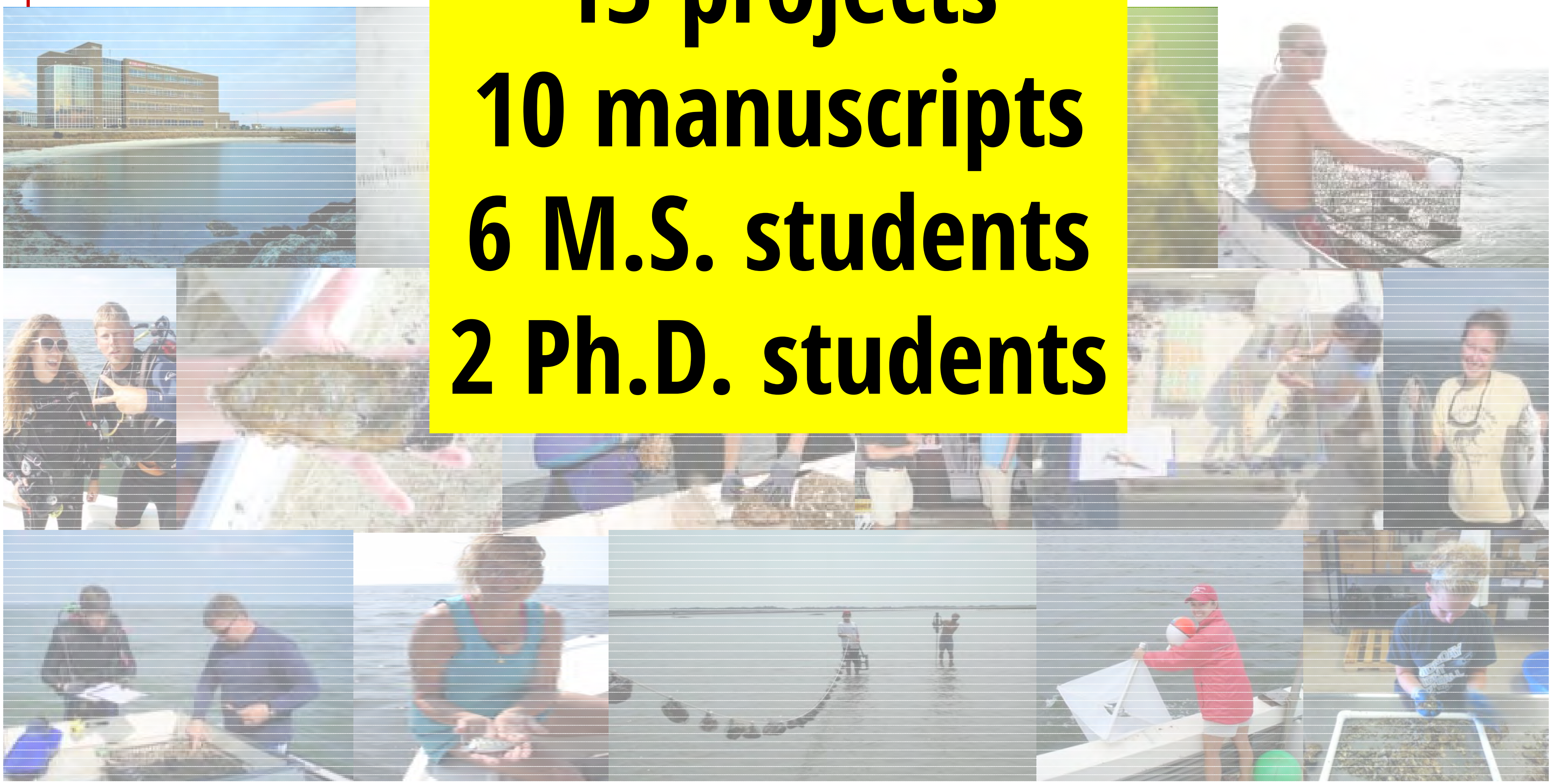
NC STATE UNIVERSITY

NC State Oyster Research Update

Summary

13 projects
10 manuscripts
6 M.S. students
2 Ph.D. students



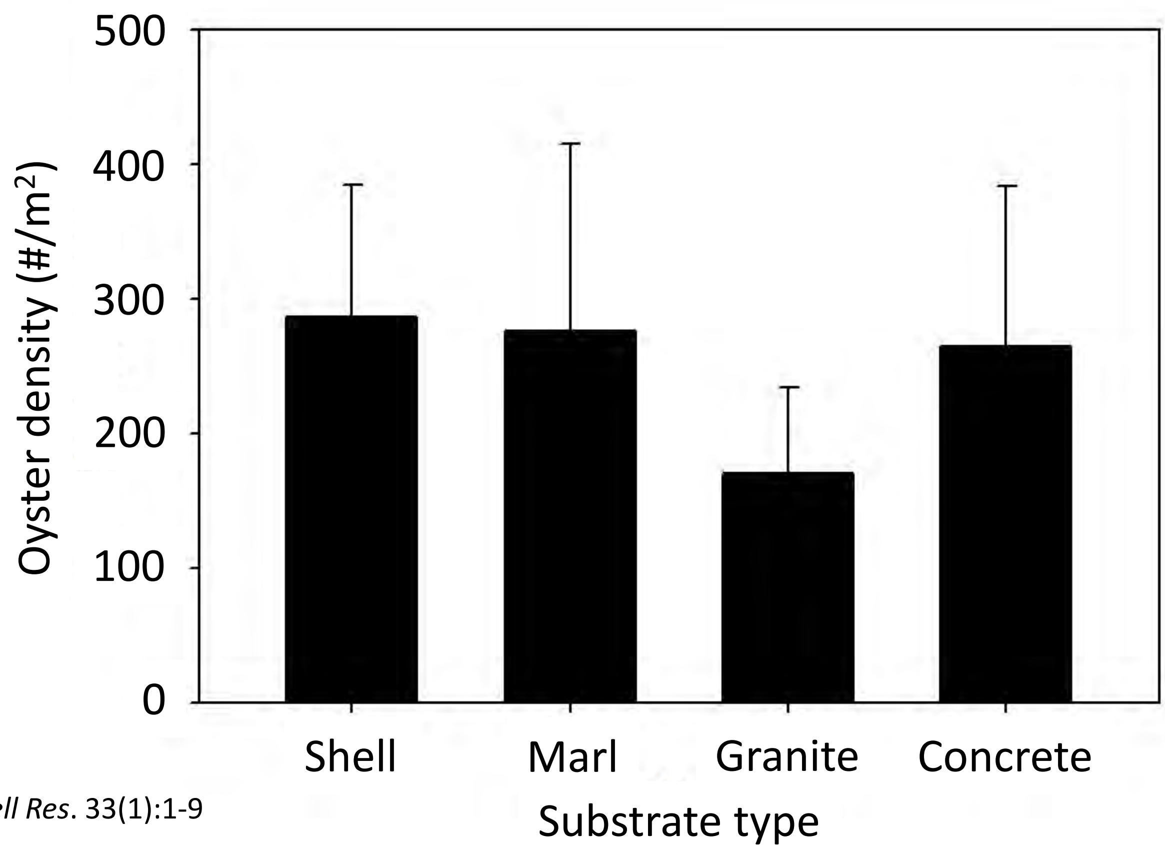
Summary


sanctuary
larvae
settlement
reefs
fish
demographic
sound
high
site-selection
substrate
connectivity
network
habitat
sites
reproduction
metapopulation
densities
crabs
species
stone
bottom
dispersal
estuarine
broodstock
restoration
growth
Reproduction
study
potential
model
salinity
using
within
relatively
dynamics
rates
habitats
variation
compared
differences
different
recruitment
enhancement
response
reef
site
two
m2
areas
data
captured
management
sampling
Crassostrea
boring
higher
used
diversity
may
shells
population
experiments
control
goal
number
assess
quantify
levels
sounds
patterns
North
Carolina
Cliona
locations
evidence
unstructured
sponge
natural
output
abundance
mounds
marine
time
materials
