- Bill Pine
- billpine@ufl.edu

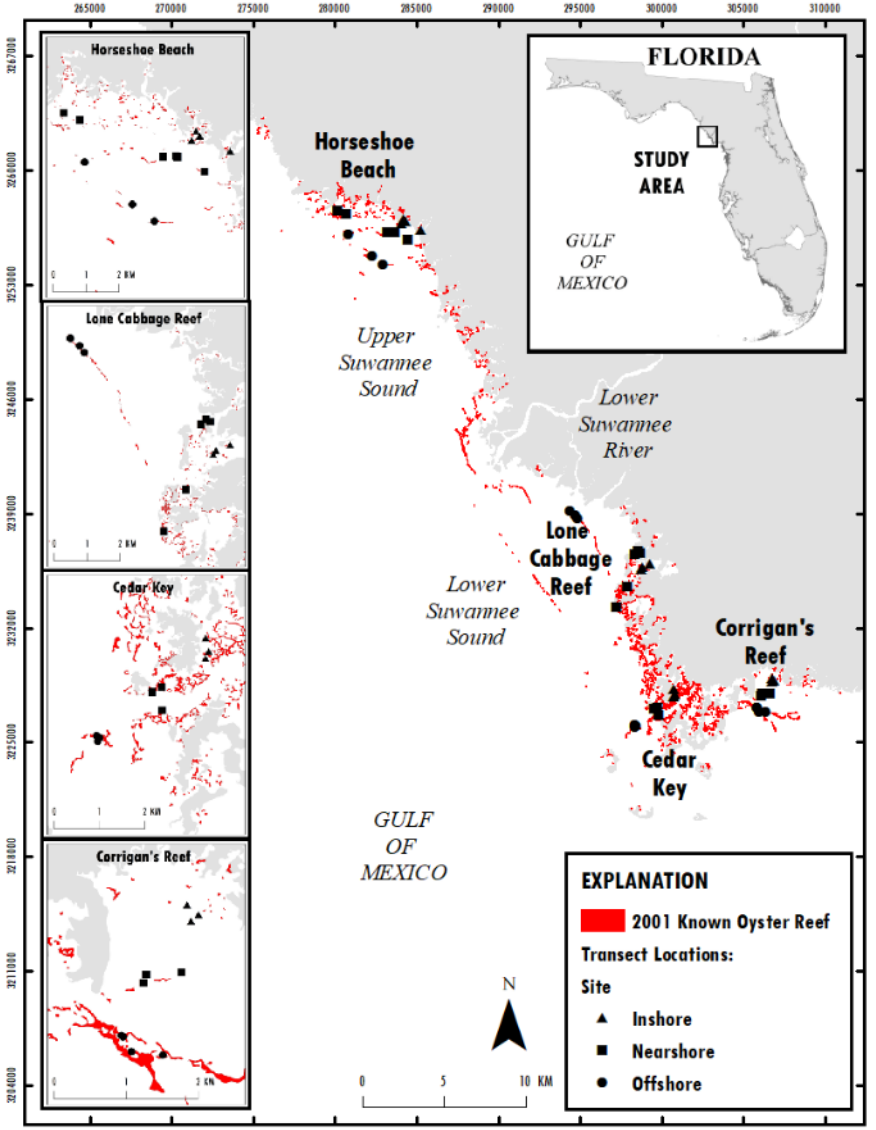

- Massive team effort

- Objective: 2009 Peter Frederick and I were interested in helping <u>people</u> by trying to understand observed declines in Suwannee Sound, FL oyster populations

