary.org/science_projects_climate_ready_products.asp)

**A Publication of the
Partnership for the Delaware Estuary
A National Estuary Program**

June 2010





How do we even begin to plan for climate change in a system as large and complex as the Delaware Estuary?

PDE Climate Ready Pilot



3 case studies



How will climate change in the Delaware Estuary?

How will changes impact key resources?



What actions are recommended to make these resources more resilient?



What if we don't take action?



How Will Climate Change Affect Flow?

↑ Temperatures

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

↑ Precipitation

*More in winter than in summer
More heavy events*

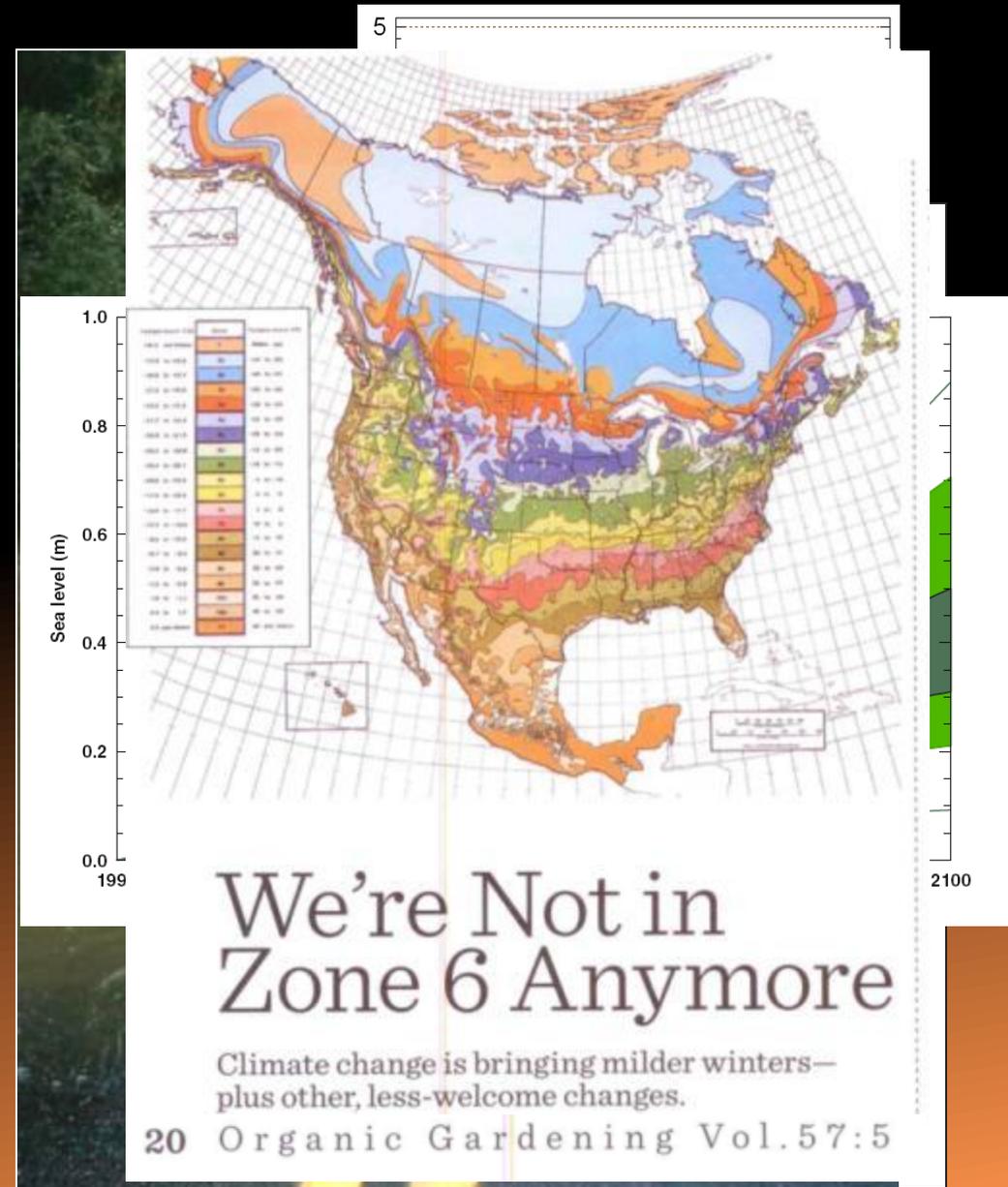
↑ Sea Level

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

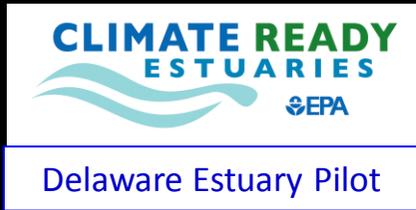
↑ Salinity

↑ Storms ?

↑ Growing Season



Case Studies



**Vulnerability
and Options**

Future Status

Rankings

Recommendations



Tidal Marshes



Bivalve Shellfish



Drinking Water

Tidal Wetlands – Why?

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



Tidal Wetland Vulnerability



Freshwater Tidal Marshes

- **Salinity Rise**
- Barriers to Landward Migration
- Others: Tidal Range, Seasonal Drying/Wetting



Salt Marshes

- **Sea Level Rise**
- Storms and Wind Wave Erosion
- Barriers to Landward Migration
- Others: Seasonal Wetting/Drying, Invasives

