Fish, Crabs, Benthos and Birds: Exploring the Land-water Interface

Land use & shoreline hardening

Denise Breitburg, Matt Kornis
Smithsonian Environmental Research Center
Tim Targett. University of Delaware
Rochelle Seitz. Virginia Institute of Marine Science
Diann Prosser. USGS

Image: www.chesapeakebay.net

SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER 1965–2015

Fish, Crabs, Jellies and Habitat

Denise Breitburg, Matt Kornis, Heather Soulen
Tim Targett

SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER
1965–2015

Outline

- Local Shoreline Effects – Direct use of habitats by macrofauna

Native Wetland

Beach

Riprap

Bulkhead

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- Subestuary Effects – Macrofauna abundance vs. watershed land cover and cumulative shoreline composition

Developed

Cropland

Riparian Forest

Wetland v Hardened

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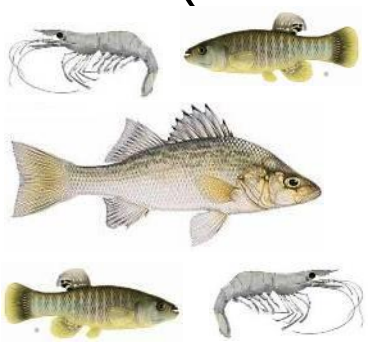
Wetland v Hardened

- *Phragmites australis* vs Native Wetland effects on fish habitat (Tim Targett's lab)



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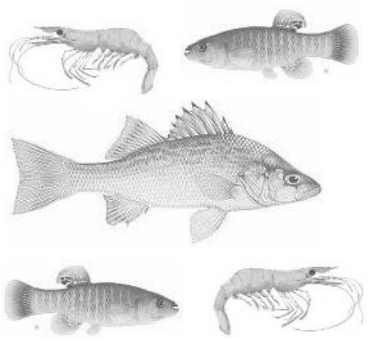
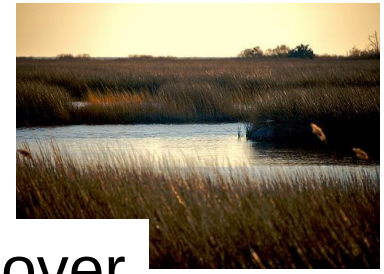
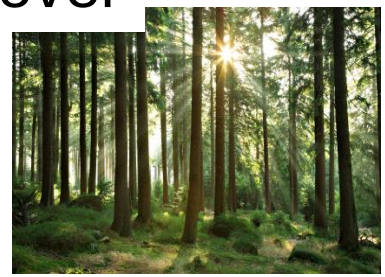


- Hardened shoreline effects on sea nettle recruitment

field sampling



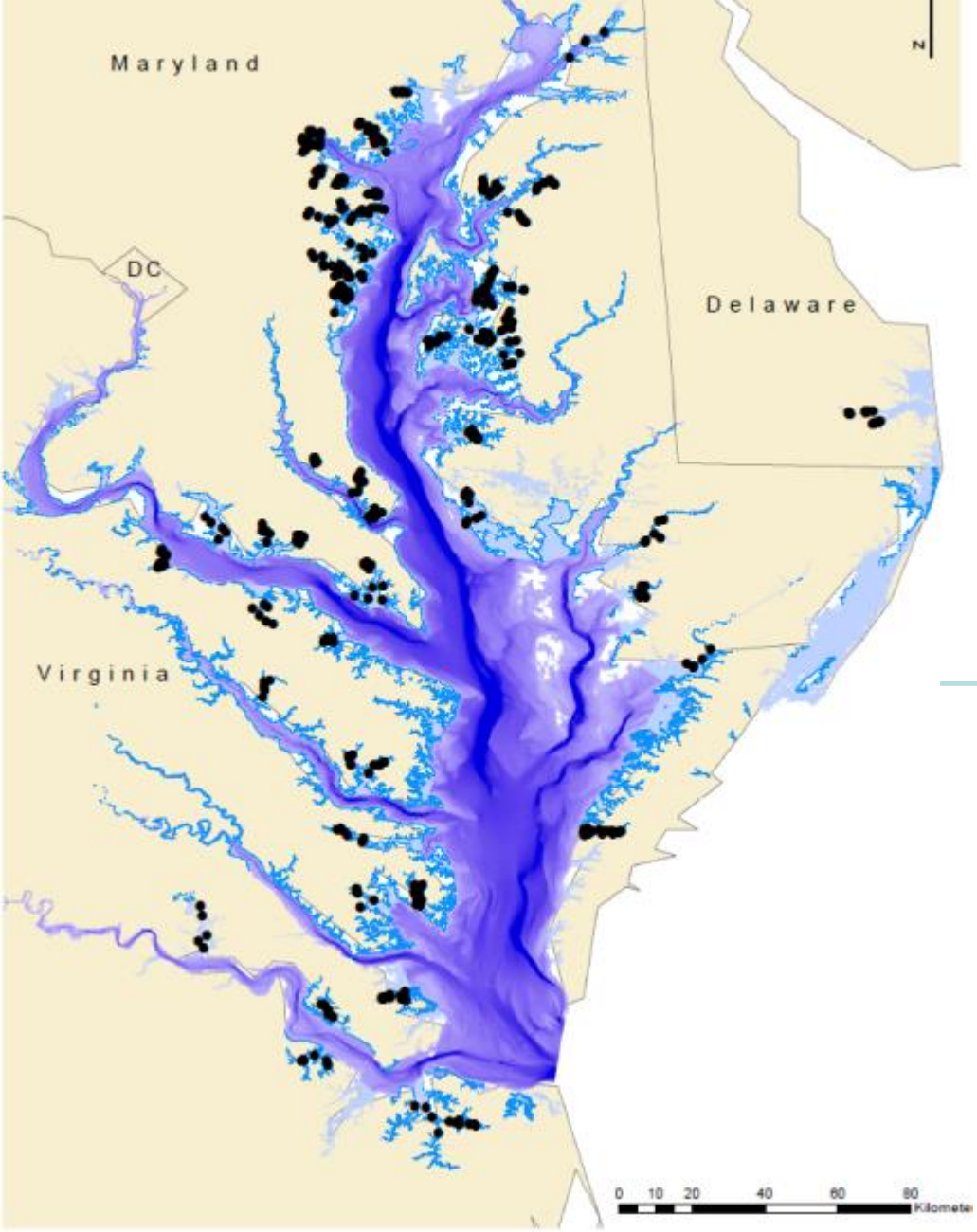
Land Cover



Shoreline hardening

Matt Kornis

Seines reached 3m & 16 m from shore



meta-analysis

- data spanning 45 subestuaries and 648 samples
- ≈800,000 individuals

Data Contributors

Denise Breitburg/Matt Kornis (SERC)
Rochelle Seitz (VIMS)
Donna Bilkovic (VIMS)
Richard Baloskus/Tim Targett (U-Delaware)
Denise Breitburg (SERC)
Ryan King (Baylor U, formerly of SERC)
Jim Uphoff (Maryland DNR)
Steve Giordano & David Bruce (NOAA CBO)
John Jacobs (NOAA Oxford Lab)

Kornis et al., in revision

Examined Abundance Patterns for 16 species

Littoral-Benthic

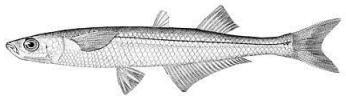

Mummichog


Striped Killifish


Grass Shrimp


Naked Goby

Planktivores


At. Silverside


Bay Anchovy


Atlantic Menhaden


Gizzard Shad


Juv. Centrarchids

Benthivore/Piscivores


Atlantic Croaker


White Perch


Striped Bass


Hogchoker

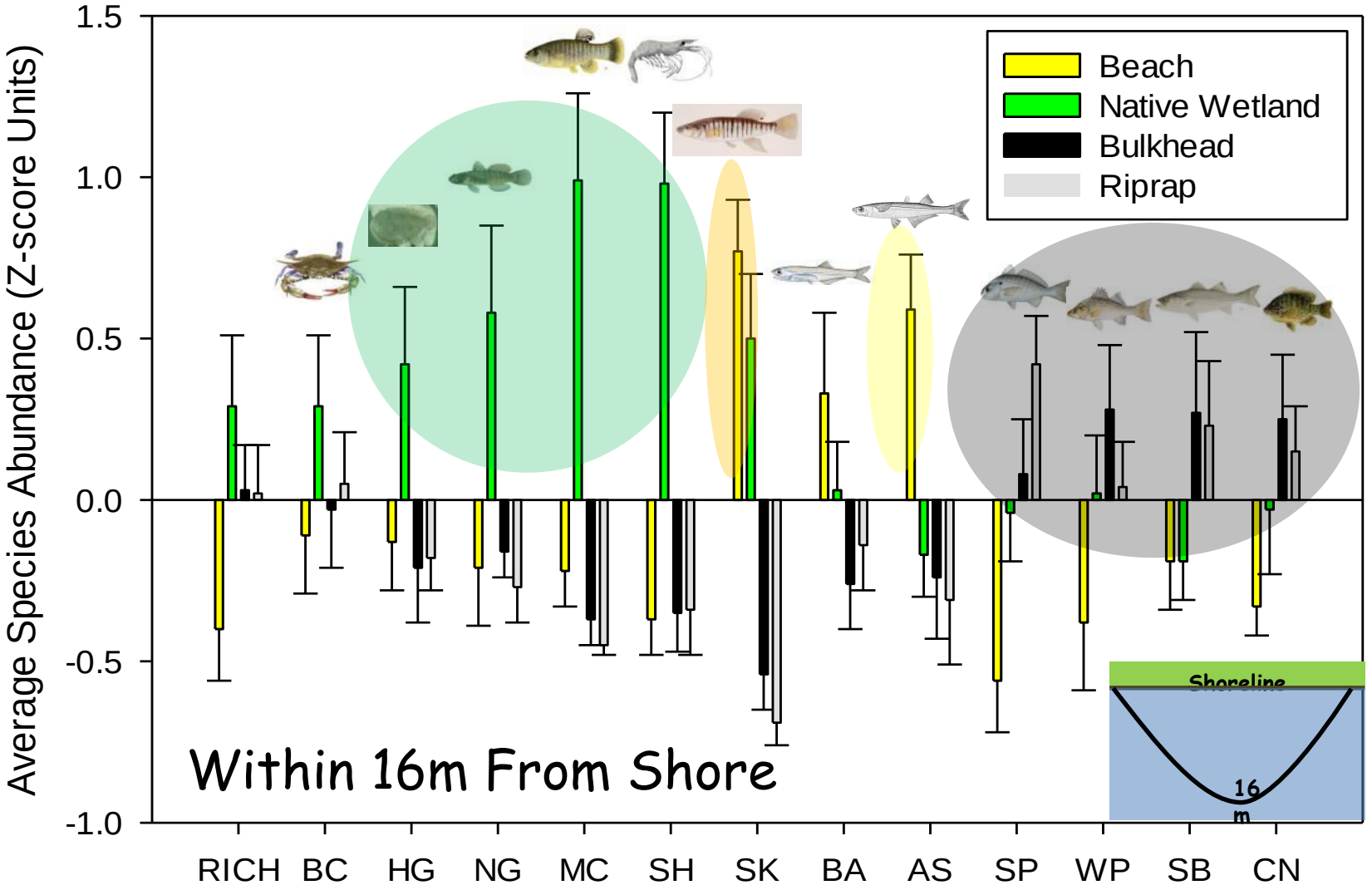

Silver Perch


Adult Centrarchids

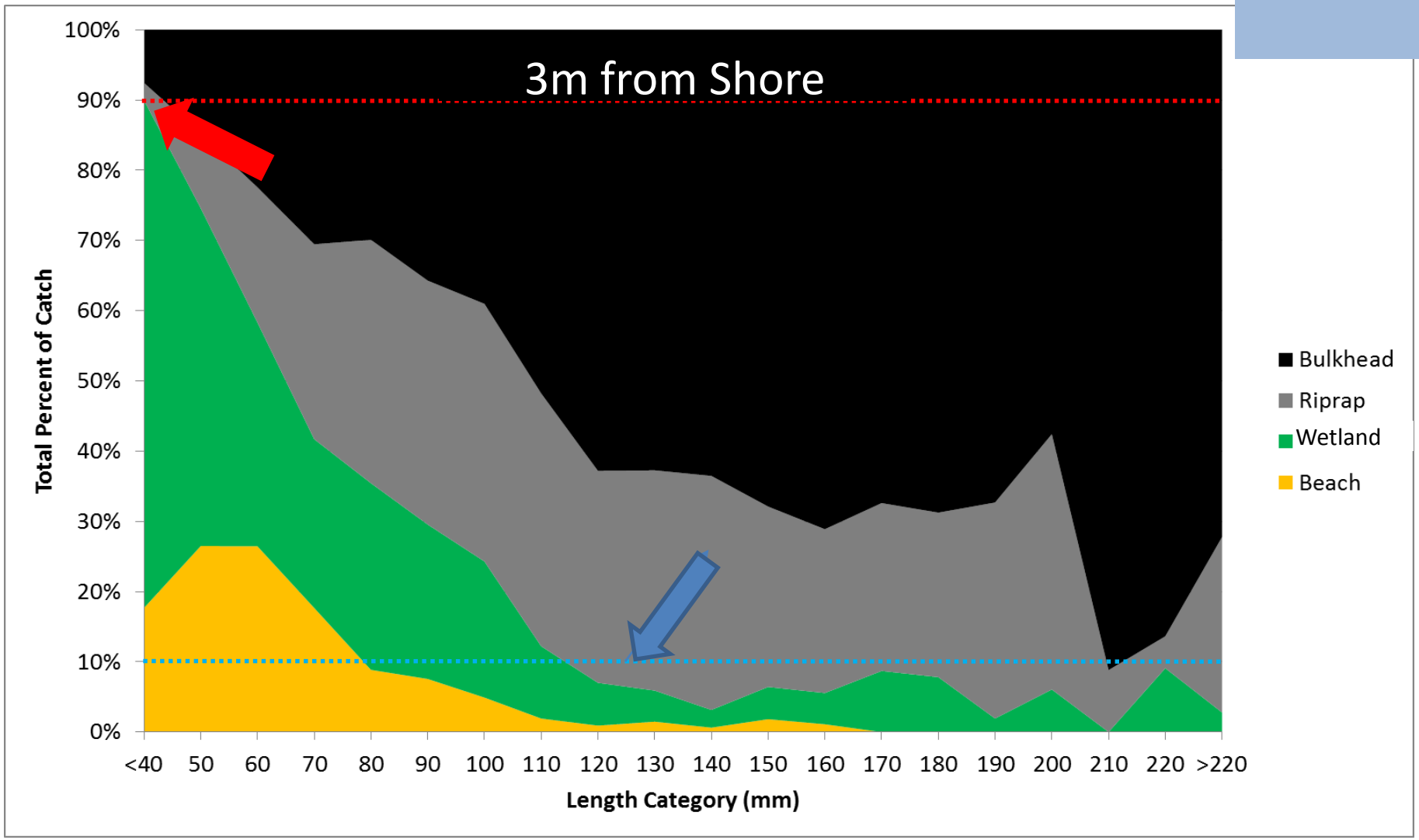

Spot


Blue Crab

1) Bulkhead and riprap shorelines had fewer small demersal species; Riprap was not better than bulkhead

