

COLLABORATIVE SCIENCE FOR ESTUARIES

WEBINAR SERIES



Beth Darrow

*Bald Head Island
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Doug Bell

National Sea Grant Program

Decision Support for Siting of Shellfish Aquaculture



National Estuarine
Research Reserve System
Science Collaborative

Date: Tuesday, October 20, 2020

Time: 3PM ET – 4PM ET

National Estuarine Research Reserve System



LIST OF RESERVES

Great Lakes

1. Lake Superior, Wisconsin
2. Old Woman Creek, Ohio

Northeast

3. Wells, Maine
4. Great Bay, New Hampshire
5. Waquoit Bay, Massachusetts
6. Narragansett Bay, Rhode Island

Mid-Atlantic

7. Hudson River, New York
8. Jacques Cousteau, New Jersey
9. Delaware
10. Chesapeake Bay, Maryland
11. Chesapeake Bay, Virginia

Southeast

12. North Carolina
13. North Inlet-Winyah Bay, South Carolina
14. ACE Basin, South Carolina
15. Sapelo Island, Georgia
16. Guana Tolomato Matanzas, Florida

Gulf of Mexico

17. Rookery Bay, Florida
18. Apalachicola, Florida
19. Weeks Bay, Alabama
20. Grand Bay, Mississippi
21. Mission-Aransas, Texas

West

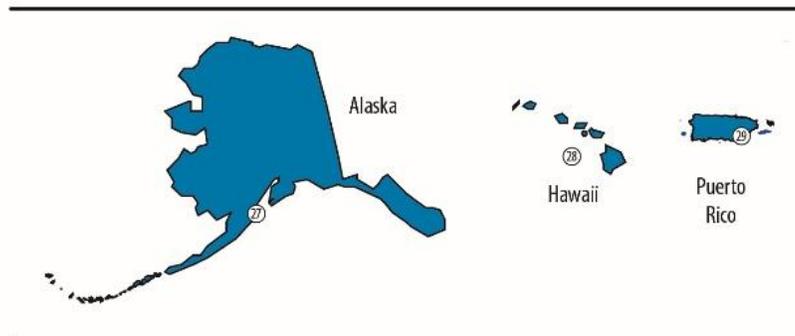
22. Tijuana River, California
23. Elkhorn Slough, California
24. San Francisco Bay, California
25. South Slough, Oregon
26. Padilla Bay, Washington
27. Kachemak Bay, Alaska

Pacific

28. He'eia, Hawai'i

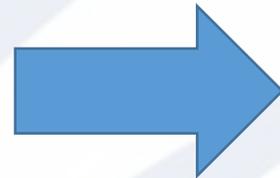
Caribbean

29. Jobos Bay, Puerto Rico



Have a question?

Use the “Questions” function to pose questions throughout the webinar.



A screenshot of a webinar interface. The top part shows audio controls with a 'MUTED' indicator and a volume slider. Below that is a 'Questions' section with a text input field containing the placeholder text '[Enter a question for staff]' and a 'Send' button. At the bottom, there is a 'Webinar Now' section with the text 'Webinar ID: 200-167-467' and the 'GoToWebinar' logo.



National Estuarine
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Poll Question:

**In your opinion, which of the following topics should influence shellfish aquaculture siting decisions?
(Choose up to 3)**

1. Commercial/recreational uses of proposed lease area
2. Protected status of proposed lease area (*e.g, state preserve; essential fish habitat*)
3. Environmental impacts of specific leases (*e.g, water, sediment, fauna*)
4. Ecosystem services of specific leases (*e.g., filtration, habitat*)
5. Viewscape of proposed lease area



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Decision Support for Siting of Shellfish Aquaculture

Beth Darrow, Martin Posey, Troy Alphin, Susanne Brander
Suzanne Bricker, Brandon Puckett, Joao Ferreira, Alhambra Cubillo
Jessica Kinsella, Madison Lytle, Kelsey Billet



Expanding Aquaculture in North Carolina

- Report submitted to the North Carolina General Assembly suggested the potential for significant growth:
 - North Carolina Strategic Plan for Shellfish Mariculture
- Siting of new aquaculture farms
 - Limits and conflicts
 - What areas within suitable biological conditions should be available for aquaculture?
- Debate about potential impacts



Shellfish aquaculture in National Estuarine Research Reserves



Masonboro Island NCNERR

- Undeveloped barrier island
- New oyster leases – 2015
- Moratorium on leases in Reserves – 2016
- Stakeholder group consulted & project funded developed – 2016
- Study began – 2017



Shellfish Aquaculture in Reserves: Ecosystem Services



NOAA NERRS Science Collaborative

Project Objectives

Assess the environmental impacts, including ecosystem services of shellfish aquaculture in the NC National Estuarine Research Reserve and other areas in SE North Carolina

Use stakeholder input to select parameters and sites of interest, guide research questions

Provide information to end users that will be useful for decision-making



End Users & Priorities Addressed by Project

State & Federal

NCNERR, NC Management agencies,
NOAA



Shellfish leasing program

- Protect benthic resource (shellfish, seagrass)
- Manage user conflicts
- Assess long-term water quality/ecosystem effects

Habitat protection & coastal management

- Balance research, education, recreation, and commercial fishing/aquaculture uses
- Ecosystem service valuation
- How management decisions impact water quality



Sustainable growth

- Economic opportunity
- Minimal financial risks
- Maximal output/profit
- High-quality production
- Aquaculture benefits (water quality, habitat)



Industry: Shellfish growers (local and regional)

Project outputs include data and models that will aid decision-making. Outcomes include relationship-building between managers and industry.

Choosing parameters: Stakeholder collaboration



Through **open communication**, **diverse perspectives**, and **shared goals**, the Stakeholder Group will advise research on the questions of **shellfish cultivation impacts on: wild oyster resource, habitat, and water quality change**; leading to a better **understanding** of the environmental influences of shellfish cultivation to ensure the **development of an informed policy** and a **common language**.

