

Natural Infrastructure Case Study: Investing in Nature's Underdogs to Promote Cleaner Water

Danielle Kreeger

Partnership for the DELAWARE ESTUARY

Benefits of Natural Infrastructure

…The Ecological Manhattan Project

Millenium Ecosystem Assessment 1º Service	2º Service	3º Service	4º Service
Provisioning	Food	Fisheries Support	
		Algae and invertebrate production	
	Genetic Materials	Phragmites control research	
	Biochemical Products	Research in Antifungal Agents	
	Fiber and Fuel	Cellulose stock	
Regulating	Sequestration	Carbon	Carbon Caps, mitigation
	Sediment Stabilization	Erosion control	Meet TMDLs for sediment
	Storm Protection/ Wave Attenuation/ Flood Protection	Protect Property Values and infrastructure	
	Gas Regulation	Carbon Sequestration	
		Oxygen production	
	Water Quality	Sequestration, Filtering	TMDLs: Nutrients, Pollutants
Cultural/ Spiritual Human Well Being	Recreation	Bird watching, hunting, boating	
	Spiritual and Inspirational	Native American Uses	
	Educational	University reasearch & school projects/trips	
	Aesthetic Value	Landscape pictures, paintings, open space	
Supporting	Habitat	Wildlife, shellfish, insects	
	Biodiversity	Maintain Plant Communities	
	Production	Primary Production	
	Water Cycling/Hydrologic Regime		
	Nutrient Cycling/Biogeochemical Processes	Maintain trophic cycles, soil building	

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Tidal Wetlands





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Natural Infrastructure:
Tidal Wetlands



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

<u>Nature's Benefits</u>

- Flood Protection
- Fish and Wildlife
- Carbon Sequestration
- Water Quality
- Property Value
- Natural Areas



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Historic Freshwater Tidal Wetlands

< 5% remains in Delaware Estuary







CTUIR Freshwater Mussel Project

Bivalve Shellfish



Kreeger

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Benefits of Shellfish



Stabilize Erosion



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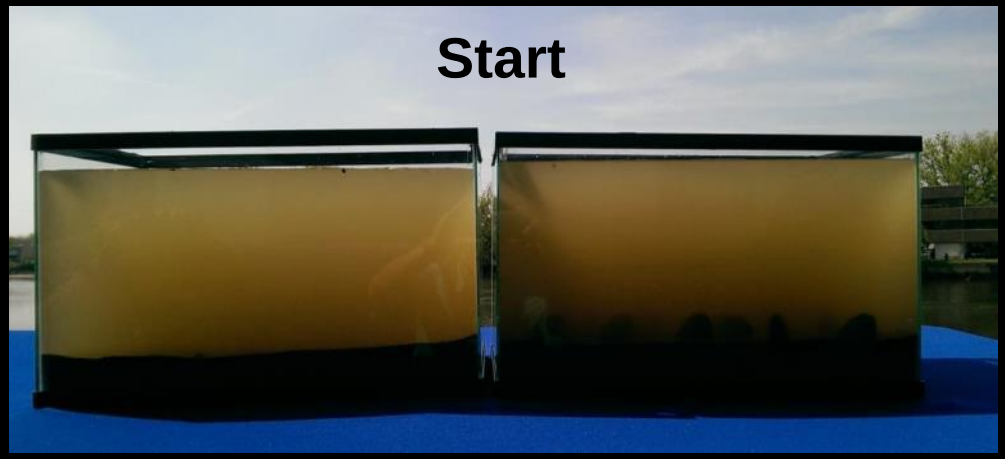


Benefits of Shellfish



Clean the Water

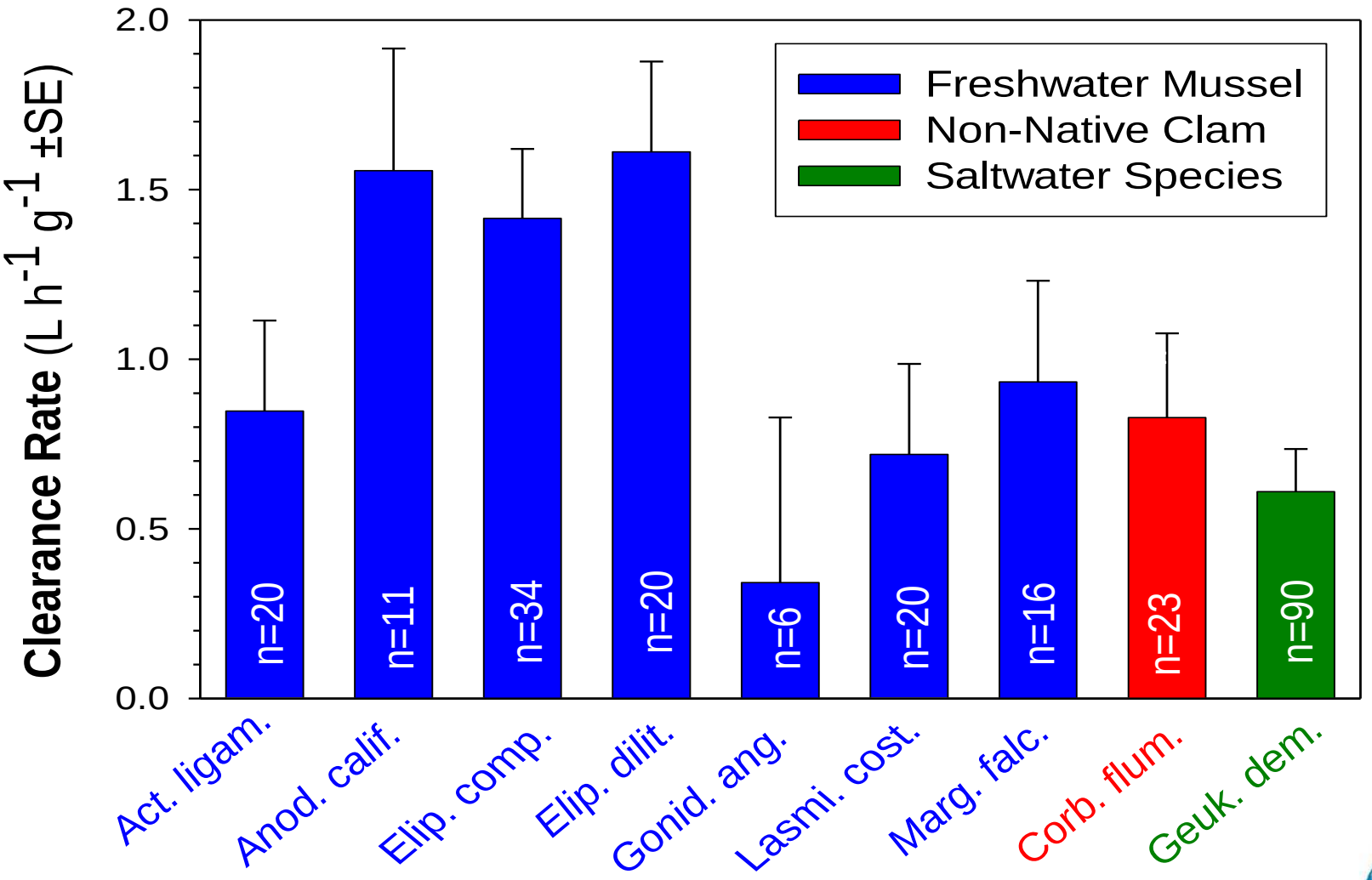
Each adult filters
> 10 gallons of water
per day





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Clearance Rates Temperatures >20°C

