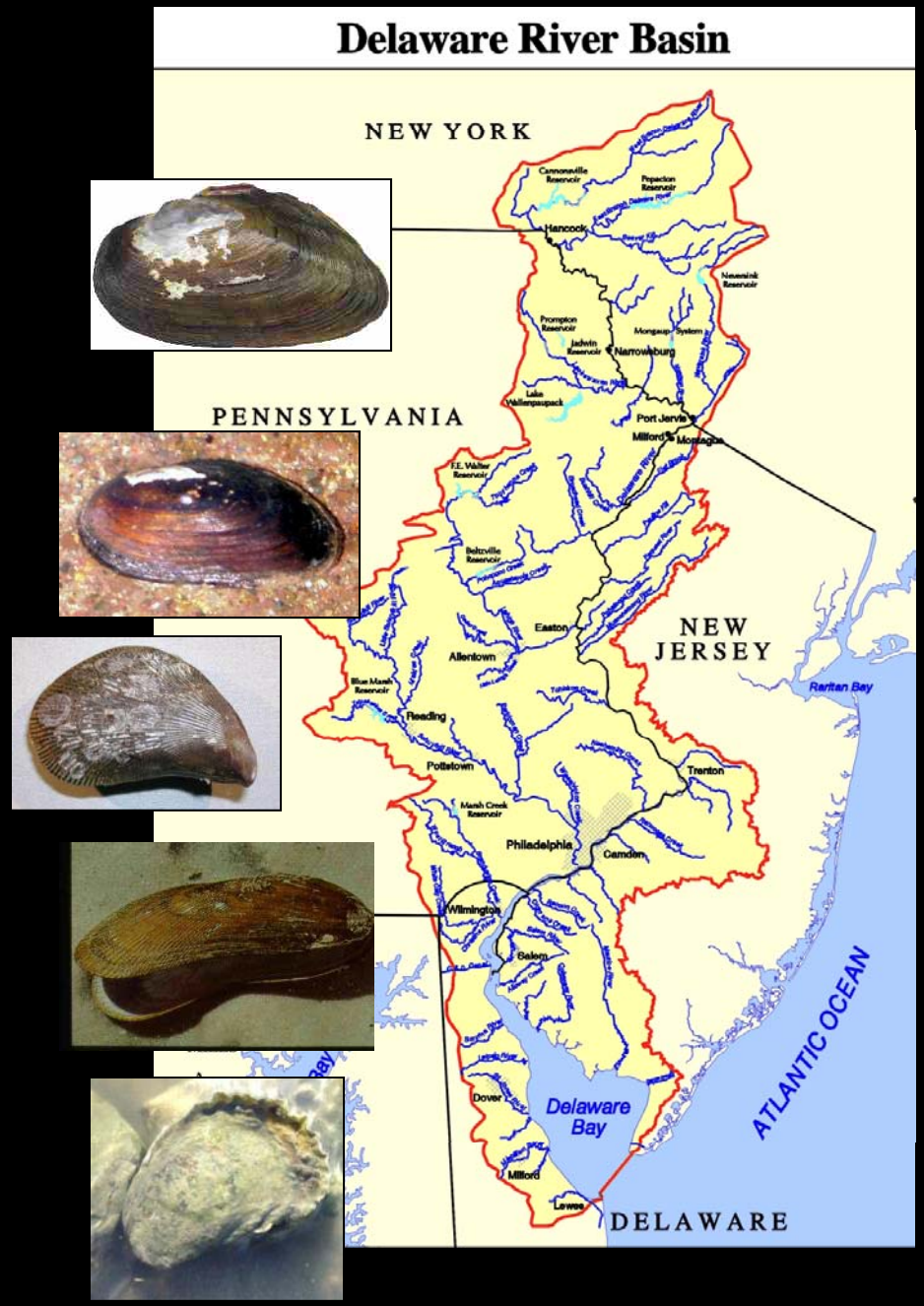
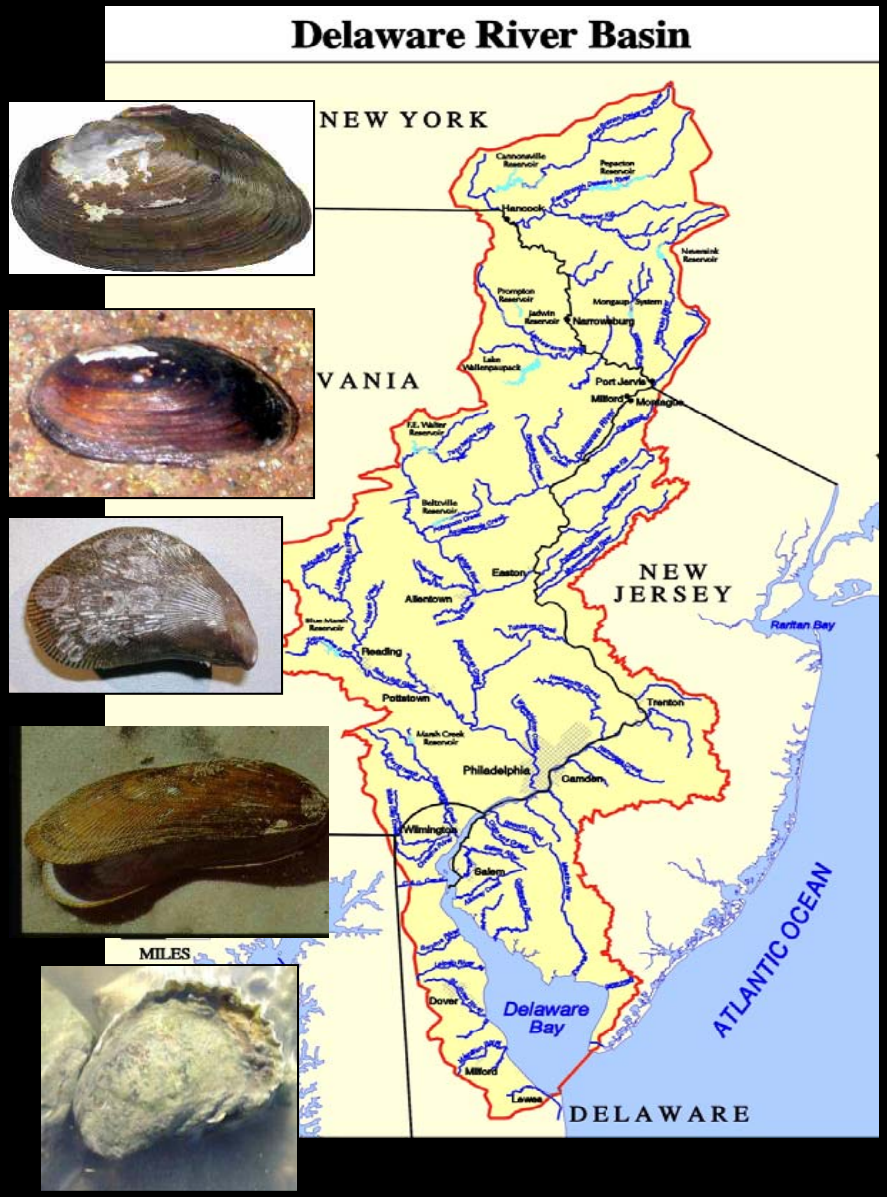
Freshwater Mussel Recovery for Water Quality and Habitat Improvement in Southeastern Pennsylvania

Danielle Kreeger
Partnership for the DE Estuary



Healthy Bivalves = Healthy Watersheds

Rebuilding Bivalve Biodiversity, Populations and Ecosystem Services as a Basis for Ecosystem Restoration



PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Danielle Kreeger
Partnership for the DE Estuary

Bivalves of the Delaware

Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea

Rangia cuneata

Mya arenaria

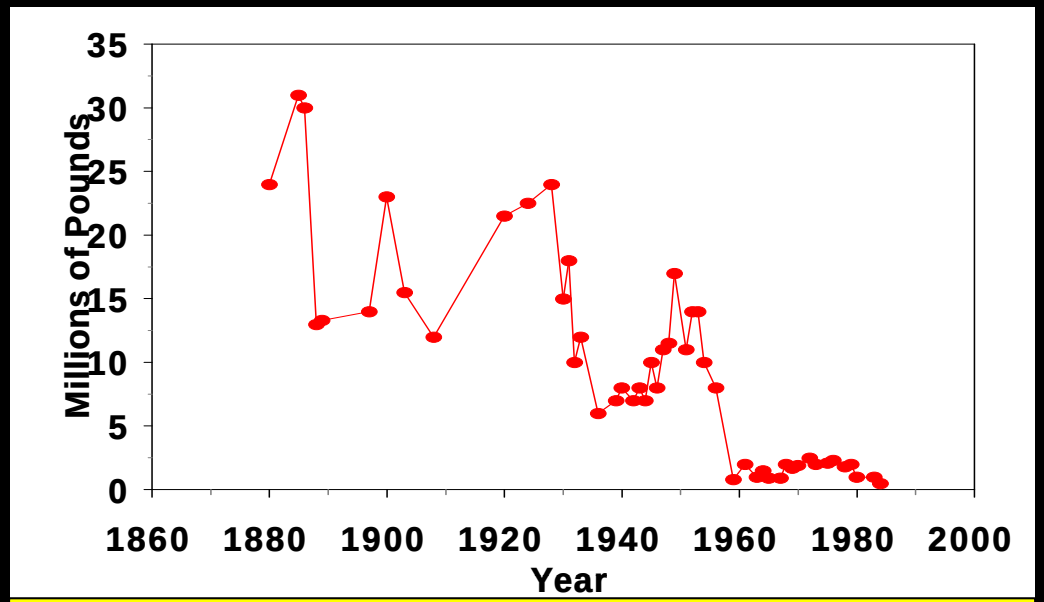
Mytilus edulis

Ensis directus

Mercenaria mercenaria

Bivalves

Oyster Trends



Oyster landings in Delaware Bay: 1880 - 1980s

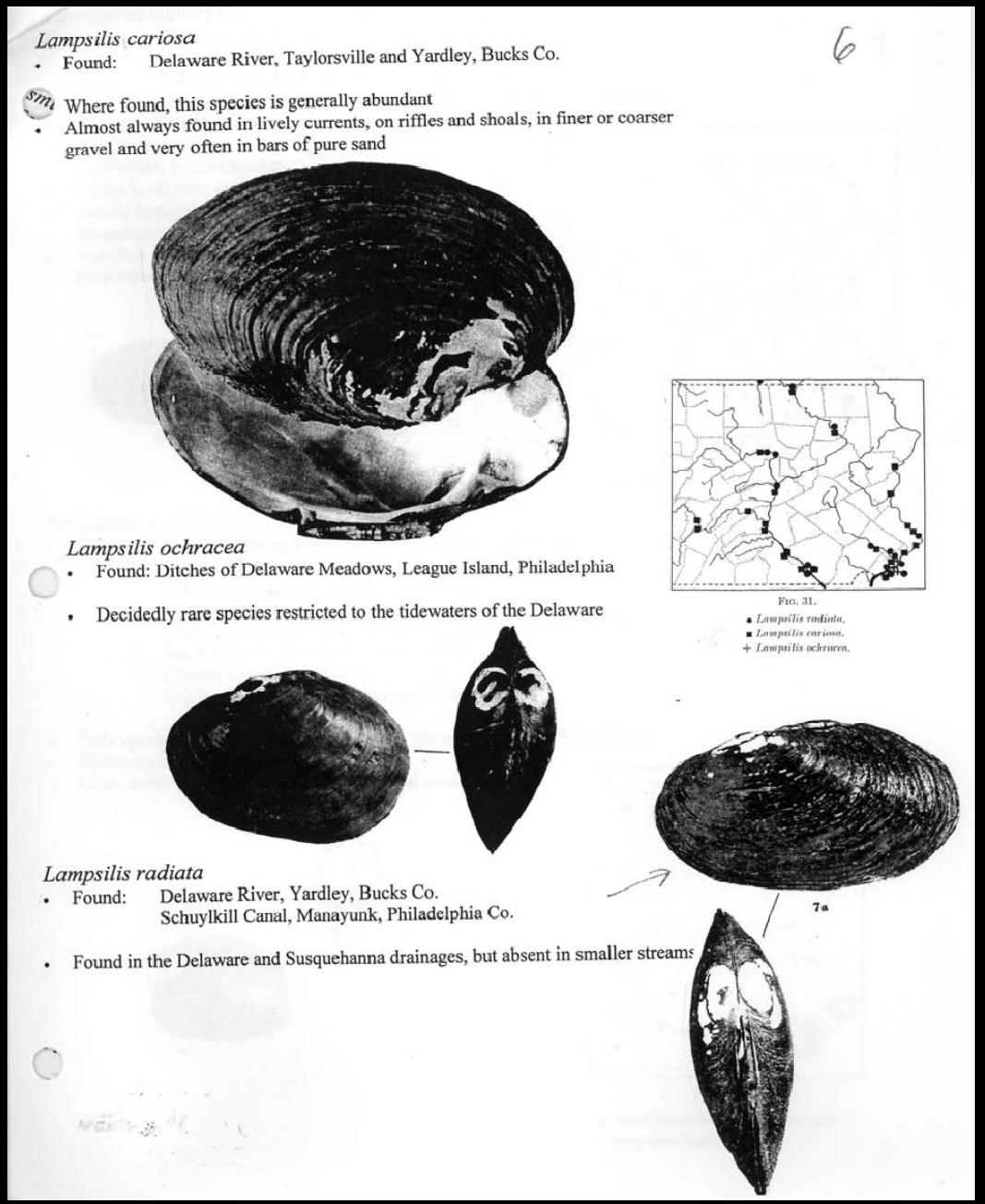
http://www.epodunk.com/cgi-bin/genInfo.php?locIndex=25475

Oyster Reef Revitalization

Bivalves

Freshwater Mussel Status and Trends

Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania. Part III: Systematic account of the genera and species. Memoirs of the Carnegie Museum 8(1):



Lampsilis cariosa

- Found: Delaware River, Taylorsville and Yardley, Bucks Co.