Decision-support tool

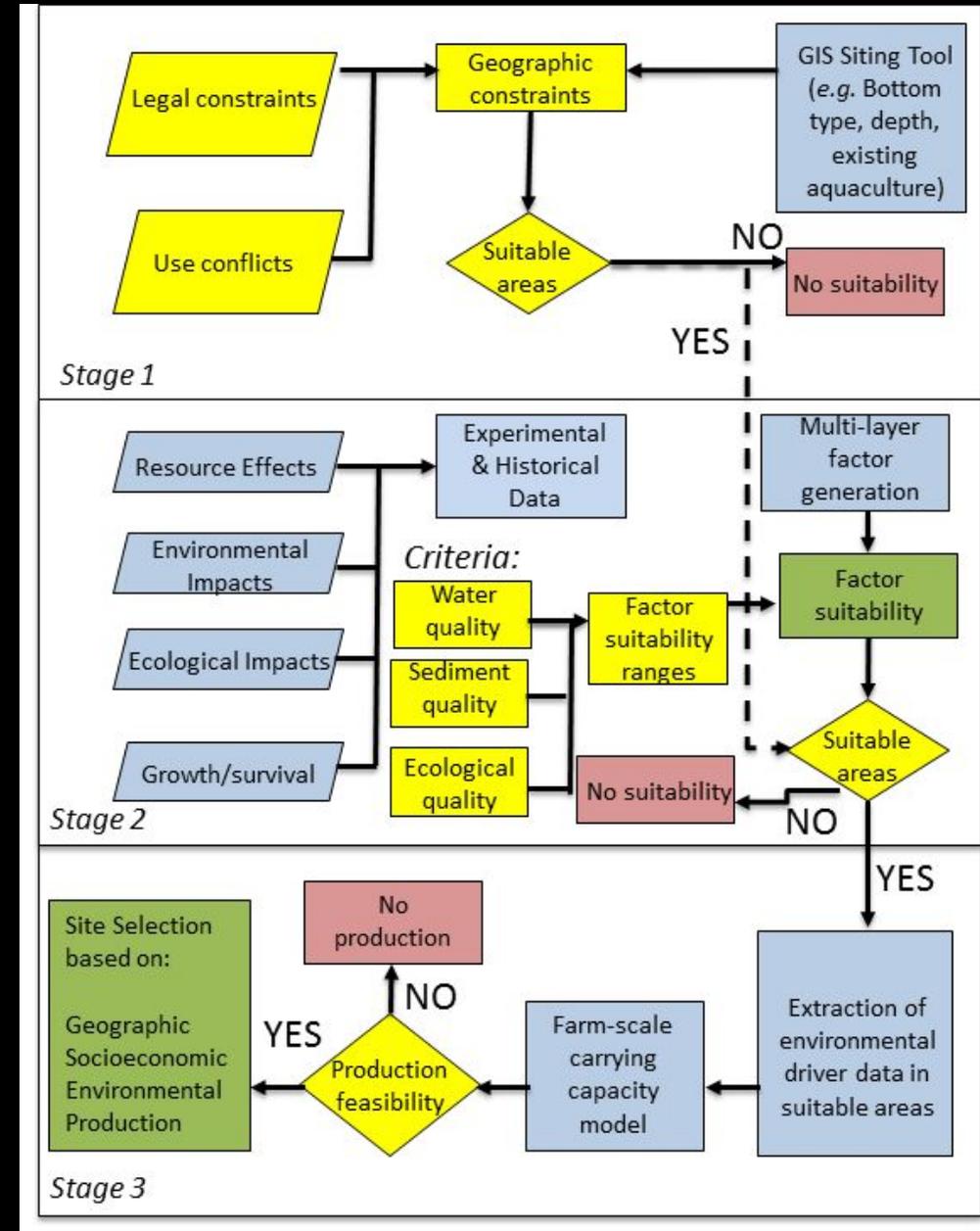
Stage 1: Current state

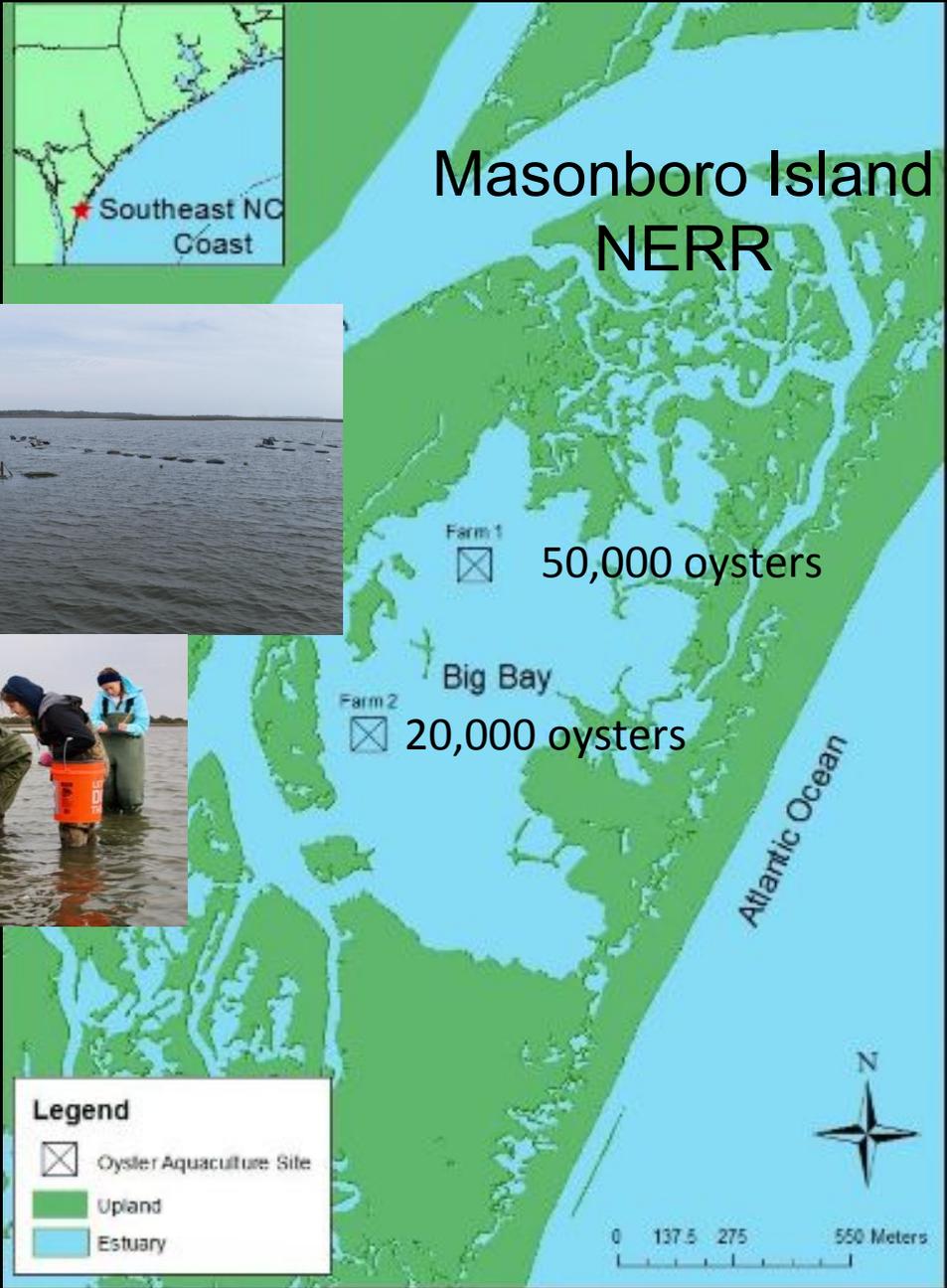
Stage 2: This project – data collection

Stage 3: Fully coupled GIS + carrying capacity model

Provide evidence-based support for management decisions

Modified from Silva et al., 2011





Timeline

Year 1: March 2017 – Feb 2018: *Masonboro*

- wild oyster, sediment, water
- Farm practices, oyster growth, physiology

Year 2: March 2018 – Feb 2019: *Masonboro & New River*

- wild oyster, sediment, water, habitat
- Farm practices, oyster growth, physiology
- Delays due to Hurricane Florence

Year 3: March 2019 – present

- Incorporate physiology & farm practice into FARM model
- Data analysis
- Discussion of results with stakeholders



Timeline

- Year 1: March 2017 – Feb 2018: *Masonboro*

- wild oyster, sediment, water
- Farm practice

2017: A determination was made by the NC Department of Natural & Cultural Resources – Natural Heritage Program finding that this activity is inconsistent with the site's purpose as a nature preserve.

- Year 2: March 2018 – Feb 2019

- wild oyster
- Farm practice
- Delays due to

The Division of Marine Fisheries sent leaseholders letters stating that leases would not be renewed based on this determination.

- Year 3: March 2019 – Feb 2020

- Incorporate physiology & farm practice into FARM model
- Data analysis

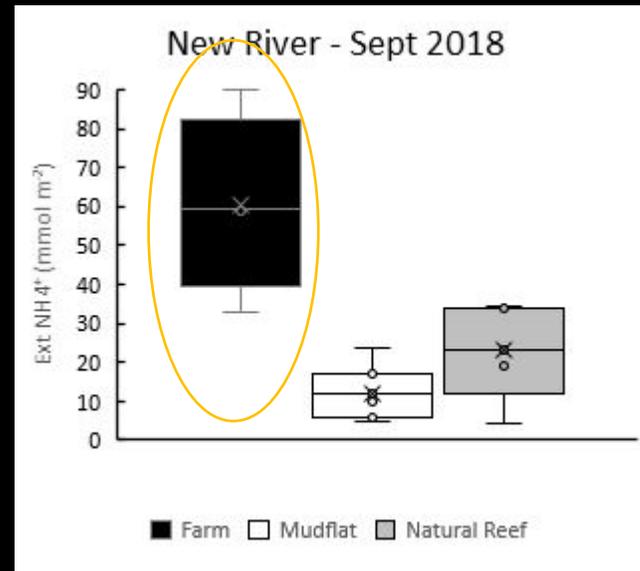
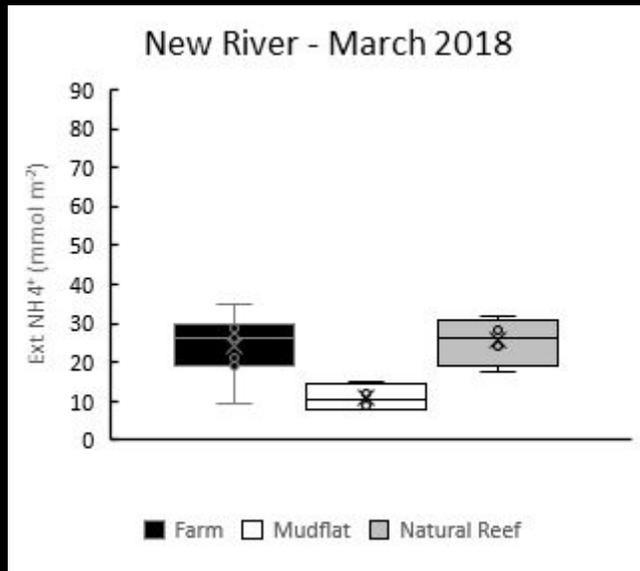
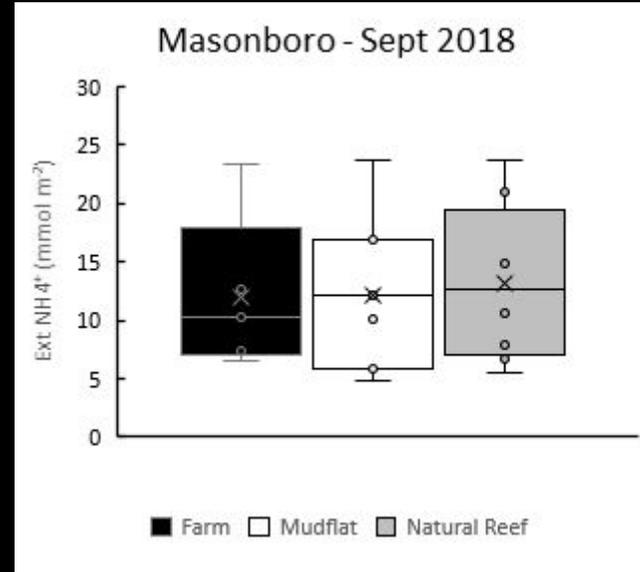
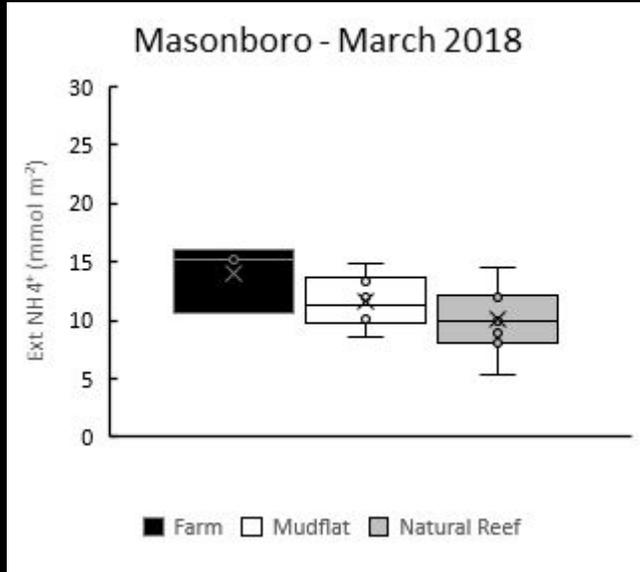


Selected Findings - Environmental Impacts



(Our undergrads were the best)

