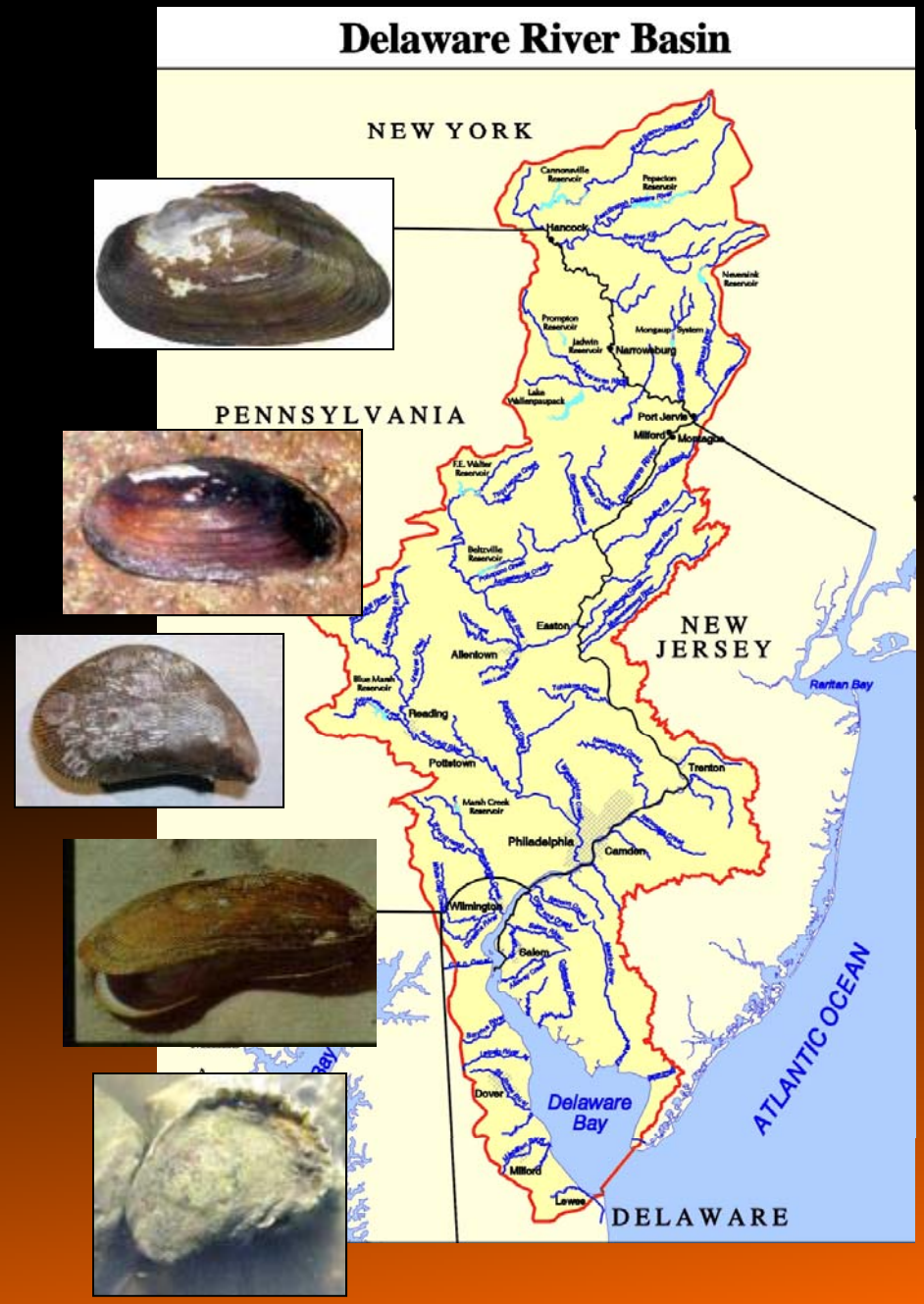
Blue Collar Bivalves Working Magic for Ecosystems

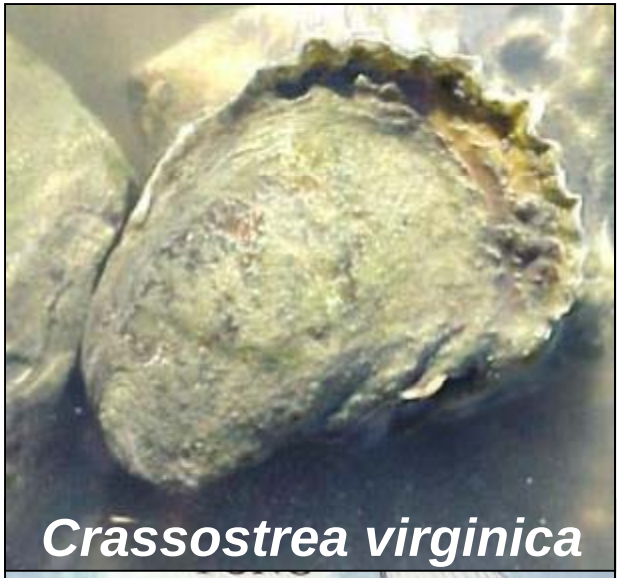


Danielle Kreeger

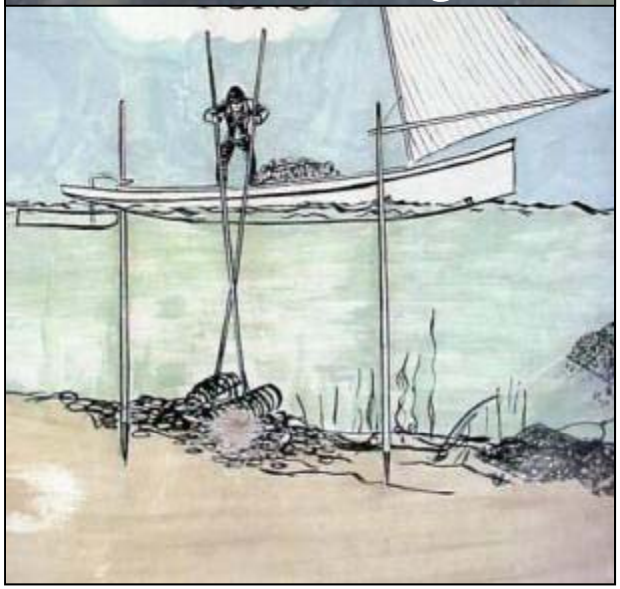
Partnership for the DE Estuary

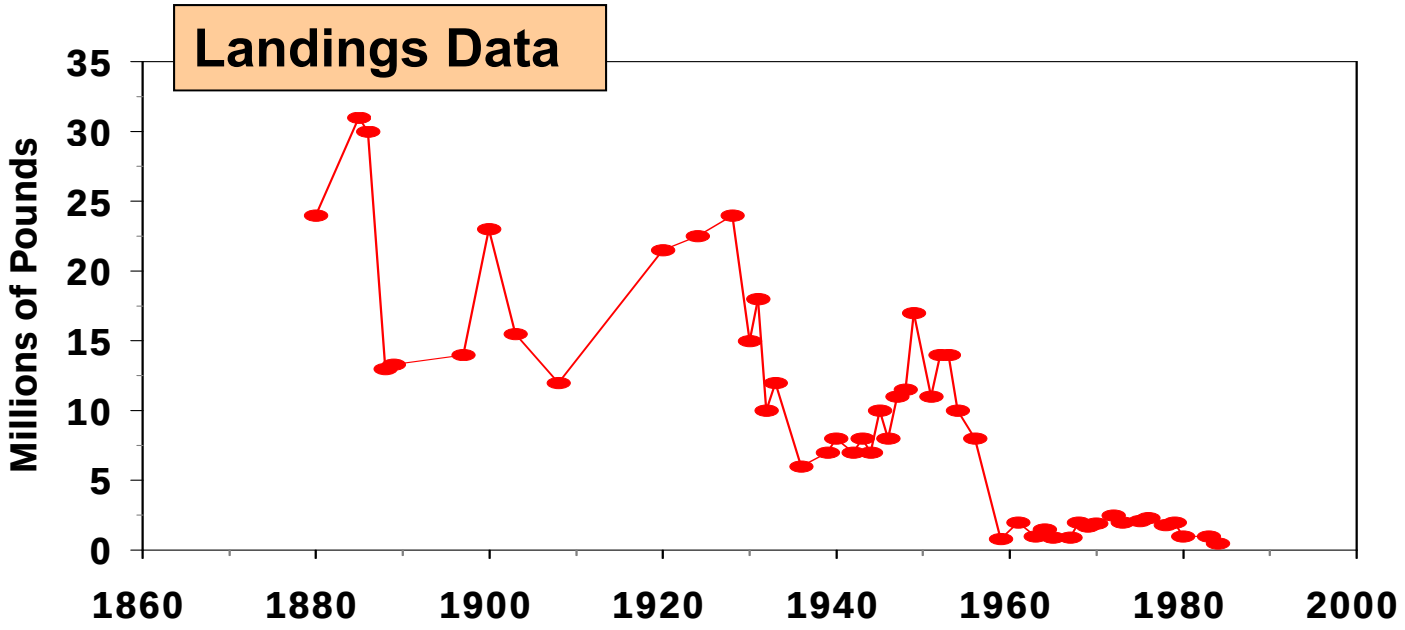
Academy of Natural Sciences
Town Square - March 5, 2012