6

- Where found, this species is generally abundant
- Almost always found in lively currents, on riffles and shoals, in finer or coarser gravel and very often in bars of pure sand

Lampsilis ochracea

- Found: Ditches of Delaware Meadows, League Island, Philadelphia
- Decidedly rare species restricted to the tidewaters of the Delaware

FIG. 31.

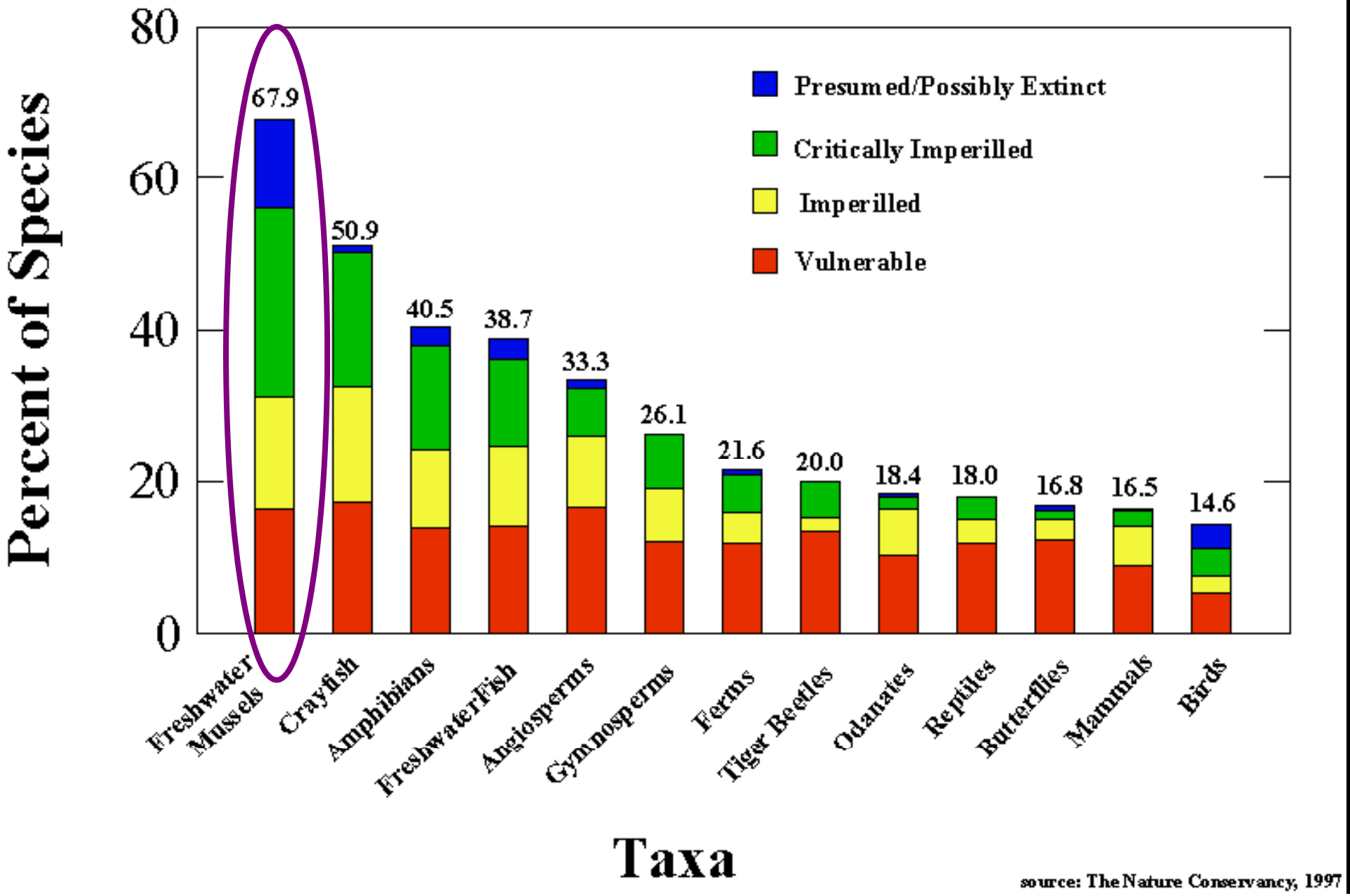
• *Lampsilis radiata.*
■ *Lampsilis carlosa.*
+ *Lampsilis ochracea.*

Lampsilis radiata

- Found: Delaware River, Yardley, Bucks Co.
  Schuylkill Canal, Manayunk, Philadelphia Co.
- Found in the Delaware and Susquehanna drainages, but absent in smaller streams

7a

Conservation Status of United States Taxa



source: The Nature Conservancy, 1997

Loss in Biodiversity

VOLUME 18 ♦ ISSUE 3 ♦ SUMMER 2008
PDE REPORT NO. 08-01

ESTUARY NEWS

A PUBLICATION OF THE PARTNERSHIP FOR THE DELAWARE ESTUARY: A NATIONAL ESTUARY PROGRAM

SPECIAL ISSUE

State of the Delaware Estuary 2008

By Jennifer Adkins, Executive Director, Partnership for the Delaware Estuary

Every three to five years, the Partnership for the Delaware Estuary works with outside experts to take a comprehensive look at the health of the Delaware Estuary and its watershed. This helps the National Estuary Program track the progress it is making implementing its long-term "Delaware Estuary Comprehensive Conservation and Management Plan." The results are presented here, for 2008, as a special issue of "Estuary News."

The Delaware River's dual identity as both a living river and a working river makes it an Estuary of many contrasts. On one hand it is a principal corridor for commerce that has sustained our region since America's Industrial Revolution, and it continues to be a major strategic port for national defense. On the other hand, it provides a wealth of natural and living resources, such as drinking water for millions of people, extensive tidal marshes that sustain vibrant ecosystems, and world-class habitats for horseshoe crabs, migratory shorebirds and more.

Given these contrasts, it should be no surprise that the 2008 State of the Estuary Report tells a story of mixed environmental conditions. In some ways, the Delaware Estuary is healthier than ever before, thanks largely to improvements in wastewater treatment and laws enacted over time. The condition of some species, like bald eagles and striped bass, for example, have remained stable or improved. Unfortunately, the status of other species appears to be getting worse. The total population of Atlantic sturgeon may number less than 1,000 — perhaps even less than 100. Freshwater mussels and brook trout now appear to be absent from much of the region's non-tidal waterways.

The Delaware Estuary has many important features that set it apart from other American estuaries. These include its freshwater tidal reach and extensive tidal marshes, which serve as the "kidneys" and "fish factories" of the Estuary. Less than five-

continued on page 2

This report is being issued as a special summer edition of "Estuary News," as well as technical report number 08-01 of the Partnership for the Delaware Estuary. Additional supporting materials like references can be found at www.DelawareEstuary.org, and a list of key definitions can be found on page 34. This assessment complements the State of the Basin Report, which is currently being developed by a team led by the Delaware River Basin Commission (DRBC) that also includes the Partnership. For information on that report, please call the DRBC at (609) 883-9500.

Freshwater Mussels

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.

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.

Common Name	Scientific Name	State Conservation Status		
		DE	NJ	PA
Dwarf Wedgemussel	*Alasmidonta heterodon*	Endangered	Endangered	Critically Imperiled
Triangle Floater	*Alasmidonta undulata*	Extirpated	Threatened	Vulnerable
Brook Floater	*Alasmidonta varicosa*	Endangered	Endangered	Imperiled
Alewife Floater	*Anodonta implicata*	Extremely Rare	No Data	Extirpated ?
Eastern Elliptio	*Elliptio complanata*	Common	Common	Secure
Yellow Lampmussel	*Lampsilis cariosa*	Endangered	Threatened	Vulnerable
Eastern Lampmussel	*Lampsilis radiata*	Endangered	Threatened	Imperiled
Green Floater	*Lasmigona subviridis*	No Data	Endangered	Imperiled
Tidewater Mucket	*Leptodea ochracea*	Endangered	Threatened	Extirpated ?
Eastern Pondmussel	*Ligumia nasuta*	Endangered	Threatened	Critically Imperiled
Eastern Pearlshell	*Margaritifera margaritifera*	No Data	No Data	Imperiled
Eastern Floater	*Pyganodon cataracta*	No Data	No Data	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 Basins. 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.