Sediment quality - extractable ammonium

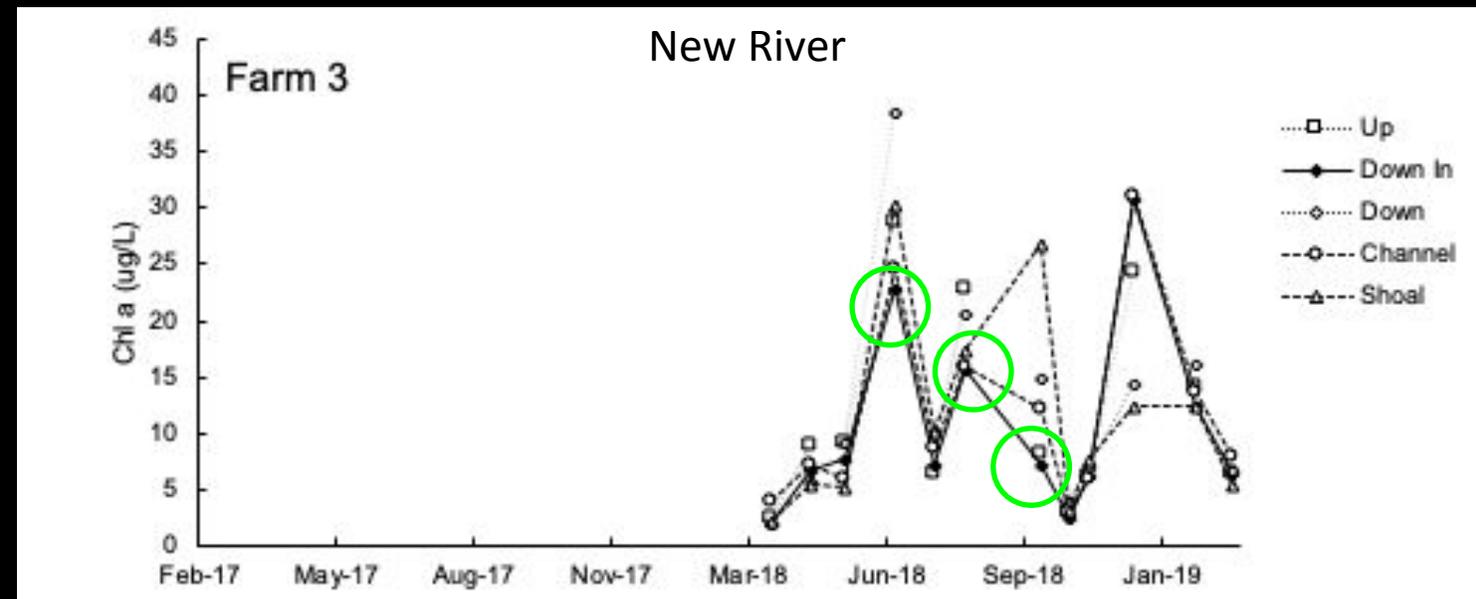
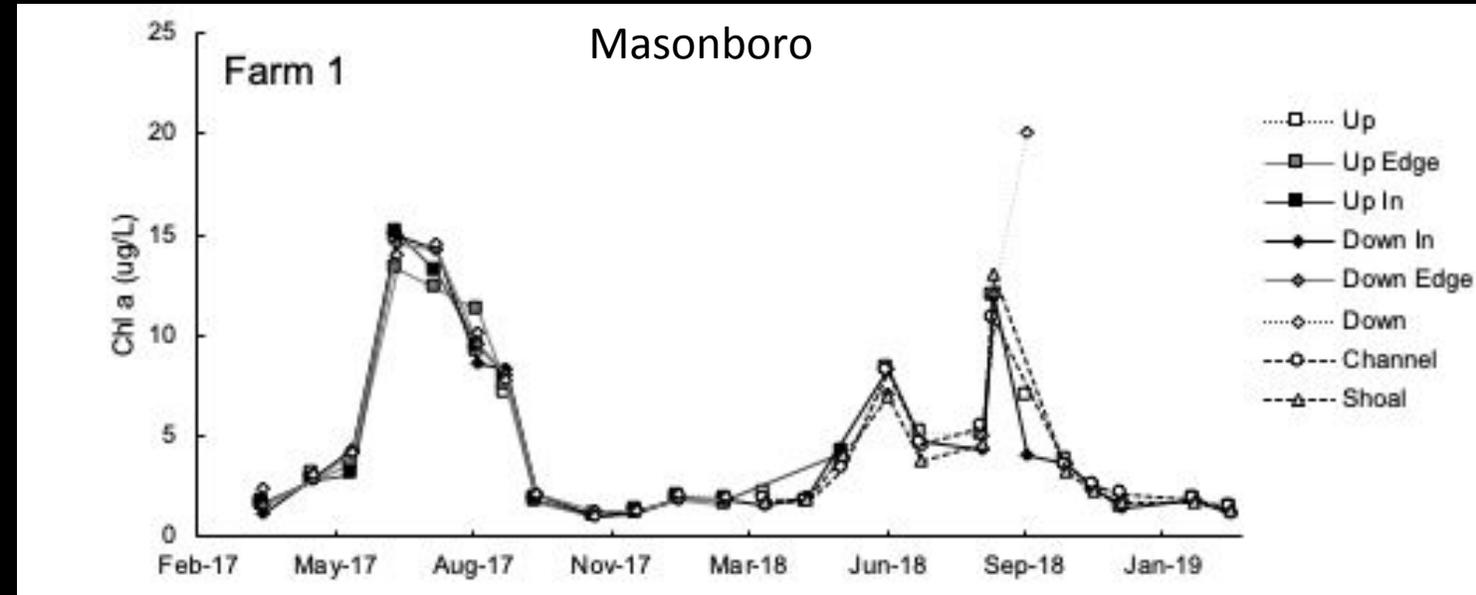


New River > Big Bay

Farms > other sites, only at New River in September

Water quality - chlorophyll *a*

- Chlorophyll – food for oysters
- Higher concentrations at Farm 3 (New River)
- No consistent change across farms (drawdown by oysters)
- No evidence of consistent seston depletion within farms
- Similar results for water column nutrients: no major change