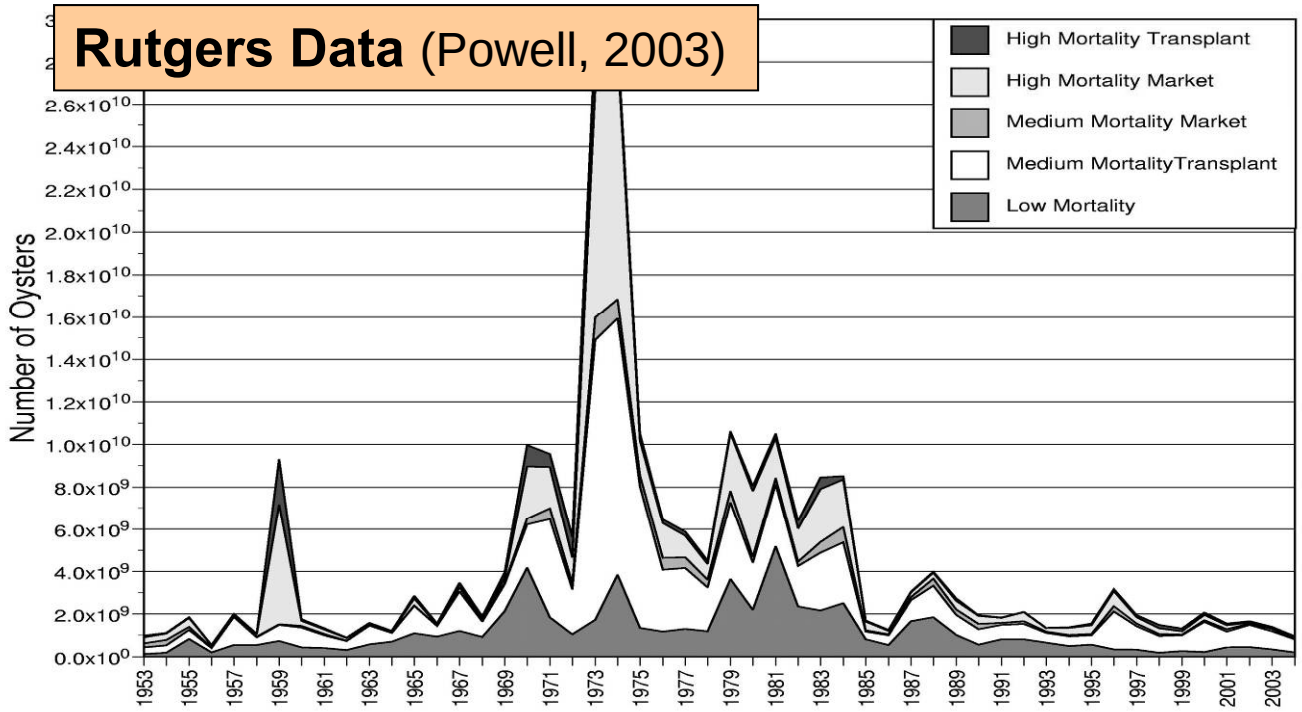
Oysters



Crassostrea virginica







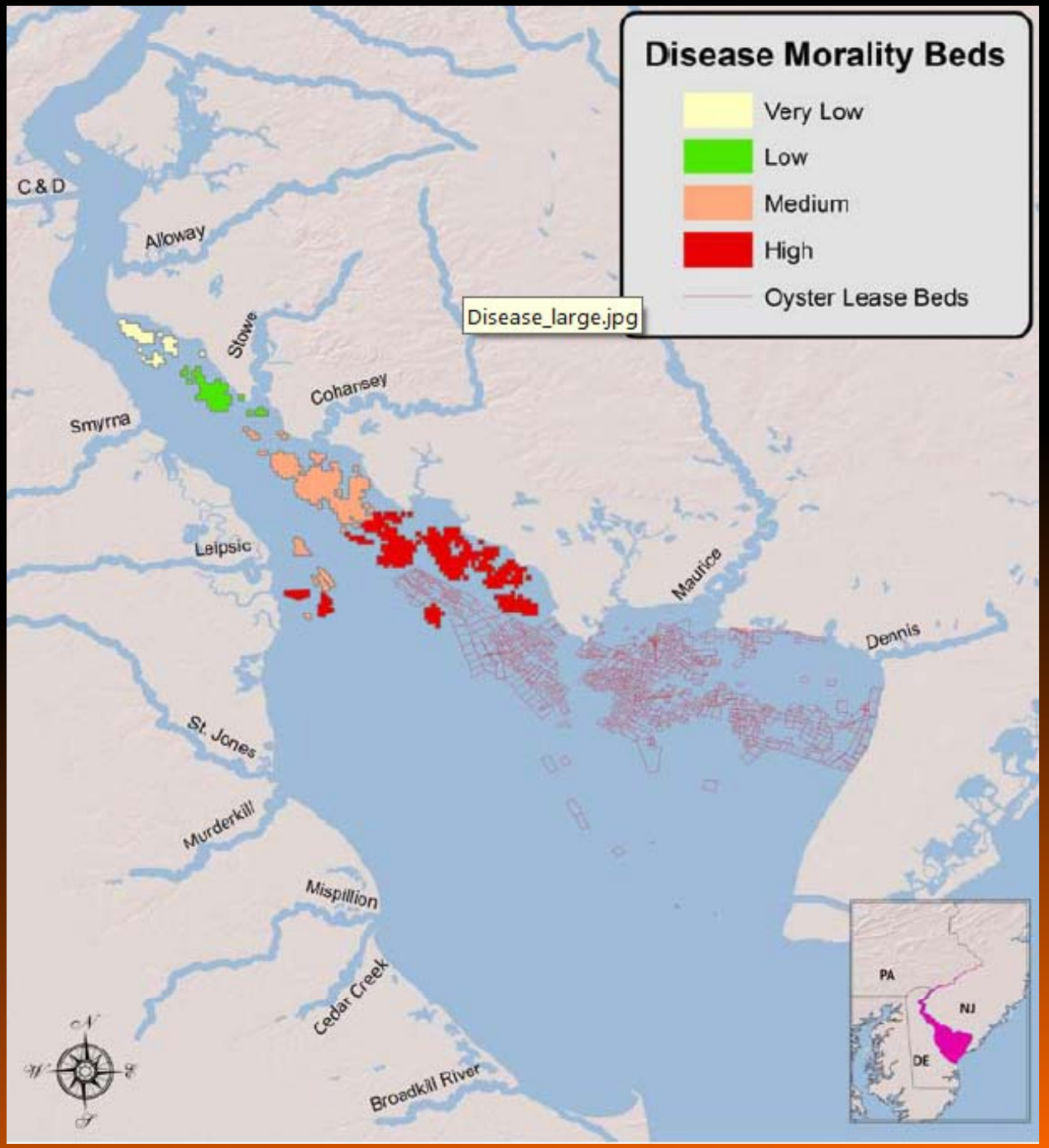
Oysters

Present Population:
~ 2 billion oysters

PDE Supports Oyster Restoration

<u>Challenges</u>:

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



>60 Species of Bivalves in the Delaware Estuary Watershed

Elliptio complanata

Geukensia demissa

Crassostrea virginica

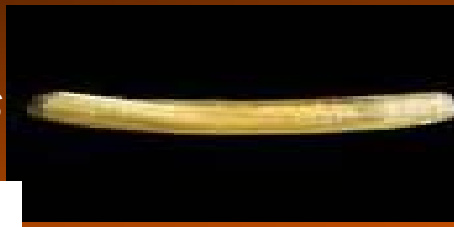
11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea

Rangia cuneata

Mya arenaria

Mytilus edulis



Ensis directus

Mercenaria mercenaria

Freshwater Mussels of the Delaware

Freshwater Mussels of the Delaware

What are they?

Status and Trends?

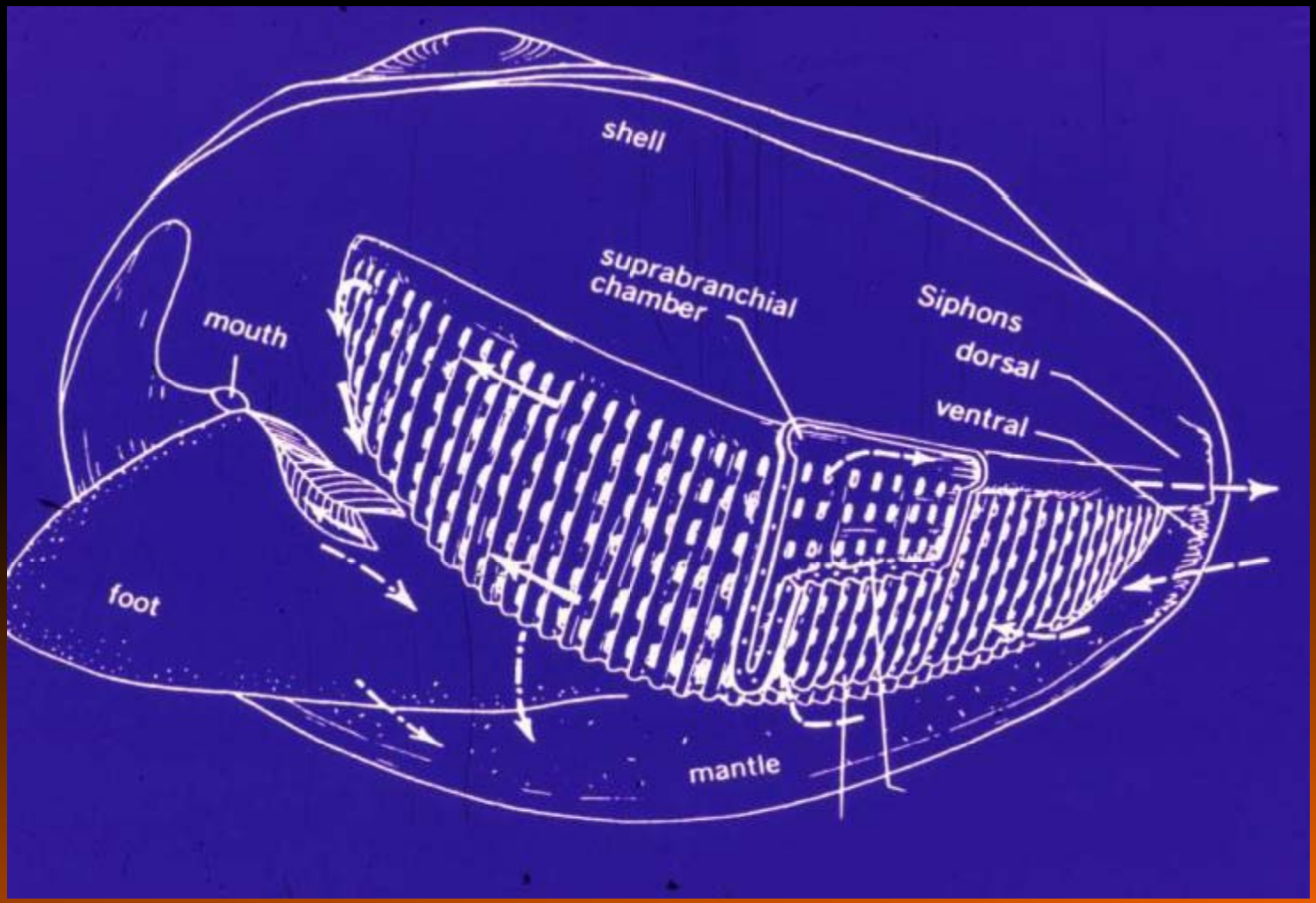
Why are they Important?

