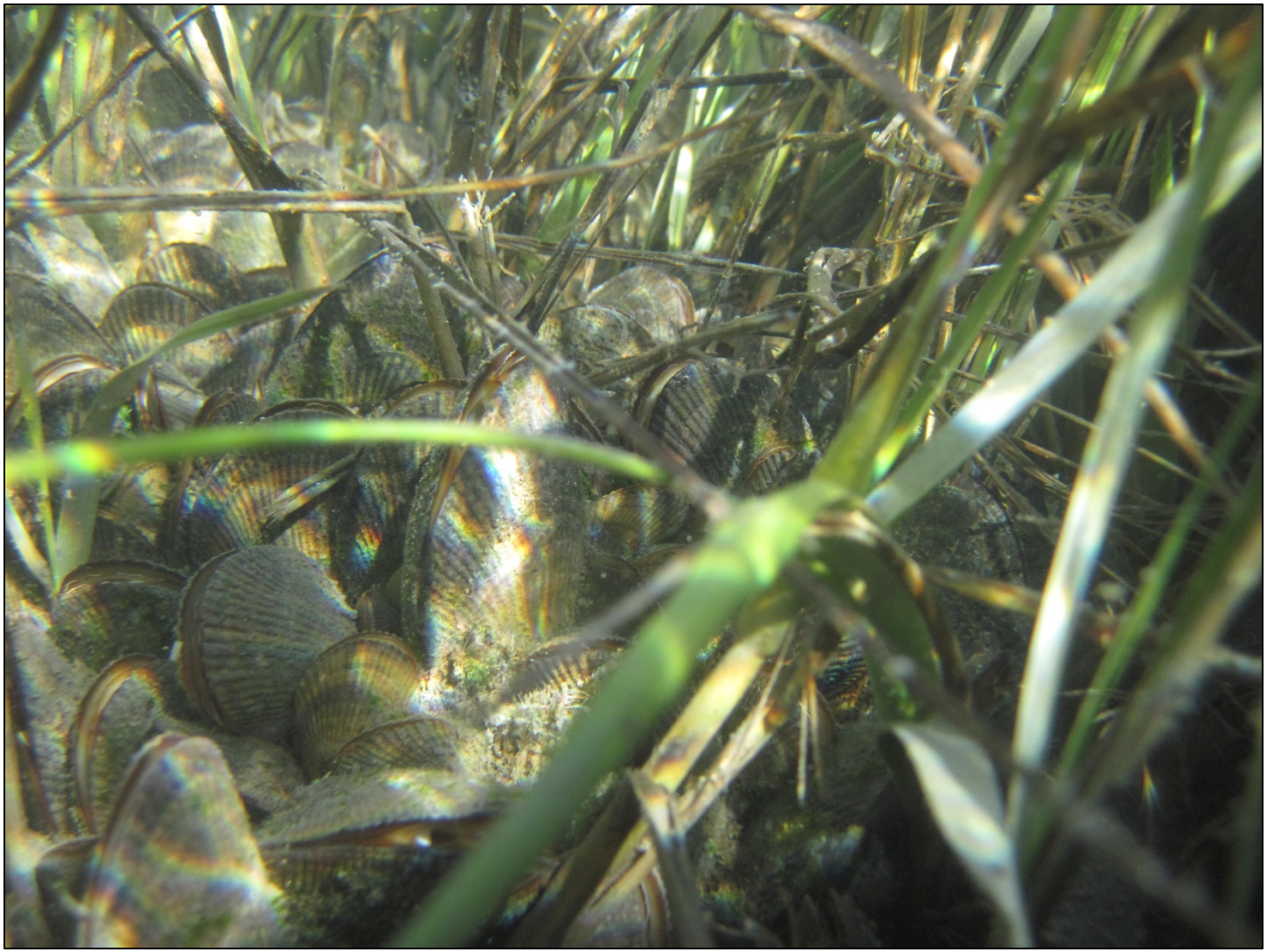
GEOSPATIAL VARIATION OF RIBBED MUSSEL (*GEUKENSIA DEMISSA*) ECOSYSTEM SERVICES ACROSS THE SALT MARSH LANDSCAPE

Joshua Moody, Danielle Kreeger and Elizabeth Watson
Delaware Department of Natural Resources and Environmental Control

Wetlands Conference
February 2, 2016
Wilmington, DE

Ribbed Mussels: Functionally Dominant Bivalve of Eastern US Salt Marshes

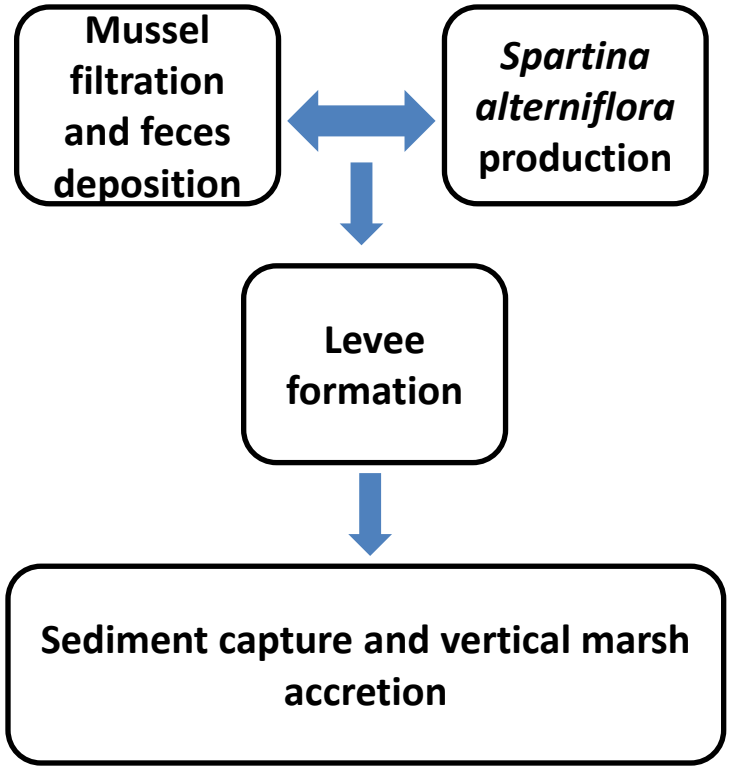
(Kuenzler 1961; Lent 1969; Jordan and Valiela 1982)