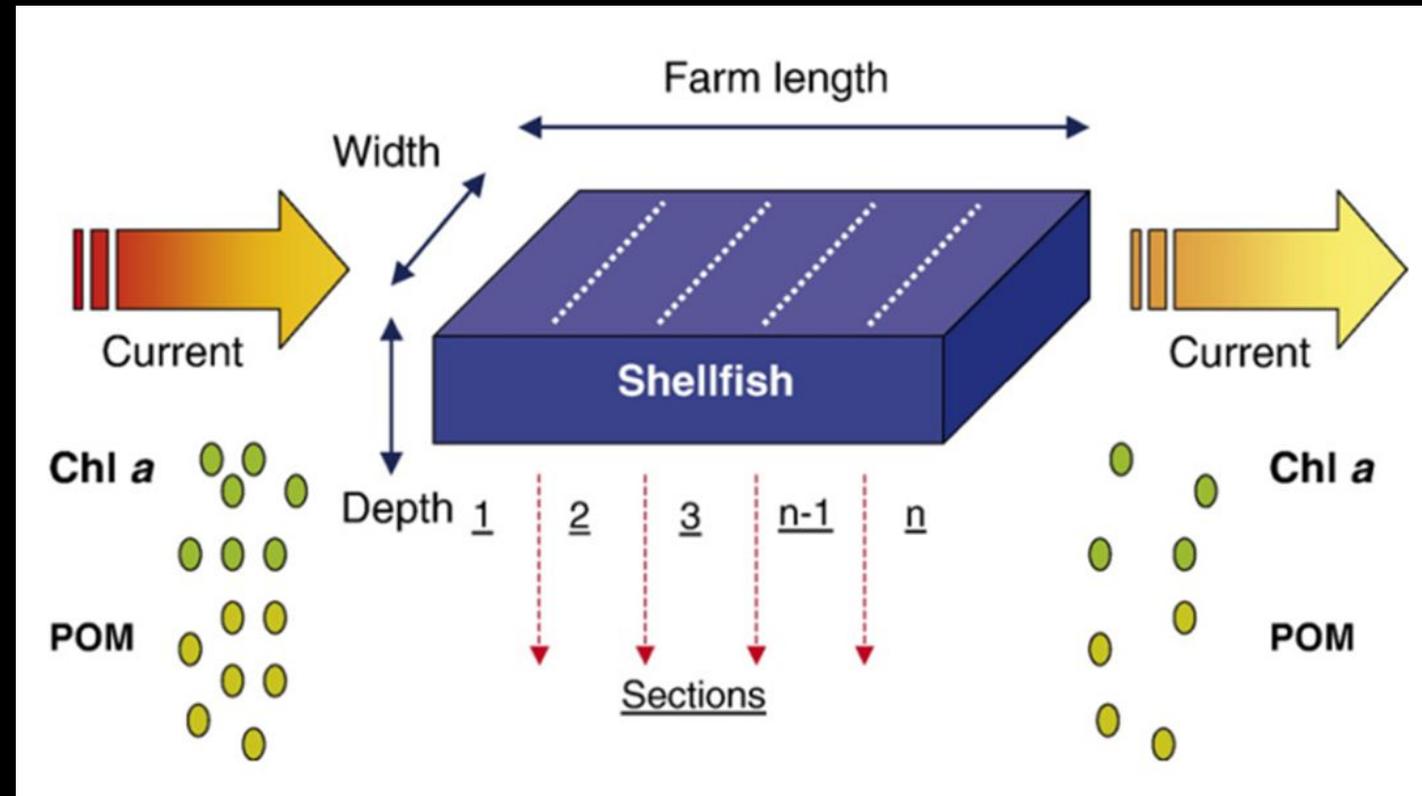


Estimating nitrogen removal: The FARM Model

Farm production

Filtration carrying capacity

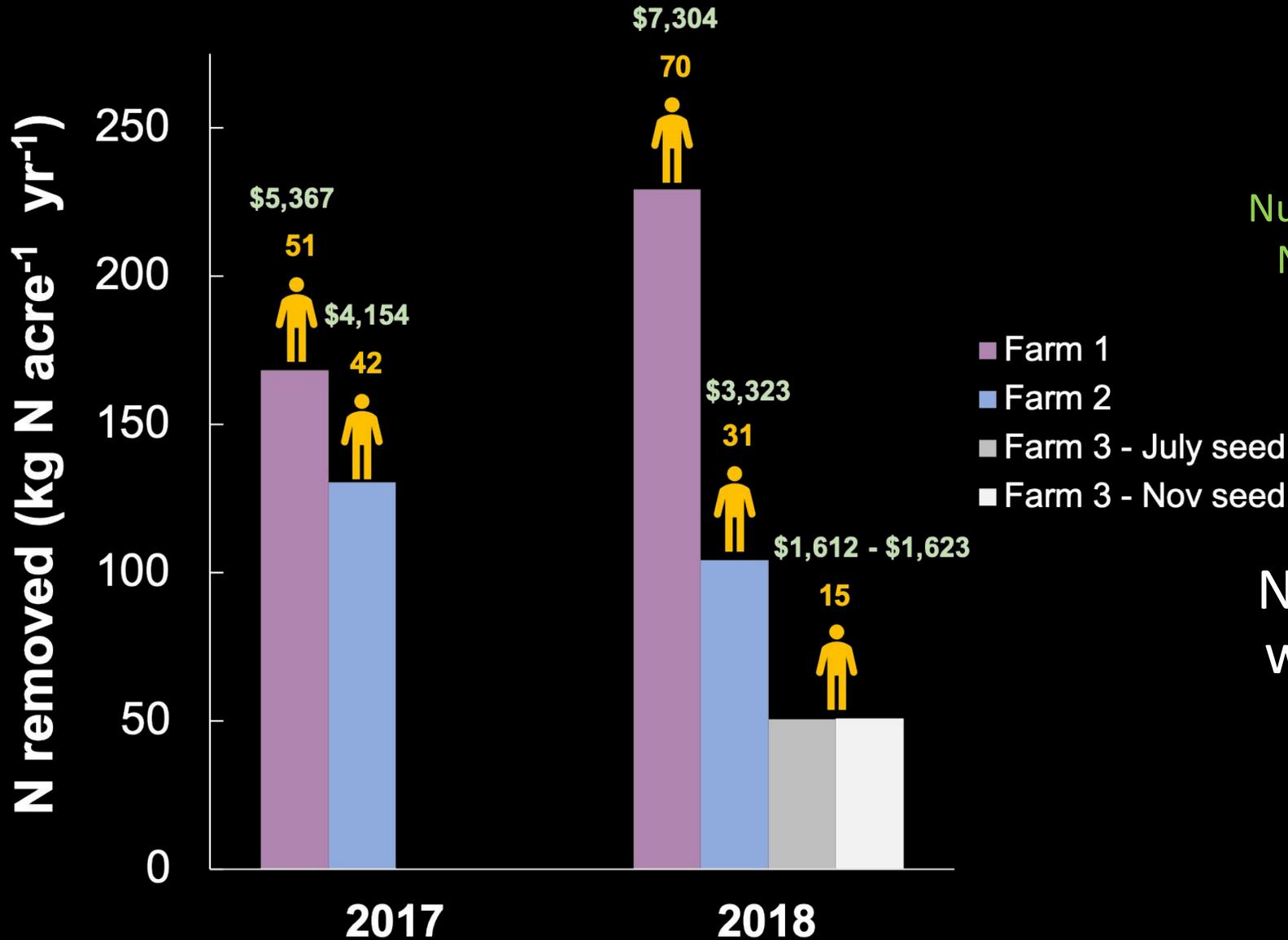
Influence on nitrogen, oxygen



PARTICULATE
NITROGEN

LESS
NITROGEN

FARM Model Results



3.3 person equivalents/kg N

Nutrient offset credit value from the Neuse River watershed: \$6.55/kg

Nitrogen removed per acre was highest for farms with higher stocking density

Wild Oysters and Associated Fauna

- Oysters

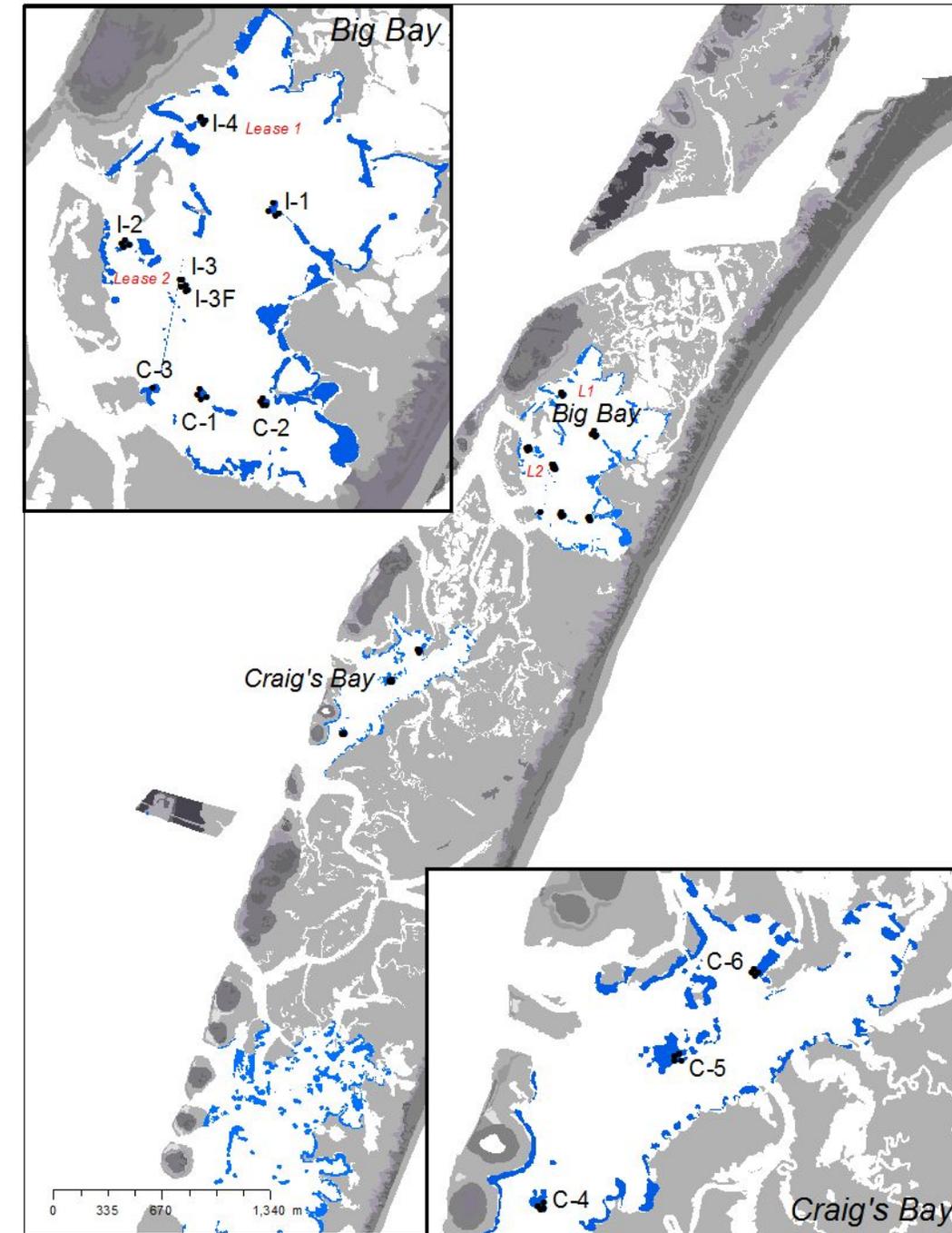
- Sampled reefs nearer (impacted) and more distant (control) from aquaculture operations
- Biomarker analysis
- Oyster demography and densities
- Settlement of oysters