laboratory
due
increased
highest
capita
density
effort
among
mean
per
presence
new
mortality
spatial
fishing
marl
reproductive
construction
hydrodynamic
project
varied
whereas
likely
quantified
off-reef
size
results
experimental
geochemical
relative
effects
also
physical
survival
virginica
found
shell
identify
suitable
NC
total
soft
system
recreational
field
range
Marine
traps
crab
general
type
support
overall
design
significantly
no-take
sources
conducted
use
cultch
June
characteristics
surveys
frequency
magnitude
sponges

1) Effect of substrate type on oyster demographics?

1) Effect of substrate type on oyster demographics?

Recruitment did NOT differ among substrate types

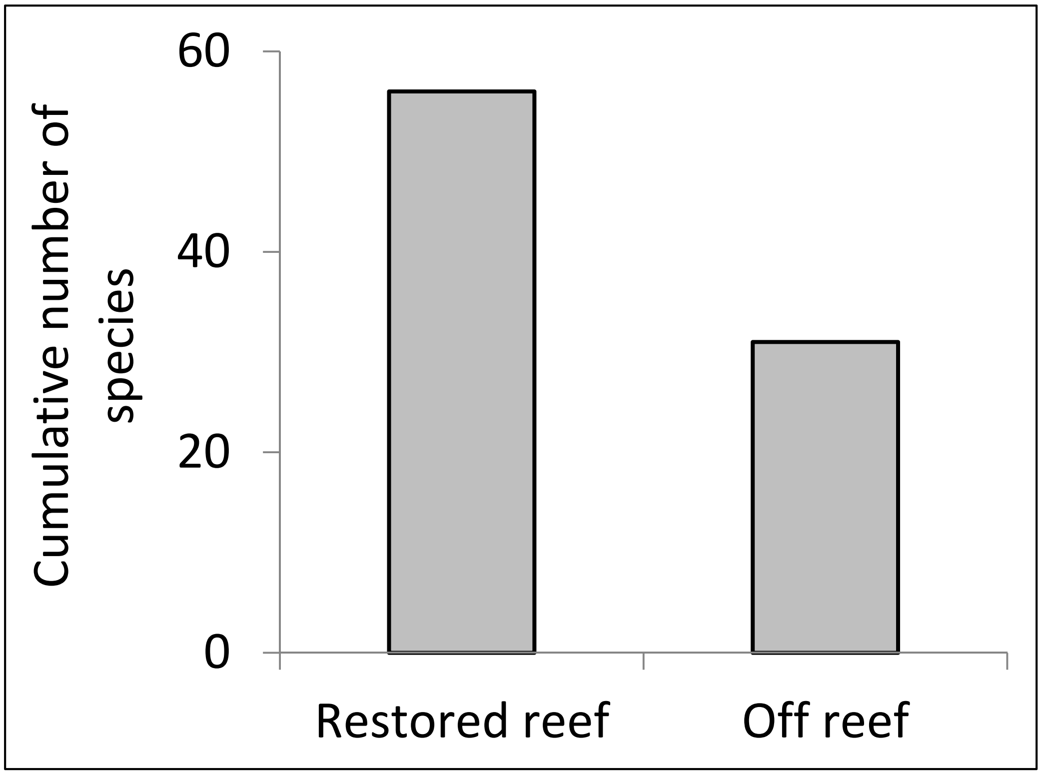


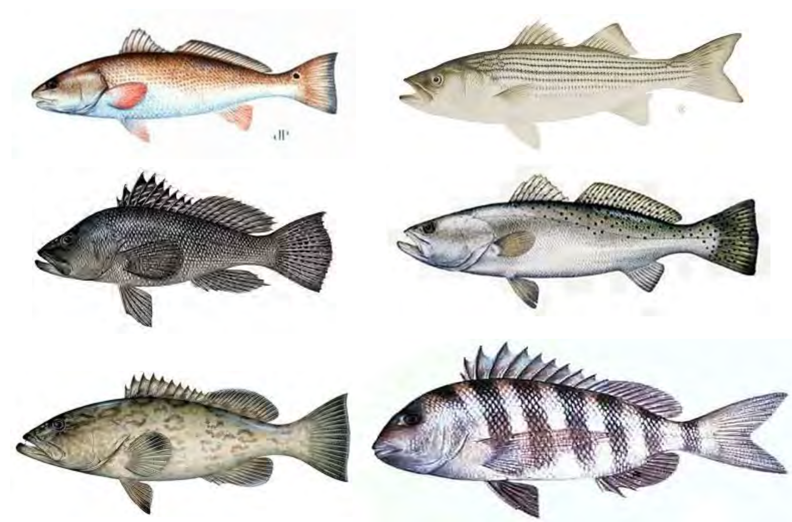
Dunn et al. 2014. *J Shell Res*. 33(1):1-9

2) Response of estuarine fish to oyster reef restoration?

2) Response of estuarine fish to oyster reef restoration?