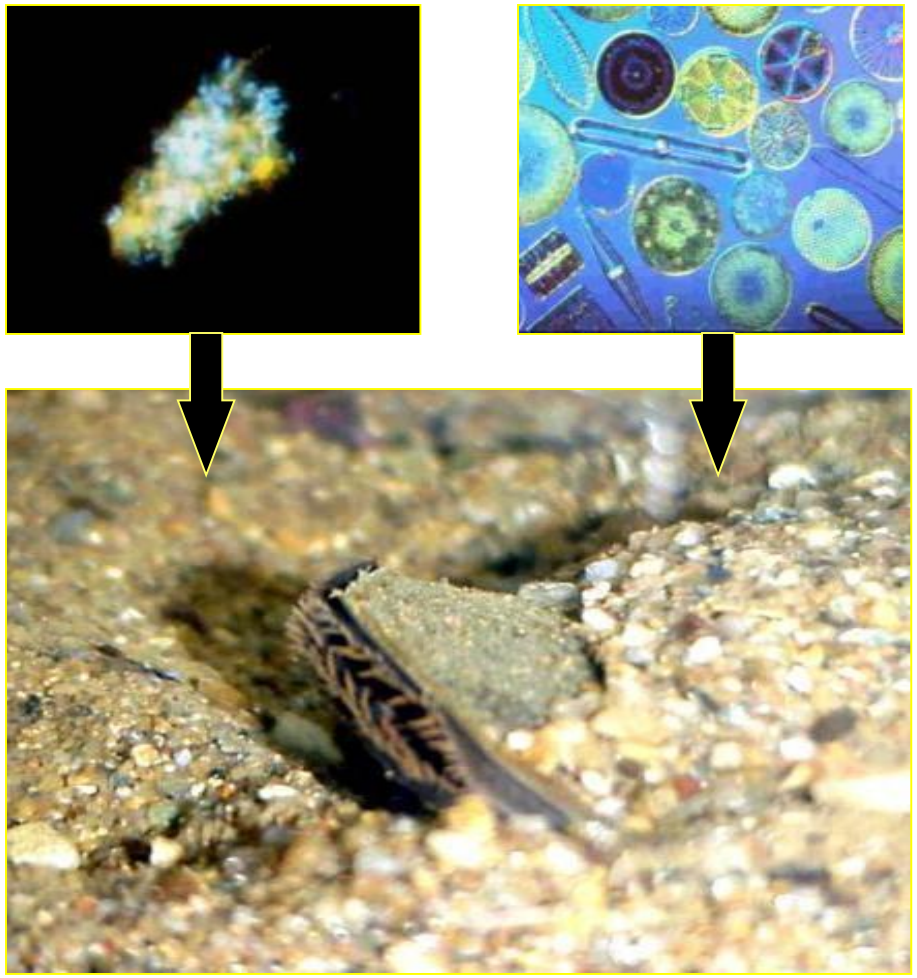


9 Species: 0.5 - 1.6 L/hr/g

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Blue Collar Bivalves

Benefit People *and* the Environment



1. Structural Ecology

↑ Habitat Complexity

Stabilize Bottoms

2. Functional Ecology

↓ Suspended Particulates

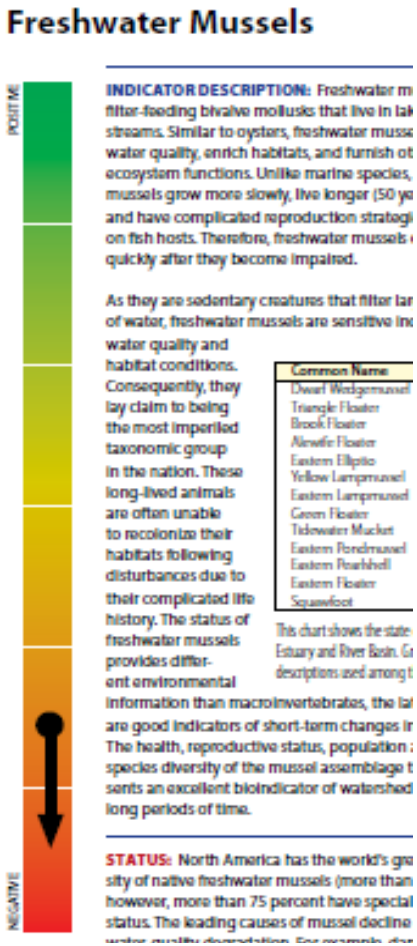
↓ Particulate N, P, pathogens

↑ Light reaching bottom

↑ Sediment Enrichment

↑ Food for Predators

FW Mussels – the Most Imperiled



Freshwater Mussels

POSITIVE

INDICATOR DESCRIPTION: Freshwater m
filter-feeding bivalve mollusks that live in lak
streams. Similar to oysters, freshwater musse
water quality, enrich habitats, and furnish ot
ecosystem functions. Unlike marine species,
mussels grow more slowly, live longer (50 ye
and have complicated reproduction strategi
on fish hosts. Therefore, freshwater mussels
quickly after they become impaired.

As they are sedentary creatures that filter lar
of water, freshwater mussels are sensitive 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 la
are good indicators of short-term changes in
The health, reproductive status, population
species diversity of the mussel assemblage t
sents an excellent bioindicator of watershed
long periods of time.

Common Name
Dwarf Wedgemussel
Triangle Floater
Brook Floater
Alewife Floater
Eastern Elliptio
Yellow Lampmussel
Eastern Lampmussel
Green Floater
Tidewater Mucket
Eastern Pondmussel
Eastern Pearlshell
Eastern Floater
Squawfoot

This chart shows the state
Estuary and River Basin. G
descriptions used among t

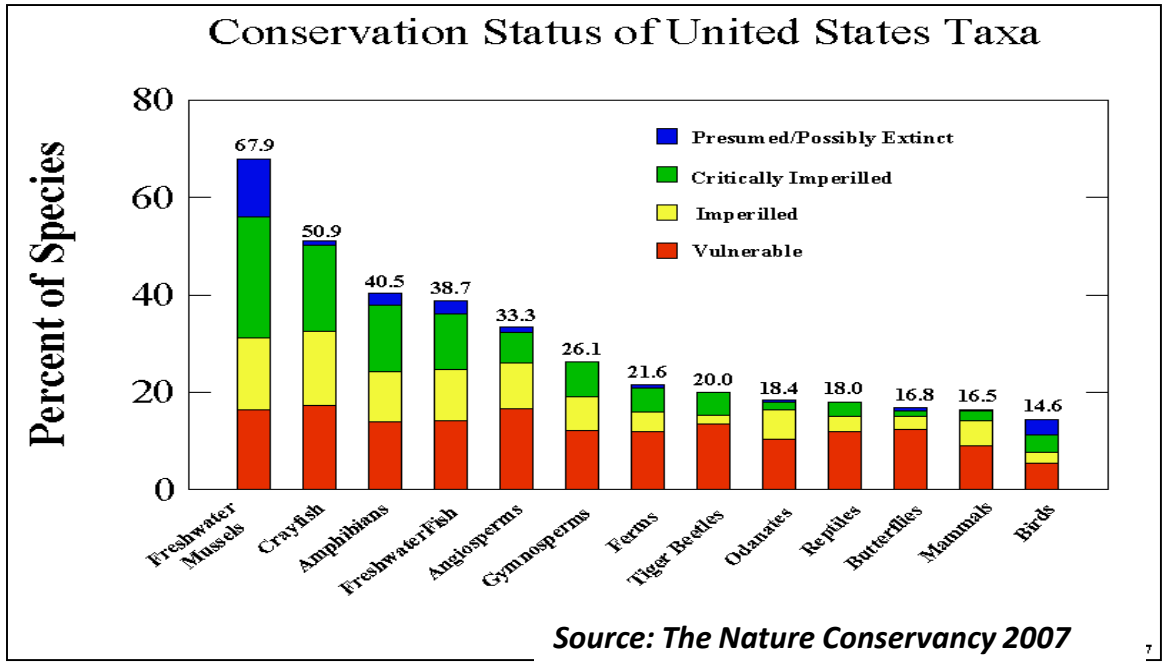
NEGATIVE

STATUS: North America has the world's gre
sity of native freshwater mussels (more than
however, more than 75 percent have special
status. The leading causes of mussel decline