- Associated fauna

- Animals living with reef
- Same reefs as oyster sampling

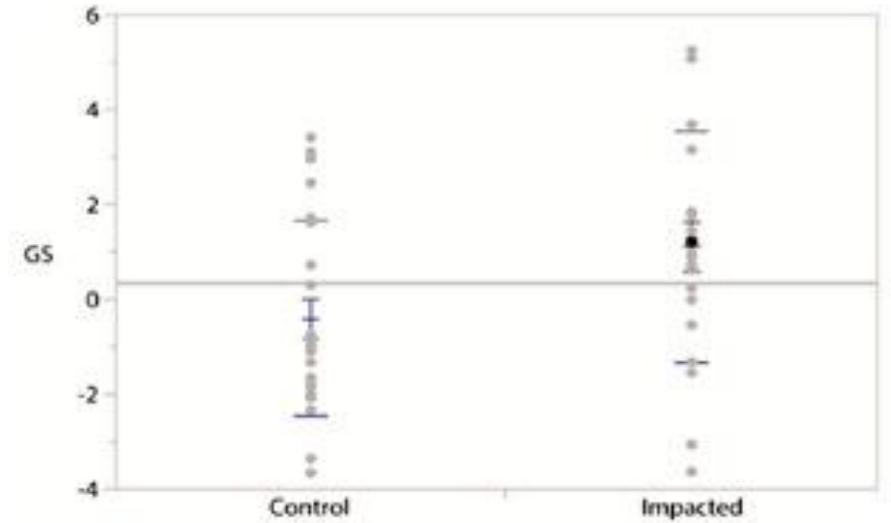
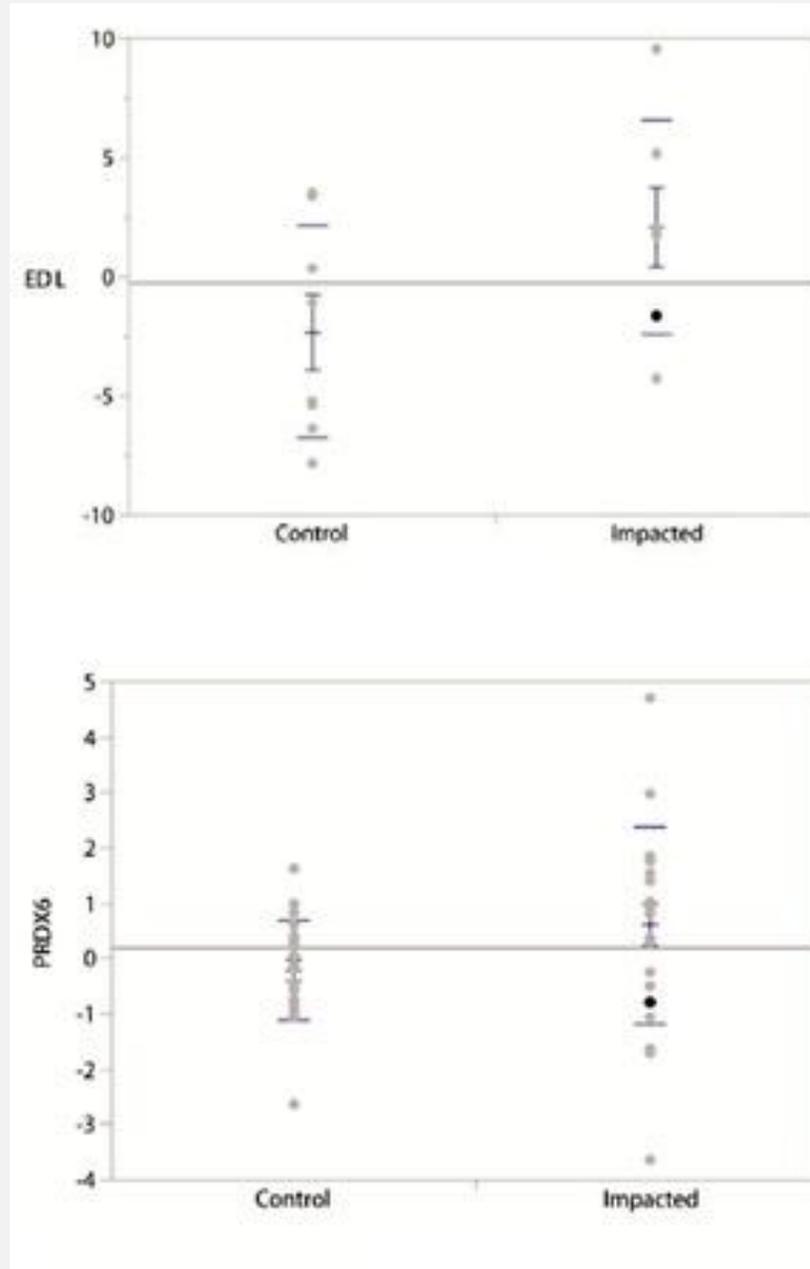
- Nekton

- Fish, crabs, and shrimp near reefs, aquaculture operations, and over tideflats



Biomarkers

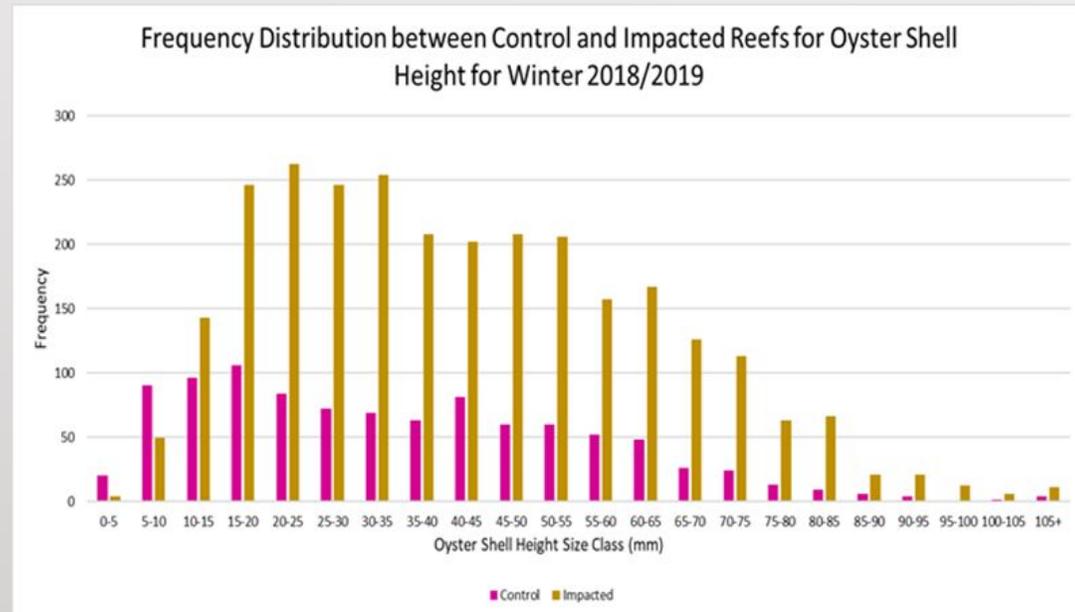
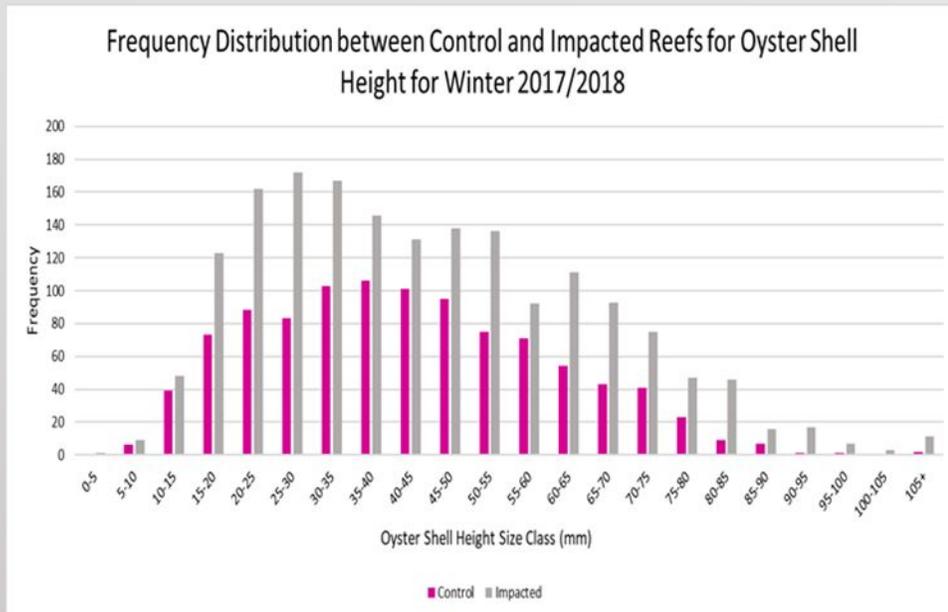
- Biomarkers are proteins produced in response stress
- Oysters near aquaculture operations had increases in three biomarkers related to physiological and metabolic stress (Brander and Marshall)