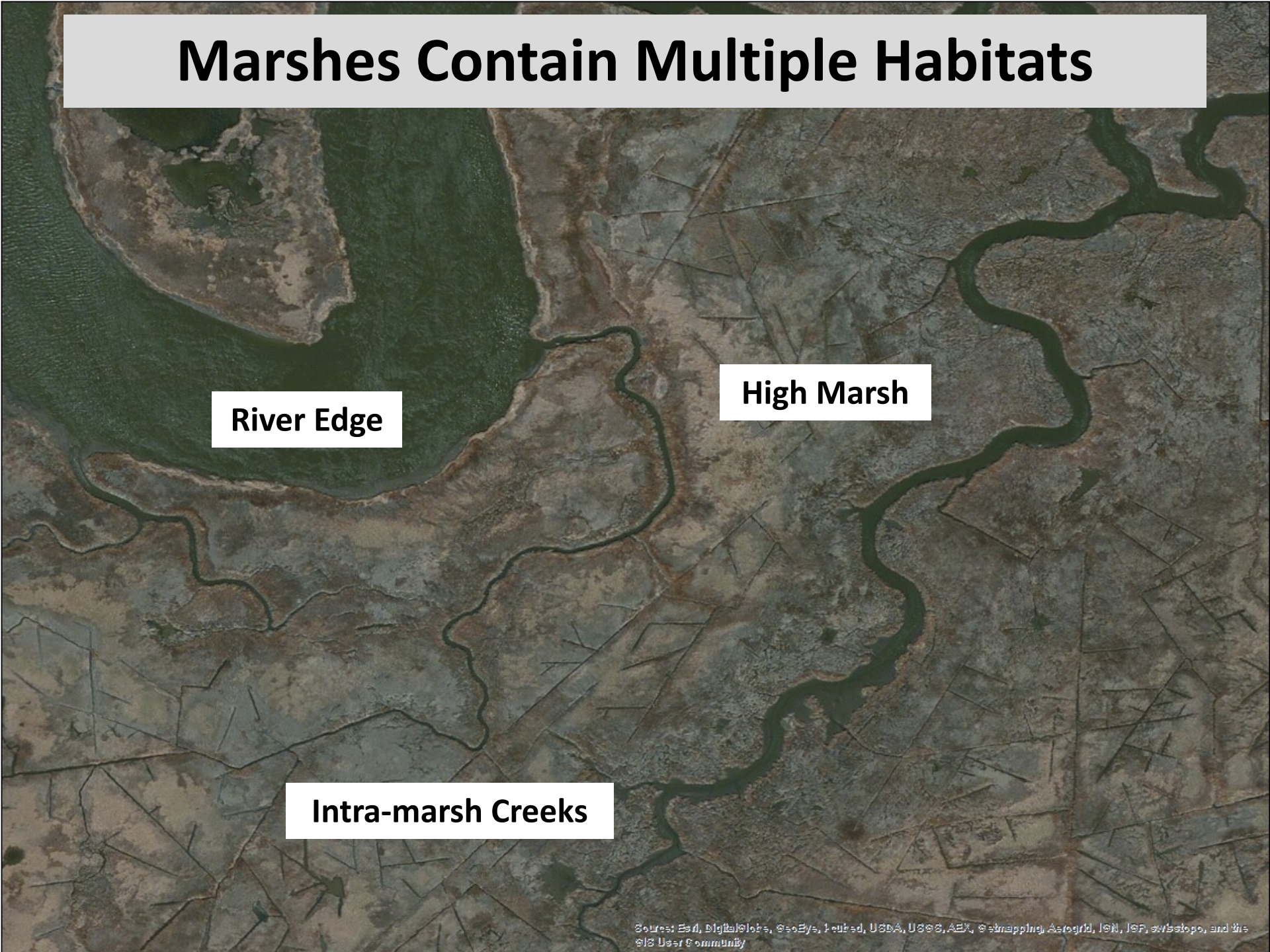
Ecosystem Services: Nutrient Uptake and Marsh Surface Accretion

Nutrient Input to Estuarine Waters

Vertical Growth and Levee Building



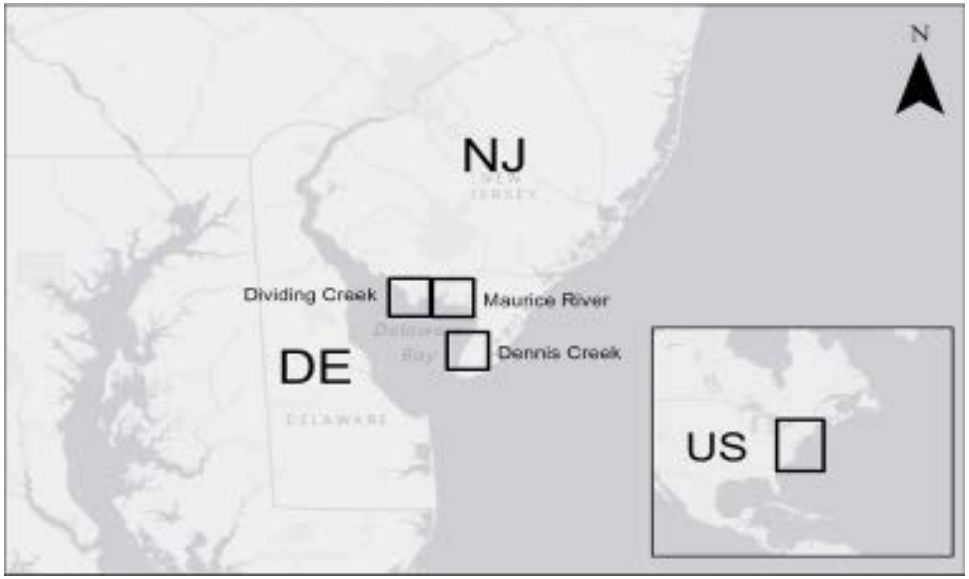
Marshes Contain Multiple Habitats



What is Spatial Distribution of Ecosystem Services?

1. Spatial distribution of water processing to meet nutritional demands (Clearance Rate)
2. Spatial distribution of TSS and Removal (Filtration Rate)
3. Does mussel biomass differ across marshes and habitat?
4. How does spatial variation of habitat size within marshes concentrate ecosystem services?

Study Design



Three Marshes

1. **DC: Dividing Creek**
2. **DN: Dennis Creek**
3. **MR: Maurice River**

One Marsh

1. **Cogshall Cove: Abbreviated as RI**

Physiology by Marsh and Habitat

Mussels by Habitat/Season (n=8)