Tidal Wetlands – Adaptation Options

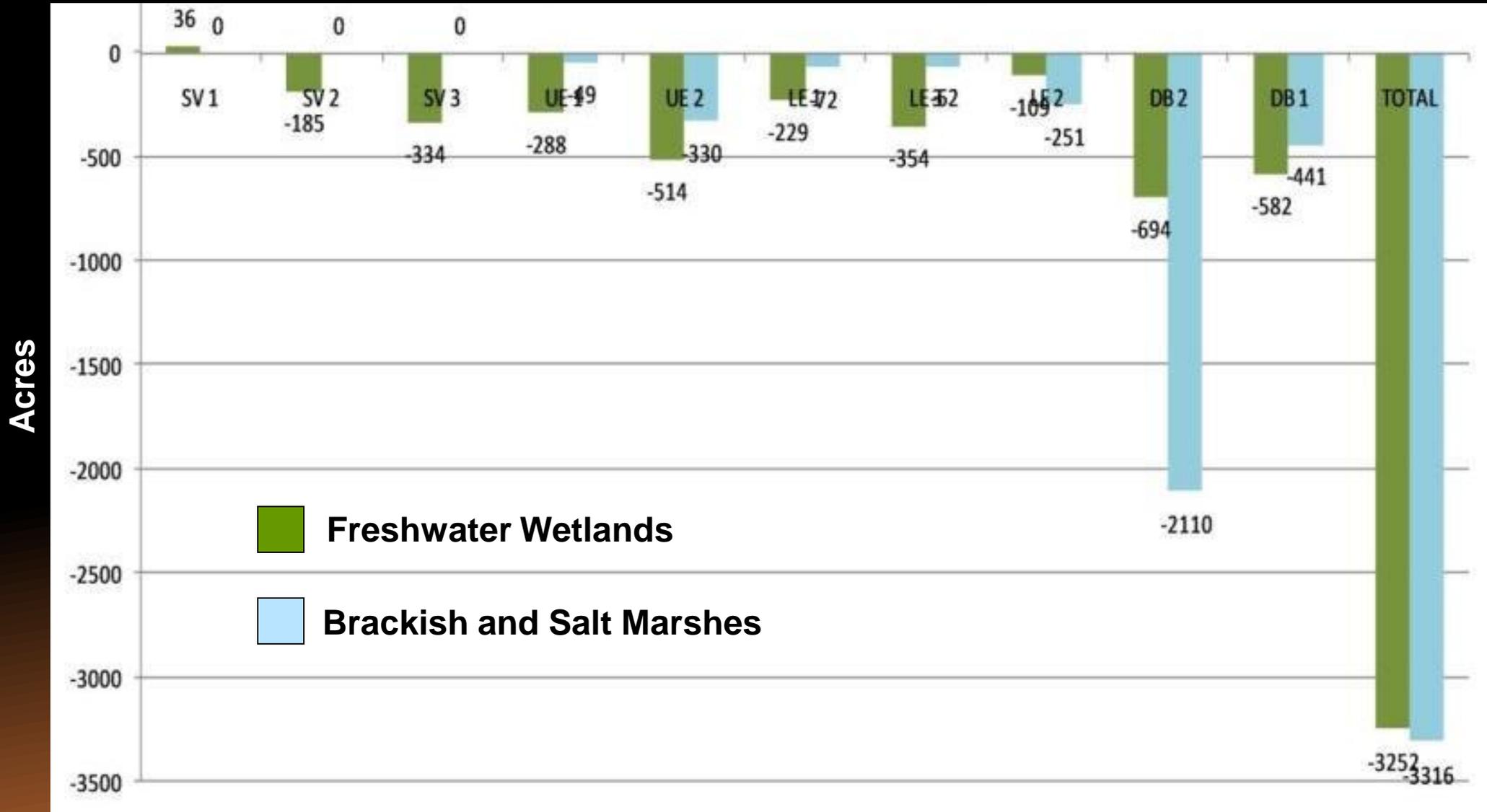
- Protection of Natural Buffers
- Structure Setbacks
- Living Shorelines
- Strategic Retreat
- **Manage Water Flows (salinity)**
- **Manage Sediments**