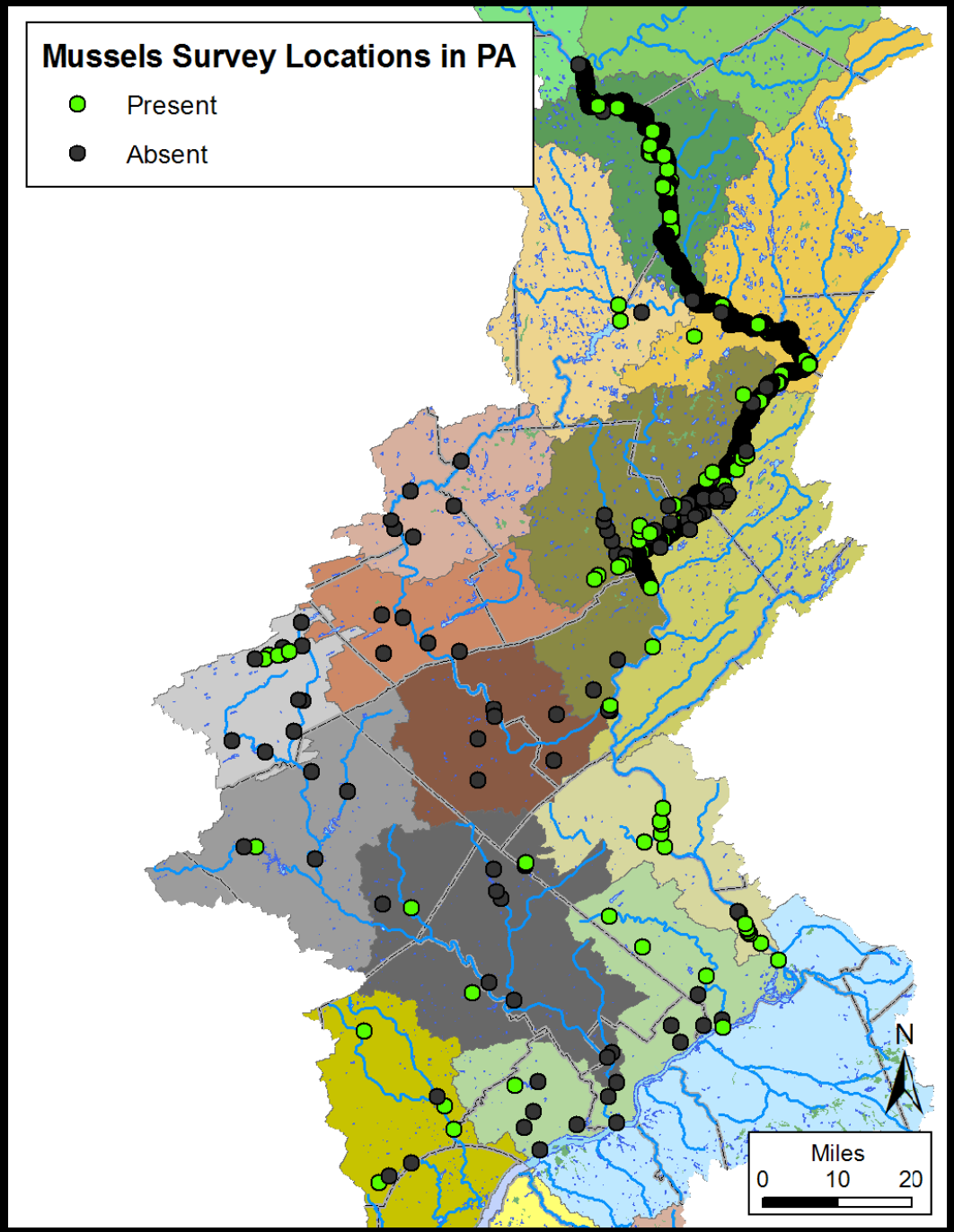
NEP Study Area

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

Culprits

Water Quality

Habitat Loss and Degradation

Photo by D. Kreeger

Exotic Species

Freshwater Mussel Larvae Require Fish Hosts

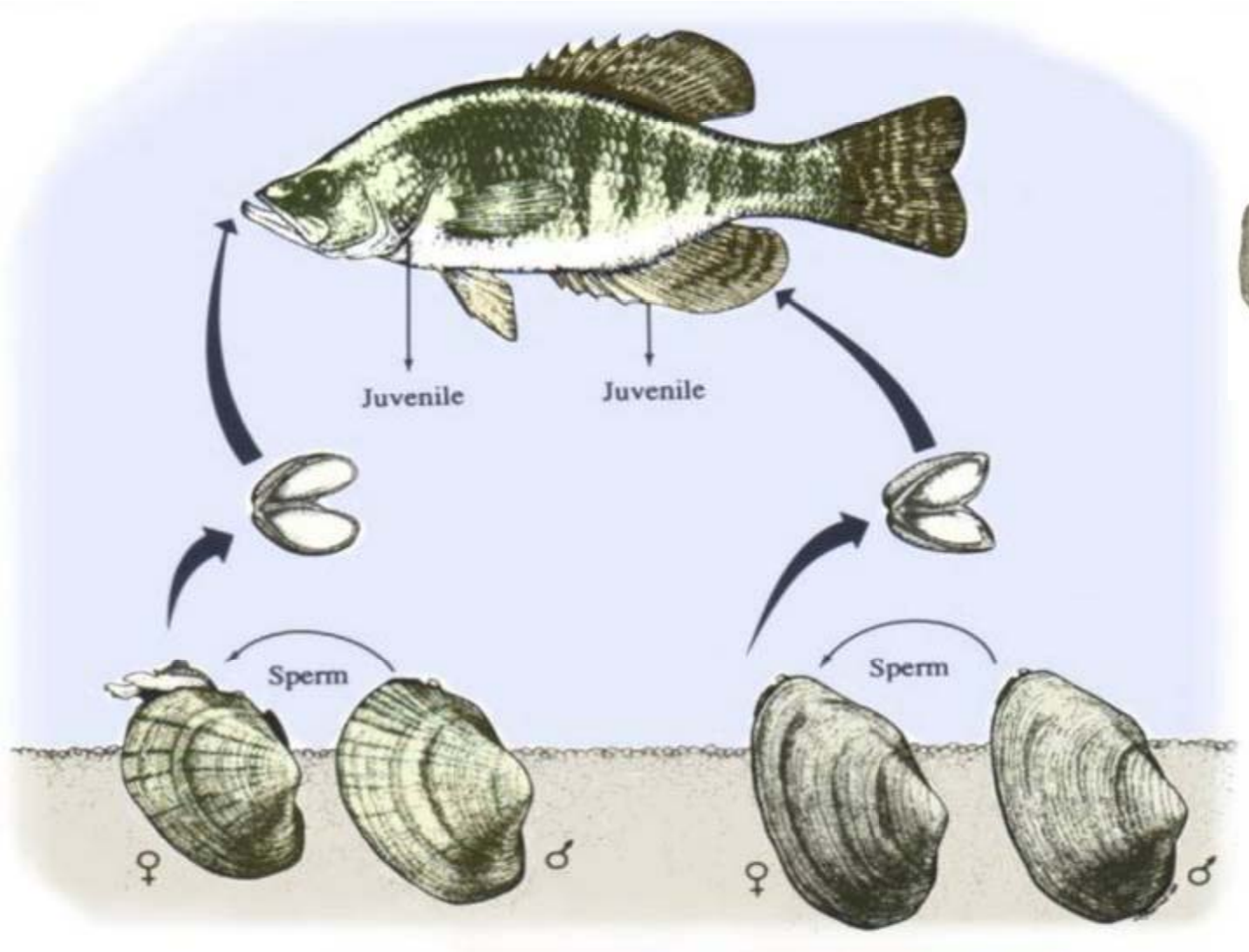
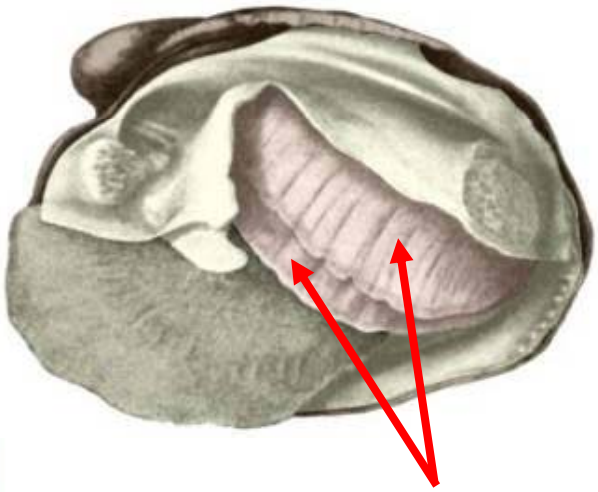


Figure from Cummings and Mayer (1992).

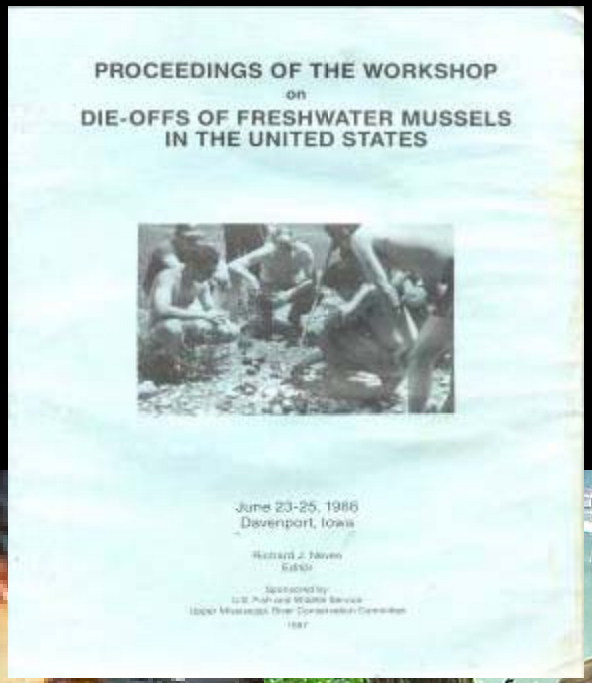


Larvae are brooded in the ctenidia

Most mussels depend on particular fish species

Documenting the Decline

Biodiversity



Population
Biomass


Nature's Benefits
Bivalve Shellfish are
"Ecosystem Engineers"
CTUIR Freshwater Mussel Project
PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

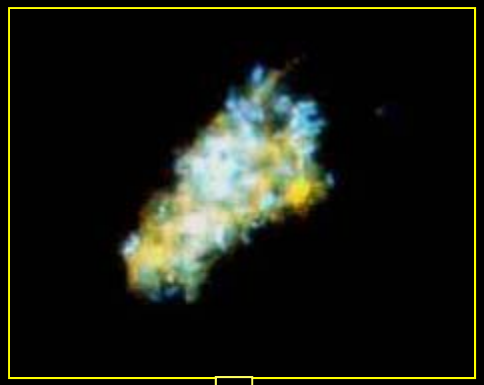
Loss of Ecological Services

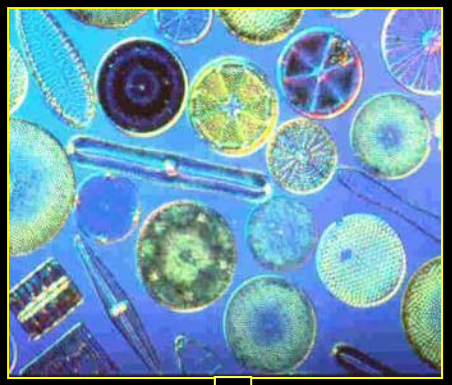
1. Structure

↑ Habitat Complexity

↑ Binding of Bottom

↑ Bottom Turbulence





2. Function

↓ Suspended Particulates

↓ Particulate N, P

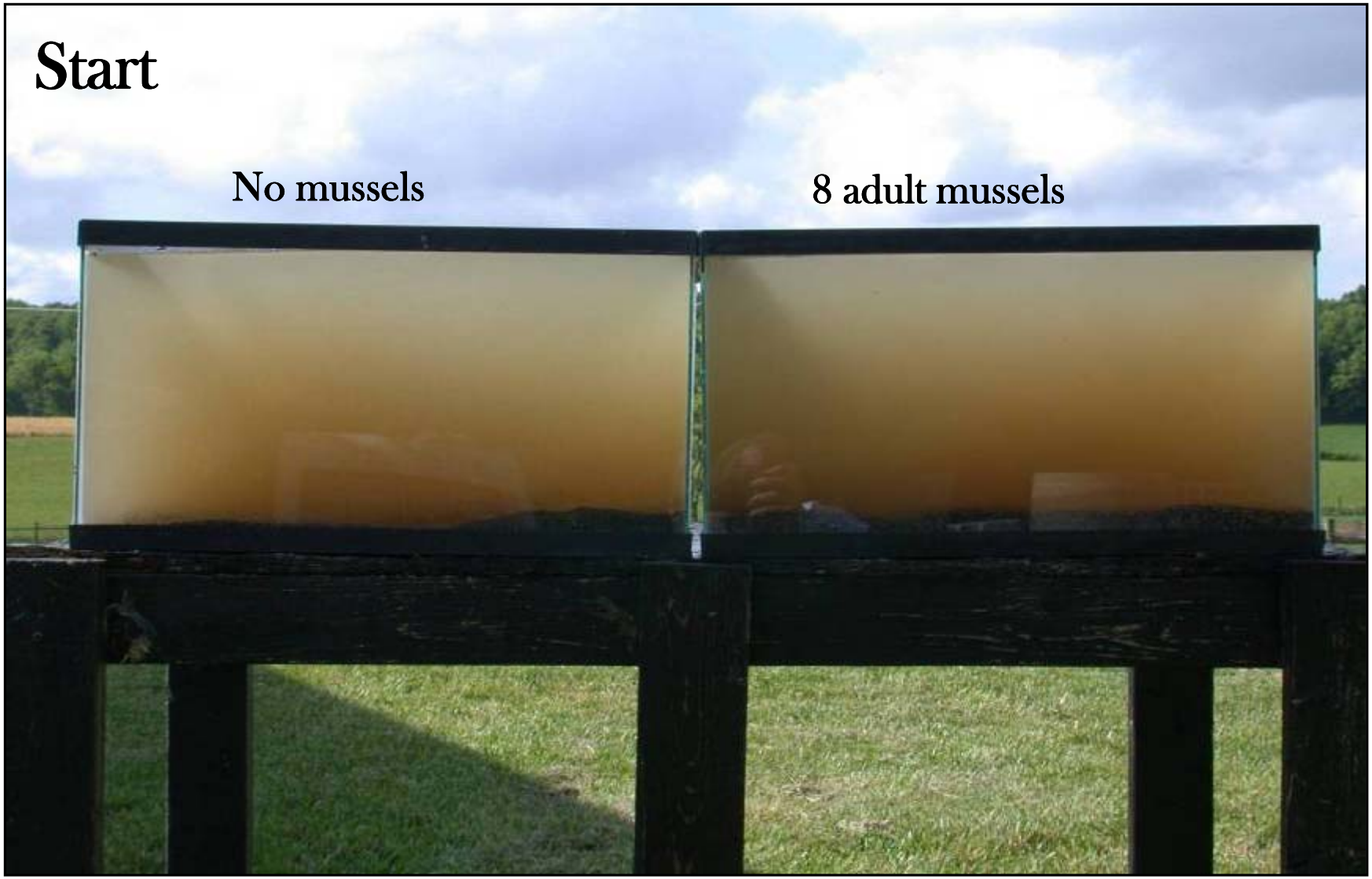
↑ Light

↑ Sediment Enrichment

↑ Dissolved Nutrients

Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

Biofiltration Potential



Slide from Dick Neves, VA Tech

Mussels Are Habitat
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Restoring Our Nation's Water Quality

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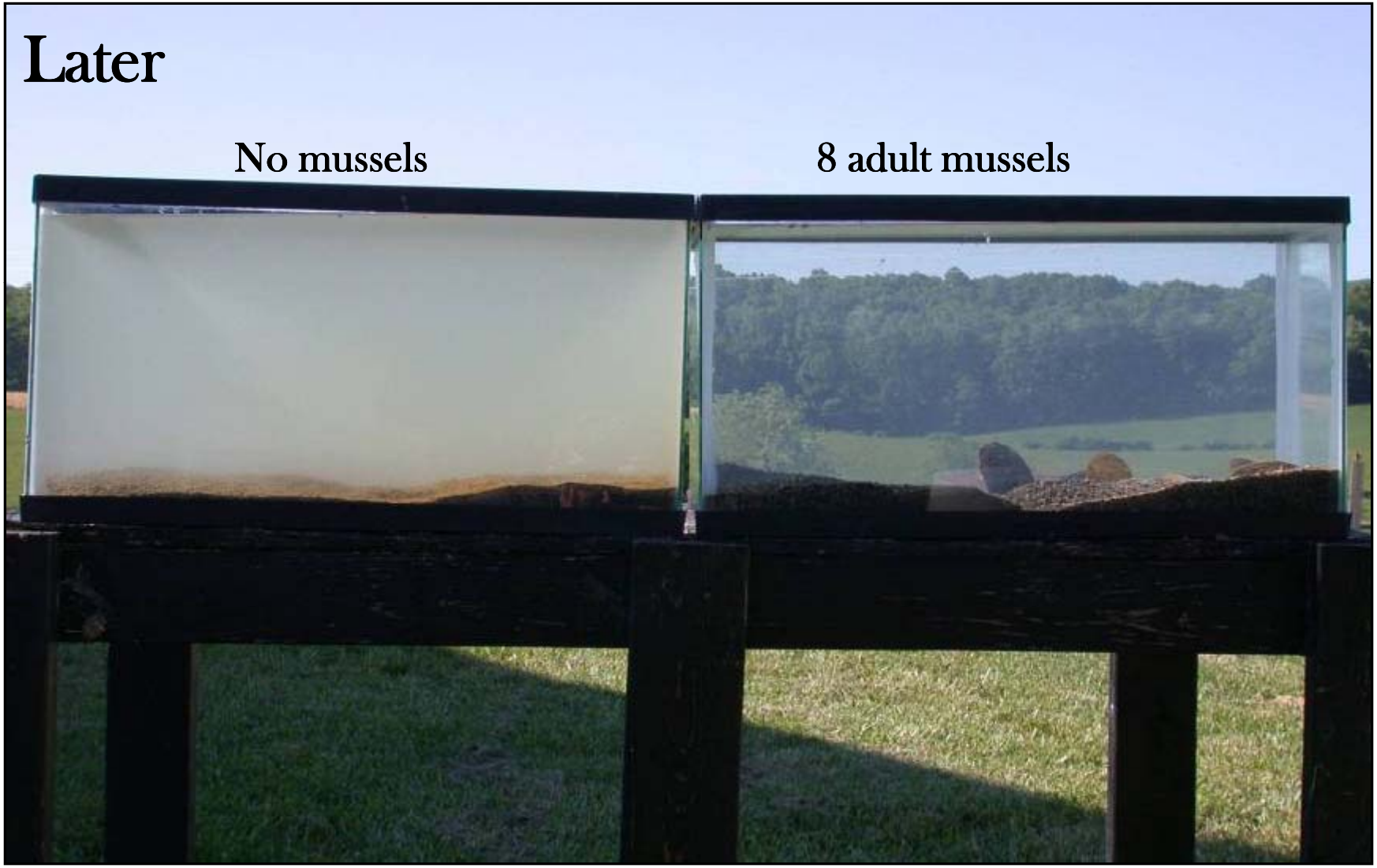
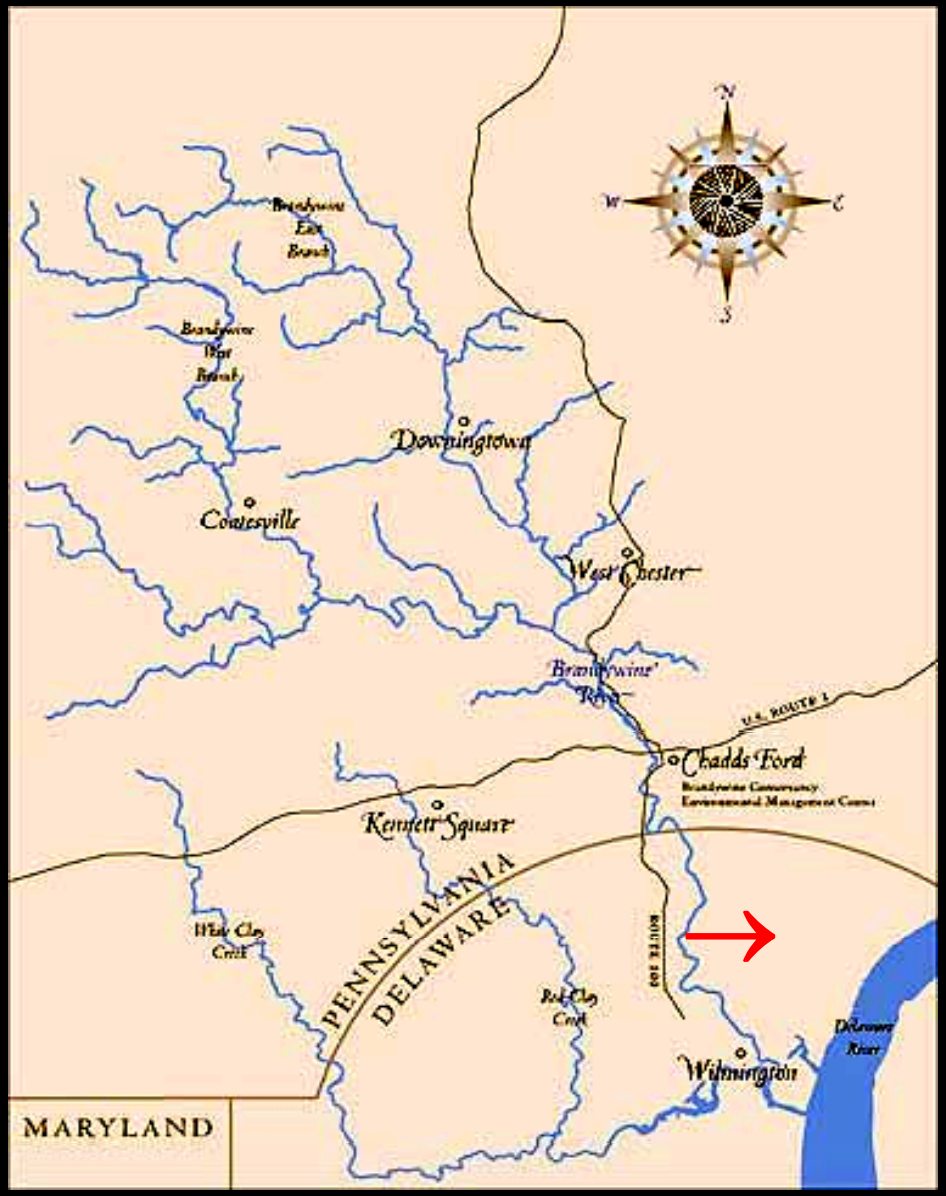