Water from each River: TSS and T_0= Particulate N

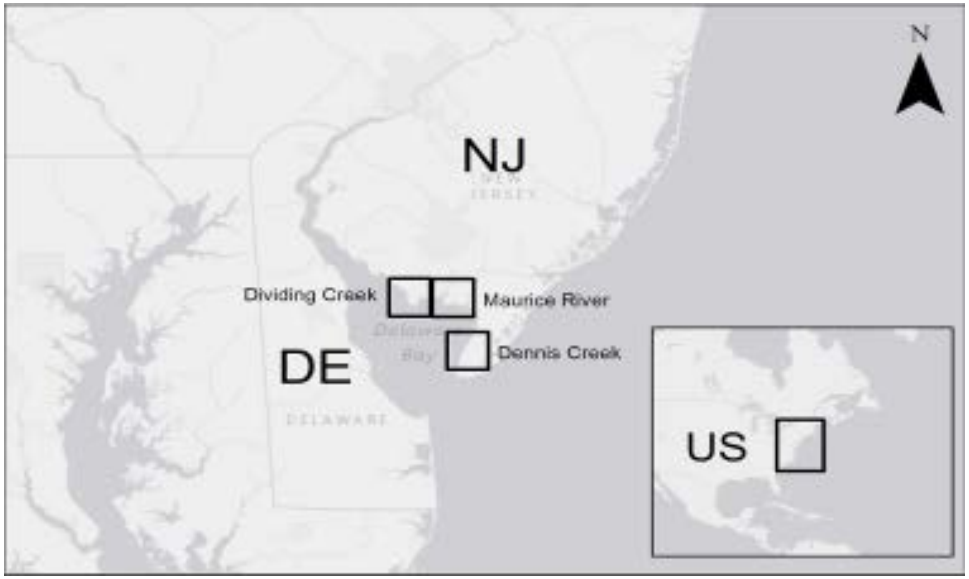
Physiology and Physical Metrics

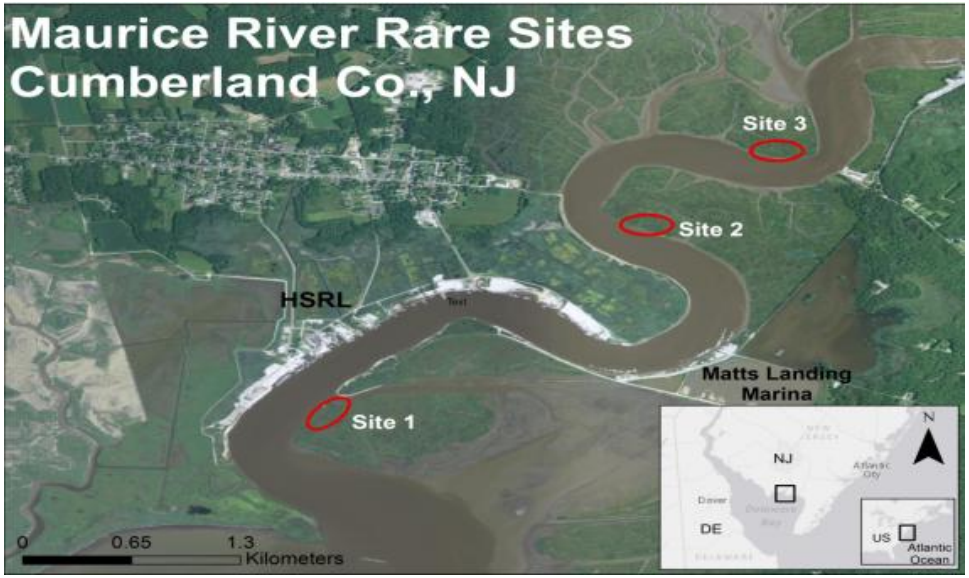
n=5 samples/animal, 2hrs

NH_3 and Feces

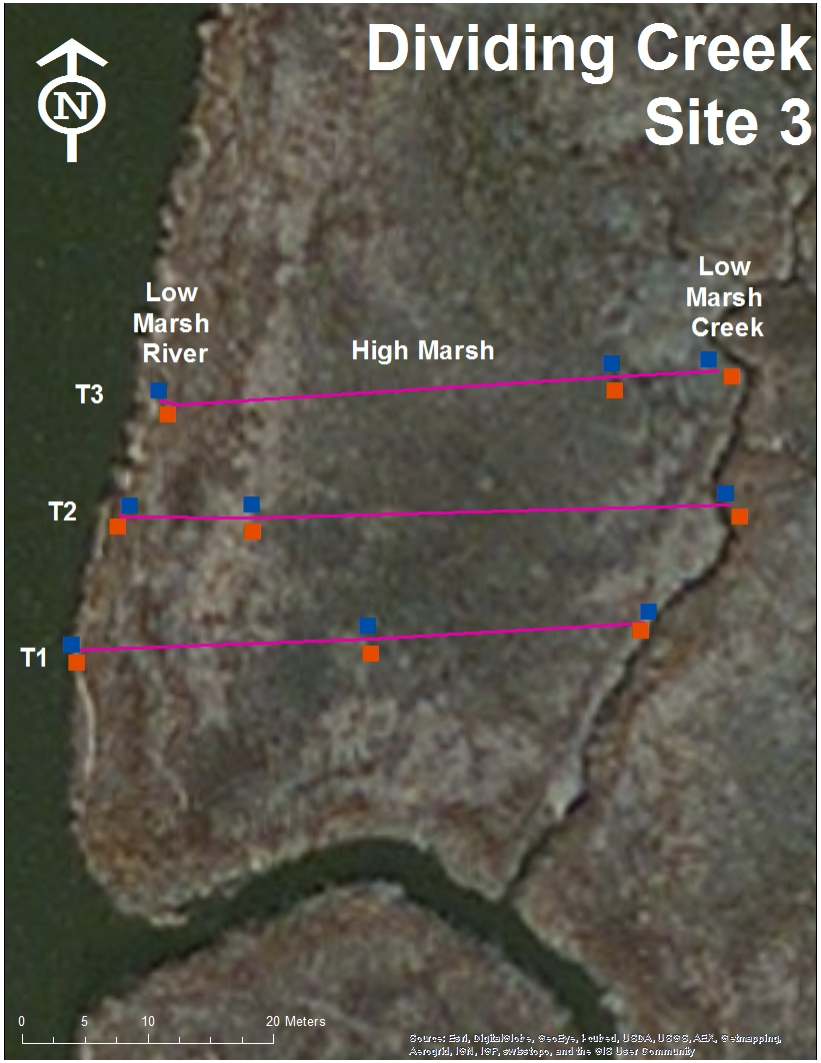
Shell height and dried Tissues weights: Allometric Relationships

Study Design





Study Design



- Three transects ~10m apart
  - Low Marsh River
  - High Marsh
  - Low Marsh Creek

Mussel Density

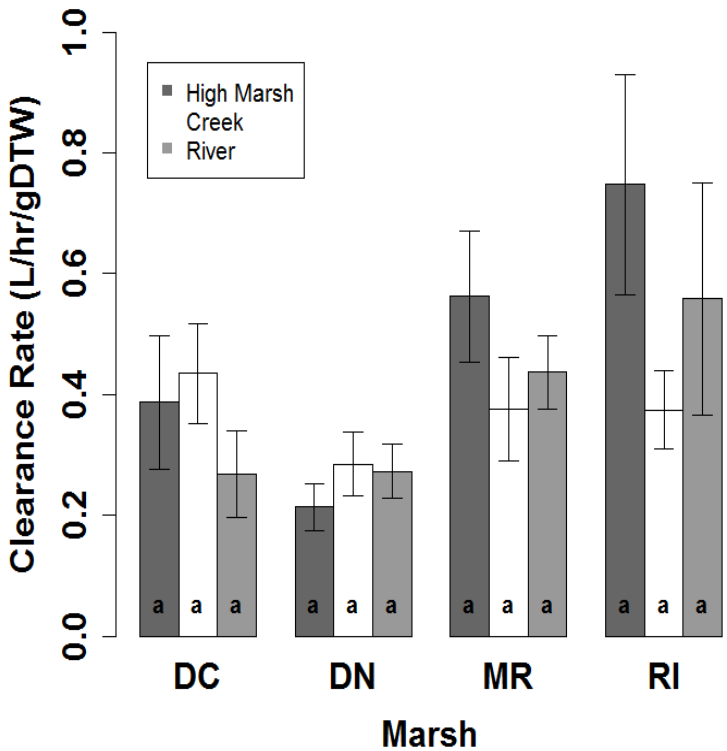
- 6 quads/habitat/site
- gDTW: Allometric relationships: Shell length:DTW

What is Spatial Distribution of Particle Removal Services?