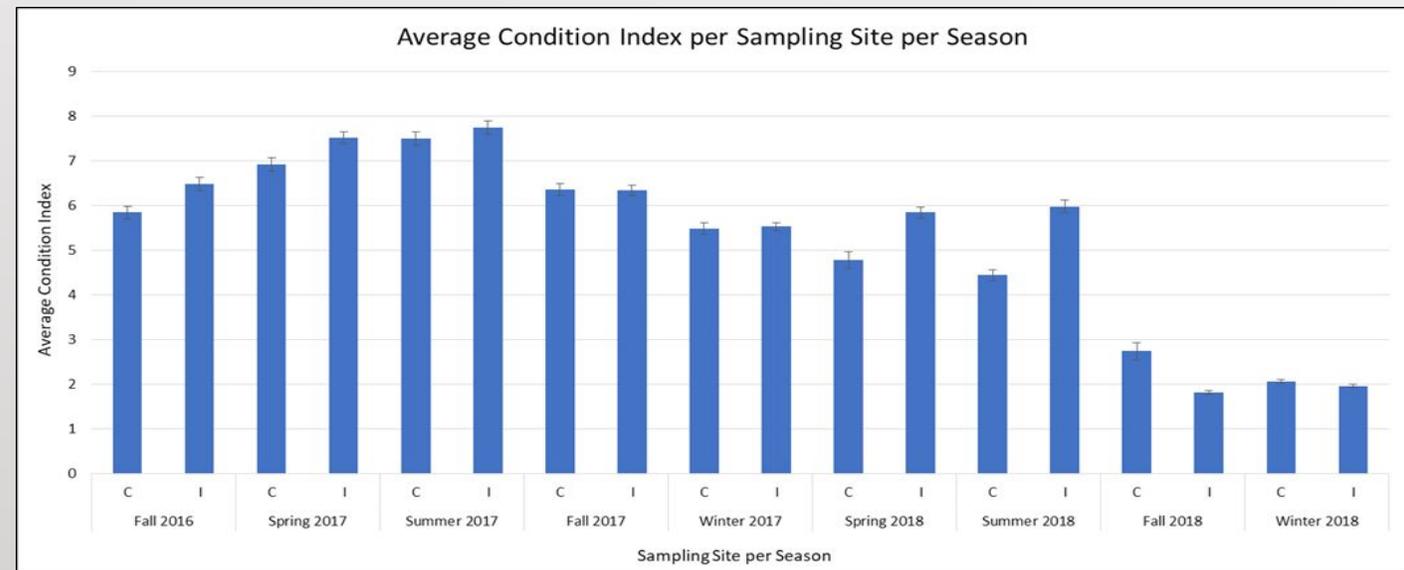
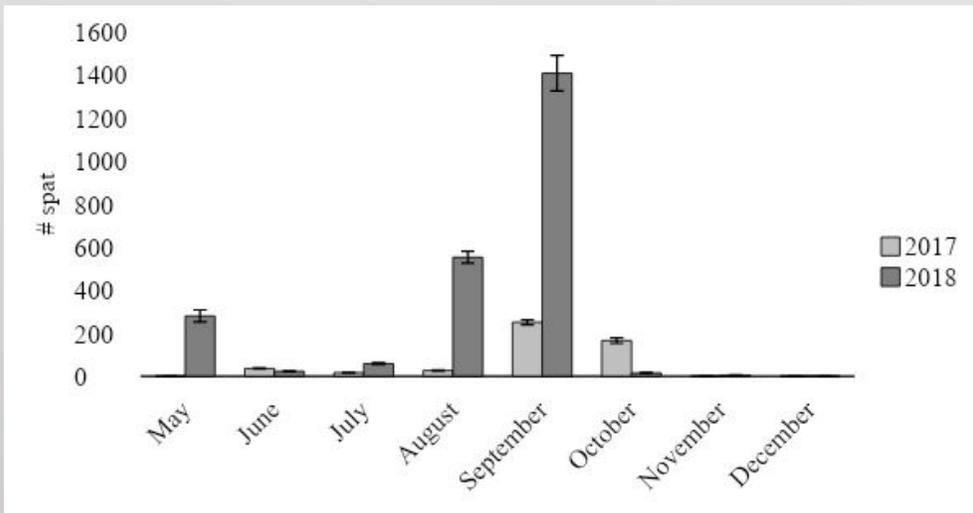
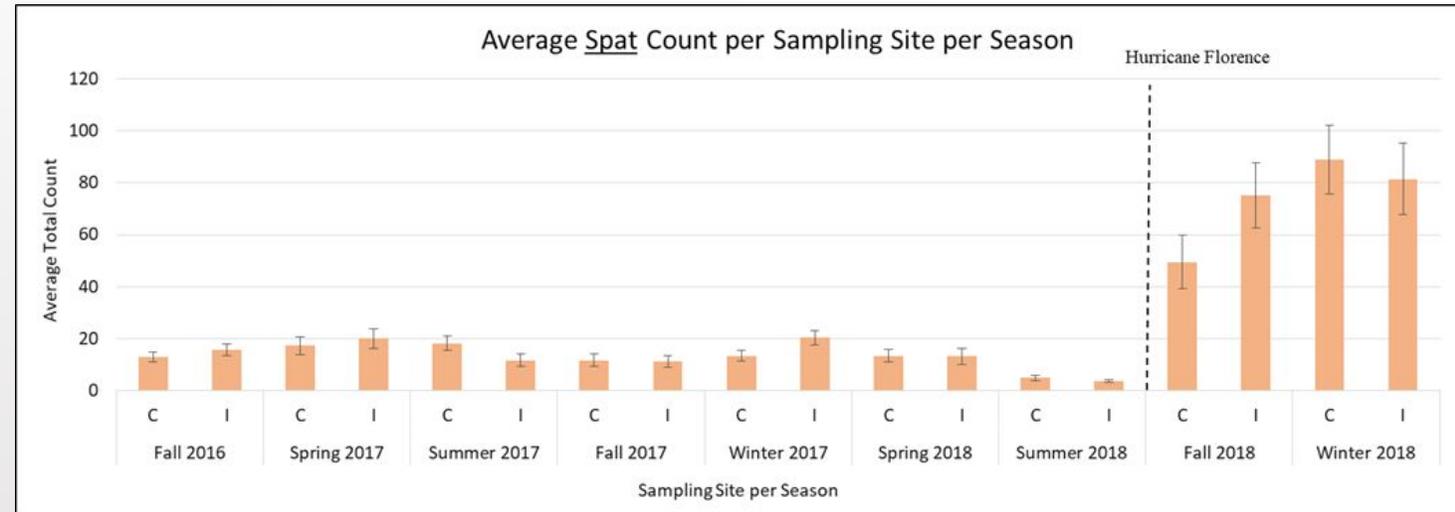
Genes measuring changes in oxidative stress (PRDX6) and metabolism (EDL, GS) all significantly increased in expression between control and impacted sites. This may mean oysters are experiencing a slight elevation in stress due to the presence of nearby mariculture activity.

Wild oysters

- Trend towards larger size in reefs nearer oyster farms most sampling periods
- Trend towards higher density in reefs nearer oyster farms most sampling periods
- Trend towards higher condition in reefs nearer oyster farms most sampling periods



- Observed several significant responses to Hurricane Florence, which strongly impacted the North Carolina coast in Fall 2018



Associated Fauna

- Reef associated fauna

- Those taxa found within the reef matrix
- Polychaete worms; xanthid crabs, mussels, slipper shells, a few other less common taxa
- Showed variability among years, but did not exhibit consistent differences among impacted and more distant reference reefs
- Several taxa, especially certain polychaetes, exhibited strong declines after Hurricane Florence relative to the same times in previous years.

- Nekton

- Includes a variety of finfish, shrimp, crabs
- Most taxa exhibited higher abundances associated with structure, whether it was aquaculture operations or wild reefs.



Summary

WATER



No changes across farms or in farms compared to non-farmed areas

SEDIMENTS



Localized, limited increases in ammonium under farms in some months

WILD OYSTERS



Higher density and larger oysters on reefs nearer to farms

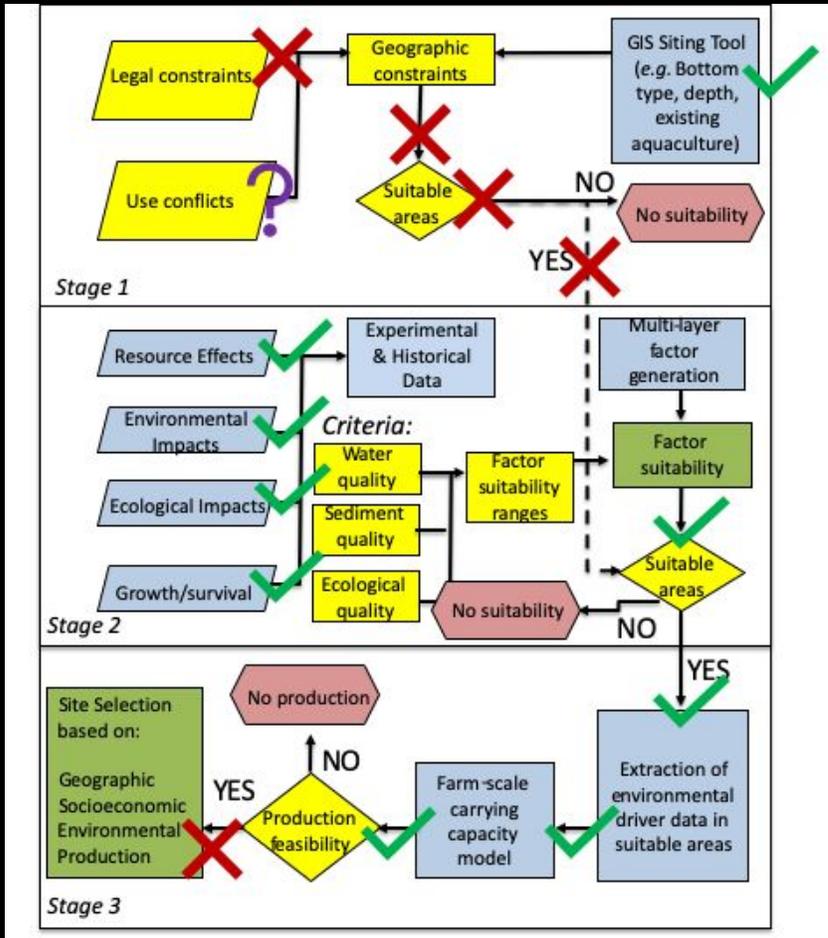
HABITAT



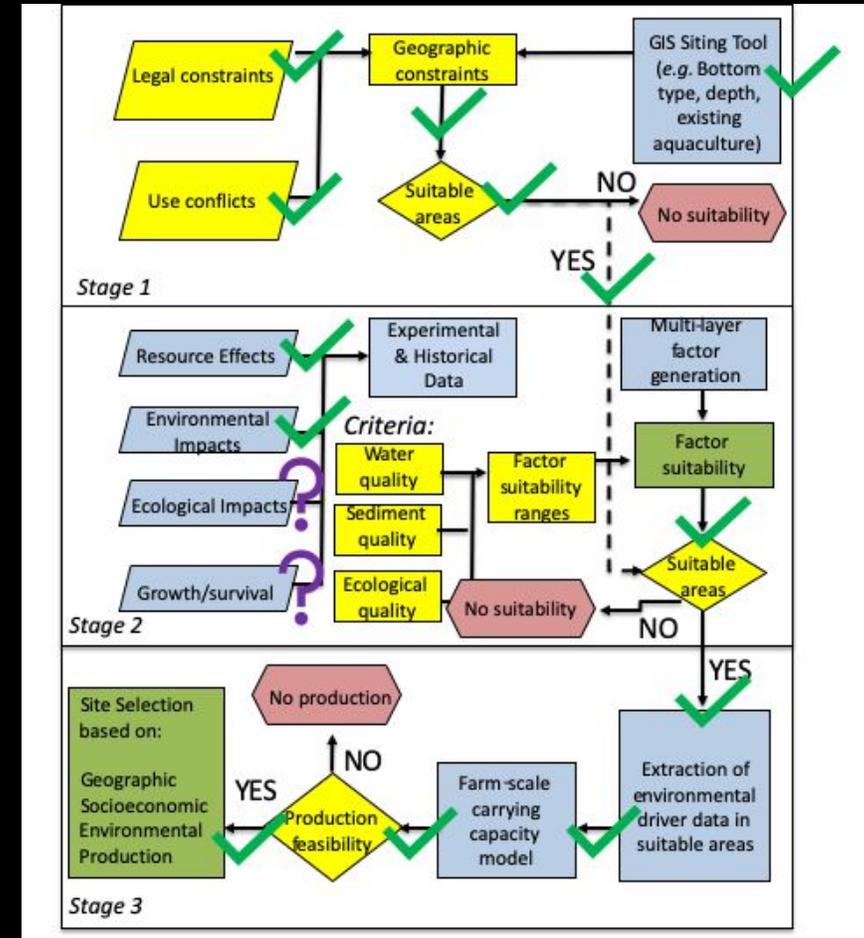
Higher abundance of motile animals around structures: wild reefs and farms