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

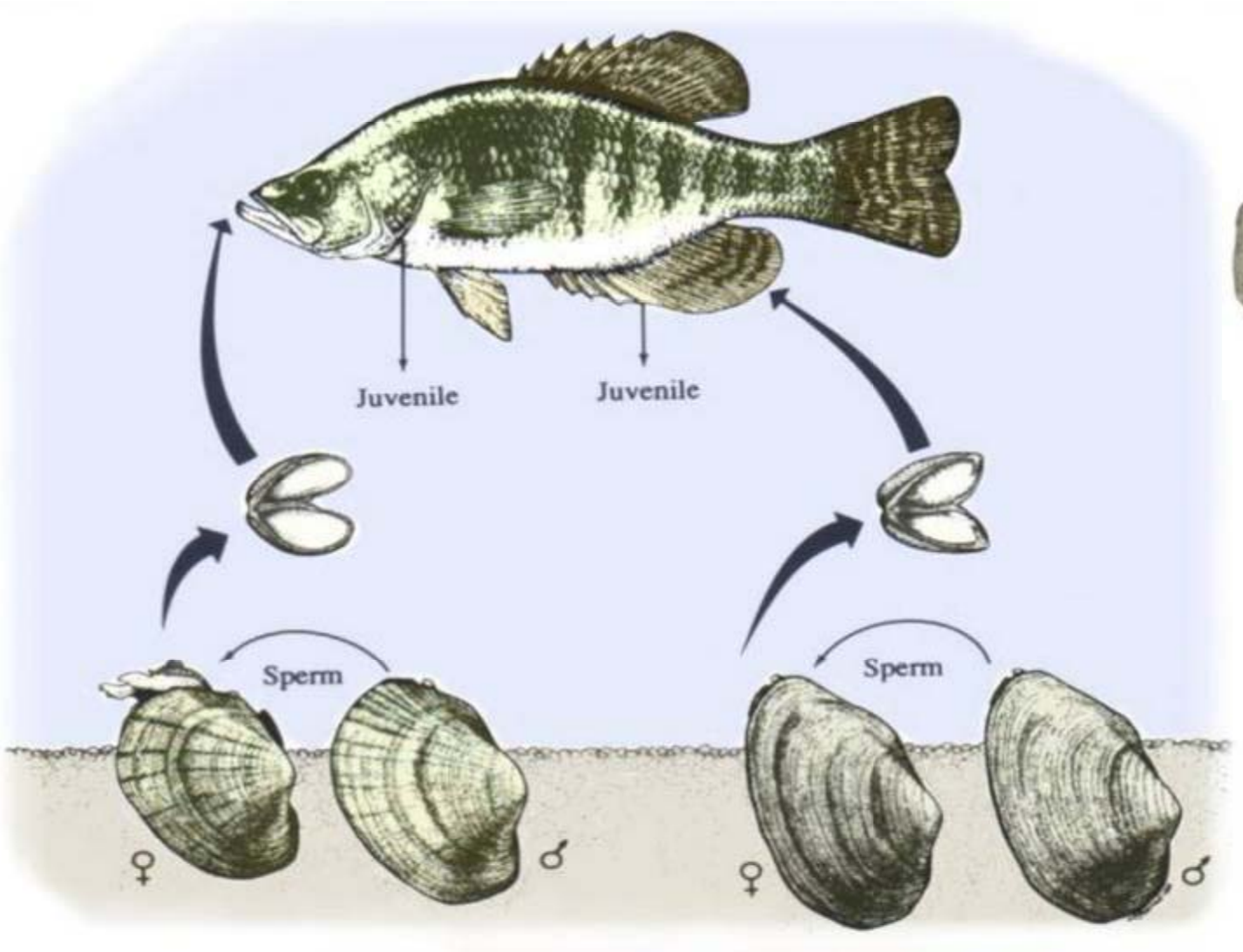
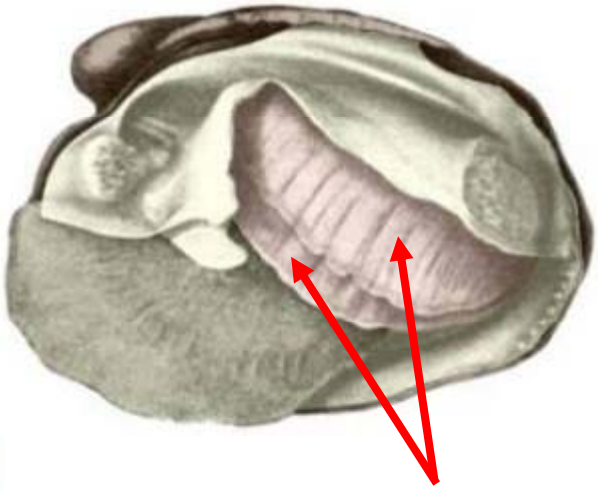


Figure from Cummings and Mayer (1992).