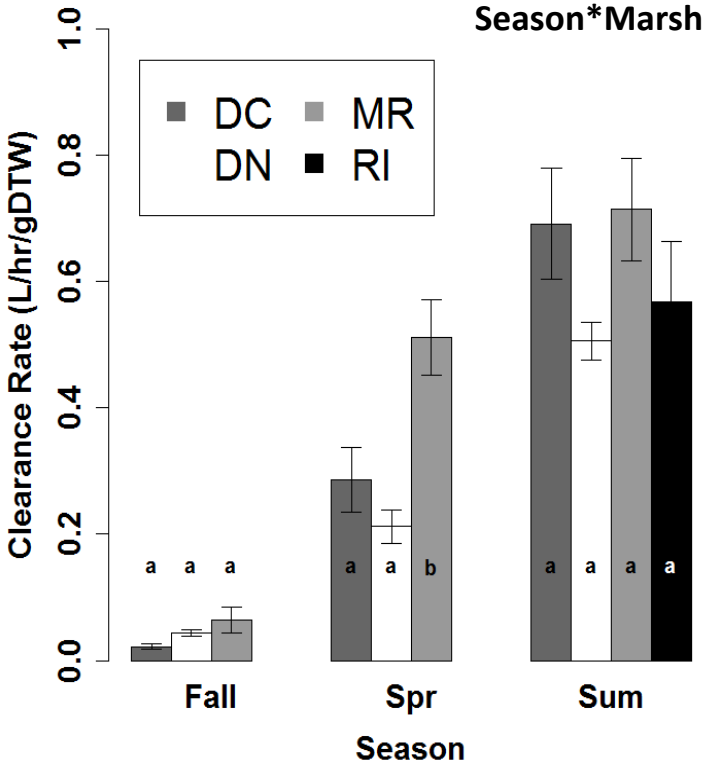
1. Spatial distribution of water processing to meet nutritional demands (Clearance Rate)
2. Spatial distribution of TSS removal (Filtration Rate)
3. Does mussel biomass differ across marshes and habitat?
4. How does spatial variation of habitat size within marshes concentrate ecosystem services?

Clearance Rate Varies Seasonally, with Minimal Spatial Variation

Summer: Clearing Water at Maximum Capacity

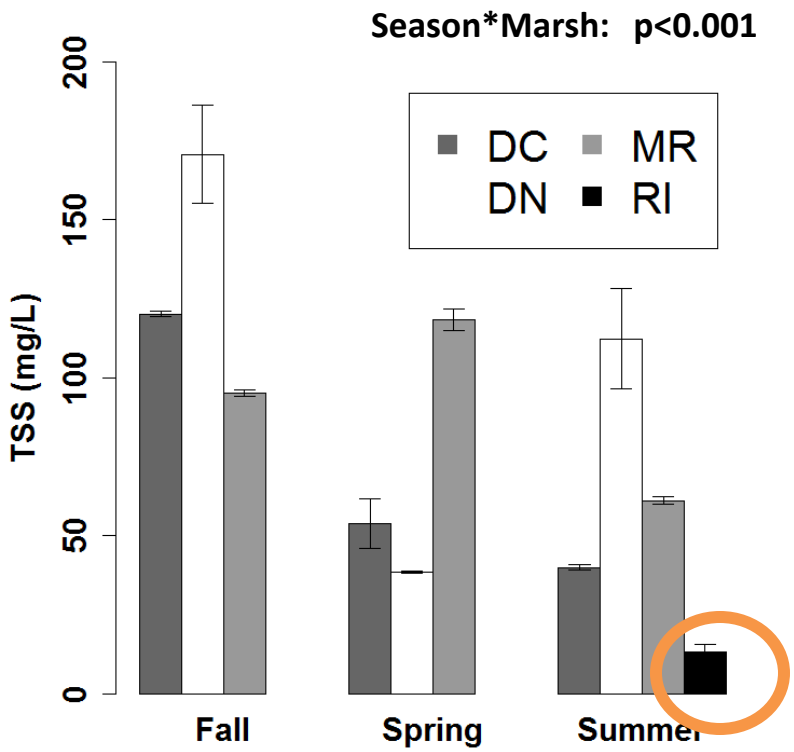


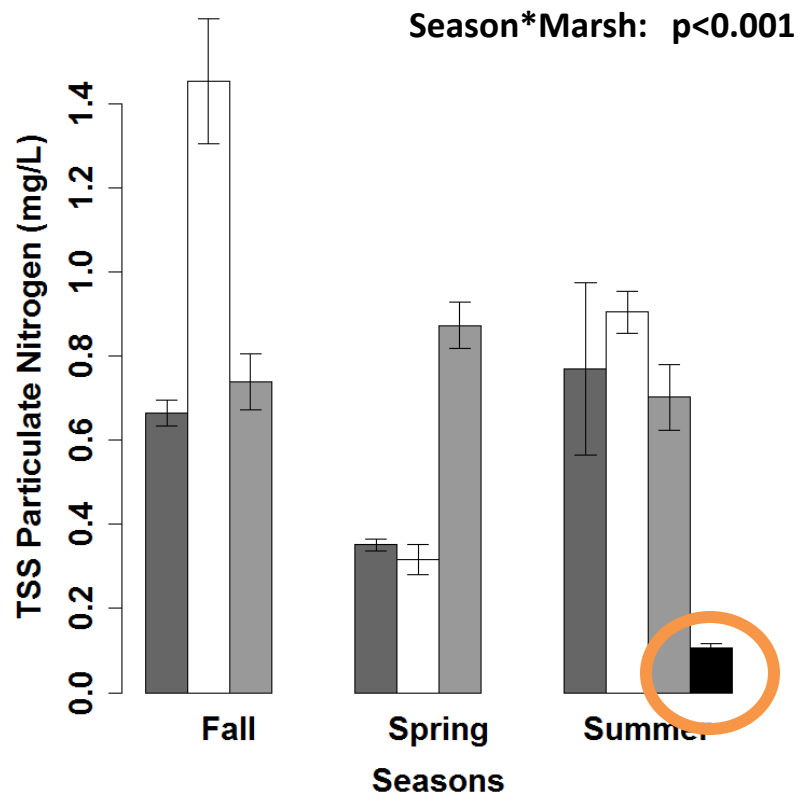
Season: p<0.001*
Marsh: p<0.002*
Season*Marsh: p>0.07



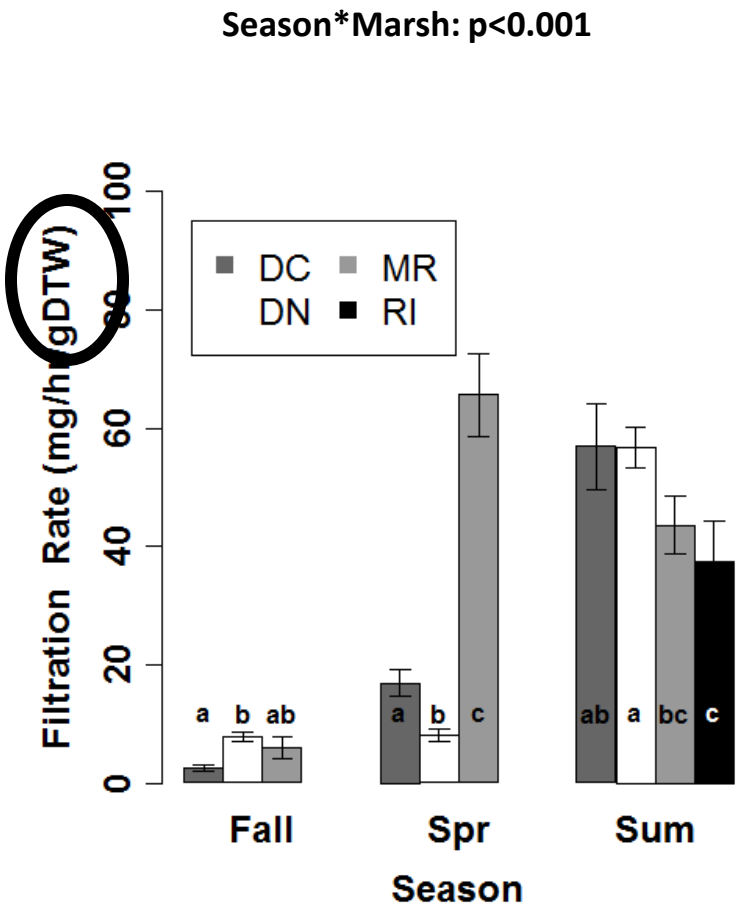
Literature: Widdows and Bayne (1971); Widdows (1976); Willows (1992)