Implications for Decision-Making

Masonboro NCNERR



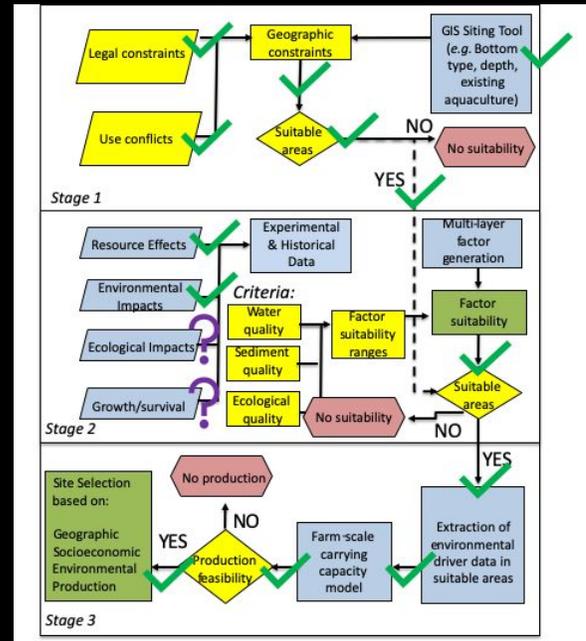
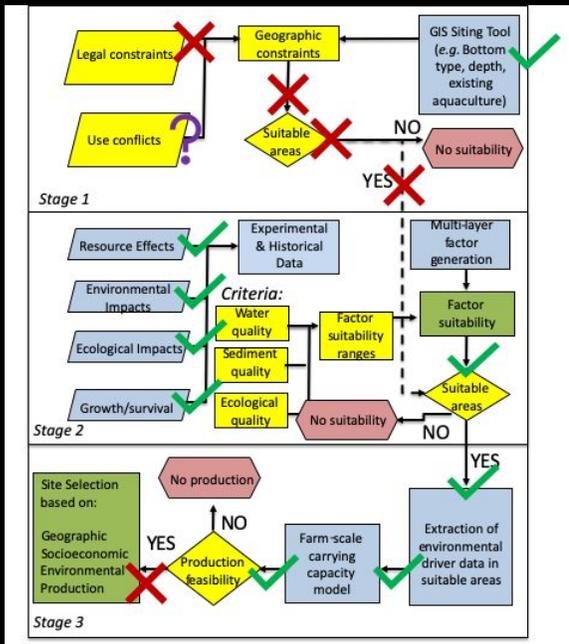
New River



Implications for Decision-Making

Masonboro NCNERR

New River



Stakeholders' Takes:

"There is possibly less environmental impact of shellfish aquaculture within a Reserve than outside, but also less opportunity to have a positive effect on water quality."

"The sites that are most preferable for aquaculture siting could be sites where water quality could benefit the most."

Download the modifiable Decision-Support Tool:

<http://www.nerrsciencecollaborative.org/project/Darrow16>

Implications of the FARM Model in North Carolina

2,044 acres of shellfish leases (DMF, April 2020)
30,660 – 143,080 PEQs of N removed per year
\$3 - 14 million in N mitigation value



Implications for Management

- Current discussion of expanding shellfish aquaculture in North Carolina
- Issues include (partially)
 - Potential environmental impacts of shellfish aquaculture, especially intensive cage culture
 - Siting – where should operations be sited
 - Potential conflicts and potential resolution
- This study helps address these issues by:
 - Providing evidence on ecosystem responses to moderate scale aquaculture operations
 - Suggest a process that may contribute to siting decisions
 - Apply a developing model to quantify certain environmental effects.





Next Steps

*How common is shellfish aquaculture in NERRS?
How are decisions made across the Reserve system?*

Shellfish Aquaculture in the NERRS

Doug Bell

Beth Darrow

Suzanne Bricker

Chris Kinkade



NCCOS

OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

2017: A determination was made by the NC Department of Natural & Cultural Resources – Natural Heritage Program finding that this **activity is inconsistent with the site's purpose as a nature preserve.**

A mandated goal of the NERRS is to “conduct and coordinate estuarine research within the System, gathering and making available information necessary for improved understanding and management of estuarine areas” (15 CFR §921.1(b)).

Origin: An initial exploratory survey of the NERRS to determine prevalence of similar issues; questionnaire survey expanded and reinitiated in 2020.

Rationale: Expansion of shellfish aquaculture will press into a continuum of estuarine systems (perturbed and unperturbed)...what has been / should be the NERRS role?

Goal: Review and highlight the current activities, regulatory framework, and approaches to shellfish aquaculture within the National Estuarine Research Reserve System (NERRS).

WEST COAST

● Padilla Bay, Washington

*
● South Slough, Oregon

● San Francisco Bay, California

● Elkhorn Slough, California

● Tijuana River, California

● Kachemak Bay, Alaska

*
● He'eia, Hawai'i

● Jobos Bay, Puerto Rico

CARIBBEAN

GREAT LAKES

● Lake Superior, Wisconsin

● Old Woman Creek, Ohio

NORTHEAST

● Wells, Maine

● Great Bay, New Hampshire

● Waquoit Bay, Massachusetts

● Narragansett Bay, Rhode Island

● Hudson River, New York

*
● Jacques Cousteau, New Jersey

● Delaware

● Chesapeake Bay, Maryland

● Chesapeake Bay, Virginia

MID ATLANTIC

SOUTHEAST

● North Carolina

● North Inlet-Winyah Bay, South Carolina

● ACE Basin, South Carolina

● Sapelo Island, Georgia

● Weeks Bay, Alabama

● Guana Tolomato, Florida

● Apalachicola, Florida

● Rookery Bay, Florida

GULF OF MEXICO

● Grand Bay, Mississippi

● Mission-Aransas, Texas

Survey Highlights

- Full participation (29 Reserves)
- Categorized presence, suitability, rationale for suitability, neighboring activity + engagement.
- 12 Reserves hold aquaculture (11 shellfish)
- 17 Reserves "Suitable" or "Potentially"
- 4 Reserves designated as a pre-existing use *
- Few reported issues / impacts; more uncertainty.

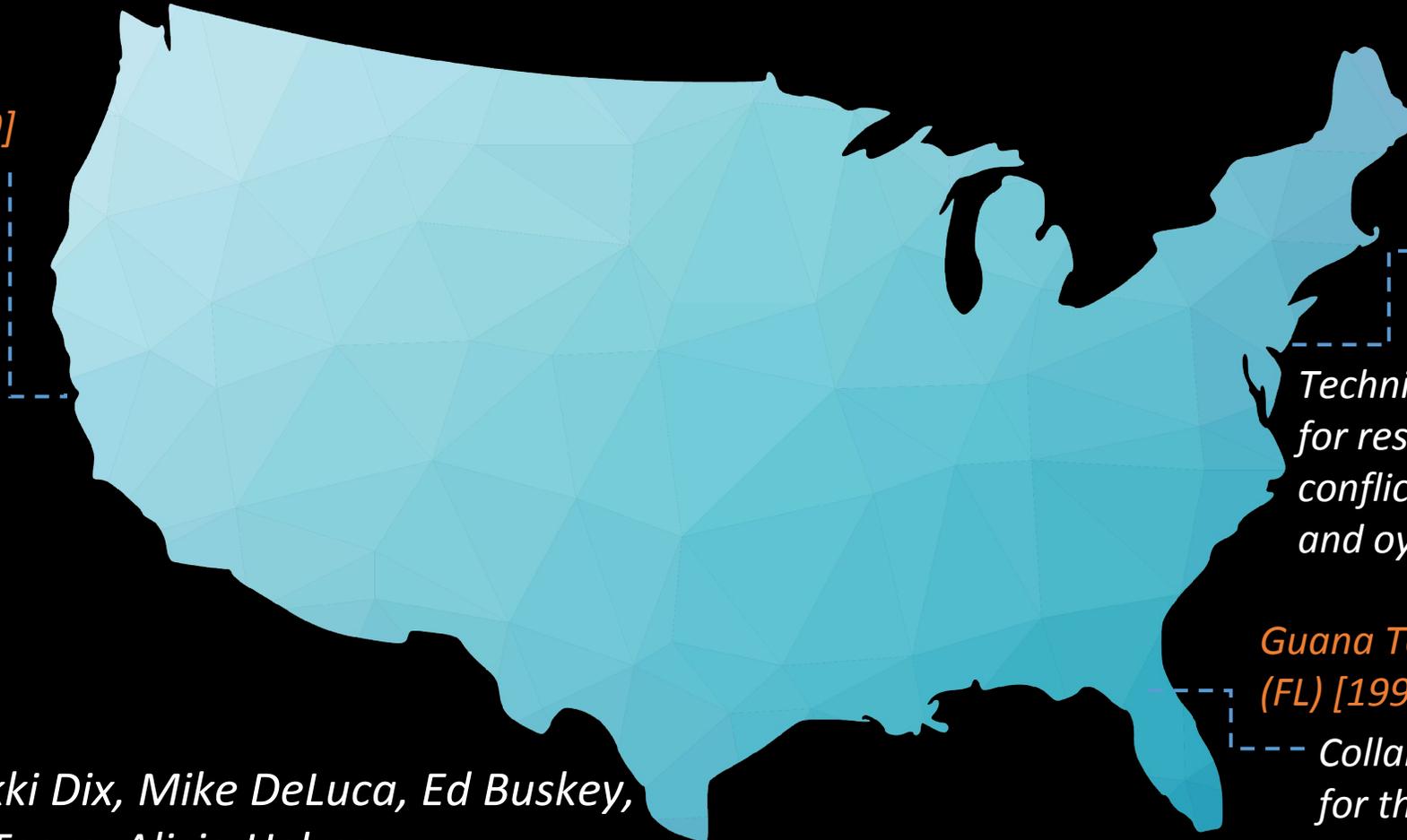
Each Reserve Unique!

