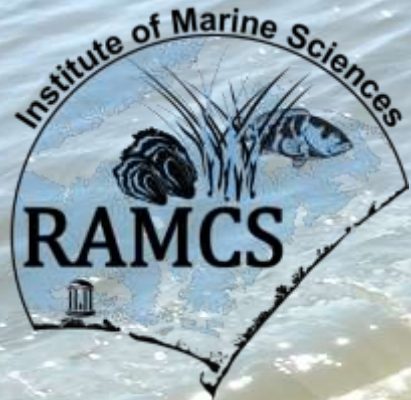


# Applying Fundamentals of Estuarine Ecology and a Novel Biodegradable Hardscape to Enhance Coastal Resilience

Niels Lindquist  
UNC Institute of Marine Sciences





A satellite view of Earth at night, showing the glowing lights of cities and urban areas along the coastlines. The lights are concentrated in the eastern United States and the western coast of Europe, with a dense network of lights following the coastlines. The ocean is dark, and the atmosphere is visible as a thin layer above the surface.

**With dense coastal habitation comes perpetual problems:**

**Environmental degradation**

**Loss of estuarine habitats and their  
valuable ecosystem services:**

**water quality**

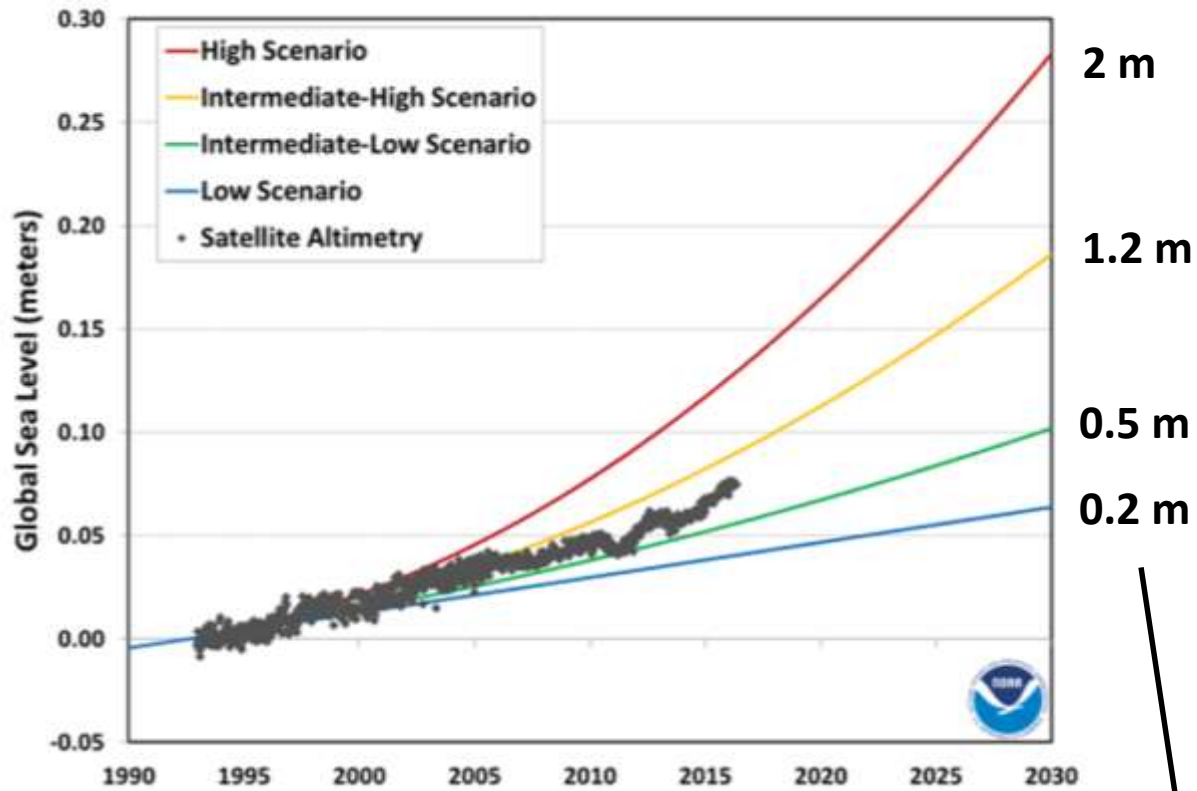
**seafood production**

**shoreline protection**

**Going forward – global change impacts, especially  
sea-level rise and stronger coastal storms, will  
be substantial challenges to coastal environmental, economic and social resilience.**