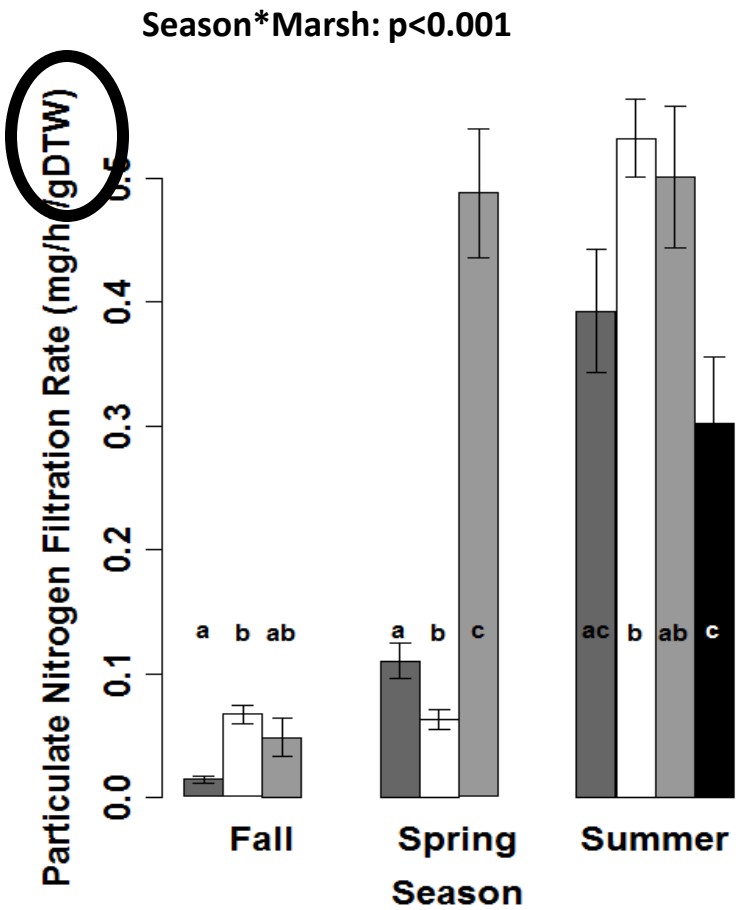
TSS and Particulate Nitrogen Vary by Season and Marsh





Filtration Rate Dependent on Season and Local Particulate Concentration





Seasonality from Clearance Rates and Spatial component from local TSS Levels

Mussel Size and Abundance Across Salt Marsh Habitats

1. Clearance Rate: dependent on Temperature (Seasonality); minimal spatial dependency
2. Filtration Rate of TSS and Particulate Nitrogen: dependent on local seasonal concentrations
3. Does mussel biomass differ across marshes and habitat?
4. How does spatial variation of habitat size within marshes concentrate ecosystem services?