Species richness higher in restored reefs than "off reef"



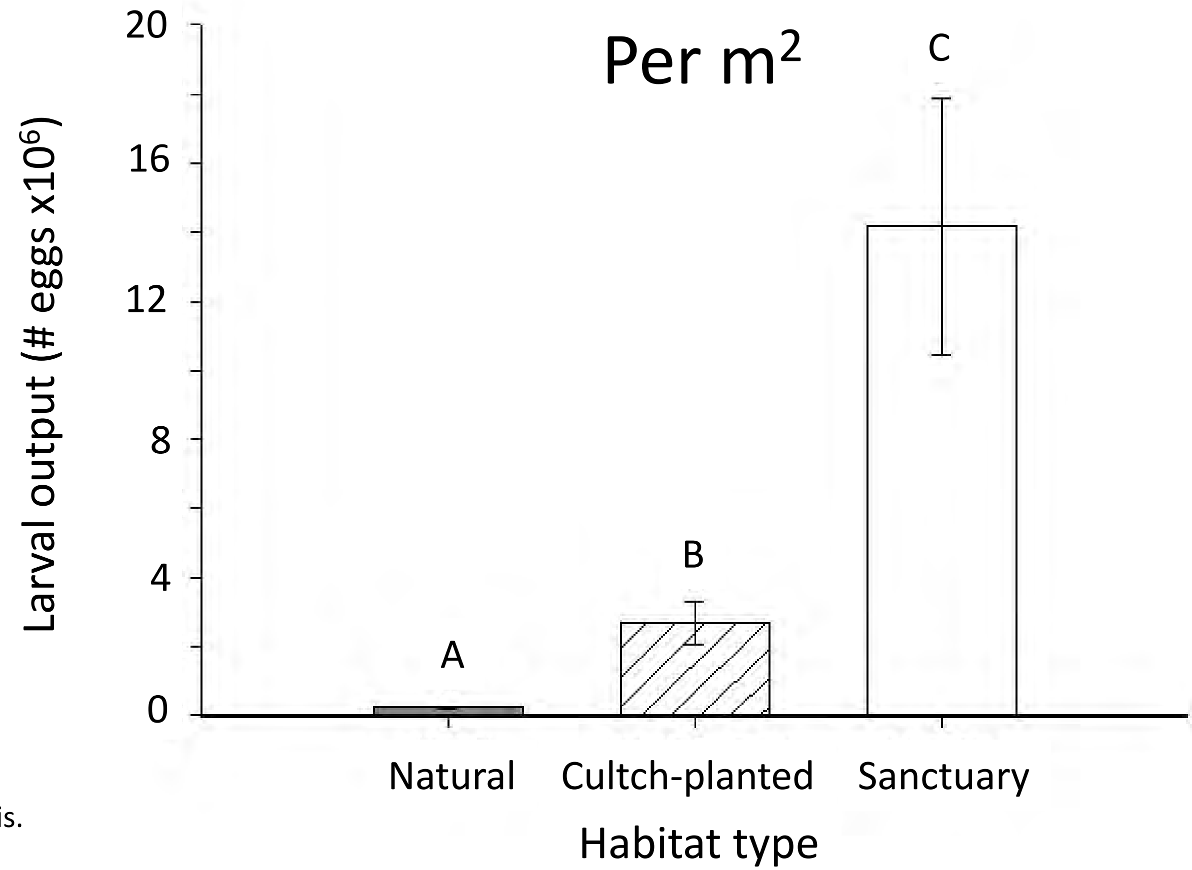


Pearson and Eggleston. 2014. *Trans Am Fish Soc*. 143: 273-278

3) Larval output of restored habitats?

3) Larval output of restored habitats?

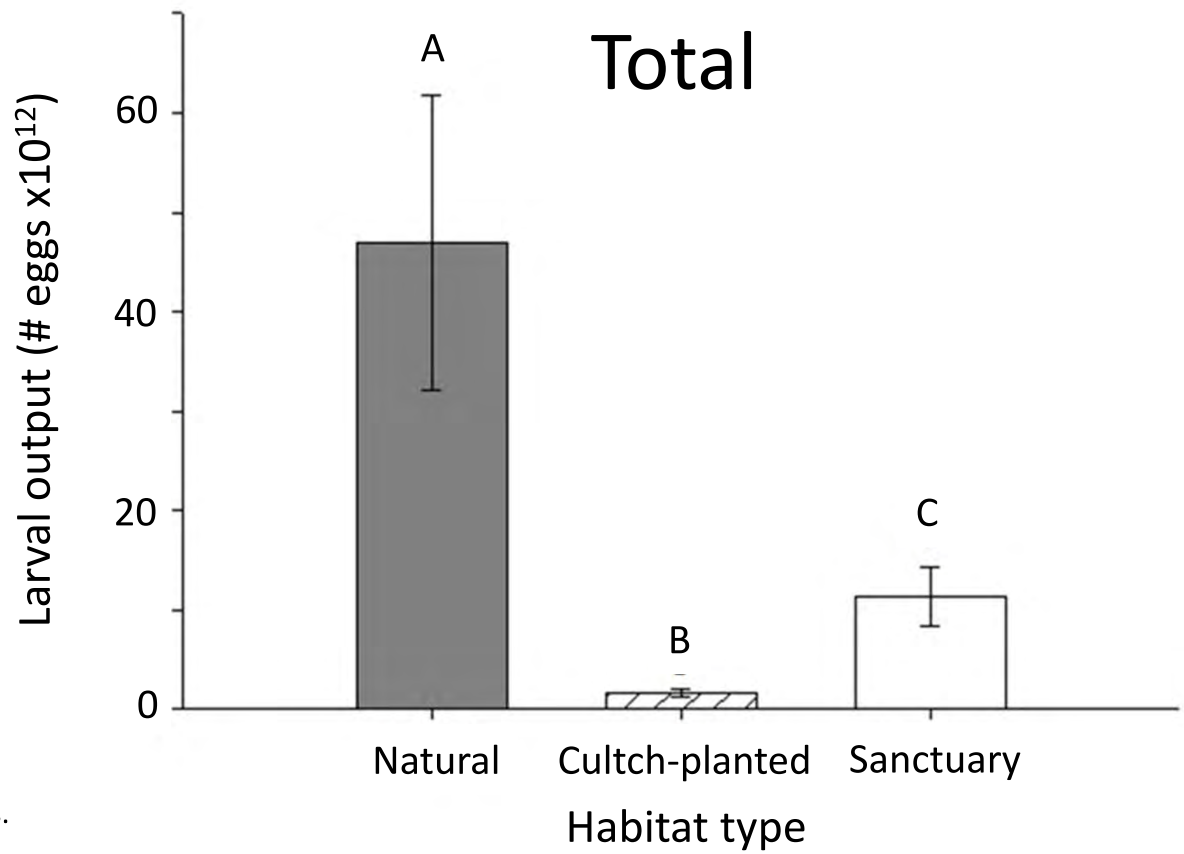
Sanctuary output greatest per unit area



Peters. 2014. MS Thesis.