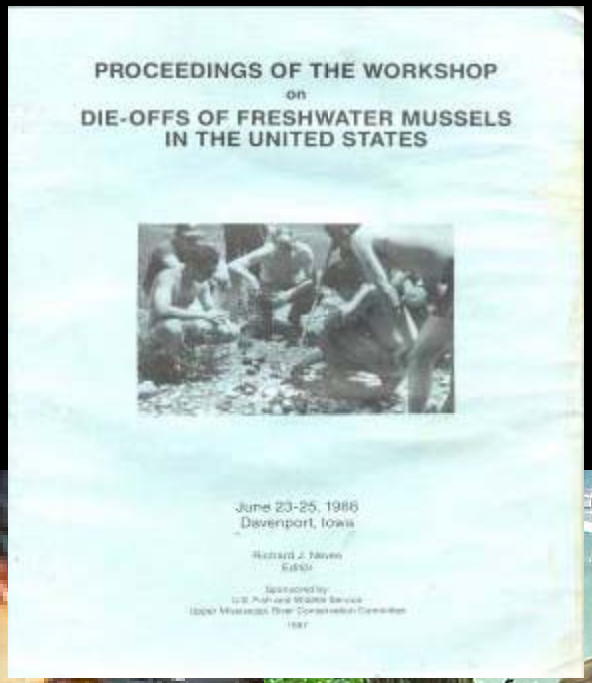


Larvae are brooded in the ctenidia

Most mussels depend on particular fish species

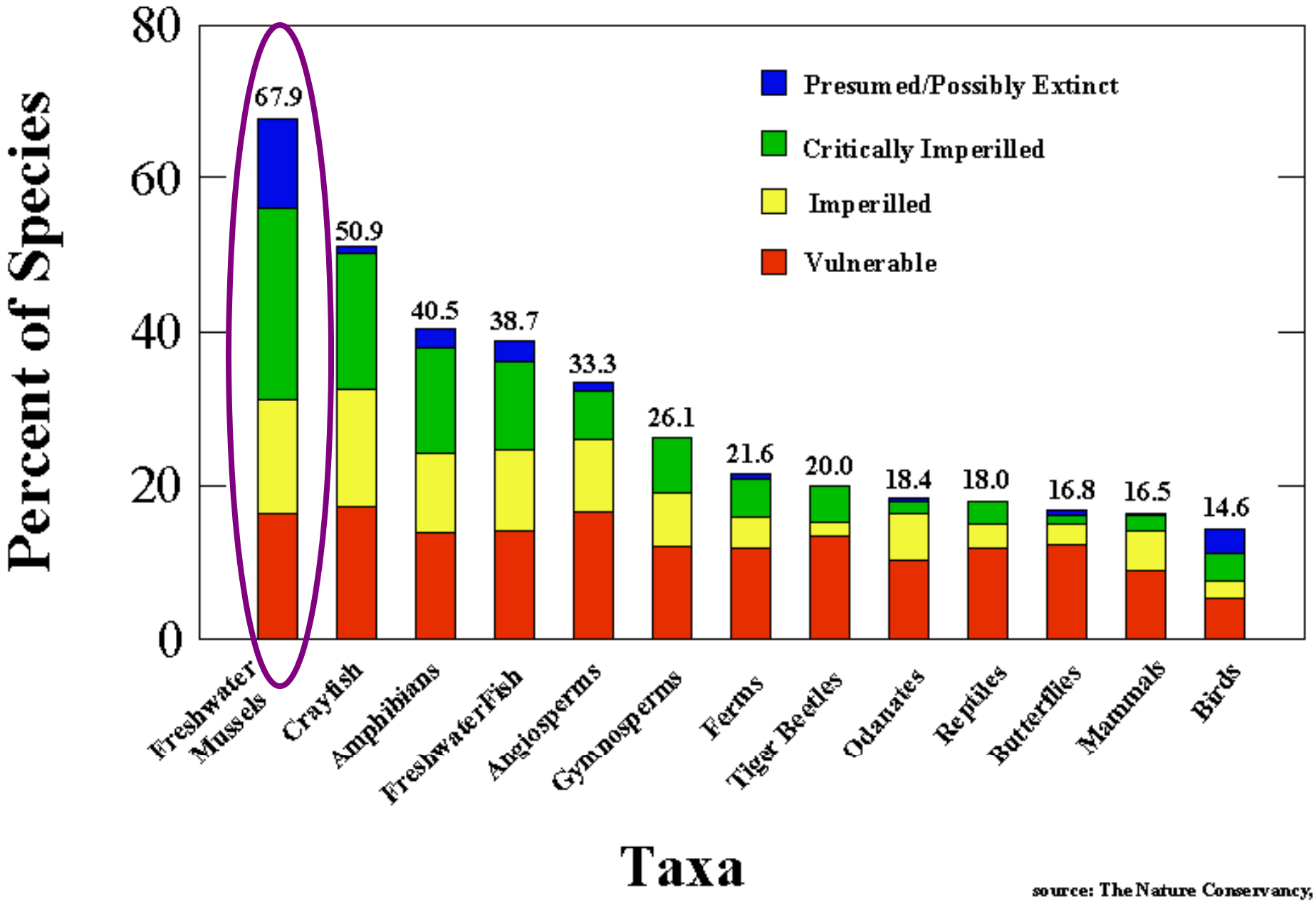
Status and Trends – A Taxa in Decline

Biodiversity



Population
Biomass

Conservation Status of United States Taxa



source: The Nature Conservancy, 1997

Delaware River Basin

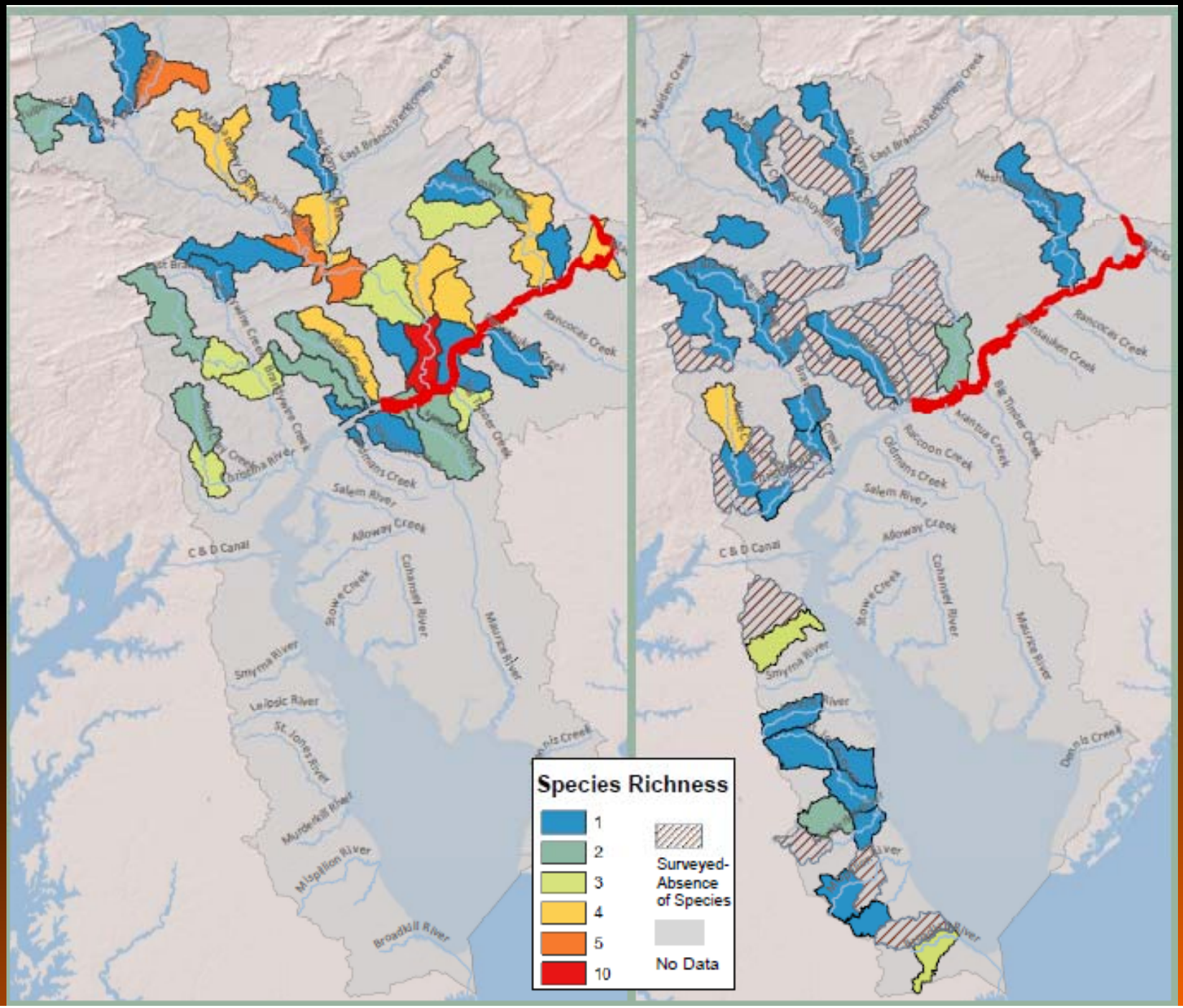
Patchy, Impaired

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**

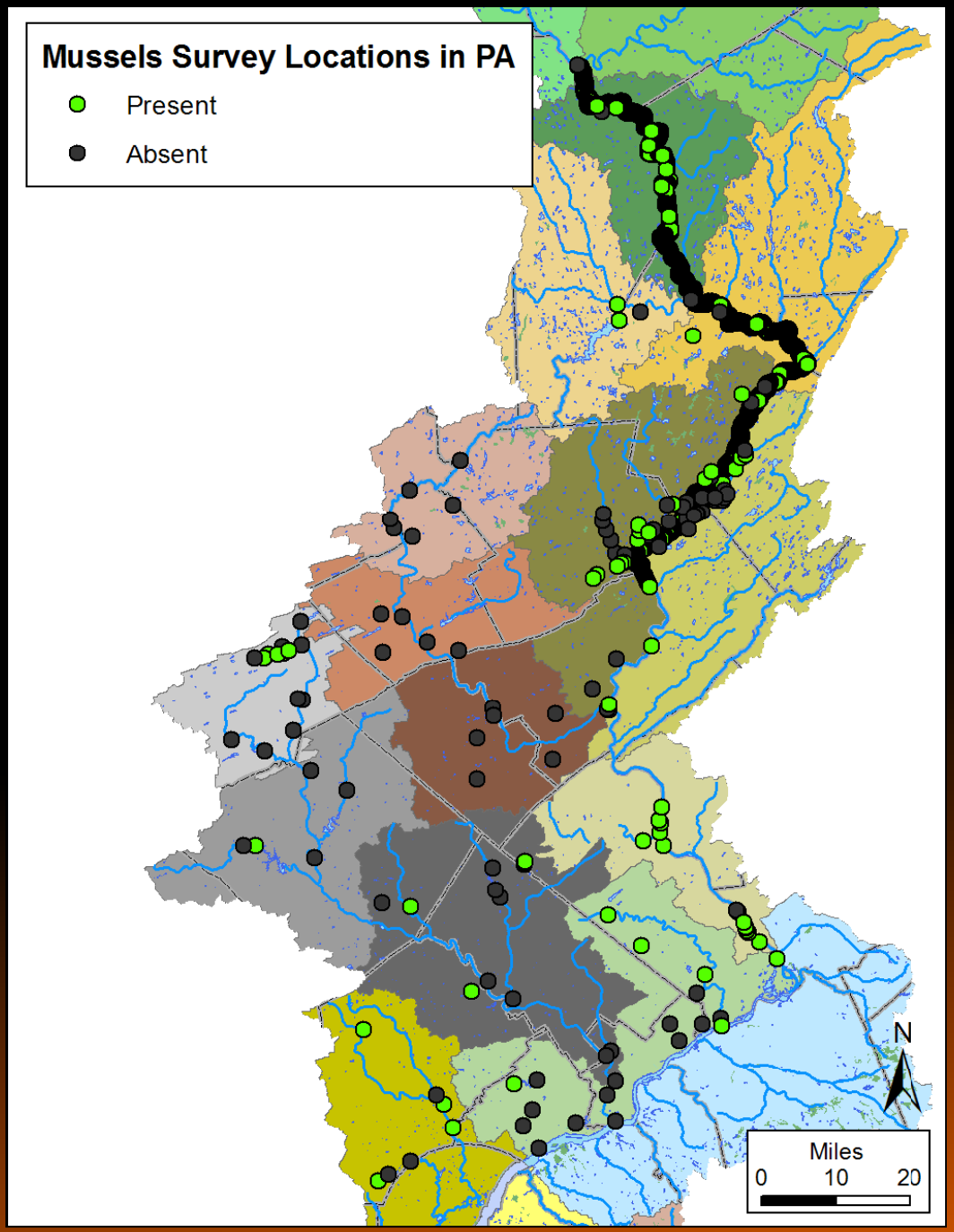
1919



Since 1996

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

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

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

Ecological Magic - Why are they Important?

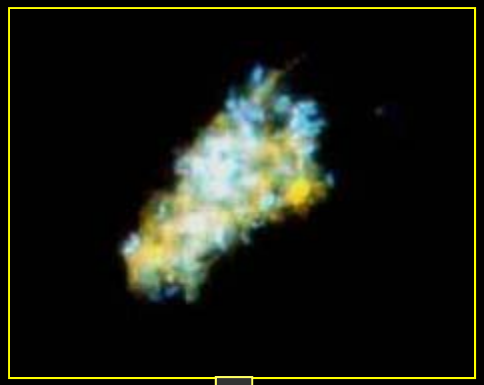
1. Structure

↑ Habitat Complexity

Bind Bottom

Stabilize Shorelines

↑ Bottom Turbulence



2. Function

↓ Suspended Particulates

↓ Particulate N, P

↑ Light reaching bottom

↑ Sediment Enrichment

↑ Dissolved Nutrients

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC.

Nature's Benefits

Bivalve Shellfish are "Ecosystem Engineers"

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Mussel Beds

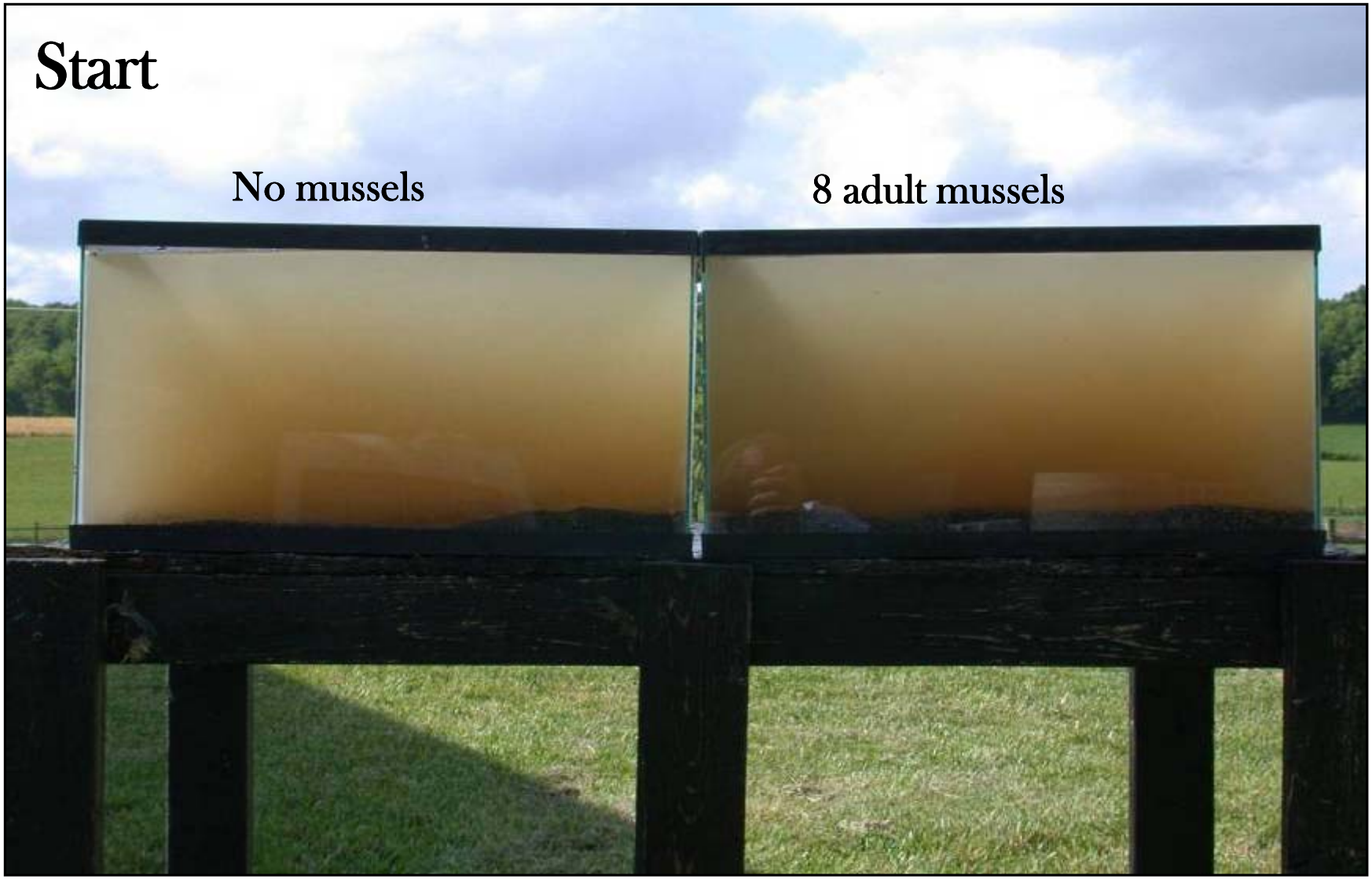
CTUIR Freshwater Mussel Project

Oyster Reefs

Kreeger

Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

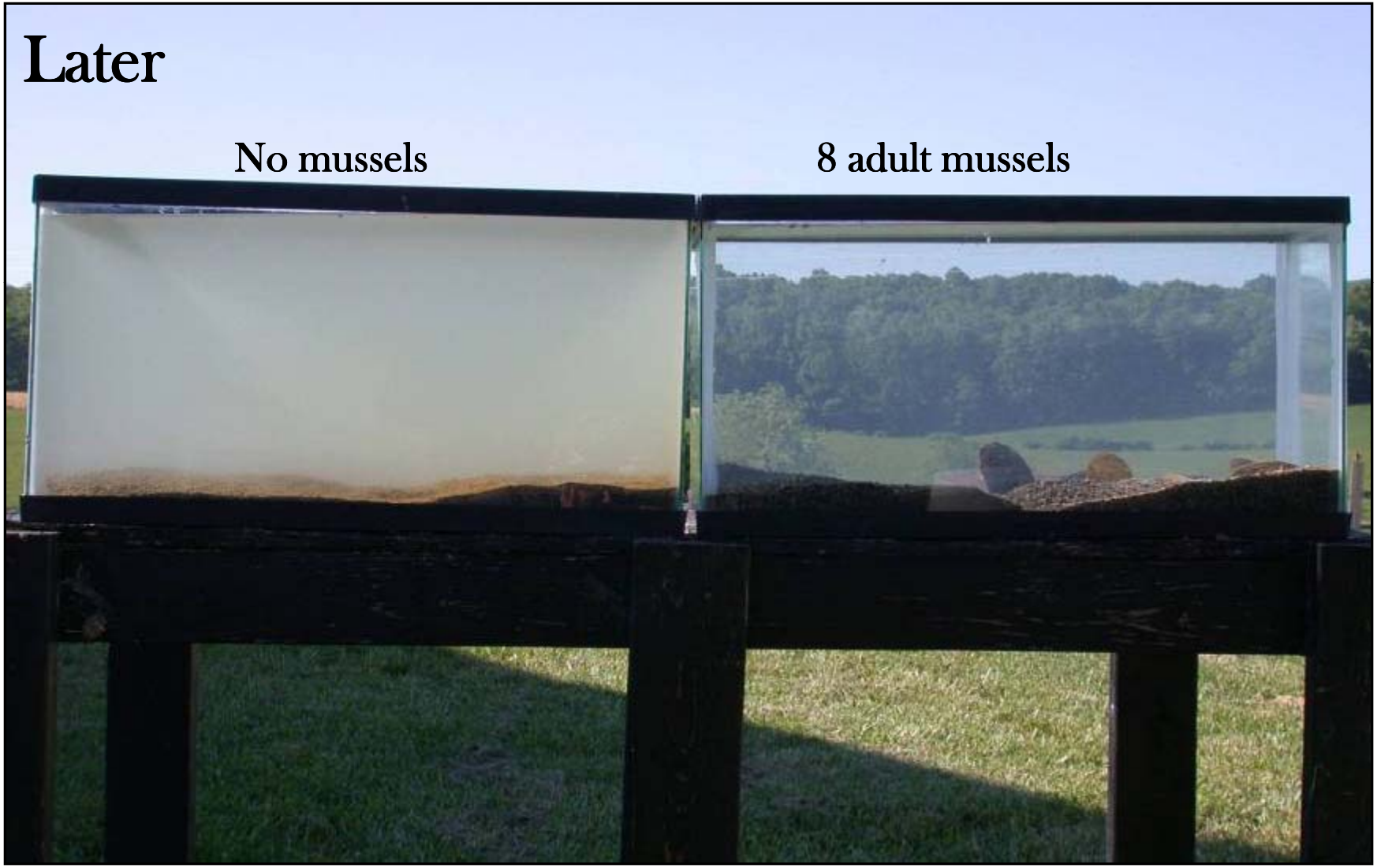
Biofiltration Potential



Slide from Dick Neves, VA Tech

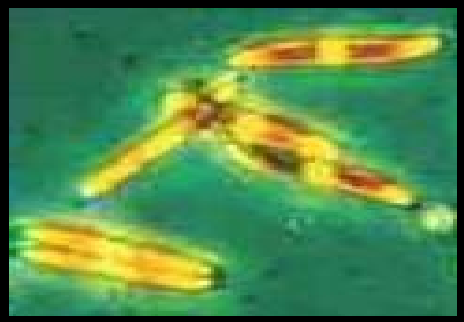
Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

