Ecosystem Services of Restored Oyster Reefs in the Lower Chesapeake Bay: Macrofauna Enhancement and Fish Foraging

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Goal: Optimize future reef restoration

Specific Objectives

- **Oyster**: Examine lower bay tributary oyster populations via patent tong survey
- **Benthos:** Examine benthic community structure on restored reefs using embedded settlement trays

- **Fish:** Determine
  - finfish and blue crab utilization of oyster reefs in relation to reef & environmental conditions
  - prey availability using gut contents

- **Crabs**: Using underwater cameras, examine role of crabs on experimental natural reef as
  - predator
  - prey

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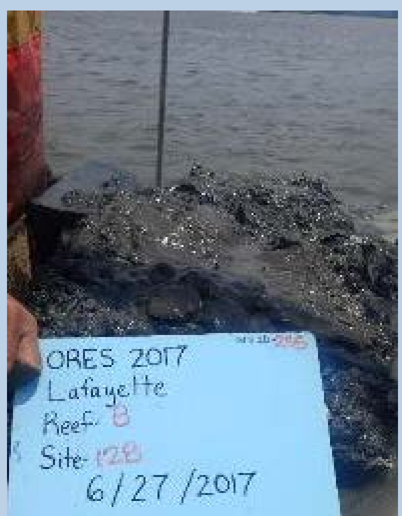
Oyster Populations

- 4 lower Bay locations
  - Great Wicomico
  - Piankatank
  - Lafayette
  - Lynnhaven
- Patent tongs used
- Sanctuary and relict oyster reefs
- Provides basis for assessment of secondary production



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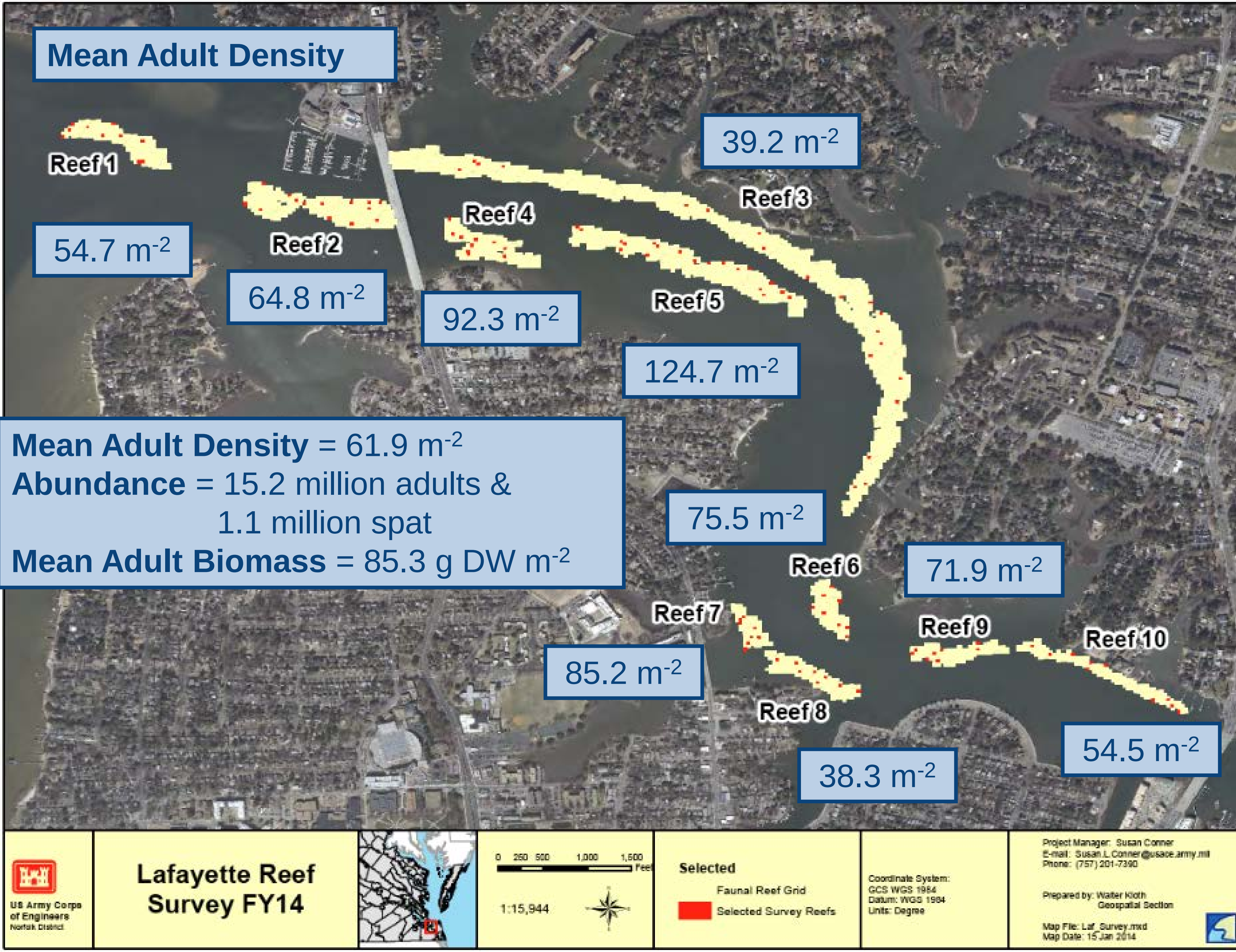

Mean Adult Density
Reef 1
54.7 m-2
Reef 2
64.8 m-2
Reef 3
39.2 m-2
Reef 4
92.3 m-2
Reef 5
124.7 m-2
Reef 6
75.5 m-2
Reef 7
85.2 m-2
Reef 8
38.3 m-2
Reef 9
71.9 m-2
Reef 10
54.5 m-2
Mean Adult Density = 61.9 m-2
Abundance = 15.2 million adults &
1.1 million spat
Mean Adult Biomass = 85.3 g DW m-2
US Army Corps of Engineers
Norfolk District
Lafayette Reef Survey FY14
0 250 500 1,000 1,500 Feet
1:15,944
Selected
Faunal Reef Grid
Selected Survey Reefs
Coordinate System:
GCS WGS 1984
Datum: WGS 1984
Units: Degree
Project Manager: Susan Conner
E-mail: Susan.L.Conner@usace.army.mil
Phone: (757) 201-7390
Prepared by: Walter Kloth
Geospatial Section
Map File: Laf_Survey.mxd
Map Date: 15 Jan 2014

Great Wicomico

- Most reefs met threshold (15 oyst./m^2) and target (50 oyst./m^2) density & biomass
  - Sanctuary reefs doing well except where poached or on mud bottom

Lynnhaven River

- Met threshold (15 oysters/m^2) and target (50 oysters/ m^2) density
  - Except in a small area where storm washed away constructed reef