Source: State of Estuary 2008

~75% of 300 species are imperiled





Source: The Nature Conservancy 2007

Historic Freshwater Mussel Beds

Most imperiled animals

But secret garden in tidal Delaware







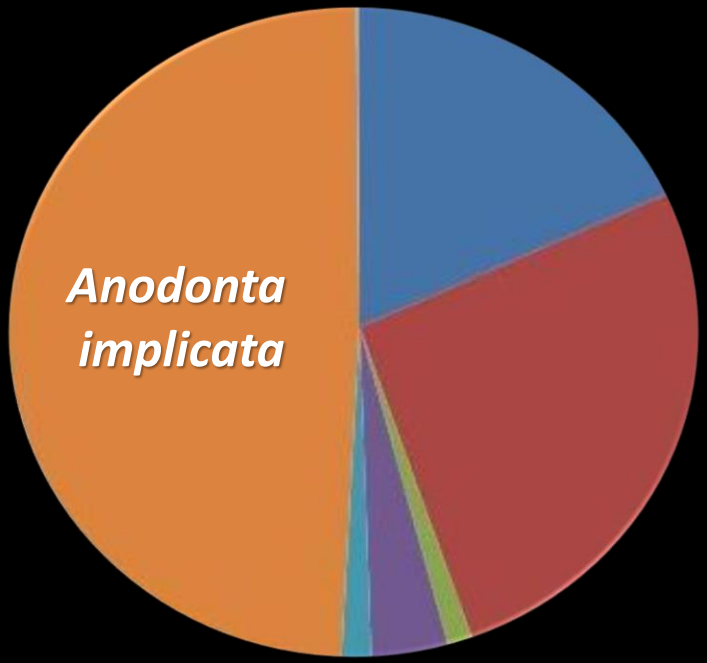


Mussel Surveys

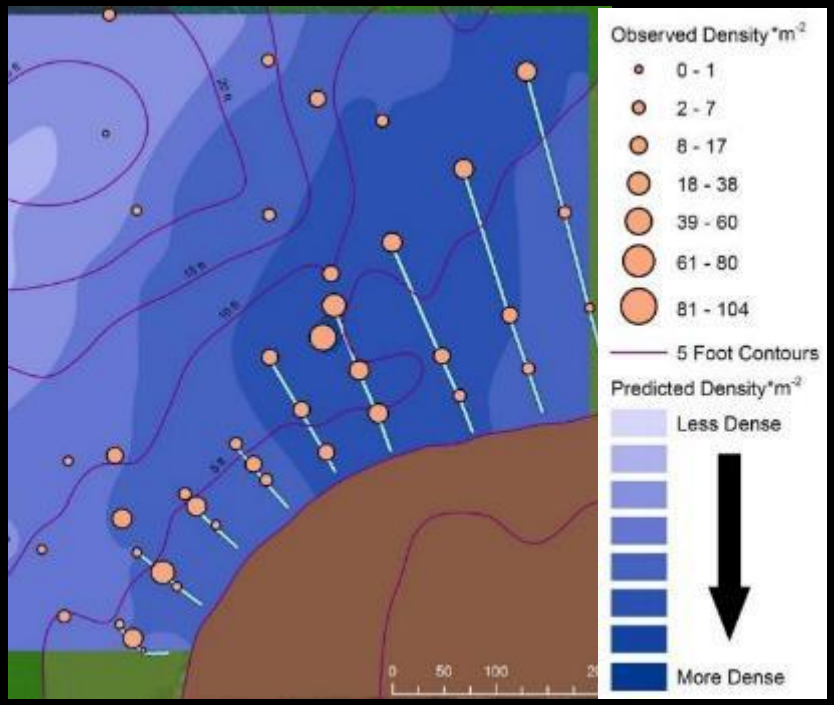


Tidal Delaware River

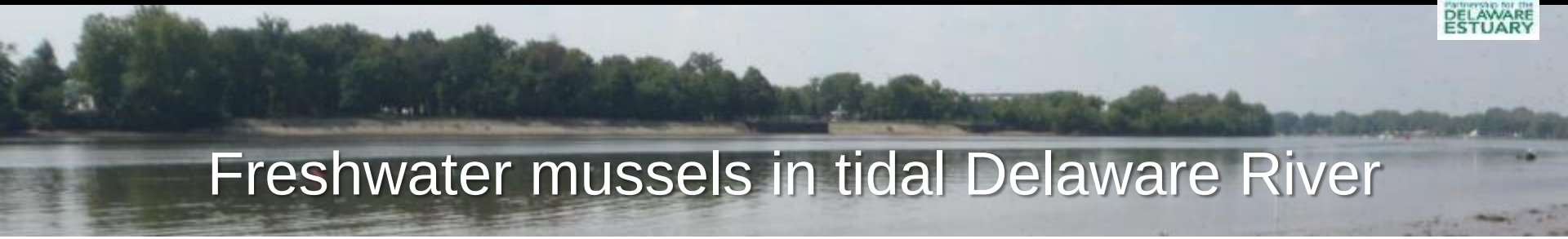
Population Biomass by Species



Densities up to 100 per square meter



Physiologically-Based BioFiltration Estimates



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**

=10 tons dry TSS per hectare per year

Kreeger et al. 2013

Delaware River FW Mussels (one species)





4.3 Billion *Elliptio*
2.9 Million kg Dry Tissue Weight

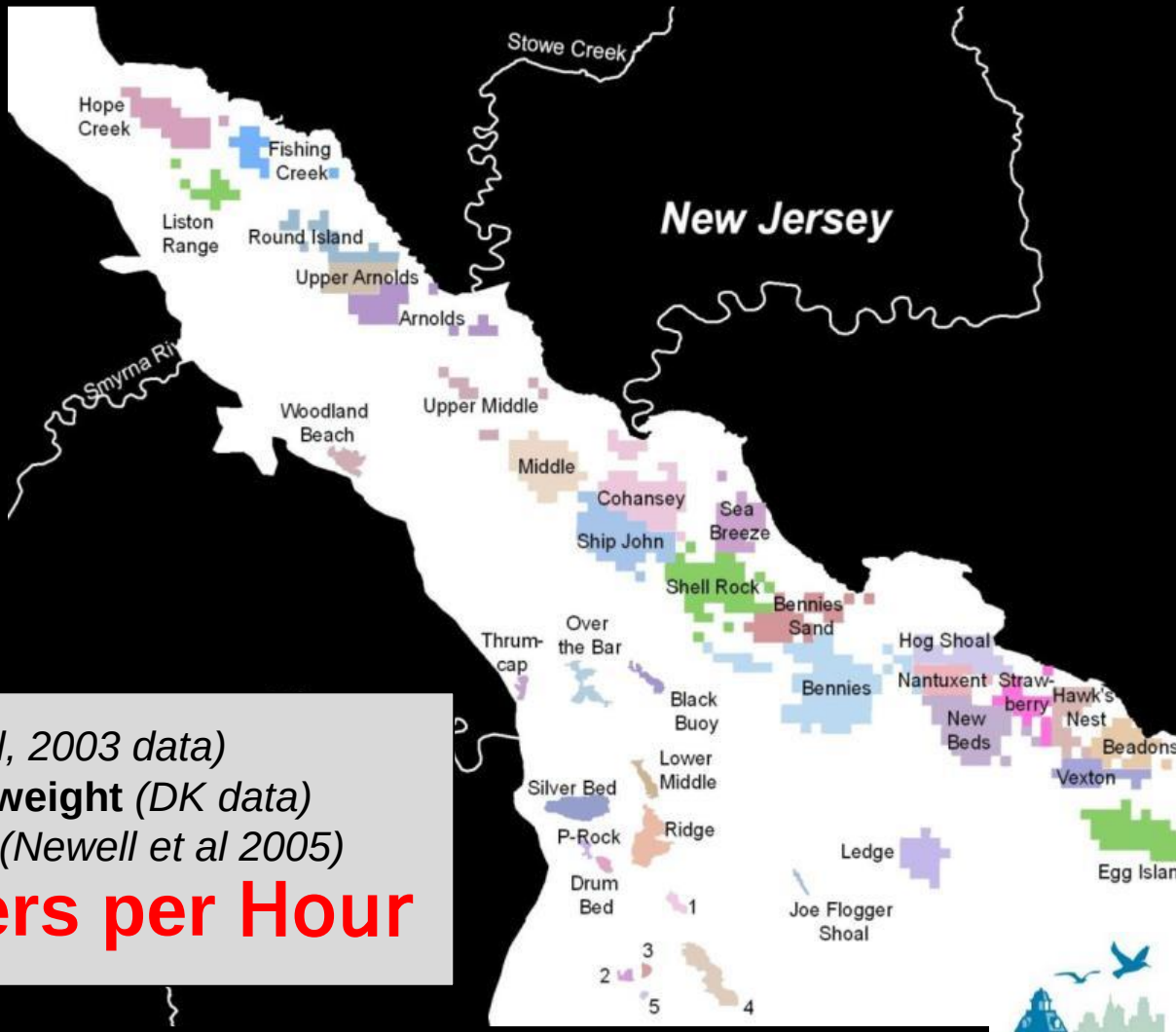
= 9.8 Billion Liters per Hour



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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)*