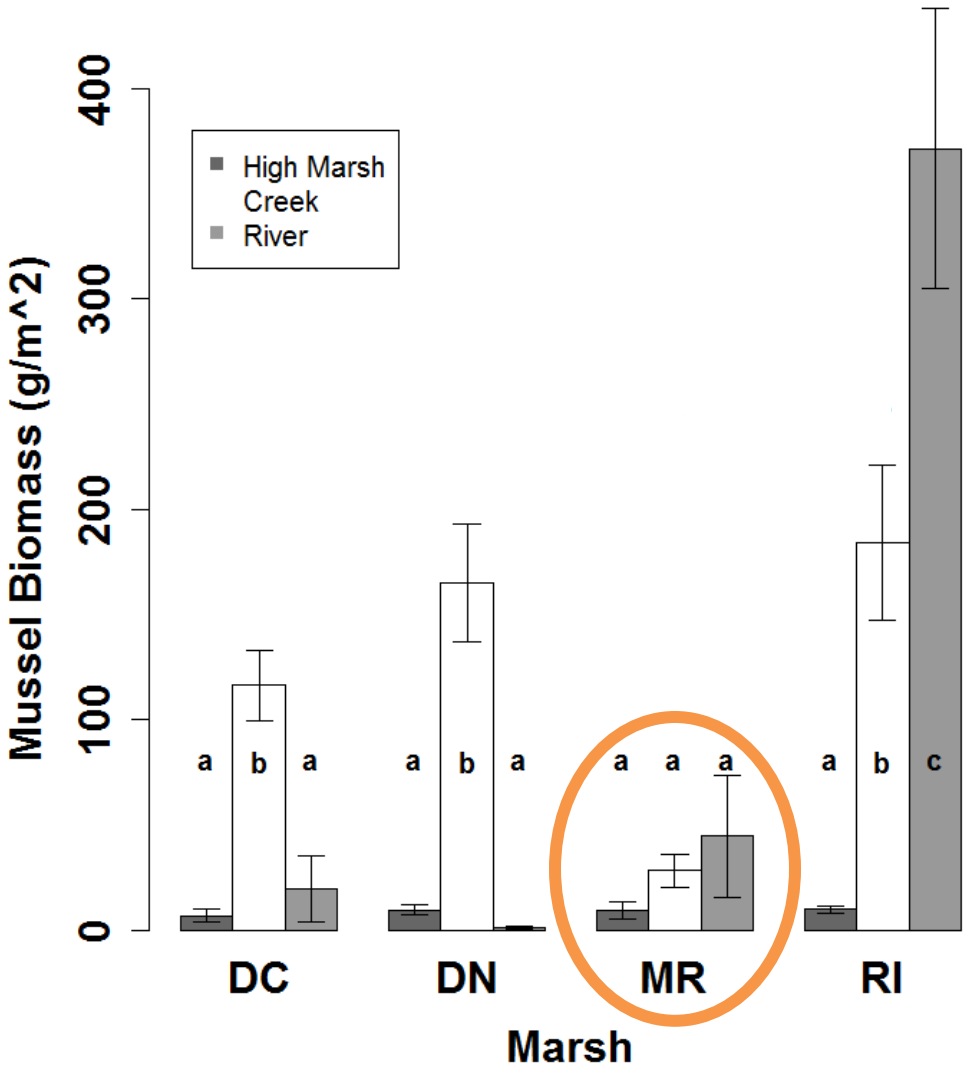
Mussel Biomass Low in High Marsh

New Jersey

Generally Concentrated in Creeks

Rhode Island

High on Marsh Edge and Creek



Spatial Variability of Salt Marsh Habitats

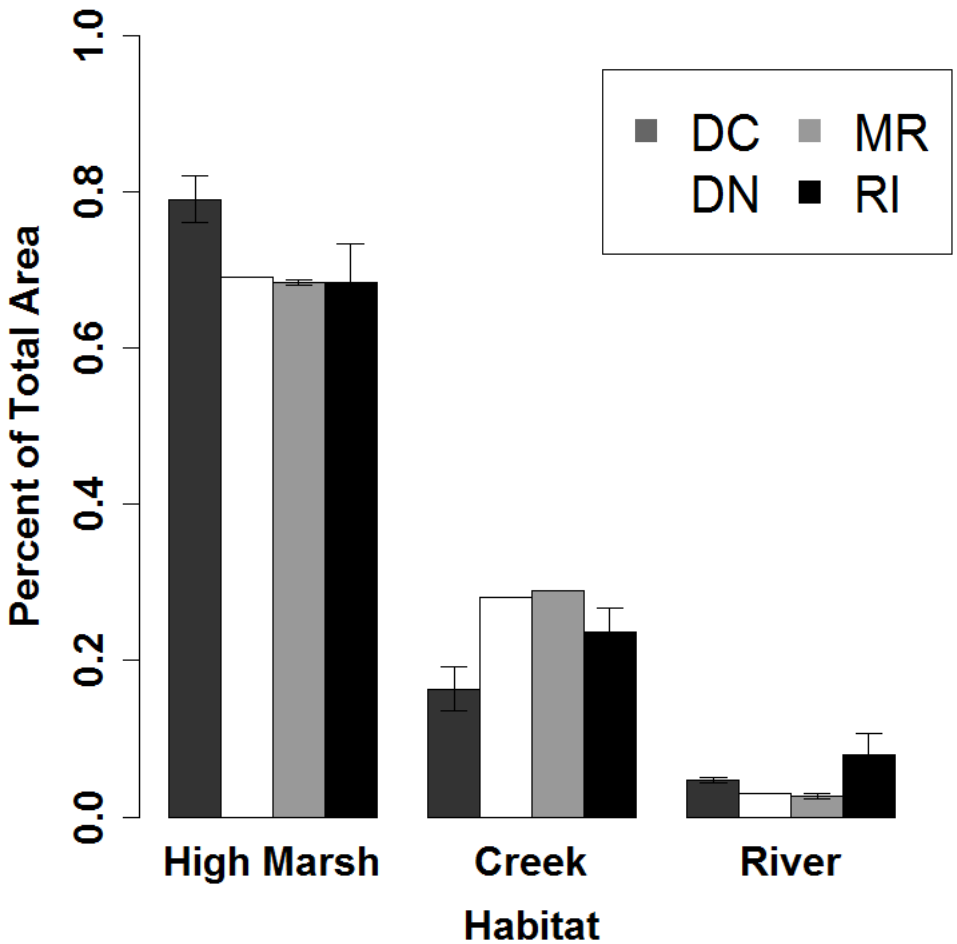
1. Clearance Rate: dependent on Temperature (Seasonality); not spatially dependent
2. Filtration Rate: dependent on local seasonal concentrations
3. Mussel biomass differs across habitats
   a. NJ: High in Creeks; Low along River/High Marsh
   b. RI: High in Creeks & along River; Low in High Marsh
4. How does spatial variation of habitat size within marshes concentrate ecosystem services?

Ecosystem Services Across Salt Marsh Habitats

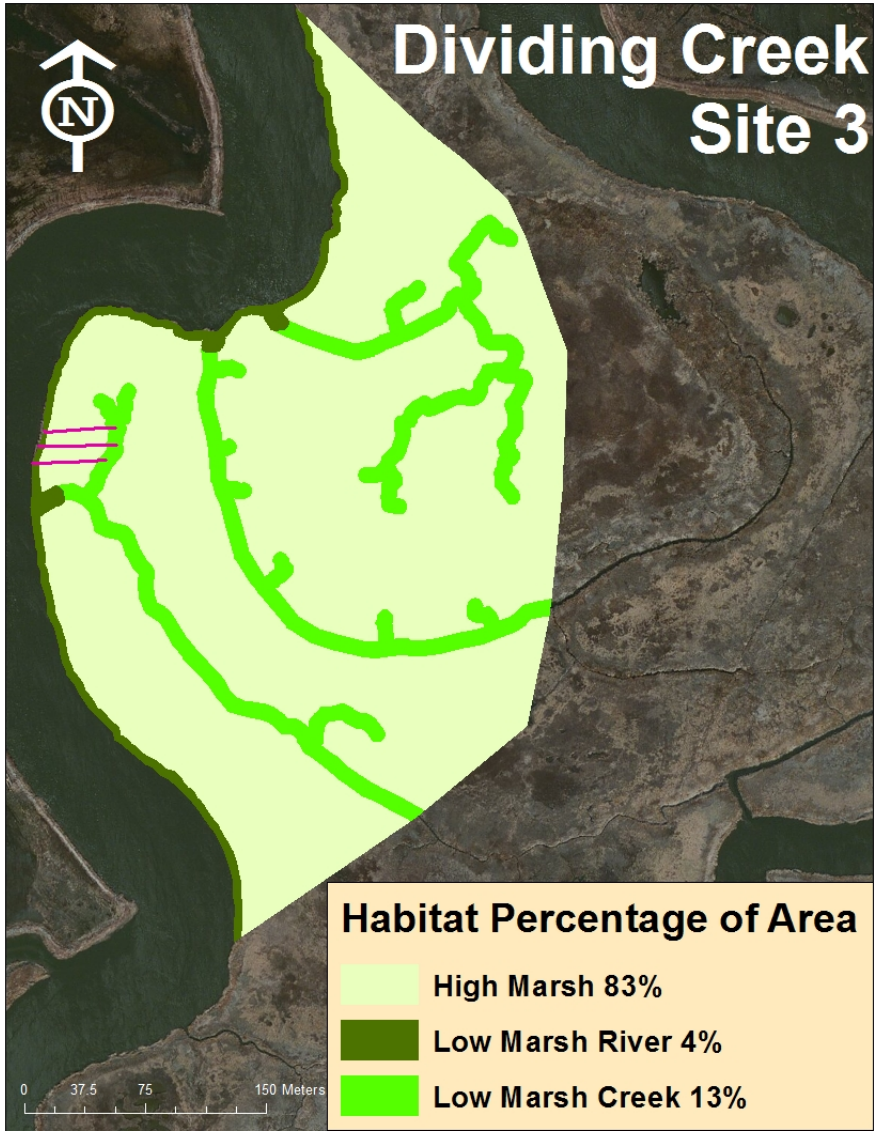
1. **300m Buffer Centered on Middle Transect**
   - Not crossing main channel
2. **Spatial Variability of Habitats**
   - Digitized edge/creeks IKONOS 2014 (1:300)
   - LMC/LMR 5m buffer on digitized edge/channel*
3. **Mussel Biomass**
4. **Filtration Rate**