Slide from Dick Neves, VA Tech

Brandywine River

Studied 2000 - present

Elliptio complanata



Map from The Brandywine River Conservancy

Elliptio complanata

Photos by Kreeger

To Understand EcoServices, Need…

Ecology

Physiology

Population Surveys

Monitoring, Variability

Physiology Measurements

e.g., Clearance Rate

In Lab

In Field

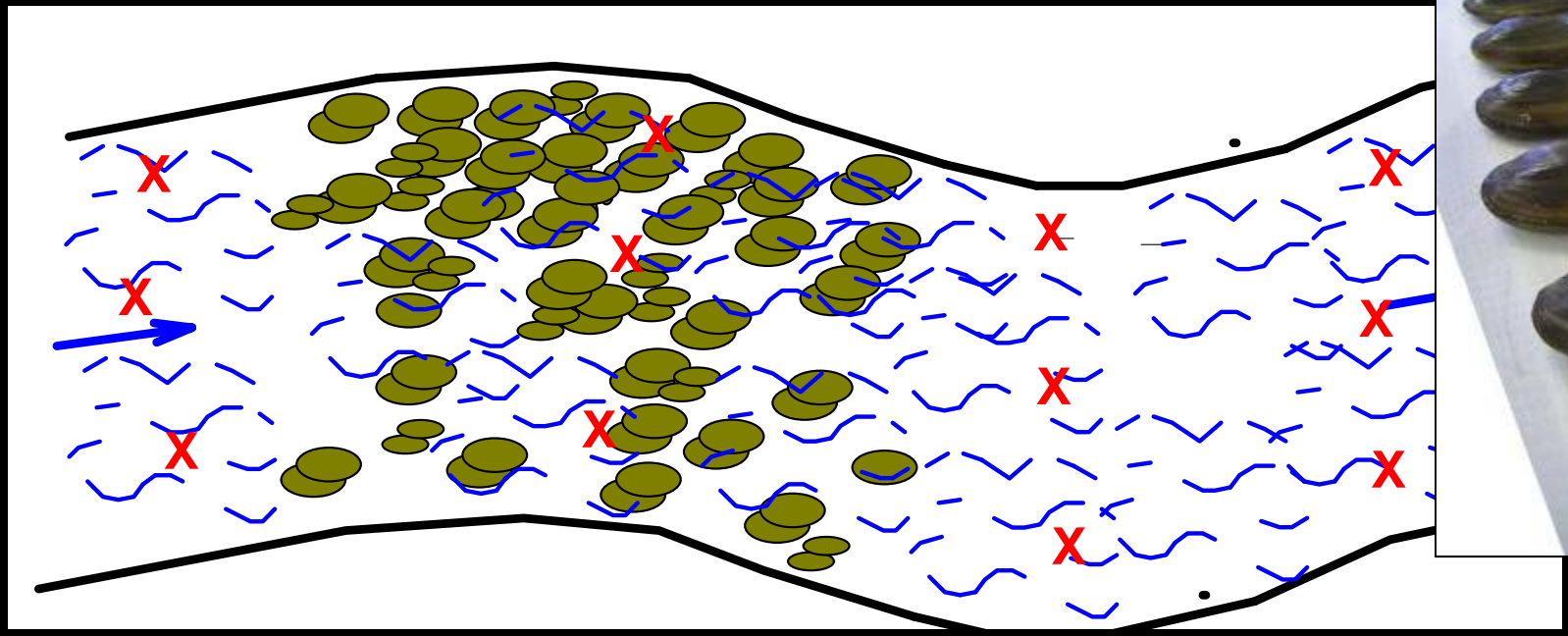
Population Measurements

Size Class Structure

Body Size

Abundance (# m^{-2}, # $mile^{-1}$)

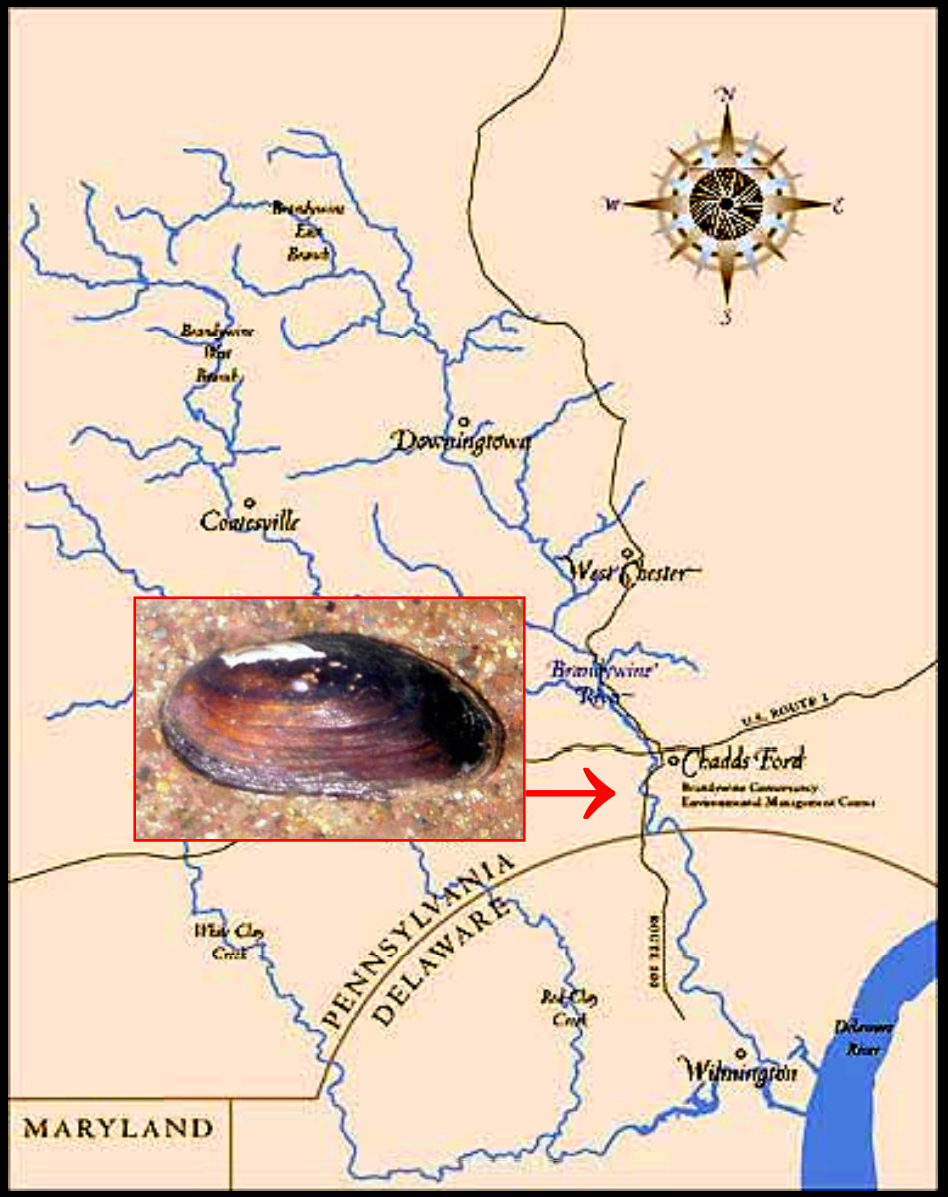
Total Area (m^2, river miles)