# Sea-Level Rise Considerations

<https://tidesandcurrents.noaa.gov/slregional/>

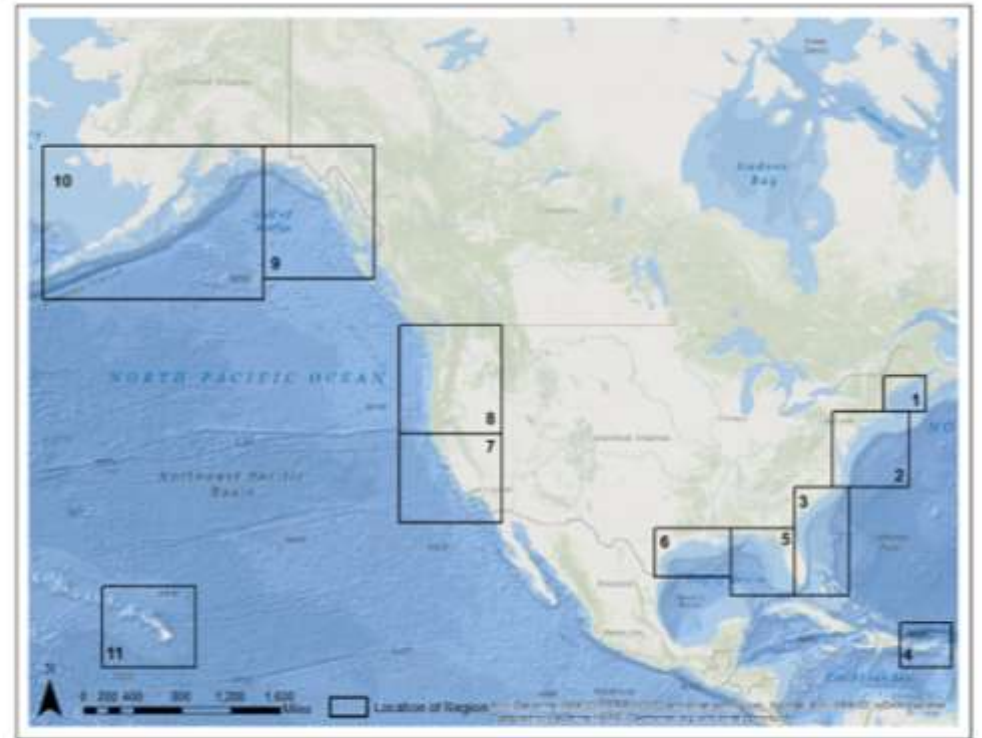


2 m

1.2 m

0.5 m

0.2 m



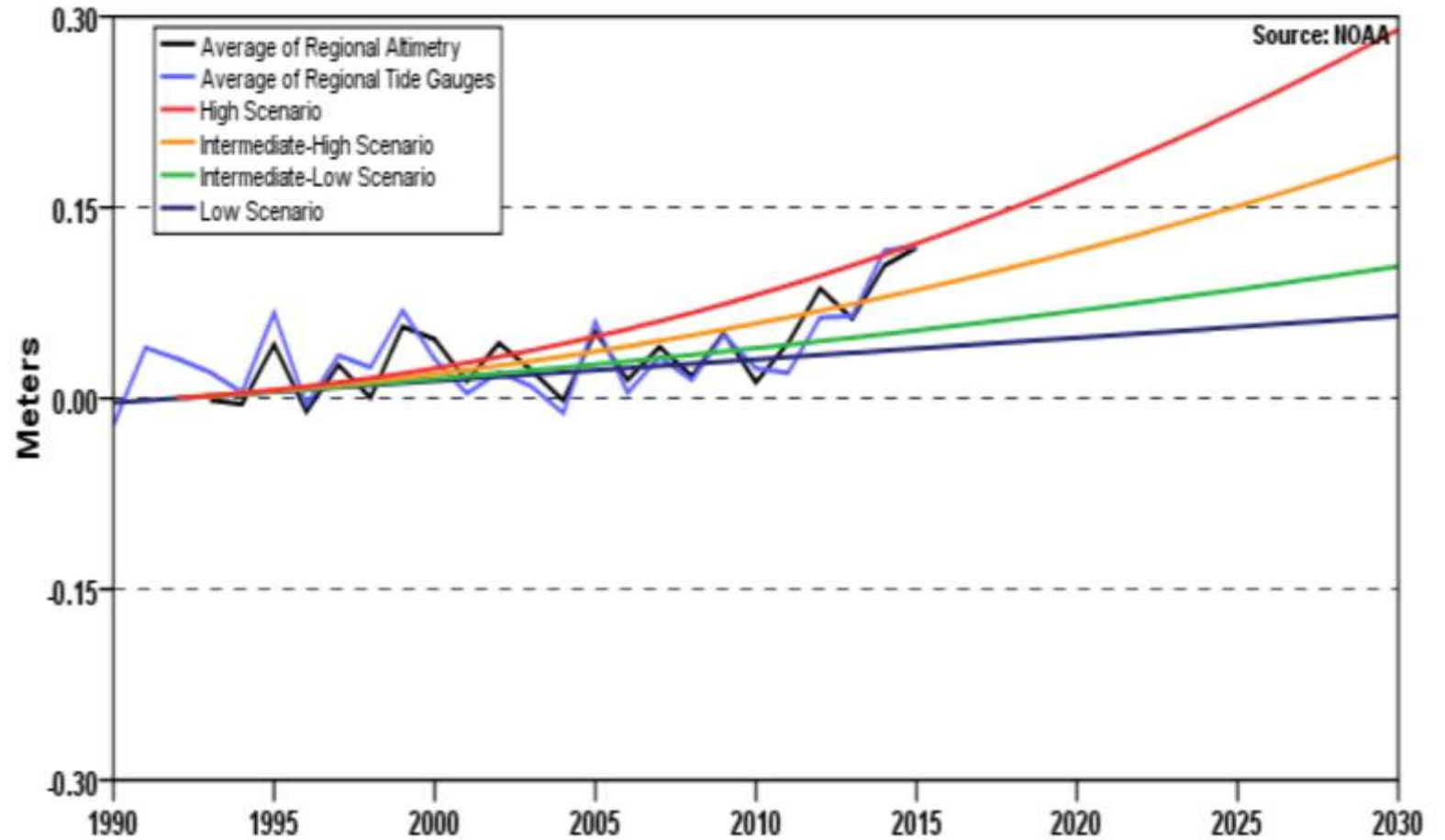
rise by 2100

# Regional Sea Levels and Future Scenarios

## South Atlantic Coast



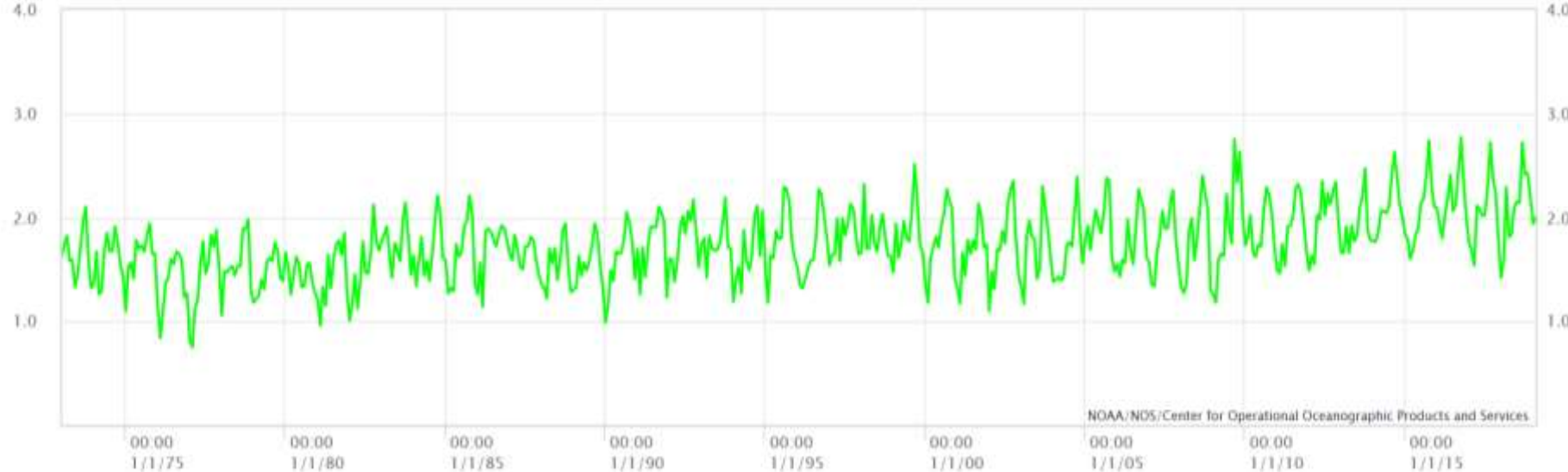
The map shows the location of the tide gauges and the satellite altimetry tracks used in the two regional indices.



NOAA/NOS/CO-OPS  
Verified Monthly Means at 8656483, Beaufort, Duke Marine Lab NC  
From 1973/01/01 00:00 GMT to 2019/02/01 23:59 GMT



Height in feet (MLLW)



NOAA/NOS/Center for Operational Oceanographic Products and Services



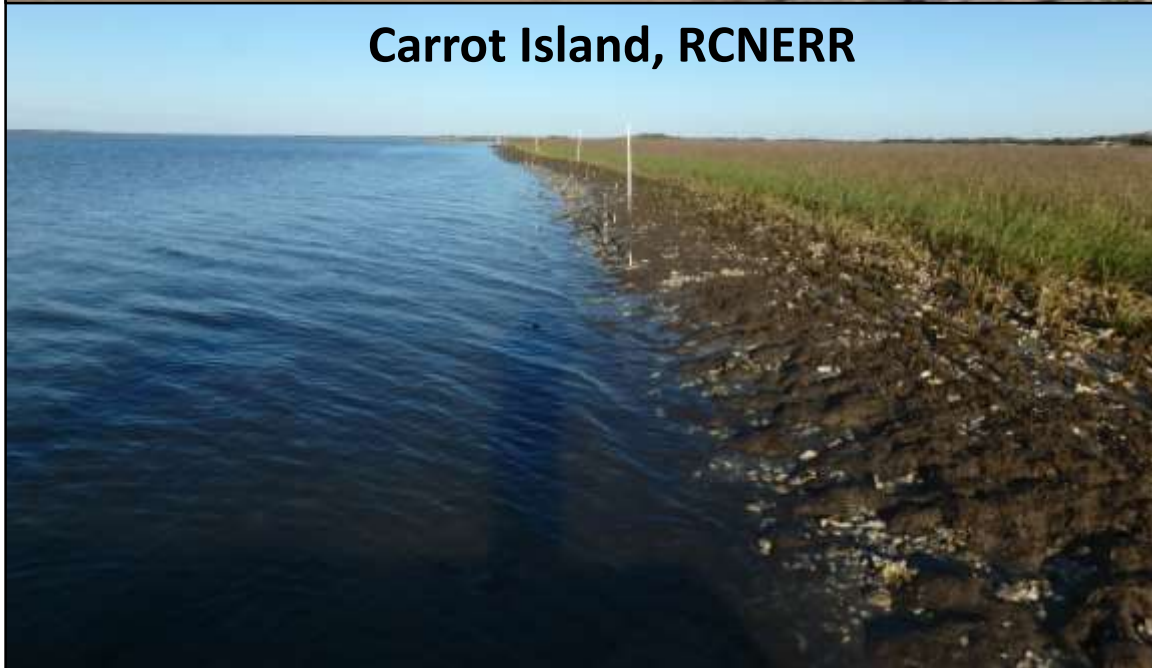
**Shackleford Banks**



**Sugarloaf Island**



**Carrot Island, RCNERR**



**Carrot Island, RCNERR**



What we want to see....





What we want to see....

**2009**

# SHELLFISH REEFS **AT RISK**

A Global Analysis of Problems and Solutions



What we want to see....

2009



**Growing desire to restore habitat foundation communities to recapture lost ecosystem services that enhance coastal resilience.**

What we want to see....

**2009**

**SHELLFISH REEFS  
AT RISK**  
A Global Analysis of Problems and Solutions

**Growing desire to restore habitat foundation communities to recapture lost ecosystem services that enhance coastal resilience.**

**To successfully restore habitat foundation species, in-depth knowledge and understanding of fundamental ecological principles is crucial!**

# Recent IMS-Based Oyster Research

nature  
climate change

LETTERS

PUBLISHED ONLINE: 28 APRIL 2014 | DOI: 10.1038/NCLIMATE2216

## Oyster reefs can outpace sea-level rise

Antonio B. Rodriguez<sup>1\*</sup>, F. Joel Fodrie<sup>1</sup>, Justin T. Ridge<sup>1</sup>, Niels L. Lindquist<sup>1</sup>, Ethan J. Theuerkauf<sup>1</sup>, Sara E. Coleman<sup>1</sup>, Jonathan H. Grabowski<sup>2</sup>, Michelle C. Brodeur<sup>1</sup>, Rachel K. Gittman<sup>1</sup>, Danielle A. Keller<sup>1</sup> and Matthew D. Kenworthy<sup>1</sup>



SCIENTIFIC REPORTS

50 YEARS WITH  
IMPACT

Journal of Applied Ecology



Journal of Applied Ecology 2014

doi: 10.1111/1365-2664.12276

## Classic paradigms in a novel environment: inserting food web and productivity lessons from rocky shores and saltmarshes into biogenic reef restoration

F. Joel Fodrie<sup>1\*</sup>, Antonio B. Rodriguez<sup>1</sup>, Christopher J. Baillie<sup>2</sup>, Michelle C. Brodeur<sup>1</sup>, Sara E. Coleman<sup>1</sup>, Rachel K. Gittman<sup>1</sup>, Danielle A. Keller<sup>1</sup>, Matthew D. Kenworthy<sup>1</sup>, Abigail K. Poray<sup>1</sup>, Justin T. Ridge<sup>1</sup>, Ethan J. Theuerkauf<sup>1</sup> and Niels L. Lindquist<sup>1</sup>

<sup>1</sup>Institute of Marine Sciences, University of North Carolina at Chapel Hill, 3431 Arendell Street, Morehead City, NC 28557, USA; and <sup>2</sup>Marine Science Center, Northeastern University, 430 Nahant Road, Nahant, MA 01908, USA