Lafayette River

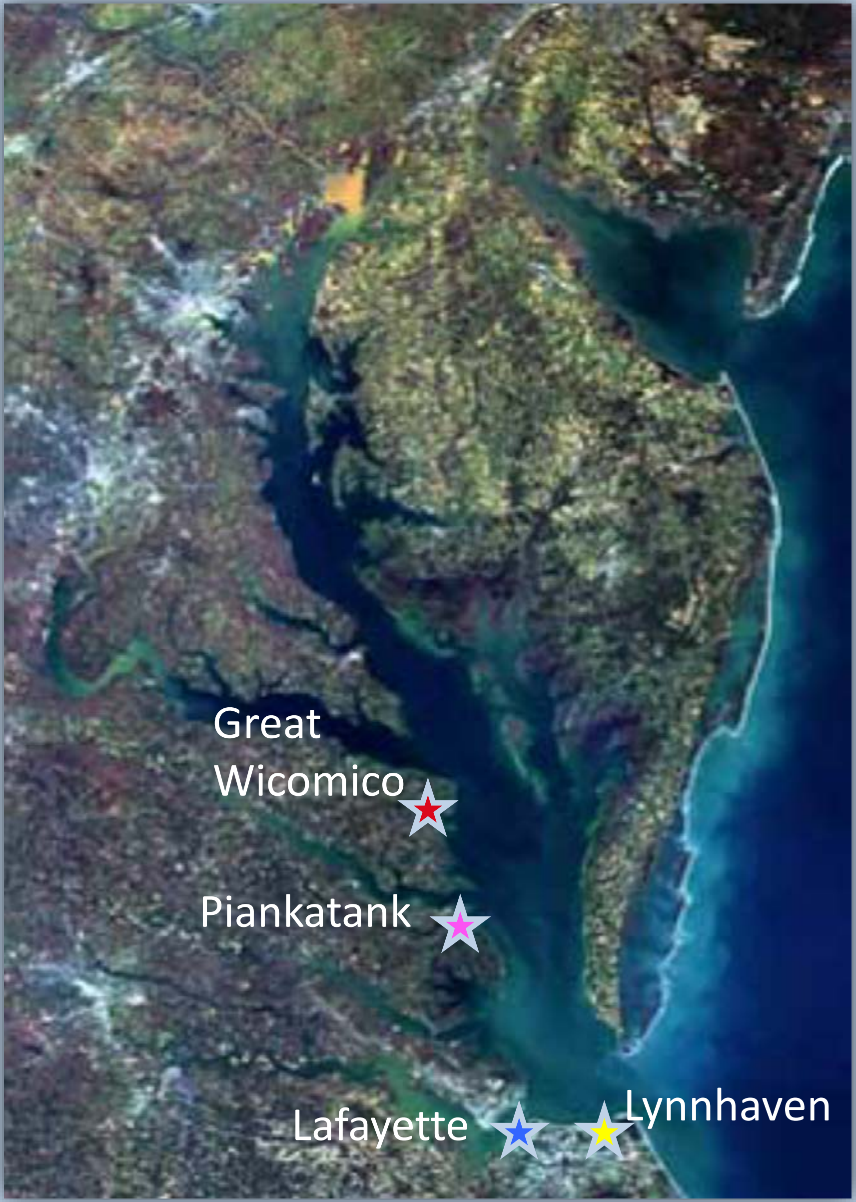
- Relict reefs located (15 million live adult oysters)
  - multiple year classes at high density (50-100/m^2) and biomass (> 50g DW/m^2)

Benthic macrofauna : main questions

1. What is the benthic community structure and productivity on large (1.62-4.86 Ha), subtidal, restored oyster reefs in Chesapeake Bay?

2. Does species composition and productivity depend on reef structure and environmental conditions?

Benthic Sampling: Trays & locations



Geographic range: 164 km north to south

- ★ 2014 and 2016
- ★ 2015 only
- ★ 2014 and 2015
- ★ 2015 and 2016

<u>Benthic trays:</u>

On 4 reefs/river

0.122 m^2

15 cm deep

1.0 mm mesh liner

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Results from benthic survey

- Restored oyster reef habitat supports diverse (66 spp.) and productive (75.6 g AFDW m^{-2} and 6,356 ind. m^{-2}) macrofaunal communities
  - Community composition differs depending on the river
  - Biomass greater than unstructured (7 to 25 g AFDW m^{-2}; Lawless & Seitz 2014, Lovall et al. 2017)

- Diversity on restored oyster reefs positively related to salinity
- Reef complexity & greater oyster density leads to enhanced ecosystem services (oysters are ecosystem engineers)
- Species present could serve as prey for higher trophic levels

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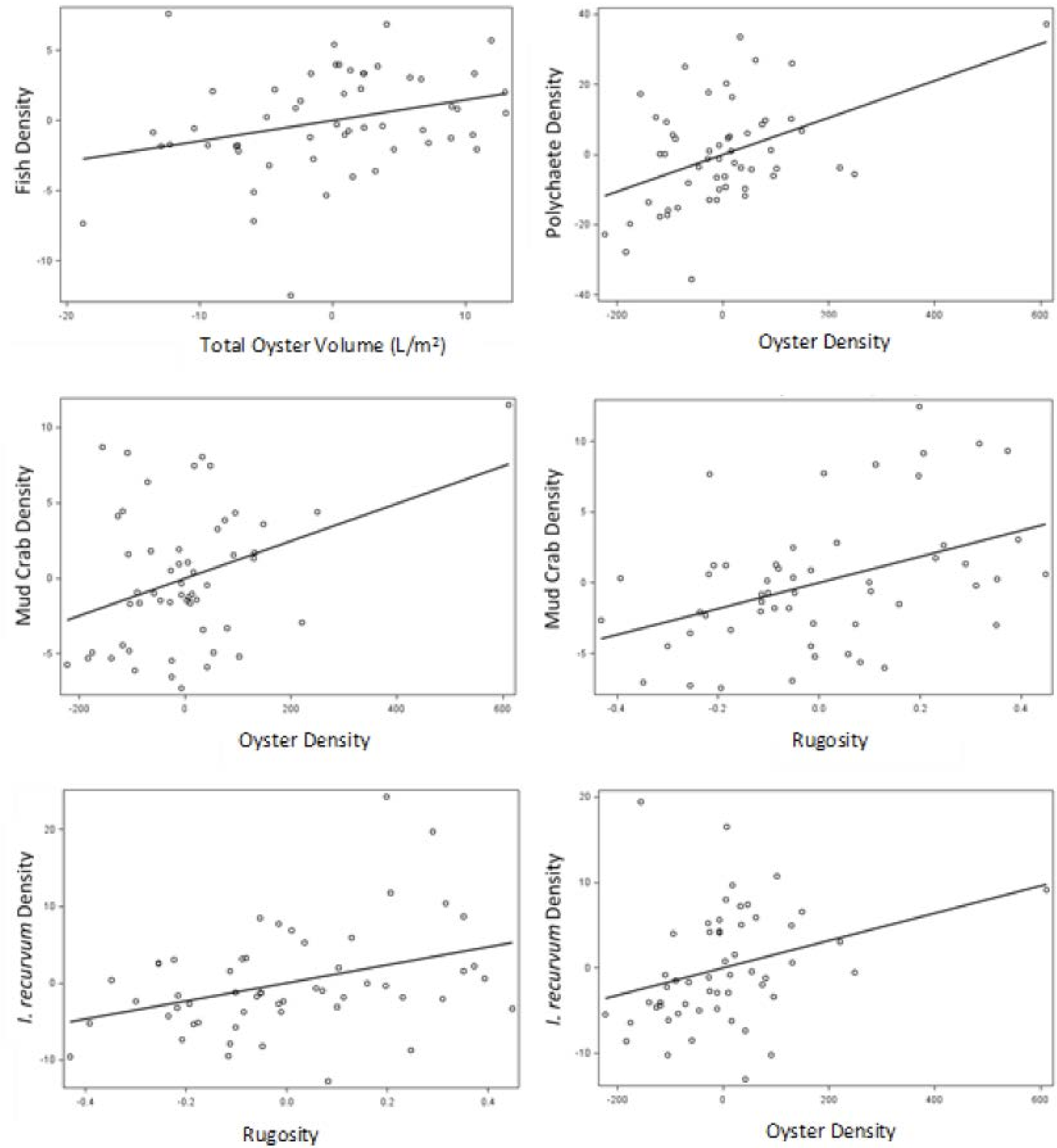
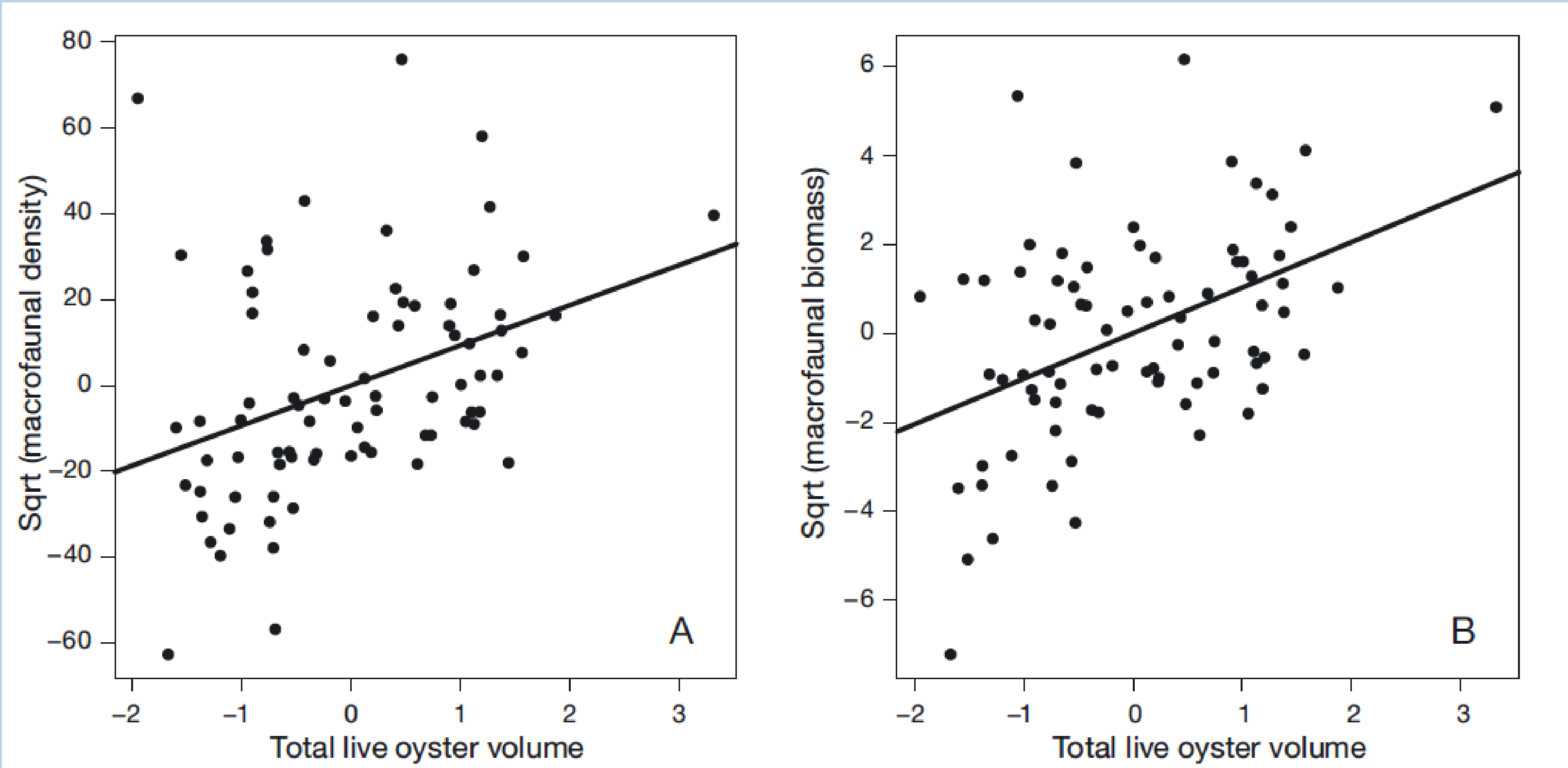
Reef complexity & benthic species