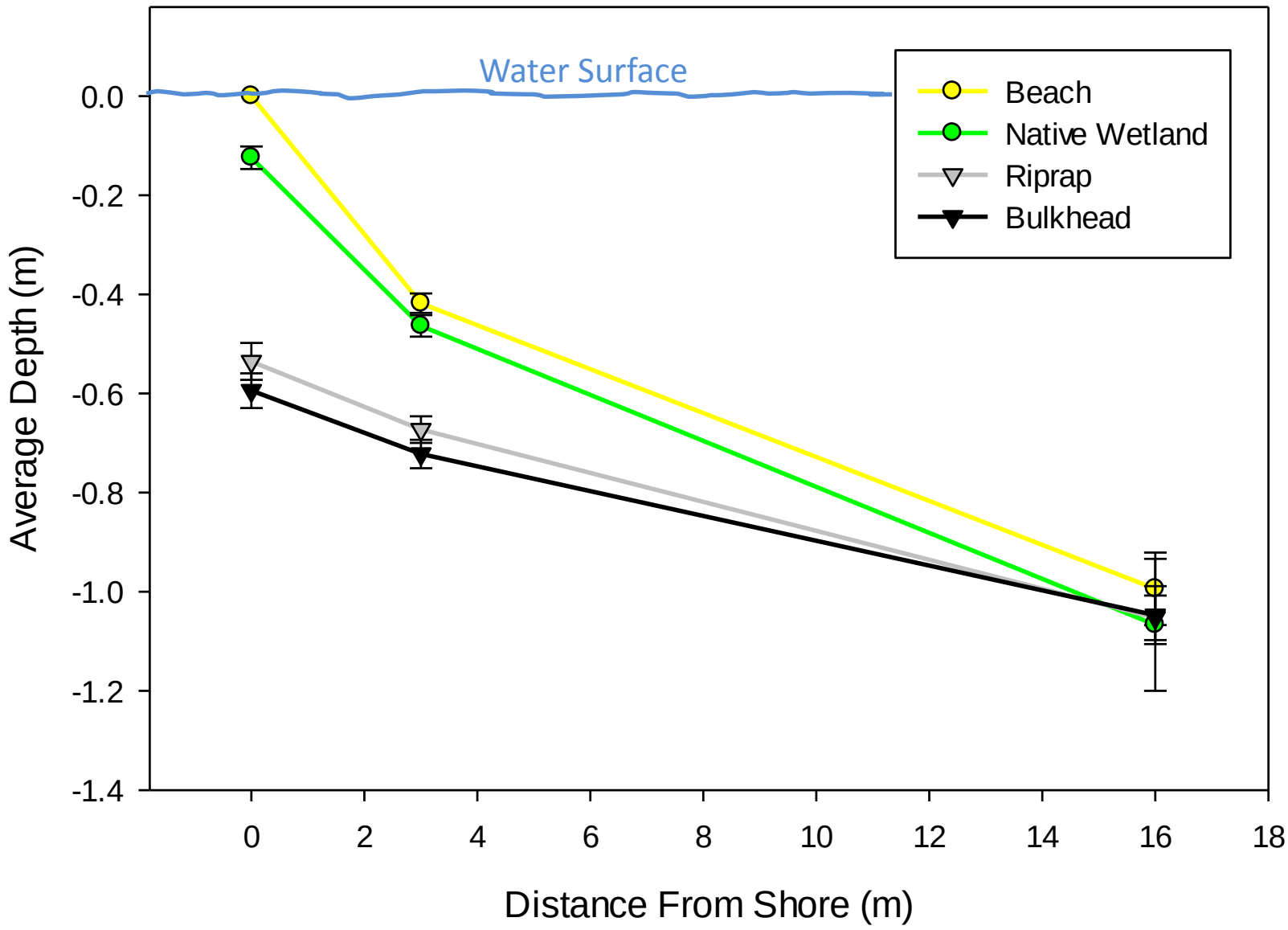


Catch By Size Class



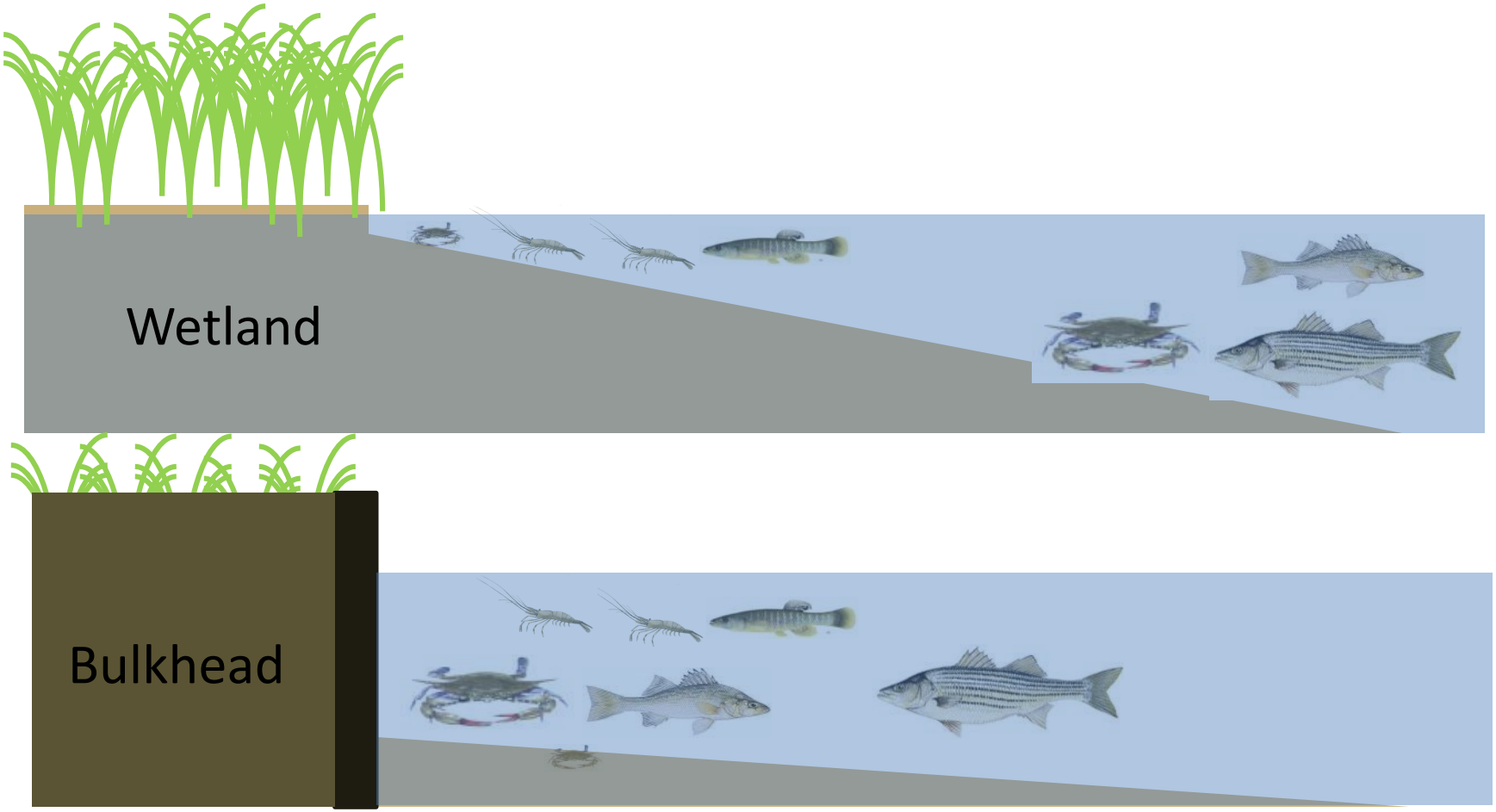
Approximately 90% of fishes ≤ 40mm are captured at natural shorelines (shallow = refuge); Approximately 90% of fishes ≥ 115 mm are captured at altered shorelines (deep = access)

Depth vs. Habitat At Various Distances From Shore



Take Home Points – Direct Use of Shoreline Habitat

- Hardened shoreline disrupts shallow water refuge habitat provided by natural shorelines (Hines and Ruiz 1995)
  - Greater depth provides access for large bodied benthivore-piscivores

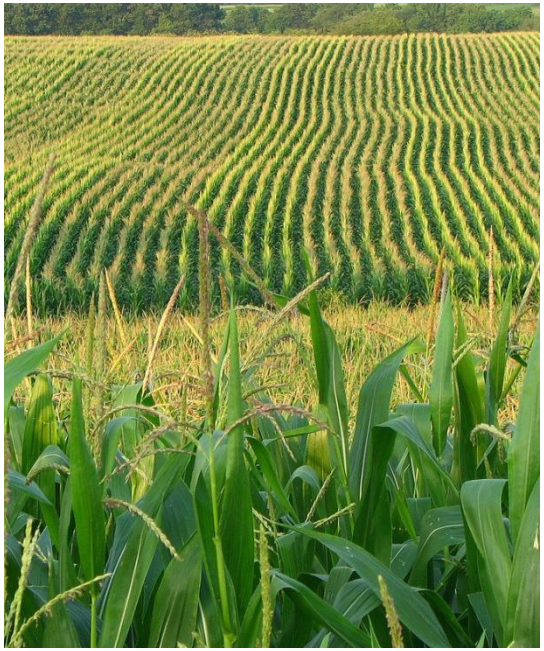


Blue Crab

Spot

Atlantic Croaker

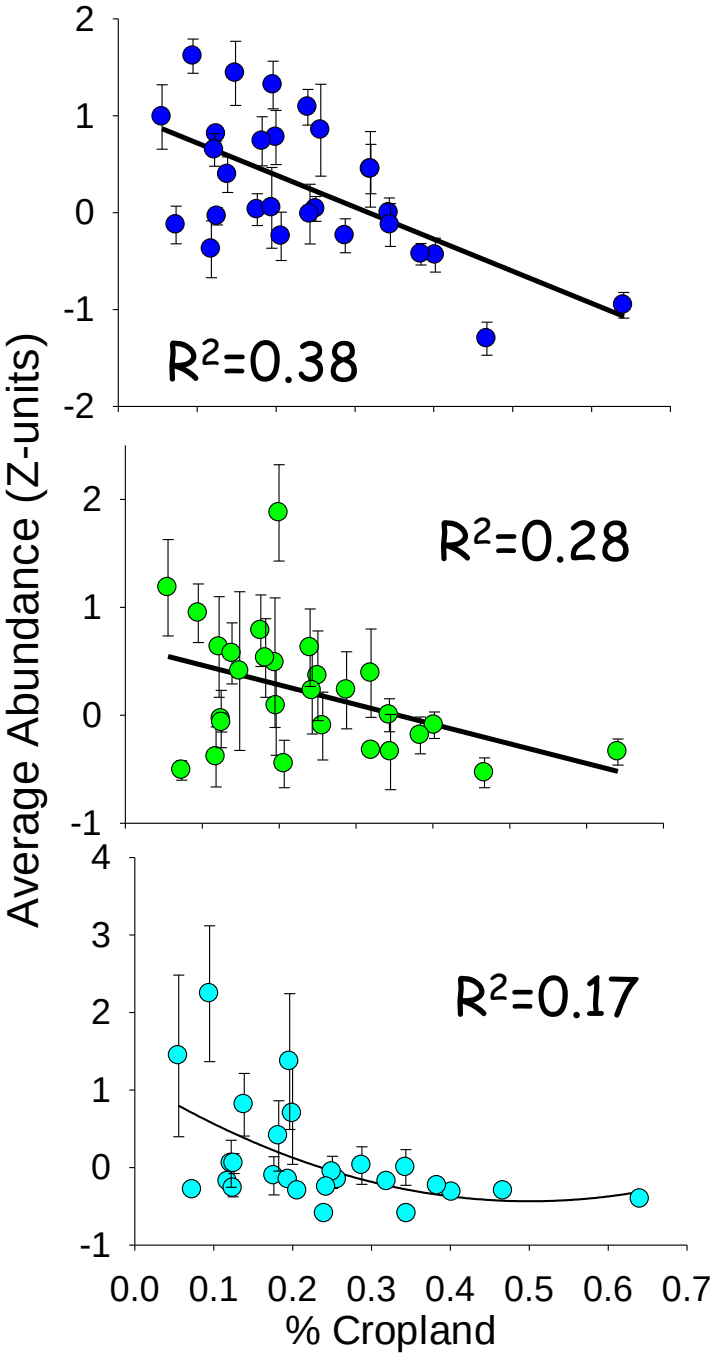
2) The proportion of the watershed land use comprised of agriculture is <u>negatively related to nearshore abundances</u> of blue crab, spot and Atlantic croaker

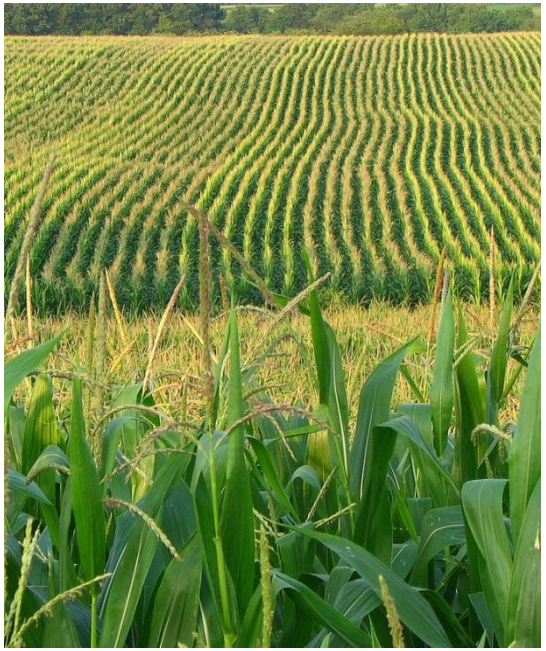


Blue Crab

Spot

Atlantic Croaker





Blue Crab

Spot

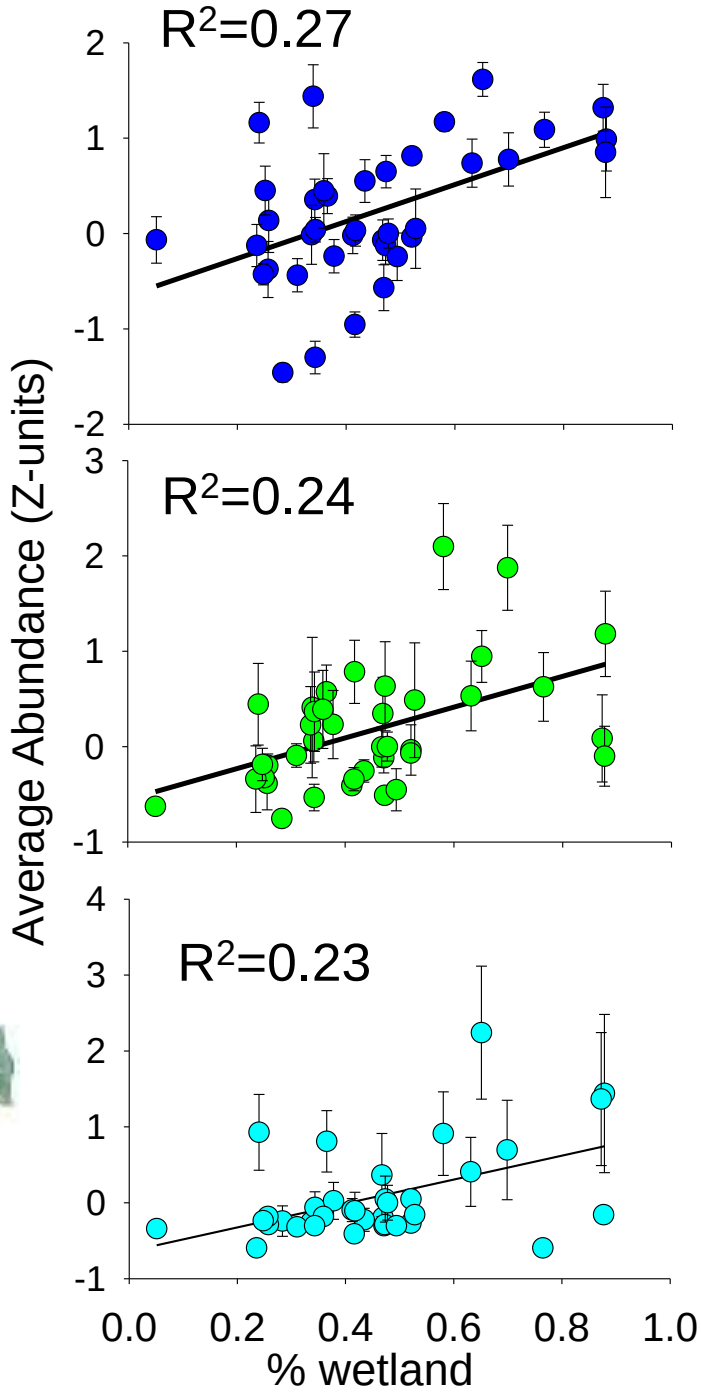
Atlantic Croaker

3) The proportion of the shoreline comprised of wetland is <u>positively related to nearshore abundances</u> of 9 of 16 species tested. In agricultural systems, this includes blue crab, spot and Atlantic croaker