OPEN

## Maximizing oyster-reef growth supports green infrastructure with accelerating sea-level rise

Received: 21 April 2015

Accepted: 20 August 2015

Published: 07 October 2015

Justin T. Ridge<sup>1</sup>, Antonio B. Rodriguez<sup>1</sup>, F. Joel Fodrie<sup>1</sup>, Niels L. Lindquist<sup>1</sup>, Michelle C. Brodeur<sup>1</sup>, Sara E. Coleman<sup>1</sup>, Jonathan H. Grabowski<sup>2</sup> & Ethan J. Theuerkauf<sup>1</sup>

PROCEEDINGS OF THE ROYAL SOCIETY B: BIOLOGICAL SCIENCES

## Oyster reefs as carbon sources and sinks

F. Joel Fodrie, Antonio B. Rodriguez, Rachel K. Gittman, Jonathan H. Grabowski, Niels L. Lindquist, Charles H. Peterson, Michael F. Piehler and Justin T. Ridge

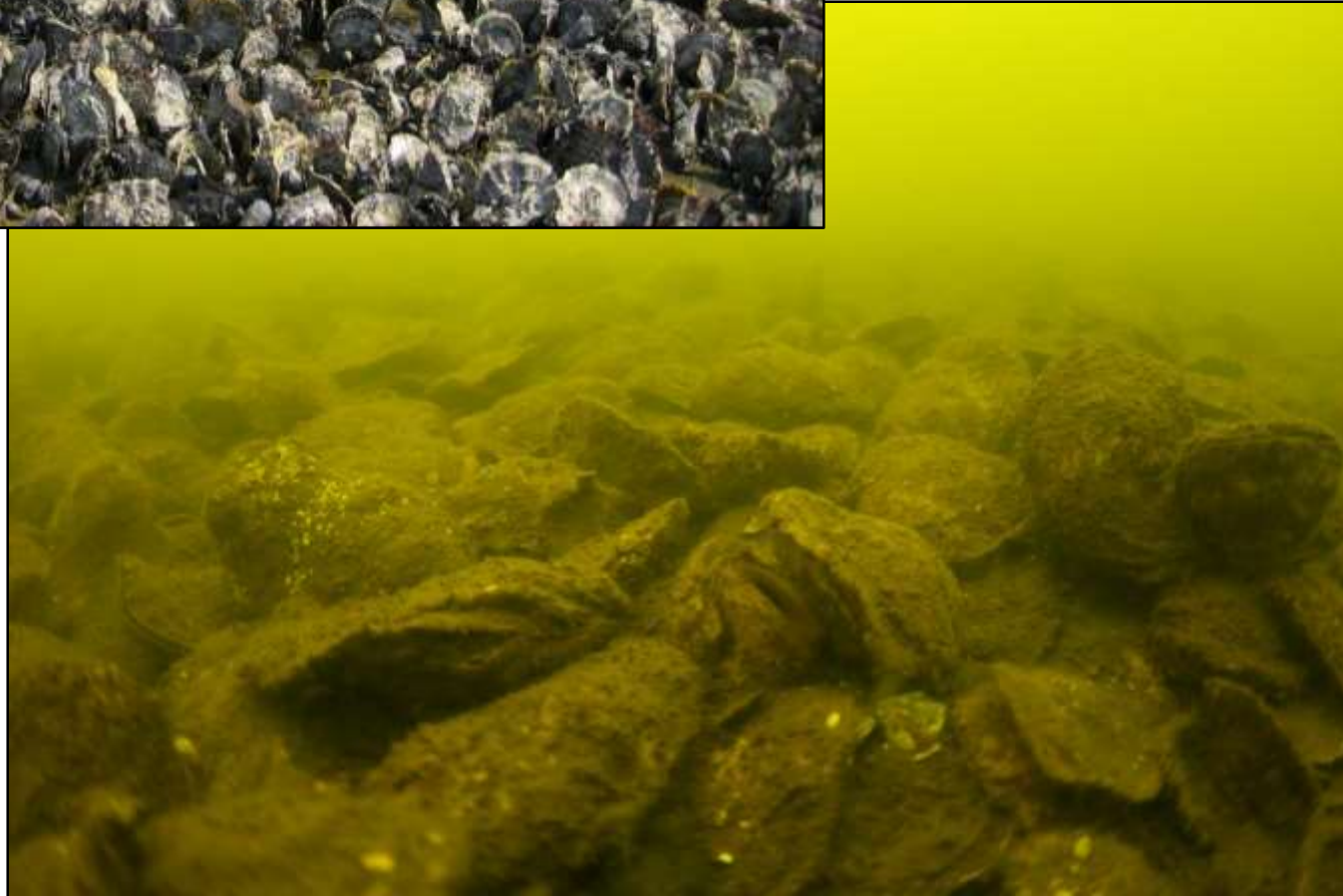
Published: 26 July 2017 | <https://doi.org/10.1098/rspb.2017.0891>



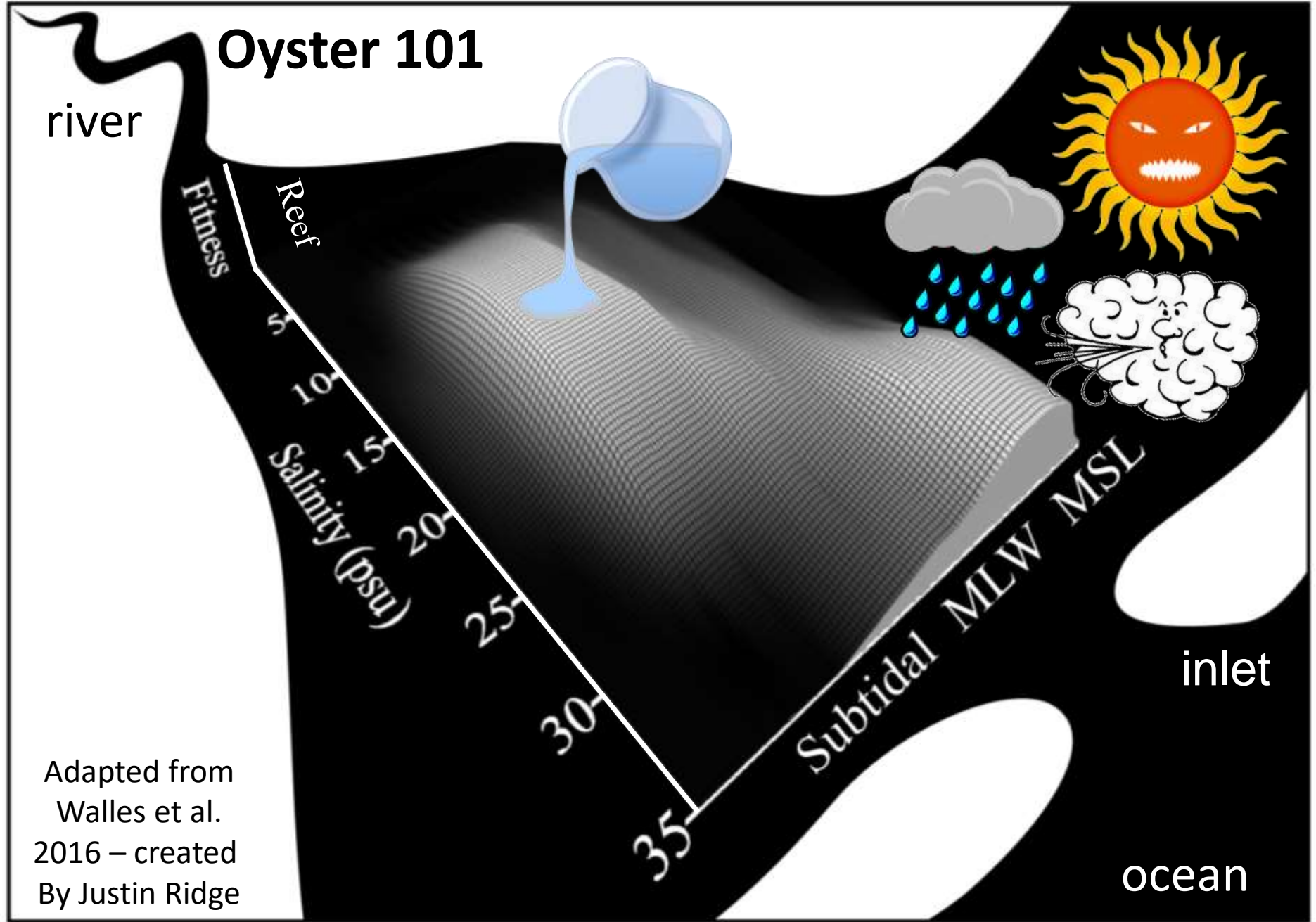
# Oyster Safe Zones

**High Salinity  
Intertidal**

**Low Salinity  
Periodic Freshets  
Subtidal**



# Oyster 101



Adapted from  
Walles et al.  
2016 – created  
By Justin Ridge

# Oyster 101

river

Fitness

Reef

Salinity (psu)