3) Larval output of restored habitats?

Total larval output of restored habitats < natural reefs



Peters. 2014. MS Thesis.

Potential "Spill-in" of Oyster Larvae to Broodstock Reserves

Jason Peters (jwpeter2@ncsu.edu), David Eggleston, and Brandon Puckett

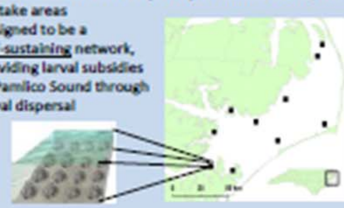
Department of MEAS, North Carolina State University, Center for Marine Sciences and Technology, Morehead City, NC

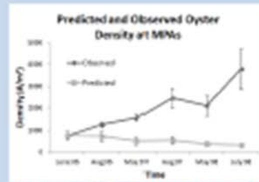
Introduction

Many fragmented habitats can be characterized as metapopulations, whereby spatially separated populations are connected via recruitment. Integral to the application of metapopulation dynamics to conservation practices is the notion of source versus sink populations or habitats. Metapopulation restoration efforts often involve creating or designating source habitat for target species.

In an effort to restore degraded oyster populations, North Carolina Division of Marine Fisheries (NCDMF) created 10 oyster broodstock reserves (MPAs) in Pamlico Sound, NC.

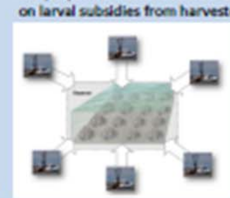
- No take areas
- Designed to be a self-sustaining network, providing larval subsidies to Pamlico Sound through larval dispersal





Predicted population densities at MPAs indicated a declining trend in abundance, suggesting the network is NOT self-sustaining. However, ground truthing at these sites revealed considerable increases in densities over ~2 years (Puckett and Eggleston 2012).

We propose that Pamlico Sound MPAs are relying on larval subsidies from harvested areas to support their growing populations. In other words, larvae from harvested areas are "spilling-in" to MPAs.



Study Objective:

Compare and contrast oyster demographics in MPAs vs. harvested areas and estimate potential contribution of harvested reefs to PS larval pool

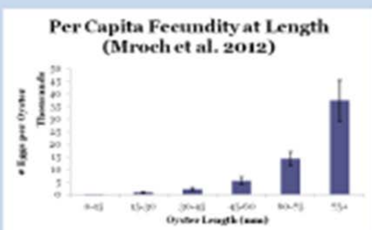
Methods

Study System: Pamlico Sound, North Carolina
Focal Species: *Crassostrea virginica* (Eastern Oyster)
Design:

- Selected 22 natural and artificial (cultch) sub-tidal reefs distributed throughout Pamlico Sound

Field Collection and Processing:

- Random 0.25m² quadrat sampling and subsequent hand excavation to a depth of 15cm
- Count and measure individuals to yield density (# oysters/m²) and size structure

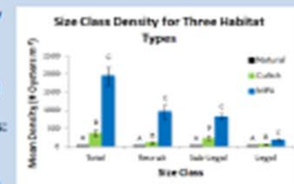


Potential Larval Output:

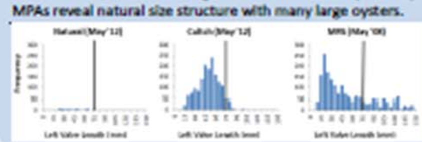
- Used per-capita fecundity at length for oysters in Pamlico Sound MPAs (Mroch et al. 2012) and our observed length frequencies (May 2012) to estimate potential larval output (m²) at each site
- To determine potential sound-wide larval output for fished reefs, we used average output per m² for each habitat type (natural, cultch, MPA) and scaled up based on total areal footprint coverage of respective habitat type. An adjustment factor of 0.44 was applied to DMF estimated natural reef area, based on the presence of only 8/18 visited natural reefs in this study.
  - •Natural: 1.3x10⁸ m²(DMF); 5.9x10⁷ m² (this study)
  - •Cultch: 4.0x10⁵ m²
  - •MPA: 8.0x10⁵ m²

Results

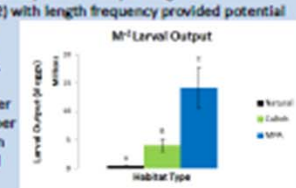
1. Oyster density (m⁻²) was significantly greater at MPAs than natural and cultch reefs for three size classes: recruit (<25mm shell height), sub-legal (25mm to 75mm), and legal (>75mm). Different letters denote significant differences between habitat types (p<0.05).



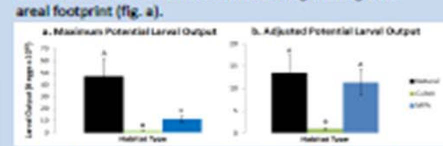
2. Length-frequency distributions highlighted variability in size structure between habitat types. Natural reefs exhibit little size structure and few or zero individuals greater than legal size. Cultch reefs possess higher densities, but similar to natural reefs, have few legal sized individuals (>75mm). MPAs reveal natural size structure with many large oysters.



3. Integration of per-capita fecundity at length data (Mroch et al. 2012) with length frequency provided potential larval output per square meter for each habitat type. MPAs have a significantly greater potential output per Square meter than cultch and natural reefs.



4. Based on DMF estimated area, naturally occurring oyster reefs have a significantly greater potential larval output than cultch reefs or MPAs due to 3 orders of magnitude greater areal footprint (fig. a).



Adjusted for natural reef area observations from this study, potential larval output is commensurate with MPAs (fig. b). Different letters denote significant differences between habitat types (p<0.05).

Conclusions

- Depending on areal footprint of natural reefs, larvae from fished areas may be subsidizing MPAs
- The population density of oysters in MPAs is ~6.7 fold higher than fished areas (total)
  - 103 times higher than natural reefs
  - 5.4 times higher than cultch reefs
- Identifying potential spill-in from fished areas to MPAs will help manage both habitats
- This study will contribute to our understanding of estuarine metapopulation dynamics

Works Cited

1. Puckett BJ and Eggleston DB (2012) Oyster dynamics in a network of no-take reserves: recruitment, growth, survival, and density dependence. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4(1):605-627
2. Mroch RM, Eggleston DB, Puckett, BJ (2012) Spatiotemporal Variation in Oyster Fecundity and Reproductive Output in a Network of No-Take Reserves. Journal of Shellfish Research 31(4):1091-1101

