Importance of Freshwater Mussels for Water Quality in the Tidal Delaware River

Danielle Kreeger, Melanie Mills, Lance Butler, Priscilla Cole, and Roger Thomas

Delaware Estuary Science & Environmental Summit
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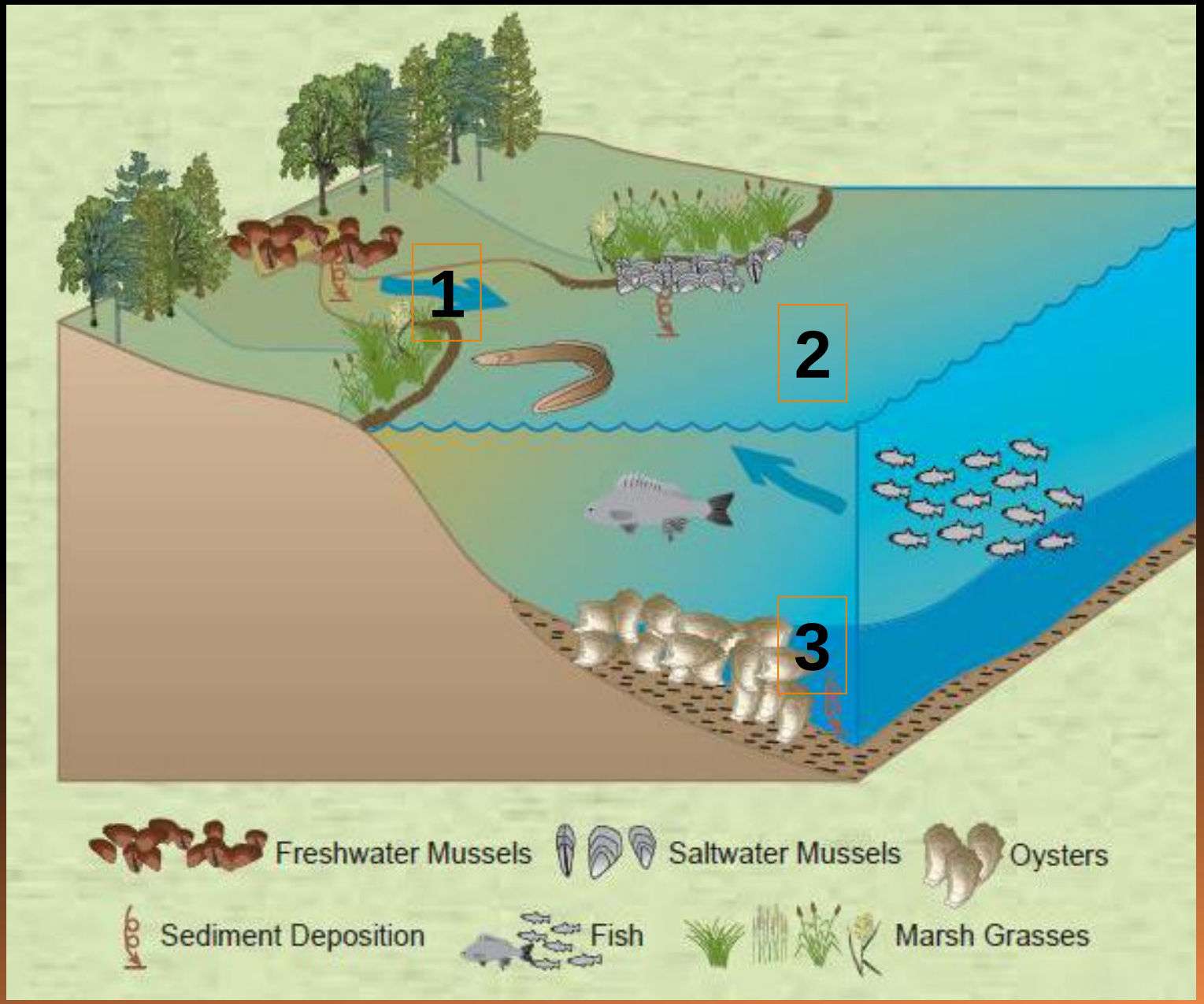
PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

THE ACADEMY OF NATURAL SCIENCES of DREXEL UNIVERSITY

Philadelphia PWD Water Department

Headwaters to Ocean Shellfish Restoration

1. Non-tidal
2. Intertidal
3. Subtidal



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Nature's Benefits

Bivalve Shellfish are "Ecosystem Engineers"