Blue Crab

Spot

Atlantic Croaker



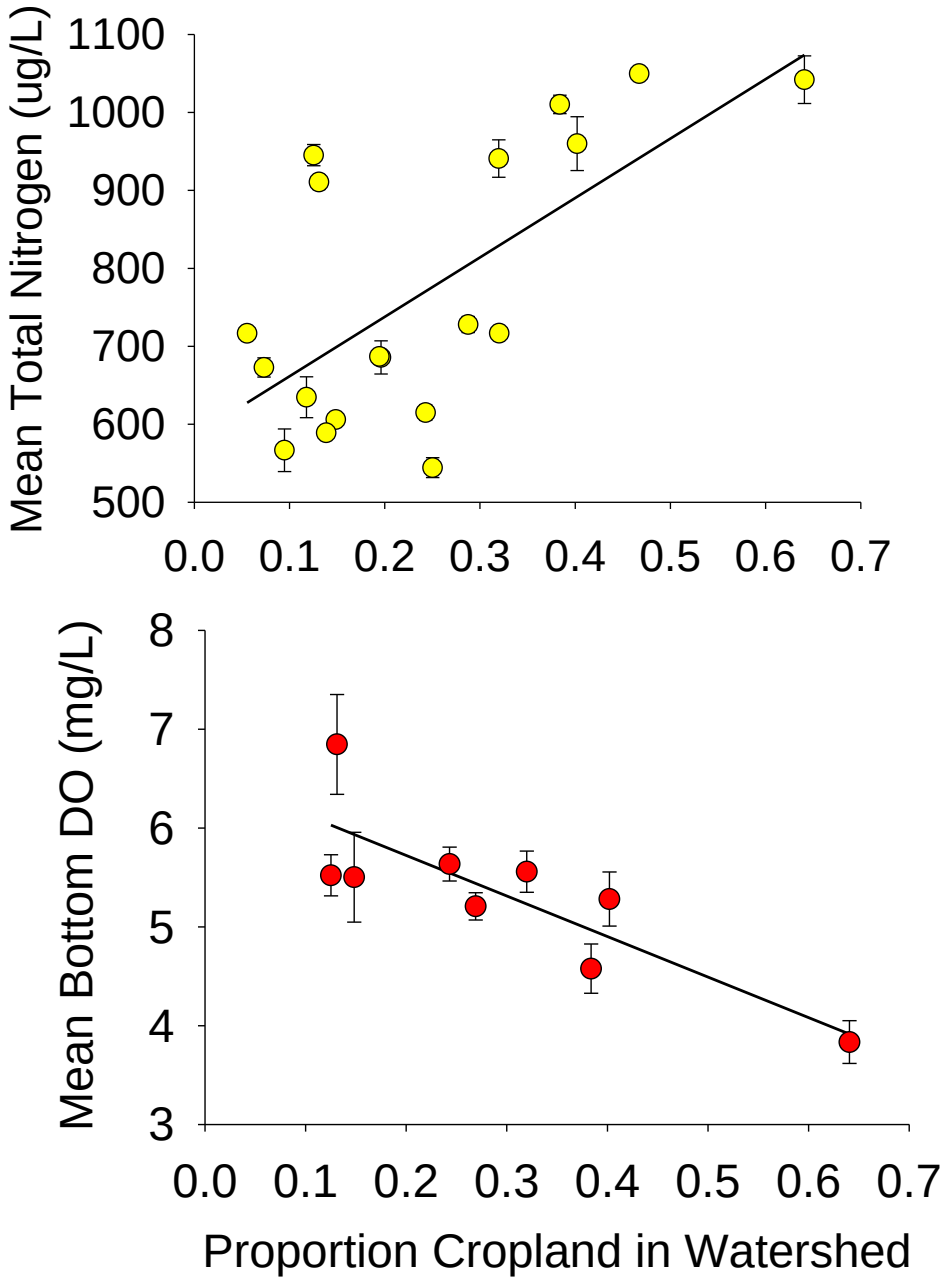
High cropland

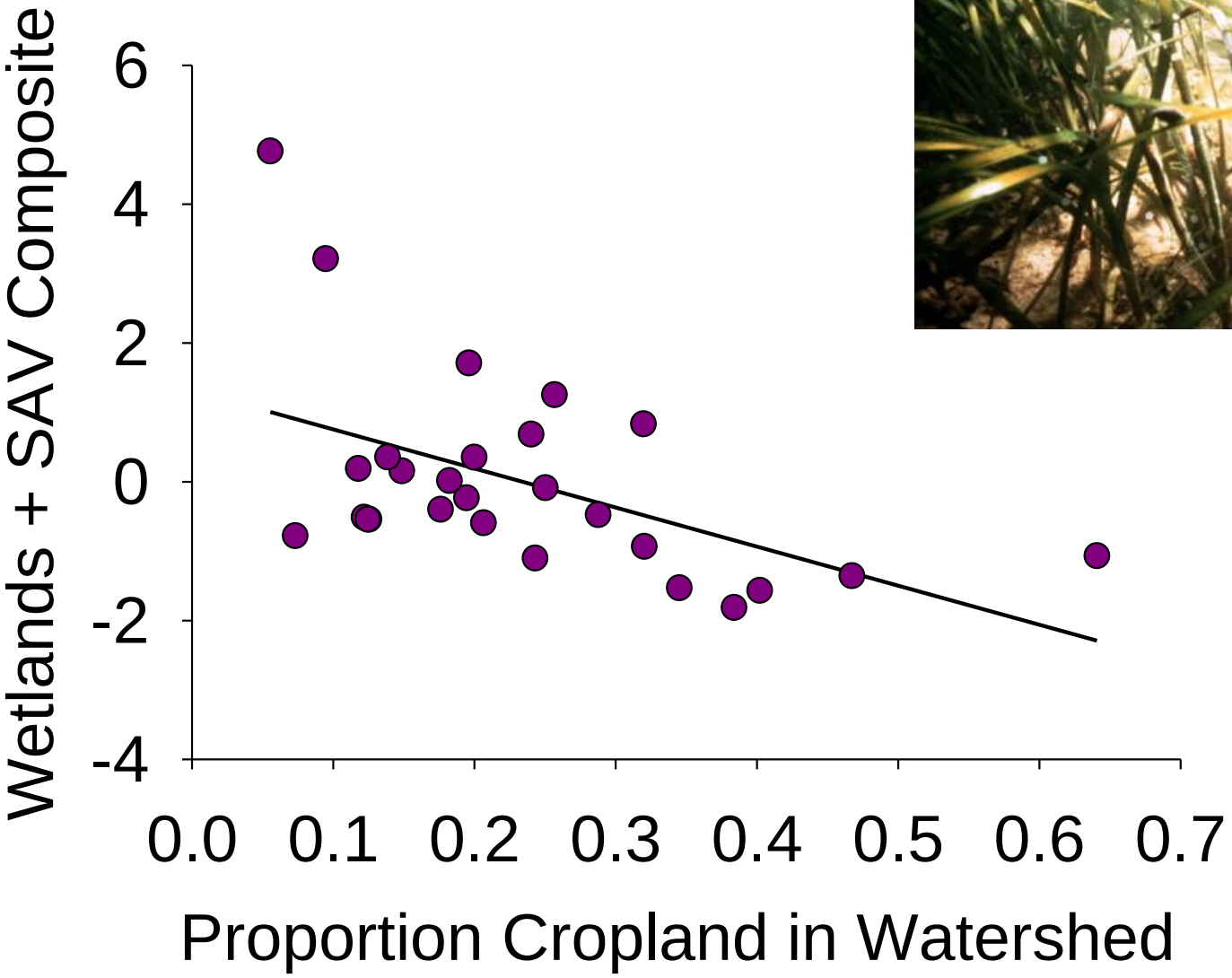
High nitrogen

Low oxygen

Low SAV

Low nearshore wetlands

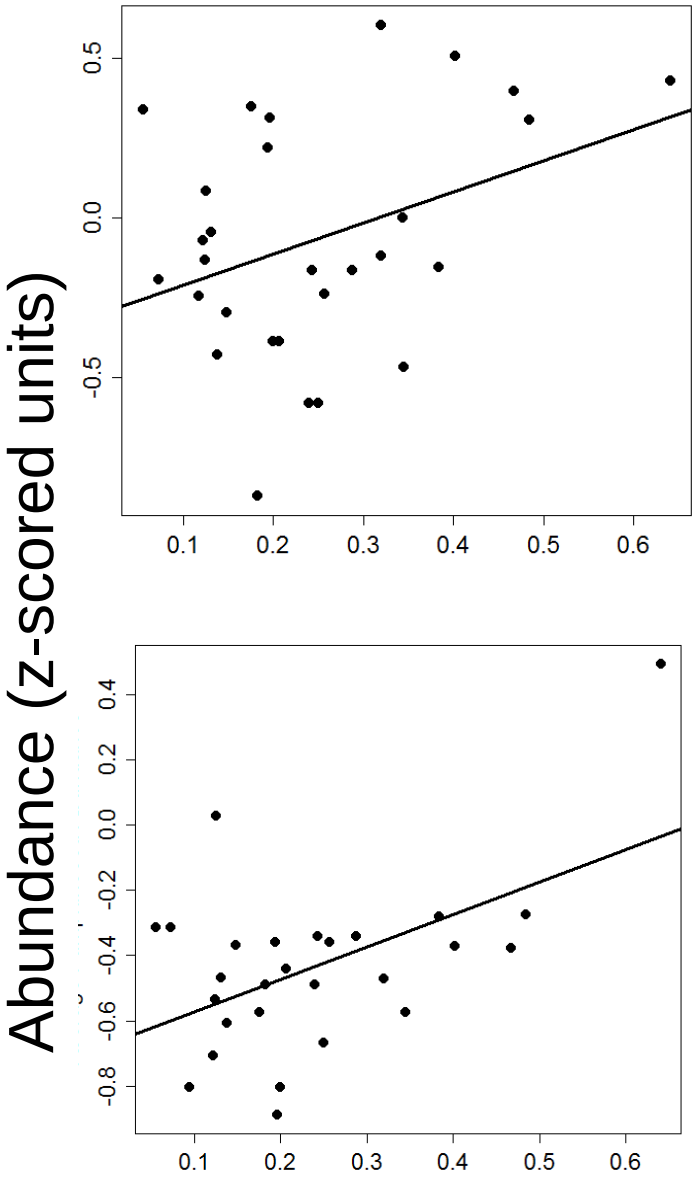

Mean Total Nitrogen (ug/L)
1100
1000
900
800
700
600
500
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Mean Bottom DO (mg/L)
8
7
6
5
4
3
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Proportion Cropland in Watershed

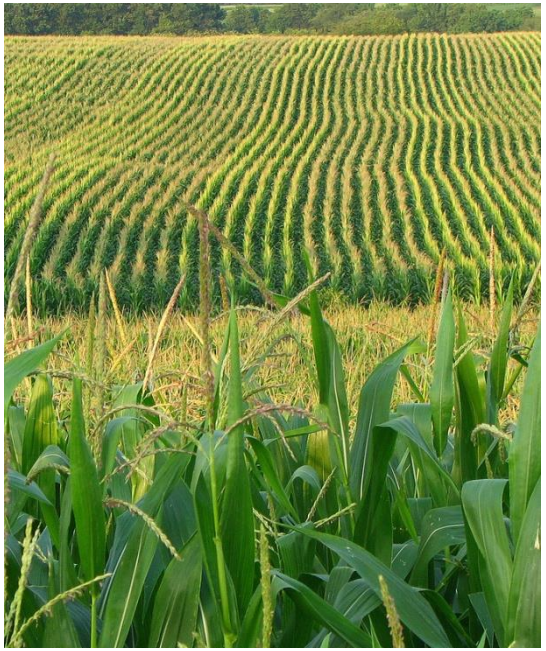

Wetlands + SAV Composite
6
4
2
0
-2
-4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Proportion Cropland in Watershed

4) But some planktivores increase with increasing agriculture

Atlantic Menhaden

Juvenile Centrarchids





Blue Crab

Spot

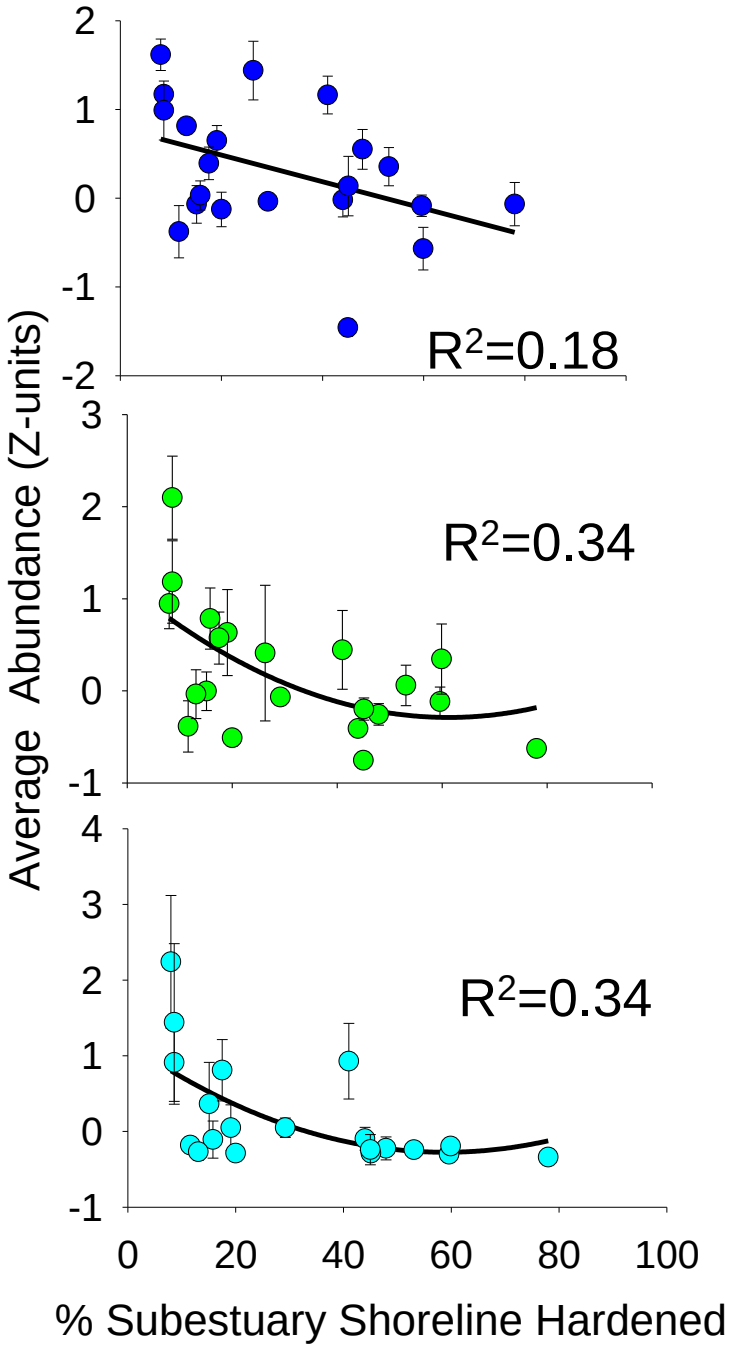
Atlantic Croaker

5) The proportion of shoreline that is hardened within a subestuary is <u>negatively related to nearshore abundances</u> of 9 of 16 species tested, including blue crab, spot and Atlantic croaker