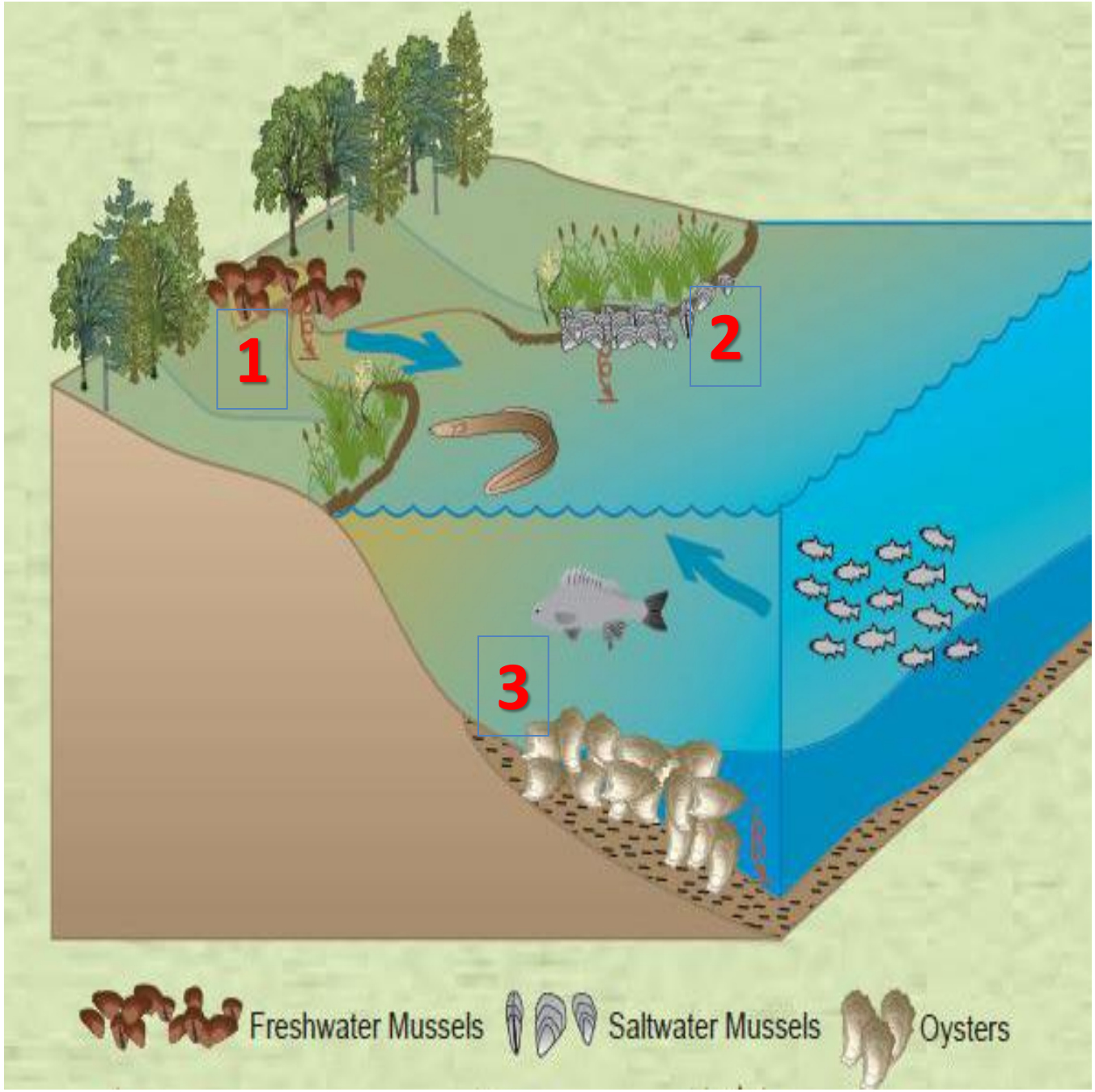
= 11.2 Billion Liters per Hour

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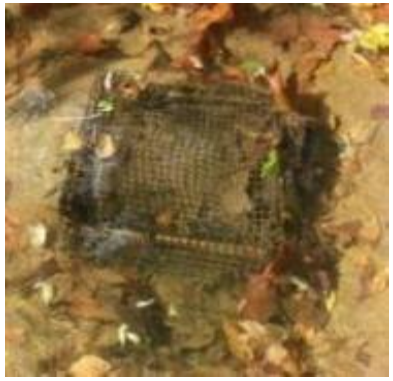
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Headwaters to Ocean Shellfish Restoration

1. Non-tidal
2. Intertidal
3. Subtidal

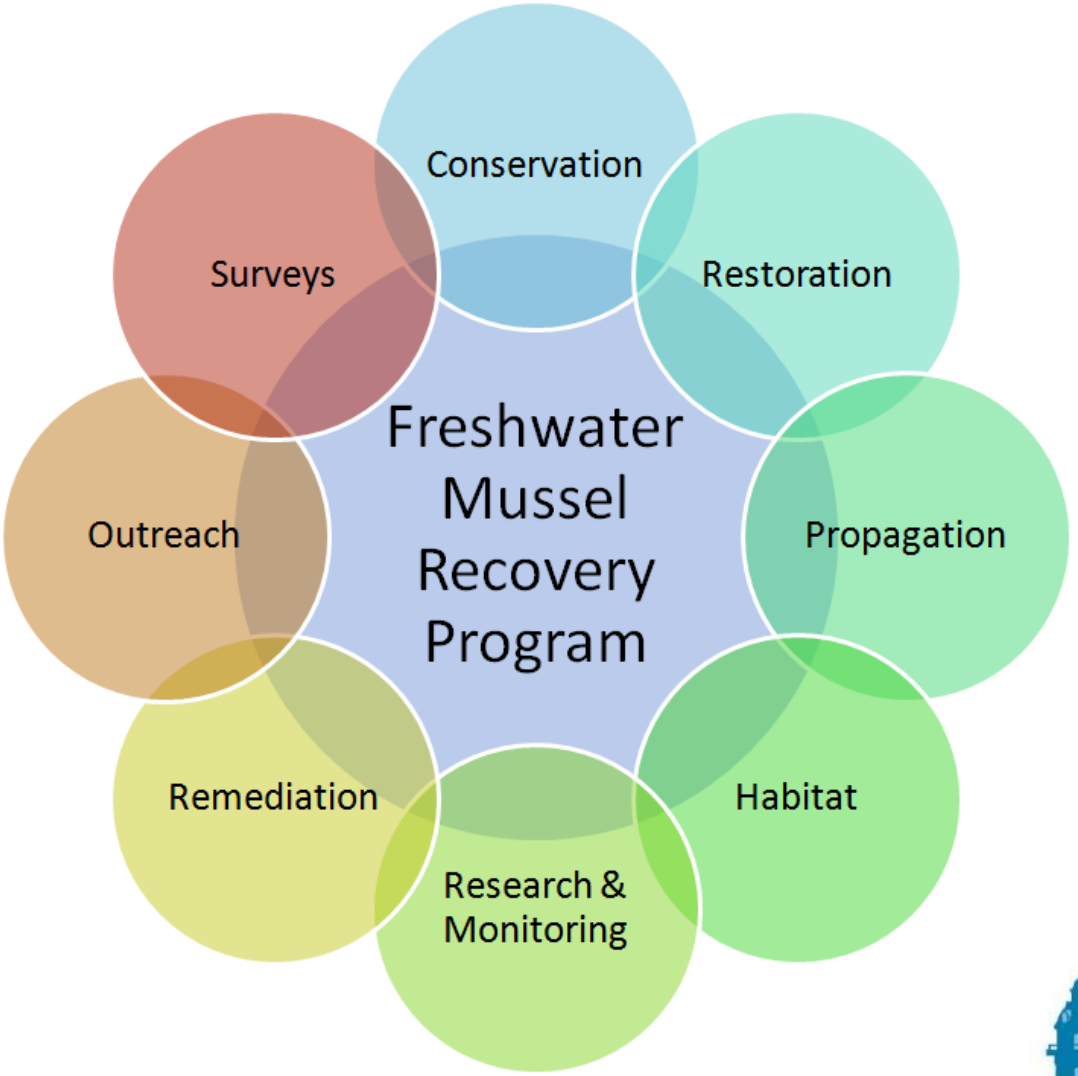


Freshwater Mussel Recovery Program (FMRP)









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Restoration Via Reintroduction

- Restock mussels in historic range
- Reproductive adults
- Electronic Tagging
- Track bed retention and growth rates