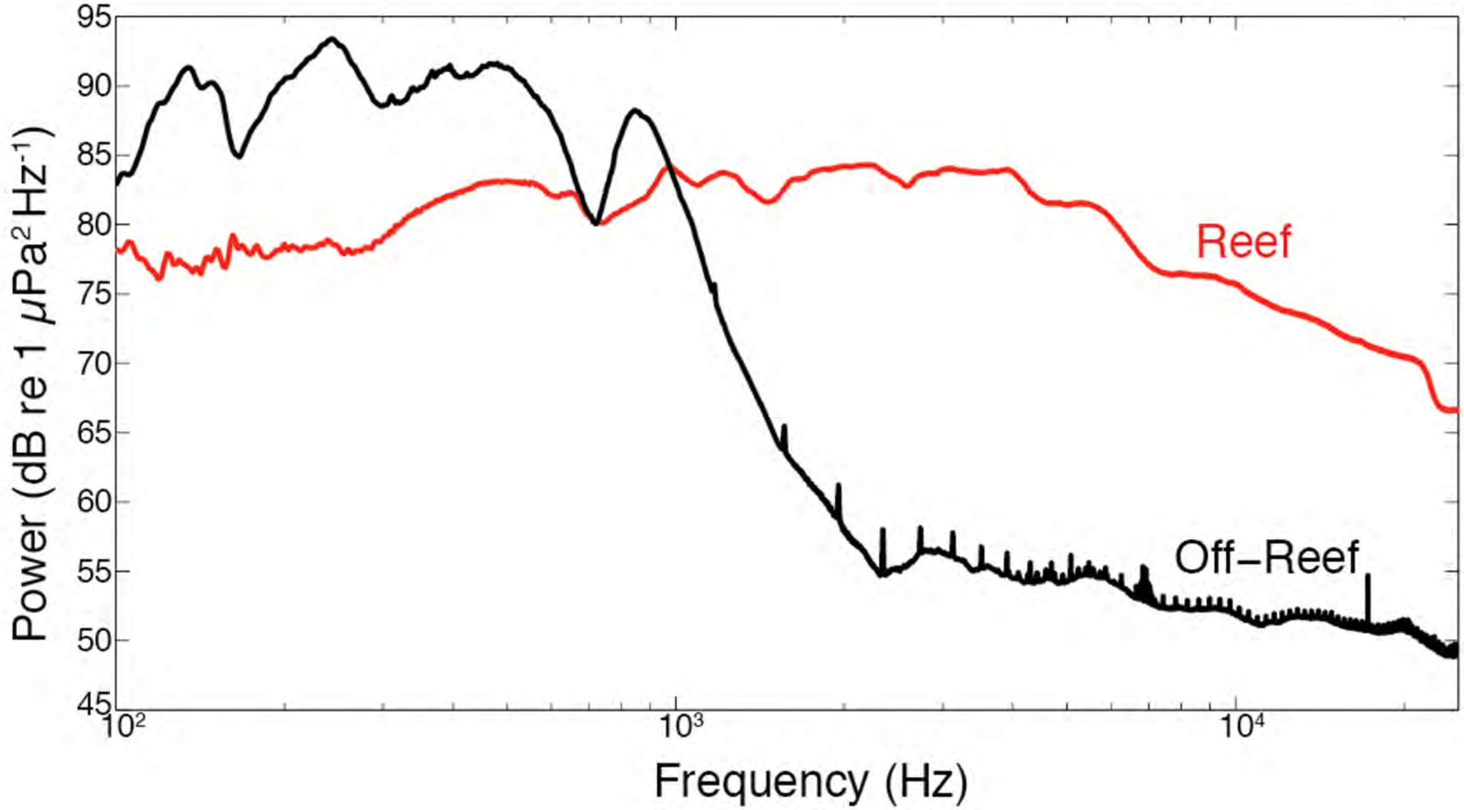
Acknowledgements

Brandon Puckett, Ashlee Lillis, Robert Dunn, Lydia Neal, Hunter Eggleston, Becky Gericke, Jordan Byrum, Seth Theuerkauf, Doreen Mcveigh, Amber Perk

4) Oyster reefs have distinct soundscape? Possible settlement cue?

4) Oyster reefs have distinct soundscape? Possible settlement cue?

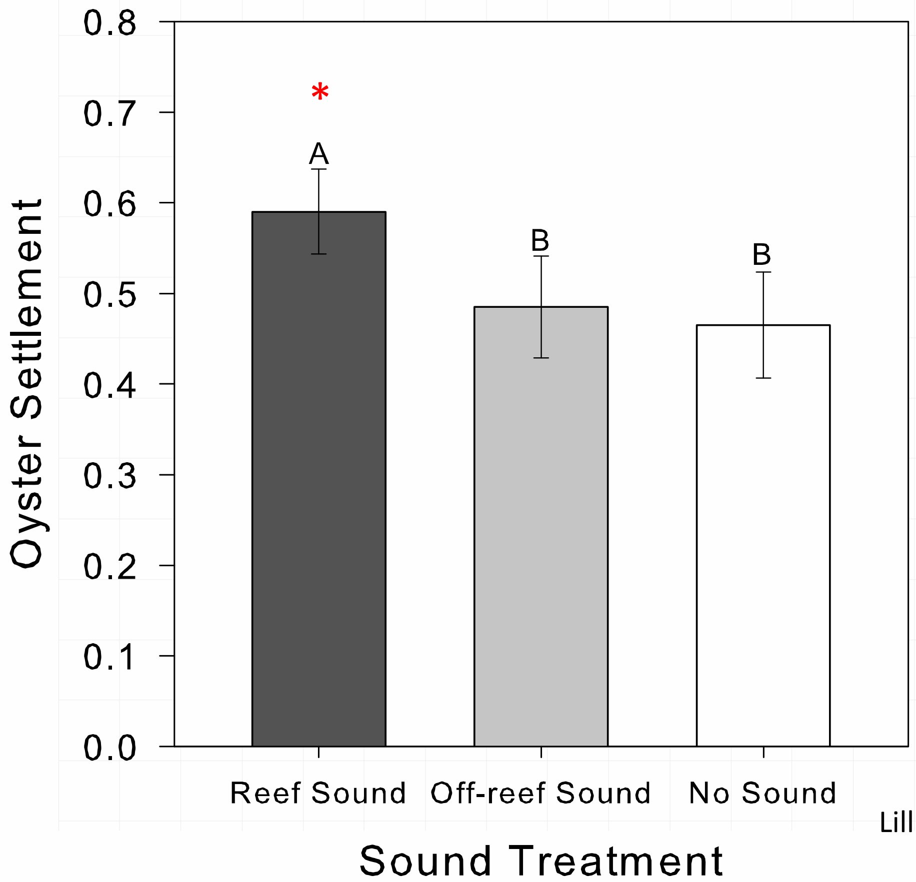
Oyster reefs have higher sound levels and distinct spectra



Lillis et al. 2013. *PLoS One*. 8(10): e79337.