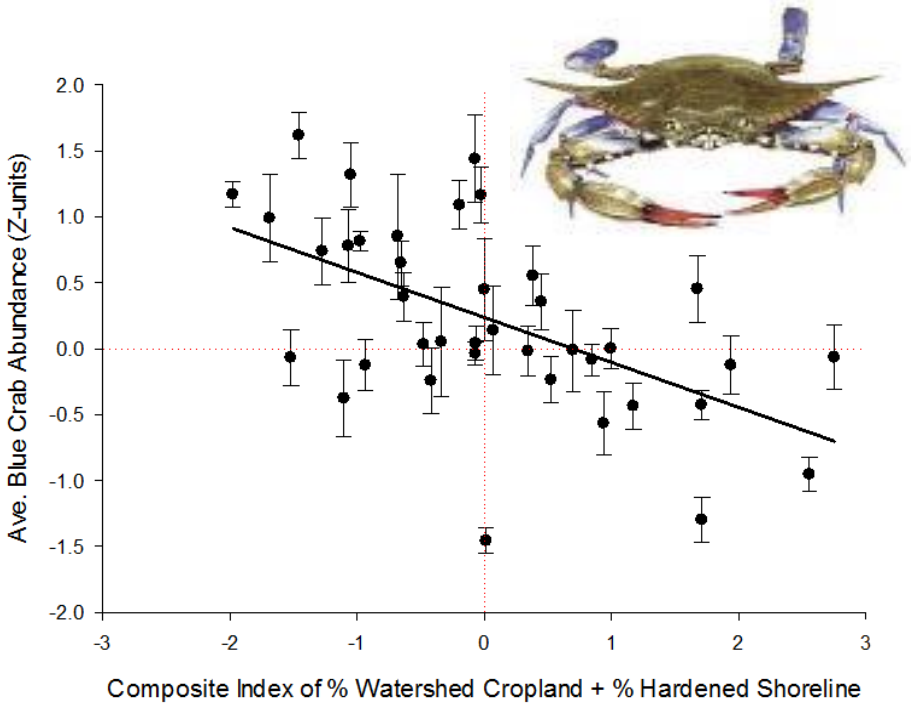
Blue Crab

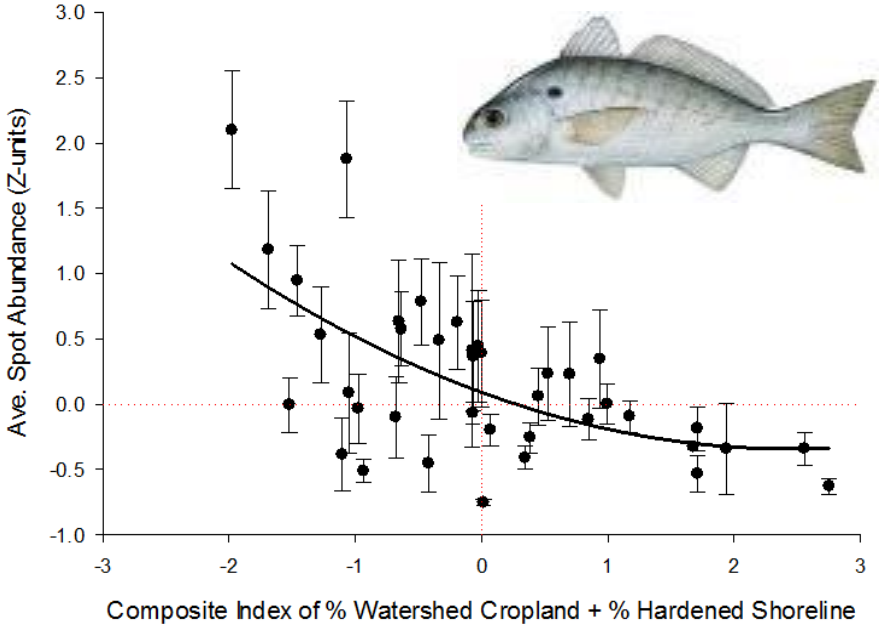
Spot

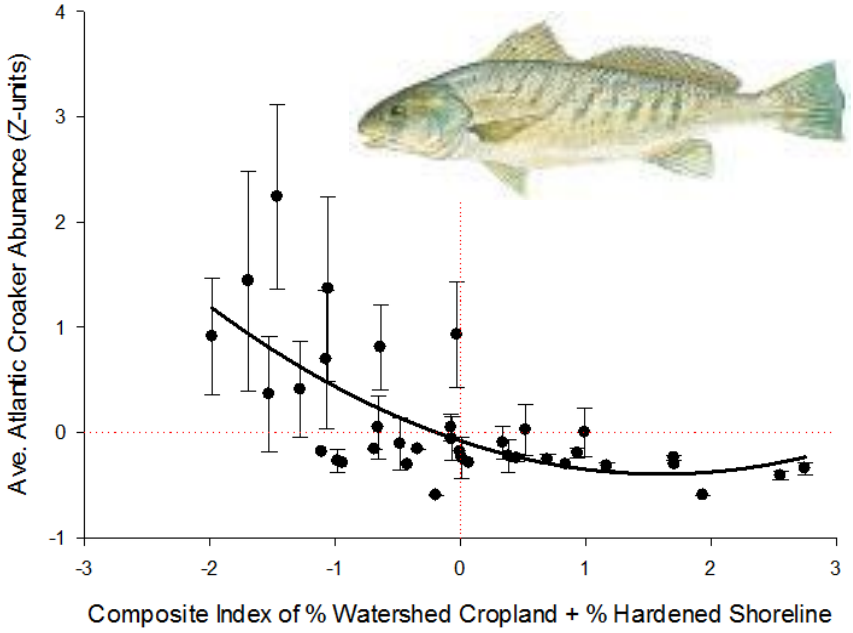
Atlantic Croaker



Variation among subestuaries





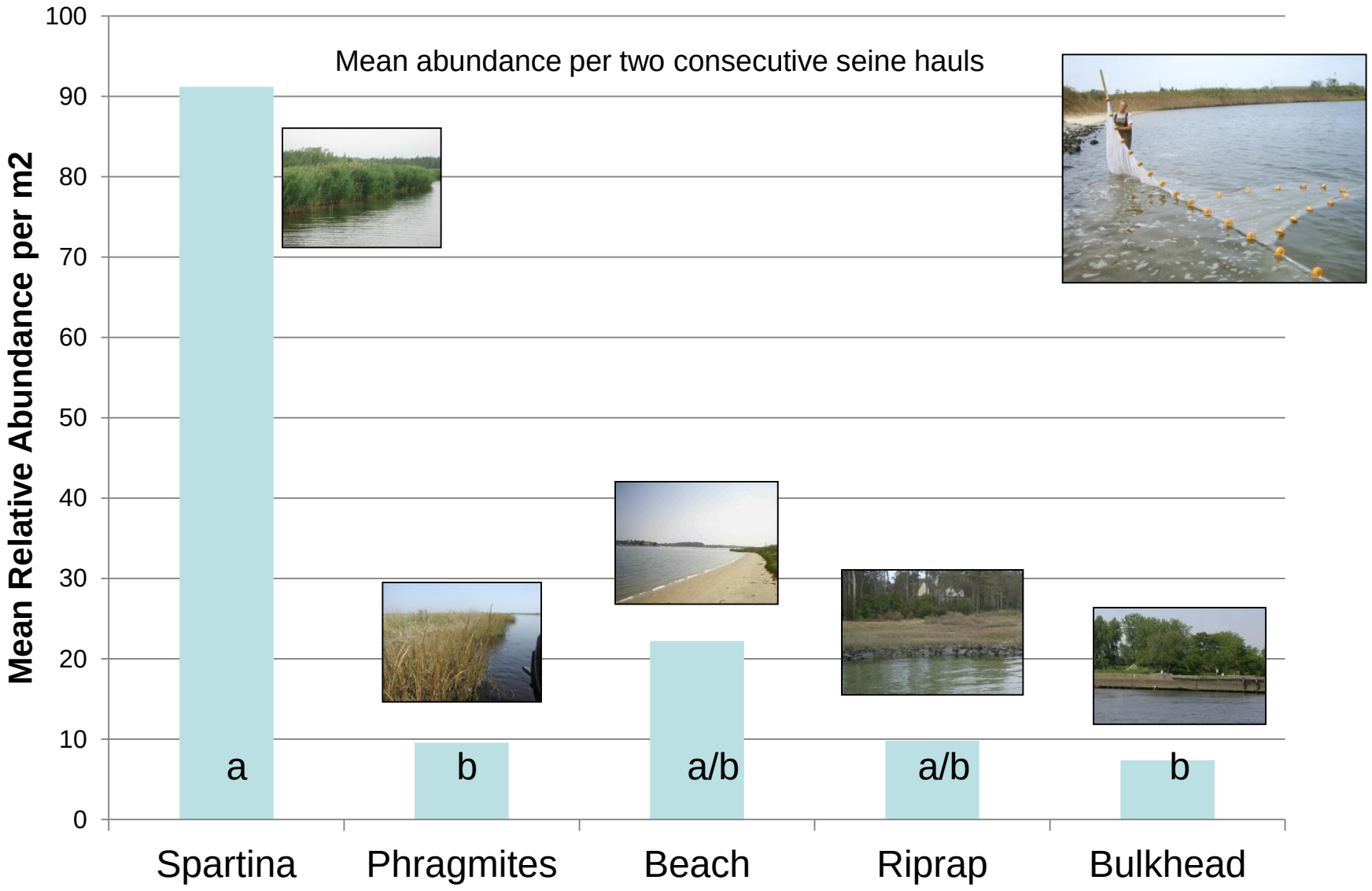


Targett Lab (University of Delaware)

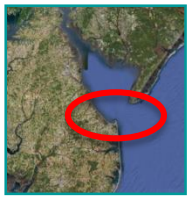
6) There are important <u>differences between native wetland vegetation and invasive *Phragmites*</u>

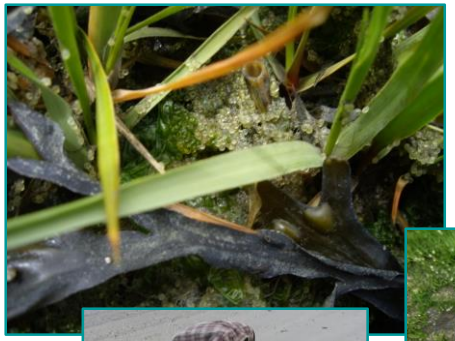
Intensive Sampling of Fishes in Delaware Coastal Bays

Fish abundance (especially mummichogs) is much higher along native marsh vegetation than *Pragmites*



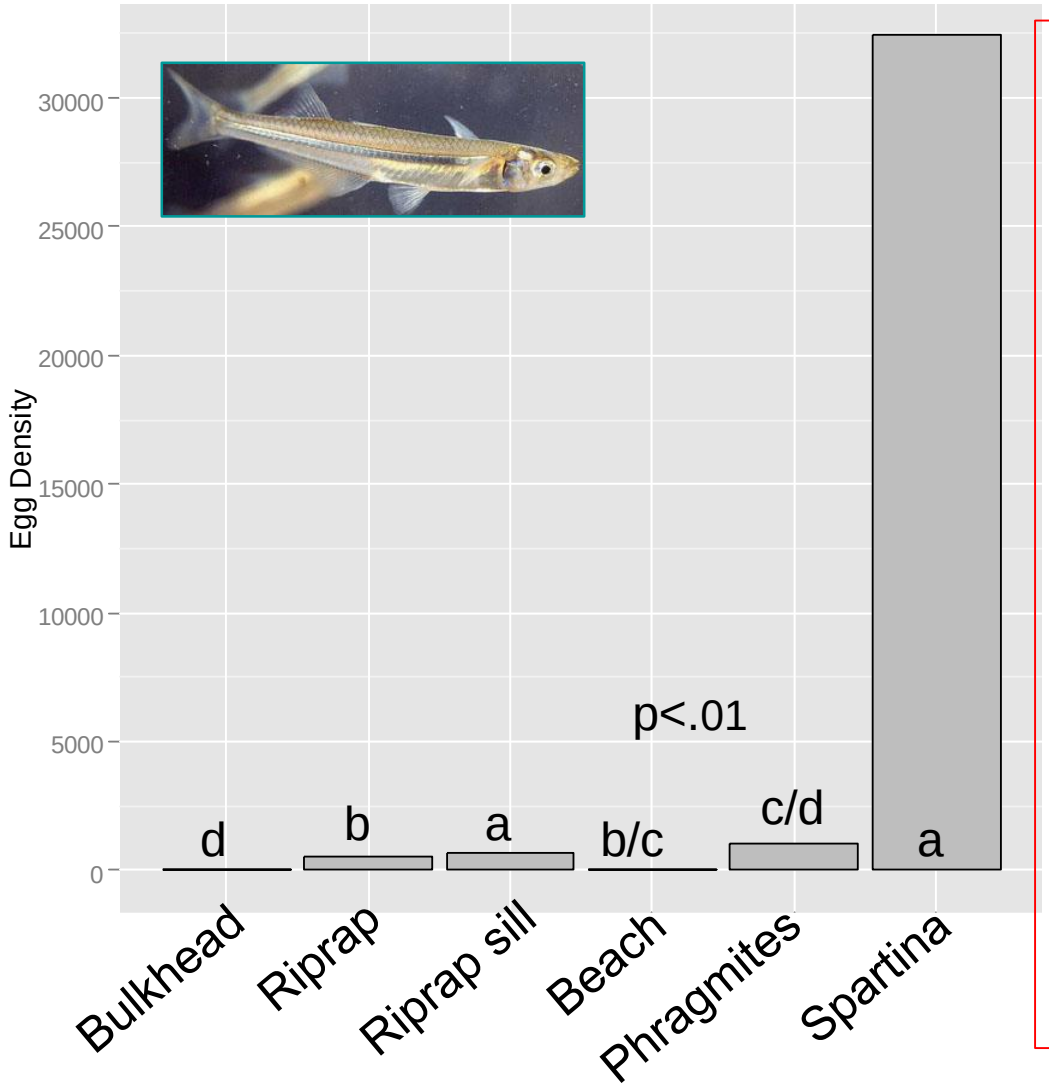
Egg deposition by Atlantic silverside (*Menidia menidia*): a comparison of 6 shoreline types





- Over 3 million eggs collected during the 50 sampling days

Mean egg density by shoreline type



- 93% of eggs (3 million over 50d) were deposited along <u>*Spartina* shorelines</u>
  - Green alga *Enteromorpha* was the most commonly used substrate, at each shoreline type
- 85% of eggs along *Spartina* shoreline, deposited on *Enteromorpha*

7) Fish abundance is higher along riprap-sill shoreline than traditional riprap (not all riprap is created equal…but does it wind up equal???)

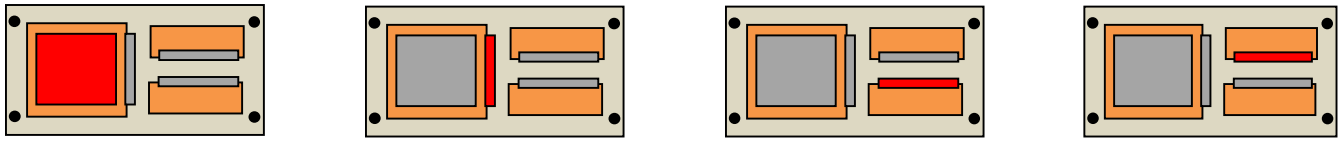
- **Riprap-sill structure provides higher habitat quality for shore zone estuarine fishes (and blue crabs) than does traditional riprap**

8) Subtidal riprap provides winter homes for sea nettle polyps

2010 experiment: During summer polyps use riprap but not bulkhead materials; more polyps are found on subtidal substrate than on substrate that is sometimes exposed to air.