Ecosystem Services: Benthos

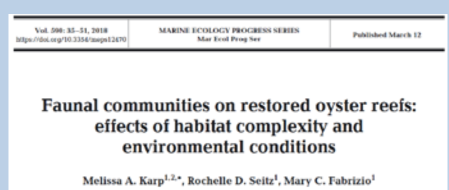


$r^2 = 0.30$, $p < 0.05$

$r^2 = 0.36$, $p < 0.05$

Total live oyster volume was a positive and significant predictor of mean macrofaunal density and biomass

Karp et al. 2018 (MEPS 590: 35-51)



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Faunal communities on restored oyster reefs: effects of habitat complexity and environmental conditions

Melissa A. Karp[1,2,*], Rochelle D. Seitz[1], Mary C. Fabrizio[1]

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Fish Utilization: Goals & Methods

- **Quantify finfish and blue crab utilization of oyster reefs using:**
  - Seasonal and 24-Hour Gill Netting
  - Diet Analysis
  - Daily Consumption Rate Estimates
- **Focused Primarily on:** Silver Perch & Spot (most abundant)

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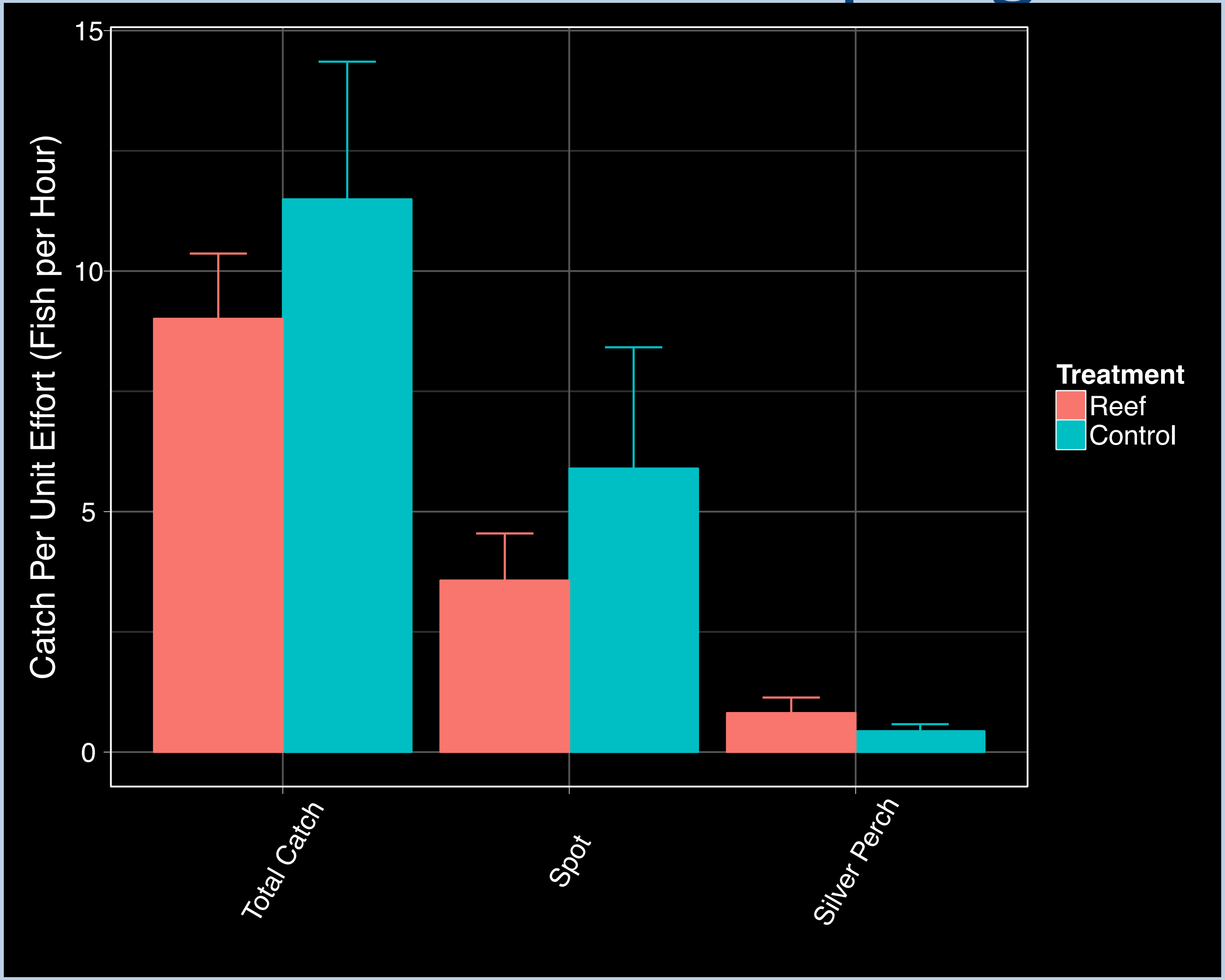
Overall Fish Abundance: Seasonal sampling