10

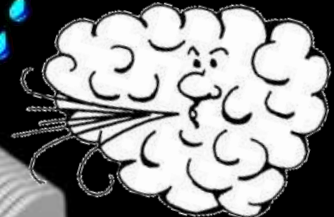
15

20

25

30

35



*Cliona celata*

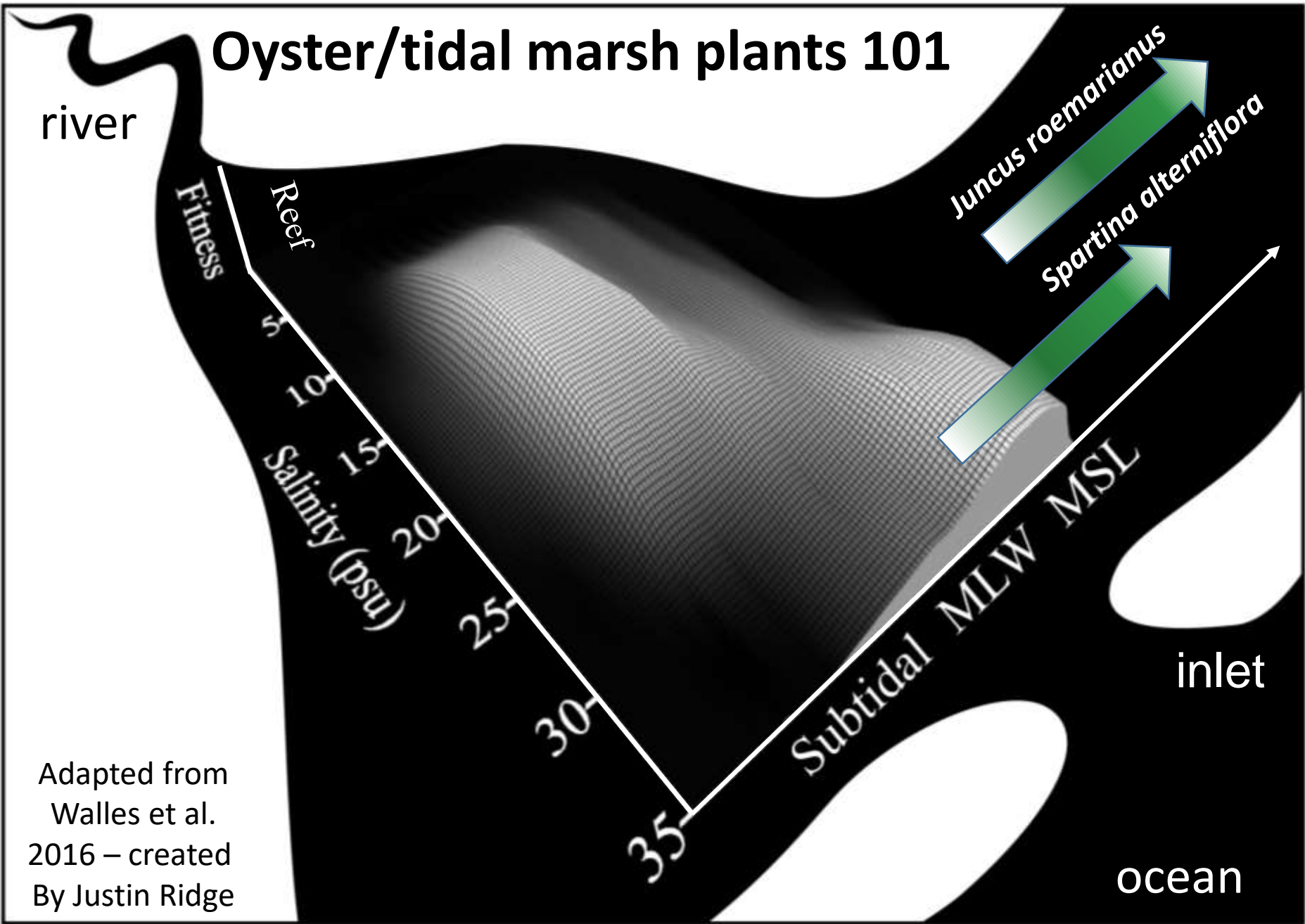
Subtidal MLW MSL

inlet

ocean

Adapted from  
Walles et al.  
2016 – created  
By Justin Ridge

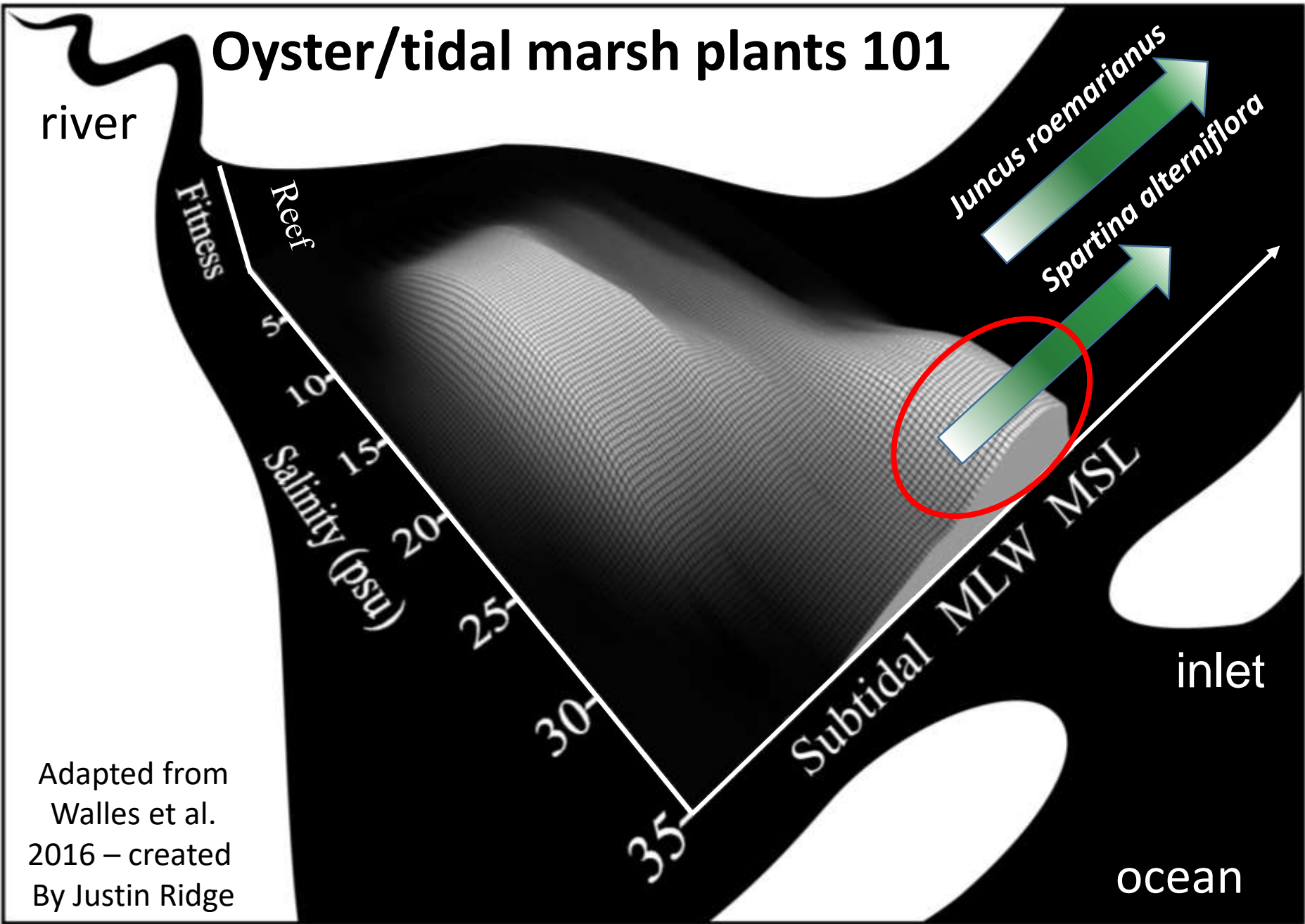
# Oyster/tidal marsh plants 101



Adapted from  
Walles et al.  
2016 – created  
By Justin Ridge

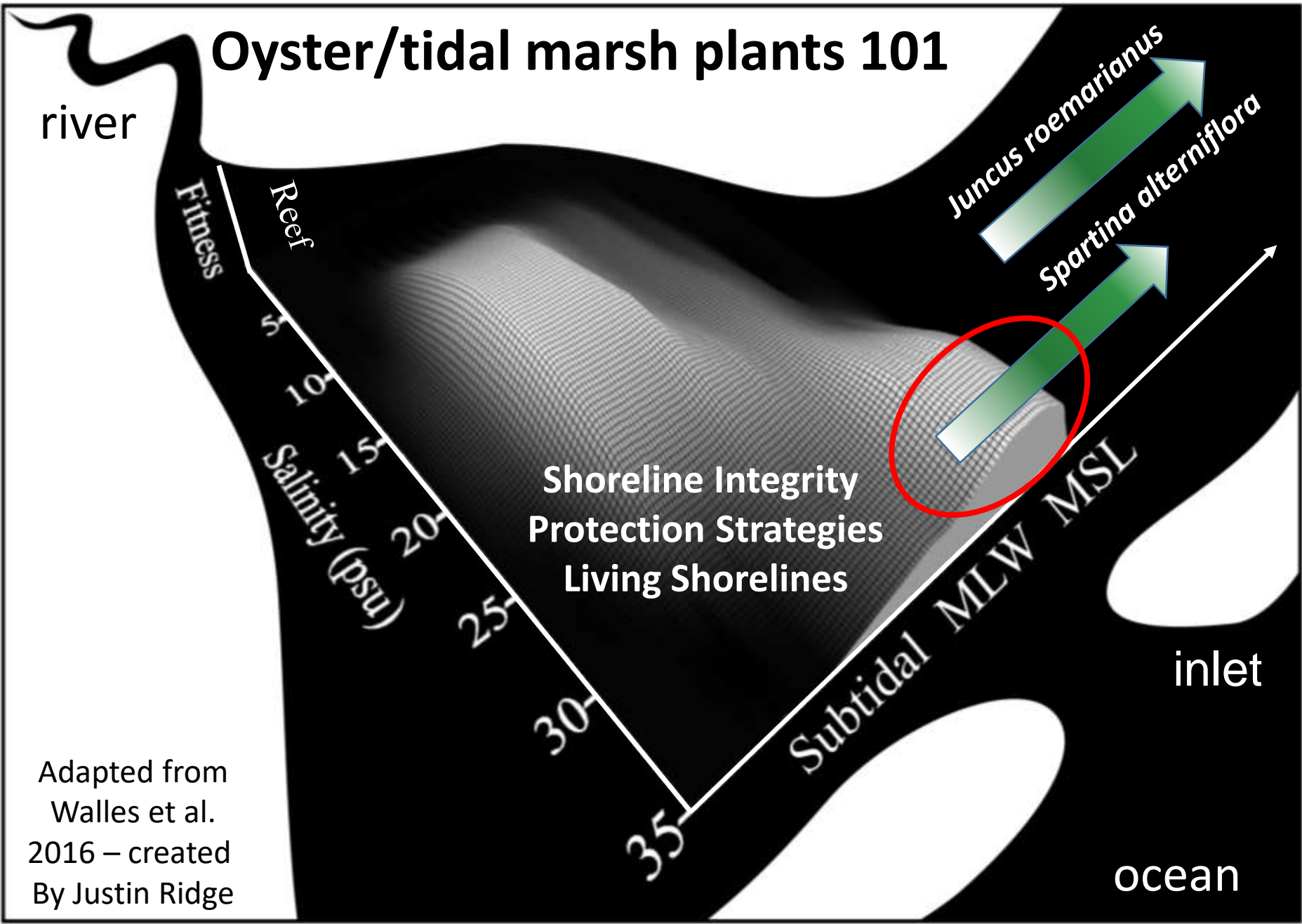


# Oyster/tidal marsh plants 101



Adapted from  
Walles et al.  
2016 – created  
By Justin Ridge

# Oyster/tidal marsh plants 101



Adapted from  
Walles et al.  
2016 – created  
By Justin Ridge

# 2018 Coastal Resilience Challenges



Hurricane Florence



Persistent Stands  
of High Waters

Hurricane Michael



# Shoreline Protection Materials/Strategies



IMAGINE



**TURNING CLOTH INTO REEFS!**

A Revolutionary Biodegradable Hardscape for Protecting and Restoring Estuarine Habitats and Living Shoreline Creation