4) Oyster reefs have distinct soundscape? Possible settlement cue?

Higher settlement when larvae exposed to reef sound



Lillis et al. 2013. *PLoS One*. 8(10): e79337.

NC STATE UNIVERSITY

SOUNDSCAPES AND LARVAL SETTLEMENT:

Characterizing the stimulus from a larval perspective

Ashlee Lillis, David Eggleston, DelWayne Bohnenstiehl   Department of Marine, Earth & Atmospheric Sciences

The Problem: How do marine larvae locate settlement habitat after pelagic dispersal?

- Most benthic marine animals have dispersing planktonic larval stages
- Settlement into appropriate habitat is critical to success– but a good habitat can be hard to find!
- Larvae respond to environmental cues during settlement and habitat selection

A role for sound in larval recruitment?

- Soundscape is a rich source of sensory information underwater –
  - **Reflects bio-physical characteristics of source environment**
  - **Can be present at all depths, day or night**
  - **Current-independent, travels efficiently**
- Larval fishes and crustaceans shown to respond to habitat-related acoustic stimuli
- Larval oyster settlement enhanced by oyster reef sound (this study)

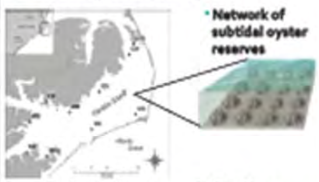
Sound could be important, but, the relevant acoustic stimuli are largely uncharacterized, particularly in estuarine habitats

How does an estuarine soundscape vary at scales relevant to larval processes?

Measuring the habitat-related soundscape in space and time using multiple approaches:

Study System

Pamlico Sound, North Carolina, USA



- Network of subtidal oyster reserves

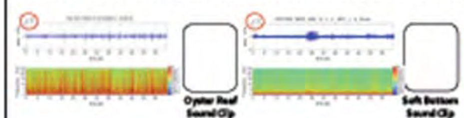
Oyster Reef vs. **Soft Bottom**

- structured
- high density resident soniferous species
- patchy distribution

- unstructured
- transient soniferous species
- common within estuary

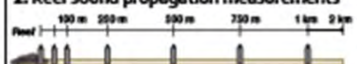
1. Simultaneous recording in reef and off-reef habitats

Habitat-related Sound : Oyster reef sound is consistently distinct from adjacent soft bottom sound

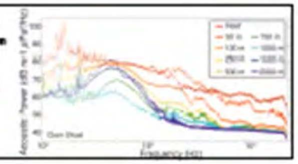


Oyster Reefs = Consistently higher levels of higher frequency sound

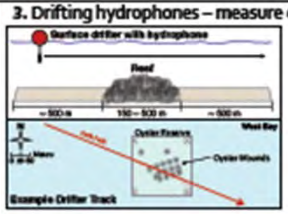
2. Reef sound propagation measurements



Sound levels & frequencies decay rapidly with distance from the reefs

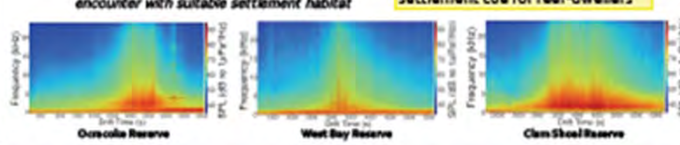


3. Drifting hydrophones – measure changing soundscape as habitats are crossed

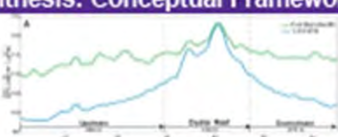


Sound level and frequencies increase over reefs
↳ Larval response to the sound could facilitate encounter with suitable settlement habitat

Localized habitat sound could provide a reliable broad-scale settlement cue for reef-dwellers



Synthesis: Conceptual Framework for Sound as a Larval Settlement Cue



A) Sound pressure level recorded by a drifting hydrophone in West Bay, NC.

B) Conceptual diagram depicting how reef sound could facilitate larval settlement and habitat selection

Could larval response facilitate encounter with settlement habitat?

Based on soundscape measurements, as the larvae move toward the oyster reef, they encounter acoustic stimuli of the reef –

If they respond by sinking or swimming to bottom at known rates for weakly swimming larvae, they can reach substrate well within reef crossing time

In concert with the collection of comprehensive soundscape data, there is a need to identify the sound levels and frequencies that elicit larval responses, to understand when and where sound affects settlement and to assess how anthropogenic noise or acoustic degradation of habitat may impact recruitment processes

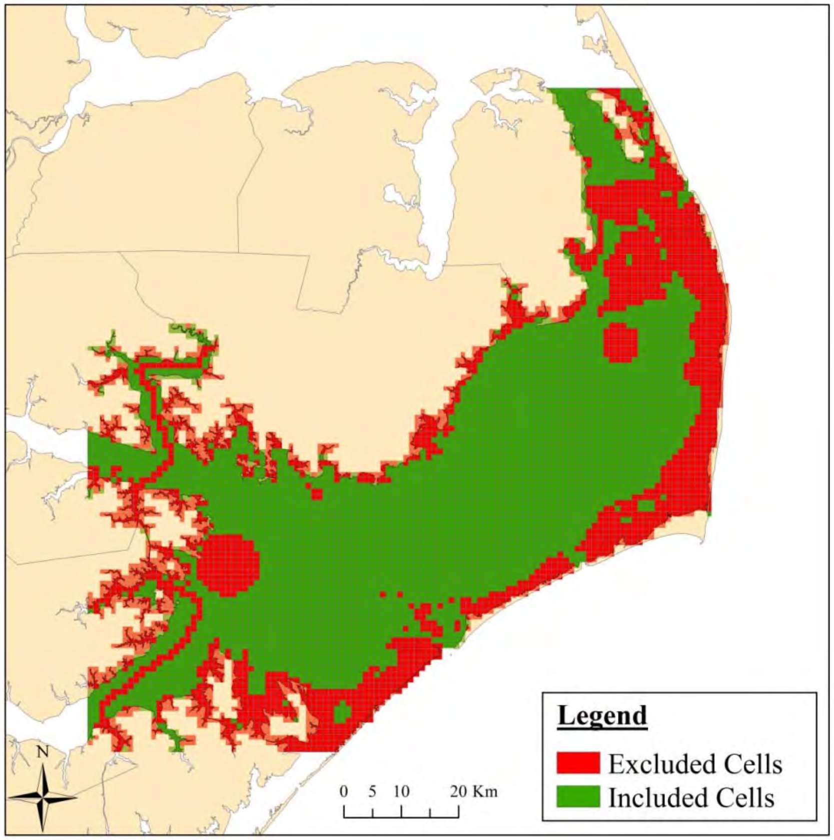
Author email: aslillis@ncsu.edu

Funding Provided By:

5) Optimal site selection for oyster sanctuaries?