- Oyster and Stone > Wood & Steel
- Oyster = Stone

Summer 2012-May 2013 recruitment & overwintering survival



F=15.22
p=0.0002

- Protected, downward facing substrate preferred
- No overwintering survival if there's any intertidal exposure: Riprap will increase sea nettles if it extends substantially into the subtidal

Fish, Crabs, Jellies and Habitat:
The Land-water Interface is Important

Fish, shellfish and jellyfish are strongly affected by

- Land use
- Shoreline hardening

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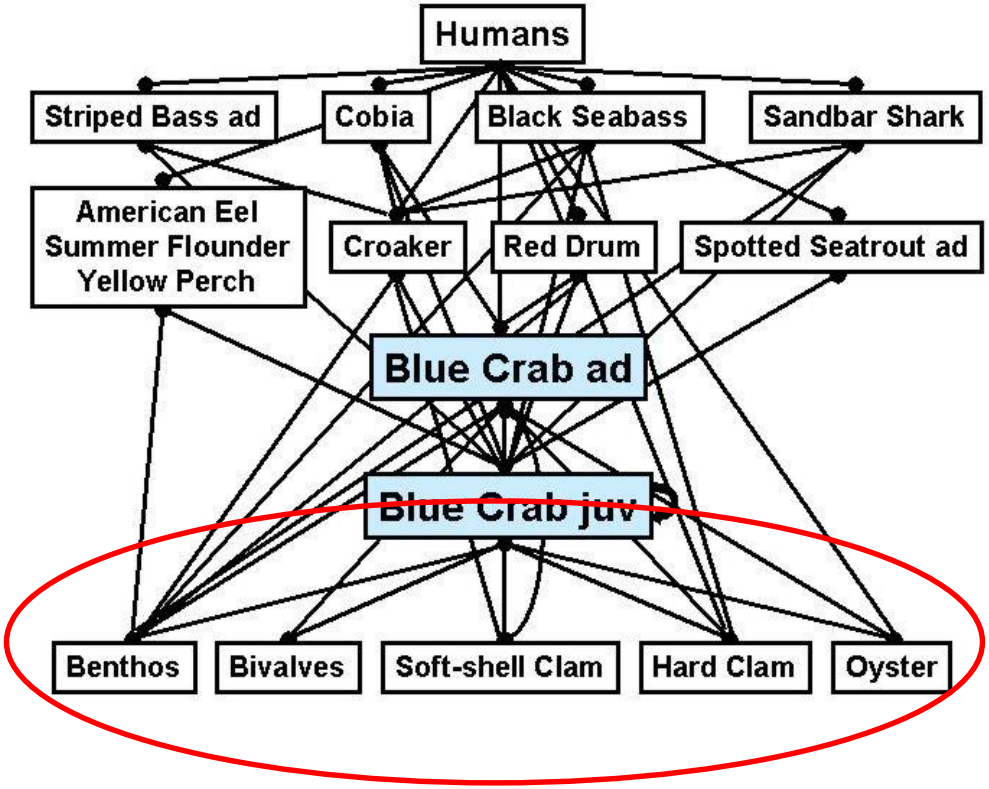
1965–2015

Loss of wetlands and SAV, and higher N loads may be proximate mechanisms for land use and riprap effects on fish/crabs/shrimp

Importance of Benthos as forage for fish & crabs



Rochelle Seitz

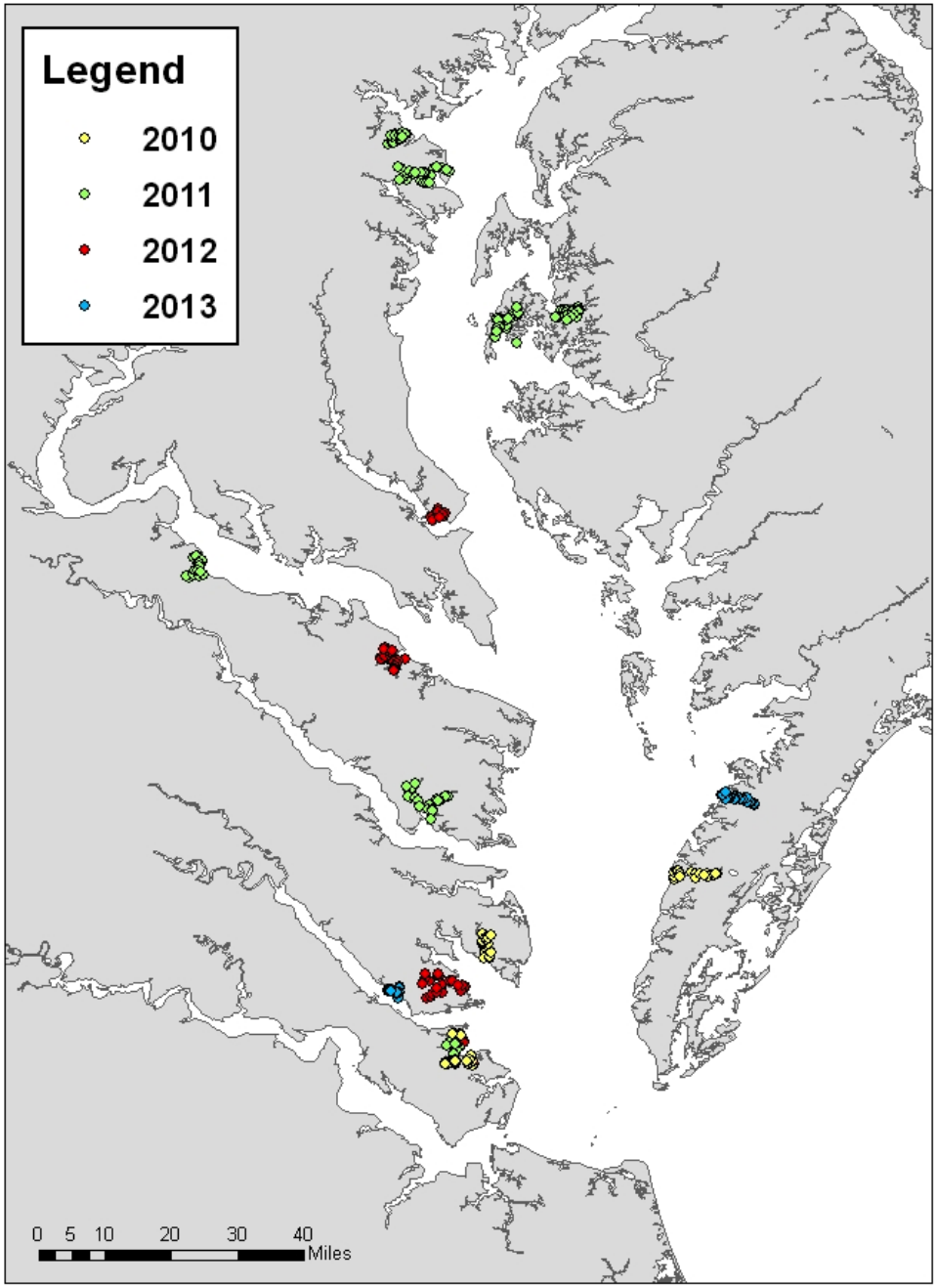
- "..carbon directly fuelling the studied fishes… is funneled through the benthic food web via filter-feeding, detritivorous or omnivorous invertebrates"

(Buccheister & Latour 2015)

VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

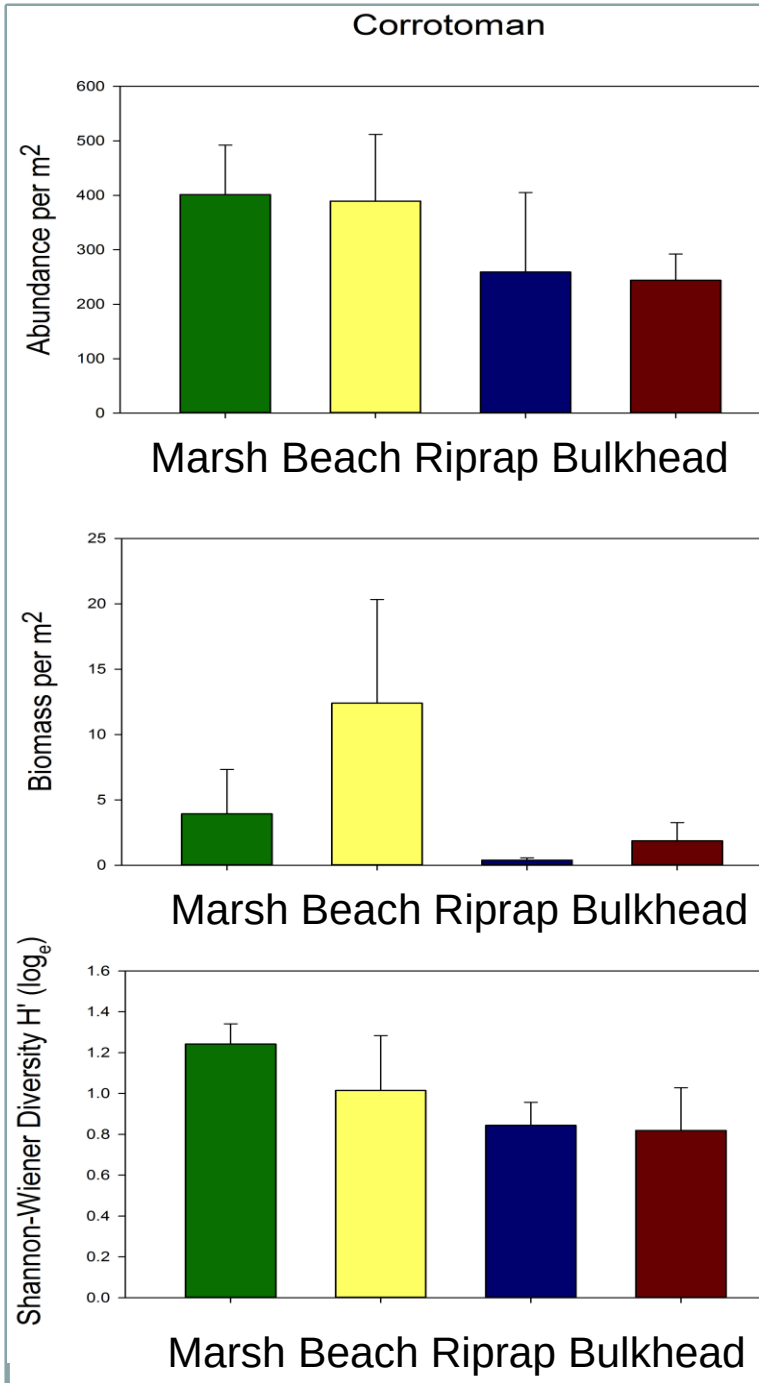
Sites

- **2010**
  - Occohannock (Ag)
  - East River (For)
  - Poquoson River (Dev)
- **2011**
  - Stony Creek (Dev)
  - Magothy River (Dev)
  - Harris Creek (Ag)
  - Miles River (Ag)
  - Monroe Bay (For)
  - Corrotoman River (For)
  - Poquoson River (Dev)
- **2012**
  - Yeocomico (MixOther)
  - Severn (For)
  - Mill Creek (Dev)
  - Poquoson River (Dev)
  - Catlett Islands (For)
- **2013**
  - Catlett Islands (For)
  - Onancock (Ag)
  - Poquoson River (Dev)



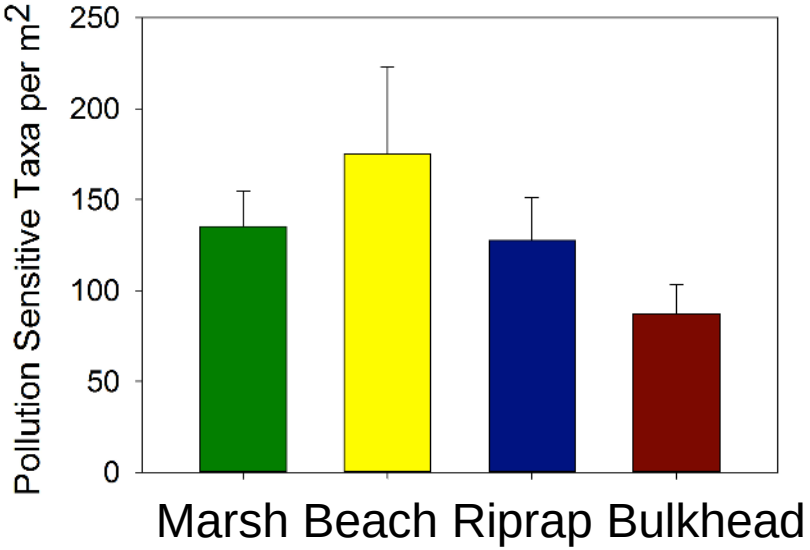
9) <u>Natural shoreline habitats have higher abundance, biomass, and diversity of benthic invertebrates</u> than developed habitats (e.g.,Corrotoman River)

Rochelle Seitz



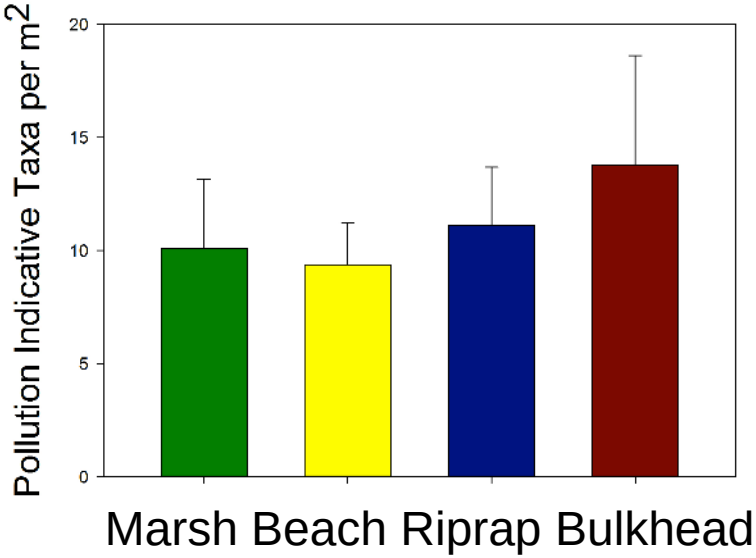
Shoreline effects: Pollution-sensitive taxa tend to be least abundant at bulkhead; pollution tolerant species are most abundant there.

Pollution-Sensitive



ANOVA:
P = 0.08

Pollution-Indicative



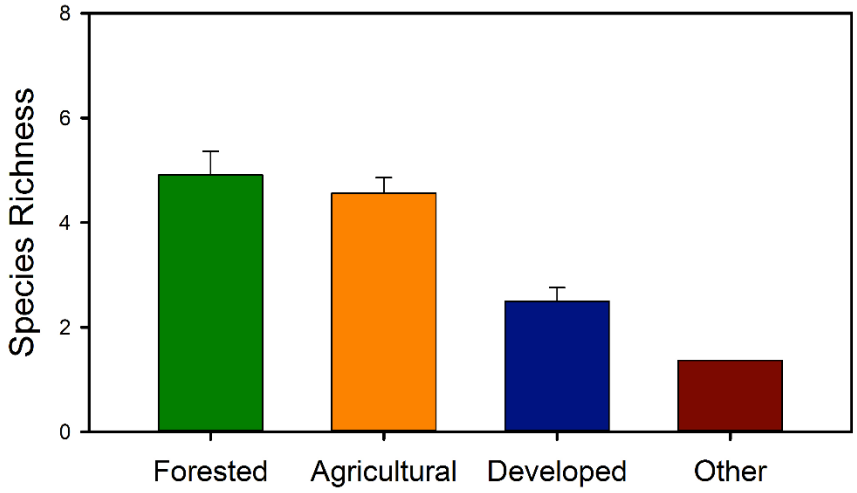
ANOVA:
P = 0.21

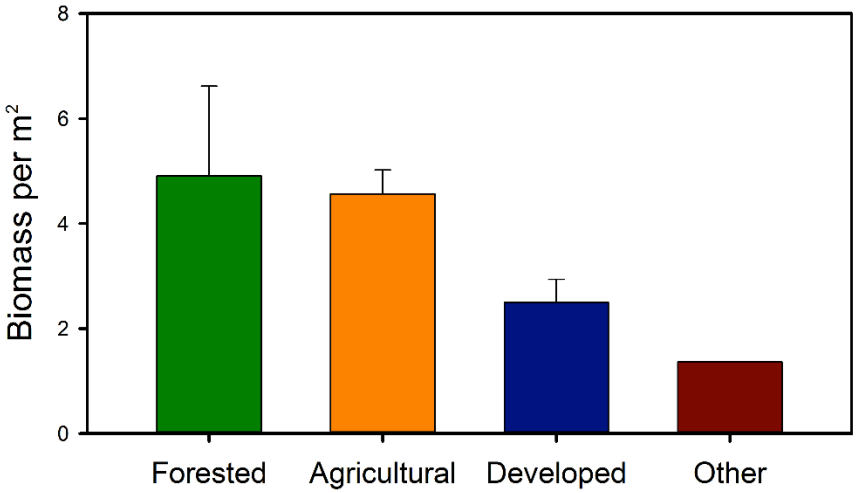
Rochelle Seitz

10) Developed and mixed-developed watersheds have reduced benthic biomass, & richness