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Mussel Beds

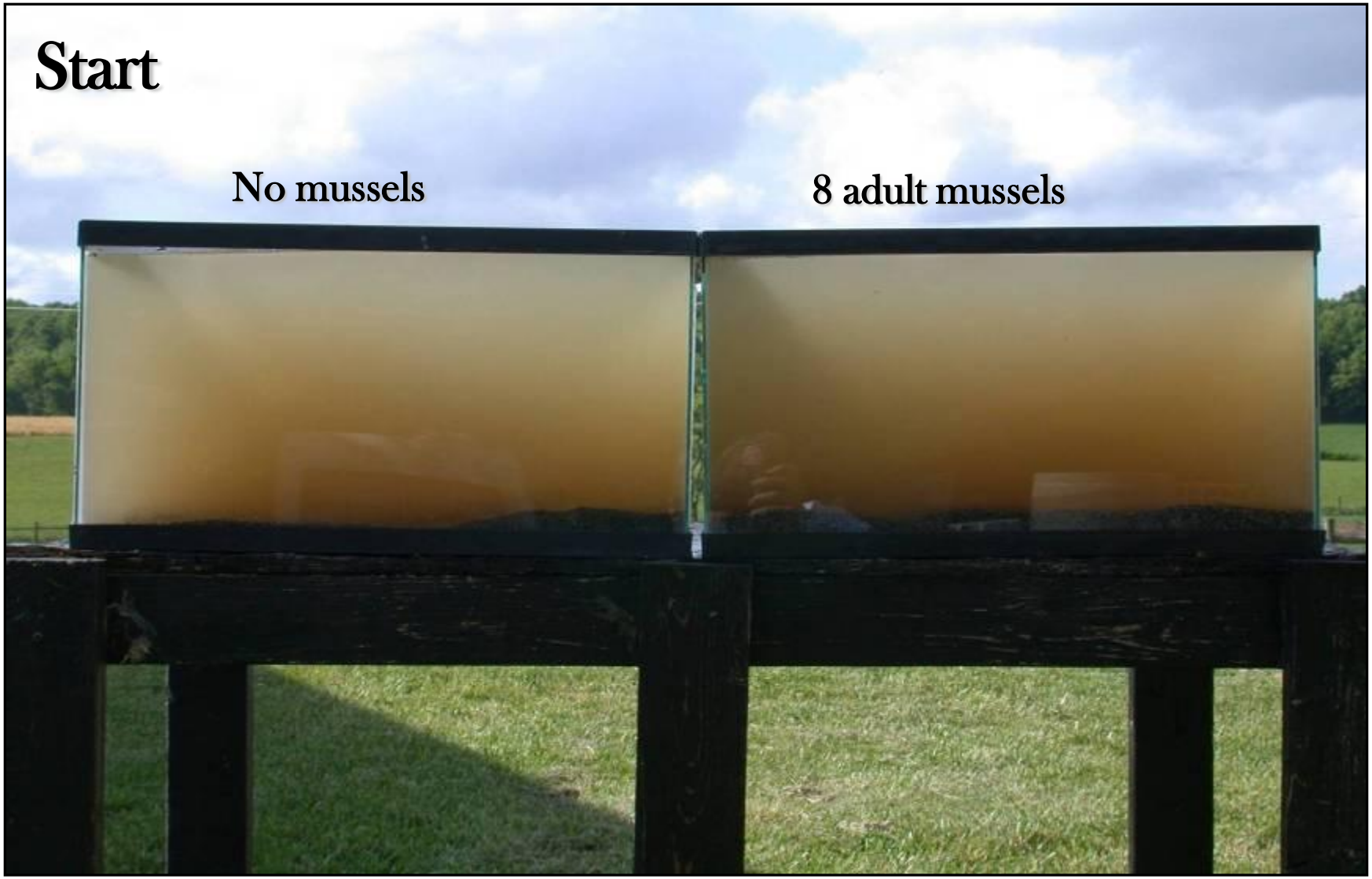
CTUIR Freshwater Mussel Project

Oyster Reefs

Kreeger

Mussels Are Habitat
INITIATIVE
Restoring Our Nation's Water Quality

Biofiltration Potential



Slide from Dick Neves, VA Tech

Mussels Are Habitat
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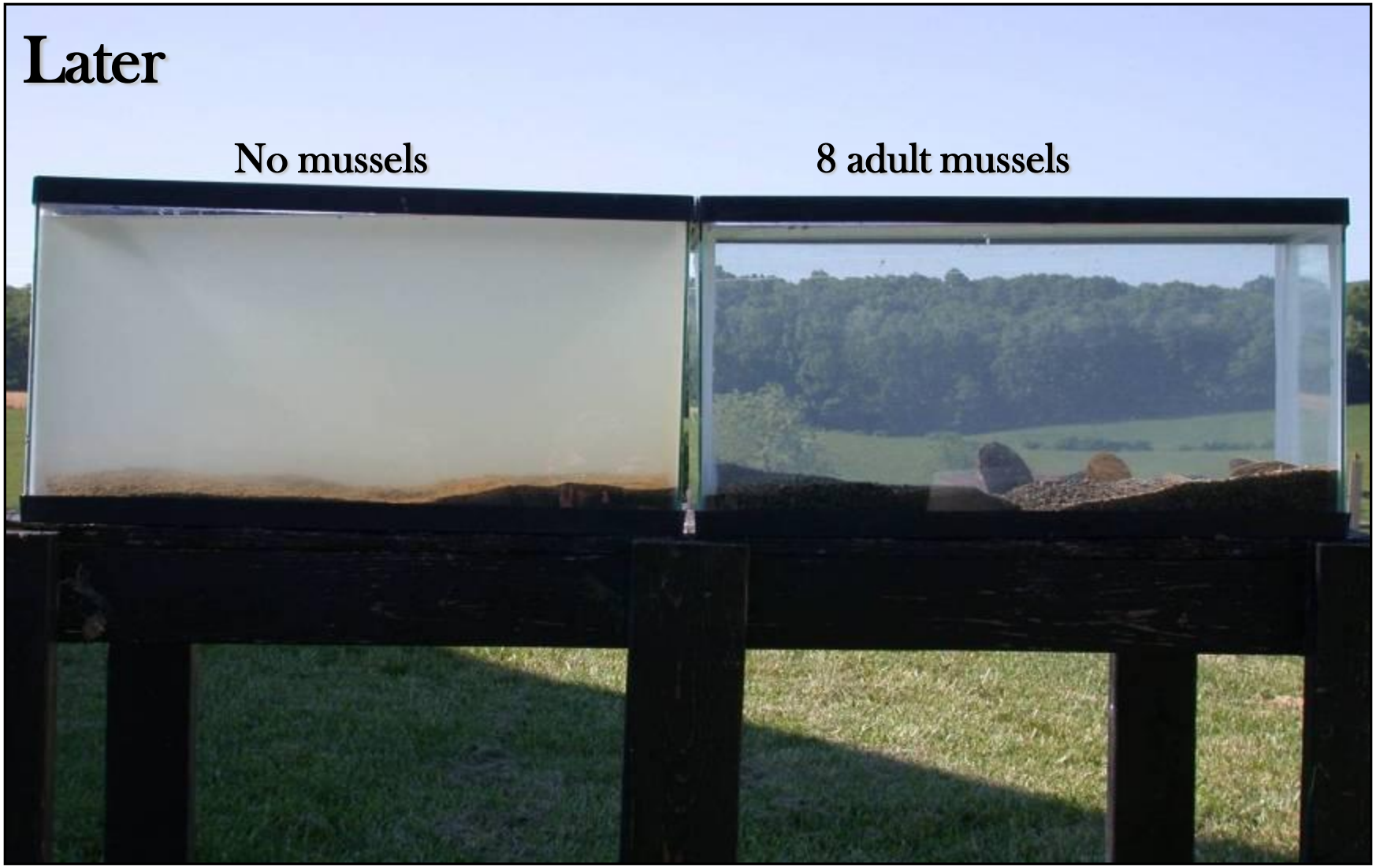
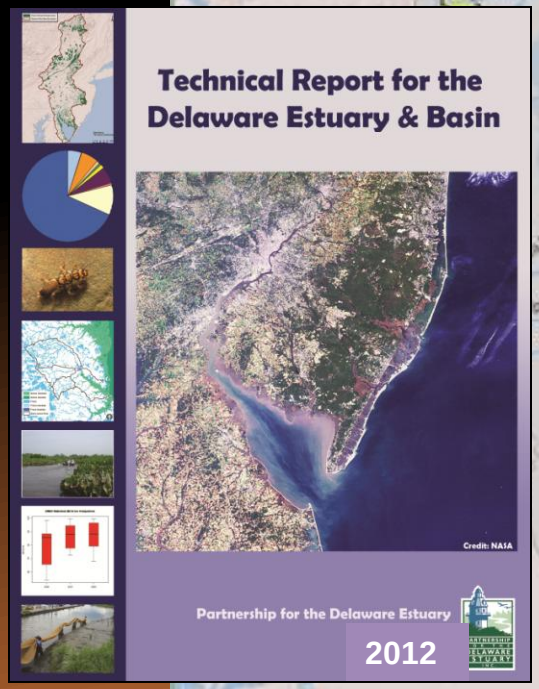


Slide from Dick Neves, VA Tech

1919

Since 1996



Species Richness

1
2
3
4
5
10

Surveyed-Absence of Species

No Data

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Kreeger

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**

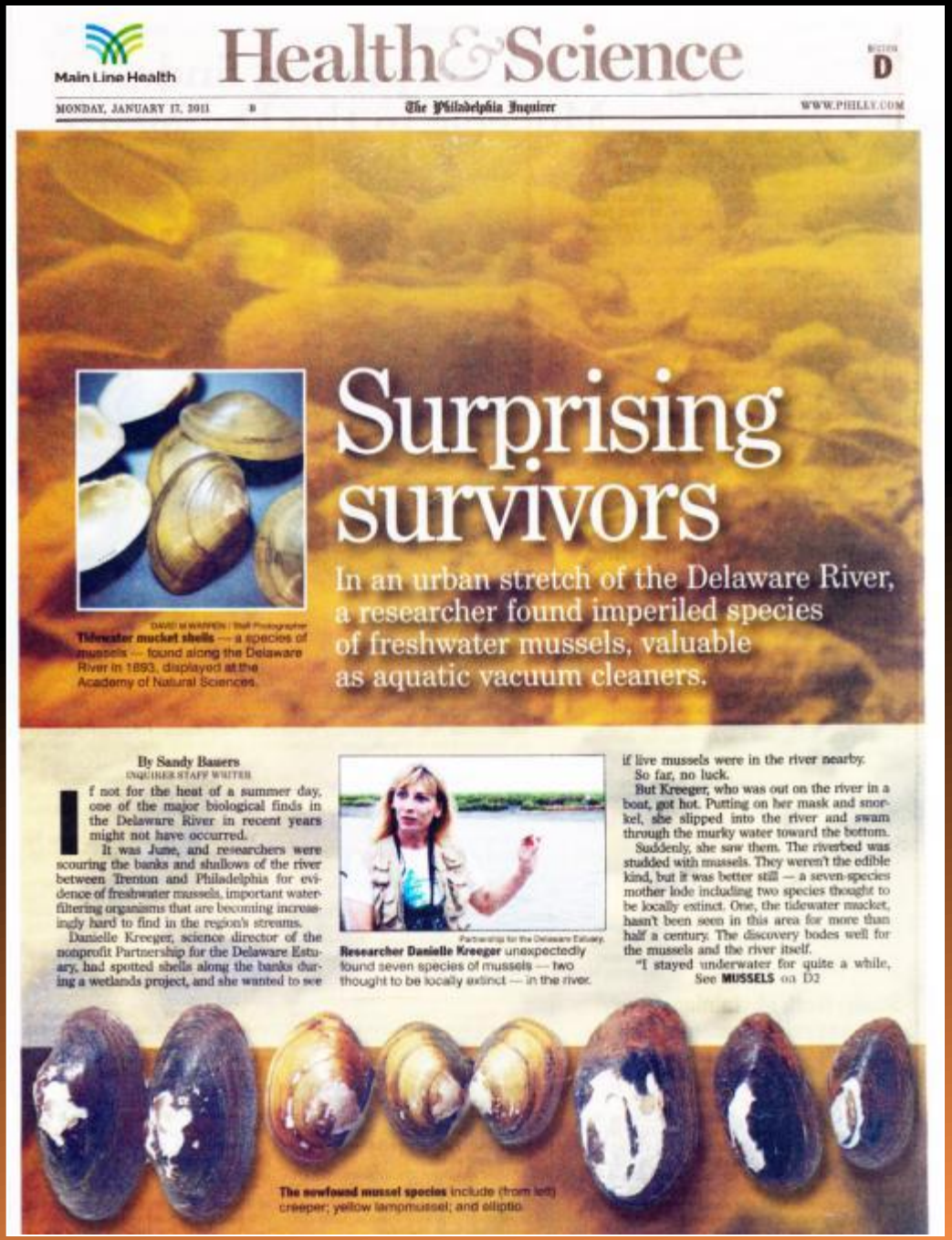
Freshwater Mussel Discoveries

Tidal Delaware River:

Lots of animals
7 Species

Genetically Appropriate

Promise for Restoration



Main Line Health

Health&Science

D

MONDAY, JANUARY 17, 2011 The Philadelphia Inquirer WWW.PHILLY.COM

Surprising survivors

In an urban stretch of the Delaware River, a researcher found imperiled species of freshwater mussels, valuable as aquatic vacuum cleaners.

Tidewater mucket shells — a species of mussels — found along the Delaware River in 1893, displayed at the Academy of Natural Sciences.

By Sandy Bauers
INQUIRER STAFF WRITER

If not for the heat of a summer day, one of the major biological finds in the Delaware River in recent years might not have occurred.

It was June, and researchers were scouring the banks and shallows of the river between Trenton and Philadelphia for evidence of freshwater mussels, important water-filtering organisms that are becoming increasingly hard to find in the region's streams.

Danielle Kreeger, science director of the nonprofit Partnership for the Delaware Estuary, had spotted shells along the banks during a wetlands project, and she wanted to see if live mussels were in the river nearby.

So far, no luck.

But Kreeger, who was out on the river in a boat, got hot. Putting on her mask and snorkel, she slipped into the river and swam through the murky water toward the bottom.

Suddenly, she saw them. The riverbed was studded with mussels. They weren't the edible kind, but it was better still — a seven-species mother lode including two species thought to be locally extinct. One, the tidewater mucket, hasn't been seen in this area for more than half a century. The discovery bodes well for the mussels and the river itself.

"I stayed underwater for quite a while,

See MUSSELS on D2

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

The newfound mussel species include (from left) creeper; yellow lampmussel; and elliptio.

Questions:

How many mussels exist here?

How much water do they filter?

What happens to filtered material?

Do current populations benefit water quality?

Can mussel restoration improve water quality?