# SANDBAR

OYSTER COMPANY | Shellfishly Motivated™



# Oyster Catcher™ The Ephemeral Substrate



# Newport River







**SANDBAR  
OYSTER CO**  
BL1800853  
WC1800861



Division of Marine Fisheries

UNC makes no endorsement of products based on licensed technologies

# Creation of Robust Intertidal Reefs

July 2015



Aug 2016



# RCNERR Tidal Creek Reef Building – Bones and Rastas

Dr. Rachel Gittman (ECU)  
and Crew

Dr. Brandon Puckett  
RCNERR

Dr. Lexia Weaver  
NCCF

Southeast Aquatic  
Resources Partnership

Atlantic Coastal Fish  
Habitat Partnership



# RCNERR Creek Reef Evolution



# RCNERR Creek Reef Sedimentation



# RCNERR Wave Exposed Shoreline Reef Construction



# Oyster Cather™ Reef Evolution

RCNERR  
Wave Exposed Shoreline



## Carrot Island Control Site – Wave Exposed Shoreline



8-10-2018



1-1-2019



# Carrot Island Shell Bag Reef – Wave Exposed Shoreline



8-10-2018



1-1-2019

# Carrot Island Oyster Catcher™ Reef – Wave Exposed Shoreline



8-10-2018

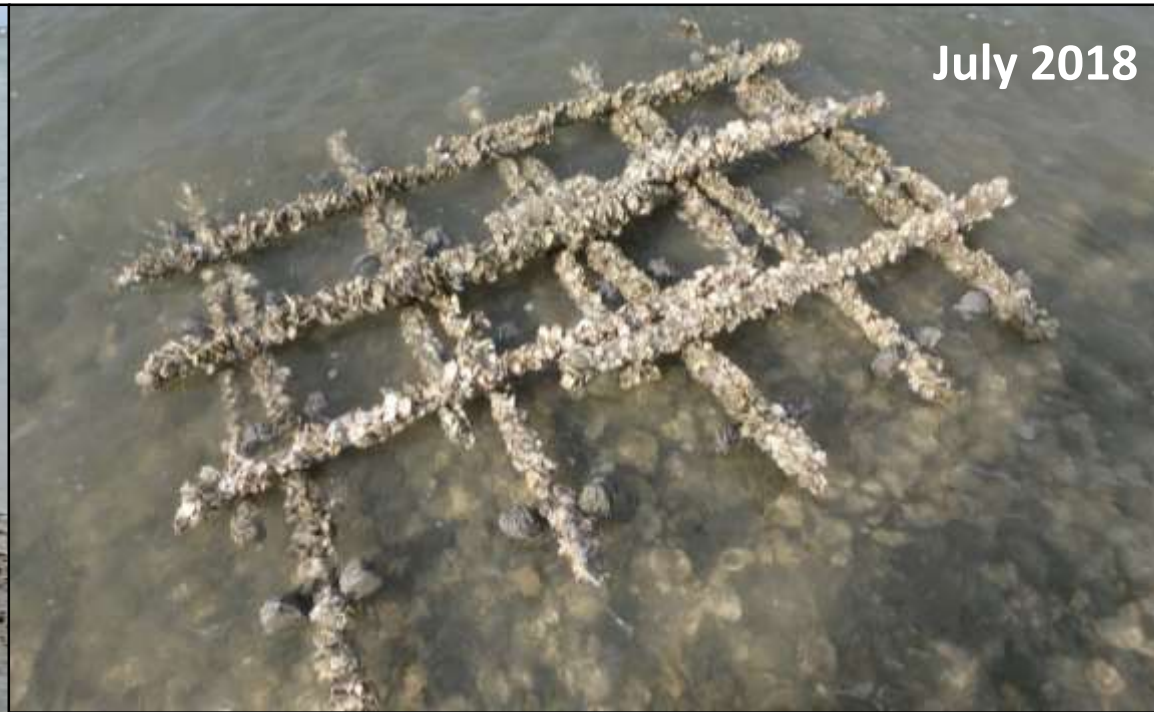


1-1-2019



UNC-IMS

July 2018



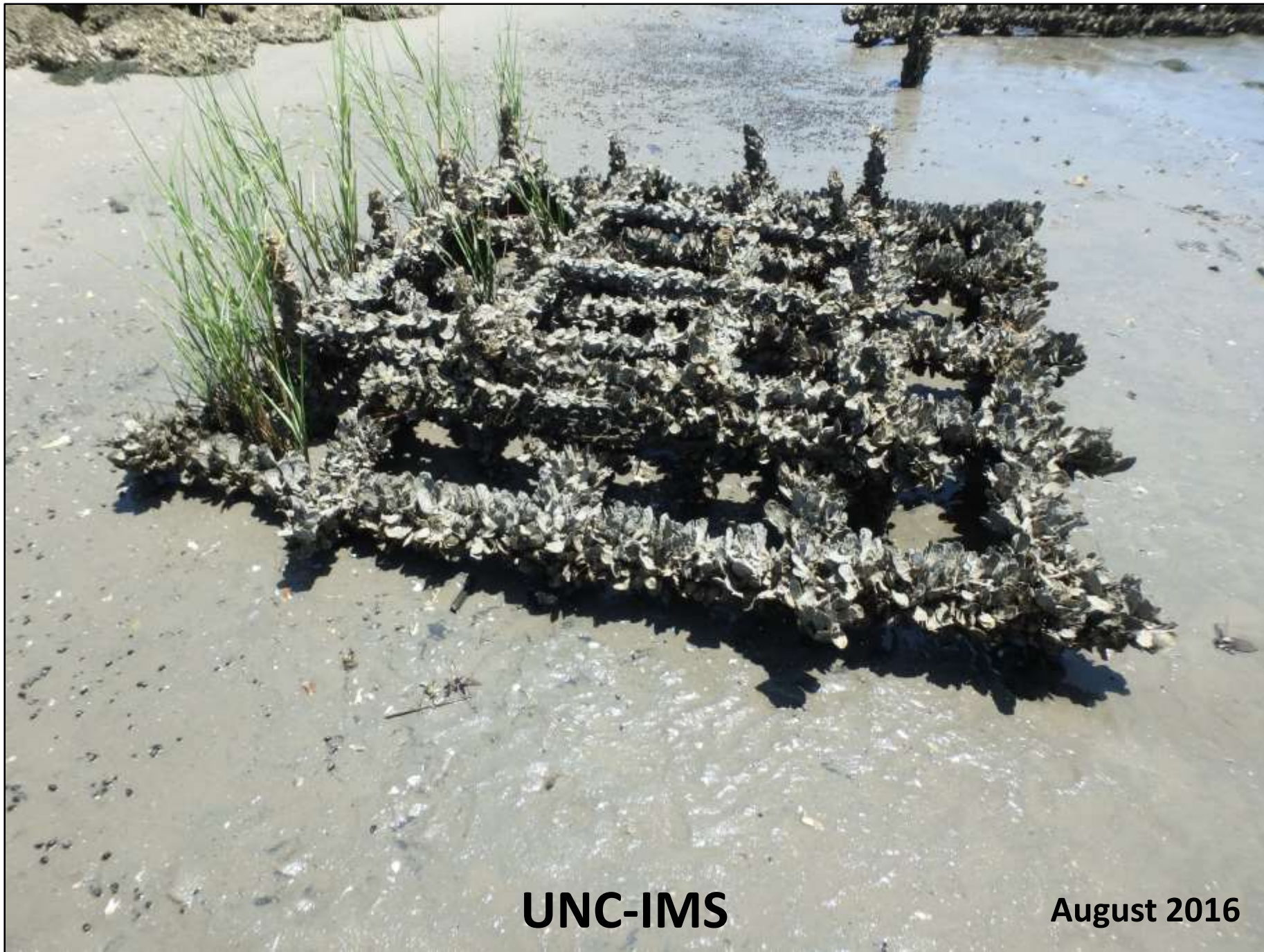
July 2018



January 2019



December 2018



**UNC-IMS**

**August 2016**



October 2017

Is there oyster facilitation of *Spartina alterniflora* through metabolic waste fertilization?



October 2017



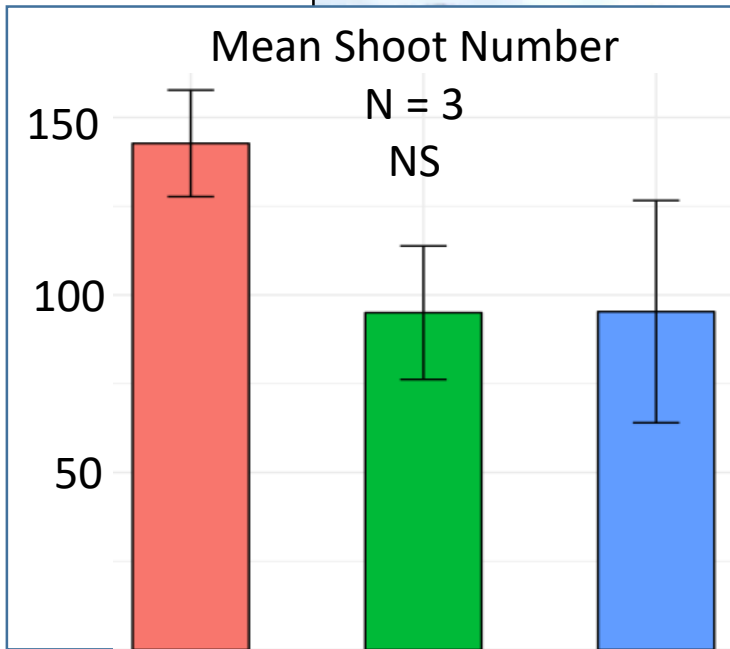
July 2018






**Lauren Glaze**  
**2017 MCFS student**

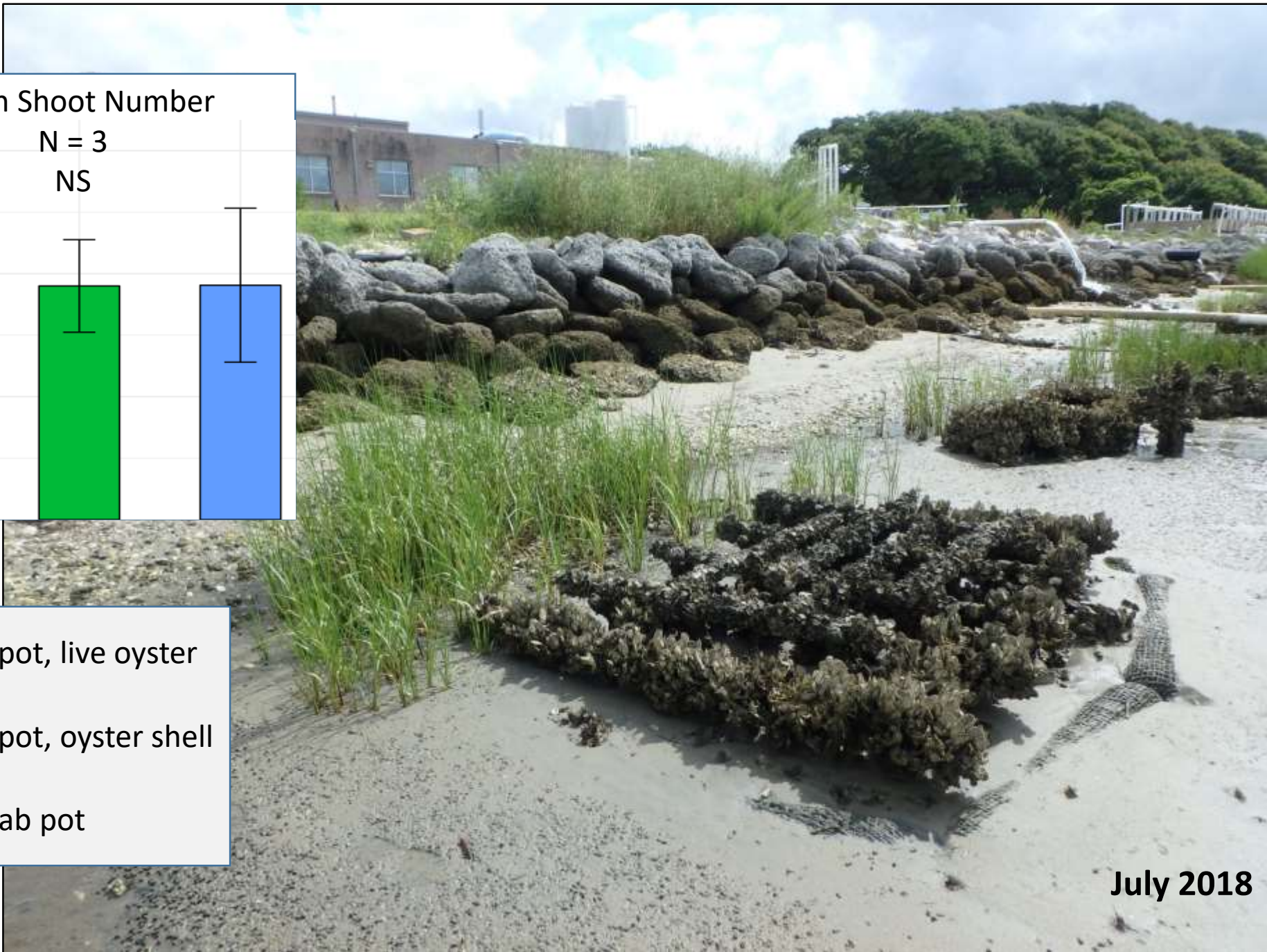
**July 2018**

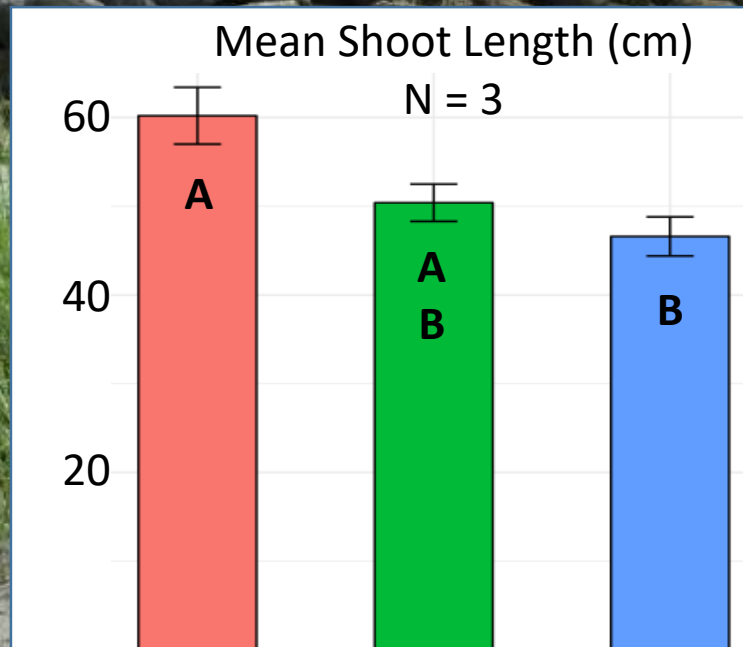
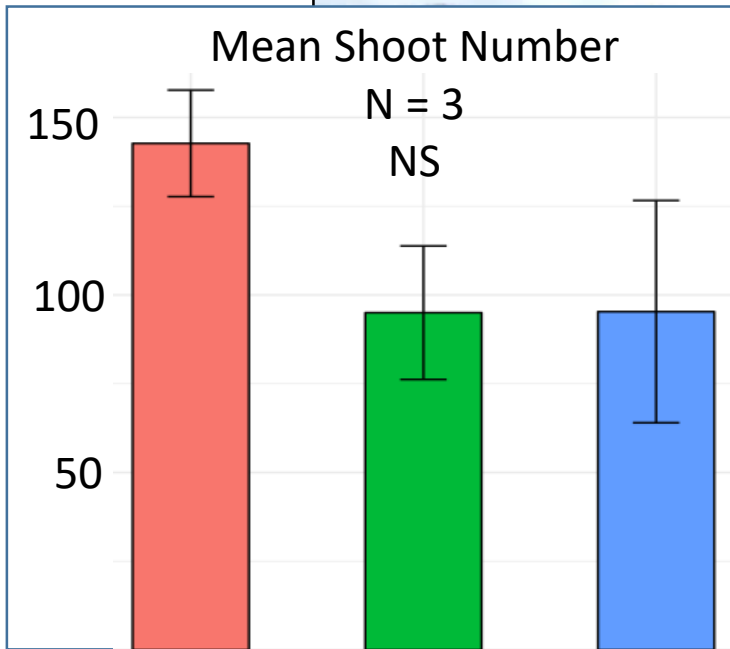