Diversity
ANOVA:
$P < 0.0005$

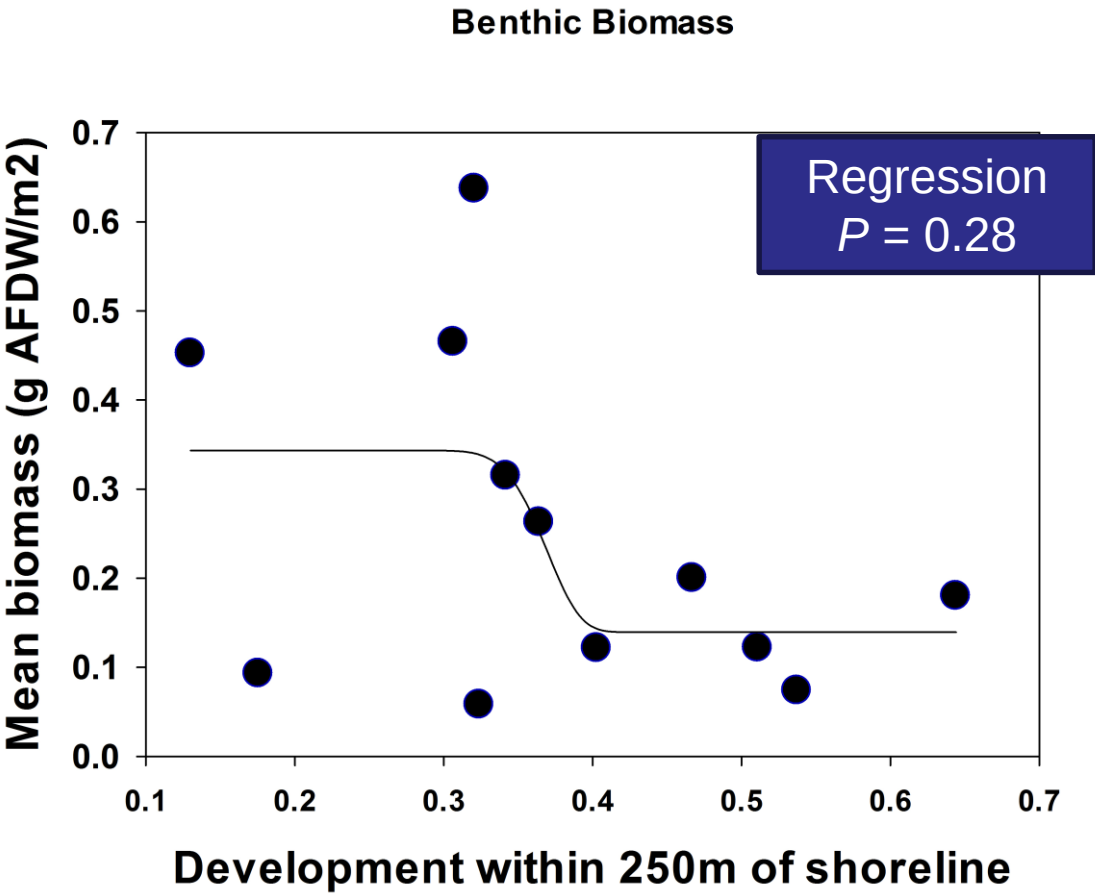
Biomass
ANOVA:
$P = 0.008$





Rochelle Seitz

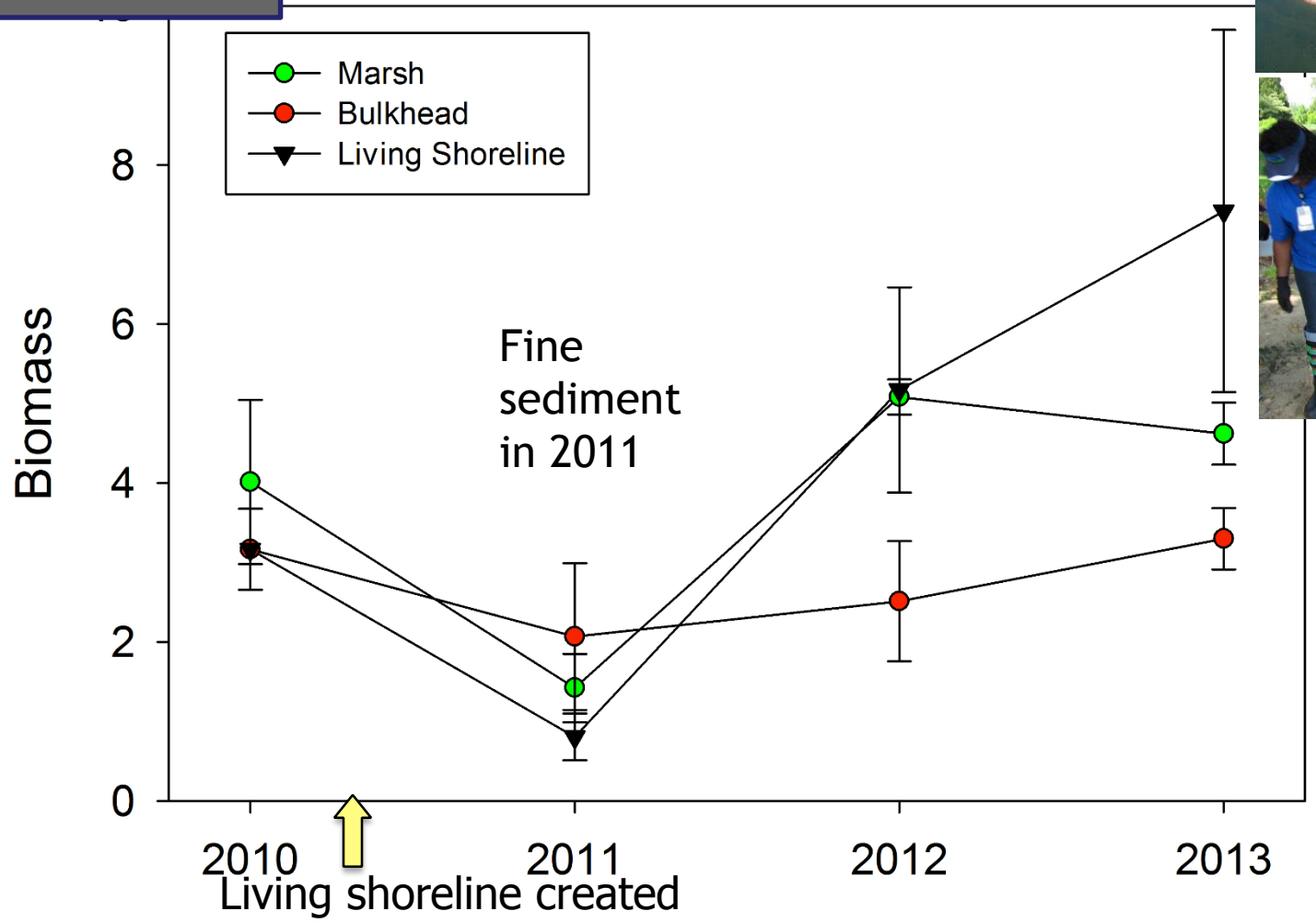
Possible threshold for loss of benthic biomass with ~35% upland **development** (but stats not significant)



Rochelle Seitz

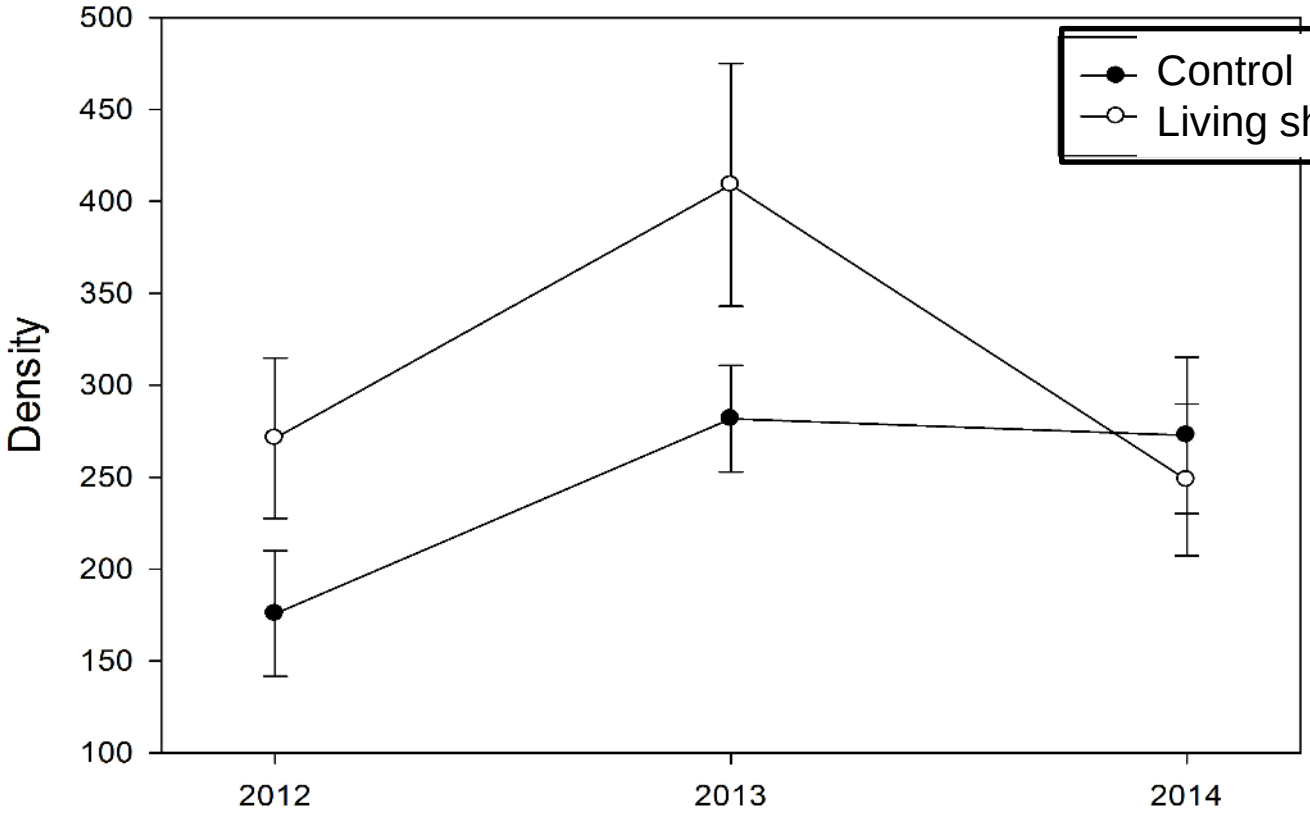
Living Shoreline - Benthic Biomass (Windy Hill)

Biomass ANOVA:
P = 0.001



Living shoreline mimics marsh increases 2 & 3 years out

Lynnhaven infaunal density



?difference = time, level of disturbance or both

Waterbirds: Diann Prosser

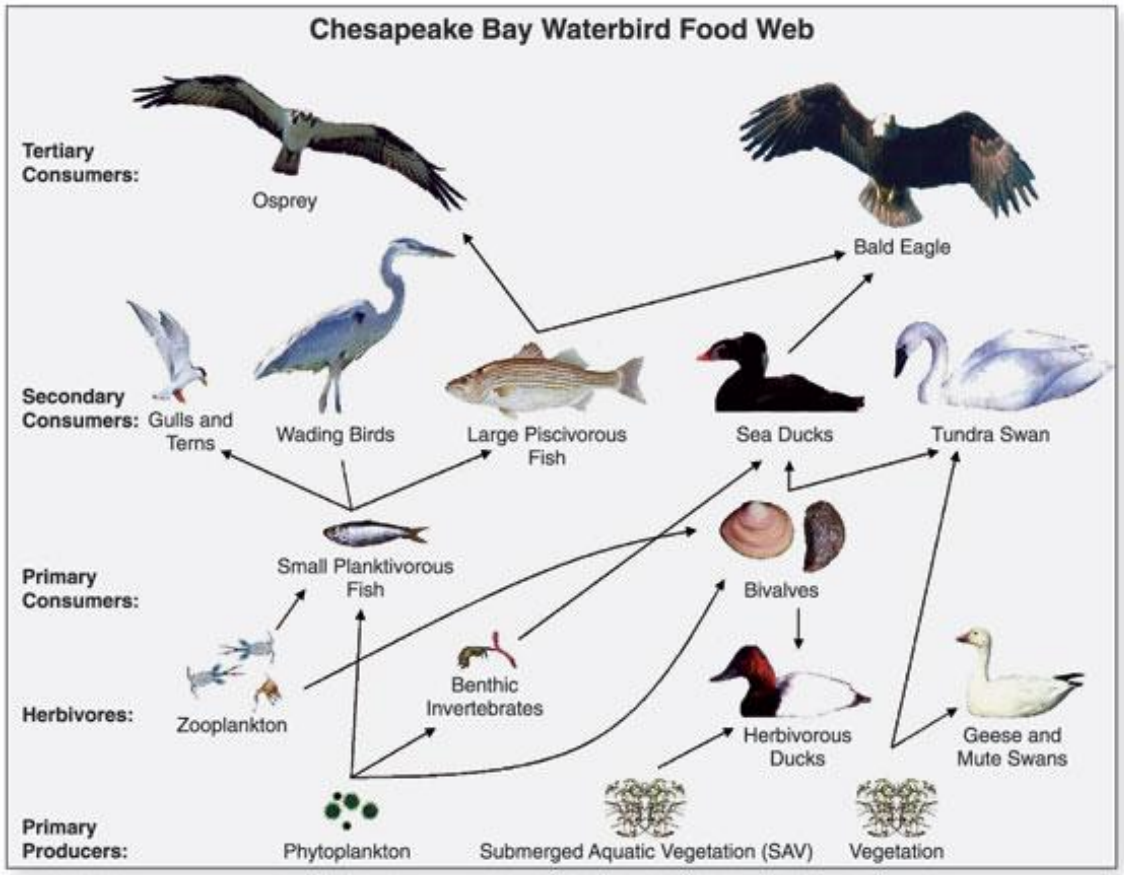


Image from Wikimedia.org

Index of Waterbird Community Integrity (IWCI)

(After DeLuca et al. 2008. Biol. Conserv.)

$$IWCI = (\sum S_{IWCI} / S_N) + (2) A_I$$

Where: S_{IWCI} = Individual Species Index

S_N = Total no. of species

A_I = Abundance score for each species (i)

ALSO:
Species Richness
Species Density
Guild Analysis

Weighted for sensitive versus tolerant species

Indices
Foraging
Breadth
Nesting
Sensitivity
Migratory

USGS

Index of Waterbird Community Integrity

S_{IWCI} (range 21 to 5)

Disturbance Sensitive Species

Royal Tern
(Thalasseus maximus)
S_{iwci} = 21

Hooded Merganser
(Lophodytes cucullatus)
S_{iwci} = 20

Semipalmated Sandpiper
(Calidrus pusilla)
S_{iwci} = 18.5

Laughing Gull
(Leucophaeus atricilla)
S_{iwci} = 17.5

Bald Eagle
(Haliaeetus leucocephalus)
S_{iwci} = 16.5

Disturbance Tolerant Species

Ring-billed Gull
(Larus delawarensis)
S_{iwci} = 9.5

Double-crested Cormorant
(Phalacrocorax auritus)
S_{iwci} = 9.5

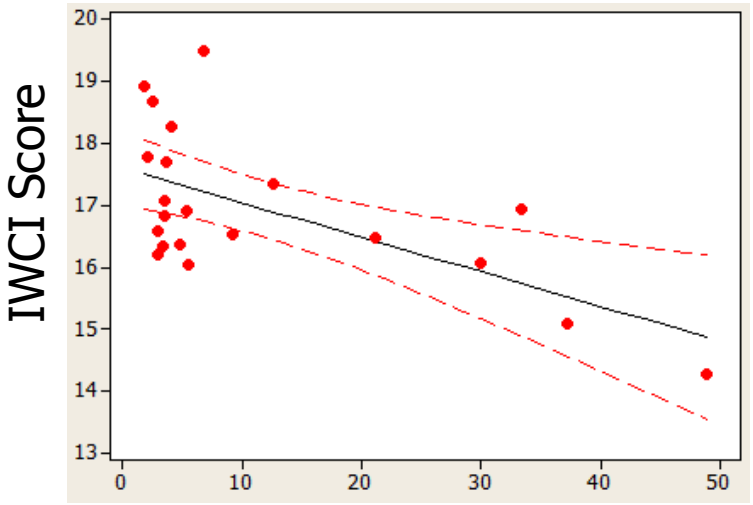
Canada Goose (resident)
(Branta canadensis)
S_{iwci} = 8.5