Needs

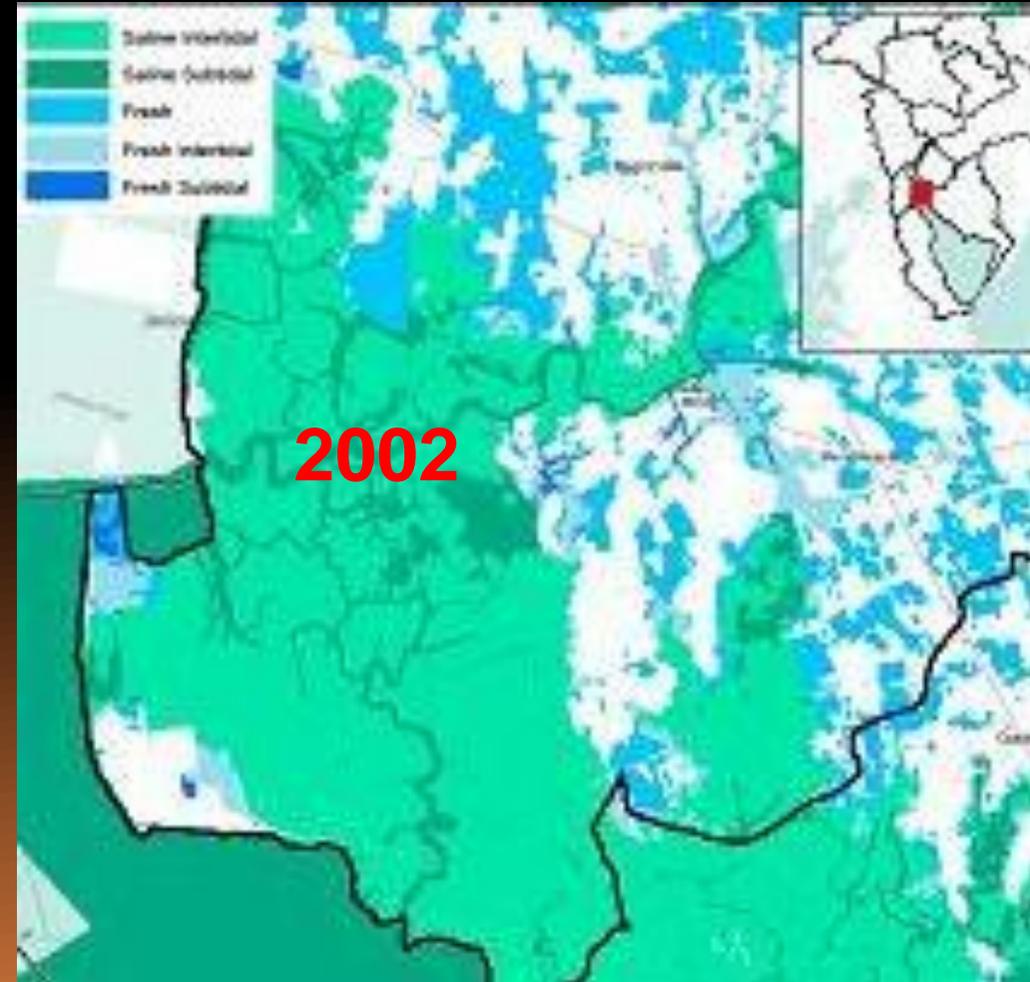
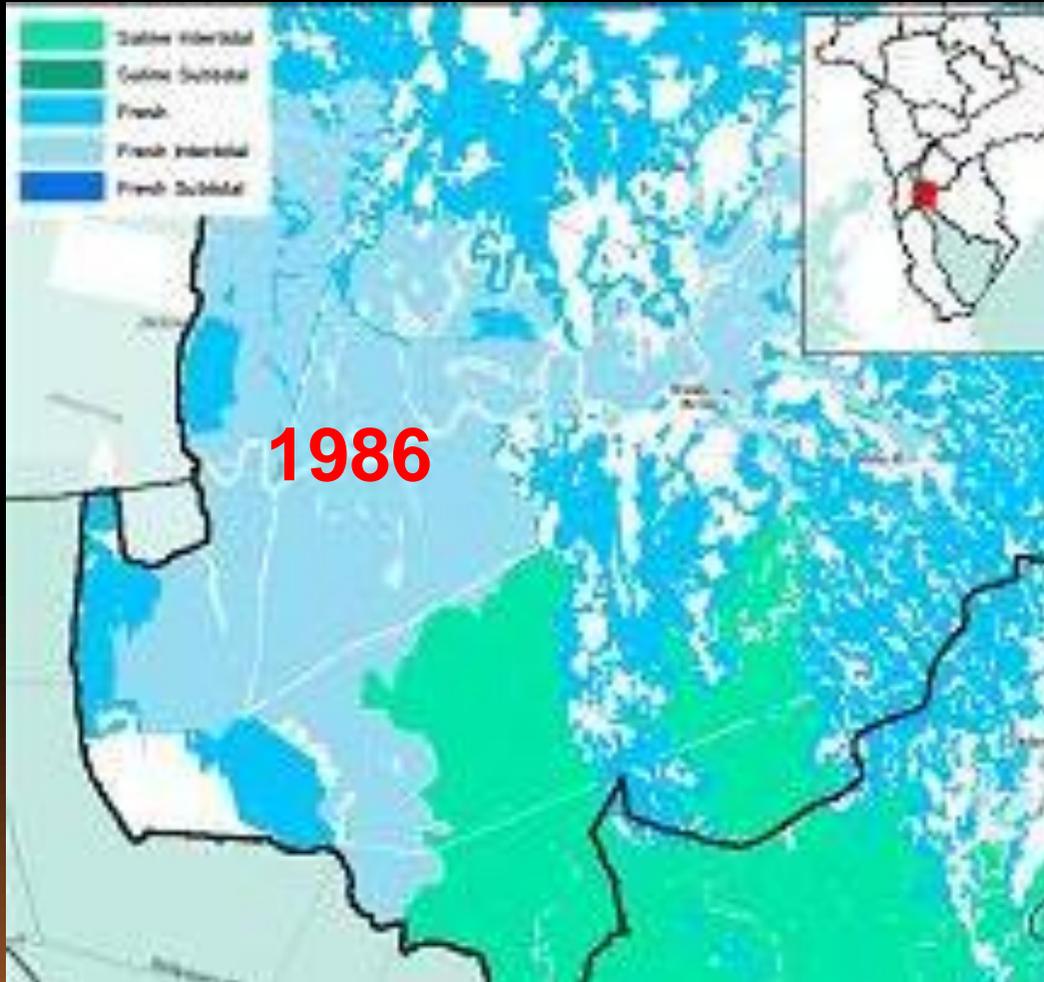
- Geospatial Approach
- Sediment Budget - Tidal Wetland Ecosystem Model
- LIDAR and Climate Monitoring Data