Biofiltration Potential

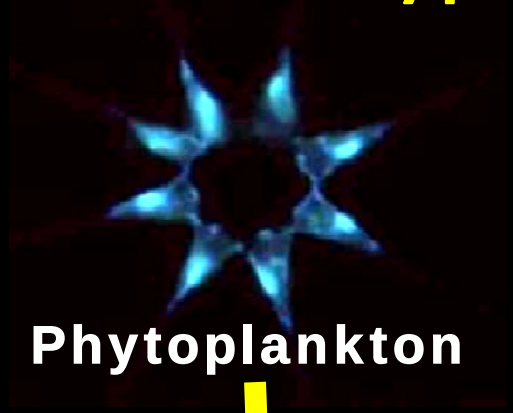


Slide from Dick Neves, VA Tech

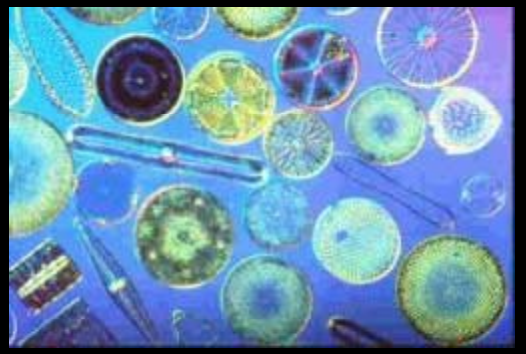
Natural Diets and Particle Type Selection



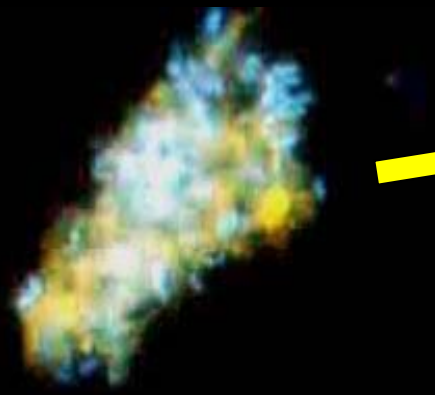
Pennate Diatoms



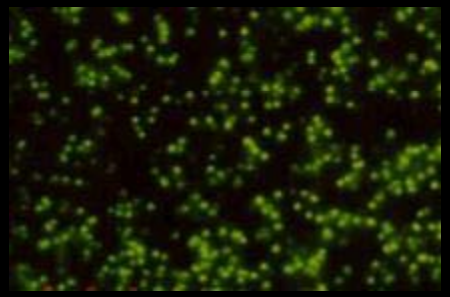
Phytoplankton



Centric Diatoms



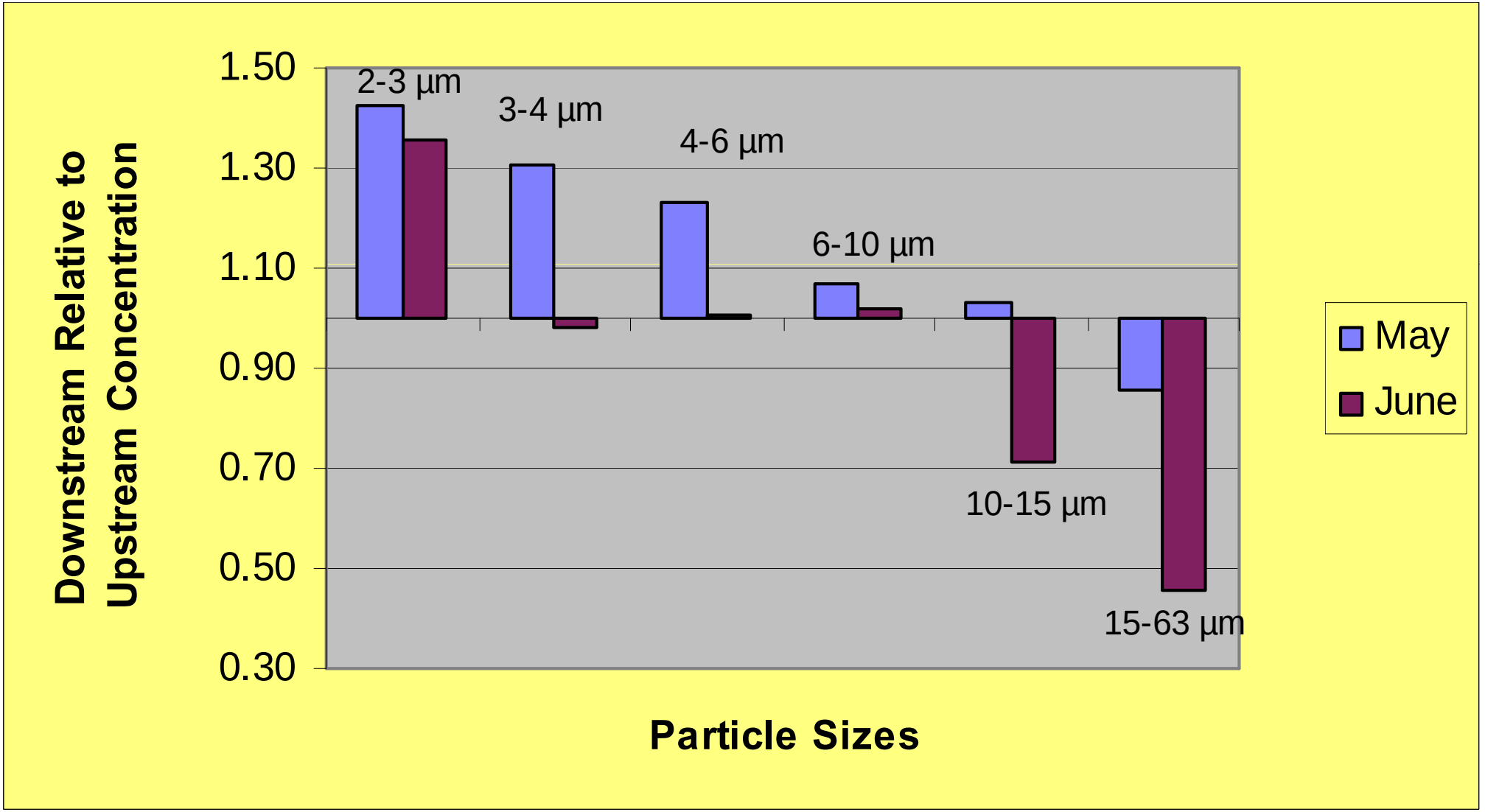
Detritus Complex



Bacteria

Heterotrophic Protists

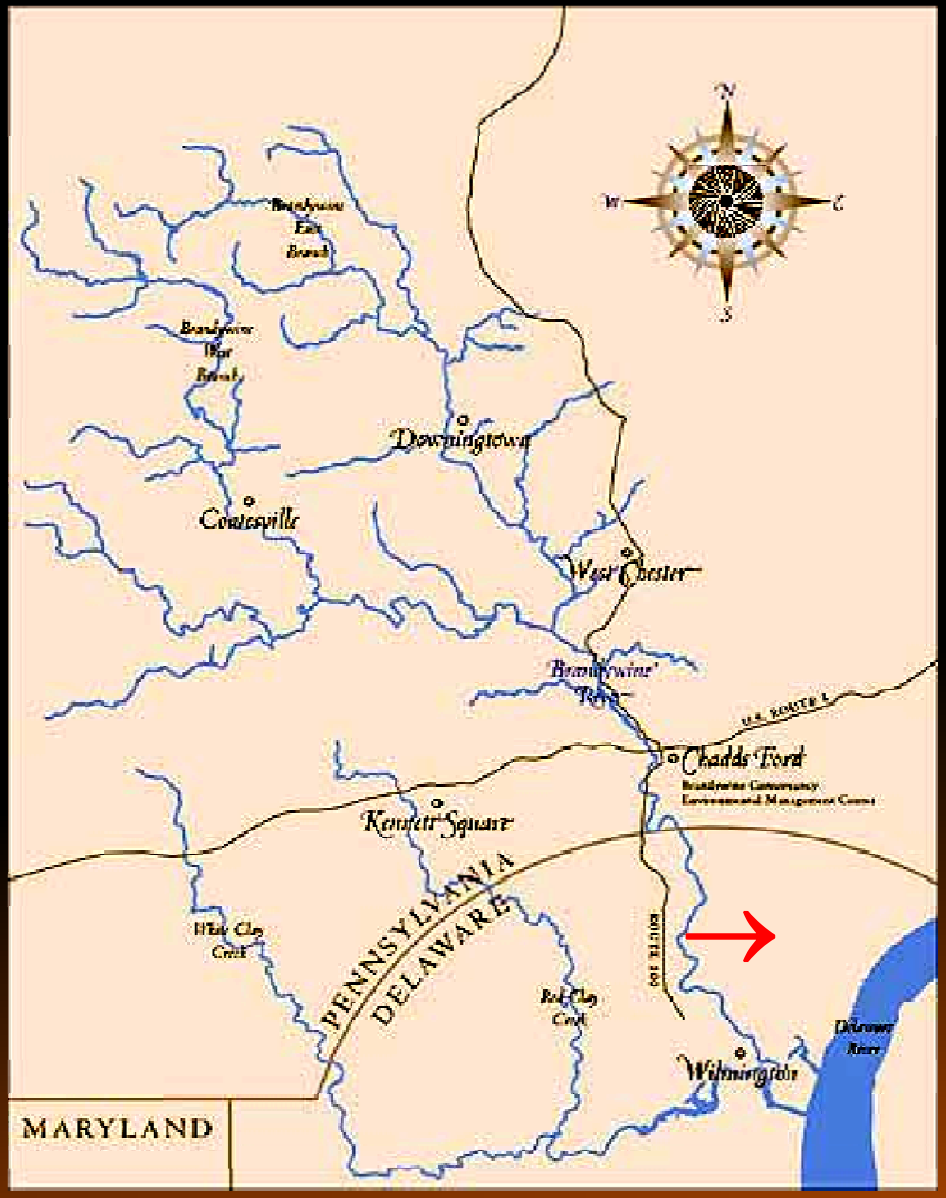
Particle Size Selection: particles below a mussel bed