-  = crab pot, live oyster
-  = crab pot, oyster shell
-  = no crab pot

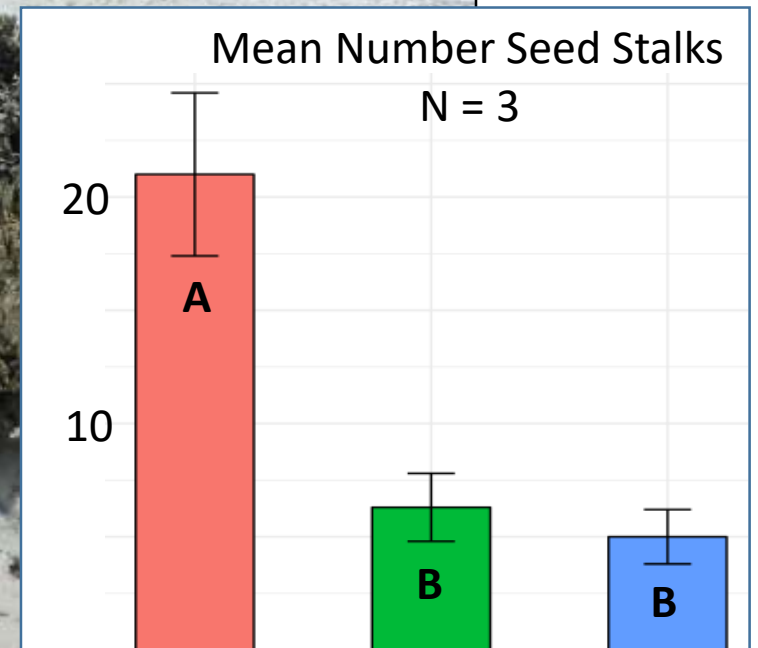
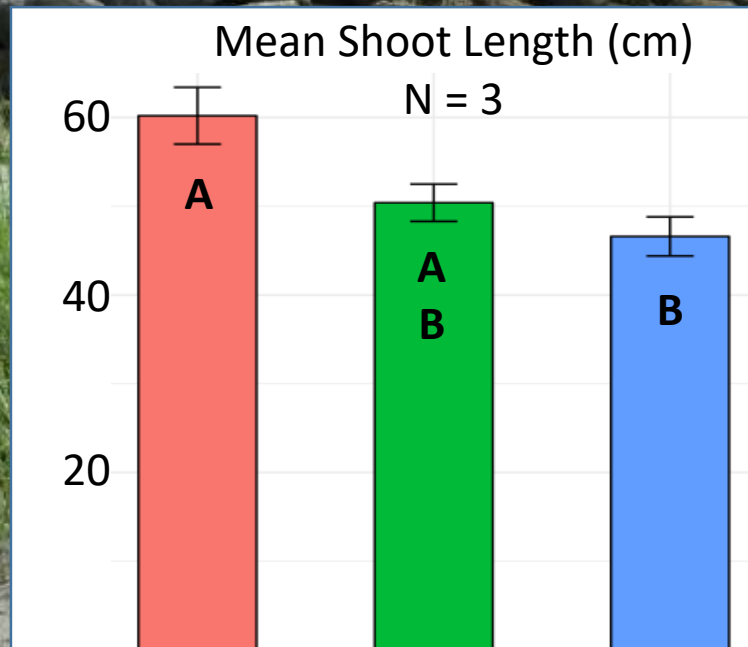
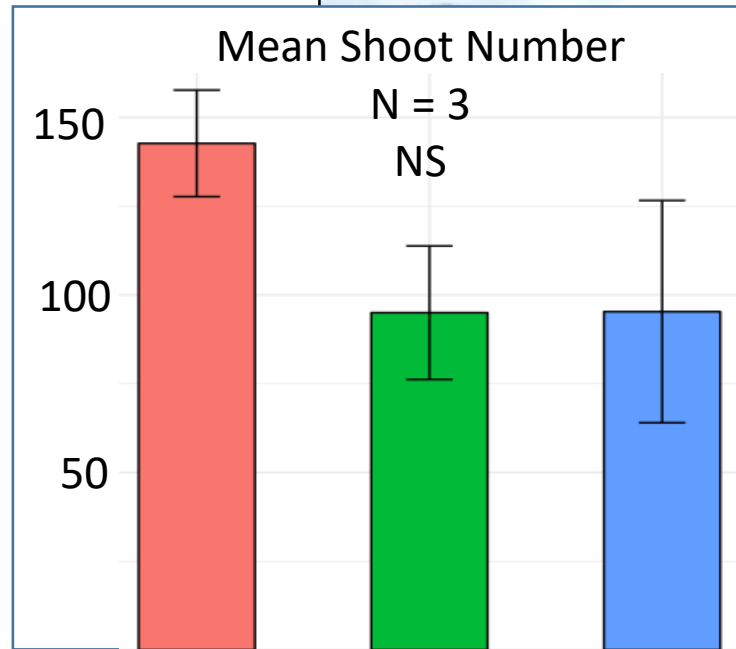
July 2018