- Assessment Methods for Adaptation Tactics

Wetland Loss in Lower Basin 1996-2006



Effect of Salinity Rise

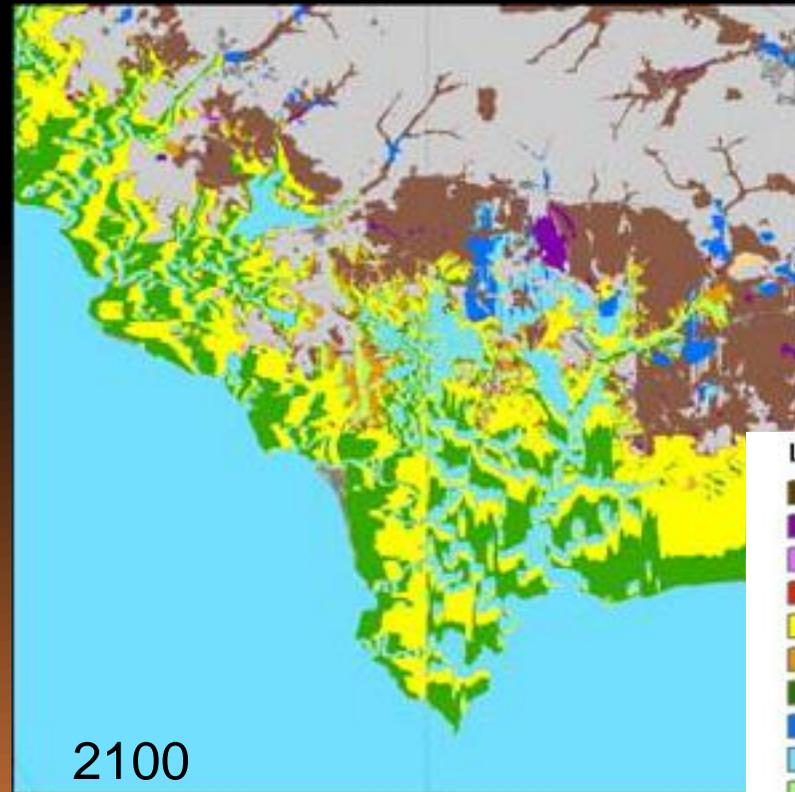
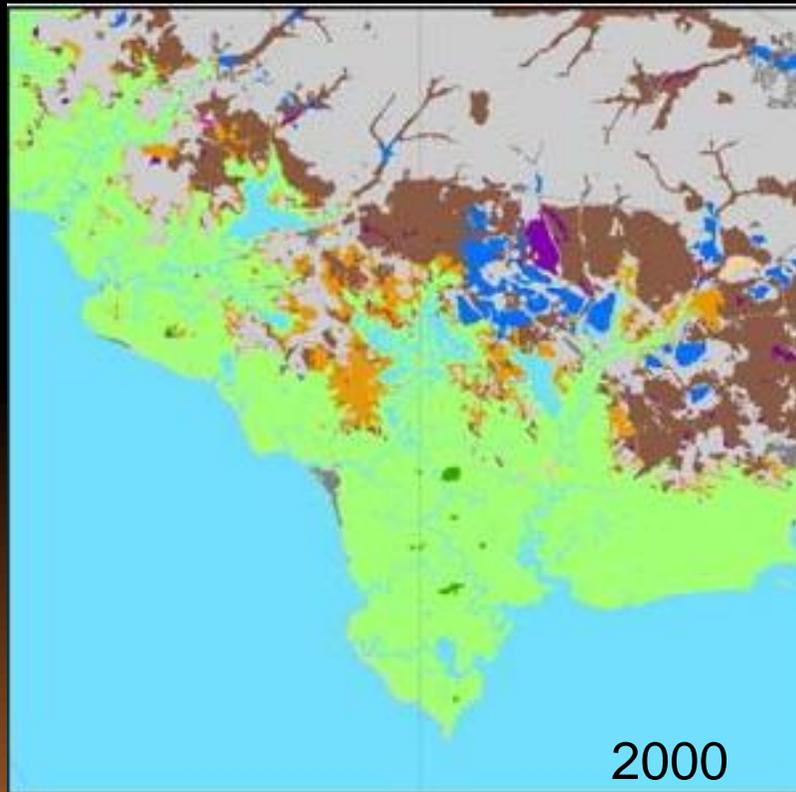
Conversion of Freshwater Tidal to Salt Marsh