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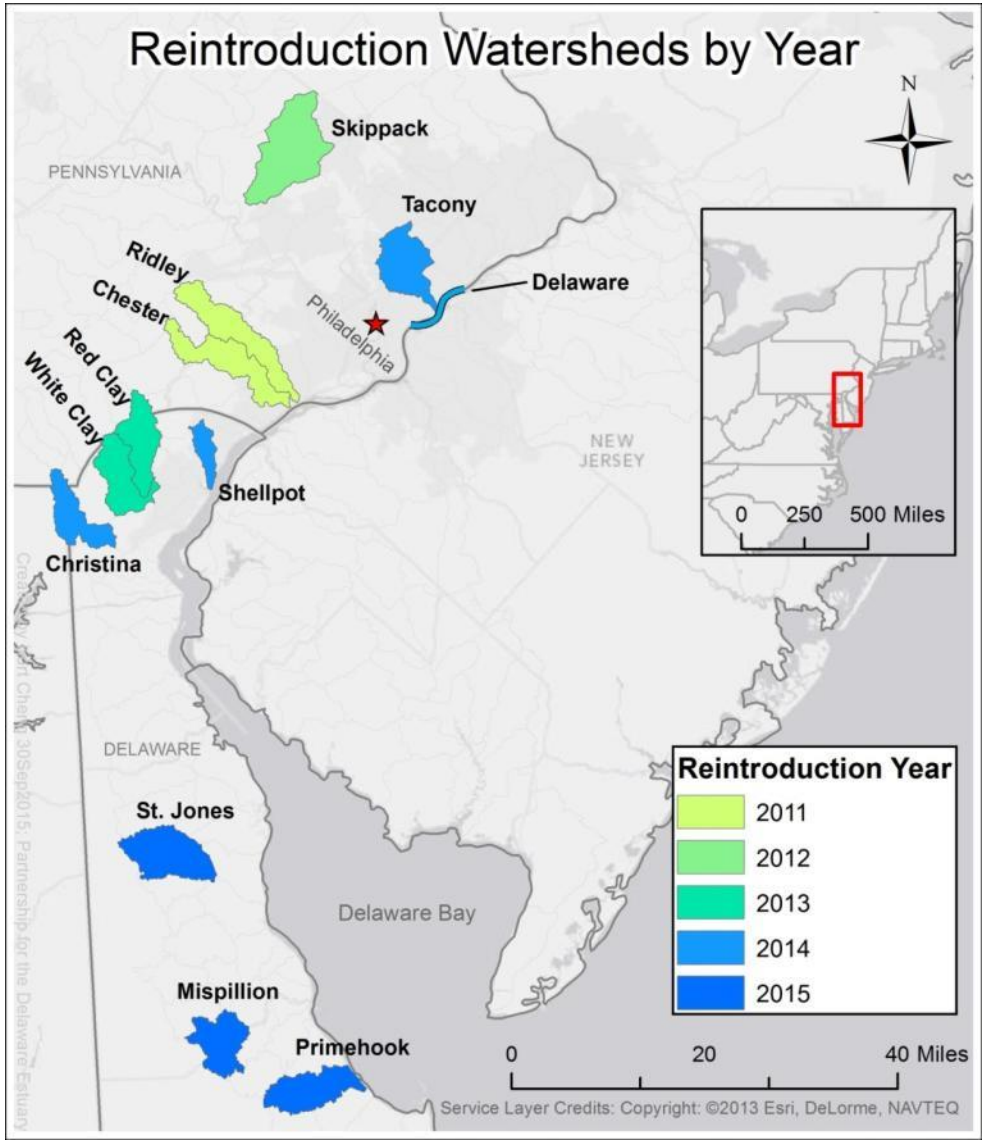
Restoration Via Reintroduction

>12 streams

>1000 mussels



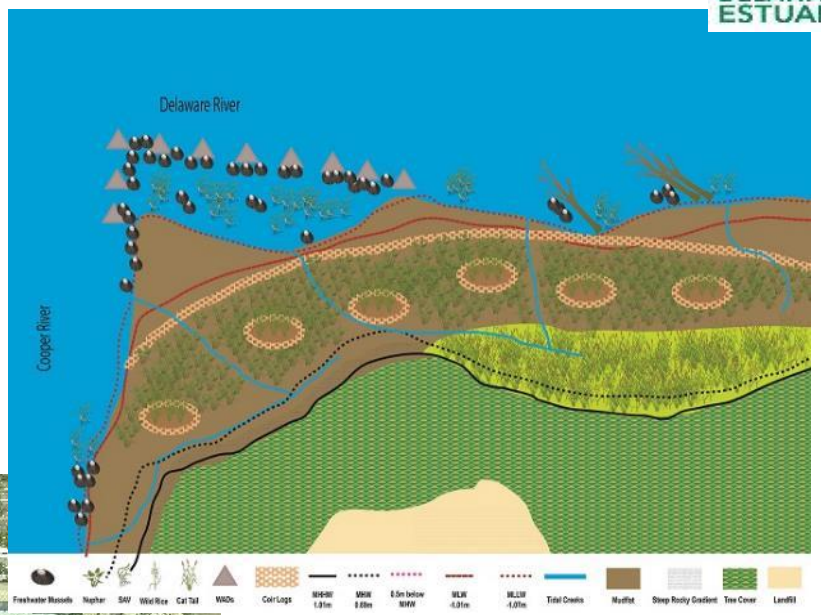
Prioritize sites for Restoration



Restoration via Habitat Enhancement

Urban Living Shorelines

Include Mussel Beds





North Camden, NJ

South Camden, NJ

Schuylkill River, PA

Delaware River, PA

Wilmington, DE

Research: Habitat Requirements of Mussels

Spencer Roberts M.S.

Habitat Suitability

Benthic Shear Stress

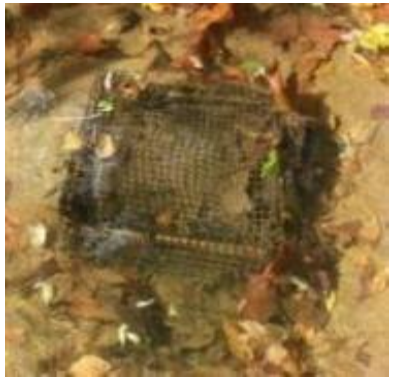
Substrate Needs





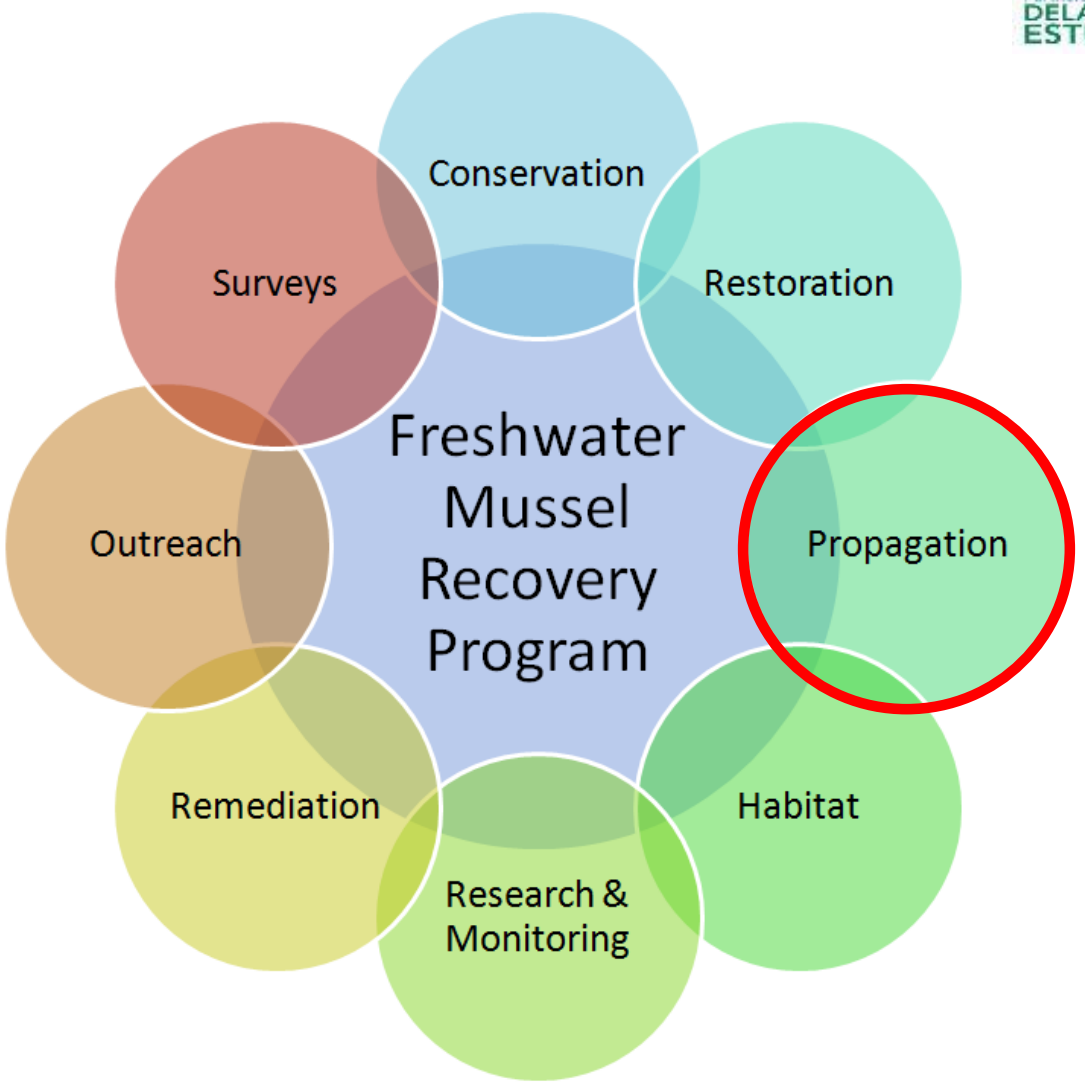
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Restoration via Reseeding