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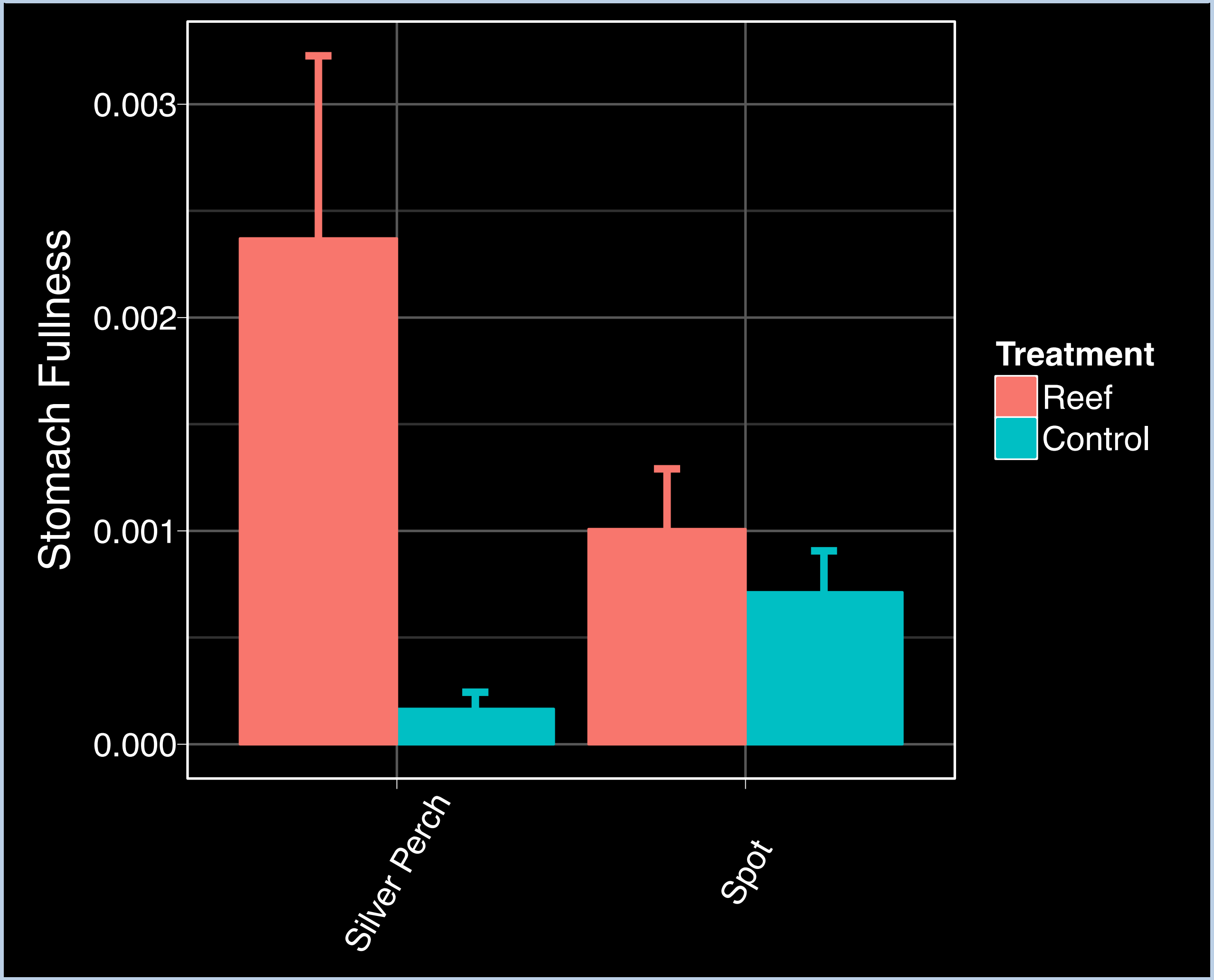
Stomach Fullness



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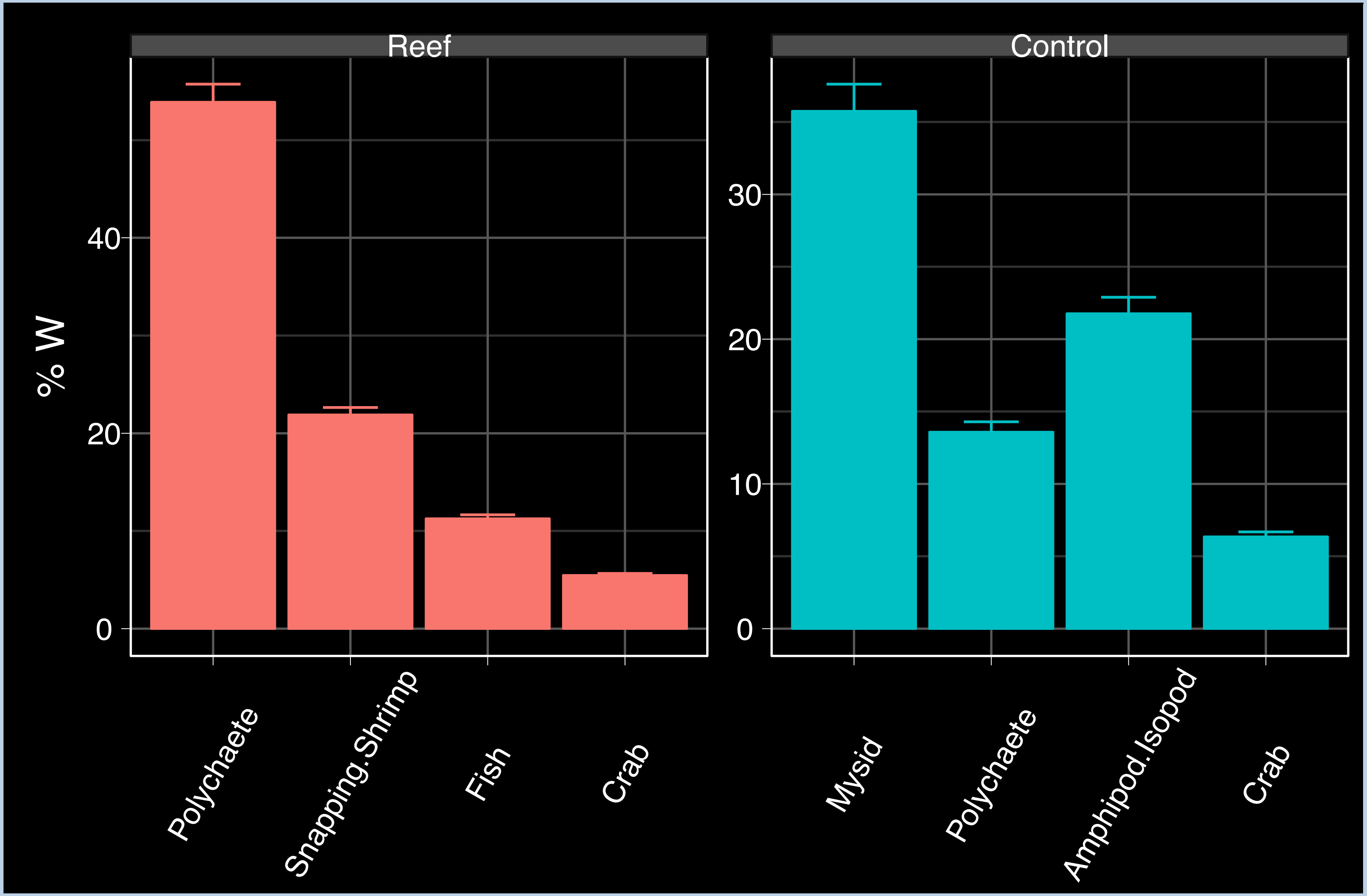
Silver Perch % Diet by Weight