Projected Changes

25-75% Loss of tidal wetlands!

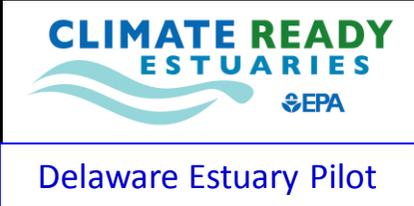
- Conversion of >40,000 ha Uplands to Wetlands
- Conversion of >100,000 ha Wetlands to Water
- Loss of Services >> Acreage Losses



Legend

- Scrub Shrub/Forested Swamp
- Non-tidal Fresh Marsh
- Tidal Fresh Marsh
- Tidal Scrub Shrub/Transitional
- Salt Marsh
- Beach
- Tidal Flat
- Non-tidal Open Water
- Tidal Open Water
- Brackish Marsh
- No Wetland Data

Case Studies



**Vulnerability
and Options**

Future Status

Rankings

Recommendations



Tidal Marshes



Bivalve Shellfish



Drinking Water



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



Nature's Benefits

Bivalve Shellfish are
"Ecosystem Engineers"

Mussel Beds

CTUIR Freshwater Mussel Project

Oyster Reefs

Kreeger



Biofiltration Potential

Start

No mussels

8 adult mussels



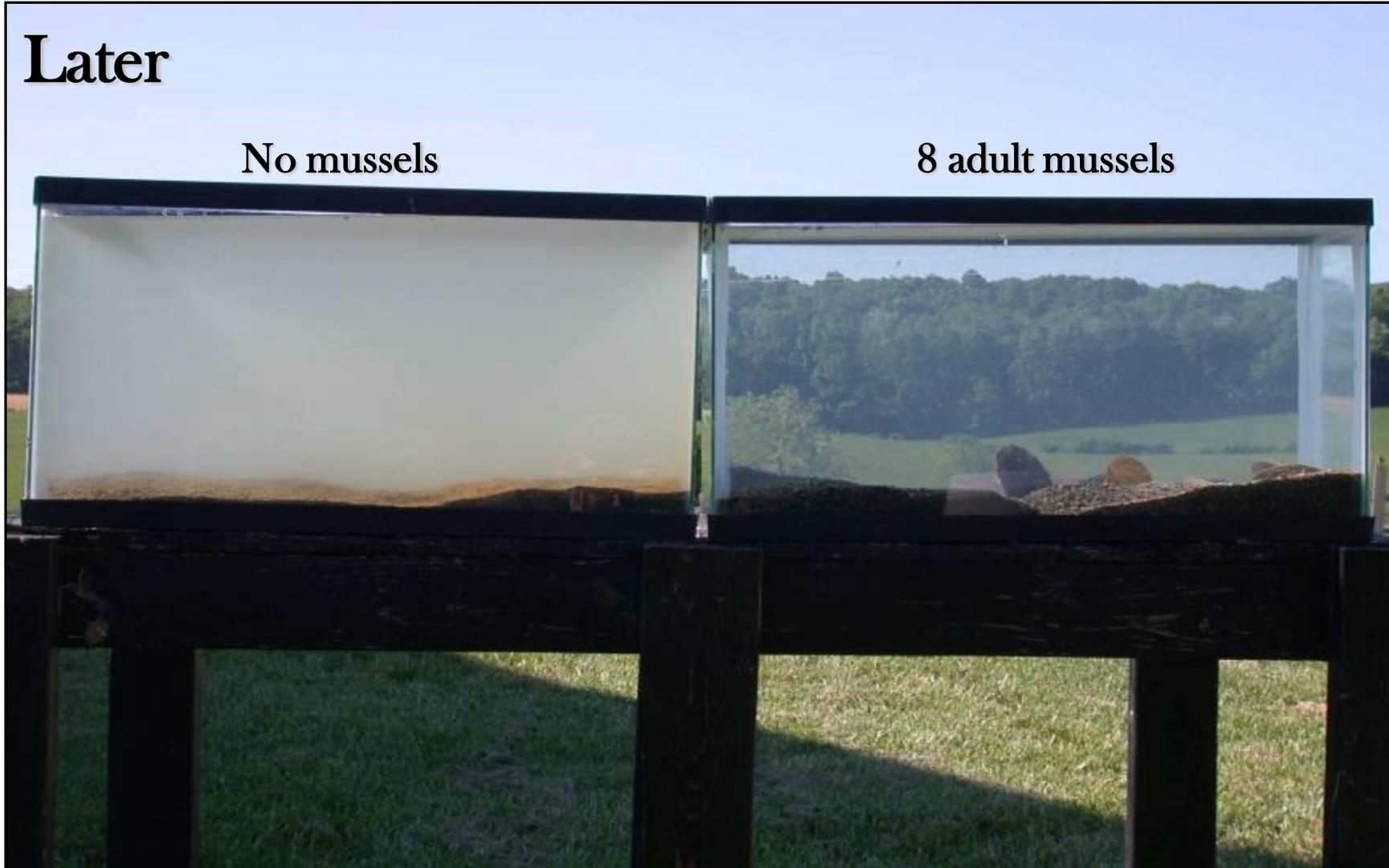


Biofiltration Potential

Later

No mussels

8 adult mussels



Freshwater Mussels



Freshwater Mussels



INDICATOR DESCRIPTION: Freshwater mussels are filter-feeding bivalve mollusks that live in lakes, streams, and rivers. Similar to oysters, freshwater mussels improve water quality, enrich habitats, and furnish other important ecosystem functions. Unlike marine species, freshwater mussels grow more slowly, live longer (50 years or more), and have complicated reproduction strategies, often depending on fish hosts. Therefore, freshwater mussels are particularly vulnerable to water quality degradation and habitat loss.

As they are sedentary creatures that filter large volumes of water, freshwater mussels are sensitive to changes in water quality and habitat conditions. Consequently, they lay claim to being the most imperiled taxonomic group in the nation. These long-lived animals are often unable to recolonize their habitats following disturbances due to their complicated life history. The status of freshwater mussels provides different environmental information than macroinvertebrates, the latter are good indicators of short-term changes in water quality. The health, reproductive status, population density, and species diversity of the mussel assemblage best represents an excellent bioindicator of watershed health over long periods of time.

Common Name
Dwarf Wedgemussel
Triangle Floater
Brook Floater
Alexander Floater
Eastern Elliptic
Yellow Lampmussel
Eastern Lampmussel
Green Floater
Tidewater Mucket
Eastern Pondmussel
Eastern Pearlbshell
Eastern Floater
Squarefoot

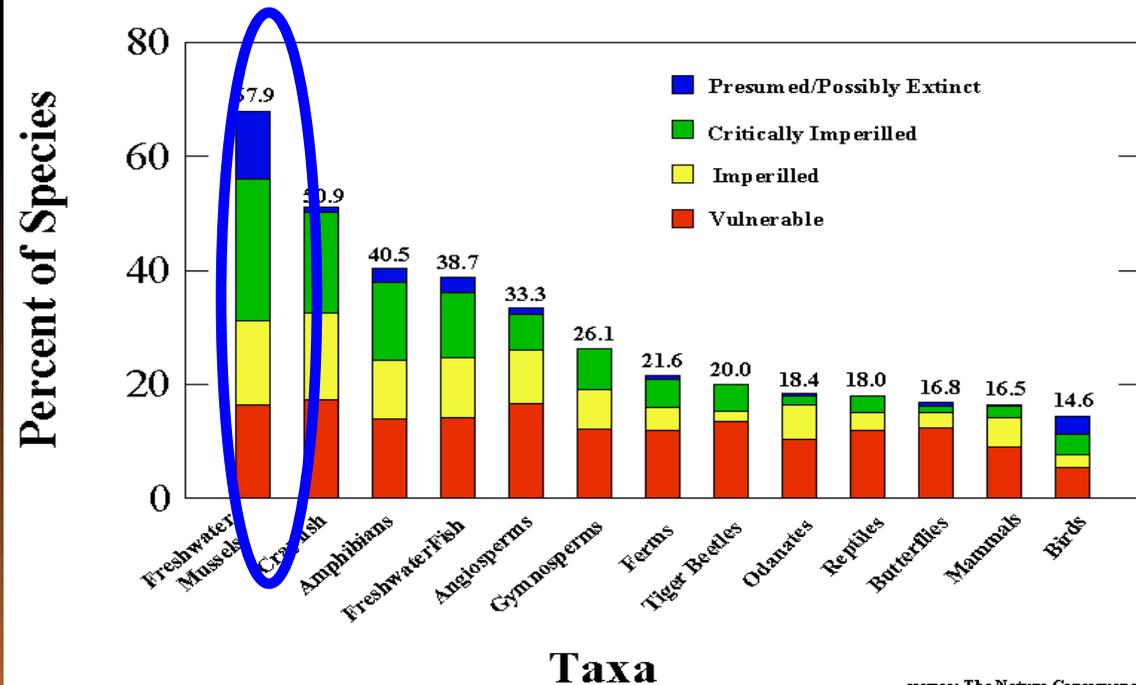
This chart shows the state of Delaware's freshwater mussels in the Delaware Estuary and River Basin. The chart uses the same color descriptions used among the...

STATUS: North America has the world's greatest diversity of native freshwater mussels (more than 300 species); however, more than 75 percent have special status. The leading causes of mussel decline are water quality degradation. For example, dam...