5) Optimal site selection for oyster sanctuaries?

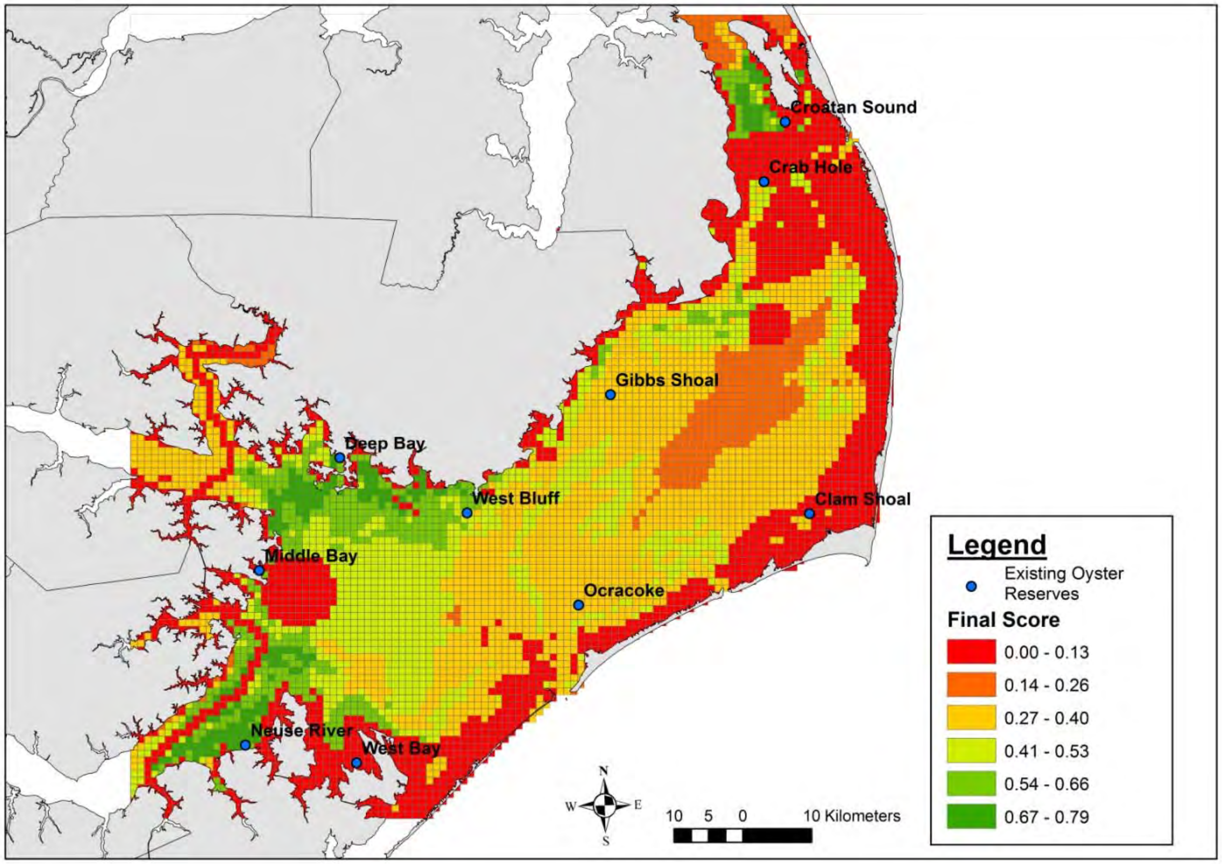
39% of Pamlico Sound unsuitable



Puckett et al. 2014. *Unpubl. data*.

5) Optimal site selection for oyster sanctuaries?

Optimal locations: SW and N portion of Pamlico Sound



NC STATE UNIVERSITY

If you build it, will they come: designing a marine reserve network for oyster restoration

Brandon Puckett (bjpucket@ncsu.edu), David Eggleston, and Rodney Guajardo
North Carolina State University Center for Marine Sciences and Technology

1. INTRODUCTION

Figure 1. Global decline of oyster reefs as a percentage of historical to current abundance. Source: Beck et al. 2011.

- Global decline of native oysters (Fig. 1)
  - Fueled large-scale oyster restoration
- Multiple restoration strategies
  - Reserve network: multiple reefs protected from harvest and connected by larval dispersal
  - Efficacy of reserve networks dependent on site selection
- To select optimal reserve sites, we included biologically and economically-relevant data within a GIS-based hierarchical optimization algorithm

2. METHODS

- Study system: Pamlico Sound (Fig. 2)
  - Contains 10 sub-tidal oyster reserves (Fig. 2)
- Focal sp.: Eastern oyster (*Crassostrea virginica*)
  - Adults sessile; disperse via pelagic larval stage
- Analysis
  - Created grid of Pamlico Sound (6,041 km^2 cells)
  - Assembled 16 GIS layers (see outer circle Figs.)
    - Two categories: exclusion and threshold
  - Calculated suitability value of all cells
    - Scale: 0 (unsuitable) to 1 (most suitable)