To Understand EcoServices, Need…

Ecology

Physiology

Population Surveys

Monitoring, Variability

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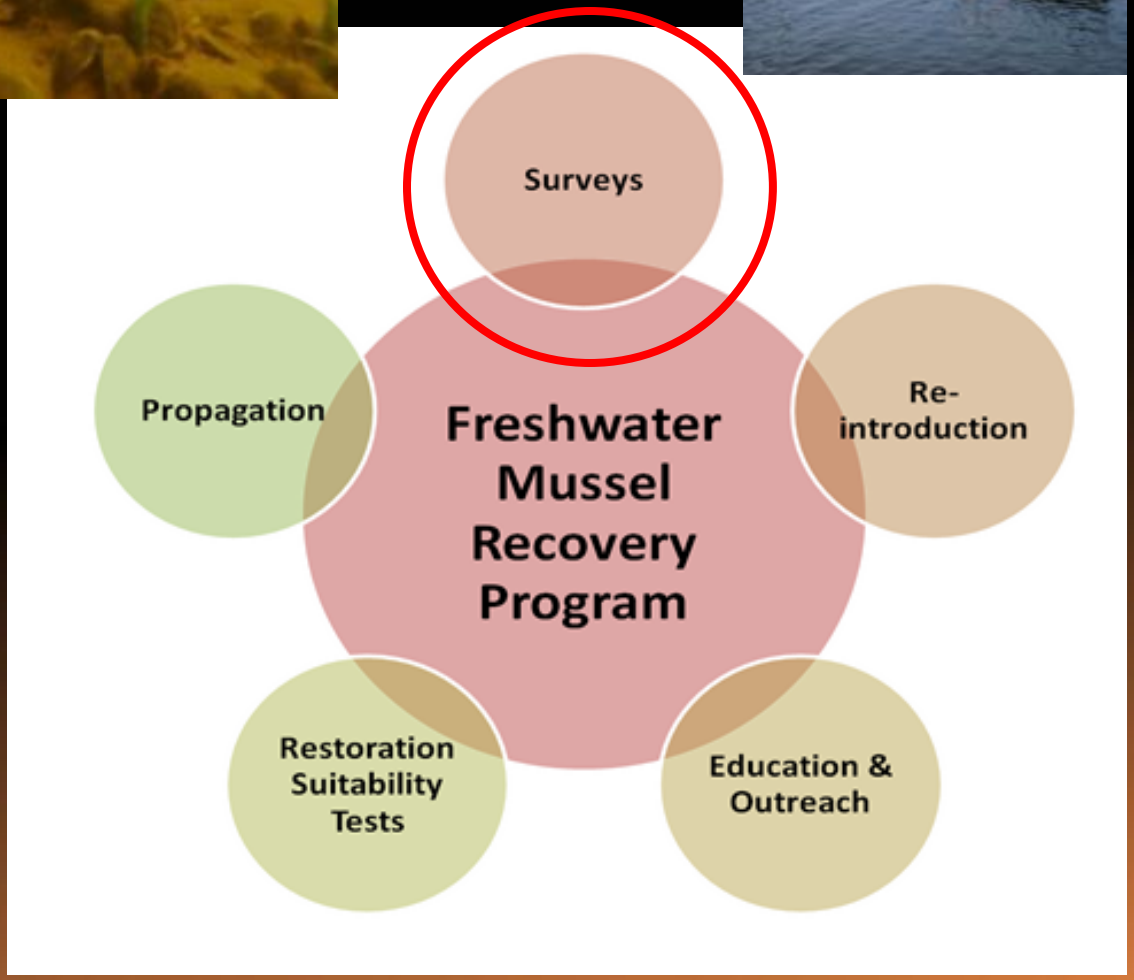
Kreeger

Surveys

- Determine current mussel population status
- Identify sources for restoration
- Areas with Mussels: Prioritize for Conservation
- Areas without Mussels: Prioritize for Restoration



Qualitative vs. Quantitative Surveys

Qualitative:

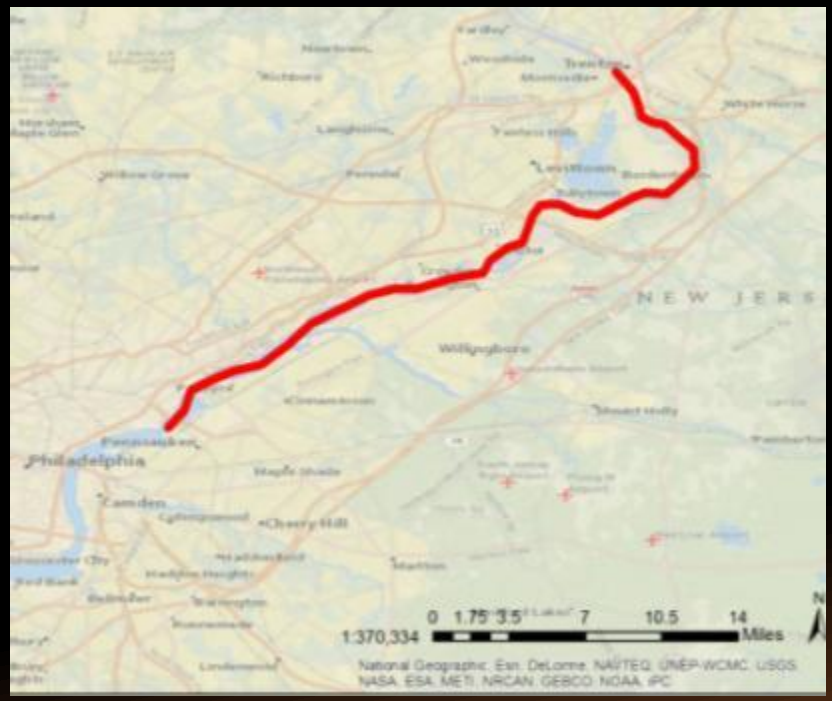
- Opportunistic methods
- Timed searches
- Data on presence/absence, catch per unit effort
- Assess large areas
- Most common, cost effective

Quantitative:

- Intensive methods
- Transects and quadrats
- Data on densities, sizes, richness
- Smaller areas
- Rare, more costly

→ Only way to assess ecosystem benefits

2012 Quantitative Surveys



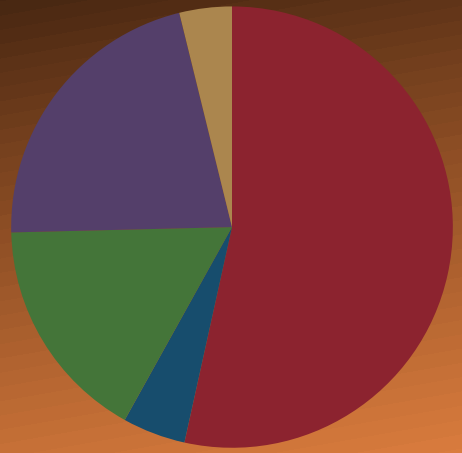
Tidal Delaware River

Shallow Subtidal Shorelines

Native Mussel Assemblages

<u>Goals</u>:

1. Quantify mussel species richness and density
2. Examine relationships with:
   - Depth (see Mills poster)
   - Substrate (see Butler talk)
3. Estimate Potential Water Filtration per Bed



Methods

Four Sites

Shallow subtidal zone
(0-8 feet below mean low water)

Transects: 8 per site

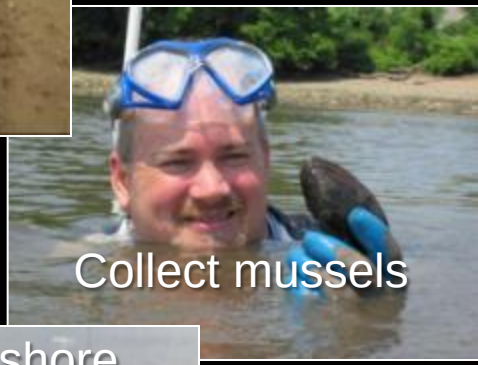
Quadrats: 3-4 per transect, stratified by depth