Brandywine River

Studied 2000 - present

Elliptio complanata

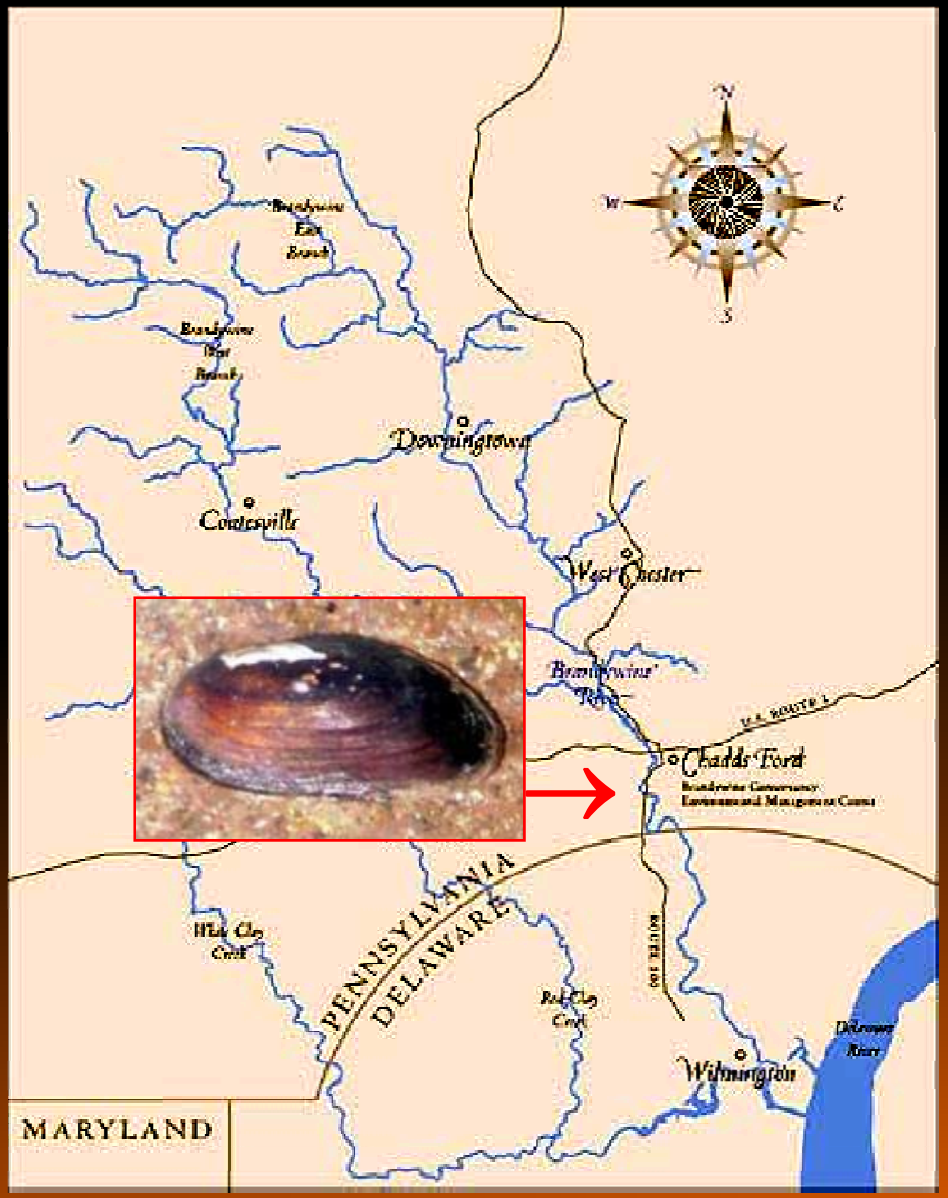


Map from The Brandywine River Conservancy

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

Delaware Freshwater Mussels

Elliptio complanata

Delaware Estuary Marsh mussels

Geukensia demissa

Delaware Bay Oysters

Crassostrea virginica

Kreeger

Ribbed Mussels in Salt Marshes

Kreeger

Ribbed Mussels in Salt Marshes

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

= 59.0 Billion Liters per Hour

Oysters 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

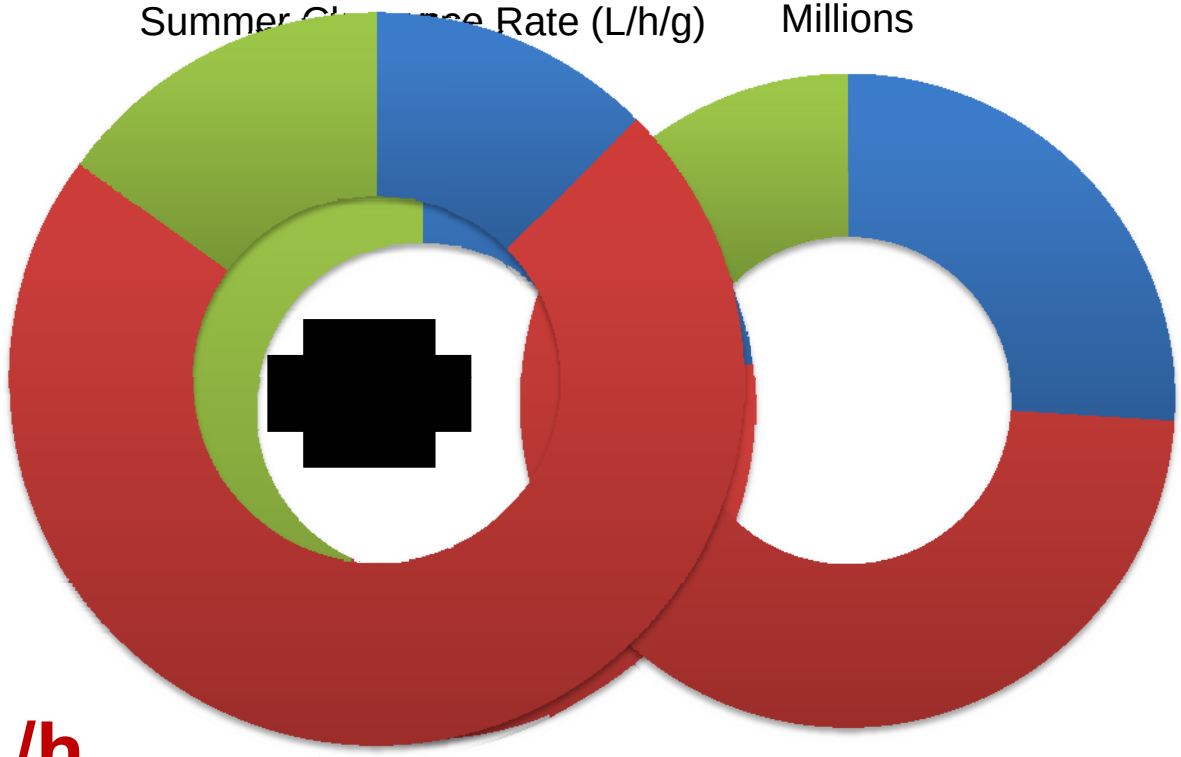
PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Kreeger

Population-level Water Processing

Water Processing per Unit Biomass

Population Abundance



= 80 Billion L/h

Freshwater Mussel

Marsh Mussel

Oyster

Bio-filtration

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Considerations

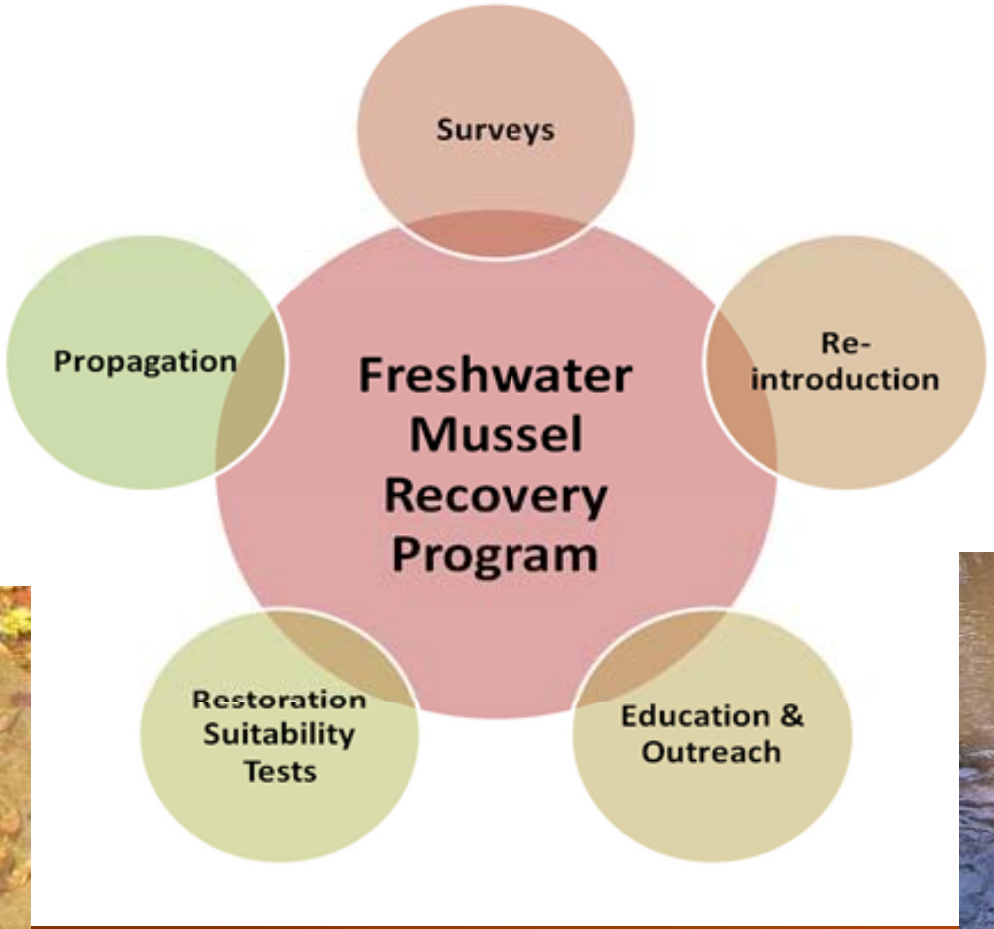
- Total filtration capacity for one fw mussel species (~10 billion L/hr) is >250X freshwater inflow from the Delaware River and other tributaries (not total volume)
- Total filtration capacity of oysters and ribbed mussels in Delaware Bay (~70 billion L/hr) is ~8% of tidal volume per day (100% in 11.5 days)
- Water processing potential is estimated with current abundances
- Although historical abundances can be informative, current and future carrying capacities are poorly understood

What are we doing?

Water Quality &
Flow Management

Freshwater Mussel Recovery Program

Freshwater Mussel Recovery Program



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

Surveys to Fill Data Gaps

PDE, ANSP, PWD

Main Line Health

Health&Science

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.