Mallard
(Anas platyrhynchos)
S_{iwci} = 7

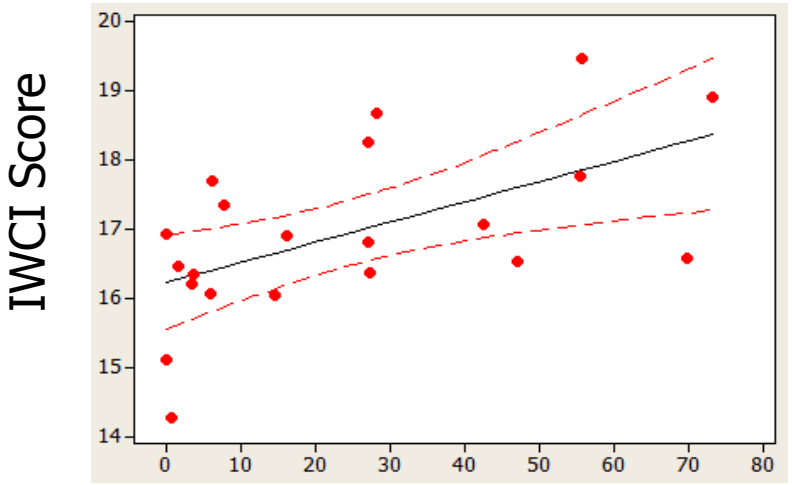
Domestic duck
S_{iwci} = 5

USGS

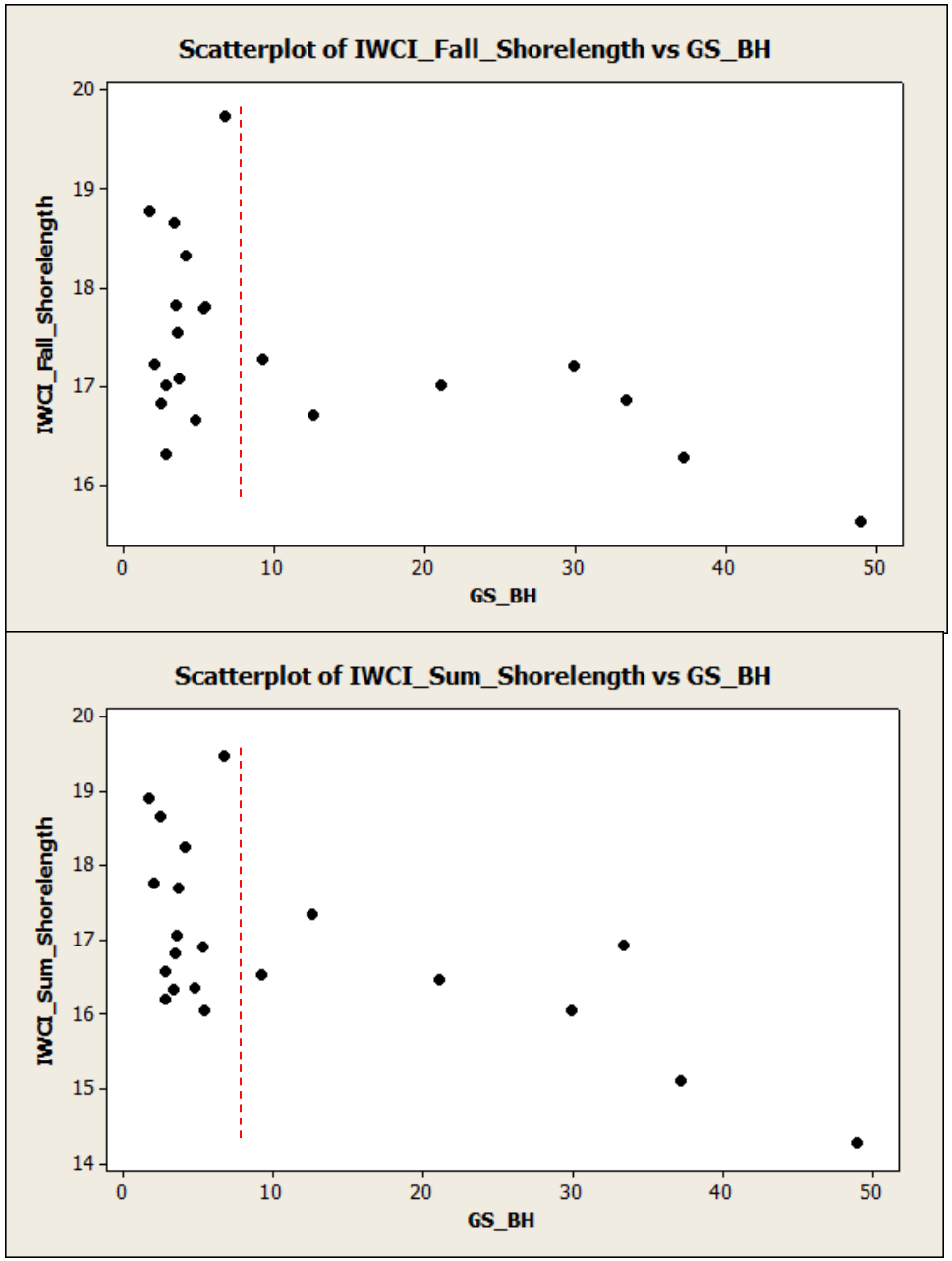
11) Birds Boycott Bulkhead



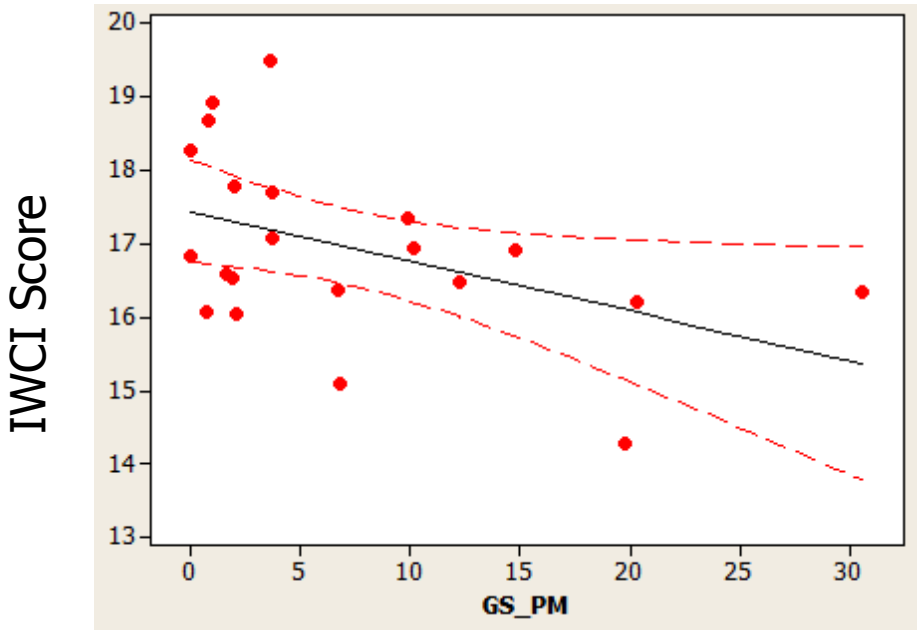
12) Waterbirds are Wild for Wetlands



Threshold Limit of Bulkhead Development on IWCI



"Waterbirds might say phooey to phragmites"



Percent Phragmites

But Pearson Correlation between Bulkhead and Phragmites is 0.24; p=0.27

Diann Prosser

Rochelle Seitz

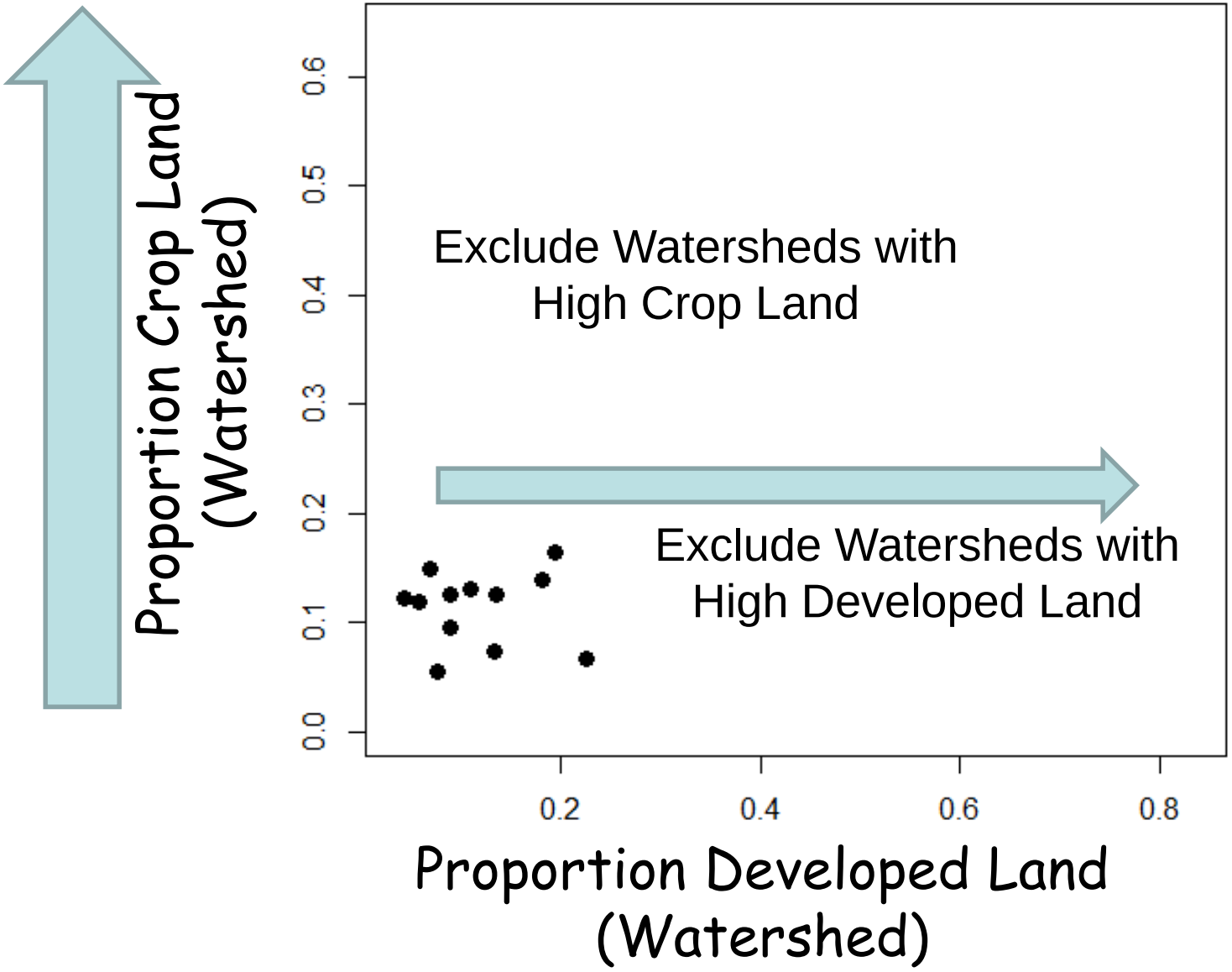
Denise Breitburg
Tim Targett, Matt Kornis

- Both shoreline hardening and watershed land use affect economically and ecologically important macrofauna species in Chesapeake Bay & Delaware Coastal Bays
- Large scale studies and good sampling design are critical to detecting effects

Thank you to
NOAA-NCOS - funding
Numerous technicians, grad students & interns in all labs

end

Separate Gradients of Crop and Developed Land

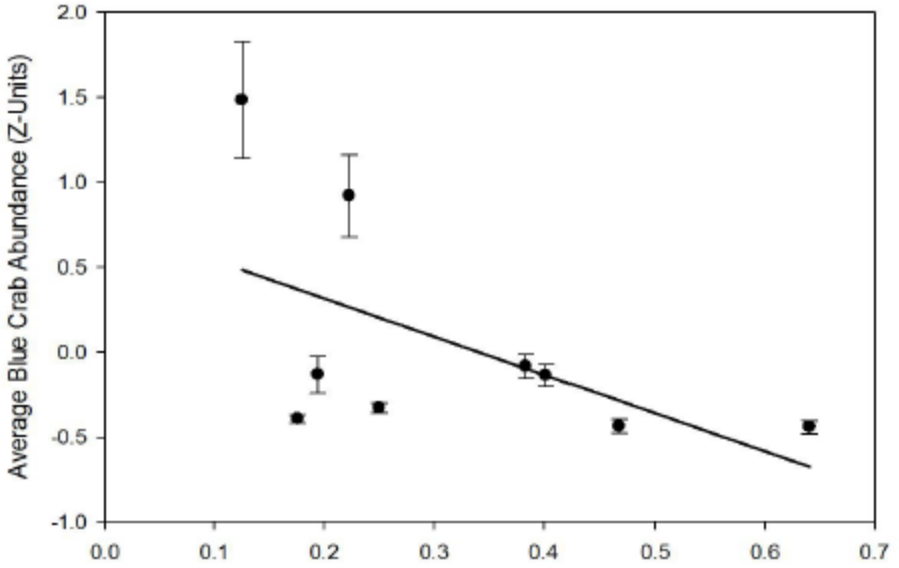


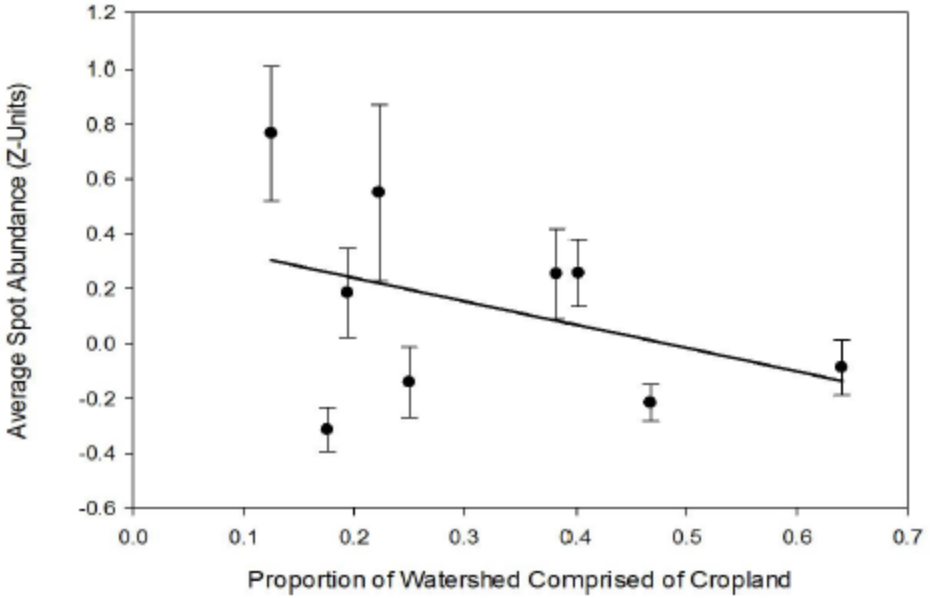
Reduced abundance is not just a shift offshore