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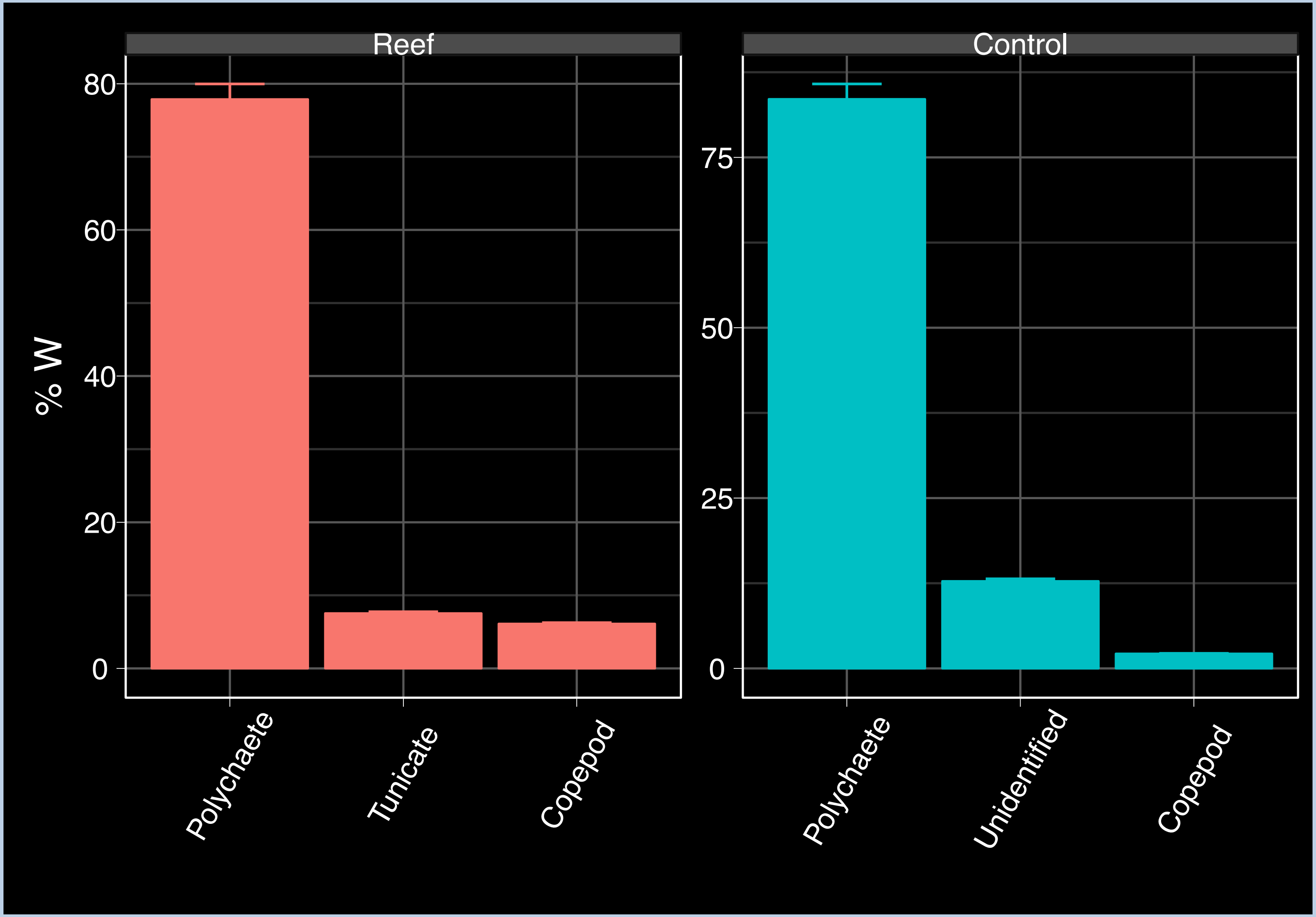
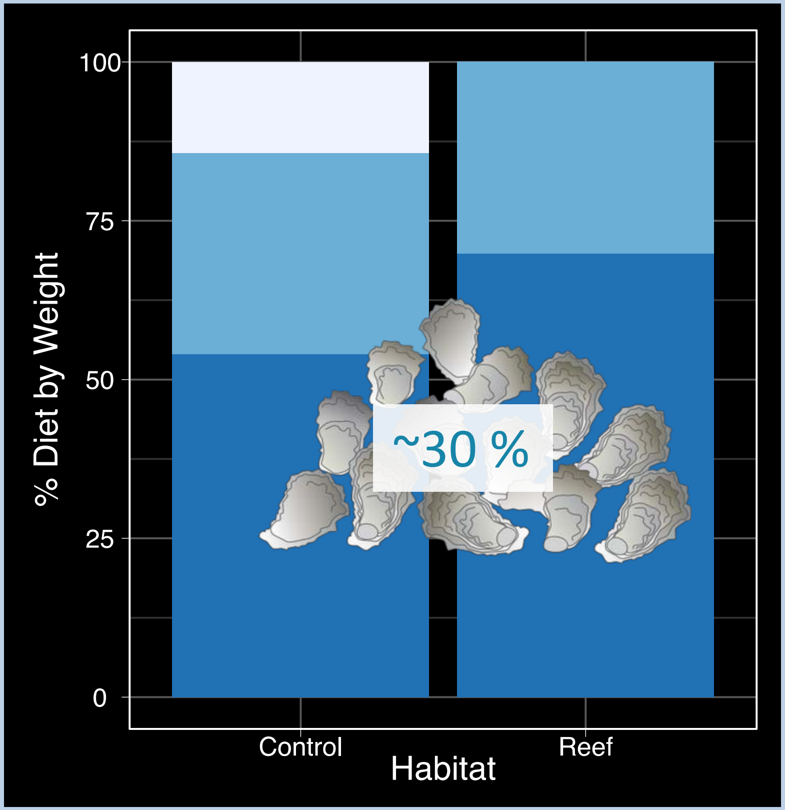
Spot % Diet by Weight

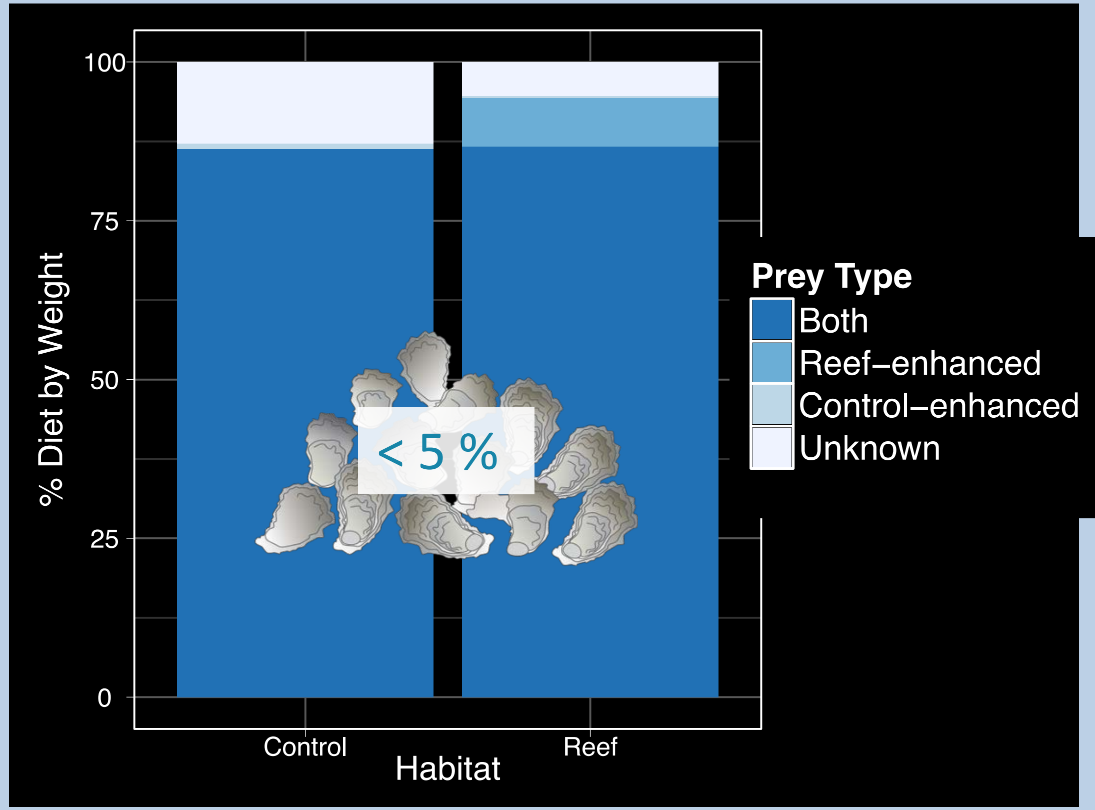


%of Reef-Associated Prey

Silver Perch



Spot



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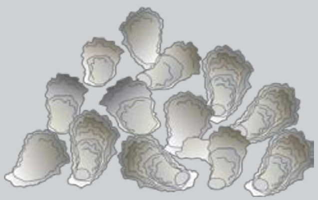
Conclusion fish foraging: Greater silver perch daily consumption

Habitat	Consumption Rate (S.E.) % Body Weight	Consumption per Individual (g prey / fish)	Caloric Intake (calories / day)
	2 % (0.7)	0.514	585.4
Control	1.1 % (0.6)	0.288	232.1

Over 2x greater caloric intake

Pfirrmann & Seitz 2019 (MEPS 628: 155-169)

Vol. 628: 155–169, 2019
https://doi.org/10.3354/meps13097
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Ecosystem services of restored oyster reefs in a Chesapeake Bay tributary: abundance and foraging of estuarine fishes

Bruce W. Pfirrmann[1,2,*], Rochelle D. Seitz[1]