Restoration via Reseeding

Cheyney Hatchery, 2008-2011

Solved technical challenges

Produced mussel juveniles







Restoration via Reseeding

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Demonstration Hatchery at Fairmount Water Works

FAIRMOUNT WATER WORKS
THE MUSSEL HATCHERY









http://www.mightymussel.com/

Restoration via Reseeding – Pond Rearing



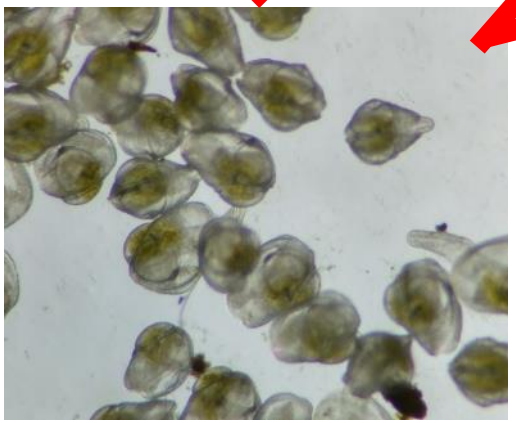
Harrison Lake National Fish Hatchery



~35,000 Seed at FWW



~35,000 Seed into Ponds
(Longwood, Winterthur)



~70,000 Seed on 5/2

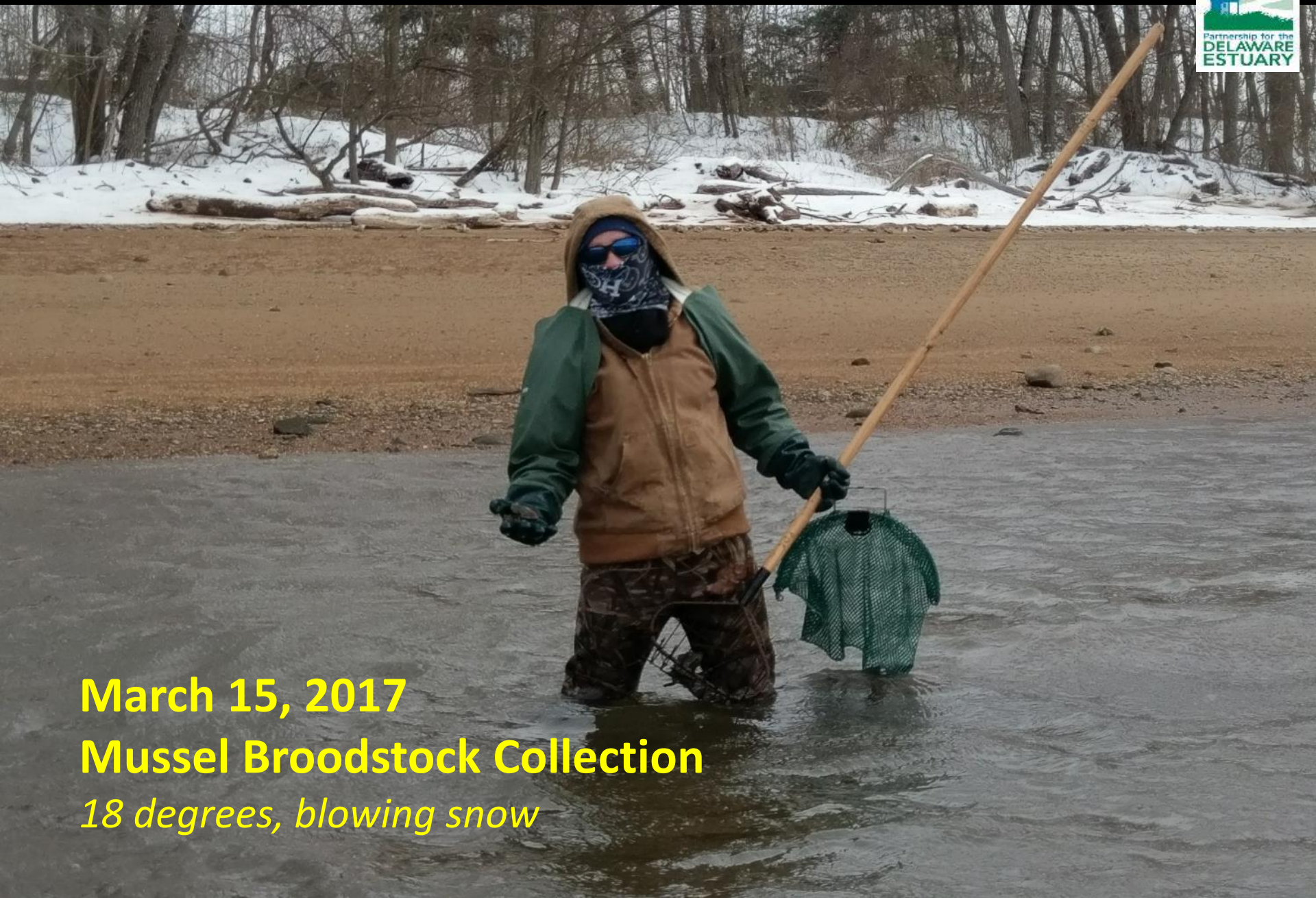