By Sandy Bauers

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

Propagation and Reintroduction

USFWS & Cheyney Hatcheries

Fish Infestation

Fish from USGS, Academy of Natural Sciences

Larval Transformation Into Juveniles

Propagation and Reintroduction

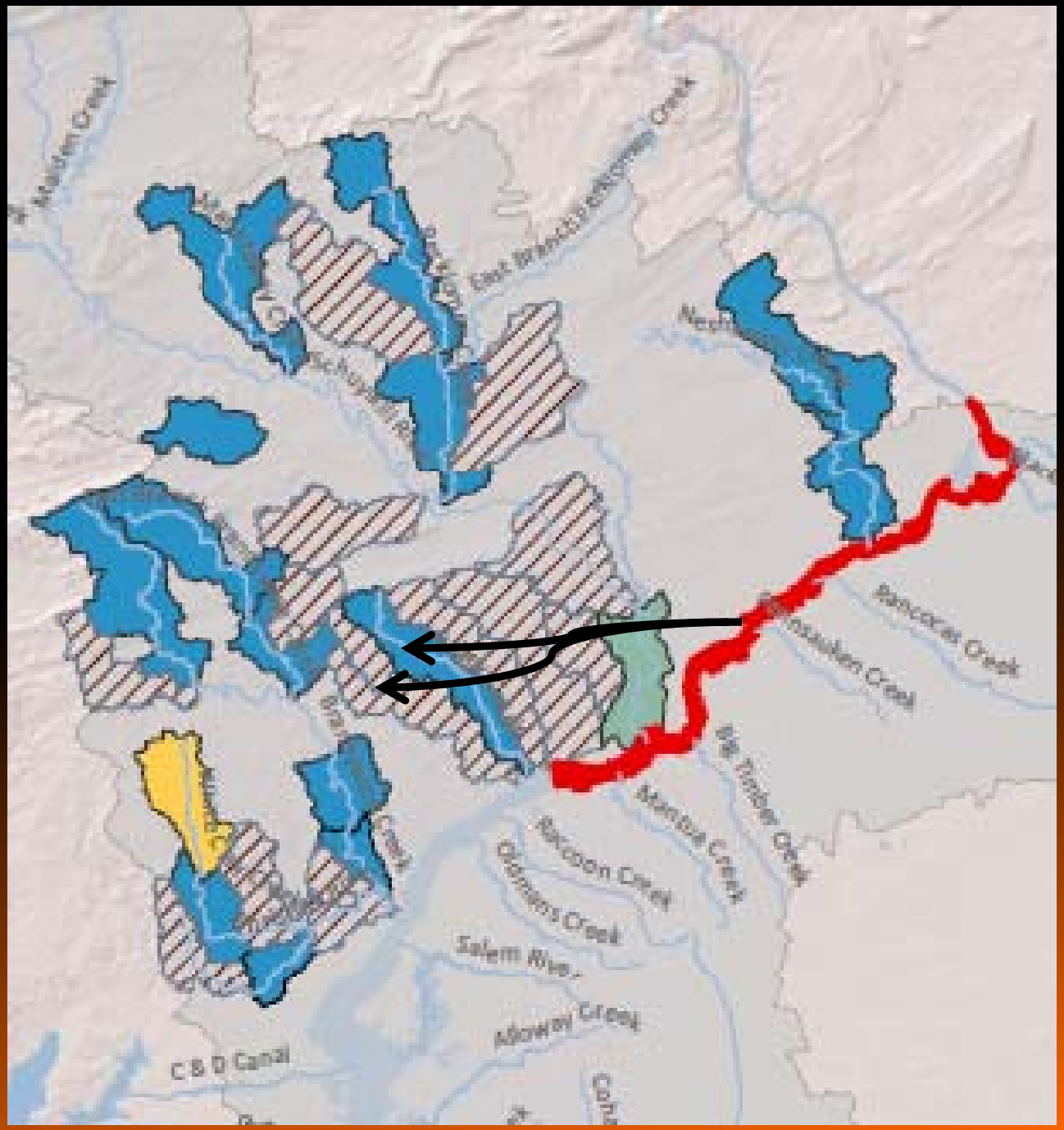
Propagated Juveniles

Photos, R. Neves, VA Tech

Reintroduction of Tagged Mussels

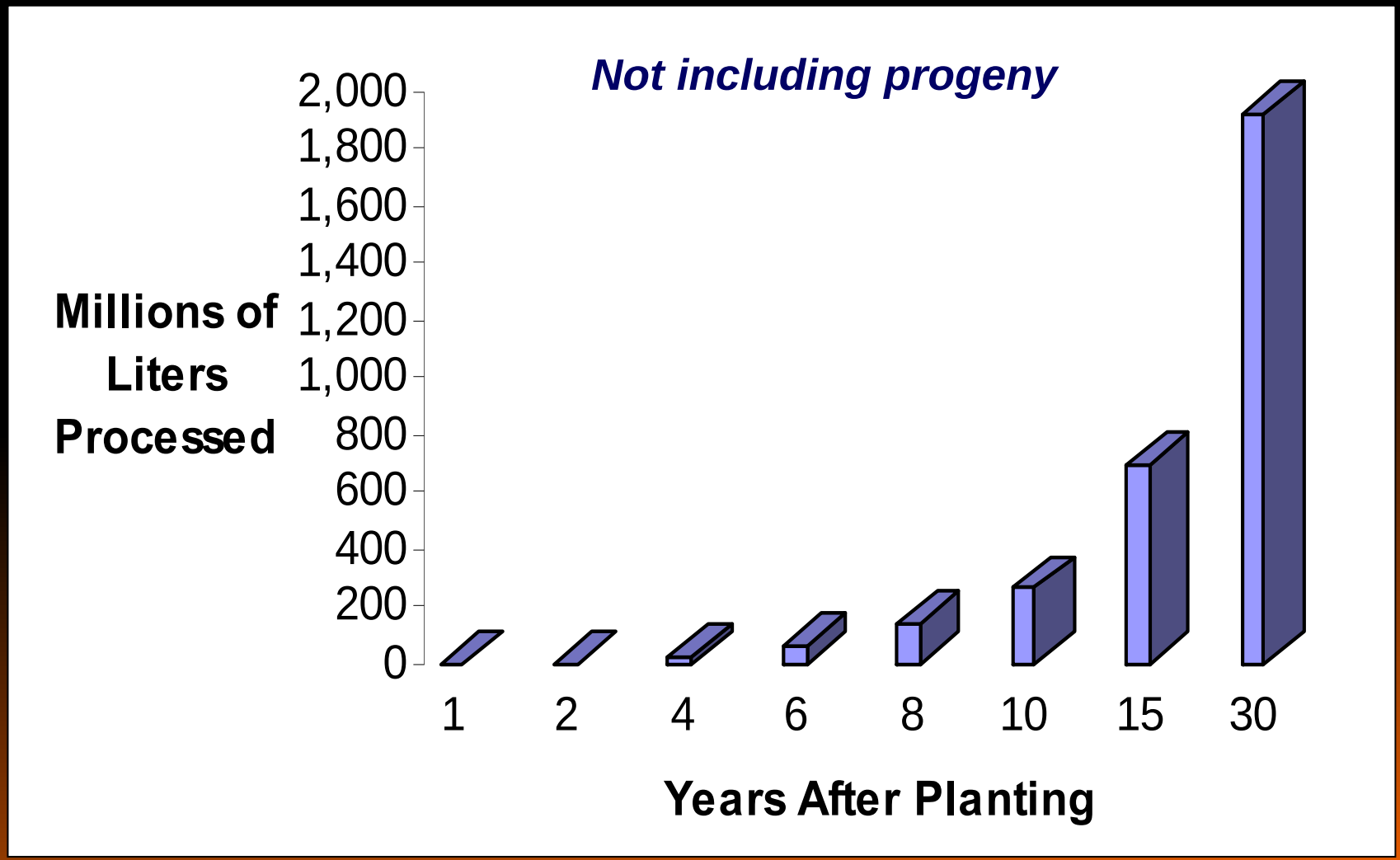
Pyganodon cataracta

Elliptio complanata



Freshwater Mussel Recovery Program

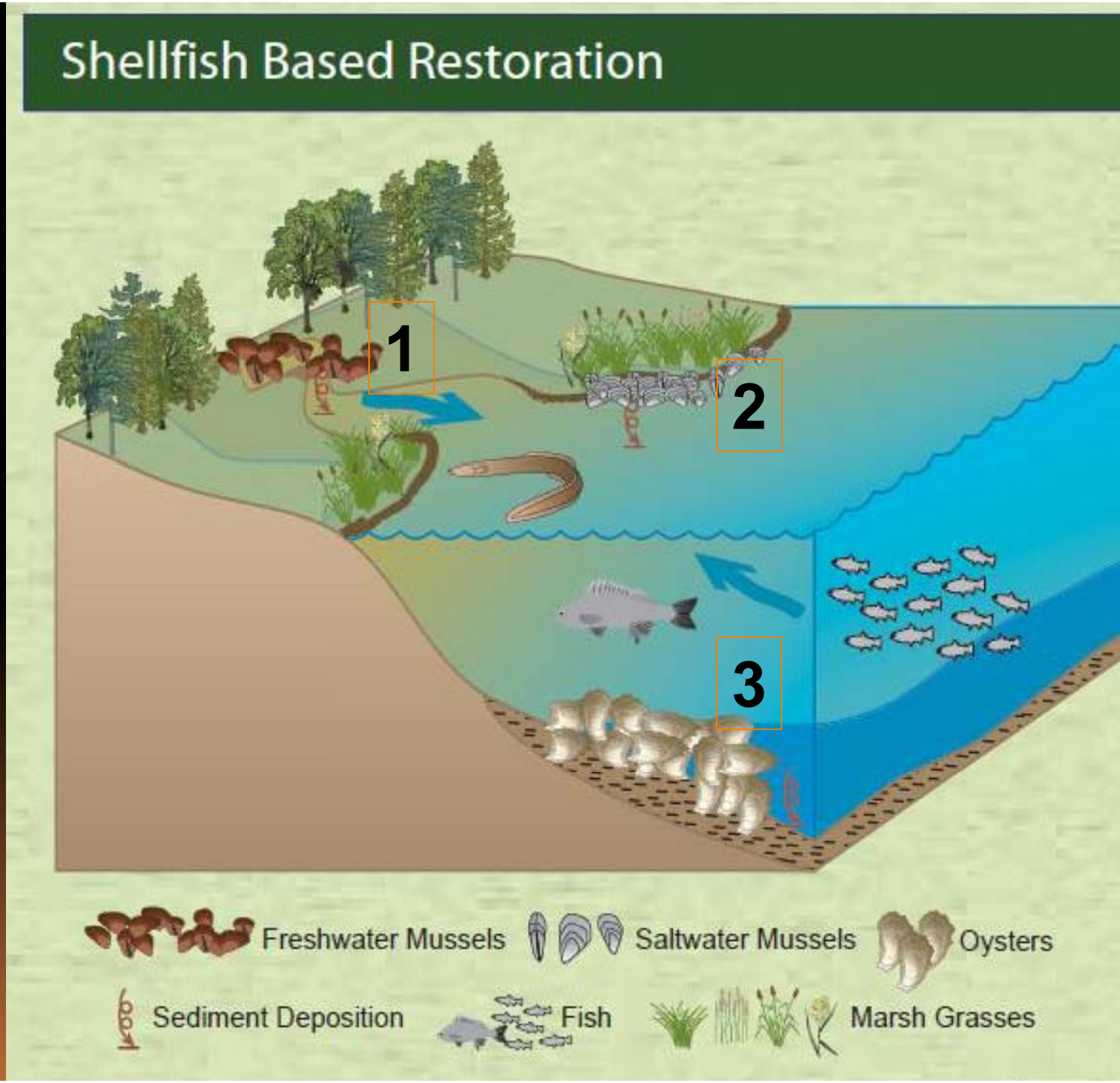
Goals Based on Ecosystem Services



Conceptual model:

Three-pronged approach to bivalve restoration to improve water quality

1. Non-tidal
2. Intertidal
3. Subtidal



System Linkages ?

Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

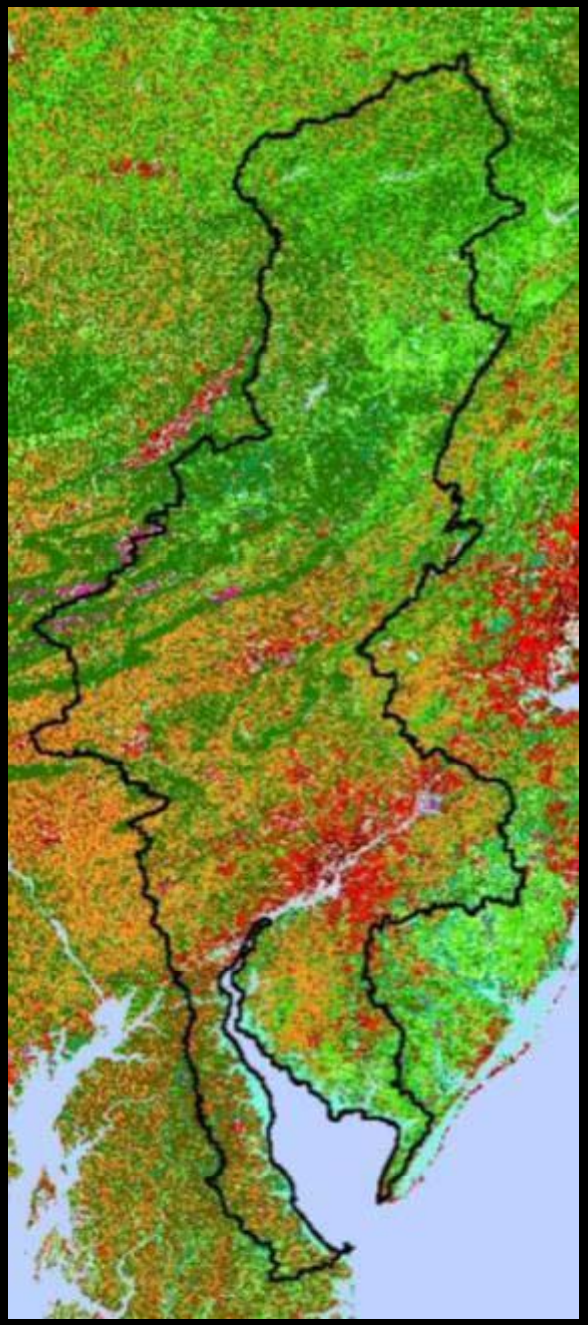
Corbicula fluminea

ilus edulis

Ensis direct

Mercenaria mercenaria

DRBC



Desired Watershed Condition:

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

Kreeger

CONCLUSIONS

- Diverse bivalve species should help reverse eutrophication under the right conditions
- Current bivalve populations help sustain water quality, and they deserve protection
- Populations of many species are below carrying capacity and could be augmented
- Protection and restoration of diverse species can augment restoration and promote positive feedbacks via ecosystem linkages
- Chesapeake Bay and Delaware Estuary partnering would be fruitful

Bivalves
Nature's Benefits
(aka Natural Capital)

Six Reasons Why We Care

1. Biodiversity

Species Loss

- ↓ Intrinsic Losses
- ↓ Niches Filled
- ↓ Human Health

2. Biomass (Populations)

Biomass Loss:

- ↓ EcoServices
- ↓ Fish & Wildlife
- ↓ Human Health

CTUIR Freshwater Mussel Project

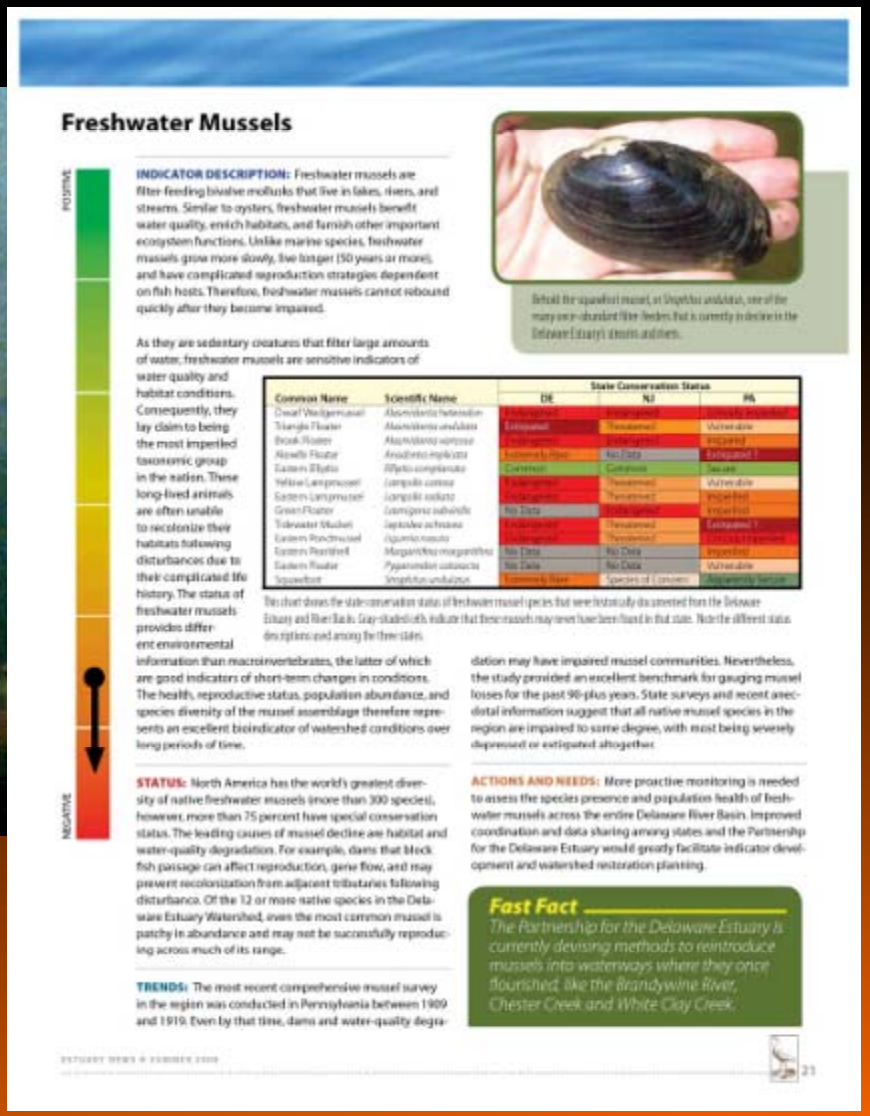
3. Bioindicator Value

International Mussel Watch

Caging Studies

Contaminant and Site-Specific Testing, Monitoring

Tributary and Regional Bioassessment



Freshwater Mussels

POSITIVE

NEGATIVE

INDICATOR DESCRIPTION: Freshwater mussels are filter-feeding bivalve mollusks that live in lakes, rivers, and streams. Similar to oysters, freshwater mussels benefit 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 dependent on fish hosts. Therefore, freshwater mussels cannot rebound quickly after they become impaired.

As they are sedentary creatures that filter large amounts of water, freshwater mussels are sensitive indicators of 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 of which are good indicators of short-term changes in conditions. The health, reproductive status, population abundance, and species diversity of the mussel assemblage therefore represents an excellent bioindicator of watershed conditions over long periods of time.

Behold the squawfoot mussel, or *Strophitus undulatus*, one of the many once-abundant filter-feeders that is currently in decline in the Delaware Estuary's streams and rivers.

Common Name	Scientific Name	State Conservation Status		
		DE	NJ	PA
Dwarf Wedgemussel	*Alasmidonta heterodon*	Endangered	Endangered	Candidate Endangered
Triangle Floater	*Alasmidonta undulata*	Extirpated	Threatened	Vulnerable
Brook Floater	*Alasmidonta varicosa*	Endangered	Endangered	Imperiled
Atlantic Pigtoe	*Fusconaia masoni*	Endangered	Endangered	Imperiled
Yellow Lampmussel	*Lampsilis cariosa*	Endangered	Threatened	Vulnerable
Eastern Lampmussel	*Lampsilis radiata*	Endangered	Threatened	Imperiled
Green Floater	*Lasmigona subviridis*	Endangered	Endangered	Imperiled
Tidewater Mucket	*Leptodea ochracea*	Endangered	Threatened	Extirpated
Eastern Pondmussel	*Ligumia nasuta*	Endangered	Threatened	Critically Imperiled
Eastern Pearlshell	*Margaritifera margaritifera*	Endangered	Endangered	Imperiled
Eastern Floater	*Pyganodon cataracta*	Endangered	Endangered	Vulnerable
Squawfoot	*Strophitus undulatus*	Extremely Rare	Species of Concern	Apparently Secure

This chart shows the state conservation status of freshwater mussel species that were historically documented from the Delaware Estuary and River Basin. Gray-shaded cells indicate that these mussels may never have been found in that state. Note the different status descriptions used among the three states.

STATUS: North America has the world's greatest diversity of native freshwater mussels (more than 300 species), however, more than 75 percent have special conservation status. The leading causes of mussel decline are habitat and water-quality degradation. For example, dams that block fish passage can affect reproduction, gene flow, and may prevent recolonization from adjacent tributaries following disturbance. Of the 12 or more native species in the Delaware Estuary Watershed, even the most common mussel is patchy in abundance and may not be successfully reproducing across much of its range.

TRENDS: The most recent comprehensive mussel survey in the region was conducted in Pennsylvania between 1909 and 1919. Even by that time, dams and water-quality degradation may have impaired mussel communities. Nevertheless, the study provided an excellent benchmark for gauging mussel losses for the past 90-plus years. State surveys and recent anecdotal information suggest that all native mussel species in the region are impaired to some degree, with most being severely depressed or extirpated altogether.

ACTIONS AND NEEDS: More proactive monitoring is needed to assess the species presence and population health of freshwater mussels across the entire Delaware River Basin. Improved coordination and data sharing among states and the Partnership for the Delaware Estuary would greatly facilitate indicator development and watershed restoration planning.

Fast Fact

The Partnership for the Delaware Estuary is currently devising methods to reintroduce mussels into waterways where they once flourished, like the Brandywine River, Chester Creek and White Clay Creek.

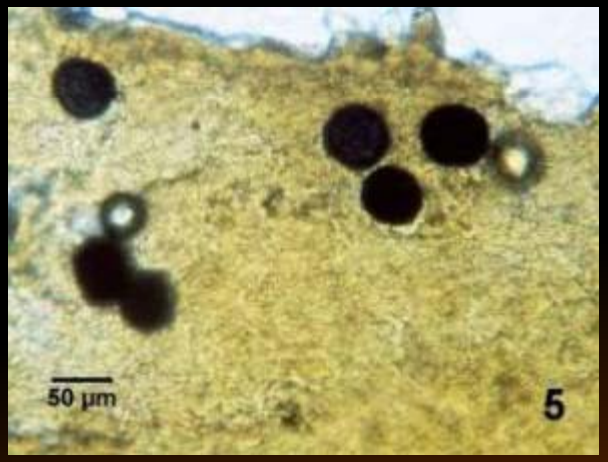
4. Commercial Value

Shellfisheries
Jewelry
Pearl Shell Industry

5. Cultural-Historical

Waterman Lifestyle
Native American Uses
Ecotourism

6. Human Health



Pathogen Removal
- filter and digest harmful bacteria and protists

Model Organisms
- for medical sciences (e.g. cancer research)

TMDL applications
- can reassembled bivalve communities help managers address TMDL's?

Nature's Benefits (Natural Capital)

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

Livelihoods

Lives

Health

Livelihoods

Health