Quadrat = $1m^2$ steel frame

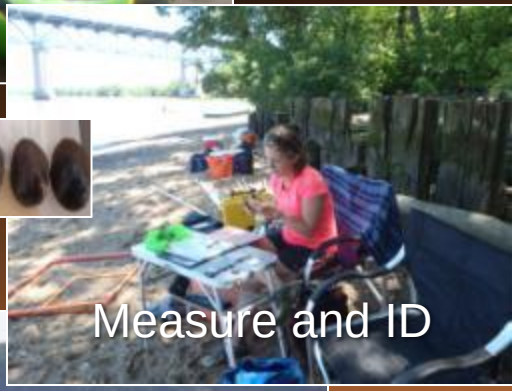

RTK GPS

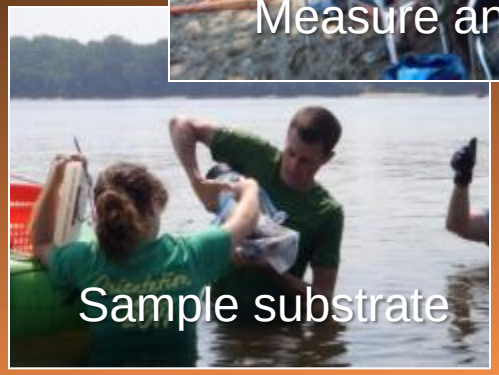

Set up transects


Quadrat searches


Collect mussels


Haul to shore

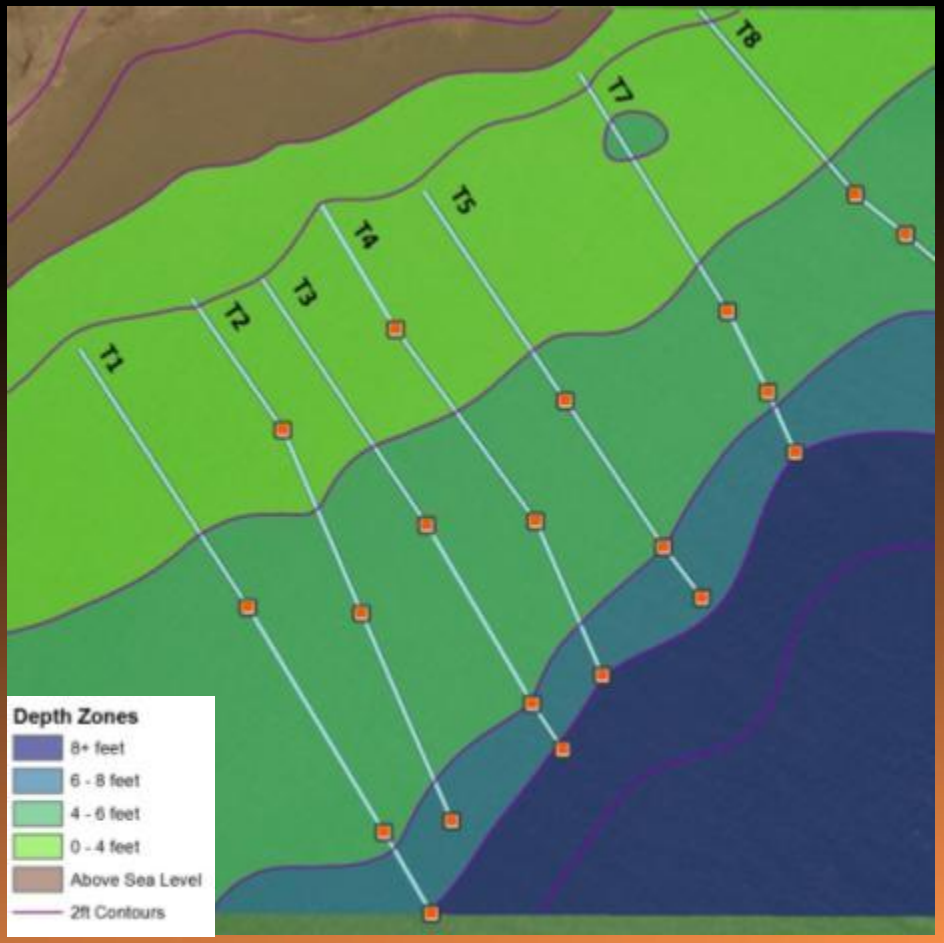

Measure and ID

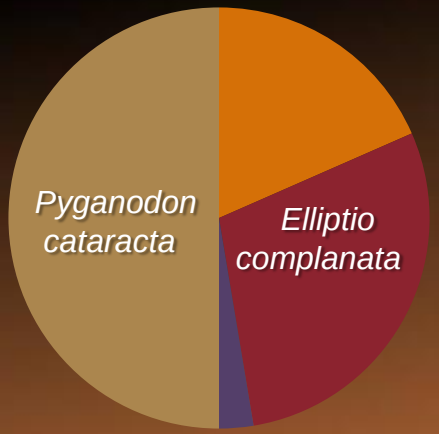

Sample substrate

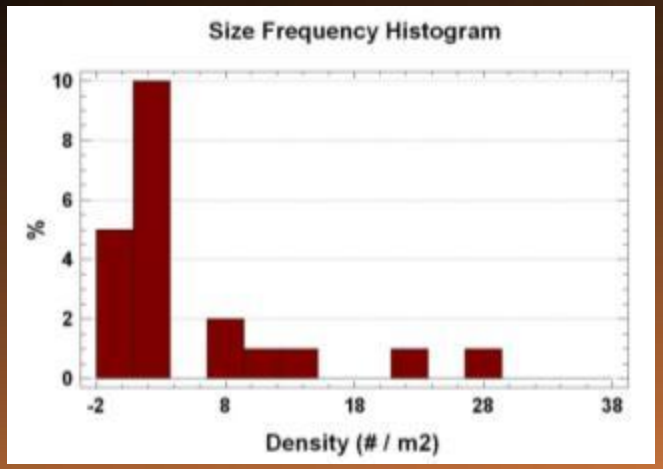
Site 1

- Four mussel species
- Richness = 1.4 species m^{-2}
- Density:
  range = 0 – 29 mussels m^{-2}
  mean = 5.5 mussels m^{-2}

See Mills and Butler presentations for depth and substrate relationships, respectively



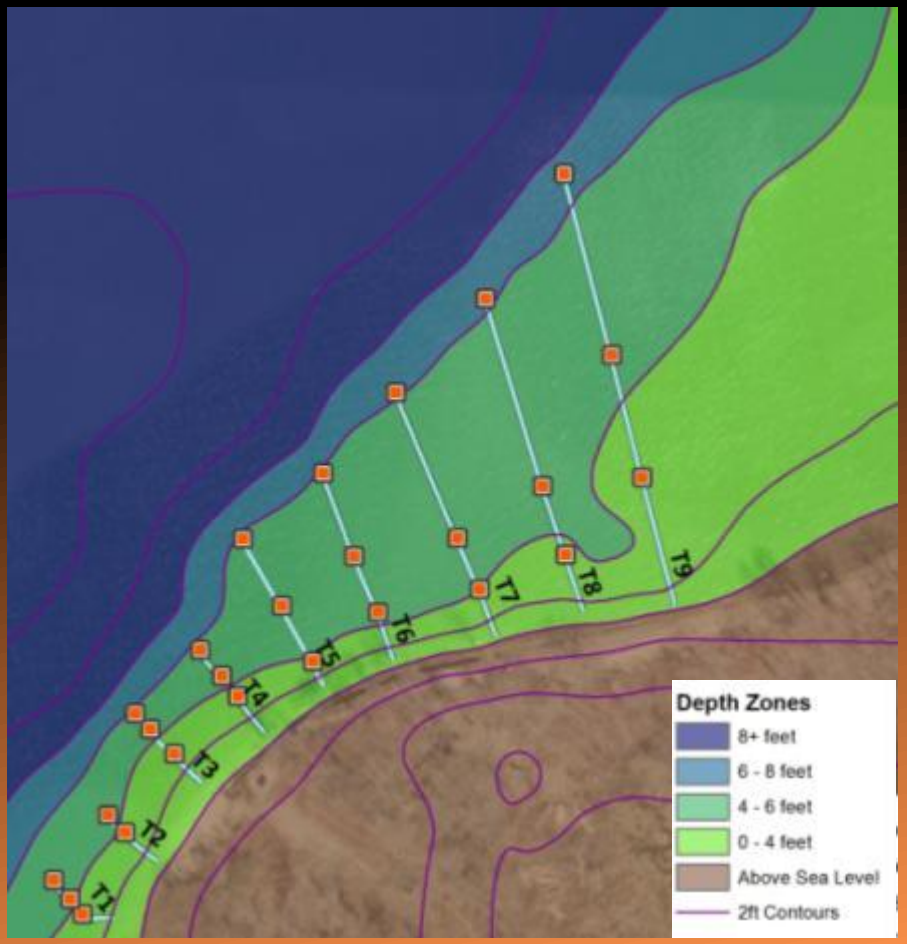


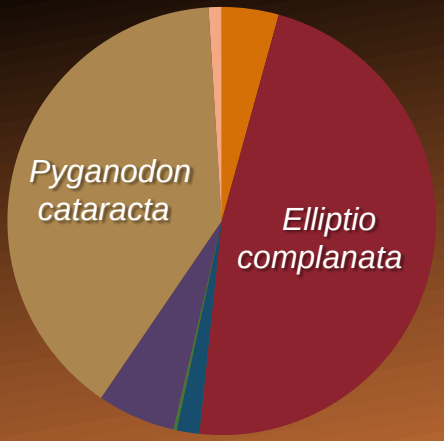


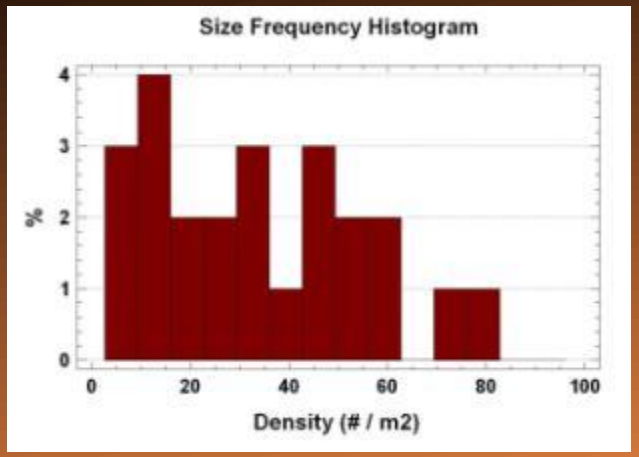
Site 2

- Six mussel species
- Richness = 3.4 species m^{-2}
- Density:
  range = 0 – 80 mussels m^{-2}
  mean = 30.1 mussels m^{-2}

See Mills and Butler presentations for depth and substrate relationships, respectively