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

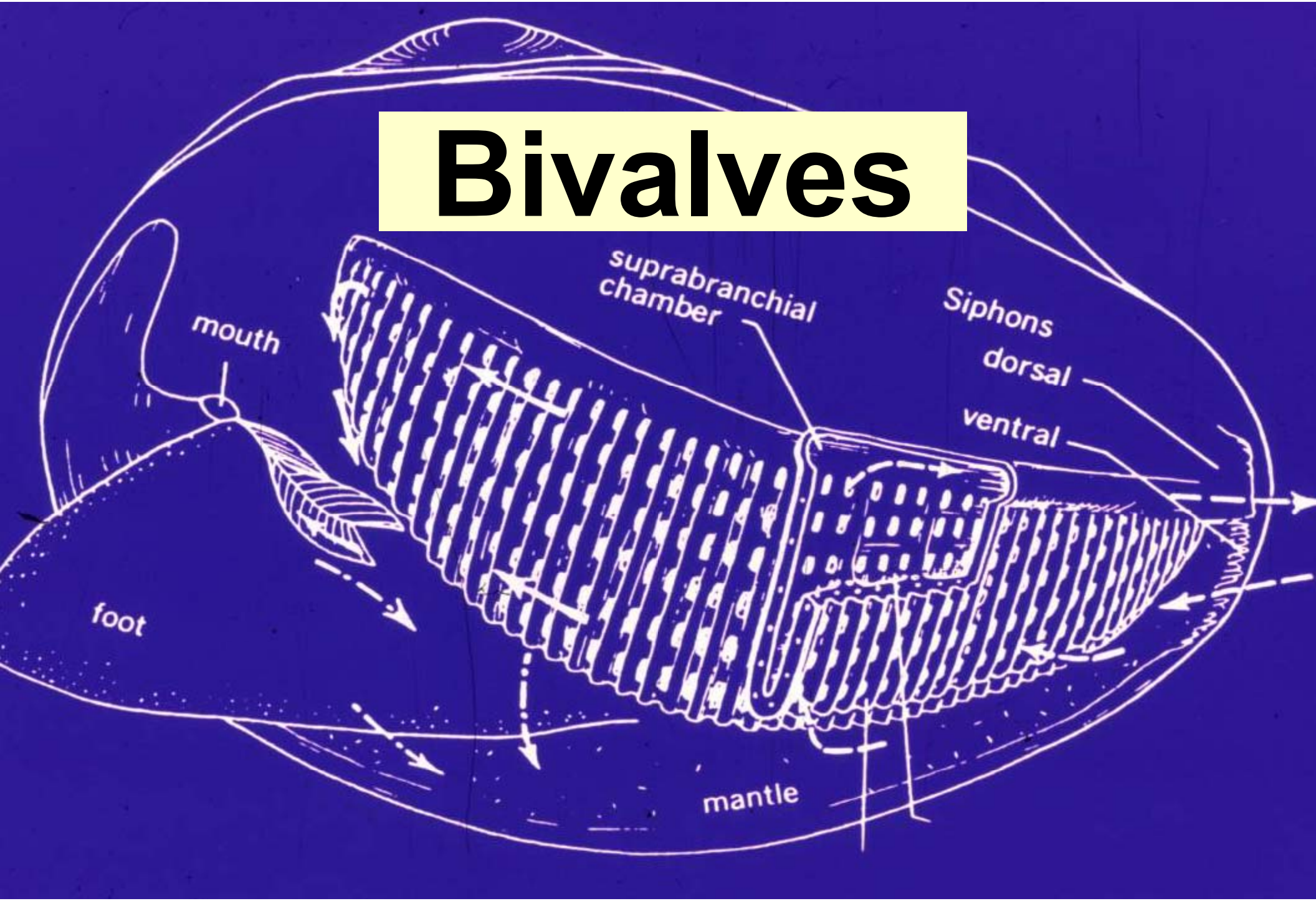
Data from Kreeger, 2006

Water Processing Estimate

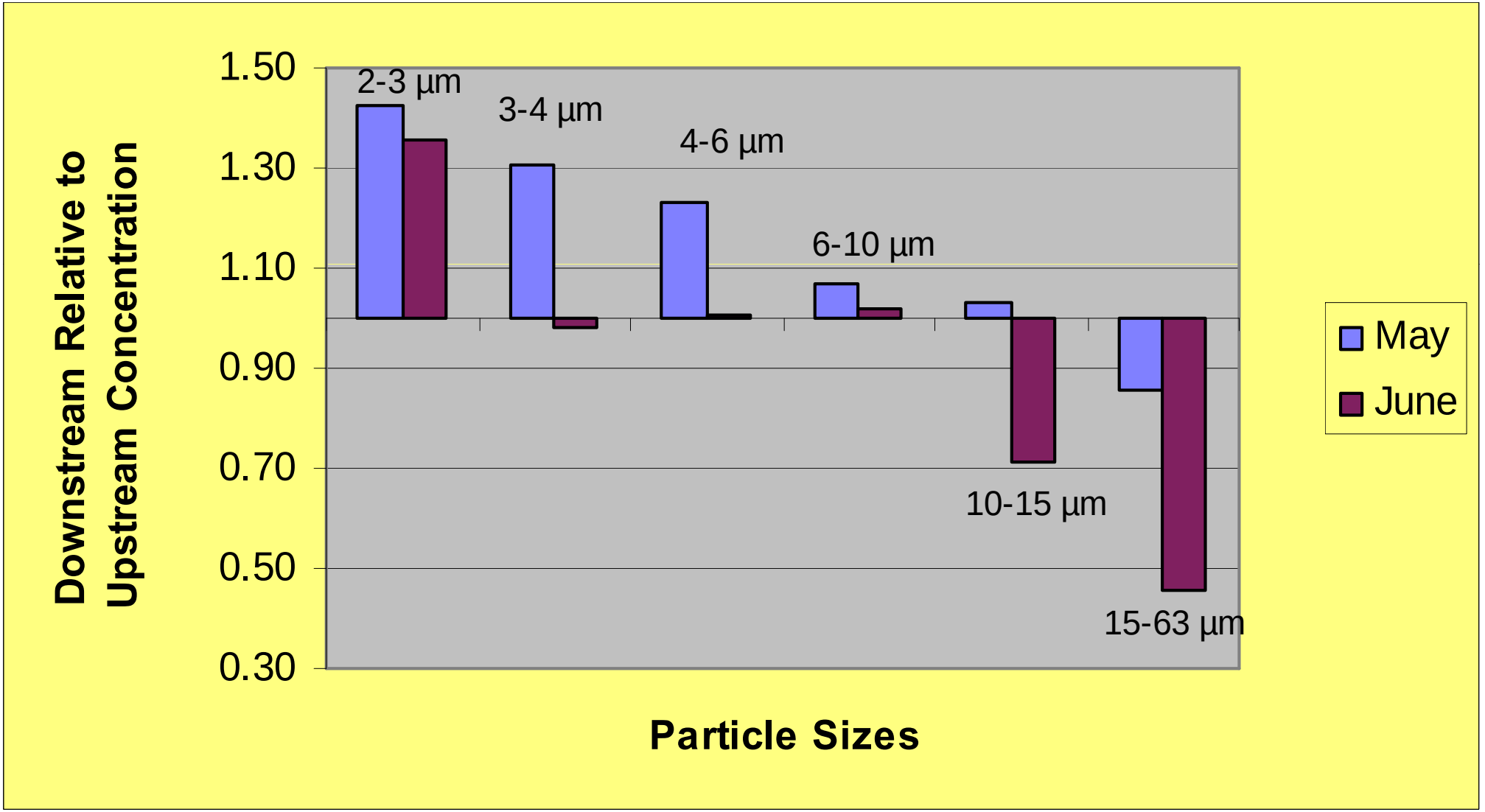
4.3 Billion *Elliptio* Filter

9.8 Billion Liters per Hour

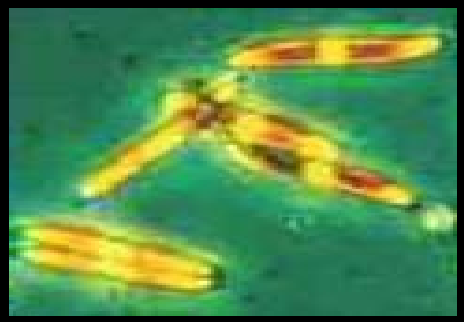
Bivalves


suprabranchial chamber
Siphons
dorsal
ventral
mouth
foot
mantle

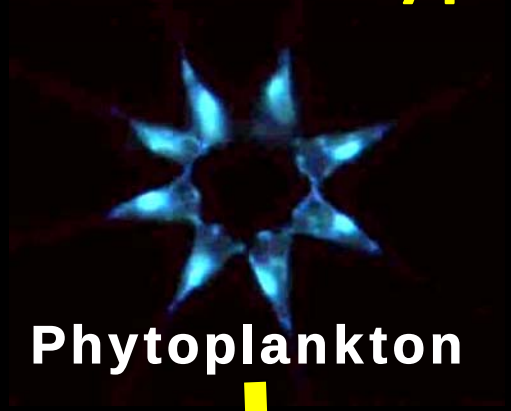
Size Selection: particle sizes below a mussel bed



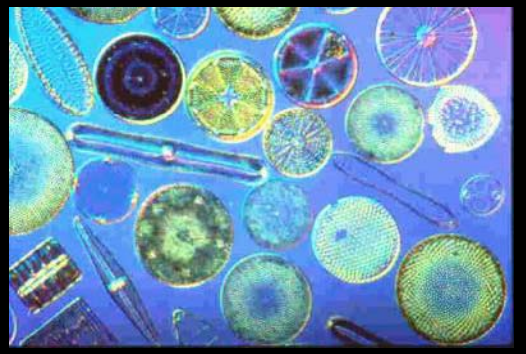
Natural Diets and Particle Type Selection



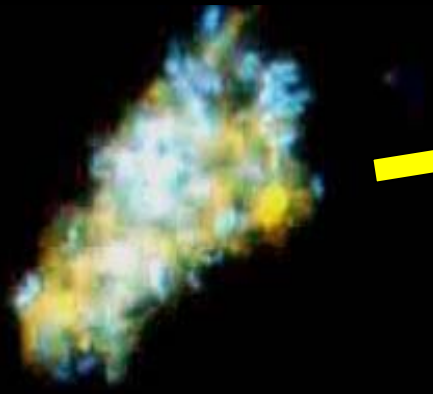
Pennate Diatoms



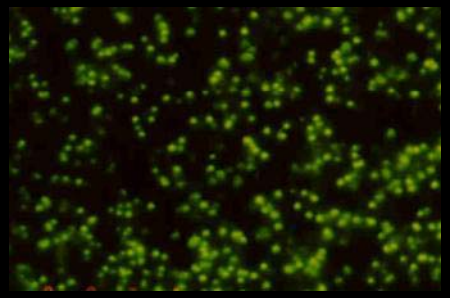
Phytoplankton



Centric Diatoms



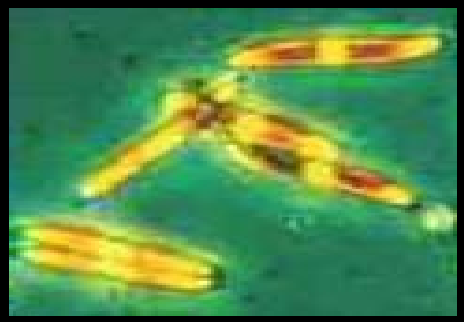
Detritus Complex



Bacteria

Heterotrophic Protists

Water Quality & Grazing Impacts of Populations



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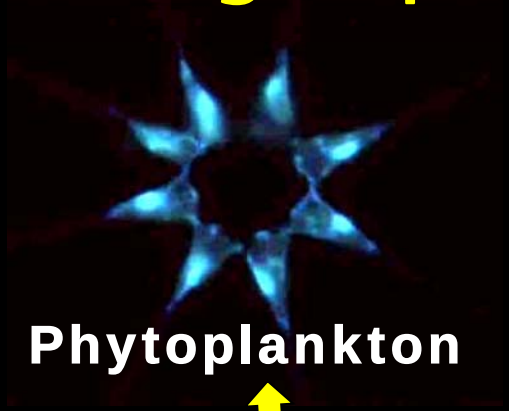
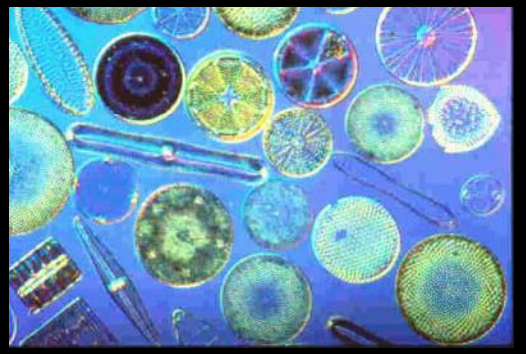


Phytoplankton



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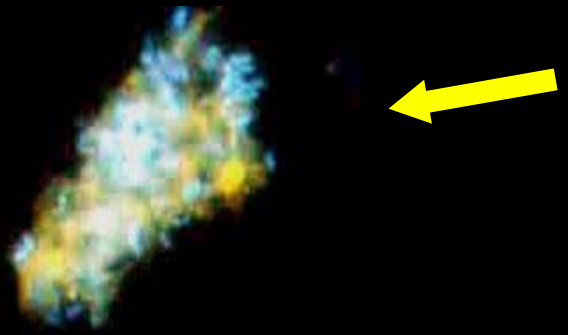

Detritus Complex

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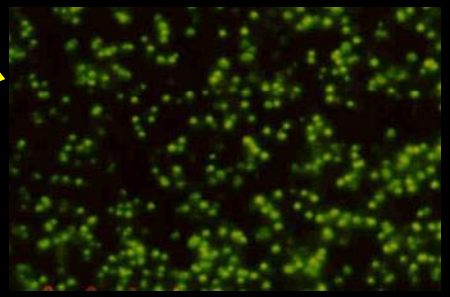