Most Imperiled Animals and Plants



Conservation Status of United States Taxa



source: The Nature Conservancy, 1997

Bivalve Projections – FW Mussels

Shifting Species Ranges, But No Dispersal

Patchy, Impaired



Elliptio complanata

Rare



Strophitus undulatus

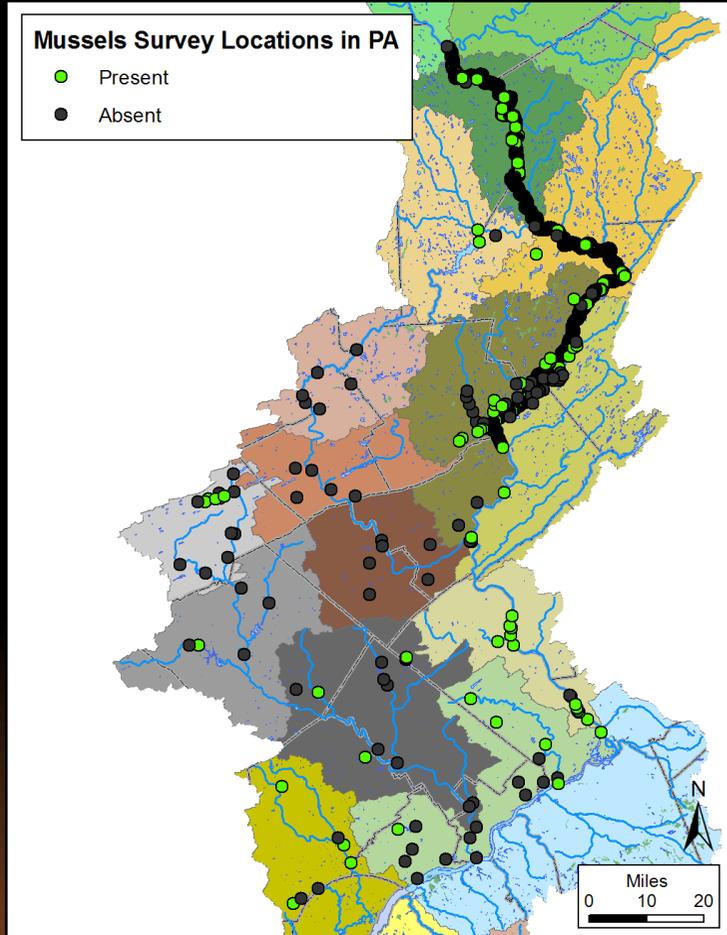
Extirpated



Alasmidonta heterodon

Scientific Name	Scientific Name	State Conservation Status		
		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

Mussel Protection and Restoration Needs

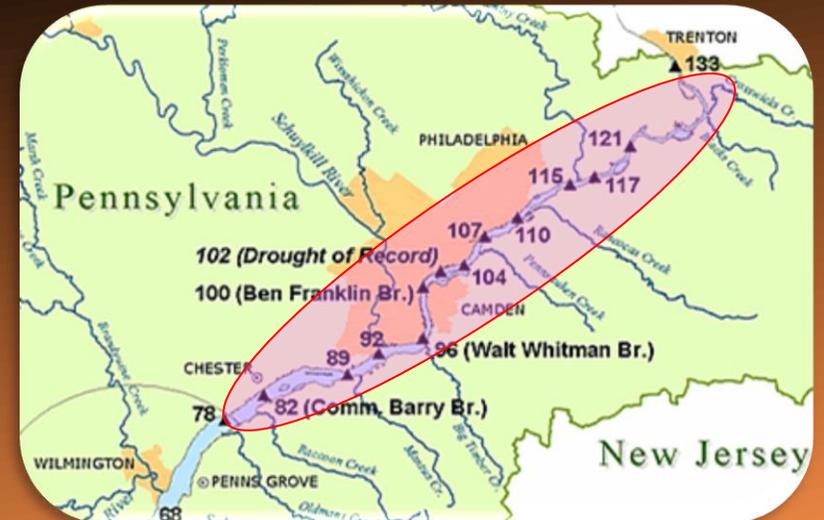


- Most streams no longer have any mussels
- When they do, they are small beds, old and only 1-2 species



- More than 7 historic species found in freshwater tidal reach in 2010
- Several state T&E species
- Reproducing
- Broodstock for restoration elsewhere

- **Freshwater flow** just as critical to sustain these beds as rare mussels in upper river



Oysters

Oysters

Crassostrea virginica



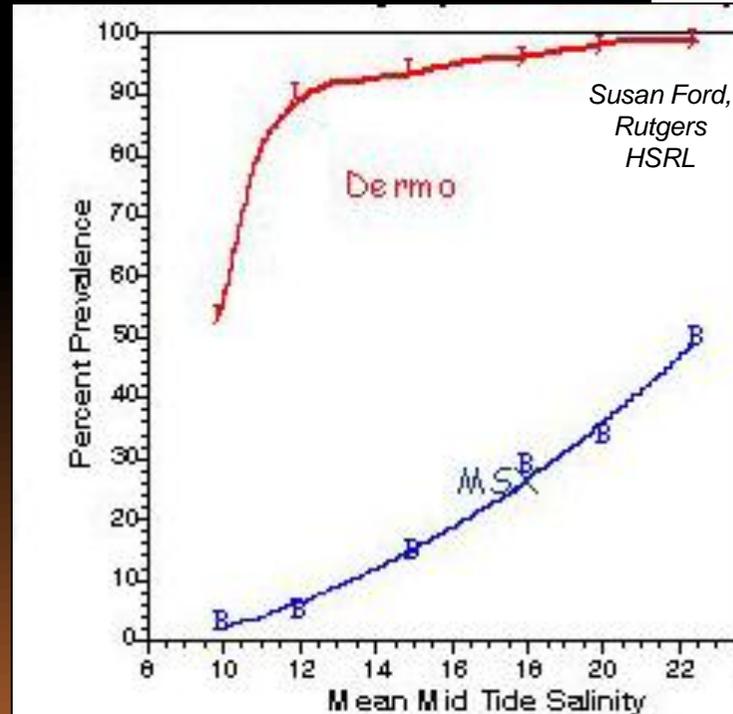
DESCRIPTION: Eastern oysters are a nutritious food and an important fishery in Delaware Bay. In 1881, 1,400 sailing vessels harvested approximately 1.5 bushels, or 22 million pounds of oysters. Today, they deliver about 100,000 bushels with a dockside value of \$3 million to \$5 million, but efforts are under way to boost those numbers. Oysters also provide important ecosystem services by creating reef habitats for fish and other organisms, filtering water, recycling nutrients, and stabilizing sediments. However, these filter-feeders are sensitive to degraded water conditions. Like other bivalve mollusks, oysters are world-renowned as bioindicators of environmental conditions.