***Deegan, 2012; PDE MACWA Report, 2014**

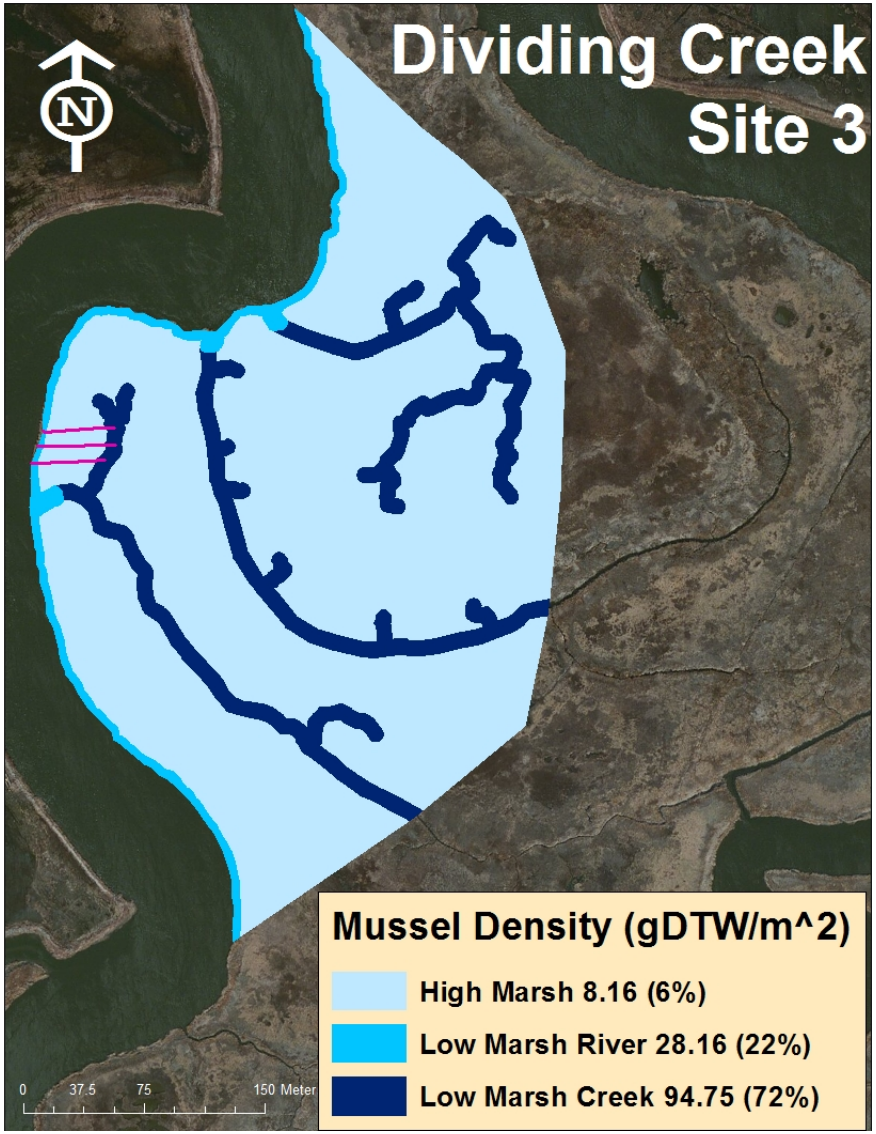
High Marsh is Significantly Larger



Habitat Variability



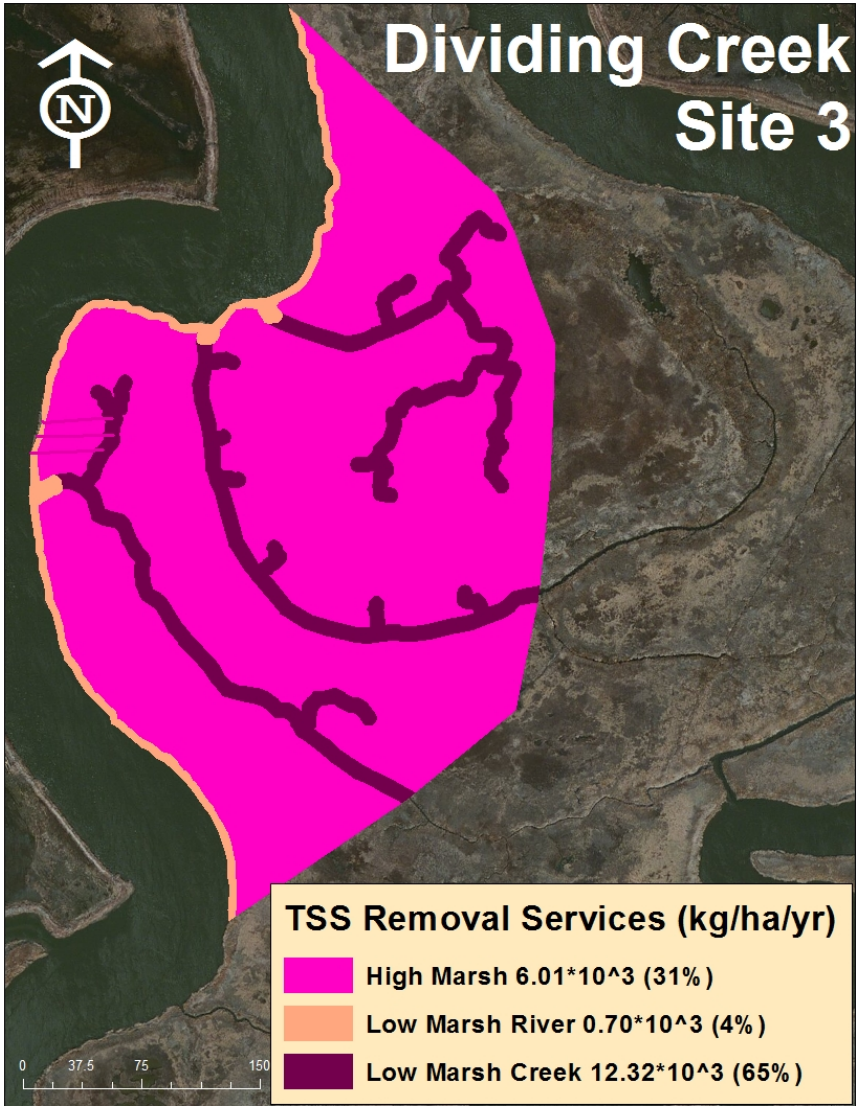
Mussel Variability

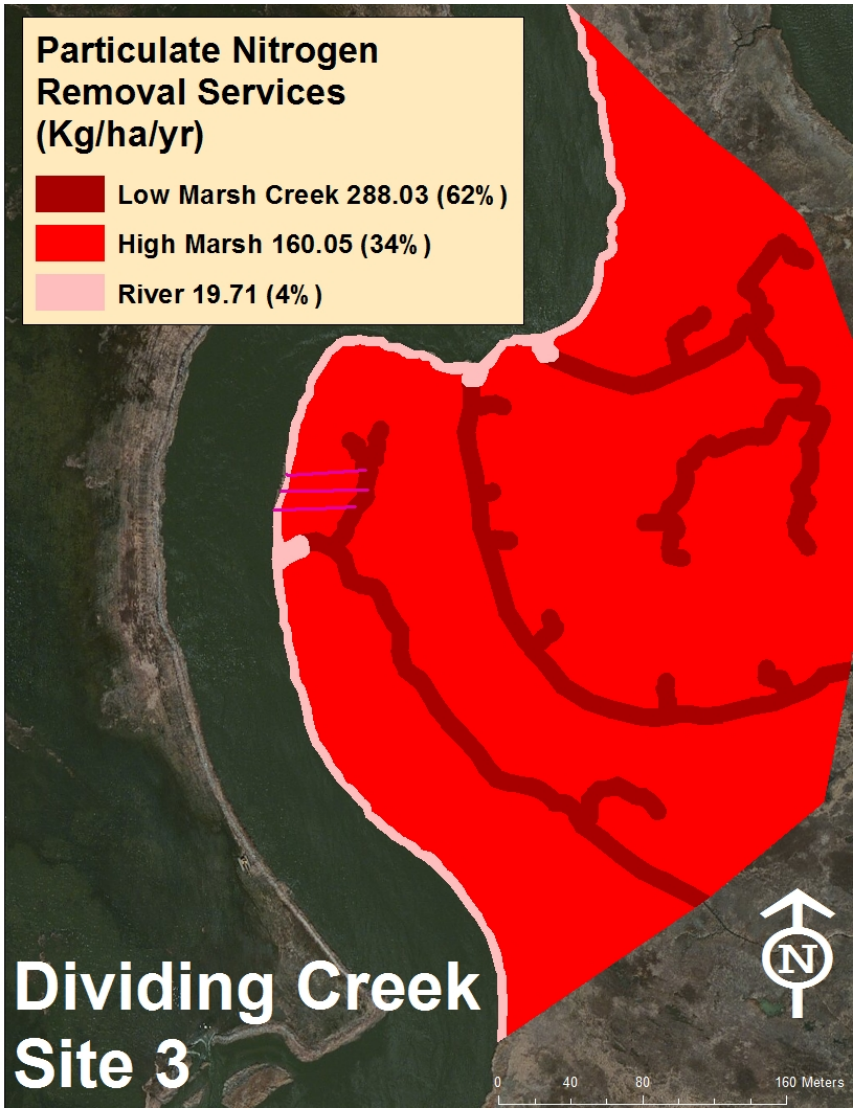


Calculation: Ribbed Mussel TSS Removal by Habitat Dividing Creek 3

		Low Marsh River	High Marsh	Low Marsh Creek
1	Mussel Biomass (g DTW m^{-2})	28.16	8.16	94.75
2	Clearance Rate (L hr^{-1} g DTW^{-1})	0.20	0.28	0.32
3	Daily Clearance Rate (L d^{-1} g DTW^{-1}) (assuming 12hr immersion; correct with hydroperiod data)	2.40	3.41	3.85
4	Clearance Rate/Area (L d^{-1} m^{-2}) (1 & 3)	67.48	27.81	364.47
5	[TSS] (mg L^{-1})	71.26	71.26	71.26
6	TSS Removal Services (mg d^{-1} m^{-2}) (4 & 5)	$4.81*10^3$	$1.98*10^3$	$25.97*10^3$
7	Area Percentage (ha)	0.04	0.83	0.13
8	Area Wide TSS Removal Services by Habitat (Kg ha^{-1} yr^{-1}) (6 & 7)	$0.7*10^3$	$6.01*10^3$	$12.32*10^3$

Ecosystem Service Mapping by Habitat





Ribbed Mussel Ecosystem Services: Gross Particle Filtration Rates

Marsh	Average Mussel Biomass (g DTW m^{-2})	Average Gross TSS Removal Services (Metric Tons/ha/yr)	Average Area Wide Gross Nitrogen Removal (Kg/ha/yr)
Dividing Creek	142.22	44.58	275.36
Dennis Creek	125.46	74.41	649.34
Maurice River	81.85	41.13	350.44
Rhode Island	598.00	37.88	305.32

Ribbed Mussel Gross TSS and Nutrient Removal

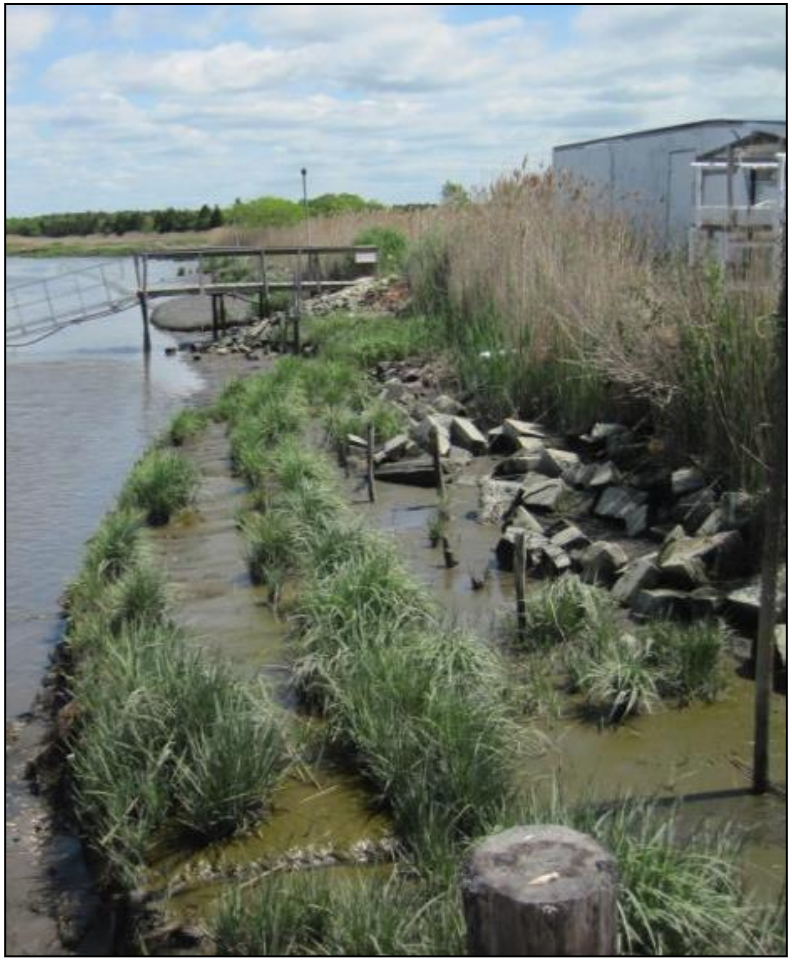
Habitat	Region	Average Square Miles of Habitat	Average Mussel Biomass (g DTW m^{-2})	Average TSS Removal Services (Kg/ha/yr)	Average Area Wide Nitrogen Removal (Kg/ha/yr)	Perecentage Gross TSS Removal	Percentage Gross Nitrogen Removal
High Marsh	New Jersey	304306.53	25.55	32,802.22	316.72	20.90%	24.84%
	Rhode Island	58561.18	28.78	17,906.17	144.33	15.76%	15.76%