Blue Crab

Spot

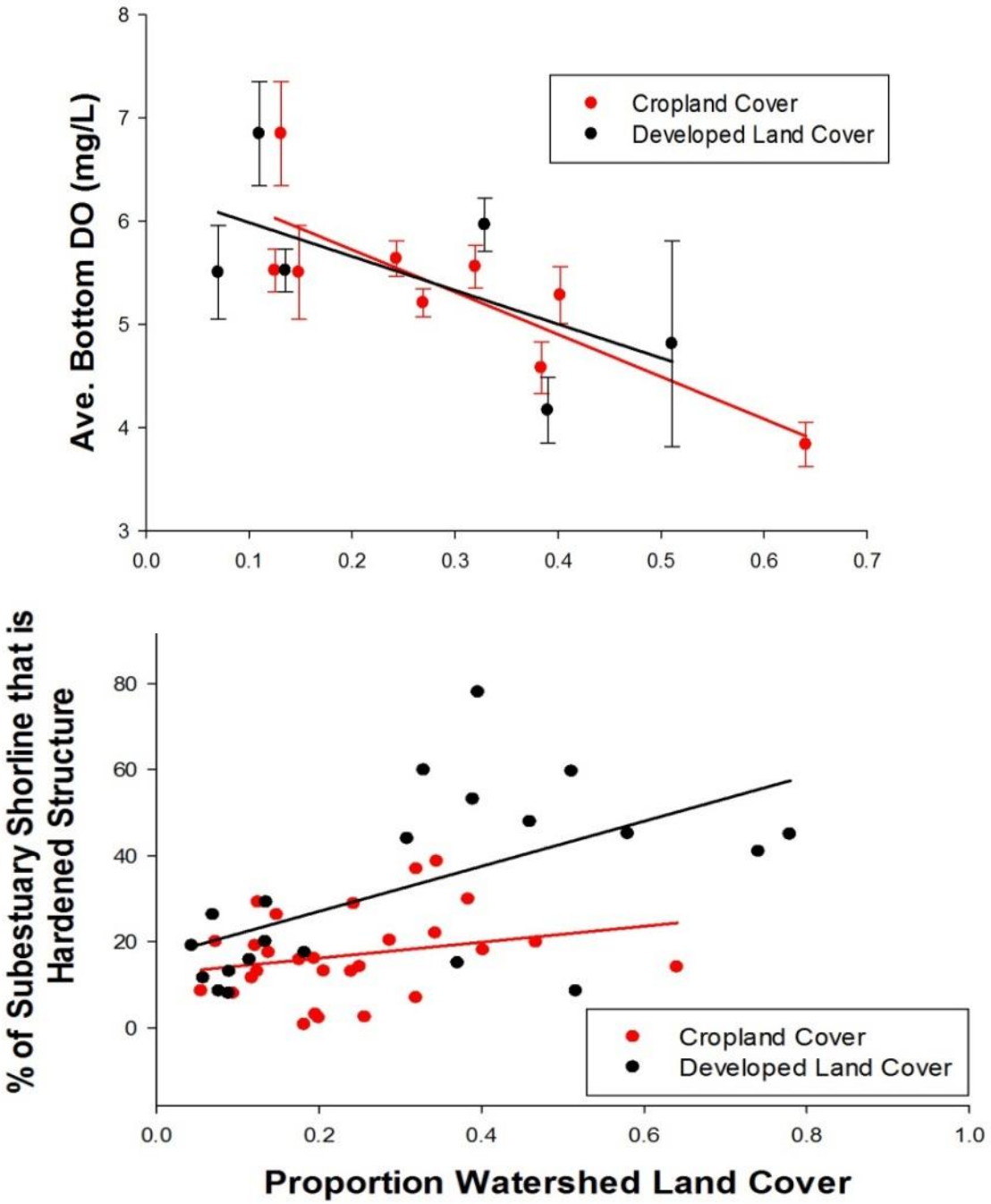
Data: Jim Uphoff, MD-DNR





Systems without high % developed land

	% variation among subestuaries explained if model includes:			
	Cropland	SAV	TN	SAV+TN
Blue crab	**67**	**66**	**69**	66
Croaker	71	**93**	84	94
Spot	71	**98**	57	92
Menhaden (w/o outlier)	35	0	**85** pos	94
Juvenile Centrarchidae	61	65	81 pos	81


Ave. Bottom DO (mg/L)
Cropland Cover
Developed Land Cover
% of Subestuary Shorline that is Hardened Structure
Cropland Cover
Developed Land Cover
Proportion Watershed Land Cover

Macro-fauna group:
28 subestuaries
8 with complete site overlap

Objectives:

- Macro-faunal communities in shallo subtidal habitats

- Factors affecting communities

  - Shoreline development
  - Upland development
  - Physical characteristics

- Objective: determine combined effects of shoreline and upland

River	Benthic	Birds	Fish
Stony Creek	2011	2012	2010
Magothy River	2011	2012	2011
East River	2010	2011	2010
Poquoson	2010-2013	2011	2010
Harris Creek	2011	2013	2011
Miles River	2011	2012	2011
Monroe Bay	2011		2011
Corrotoman River	2011	2013	2011
Yeocomico	2011		2012
Occohannock	2010		2010
Mill Creek (Pax)	2012	2013	2012
Honga		2010	2010
Langford Creek		2010	2010
Rhode		2010	2010-2012
St. Leonard		2010	2010
Ware		2011	
St. Mary		2010	
Corsica		2010	
Back		2011	
South (MD)			2010
Wye River			2012
Main Creek			2012
Severn (VA)	2012		
Catlett Islands	2013		
Onancock	2013		
Indian River			2010-2011
Pepper Creek			2010-2011
Delaware Bay			2012-2013

Study Sites (n=20)

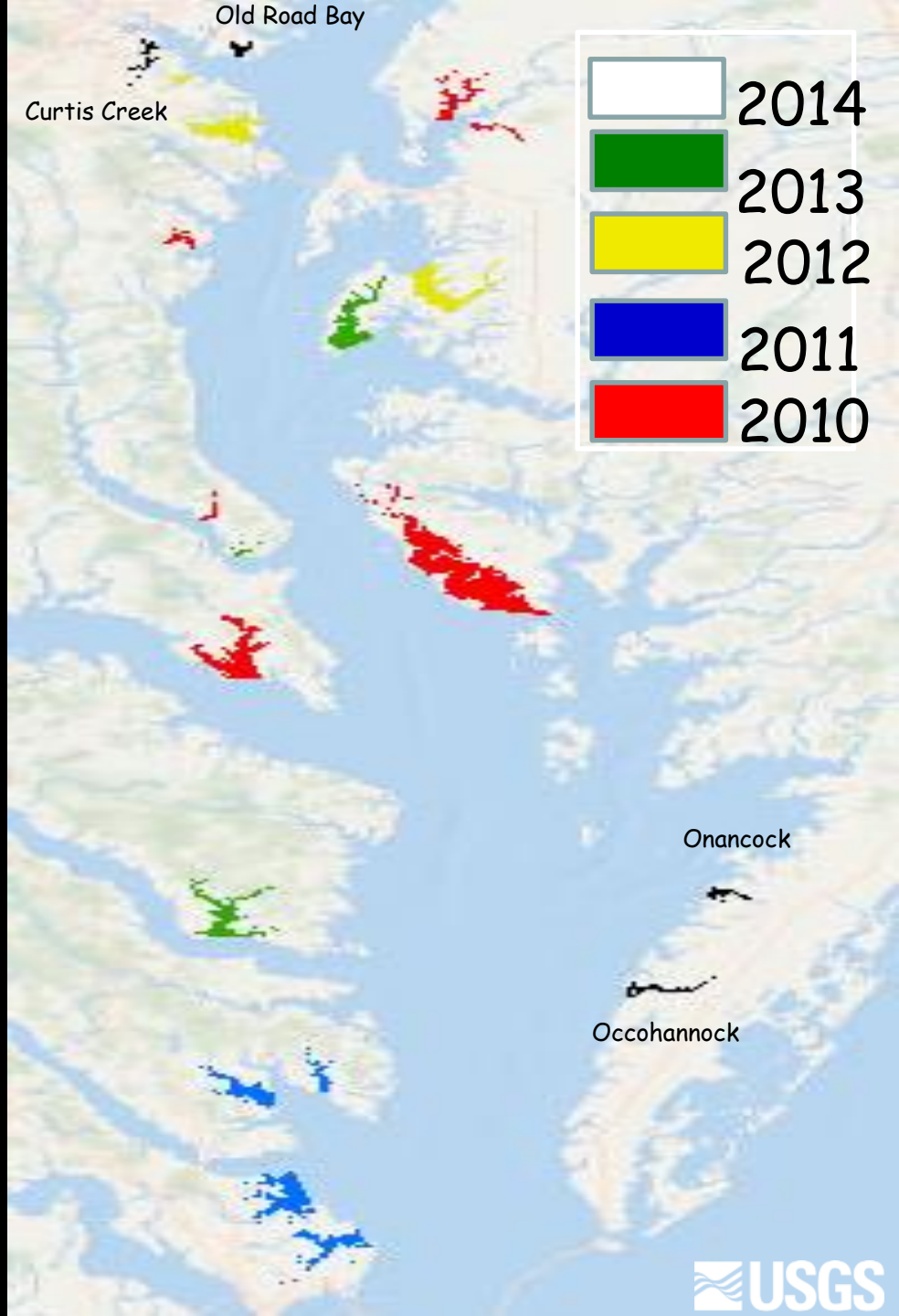
2014
Curtis Creek (Dev)
Old Road Bay (Dev)
Onancock River (Mix Ag)
Occohannock River (Mix Ag)

2013
Corrotoman River (For)
Harris Creek (Agr, MixDev)
Mill Creek (MixDev)

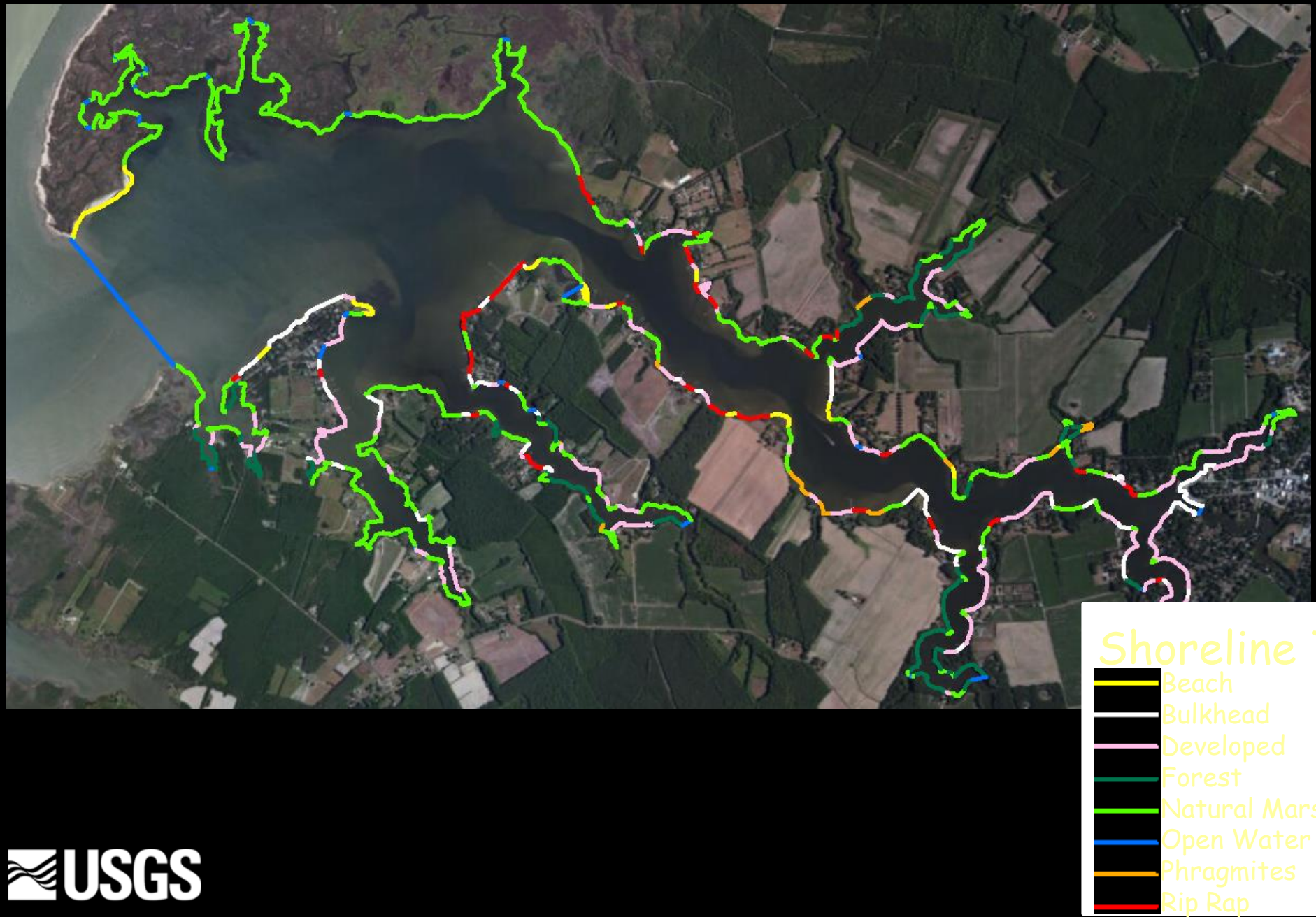
2012
Magothy River (MixDev, Dev)
Miles River (Agr, MixDev)
Stony Creek (Dev)

2011
Back River (Dev)
East River (For)
Poquoson River (Mix Dev)
Ware River (For)

2010
Corsica River (Agr)
Honga River (Oth Mix)
Langford Creek (Agr)
Rhode River (For)
St. Mary River (Oth Mix,For)
St. Leonard Cr. (For)

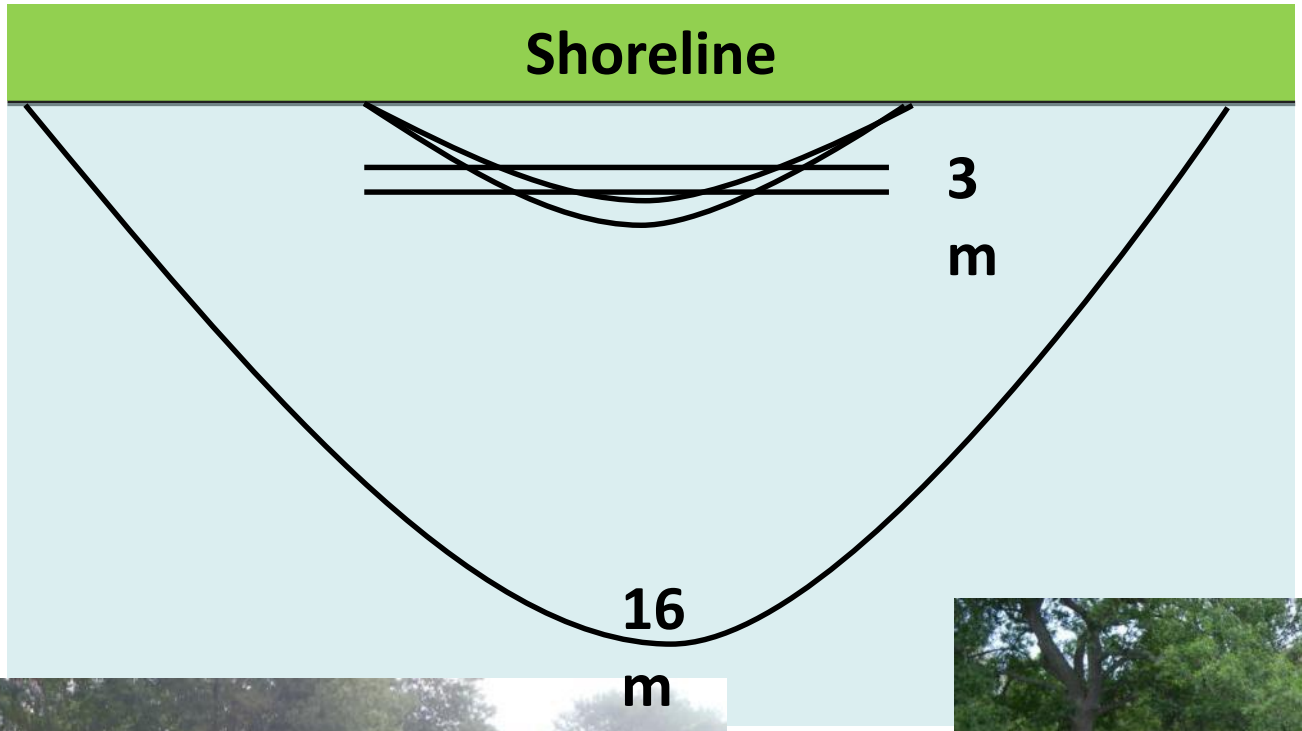


Shoreline Delineations (GIS and Groundtruth)



USGS

Two Zones of Sampling



What happens at the subwatershed scale matters for birds

Top model by AIC for each scale
Relating IWCI to shoreline habita

Subestuary	P-value
BH+RR+NM	0.02

Landscape 500m	P-value
Percent Wetland	0.05

Watershed	P-value
null	NS
Percent Wetland	NS

Systems without high % developed land

	% variation among subestuaries explained if model includes:			
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