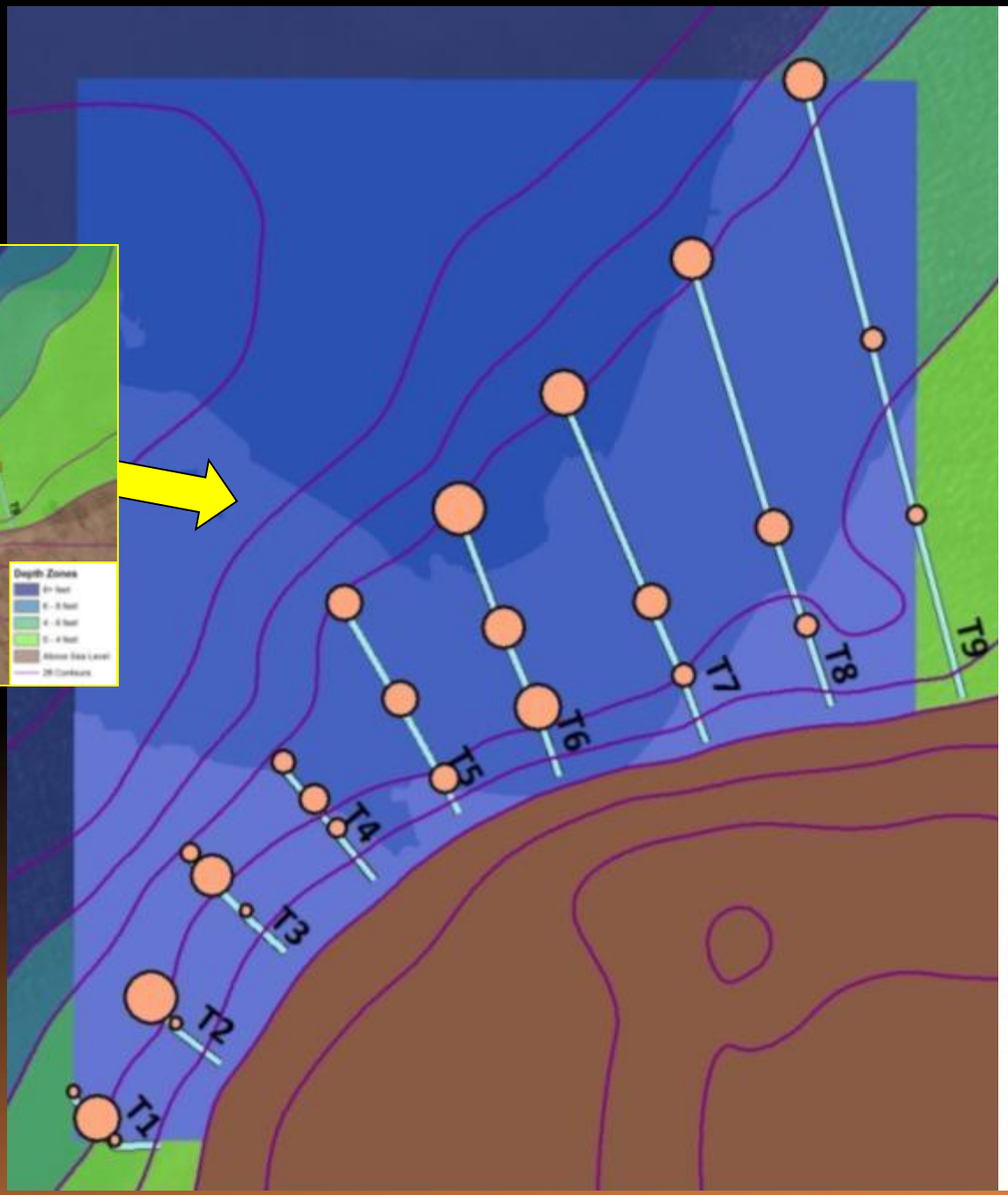






Site 2

See Mills poster



Measured Quadrat Density

Less Dense

More Dense

2ft Contours

Predicted Bed Density

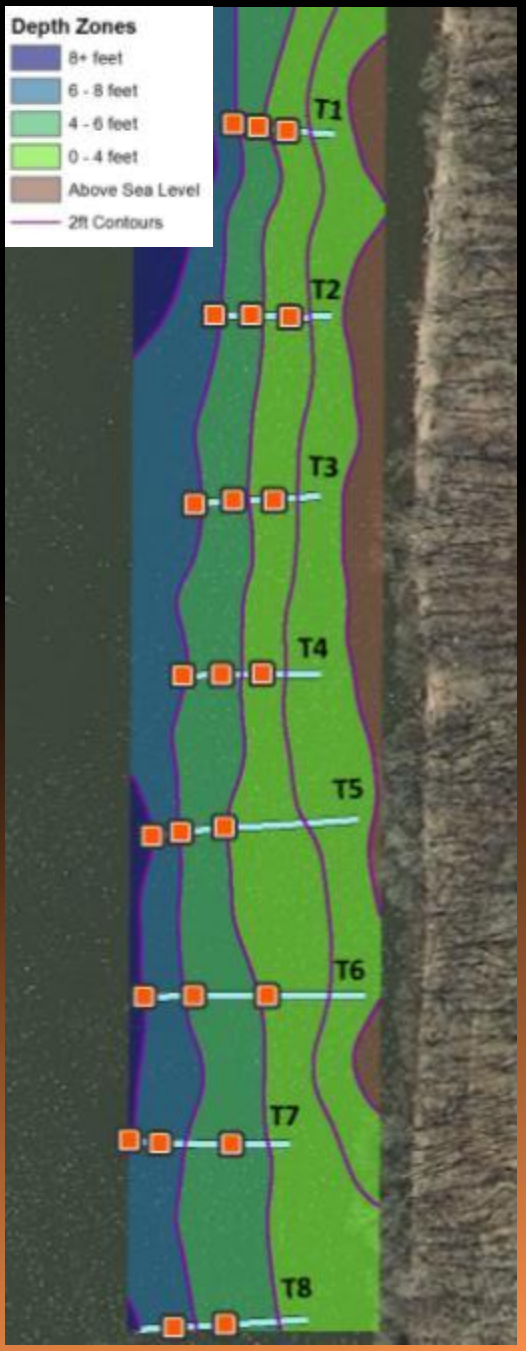
Less Dense

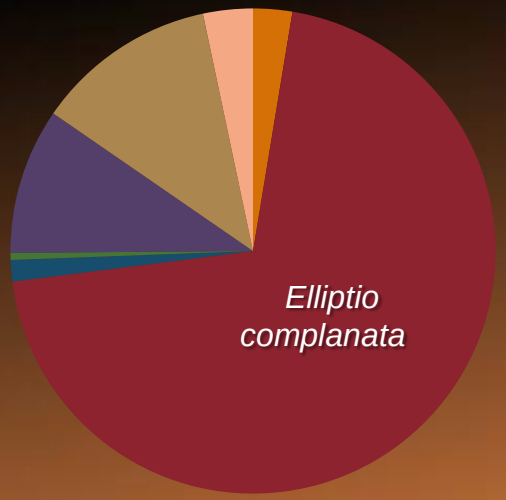
More Dense

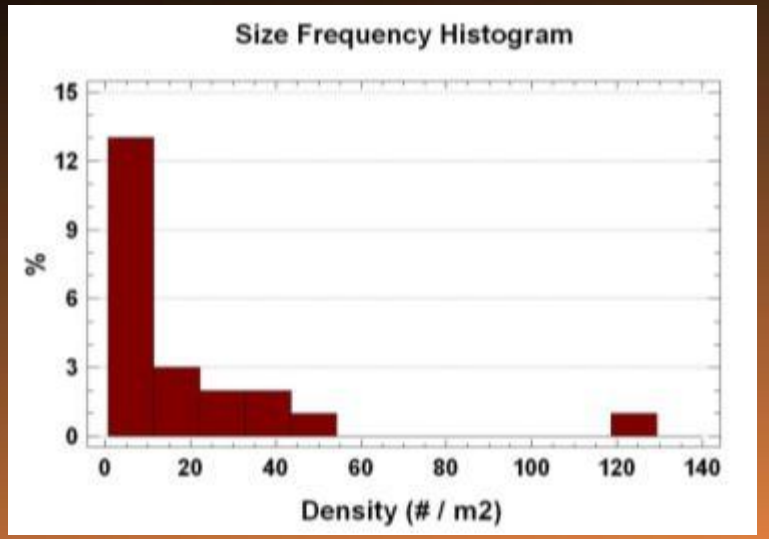
Site 3

- Five mussel species
- Richness = 2.4 species m^{-2}
- Density:
  range = 0 – 129 mussels m^{-2}
  mean = 17.6 mussels m^{-2}

See Mills and Butler presentations for depth and substrate relationships, respectively



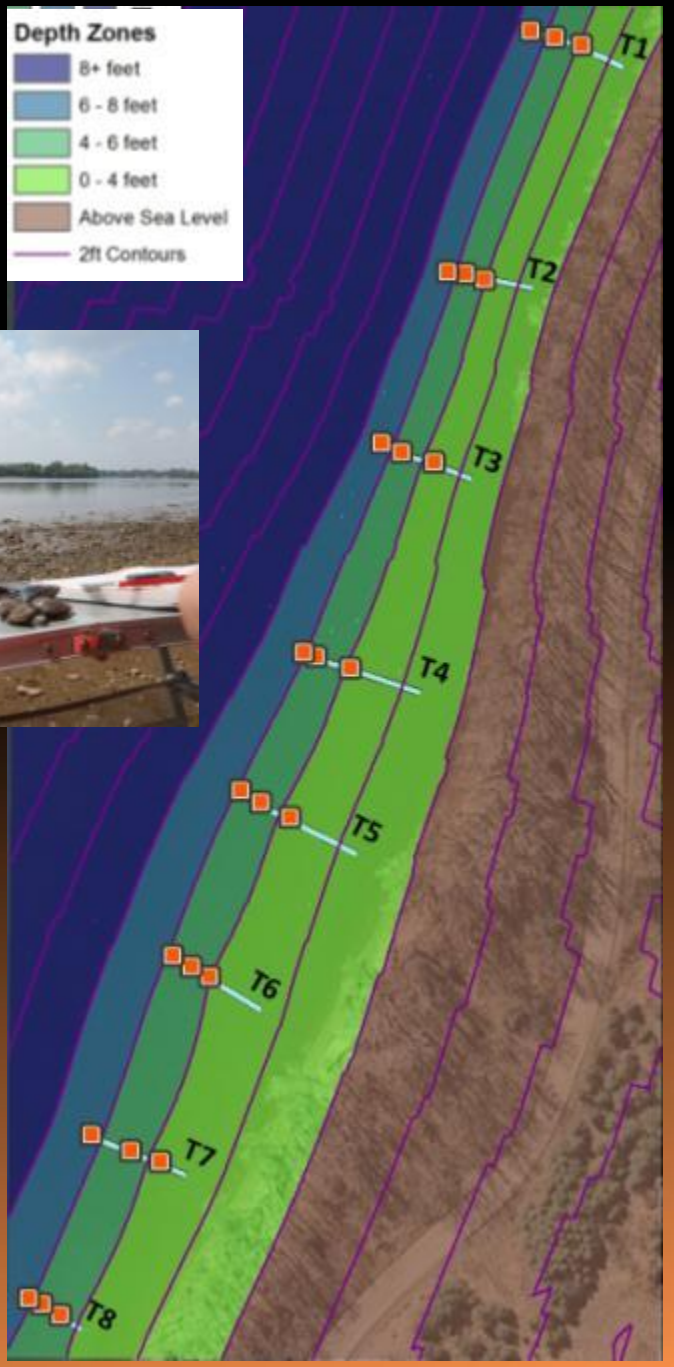


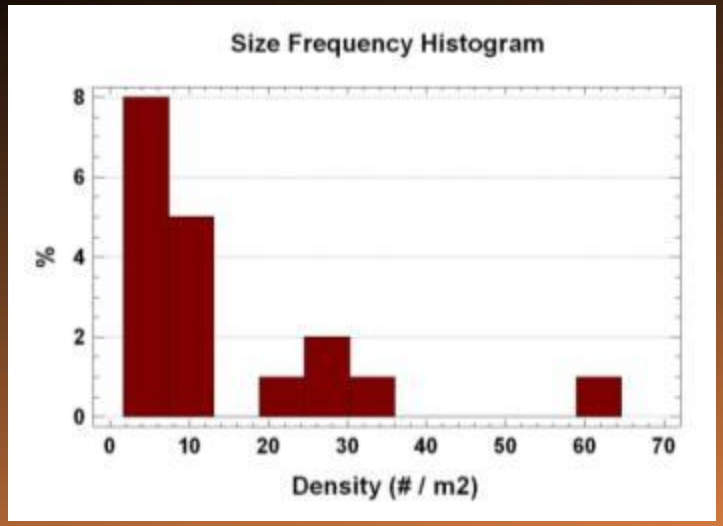


Site 4

- Five mussel species
- Richness = 2.4 species m^{-2}
- Density:
  range = 0 – 64 mussels m^{-2}
  mean = 10.8 mussels m^{-2}