Lessons Learned:

- Reserves that we interviewed displayed key roles as coordinating entities and a trusted source of science.*
- Approaches were locally focused, but patterns likely have a regional influence.*

Elkhorn Slough (CA) [1979]

First aquaculture project to restore the native Olympia population.



Jacques Cousteau (NJ) [1998]

Technical advisory function for resolving management conflict between Red Knot and oyster farms.

Guana Tolomato Matanzas (FL) [1999]

Collaborative momentum for the Water Quality Task Force of the GTM Rivers.

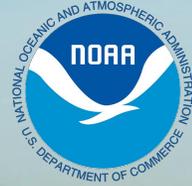
Thank you to:

- All 29 Reserves!*
- Kerstin Wasson, Nikki Dix, Mike DeLuca, Ed Buskey, Jamie Vaudry + CT Team, Alicia Helms*

Lessons Learned

1. Sometimes it pays to leave your gear in the field during a hurricane
2. Hire a great technician
3. Pick up the phone and call people
4. Use your network and the snowball approach to bring in stakeholders
5. Often policy moves faster than science... but that doesn't mean the science won't be used (there is always the next policy)
6. Have a consistent group of stakeholders *across projects/grants*

Thank you!



National Estuarine
Research Reserve System
Science Collaborative



Q&A

Use the “Questions” function in the GoToWebinar console



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Senior Scientist

Bald Head Island Conservancy,
NC



Martin Posey

Professor

University of North Carolina
Wilmington



Doug Bell

Data and Budget Coordinator
NOAA National Sea Grant
Program

**National Estuarine
Research Reserve System
Science Collaborative**



Further questions? darrow@bhic.org

Q&A

Q: Did Hurricane Florence or other storms cause some farm gear to be lost? I'm wondering if gear loss and litter will become a problem as oyster farming expands?

- **A:** In our case, these farms did not lose much gear, though that's often been a challenge in other areas, and it's been brought up by stakeholders. Minimizing impacts of marine debris is definitely something the aquaculture industry needs to consider if it's looking to expand. It's likely that floating cage aquaculture would be more susceptible to loss than heavy bottom cage aquaculture.

Q: A question of clarification about your findings - Your summary results indicate there was no difference in water quality due to shellfish farming, but the FARM model estimates nitrogen removal as being substantial. Are the fluxes just too high to detect differences in Nitrogen in the water quality monitoring?

- **A:** Yes, that's exactly it. These areas have a lot of flow, so anything being drawn down by the oysters is very difficult to observe. Measuring upstream and downstream, you aren't likely to see a huge impact unless it's a pond that's overstocked.

Q: Is there population connectivity among farmed and wild populations? If so, are there potential genetic benefits and risks to this connectivity?

- **A:** The oysters used in North Carolina are primarily triploid, so they're sterile for the most part. In some other areas, there are some diploid oysters that are deployed as well, which is cause for consideration additional considerations.

Q: In waters unsuitable for shellfish consumption, is there a possibility for oyster farmers to grow and receive income for water quality remediation, for example, through nutrient trading credits?

- **A:** Nutrient trading credits don't exist in North Carolina yet. These are just starting to be developed in areas like Chesapeake Bay for harvestable shellfish, but there are a few steps to go in North Carolina before money can go to farmers for nutrient mitigation.

In terms of areas not suitable for shellfish growth, North Carolina has a relay policy, so some growers will move oysters from closed areas to uncontaminated areas where they have to sit for a period of time. It's worth pointing out that the relay system is very strictly overseen and very limited, and likely won't end up being a major effort compared to something like restoration in closed areas for the enhanced denitrification benefits.

Currently, North Carolina does not allow any aquaculture in closed areas, though it's possible to find areas that are closed, but are more eutrophic. Pamlico sound has had water quality issues for a long time, not necessarily from bacteria but from nutrients causing algal blooms. There are spots that have nitrogen issues but aren't necessarily closed to shellfish.

Q: I noticed that harmful algal blooms are not included in your decision support tool. They can make shellfish unsafe to eat but another problem that is not well known is that some algal blooms can kill shellfish or hurt recruitment. Any comments?

- **A:** That is something we discussed in stakeholder meetings, but it hasn't been a major concern for our stakeholders in the areas we had proposed. That being said, this is the type of concern that can be included in the decision support tool when it's adapted for individual regions.



Q&A

Q: Could you provide more explanation of any opposition to expanding shellfish aquaculture? What are the issues?

- **A:** One issue, particularly in the southern part of the state, is the viewscape. We had relatively narrow sounds, and even those areas outside the reserve are relatively narrow water bodies, so there was quite a bit of concern with respect to people not wanting these operations to be visible “in their backyards.”

Another issue is public use waters. Waters need to be available for a variety of uses, and aquaculture is not supposed to significantly impact other uses. North Carolina is working through placing shellfish operations, and many farmers would prefer to site closer to access areas due to concerns of cost and effort.

Others include choosing between commercial and recreational uses, and potential impacts on other types of habitat, especially areas that are being actively restored. In North Carolina, there are regulations that prevent leasing areas where there’s a certain percentage of seagrass already there.

Q: What is the flushing time for this bay system?

- **A:** The mean flushing time for the New River Estuary (Farm 3) is 70 days (Ensign et al. 2004). Flushing time for Big Bay within the Masonboro NCNERR (Farms 1 and 2) is unknown, but it has high tidal flushing rates (>1 m/s peak spring tide).

Q: Does North Carolina consider existing shellfish and submerged aquatic vegetation habitats in making a siting determination? If oyster farming is desired in an area of hard clams or submerged vegetation, what does the decision tree look like for that circumstance?

- **A:** With both oysters and seagrass, there are rules that specifically restrict establishment of oyster operations when seagrass exceeds a (fairly low) threshold of seagrass blade presence; the same goes for existing oyster areas. There’s a rule for hard clams as well. All of these considerations would be factored into stage 1 of the decision support tool; i.e., where are we now in the current framework.

Q: Are there any plans to examine changes after leases and farm operations ended?

- **A:** Not right now; we’d need an additional project to continue some of this work. That would be a good thing to investigate, to see if there have been any changes through time. Farm 3 is still going strong, they just added new aquaculture operations.

Q: Is there any monitoring for shellfish disease transmission between wild populations and cultured stocks; for example, Dermo or MSX?

- **A:** We did not monitor for shellfish disease transmission during this project. The idea came up in stakeholder meetings, but the general consensus was that these diseases are known to be prevalent in this region but are not currently responsible for large mortality events and that adding a disease transmission component would be beyond the scope of this project. This would be an interesting follow-up project and disease prevalence/intensity could be included as criteria in the decision-support tool if an end user was interested in adding it.

Q: Do you foresee any integration of long term climate change effects (increased salinity, freshwater input decreases, sea level rise, etc.) being integrated into site selection models?

- **A:** This would be a possibility for the FARM model, which is based on known physiological response of oysters to varying temperature and salinity - different environmental scenarios such as temperature and salinity, could be used to predict a farm's production. We are not doing this yet, but it would be a possible expansion of this project. Our collaborators at Longline are doing this kind of work in Europe through the [CERES Project](#), for example.



Webinar Announcements

Upcoming Schedule

Measuring Climate Adaptation Success and Progress: System-wide Introduction to the Resilience Metrics Toolkit

3.00 - 4.00 PM Eastern Time, November 18, 2020

Speakers: Kristen Goodrich and Susi Moser



**National Estuarine
Research Reserve System
Science Collaborative**

COLLABORATIVE SCIENCE FOR ESTUARIES

WEBINAR SERIES



National Estuarine
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Thank you for joining us

Please complete the short survey at the end of the webinar, and
be on the lookout for the webinar recording!



Beth Darrow

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Bald Head Island Conservancy,
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Martin Posey

Professor

University of North Carolina
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Doug Bell

Data and Budget Coordinator
NOAA National Sea Grant
Program

EXTRA SLIDES

Biomarkers

- **Stress Response**^{40 41 42 43}

- Elevated temperature, bacterial infection, pH, mechanical disturbances
- Up regulation of genes

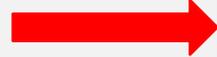
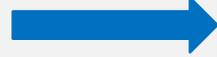
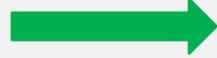
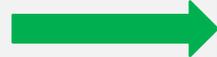
- **Immune Response**^{37 38 44 45 46}

- Increase in bacterial and viral disease, parasitic infection
- Up regulation of genes

- **Metabolism**^{37 38 39 47 48}

- Elevated temperature, CO₂ level, salinity
- Down regulation of genes

- **Reference Genes**^{37 49 50}



Gene	Symbol	Function
Killer cell lectin-like receptor	KCrec	Non-self recognition (lectin receptor family)
ATP synthase f0 subunit 6	AS6	Energy metabolism (complex V of electron transport chain)
Endothelial lipase precursor	EDL	Lipid metabolism (phospholipase)
Heat shock protein 70	HSP70	Chaperone protein (cytoprotection)
Peroxiredoxin 6	PRDX6	Oxidative stress (antioxidant enzyme)
Glutamine synthetase	GS	Protein metabolism (amino acid synthesis)
RAS supressor	SUP	Cell division inhibitor
Ribosomal protein I8s	R18s	Reference
Beta-actin	BActin	Reference

⁴²Clark et al., 2013 ⁴³Wang et al., 2012 ⁴⁴Ackerman et al., 2001 ⁴⁵McGreal et al., 2004 ⁴⁶Ymaura et al., 2008 ⁴⁷Ivanina et al., 2013 ⁴⁸Zacchi et al., 2017 ⁴⁹Etschmann et al., 2006 ⁵⁰Radonic et al., 2004

Water quality - nutrients

- Ammonium, nitrate, phosphate
- Could increase locally within farms with concentration of biodeposits
- Large seasonal variability
- No evidence of consistent change within farms