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

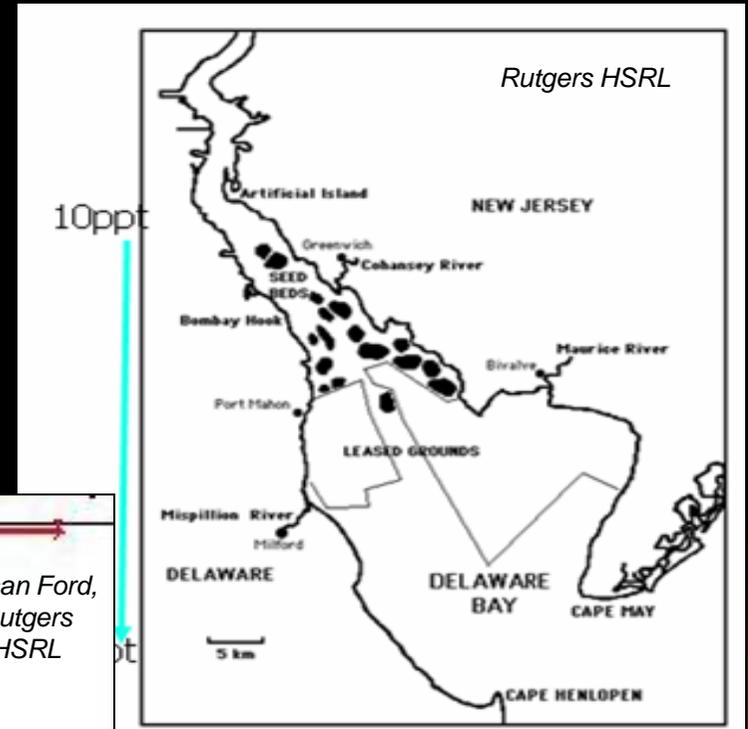
TRENDS: Oyster abundance was not accurately measured before the 1950s, but landings data suggest that current populations are a fraction of their historic size in the 19th and early 20th centuries. Seed-bed data indicate that abundance is 39 percent of the 1953 to 2007 long-term average and 78 percent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

ACTIONS AND NEEDS: Oyster population health

Oyster Disease and Salinity



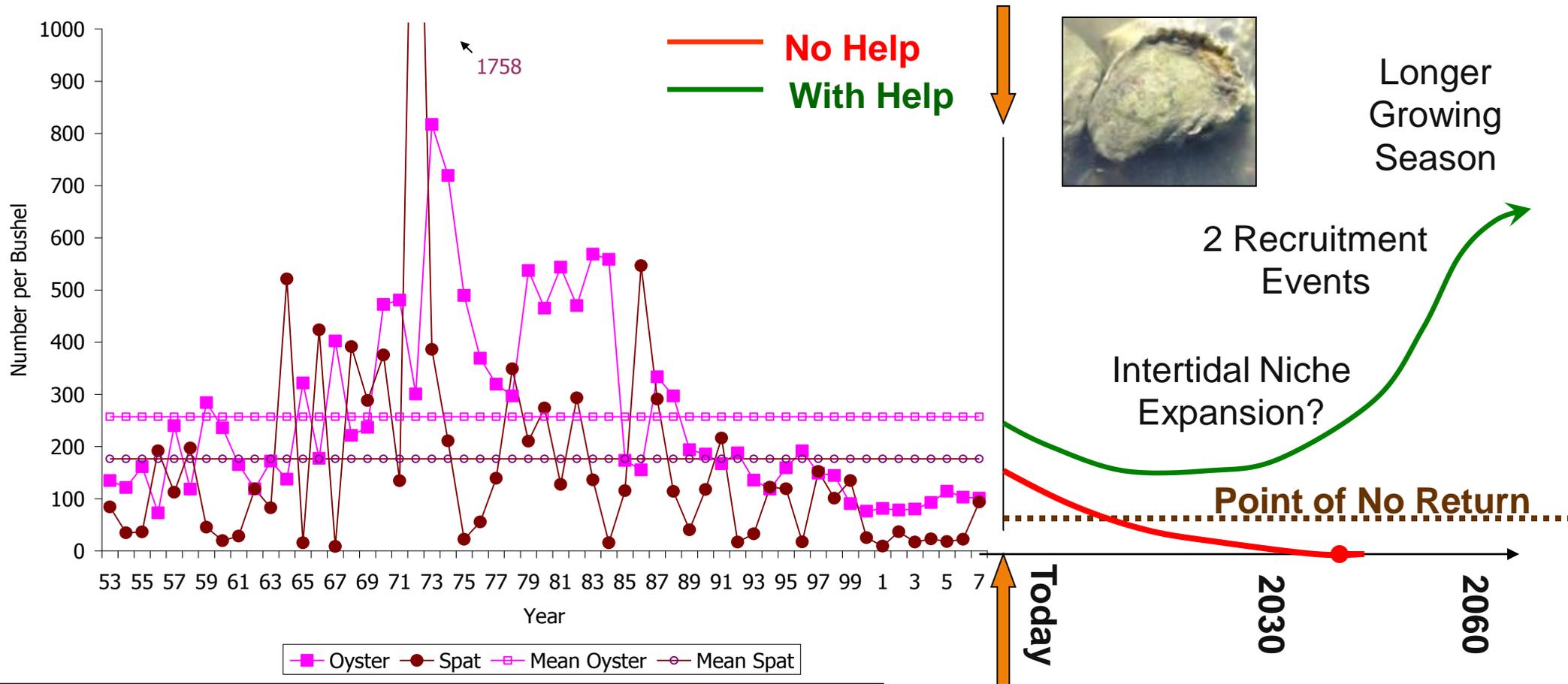
Susan Ford,
Rutgers
HSRL



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

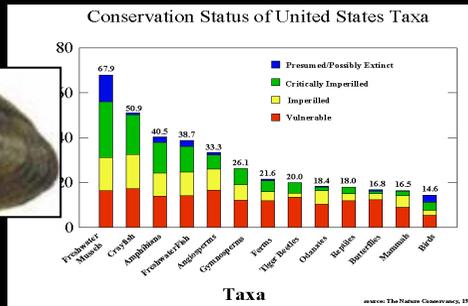
Bivalve Projections – Oysters

Can they be maintained until they might see better conditions?

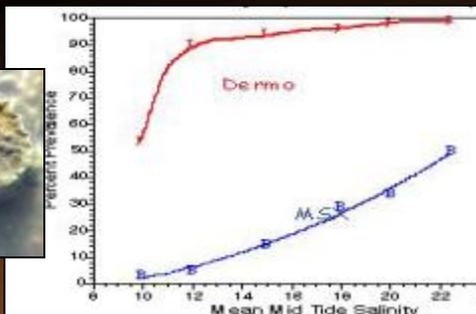


Historical data from Rutgers Haskin Shellfish Laboratory

Flow/Salinity Impacts Depend on Species and Location



Freshwater Tidal Mussels:
salinity, low flows and
higher temperature



Oysters:
disease and salinity

Options for Making Shellfish More Resilient

Shellplanting for Oysters



Propagate Mussels



Monitoring & Research



Water Quality & Flow Management

Living Shorelines



Fish Passage Restoration



Riparian Restoration



What if We Don't Manage Flow Wisely?