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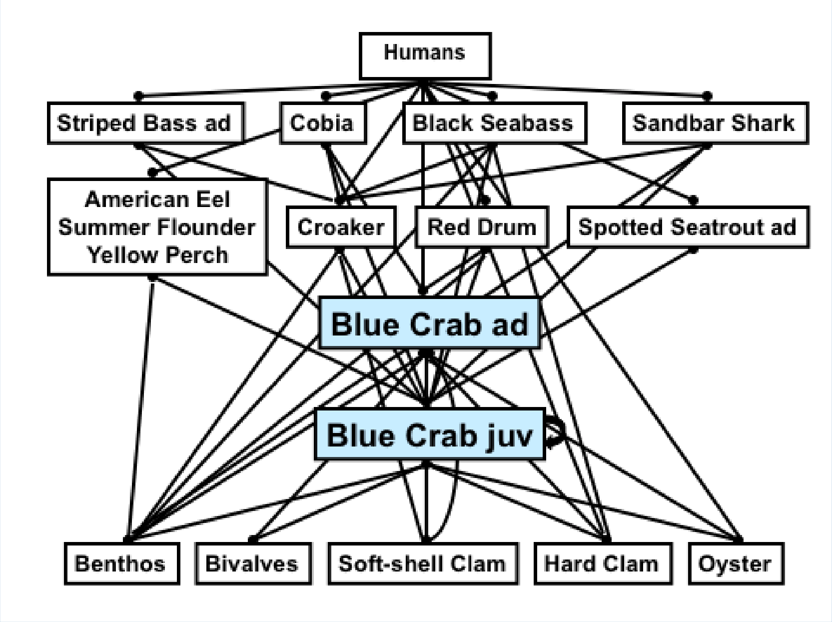
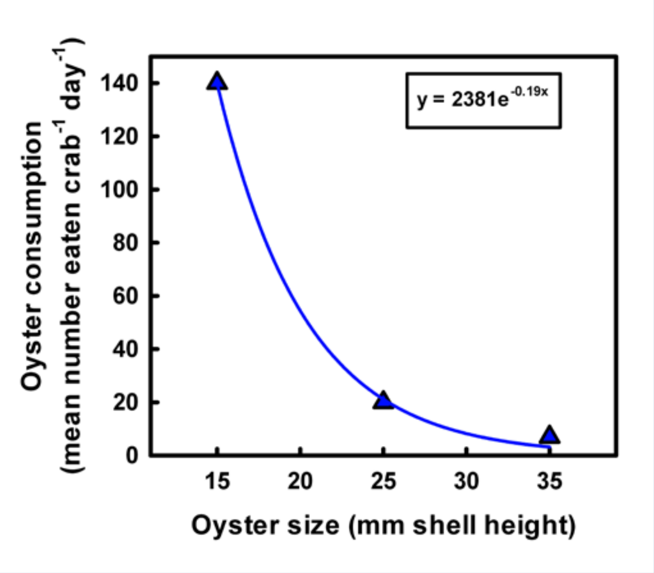
Food Web of the Blue Crab and Eastern Oyster

- Predation on *Crassostrea virginica* is well documented
- Scavenging has been little studied
- Current paradigm is that young oysters are prey, but adults fall to detrital pool
- No direct link from oysters to scavengers



Lipcius, R.N. and R.J. Latour. 2006. Food web interactions and modeling. Pp. 91-128, In **Fisheries Ecosystem Planning for the Chesapeake Bay**. American Fisheries Society, Trends in Fisheries Science and Management 3, Bethesda, Maryland.



Eggleston, D.B. (1990)

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Methods:
Predators on oyster reefs

Experimental Oysters cracked or gaping

Underwater video set up

Reef developed on racks used for aquaculture, structure mimics natural reefs

Oysters placed on reef

Video footage examined for predators of oysters

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Crushed oysters

Gobies first, then blennies, then mud crabs, then blue crabs;
All consumed within 30 min

Gaping oysters

Gobies first, then mud crabs, then blennies, then blue crabs –

(blue crabs required before others could feed)

All consumed within 105 min

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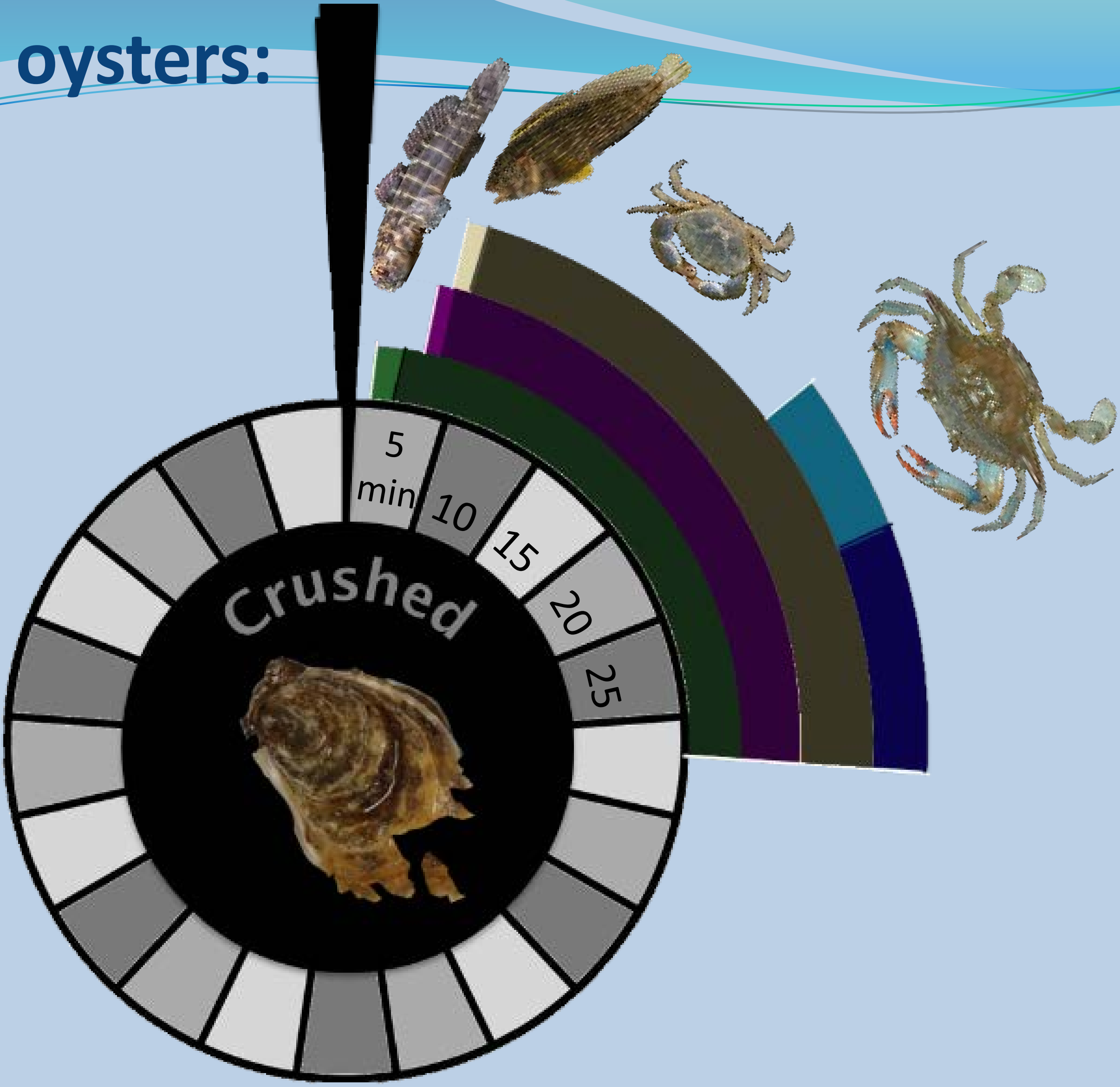
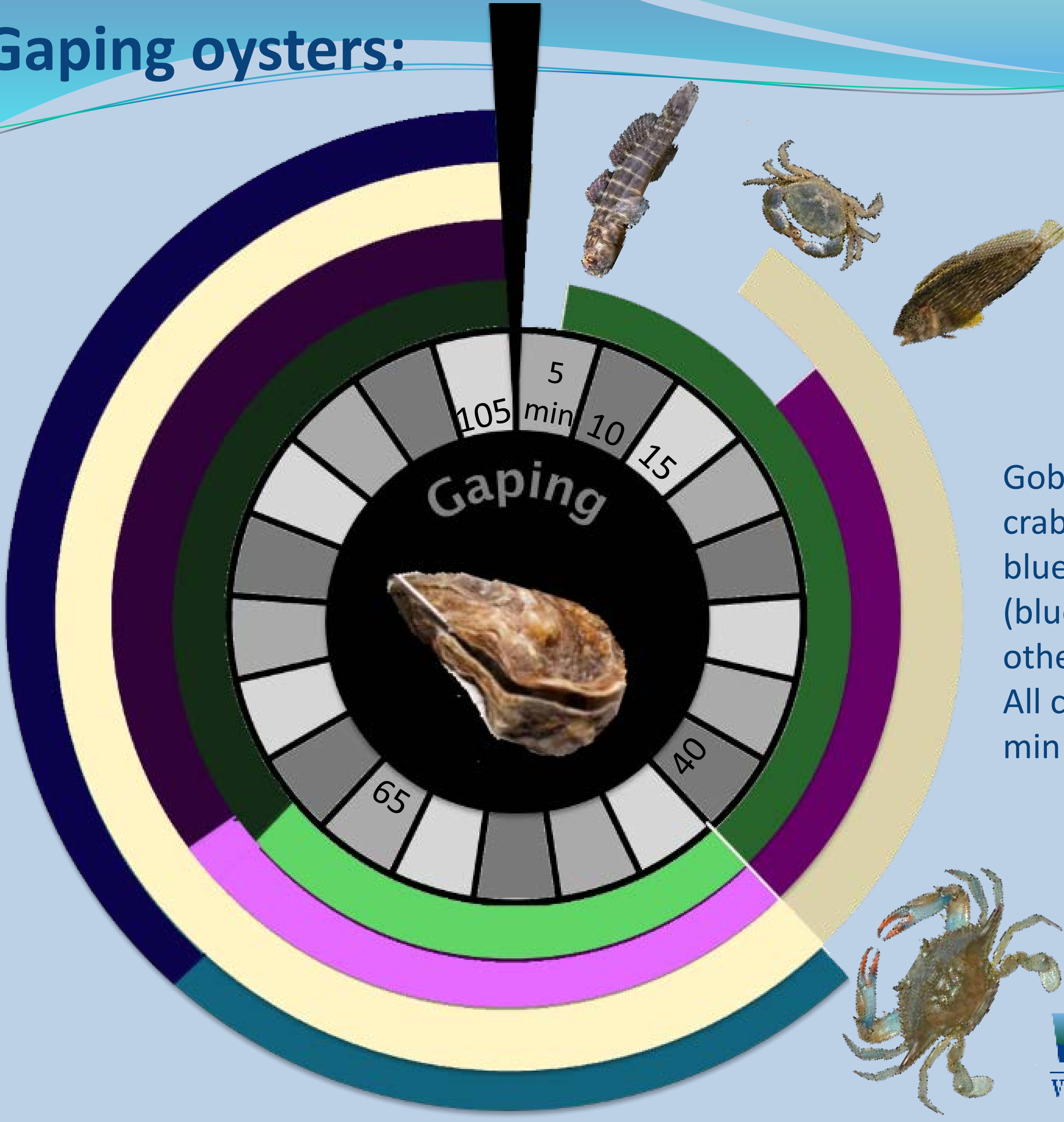
Crushed oysters:



Gobies first, then blennies, then mud crabs, then blue crabs;
All consumed within 30 min

Gaping oysters:



Gobies first, then mud crabs, then blennies, then blue crabs –
(blue crabs required before others could feed);
All consumed within 105 min

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Conclusions: scavenging

- All oysters were scavenged in hours (little decomposition)
  - Decomposition in 2-4 days without scavengers (Hoese 1962)
- Specific suite of scavengers during this summer experiment
- Differences in pathways between treatments
- Blue crabs both main competitors and main facilitators → Treatment reversed roles

Implications

- Dead oysters moving to higher trophic levels (not detrital web)
- Ecosystem service- enhanced production of blue crab
- Revise and transform food web to bioeconomic model
  - Estimation of value

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Oysters as prey: oyster reefs shield juvenile blue crabs

Goal: Examine relative predation on juvenile blue crabs on structured and unstructured habitats

- Juvenile *C. sapidus* (10-50 mm CW) tethered
  - on subtidal sand (n = 42)
  - on experimental natural oyster reef (n = 42)
  - examined during late summer/early fall of 2017

- Underwater camera recorded 24-hour trials to capture predation
- Crab survival was recorded after trial

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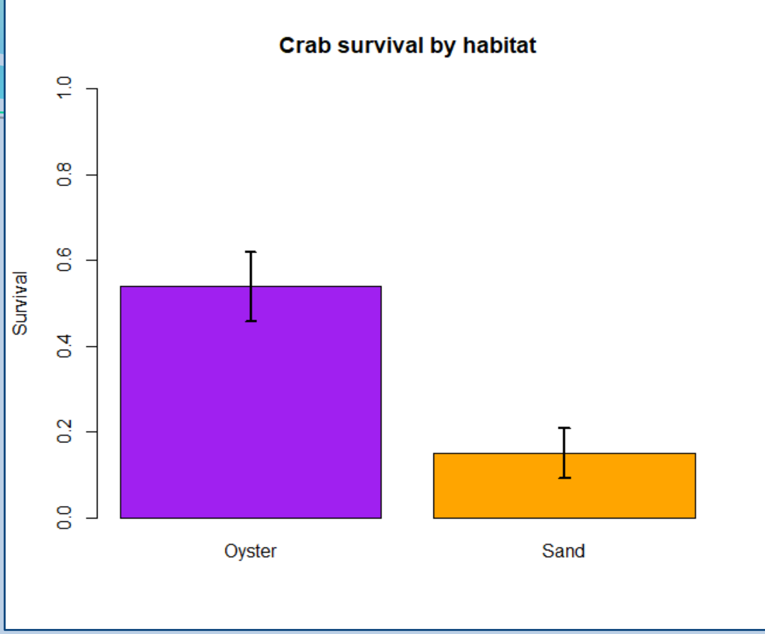
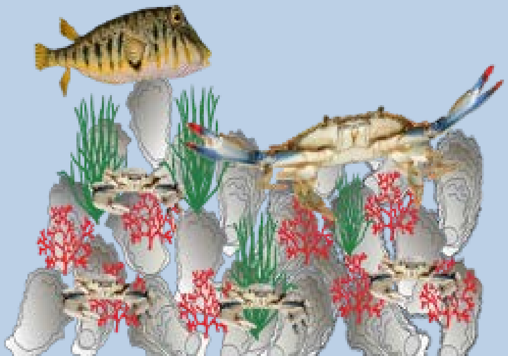
Results

- Crab survival was higher on oyster reef (52.7%) than bare sand (15.0 %)
- Major predators were
  - Adult Blue Crab (Sand)
  - Northern Puffer (Oyster)



Implications

- High juvenile survival suggests that reef structure can provide predator refuge in Chesapeake Bay
- Caveat: mud crabs can exclude small juvenile blue crabs from reefs, and few juvenile oysters found on oyster reefs in Chesapeake Bay
- Larger juveniles/adults use oyster reef as foraging grounds



Young blue crabs exposed on sand are easily

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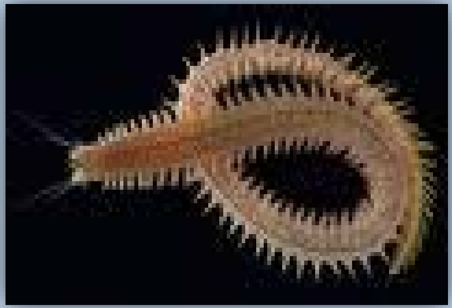
Overall:
Key Findings & Management Implications

- **Oyster:**
  - Oyster restoration is succeeding in lower Ches Bay (most reefs meet GIT measures for success)
  - Relict reefs productive for 5 decades
- **Benthos:**
  - Dense and productive macrofauna
  - Restored reefs w high live oyster volume magnify benthic macrofaunal communities
- **Fish:**
  - Reefs serve as productive foraging ground for silver perch; important for higher trophic levels
- **Crabs:**
  - Predator study
    - Consumption of dead oysters enhances higher trophic levels
  - Prey study
    - Reefs can protect juvenile blue crabs from predation, but crabs excluded by mud crabs
- ***Overall: Multiple important ecosystem services provided***



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Live oyster density and biomass:
yellow = meets threshold, green= meets target