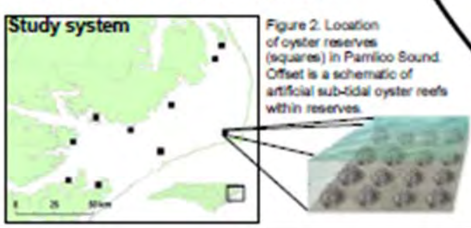
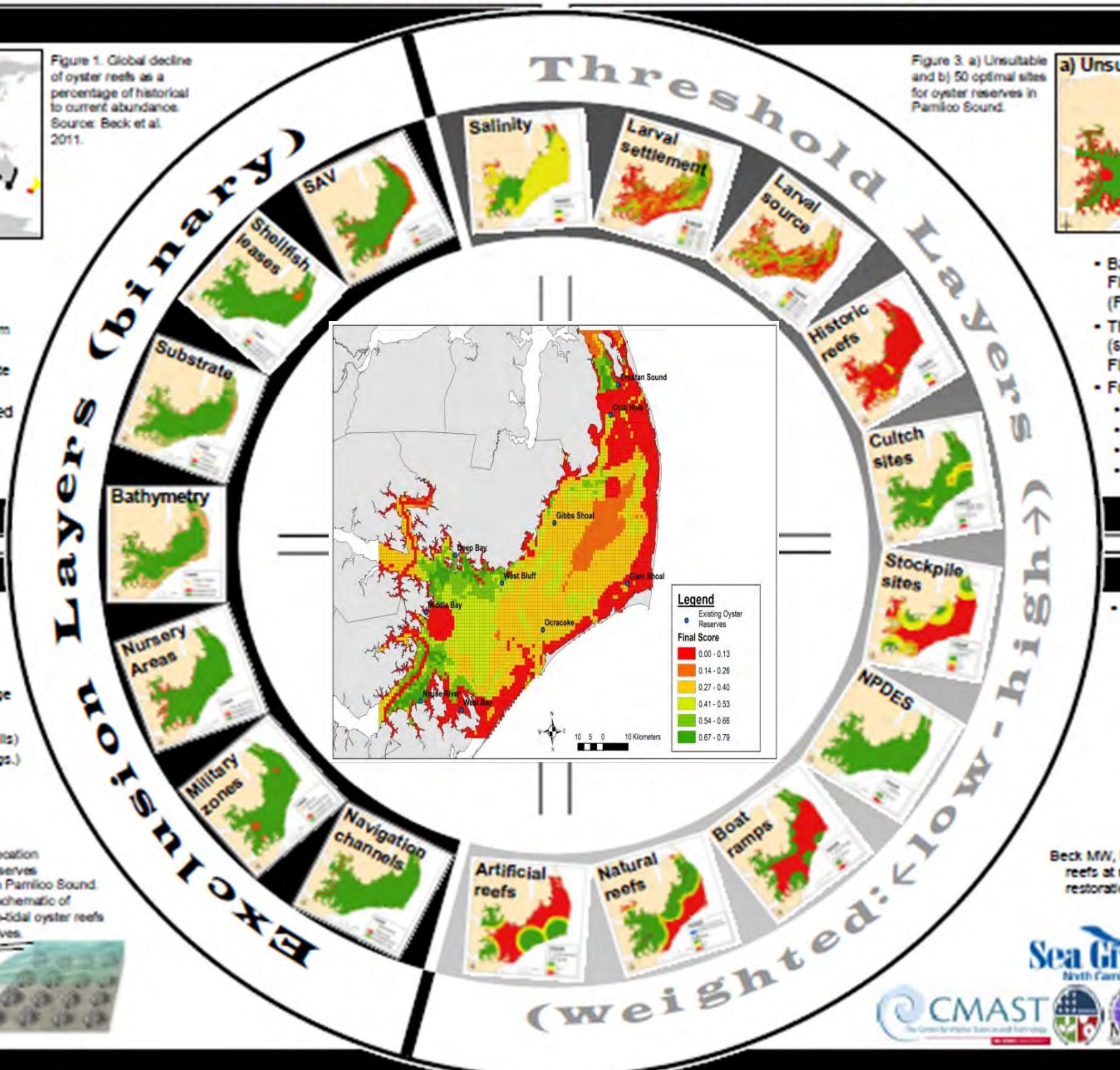
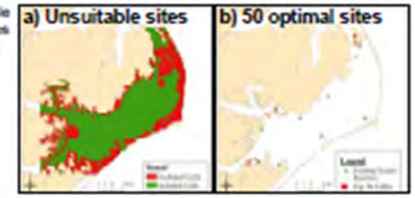


Figure 2. Location of oyster reserves (squares) in Pamlico Sound. Offset is a schematic of artificial sub-tidal oyster reefs within reserves.



3. RESULTS

Figure 3. a) Unsuitable and b) 50 optimal sites for oyster reserves in Pamlico Sound.



- Based on exclusion layers (outer circle Figs), 37% of Pamlico Sound unsuitable (Fig. 3a)
- Threshold layers weighted from 30% (salinity) to 2% (artificial reefs; outer circle Figs)
- For reserve suitability, see inner circle Fig.
  - Modal suitability value ~0.5
  - Max suitability value 0.87
  - 87 cells (1.4%) scored ≥ 0.8
  - Optimal sites clustered in SW portion of Pamlico Sound (Fig. 3b)

4. CONCLUSIONS

- GIS-based hierarchical approach to site selection is effective for:
  - Narrowing vast water bodies to a manageable number of sites for more detailed study
  - Identifying restoration "hot spots" where optimal sites are clustered
  - Designing reserve networks with biological and economic considerations

Literature cited

Beck MW, Brumbaugh RD, Airoldi L, et al. (2011) Oyster reefs at risk and recommendations for conservation, restoration, and management. BioScience 61:107-116

Sea Grant North Carolina
CMAST

Summary


sanctuary
larvae
settlement
reefs
fish
demographic
sound
high
site-selection
substrate
connectivity
sites
habitat
network
crabs
densities
metapopulation
reproduction
estuarine
stone
species
dispersal
restoration
growth
Reproduction
study
reef
potential
bottom
variation
compared
salinity
using
model
within
relatively
rates
dynamics
habitats
mean
enhancement
response
site
two
m2
broodstock
sponge
marine
mounds
recruitment
due
increased
density
effort
capita
highest
among
frequency
magnitude
per
presence
new
fishing
spatial
mortality
North
Carolina
general
patterns
levels
sounds
different
differences
hydrodynamic
quantify
project
crab
number
assess
construction
marl
reproductive
varied
characteristics
surveys
Marine
experiments
traps
population
shells
range
field
recreational
June
may
diversity
control
goal
higher
used
boring
Crassostrea
cultch
total
NC
sampling
management
use
captured
soft
system
areas
conducted
data
suitable
identify
unstructured
shell
likely
whereas
no-take
sources
evidence
Cliona
locations
significantly
quantified
off-reef
size
results
experimental
natural
geochemical
relative
output
effects
also
abundance
physical
found
virginica
survival
time
design
materials
support
laboratory
overall
type
sponges

Acknowledgements

Collaborators

- UNC-IMS
  - Rick Luettich, Niels Lindquist, Joel Fodrie, Rodney Guajardo
- NC DMF
  - Craig Hardy, Pelle Holmlund, Stopher Slade, Michael Jordan
- NC Coastal Federation
  - Erin Fleckenstein, Lexia Weaver, Christine Miller
- NCSU
  - Del Bohnenstiehl, Dan Kamykowski, Cynthia Cudaback
- NOAA
  - Kyle Shertzer
- TNC
  - Aaron McCall, Brian Bouton
- NC Sea Grant
  - Brian Efland
- Gene Ballance
- US Coast Guard Auxiliary

Funding

Sea Grant North Carolina

NSF

NOAA Sea Grant NOAA National Sea Grant College Program

RECOVERY.GOV

AAUS American Academy of Underwater Sciences

North Carolina Coastal Federation

PADI Foundation

Raleigh Salt Water Sportfishing Club

NSERC CRSNG

National Shellfisheries Association