See Mills and Butler presentations for depth and substrate relationships, respectively





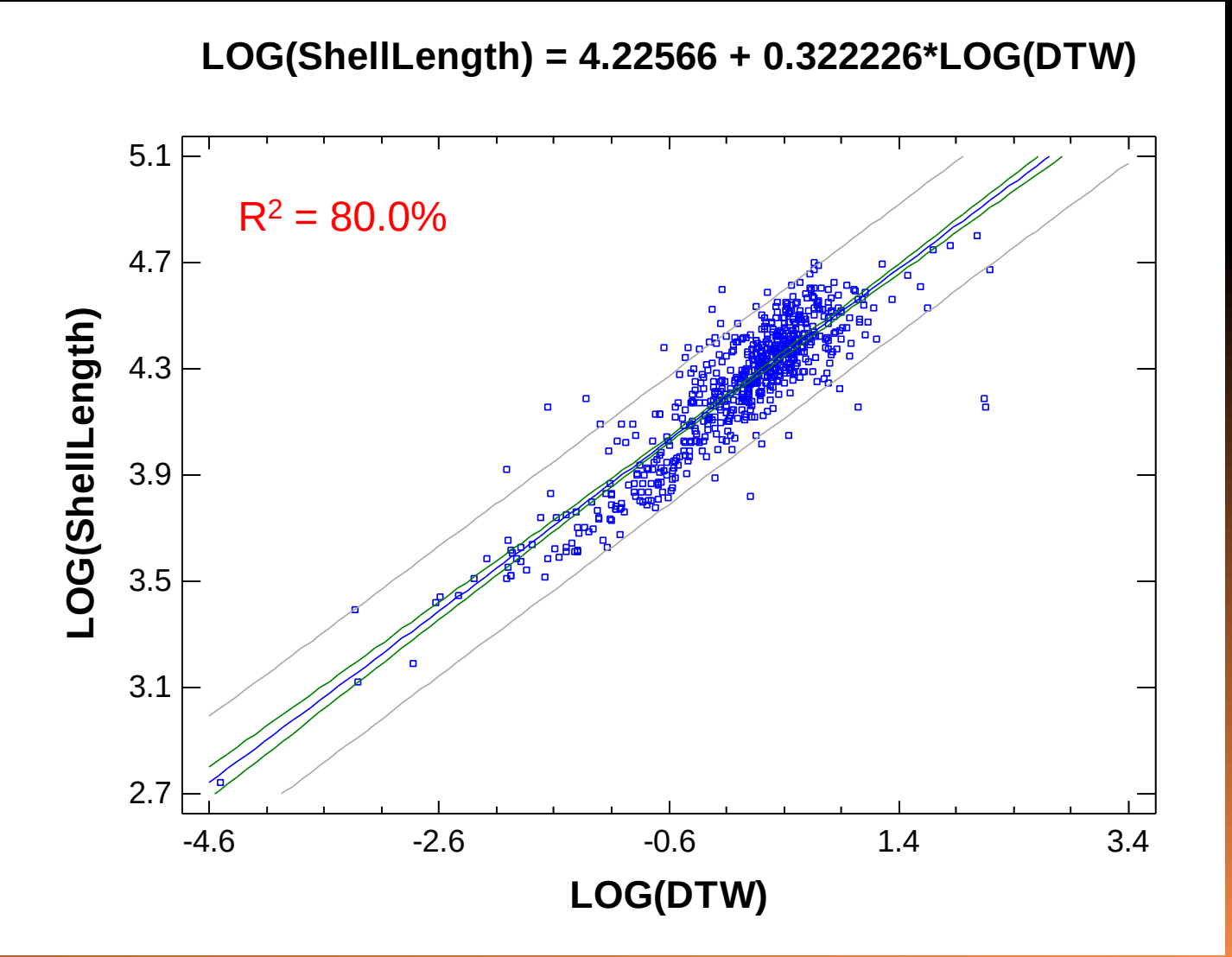
How much do they weigh?

No animals sacrificed in 2012

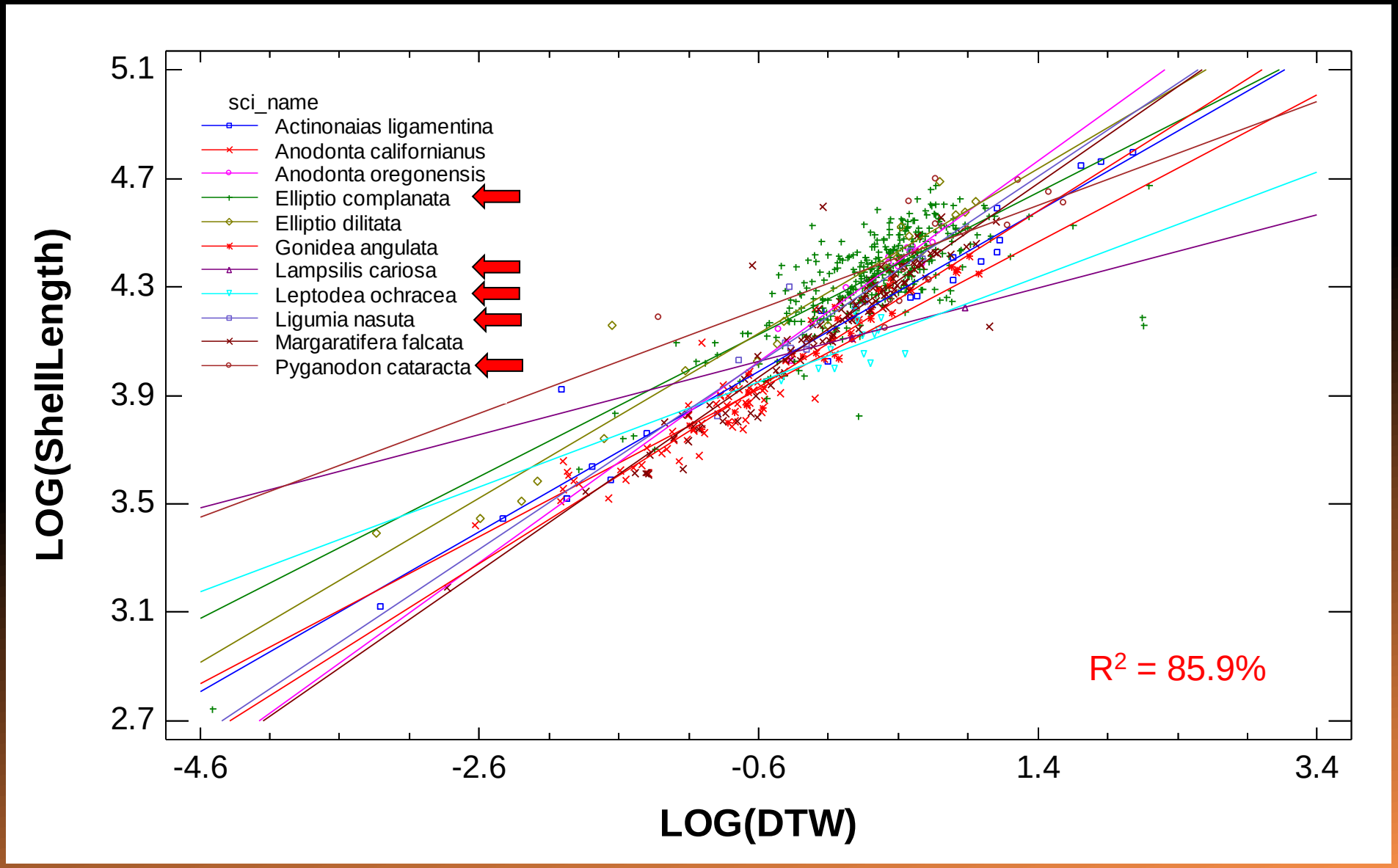
Dry tissue weights estimated from from earlier studies

11 species of freshwater mussels

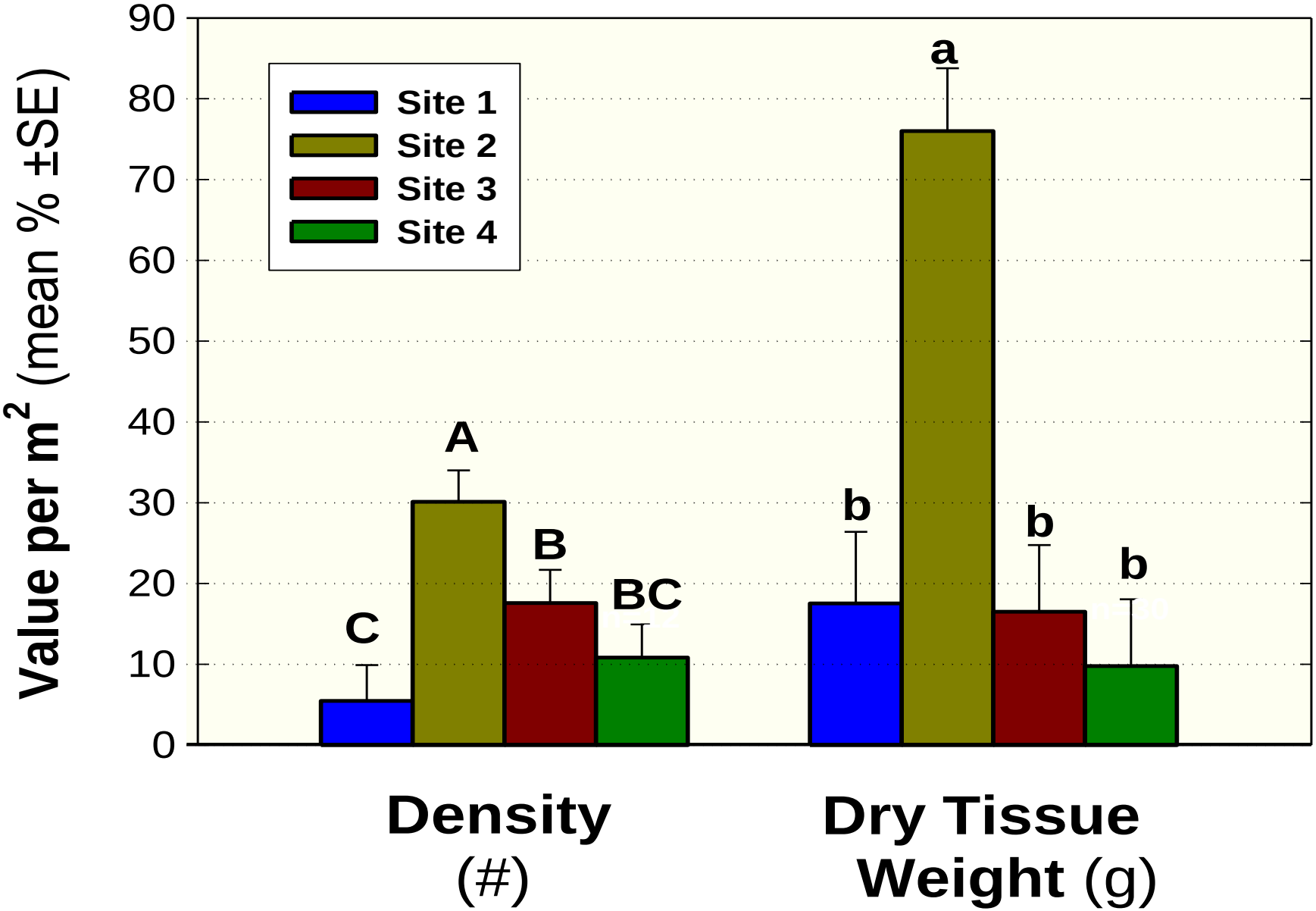
653 animals
(harvested 2000-2011)