Tagging on 9/9/17



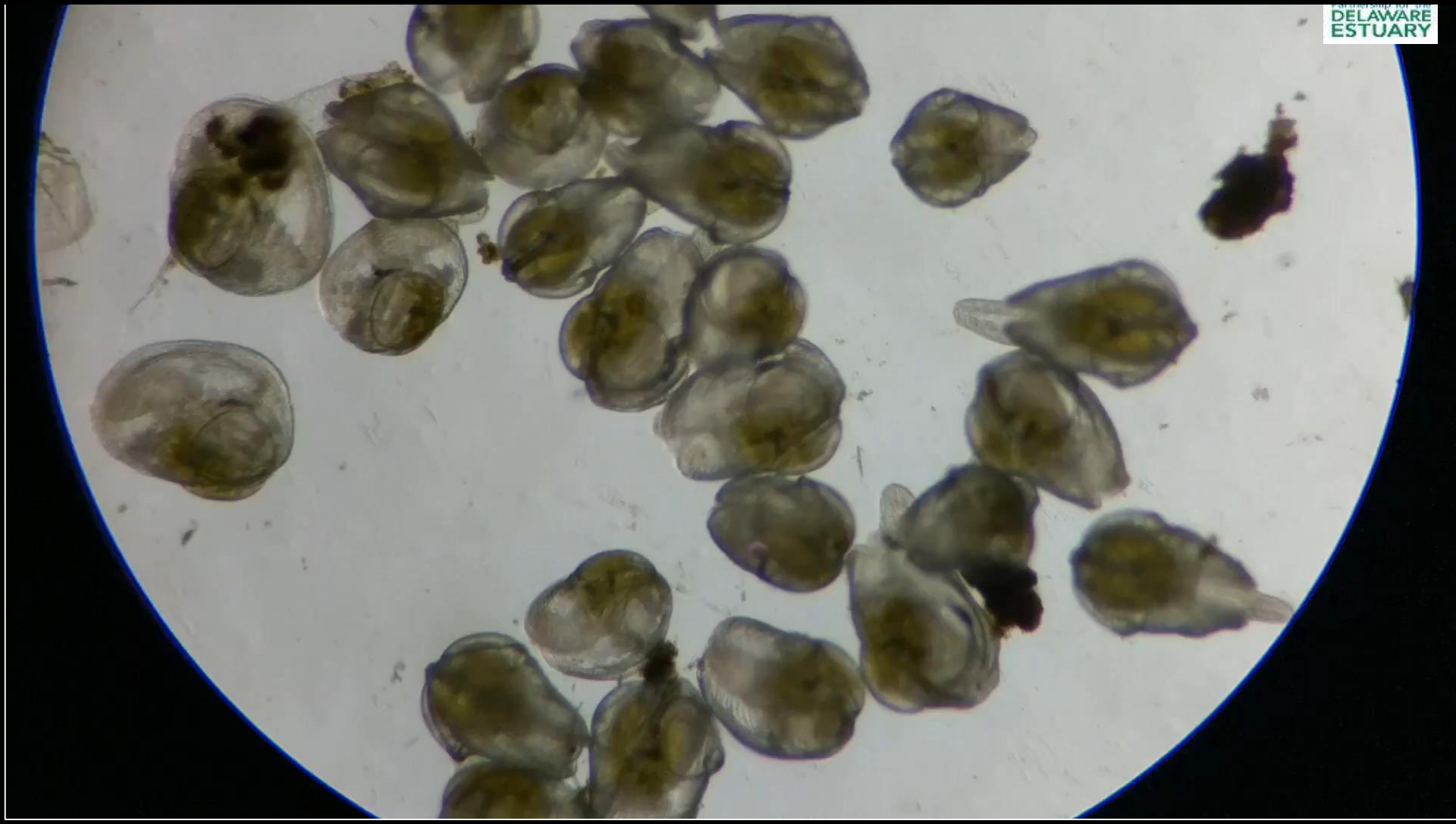
Eventually to
Prioritized Streams

Reintroductions – Juvenile Mussels



March 15, 2017
Mussel Broodstock Collection
18 degrees, blowing snow

Reintroductions – Juvenile Mussels



Pond Rearing Trials



Pond Rearing Trials



July 20, 2017
Juvenile Mussels

Pond Rearing Trials



Sept. 9, 2017

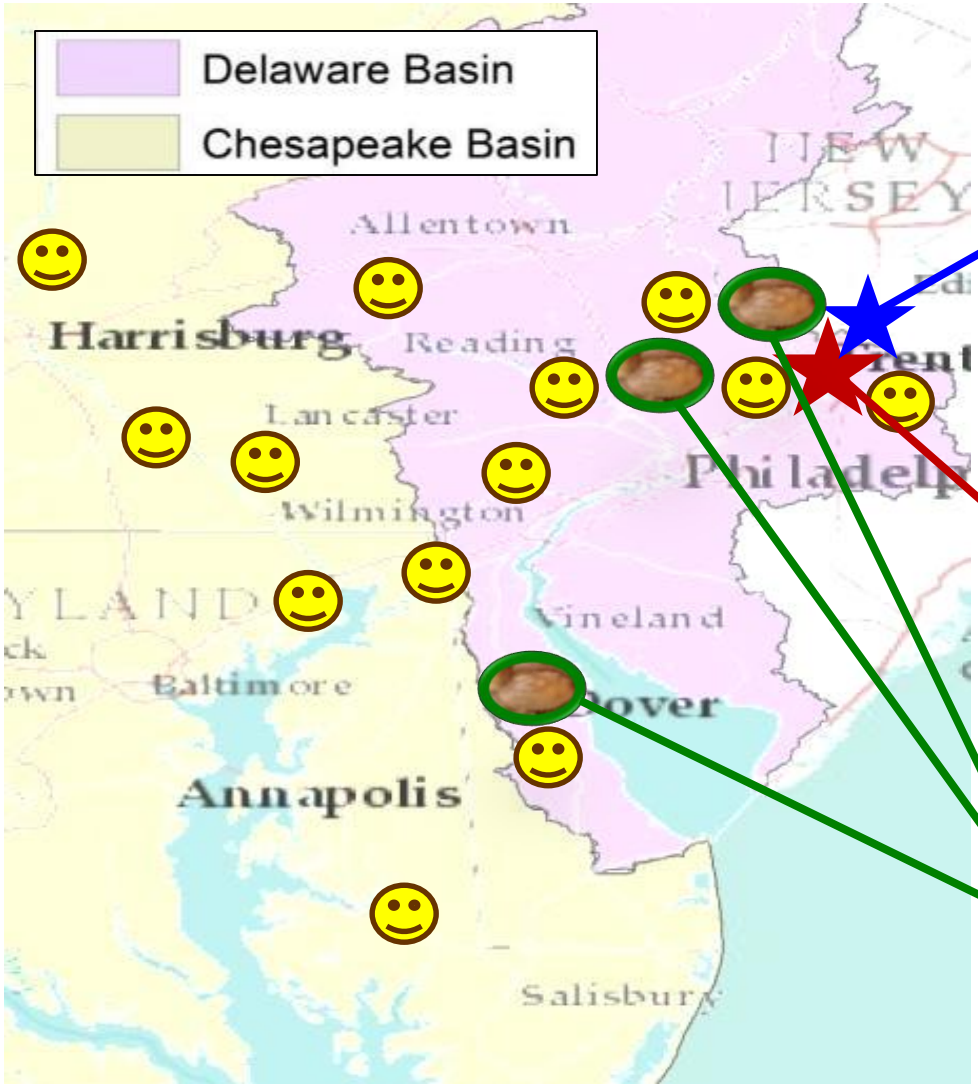
5-Month Old Juveniles Compared to Old Adults

Propagation & Reseeding Plan

Restoration Targets







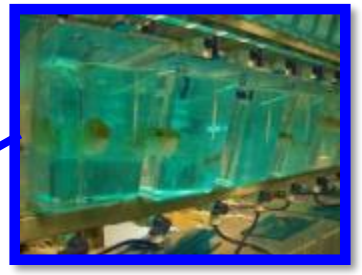


Exhibit Hatchery
(FWWIC, 2017)