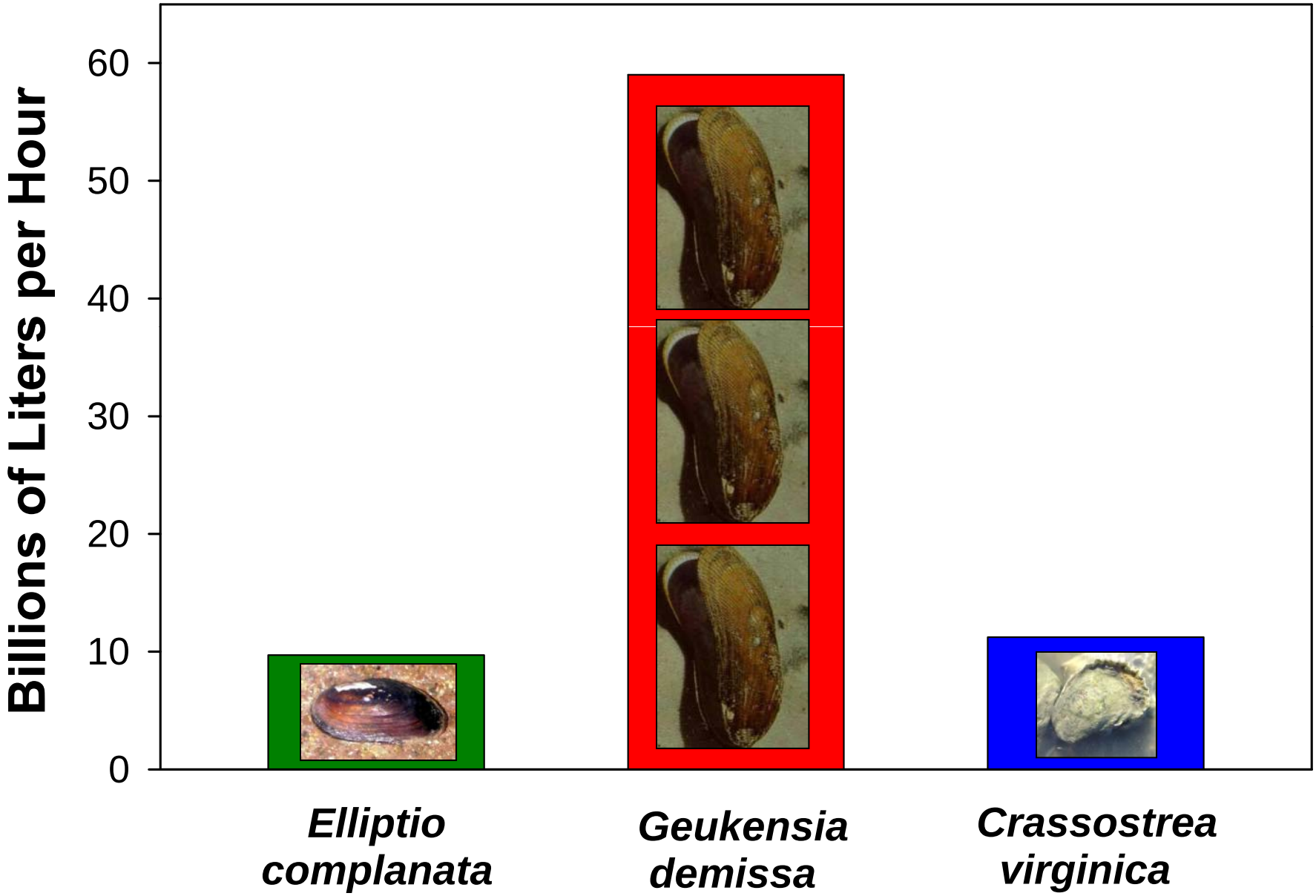
Bacteria

Elliptio complanata

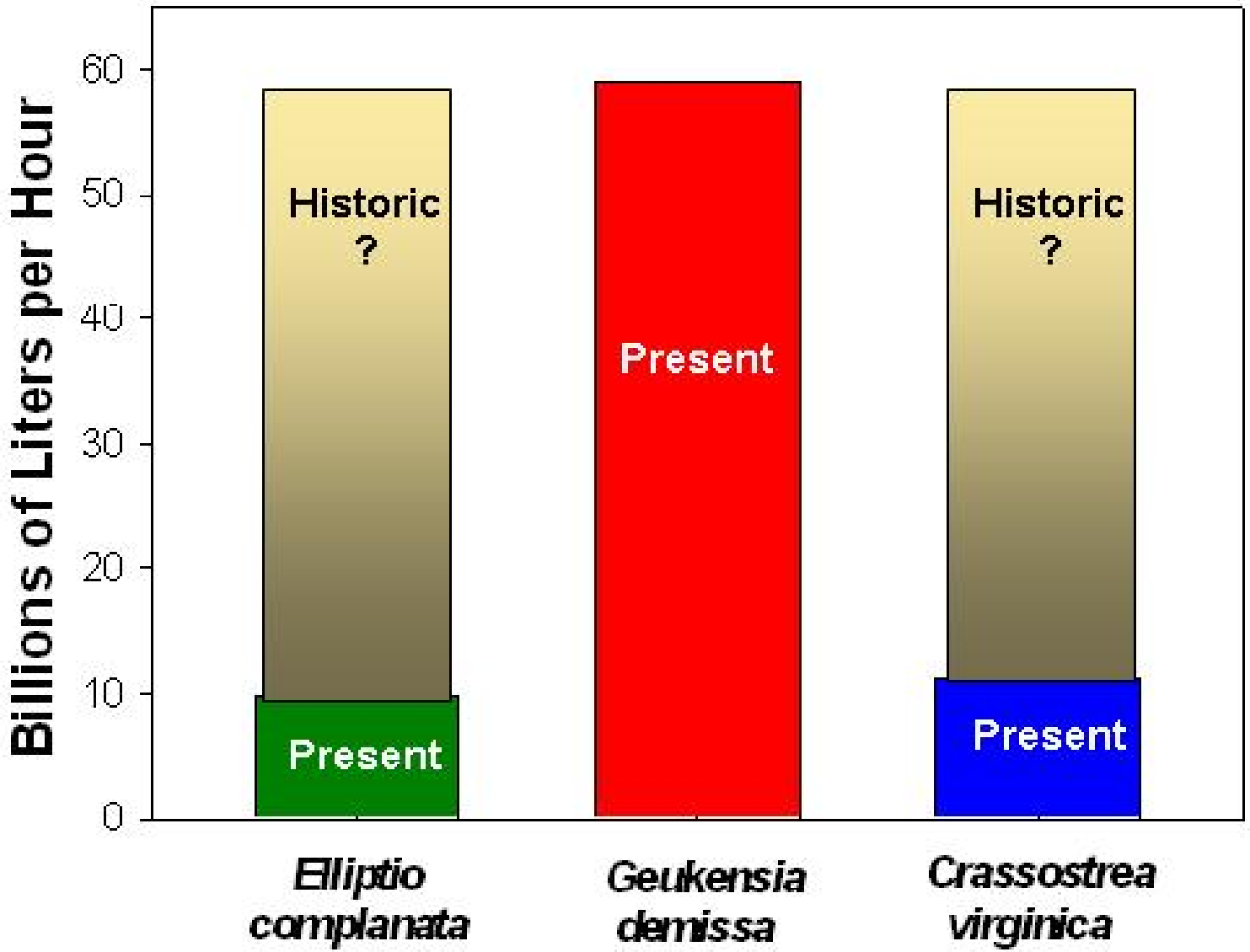
Geukensia demissa

Crassostrea virginica

Population-Level Water Processing



Restoration of Nature's Benefits?



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

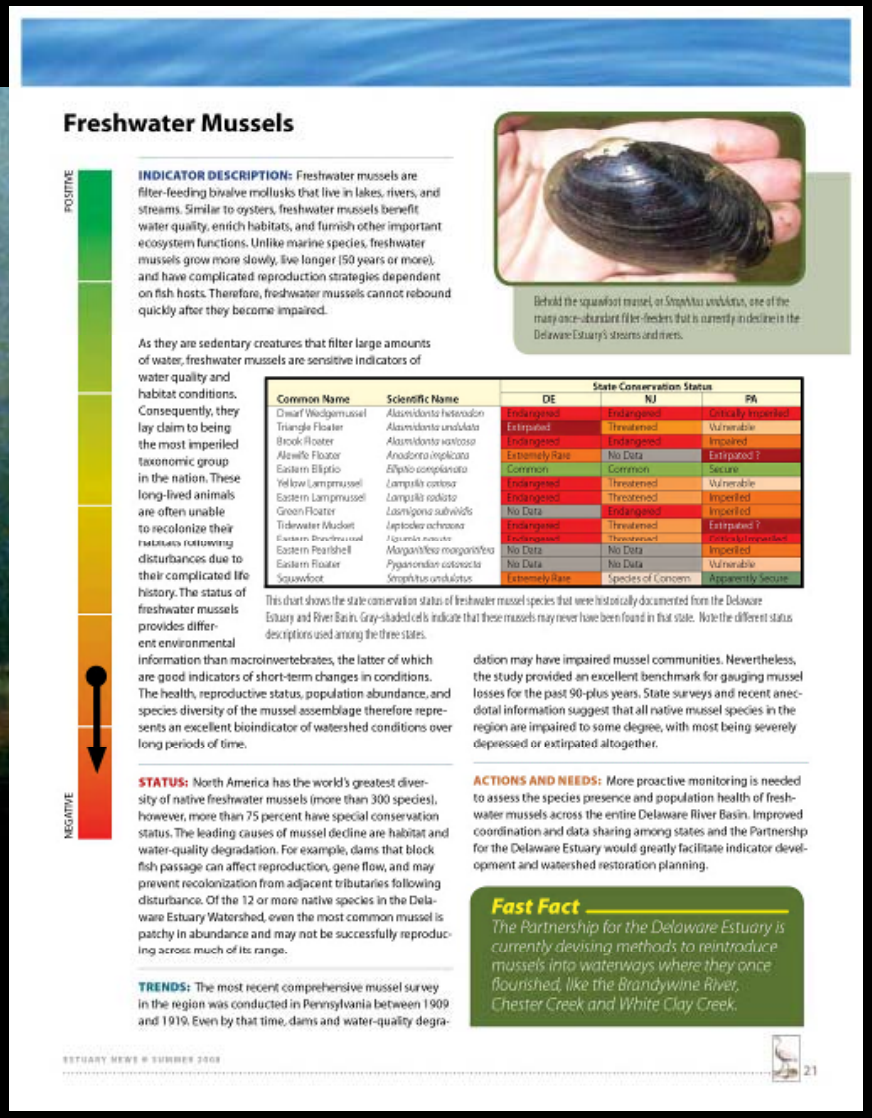
3. Bioindicator Value

International Mussel Watch

Freshwater Caging Studies

Contaminant and Site-Specific Testing, Monitoring

Tributary and Regional Bioassessment



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Yellow Lampmussel	*Lampsilis cariosa*	Endangered	Threatened	Vulnerable
Eastern Lampmussel	*Lampsilis radiata*	Endangered	Threatened	Imperiled
Green Floater	*Lasmigona subviridis*	No Data	Endangered	Imperiled
Tidewater Mucket	*Leptodea ochracea*	Endangered	Threatened	Extirpated ?
[illegible]	[illegible]	Endangered	Threatened	Critically Imperiled
Eastern Pearlshell	*Margaritifera margaritifera*	No Data	No Data	Imperiled
Eastern Floater	*Pyganodon cataracta*	No Data	No Data	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.

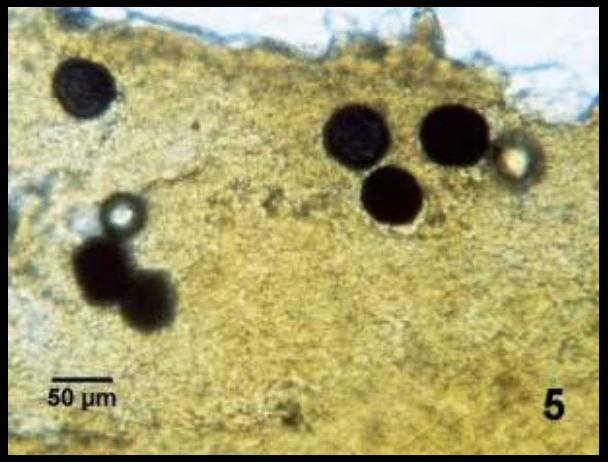
4. Commercial Value

Shellfisheries
Jewelry
Pearl Shell Industry

5. Cultural-Historical

Native American Uses
Waterman Lifestyle
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)		Oysters	Marsh Mussels	FW Mussels
Millennium Ecosystem Assessment Categories	***Specific Services/Values***	***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 Lifes Ecotourism*	✓✓		
	Native American	✓✓		✓✓✓
	Watershed Indicator	✓✓✓	✓✓	✓✓✓
	Bio-Assessment	✓✓✓	✓✓	✓✓✓

Livelihoods

Lives

Health

Livelihoods

Health

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.

System Linkages ?

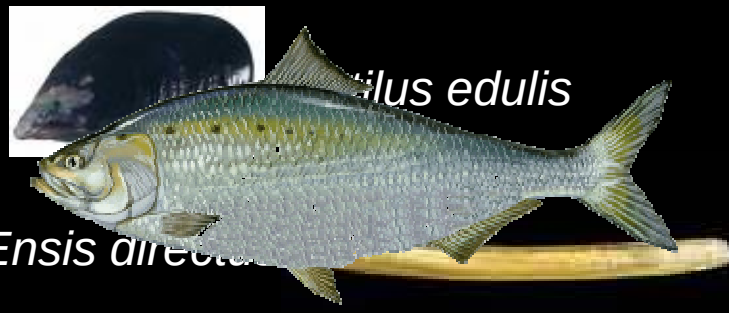
Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea



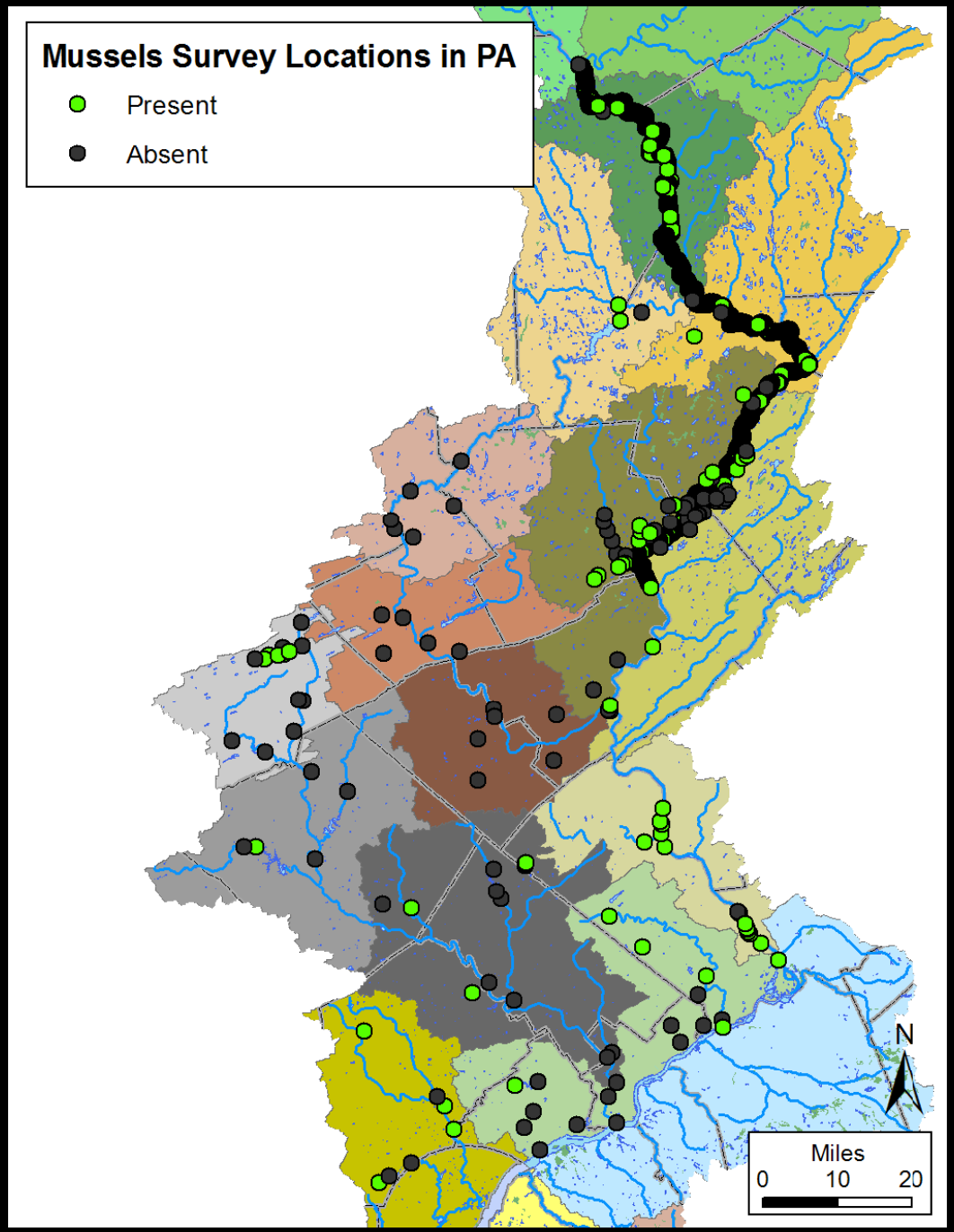
ilus edulis

Ensis direct

Mercenaria mercenaria

Freshwater Mussel Recovery Program

Elliptio complanata



Phase 1 Prioritize Streams for Restoration

Phase 1
Reciprocal Transplants and Condition Monitoring

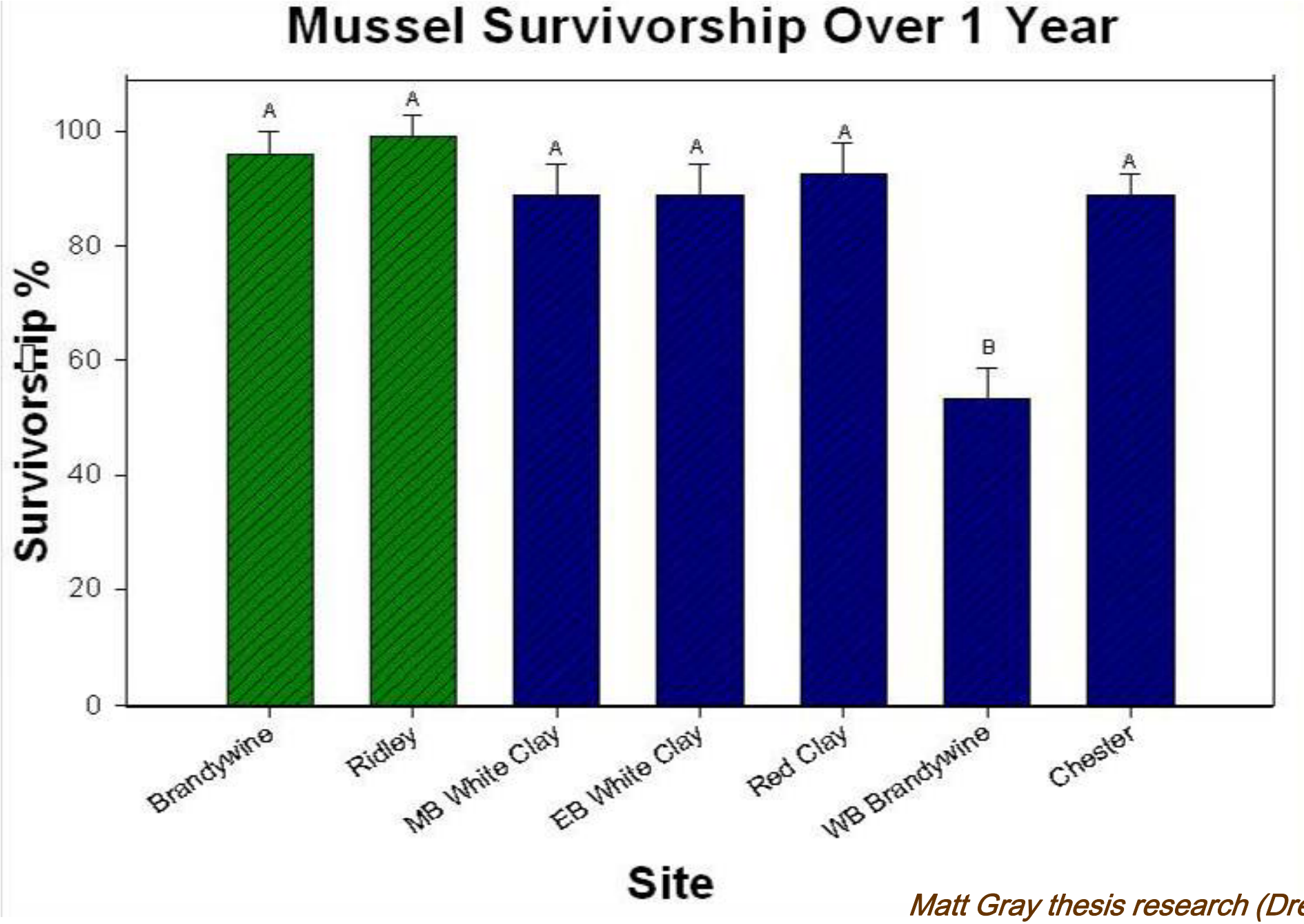
Tagging Mussels

Phase 1
Reciprocal Transplants and Condition Monitoring

Cage Deployment

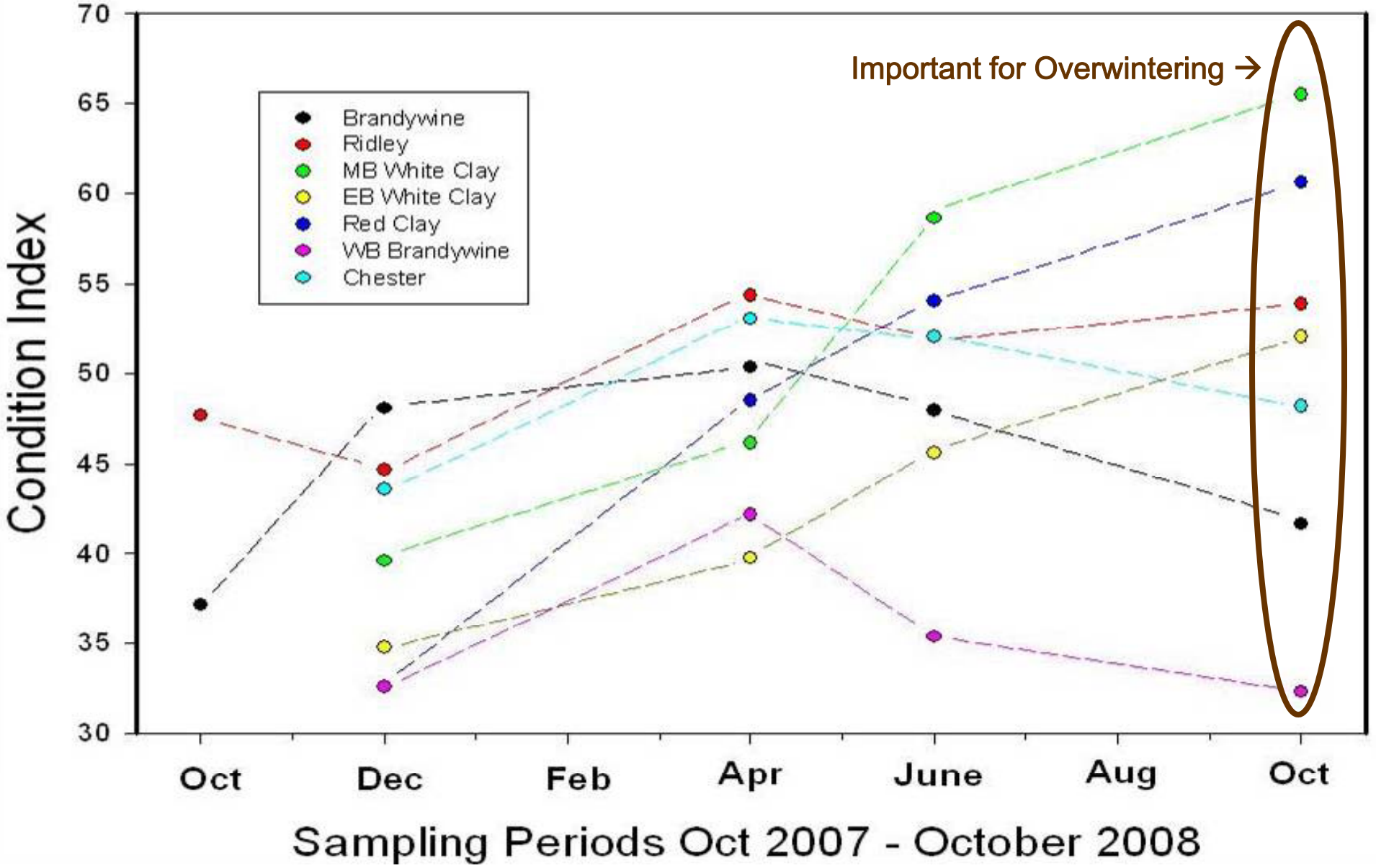
Phase 1
Reciprocal Transplants and Condition Monitoring

Deployed Cages

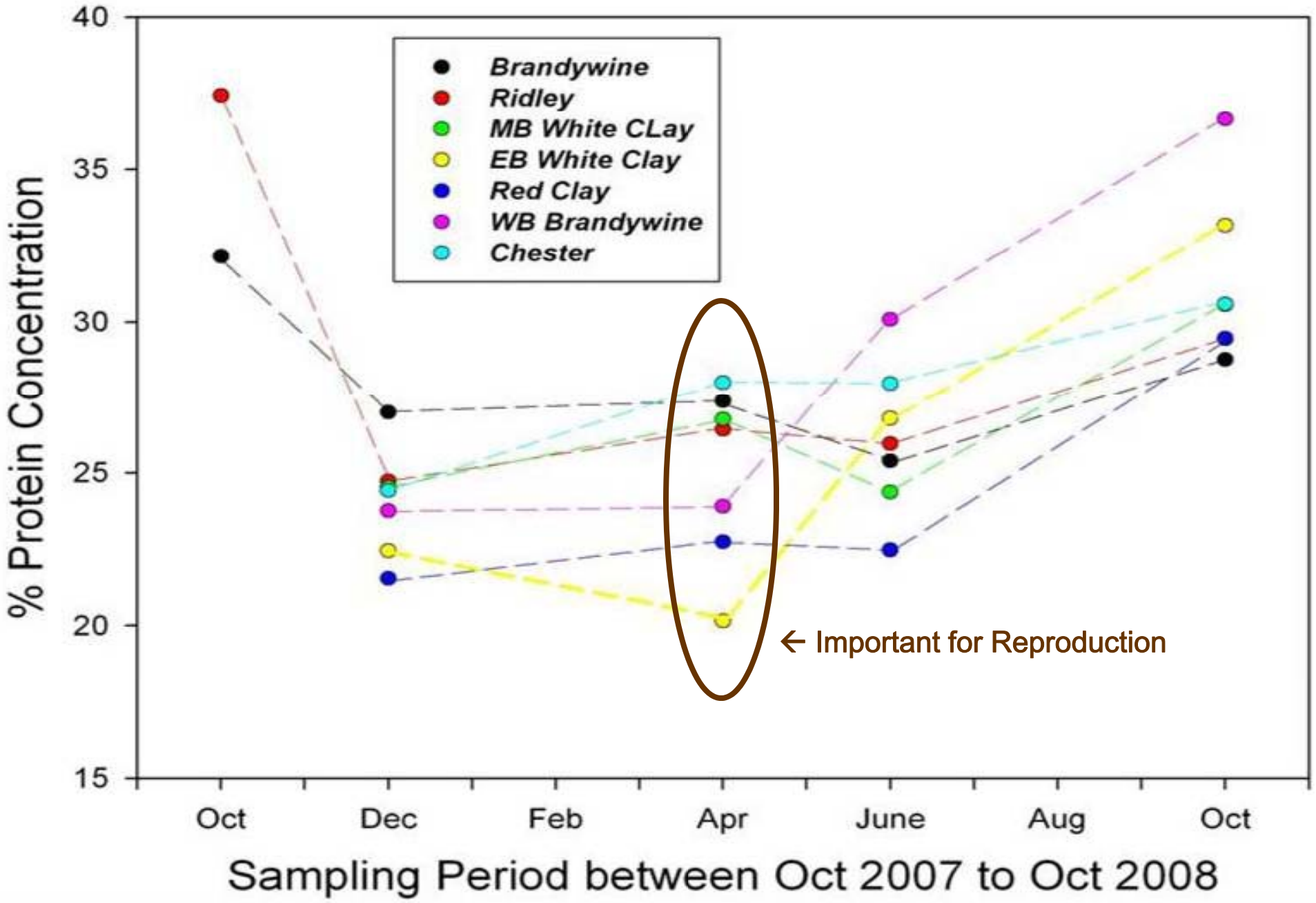


Matt Gray thesis research (Drexel)

Condition Index Over 1 Year



Matt Gray thesis research (Drexel)



Matt Gray thesis research (Drexel)