Low Marsh Creek	New Jersey	91424.66	259.08	115,827.97	922.95	73.81%	72.38%
	Rhode Island	14173.17	651.61	62,290.75	502.07	54.81%	54.81%
Low Marsh River	New Jersey	20080.84	64.91	8,289.06	35.47	5.28%	2.78%
	Rhode Island	5073.93	113.61	33,442.35	269.55	29.43%	29.43%

Ribbed Mussels Not Utilizing All Available Habitat in NJ

NJ Experiencing Higher Erosion Rates Than RI: River Edge Data

Marsh	Mussel Biomass (g DTW m^{-2})	Lateral Marsh Movement (m yr^{-1})	Elevation (m NAVD88)	TSS Particulate Nitrogen (mg/L)
Dividing Creek	19.41 ± 15.49	-0.14 ± 0.06	0.37 ± 0.05	0.52 ± 0.03
Dennis Creek	1.07 ± 0.49	-0.43 ± 0.19	0.28 ± 0.06	0.90 ± 0.12
Maurice River	44.41 ± 29.27	-1.18 ± 0.34	0.62 ± 0.11	0.77 ± 0.04
Rhode Island	371.20 ± 66.48	0.05 ± 0.04	0.45 ± 0.04	0.10 ± 0.01

Implications and Application



- Local Ecosystem Services:
  - Seasonal Clearance Rates not spatially dependent
  - Need Info Regarding TSS/Particulate Nitrogen
- Ribbed Mussels as:
  - Water Quality
  - Nutrient Removal
  - Elevation Enhancement
- In Delaware Bay:
  - Suitable Habitat Available
  - Living Shoreline Components

Thank You

- EPA R2
- EPA ORD Narragansett
  - Elizabeth Watson (formerly; now Academy of Natural Science of Drexel University)
  - Marty Chintala
  - Suzanne Ayvazian
- Rutgers Haskin Shellfish Research Laboratory
  - David Bushek
  - Jenny Paterno
- Partnership for the Delaware Estuary
  - Kurt Cheng
  - Angela Padeletti
  - LeeAnn Haaf
  - Jessie Buckner

Ribbed Mussel Ecosystem Services: Biodeposits Across Marsh Surface

Caveats:

1. Resuspension
2. Microbial Transformation

But some portioned was buried

Strong Correlations Between Nitrogen Content of Above and Below Ground Biomass were strongly correlated with Mussel Density

Averaged Across All Sites

55.6 Tons/ha/yr

Translated Across Marsh Surface

5.6 mm/yr