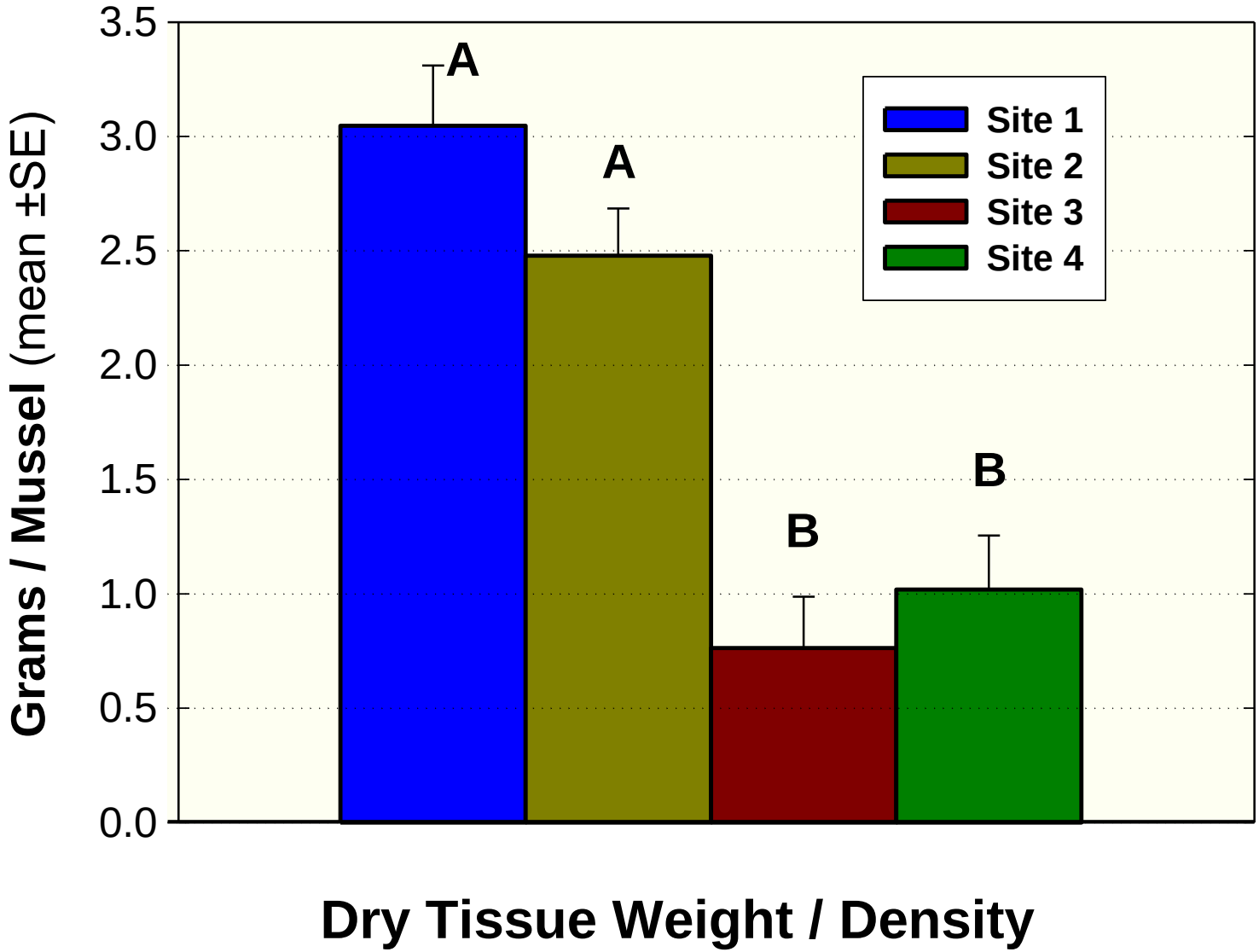
Species-specific weight estimates



Mussel Density and Total Weight by Site



Mussel Size by Site



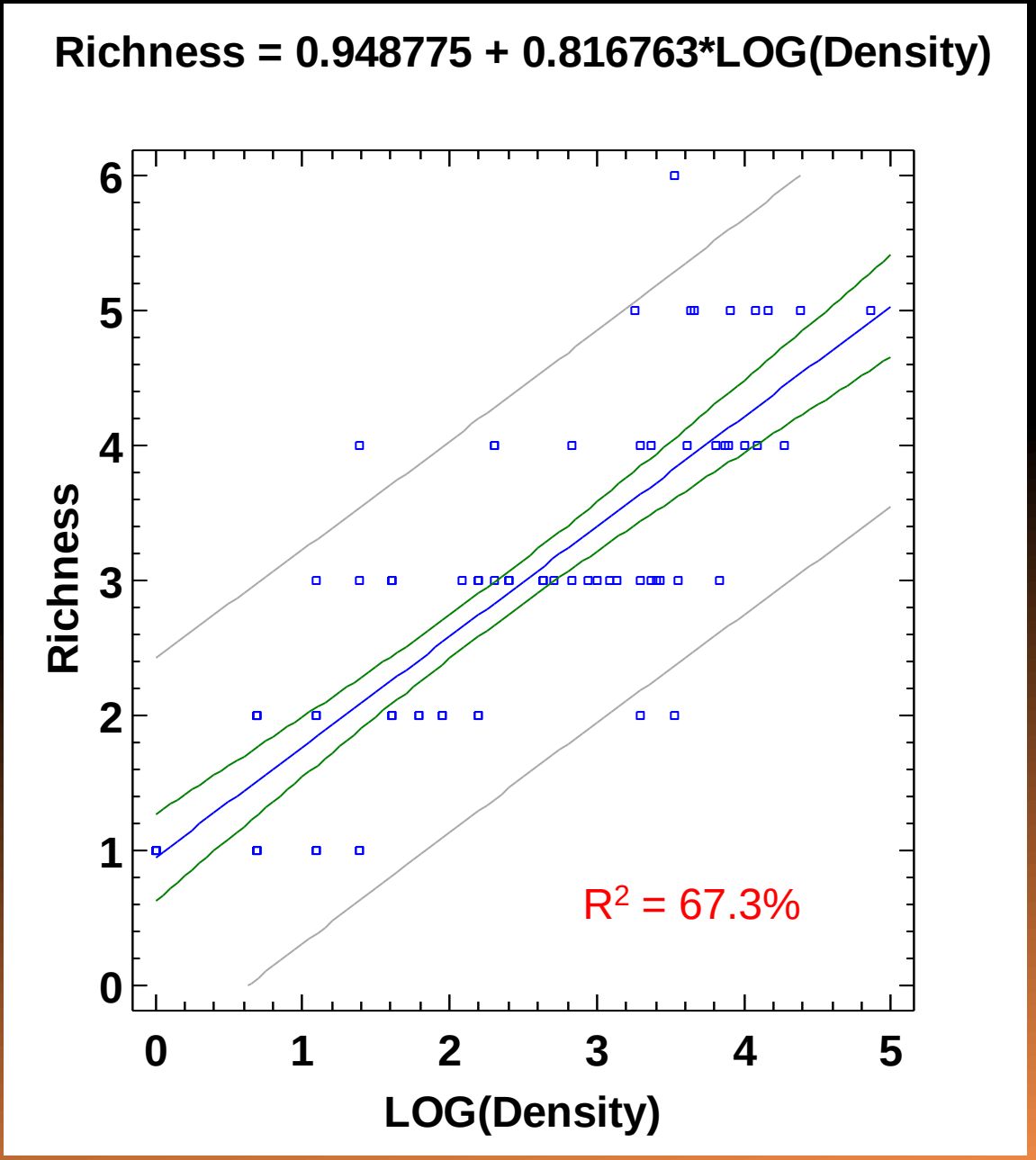
Other Findings

Species richness was positively related to density

Rarest species was *Ligumia nasuta*, eastern pondmussel – healthy size range from juveniles to old adults

Tidewater muckets were abundant

Juvenile mussels were abundant at 2 of 4 sites, suggesting reproduction is occuring



Total Mussel Population Size

Densities Extrapolated to Survey Areas

	Quads (n)	**Mussels per Quad** (# m^{-2})		**Survey Area** (m^2)	**Mussel Number**
		Average	Std. Error (pooled)		
Site 1	21	5.5	4.4	4,230	23,163
Site 2	27	30.1	3.9	9,504	286,175
Site 3	24	17.6	4.1	13,983	245,863
Site 4	24	10.8	4.1	10,658	115,458
4 Bed Totals>	**96**	**16.8**		**38,375**	**670,660**