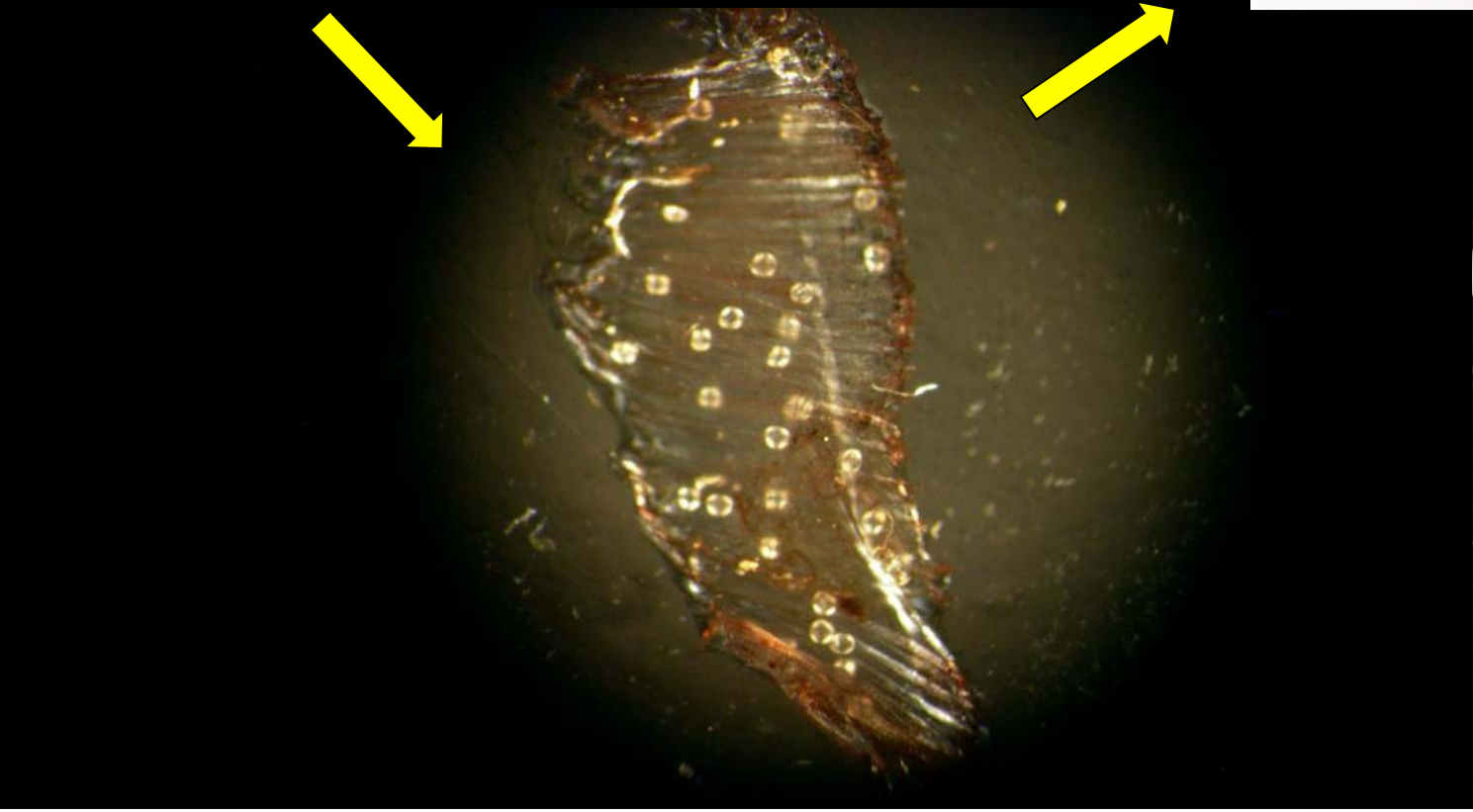
Phase 2
Propagation and Reintroduction

Cheyney Hatchery

Fish Infestation

Fish from Academy of Natural

Larval Transformation Into Juveniles



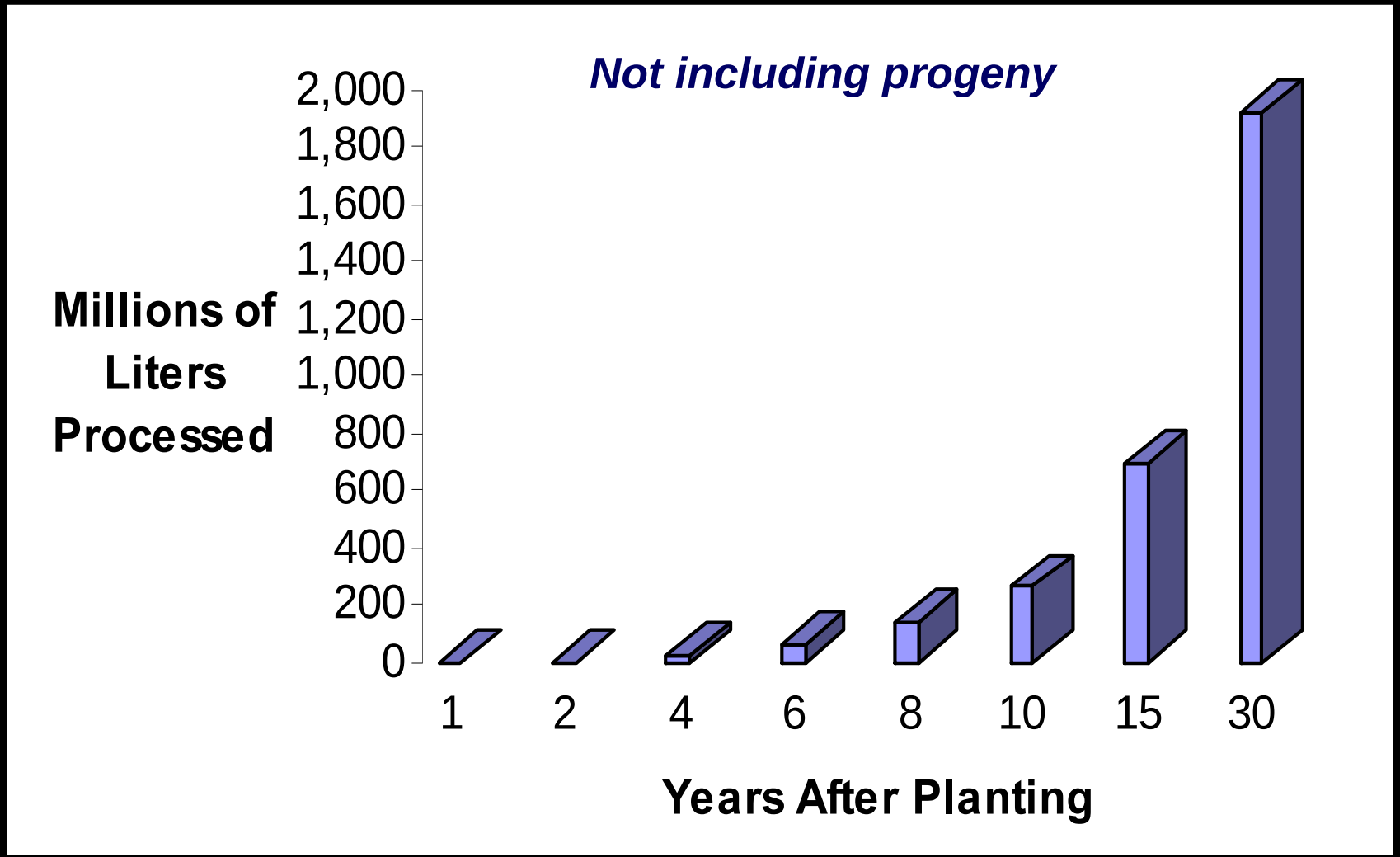
Phase 2
Propagation and Reintroduction

Propagated Juveniles

Photos, R. Neves, VA Tech

Freshwater Mussel Recovery Program

Goals Based on Ecosystem Services



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ESTUARY NEWS

NEWSLETTER OF THE PARTNERSHIP FOR THE DELAWARE ESTUARY: A NATIONAL ESTUARY PROGRAM

Climate Change Hits Home

By Kathy Klein, Executive Director, Partnership for the Delaware Estuary

As I was driving to work one recent morning, thinking about writing this article and listening to National Public Radio, I learned that the Bulletin of Atomic Scientists has concluded that the threat posed by climate change is second only to that posed by nuclear weapons. Although I am actually relieved that climate change is finally getting the attention it deserves, I am also keenly aware that time continues to tick away as world leaders and other policymakers explore ways to address global warming and its environmental impacts.

Being the visual person that I am, I can't seem to forget the recent image in the media of a lone polar bear floating on a piece of ice that had broken off the Arctic icecap as a result of melting. What most people do not realize, however, is you do not have to go to the Arctic to see the results of global warming. For many years, scientists in the Delaware Estuary have noted the dieback of upland

tant to realize, however, that there are small steps each one of us can take in our daily lives that, when multiplied, can make a meaningful impact.

One of these small steps is the use of compact florescent light bulbs (CFLs). CFLs use up to 75 percent less energy than regular incandescent light bulbs while lasting approximately eight times longer, and this results in less production of greenhouse gas emissions, air pollution, and toxic waste. The average CFL will save its owner at least $55 in energy costs over its lifetime. If every U.S. household replaced one bulb with a CFL, it would have the same impact as removing 1.3 million cars from the road.

I love a challenge and I hope you do too. Therefore, I would like to challenge the readers of "Estuary News" to make the switch at home, in at least one light fixture, from an incandescent light bulb to a CFL. If you already use CFLs in your home, why not make the

Bivalve Vulnerability?

Oyster Reefs

- Salinity Driven Disease Epizootics
- Others: Food, pH

Salt marsh Mussel Beds

- Loss and Degradation of Wetland Habitat
- Others: Food, PH

Freshwater Mussel Beds

- Range Shifts with No Dispersal
- Habitat Degradation (T, salinity, pH, fish hosts)

Shifts in Species Ranges of Freshwater Mussels

Patchy, Impaired | **Rare** | **Extirpated**

Elliptio c

Tough Decisions

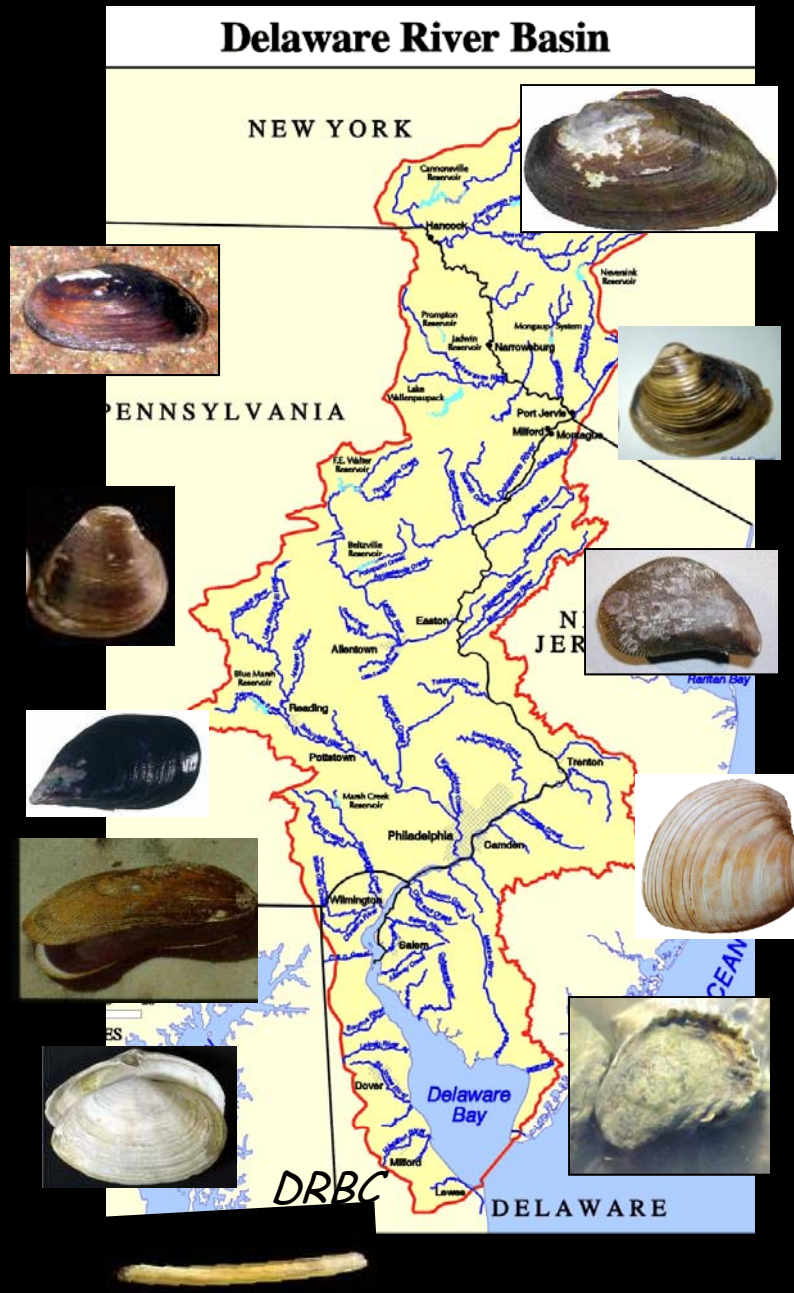
Which species and associated benefits can be sustained?

Which should we invest in? (*since funding will always be limited)*

Scientific Name				PA
ALASMIDONTA HETER				cally 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

Summary

- Freshwater mussels are the most imperiled plants and animals, including in our watershed
- Like marine species, freshwater mussels provide multiple benefits to people
- Restoring mussel species and populations can improve water quality and ecological health downstream
- Freshwater mussels are great targets for "ecosystem-based management." If they are present, diverse and abundant, then the system is healthy



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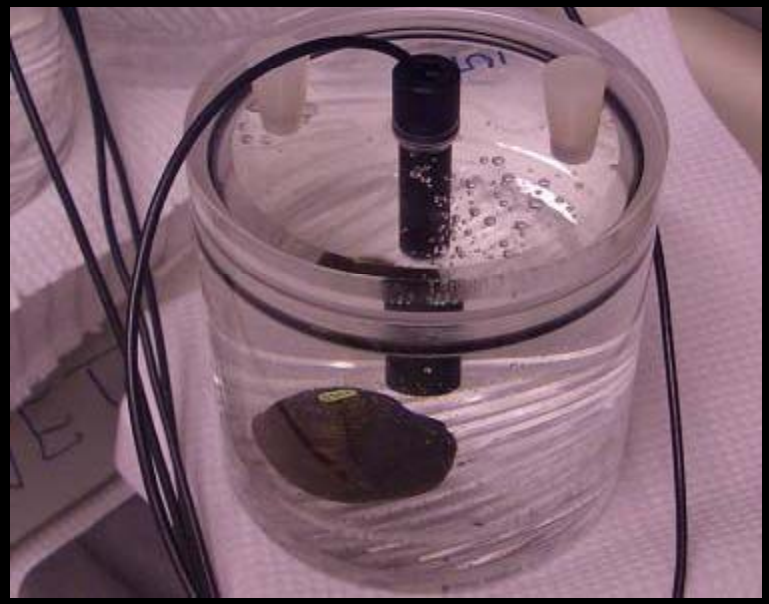

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