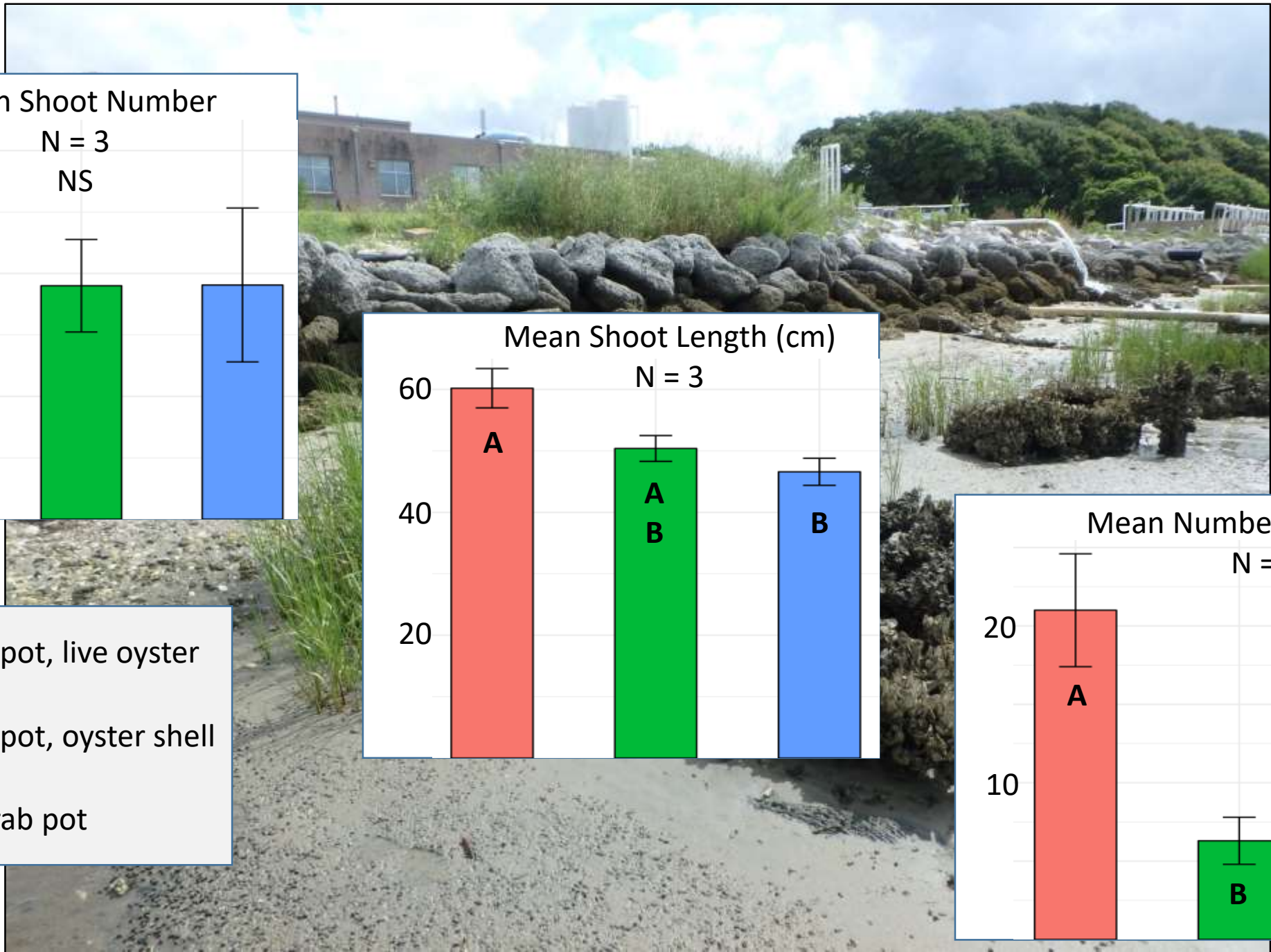


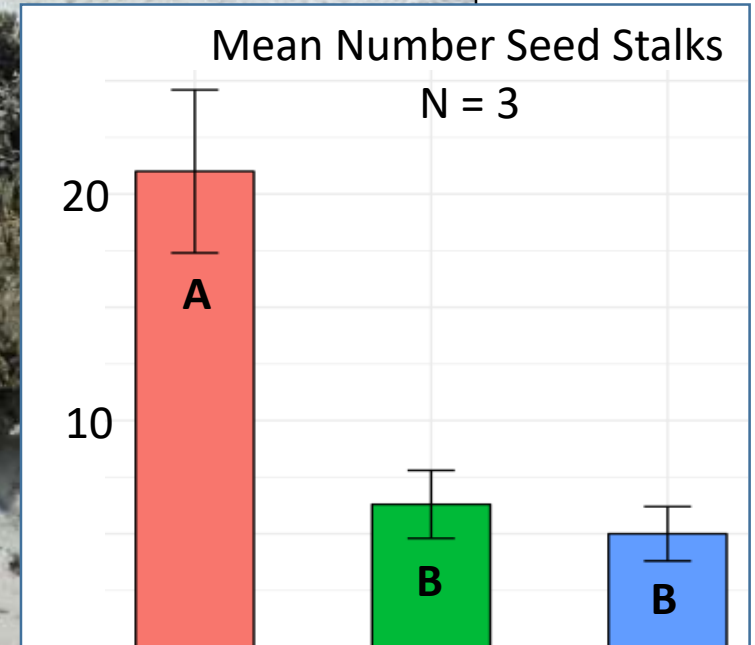
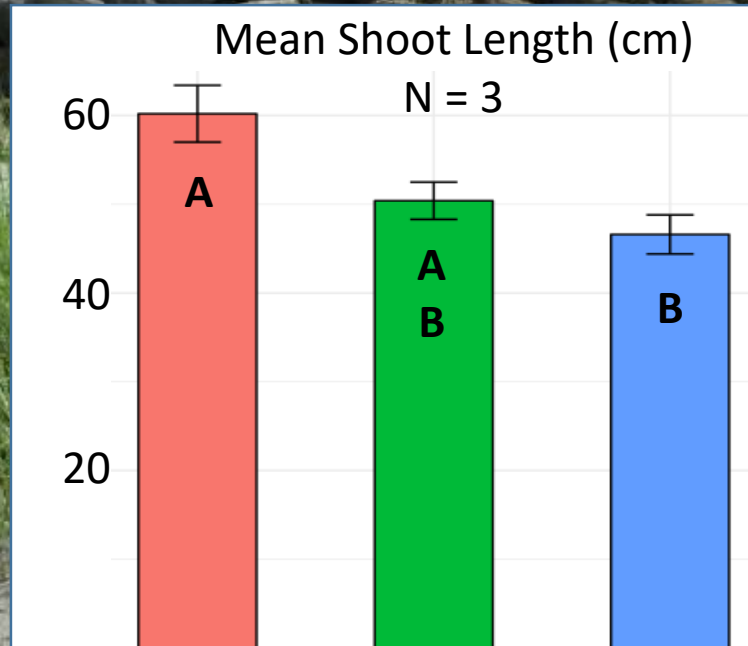
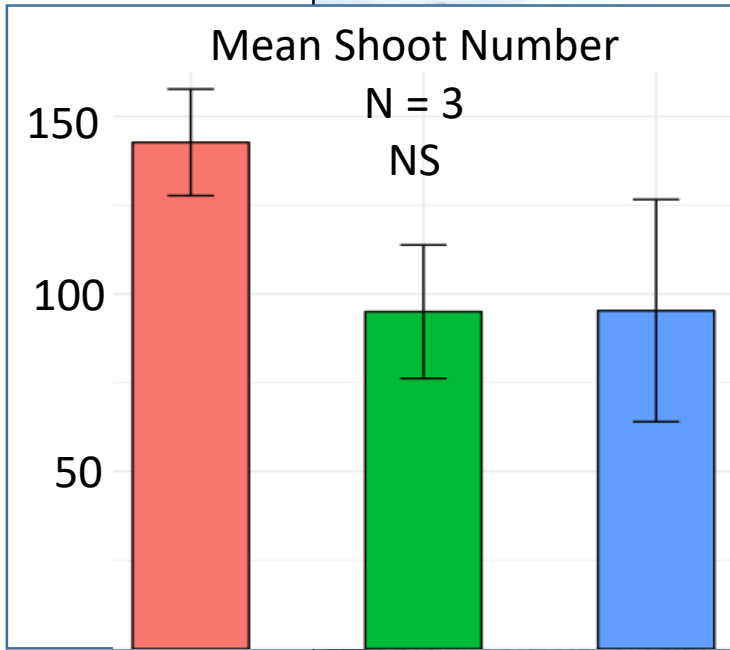
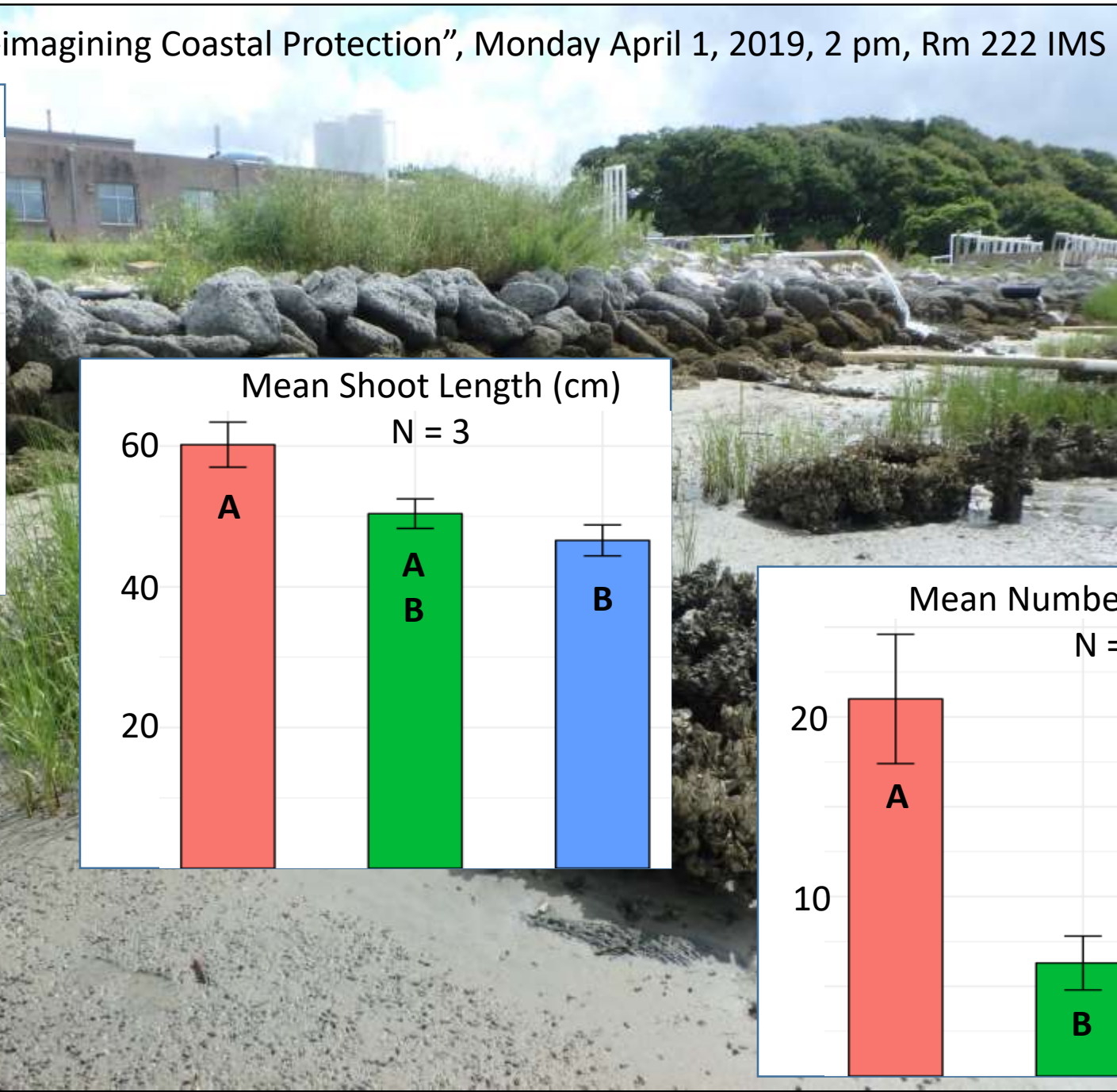
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-  = crab pot, oyster shell
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

July 2018



-  = crab pot, live oyster
-  = crab pot, oyster shell
-  = no crab pot





-  = crab pot, live oyster
-  = crab pot, oyster shell
-  = no crab pot



**Harnessing Biological Partnerships to Improve Coastal Restoration – Pew Foundation Webinar, 2/5/2019, Brian Silliman**

# Questions?

**Harnessing Biological Partnerships to Improve Coastal Restoration – Pew Foundation Webinar, 2/5/2019, Brian Silliman**