Production Hatchery

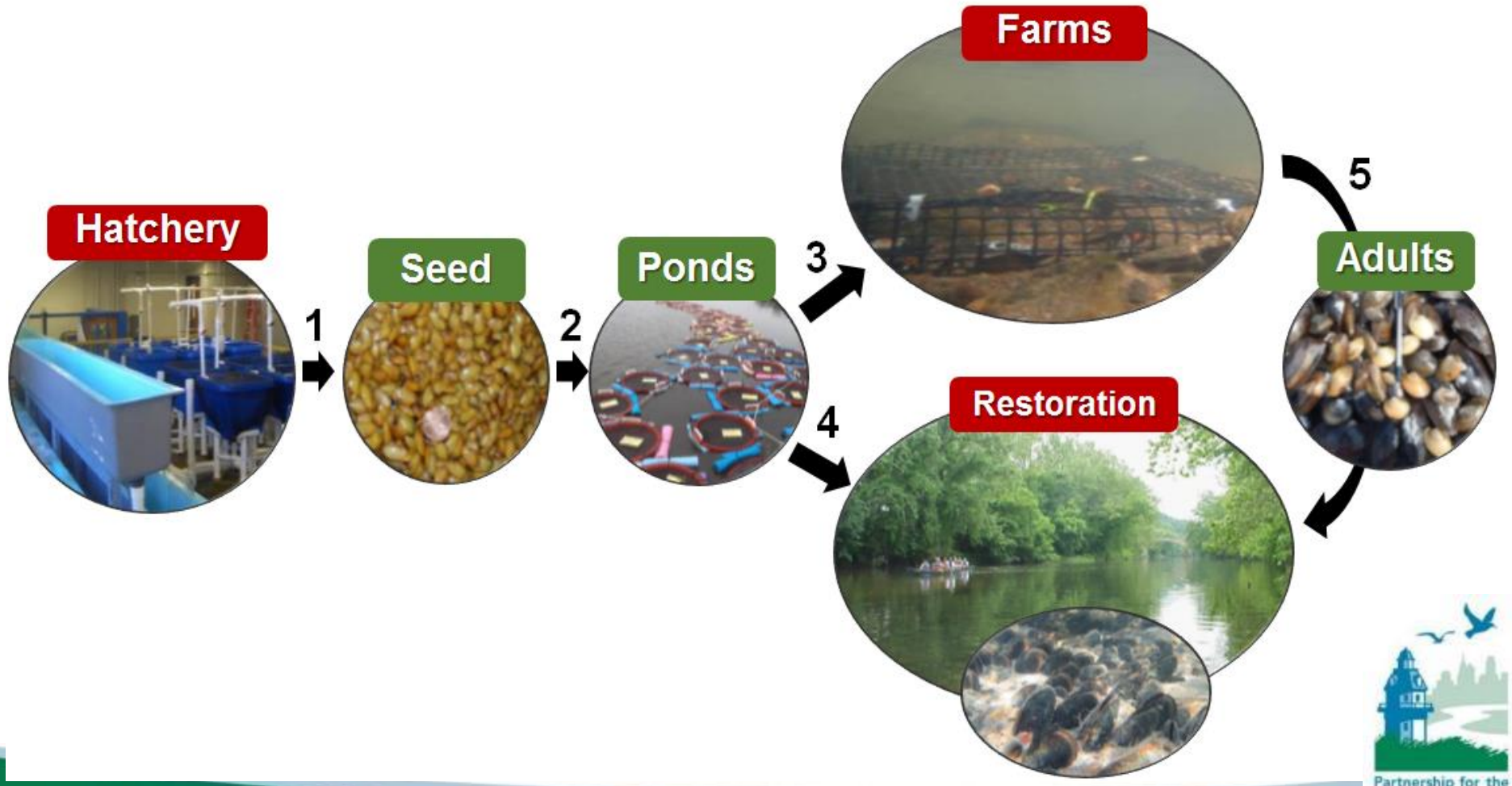


Pond Grow-Out

THE MUSSELS FOR CLEAN WATER INITIATIVE

OF THE DELAWARE AND SUSQUEHANNA RIVERS

WATER QUALITY ENHANCEMENT BY BEDS OF FRESHWATER MUSSELS



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Alewife Floaters

Investment in Mussel Hatchery

- Produce 500,000 seed per year
- Seed are stocked into impaired streams
- Survival ~90%, lifespan ~30 years, normal growth
- Costs $400,000 per year



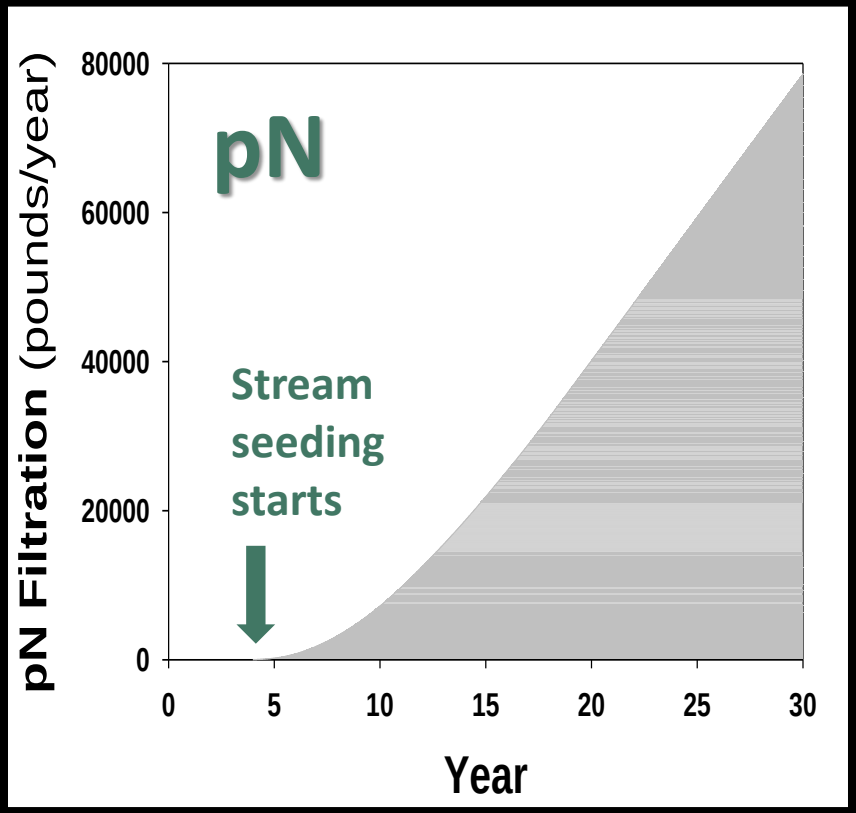


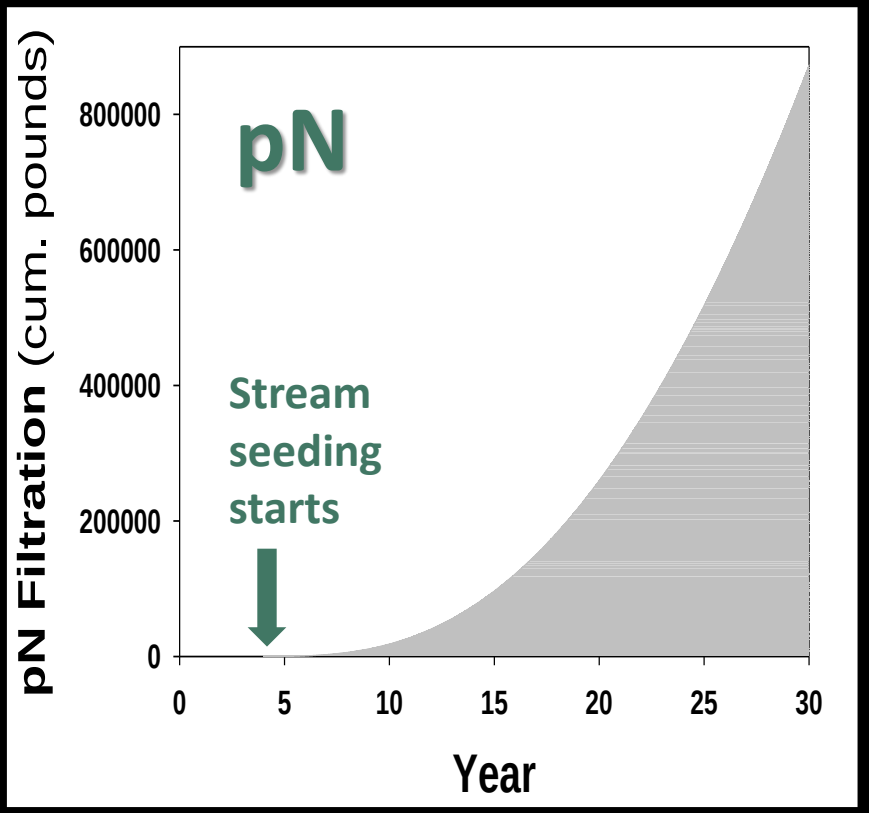




Alewife Floaters

Predicted Outcomes: Nitrogen Filtration





~78,000 lbs/yr by Year 30

>870,000 total lbs by Year 30



Alewife Floaters

Return on Investment ?

- Healthy mussel bed ~400 pounds N per ha/yr
- TSS removal would cost **$400 per ton** (dry weight)
- Nitrogen removal would cost **$14 per pound**

ROI analyses ignore other ecological benefits

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Take Home



- **Freshwater mussel beds clean the water (a lot!)**
- **Most areas no longer have mussel beds, which means we have to spend more money to mechanically treat**
- **We now have the technology to rebuild mussel beds, such as in living shoreline projects**
- **There are lots of opportunities in the tidal Schuylkill and Delaware, the world's largest freshwater tidal estuary**



CTUIR Freshwater Mussel Project

Healthy Bivalves = Healthy Estuaries



Kreeger

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Thank You!

Danielle Kreeger
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(302) 655-990, x104 | DelawareEstuary.org

Connecting people, science, and nature for a healthy Delaware River and Bay