Natural Capital at Risk

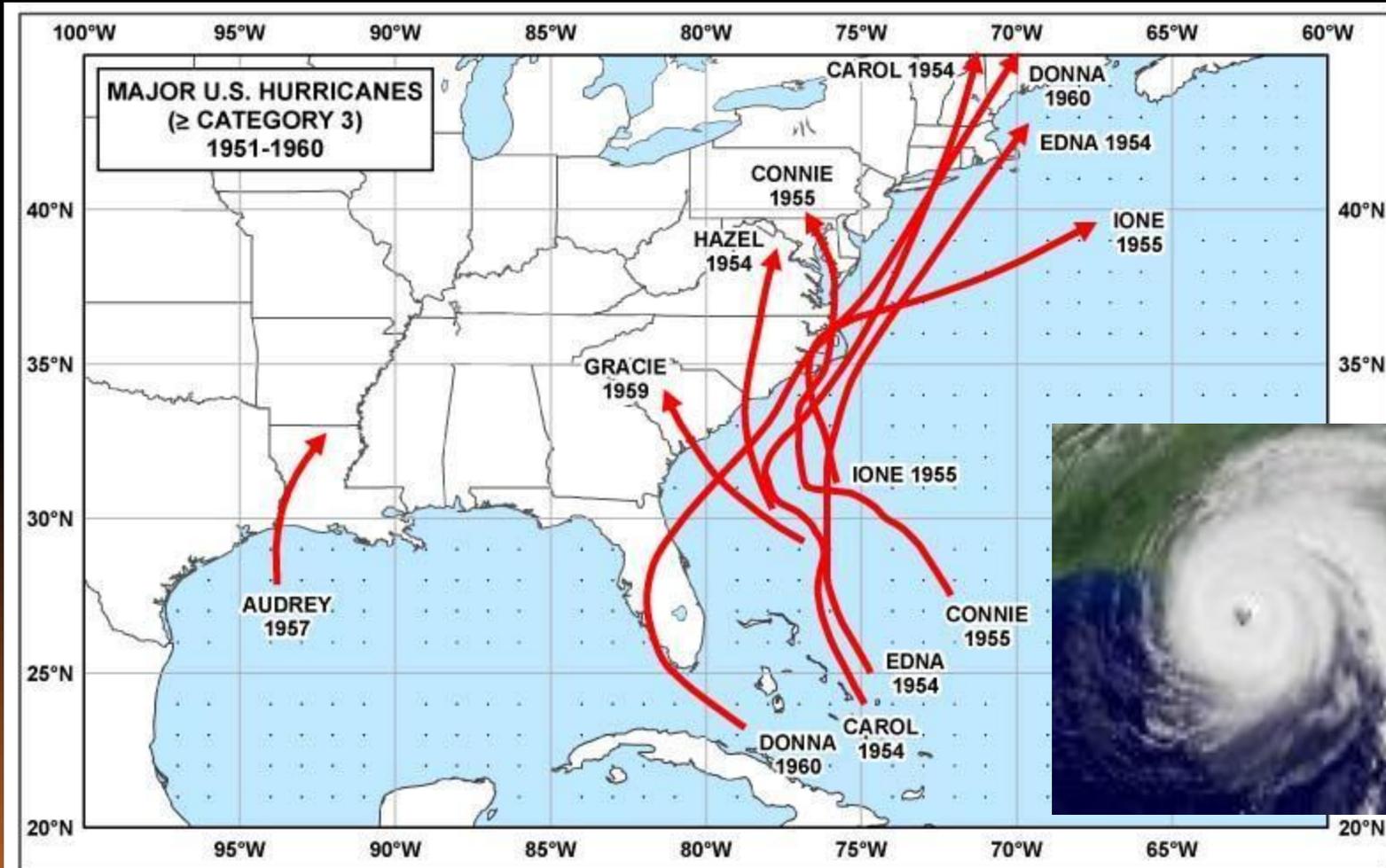
Bivalve Natural Capital		Oysters	Marsh Mussels	FW Mussels
<i>Millennium Ecosystem Assessment Categories</i>	<i>Specific Services/Values</i>	<i>Relative Importance Scores</i>		
Provisioning: Food & Fiber	<i>Dockside Product</i>	✓✓✓		✓
Regulating	<i>Shoreline & Bottom Protection</i>	✓✓		
	<i>Shoreline Stabilization</i>	✓✓	✓✓✓	✓✓
Supporting	<i>Structural Habitat</i>	✓✓✓	✓✓	✓✓
	<i>Biodiversity: Imperiled Species</i>			✓✓✓
	<i>Bio-filtration</i>	✓✓✓	✓✓✓	✓✓✓
	<i>Biogeochemistry</i>	✓✓	✓✓	✓✓
	<i>Prey</i>	✓	✓✓	✓
Cultural/ Spiritual/ Historical/ Human Well Being	<i>Waterman Lifestyle, Ecotourism</i>	✓✓		
	<i>Native American</i>	✓✓		✓✓✓
	<i>Watershed Indicator</i>	✓✓✓	✓✓	✓✓✓
	<i>Bio-Assessment</i>	✓✓✓	✓✓	✓✓✓

Climate Change + Other Changes

- Marcellus Shale
 - Dredging
 - Withdrawals
 - Wind Farms
 - Land Use Change
 - Development
 - Emerging Pollutants
- **Ecological Flows**
 - Spills, NRDA
- Added Complexity*

11/27/2004

The Wild Card Storms



Big Picture for Flow Management

Precipitation will Increase

- but at the wrong time and not evenly, no more snow pack
- insufficient volume to offset sea level rise and maintain salinity



Salinity will Increase

- sea level rise will swamp any added runoff, particularly in summer

Population will Increase

- expected 80% increase by 2100, increasing demand for water



Estuarine Natural Resources Need Stronger Protection

- flow management recommends “protection” of upper basin resources
- flow management recommends “study” of lower basin resources
- lower basin natural resources sustain lives and livelihoods



- End -