2012 Abundance Surveys

Estimated Population Biomass per Site

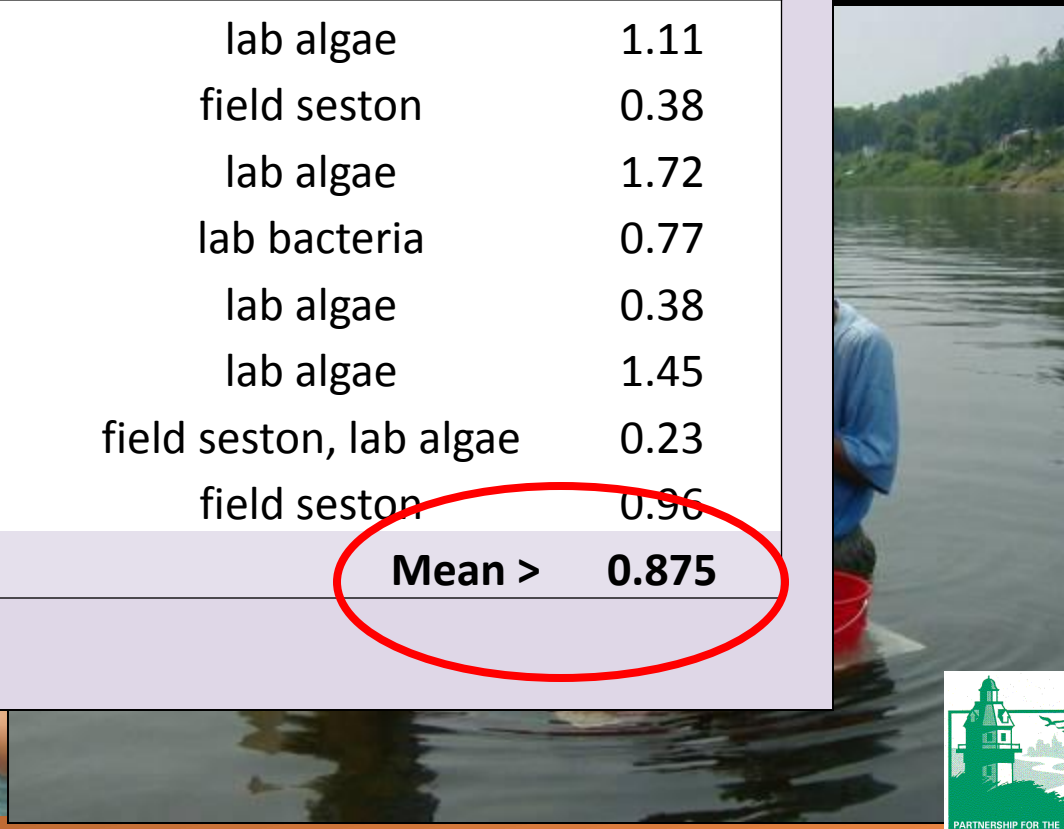
	Quads (n)	Mussels per Quad (# m^{-2})		Dry Tissue Weight per Quad (g m^{-2})		Survey Area (m^2)	Mussel Number	Mussel Tissue Dry Weight (g)
		Average	Std. Error (pooled)	Average	Std. Error (pooled)			
Site 1	21	5.5	4.4	17.5	8.8	4,230	23,163	74,210
Site 2	27	30.1	3.9	76.0	7.8	9,504	286,175	722,145
Site 3	24	17.6	4.1	16.5	8.3	13,983	245,863	230,725
Site 4	24	10.8	4.1	9.8	8.3	10,658	115,458	104,226
4 Bed Totals>	**96**	**16.8**		**31.8**		**38,375**	**670,660**	**1,131,307**

How much do they filter?

Appl Existing Clearance Rate Data

Revi er

Study	Number of Species	Diet	Clearance Rate (L h^{-1} g^{-1})
Kryger and Riisgard (1988)	4	lab algae	1.11
Pusch et al. (2001)	2	field seston	0.38
Gatenby (2000)	3	lab algae	1.72
Silverman et al. (1995, 1997)	5	lab bacteria	0.77
Patterson (1984)	1	lab algae	0.38
Vanderploeg et al. (1995)	1	lab algae	1.45
Gatenby & Kreeger (2003)	6	field seston, lab algae	0.23
Kreeger (2011)	3	field seston	0.96
		Mean >	**0.875**



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Estimated Water Filtration

Bed Clearance Rate (gal day^{-1})	Typical TSS Filtration (metric tons DW day^{-1})
411,867	0.54
4,007,906	5.29
1,280,524	1.69
578,456	0.76
6,278,754	**8.29**

	Quads (n)	Mussels per (# m^{-2}) Average	St (r	el Dry nt	Typical Clearance Rate (L hr^{-1} g DTW^{-1})	Typical Clearance Rate (gal day^{-1} g DTW^{-1})	Bed Clearance Rate (gal day^{-1})	Typical TSS Filtration (metric tons DW day^{-1})
Site 1	21	5.5		0	0.875	5.55	411,867	0.54
Site 2	27	30.1		45			4,007,906	5.29
Site 3	24	17.6		25			1,280,524	1.69
Site 4	24	10.8		26			578,456	0.76
4 Bed Totals>	**96**	**16.8**		**07**			**6,278,754**	**8.29**

Observations

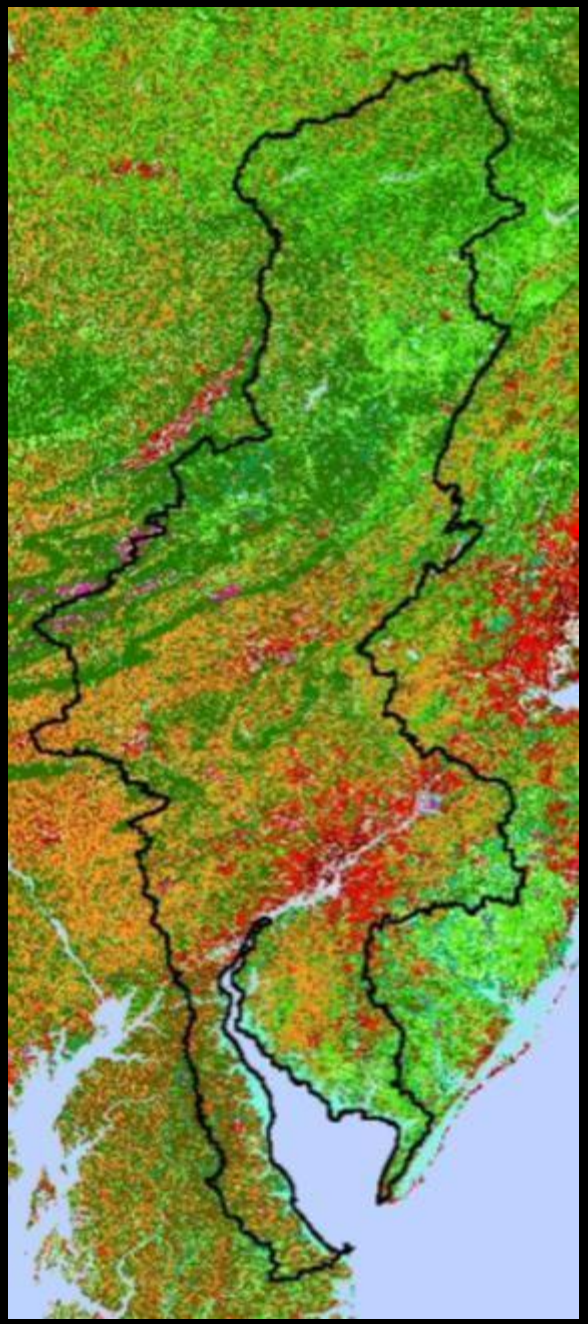
- Potential filtration of 6.3 million gallons per day for these 4 beds is:
  - 2.5% of freshwater inflow from the Delaware River; and
  - 1.6% of drinking water withdrawals for Philadelphia
- Estimated suspended solids removal of 8.3 metric tons per day is:
  - 121 times that by mussels in 6-mile reach of Brandywine River
- More beds exist, especially in New Jersey
- Study is limited to shallow subtidal shorelines, mussel densities increased with depth to limit of sampling
- Water processing potential may not reflect actual water filtration
- Many expected suitable sites had few or no mussels, especially where bed stability appeared compromised; habitat restoration would benefit mussel populations and ranges

Summary

- Freshwater mussels are the most imperiled animals nationally and locally
- Current freshwater mussel populations in the tidal Delaware River are abundant enough to measurably help sustain water quality
- For these reasons, critical habitat for mussels needs to be mapped and protected
- Populations are far below historic levels basin-wide, and mussel restoration would promote water quality and other benefits
- More research is needed on physiological ecology of mussels identify fates of filtered material and improve ecosystem service models


Thanks to Our Funder:
Pennsylvania Coastal Zone Management Program
www.DelawareEstuary.org

Extra Slides



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.

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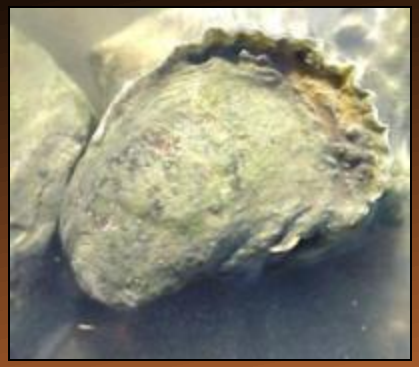
Kreeger

>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 Mussel Recovery Program

1. **Surveys**
   - Establish current range and density for historically present species
   - Identify candidate areas to be conserved and/or restored
   - Qualitative (rapid) and Quantitative (intensive)
   - Delineate critical habitat to be protected
2. **Restoration Suitability Tests**
   - Assess if candidate restoration sites can sustain healthy mussel assemblages
3. **Reintroduction**
   - Transplant gravid broodstock from healthy extant populations nearby
   - Monitor success
4. **Propagation**
   - Produce genetically appropriate seed mussels in hatcheries for restocking
5. **Education**
   - Build awareness for mussel conservation and holistic restoration
6. **Promote Habitat and Water Quality Improvement (e.g. dam removal)**

Freshwater Mussel Recovery Program

Goals Based on Ecosystem Services