Tributary	Reef	2015		2017	
		Number per m^2	Biomass (g) per m^2	Number per m^2	Biomass (g) per m^2
Great Wicomico	1	480.40	21.32	145.03	35.54
	2	9.59	3.11	53.54	13.46
	3	297.26	9.15	355.99	93.45
	4	394.74	25.58	660.03	96.22
	8	64.72	21.34	19.71	5.95
	9	226.14	47.24	142.24	36.97
	10	28.77	9.18	64.72	19.39
	11	277.21	54.59	194.83	41.67
	12	426.71	11.89		
	13	977.67	62.01	775.50	90.65
	15	19.18	8.07	22.37	7.82
	16	411.12	45.47	979.66	151.85
Lafayette	1	30.68	10.00	28.77	11.46
	2	124.31	35.99	162.33	104.80
	3	95.89	34.63	79.11	45.09
	4	50.82	17.83	89.04	49.29
	5	150.23	70.18	178.46	144.78
	6	105.48	39.19	220.54	153.64
	7	77.91	32.00	105.48	93.68
	8	121.30	42.76	55.62	69.60
	9	55.94	32.45	57.53	37.04
	10	47.94	33.92	47.94	56.96
	11	56.73	35.84	62.33	60.24
Lynnhaven	BB1	184.24	94.60	347.60	125.46
	BB2	206.16	101.27	209.36	77.24
	BB3	118.26	61.61	131.05	59.31
	LB1	188.58	105.06	63.70	45.81
	LB2	109.37	63.63	145.03	59.90
	LB3	220.54	134.98	60.73	43.04
	LB4	357.98	199.69	258.90	155.83
	LB5	139.04	113.00	1.60	0.15
	UEB	349.99	151.91		

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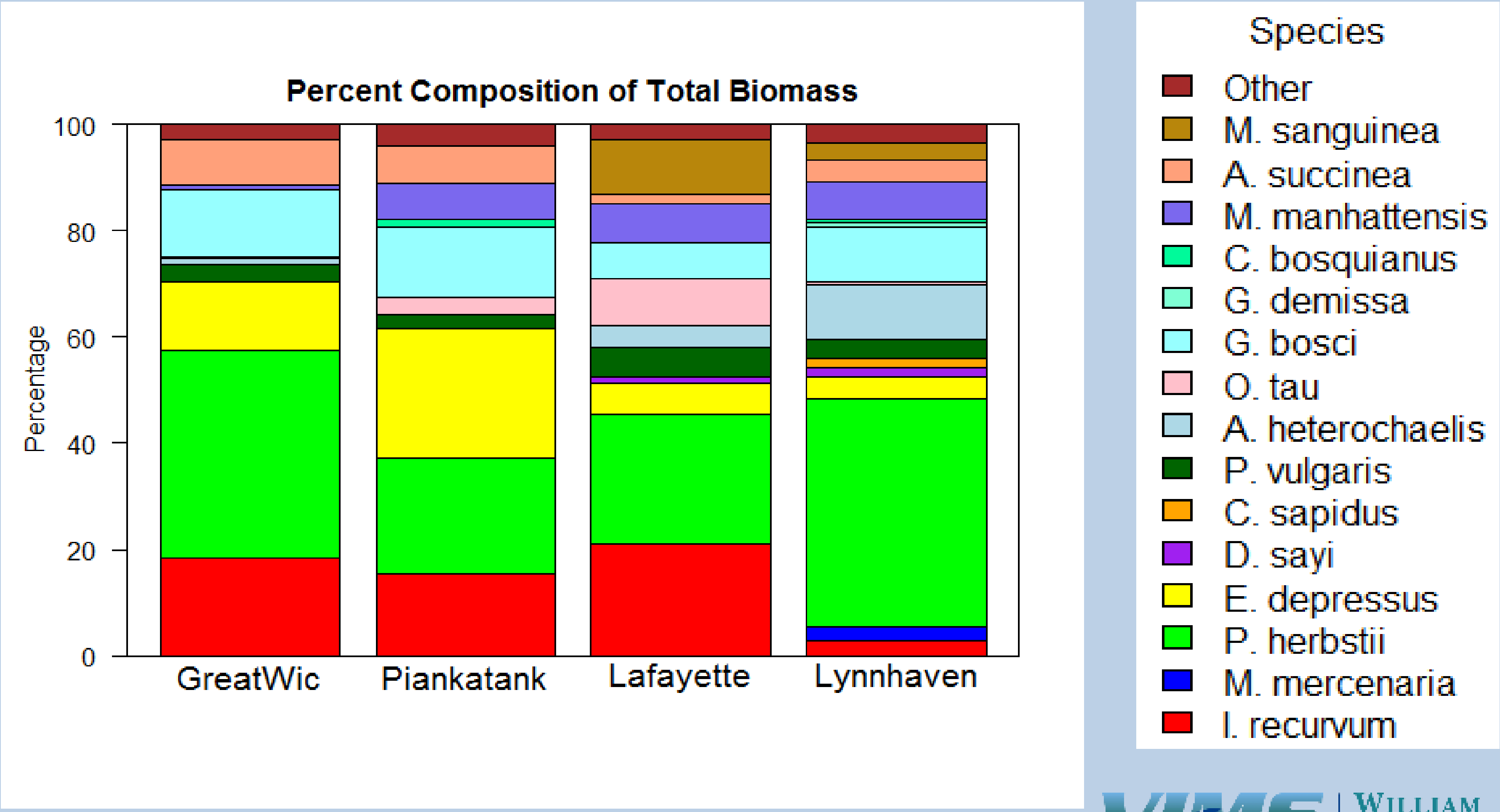
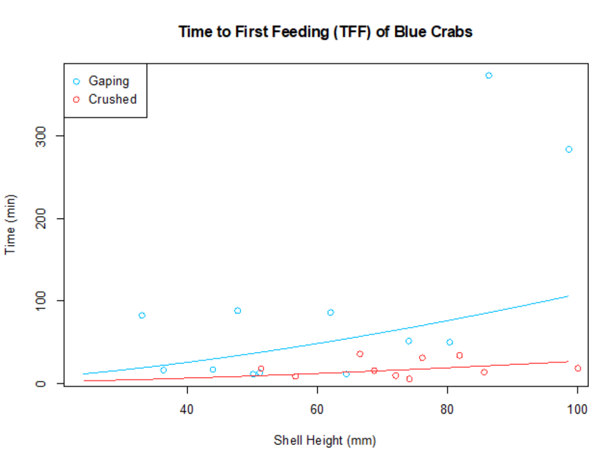
Macrofauna biomass by river



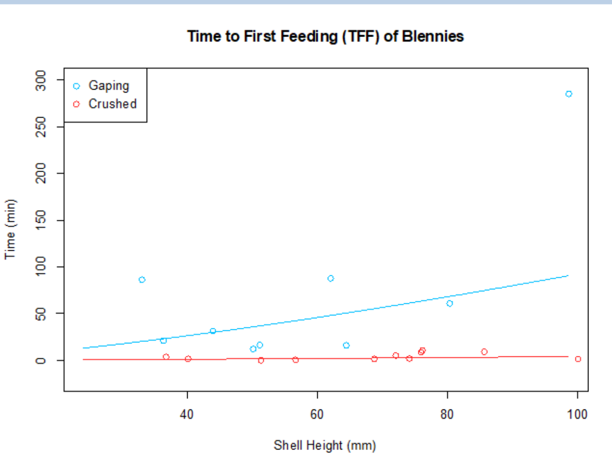


$$TFF_{Crushed} = 0.0186 \cdot SH^{1.5793}$$

$$TFF_{Gaping} = 0.0752 \cdot SH^{1.5793}$$

$R^2 = 0.38$

$p = 0.01$

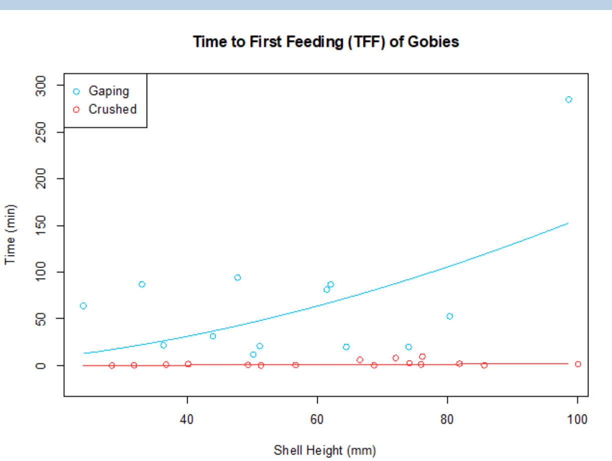


$$TFF_{Crushed} = 0.0006 \cdot SH^{1.7565}$$

$$TFF_{Gaping} = 0.0480 \cdot SH^{1.7565}$$

$R^2 = 0.75$

$p = < 0.001$



$$TFF_{Crushed} = 0.0078 \cdot SH^{1.3674}$$

$$TFF_{Gaping} = 0.1702 \cdot SH^{1.3674}$$

$R^2 = 0.67$

$p = < 0.0001$

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