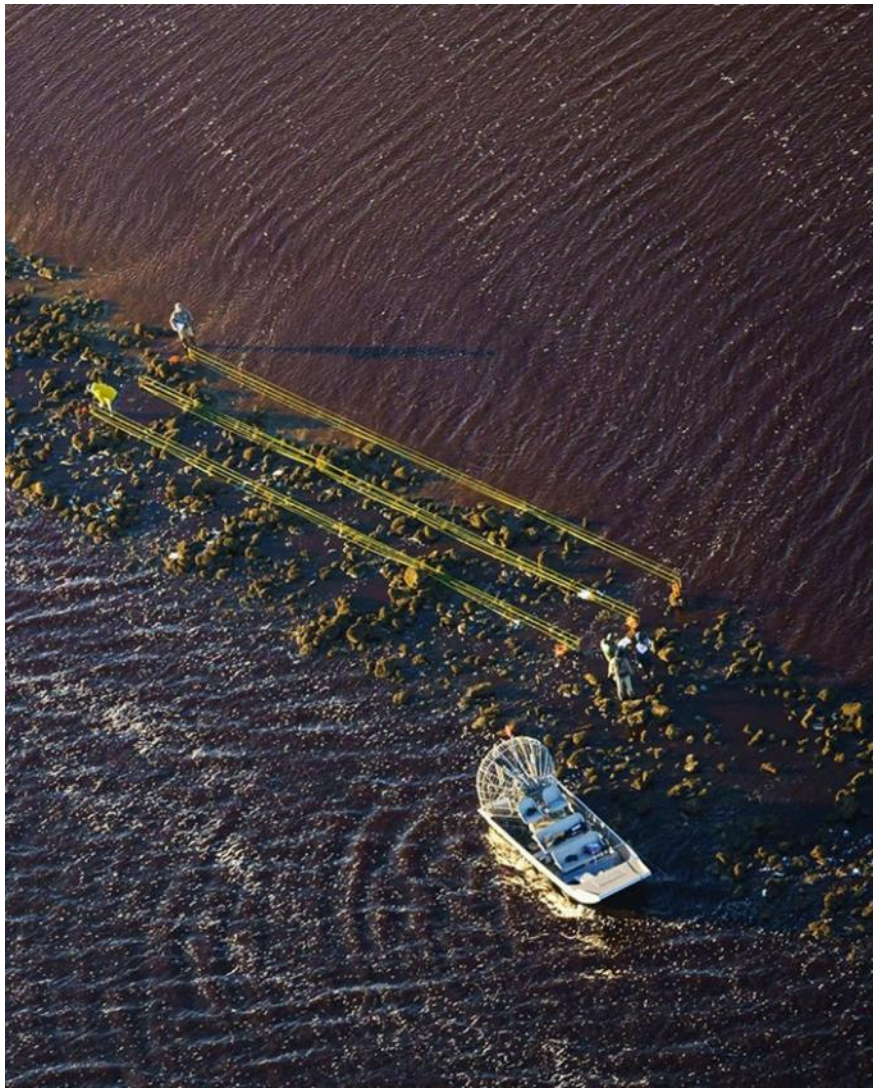
# Initial assessments…

Large spatial scale

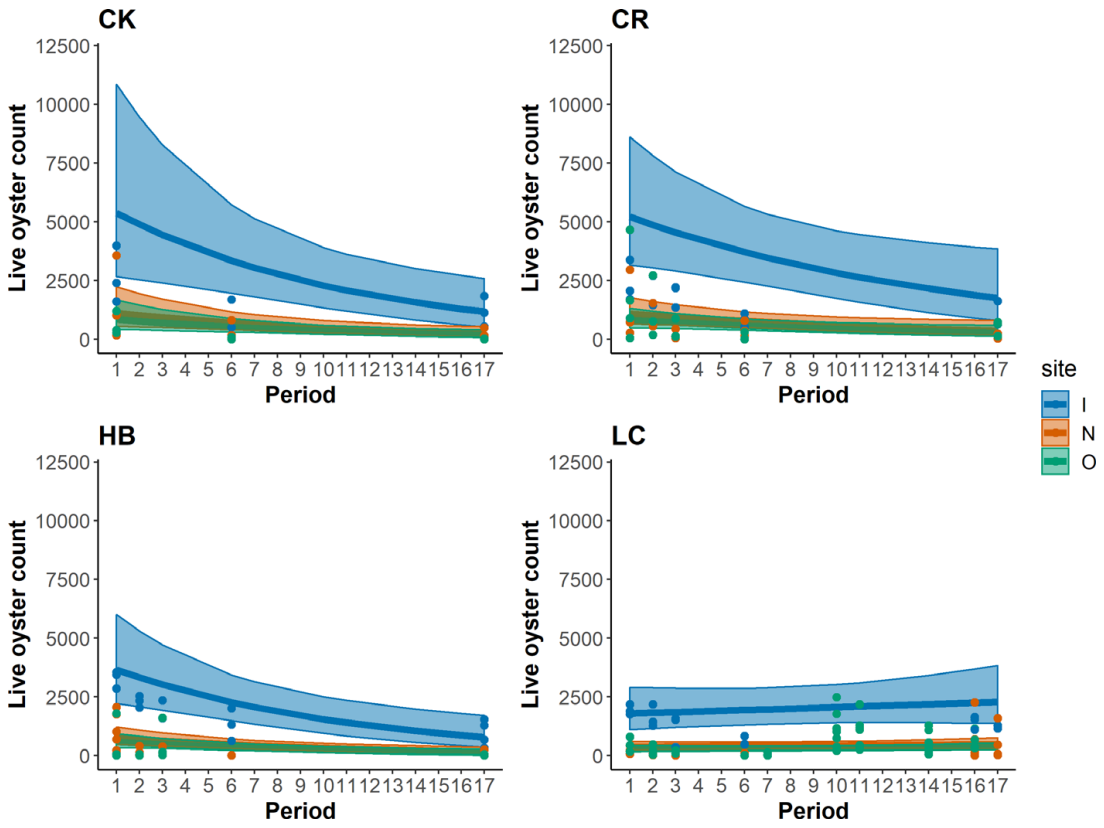
Small spatial scale



# Multiple spatial scales…

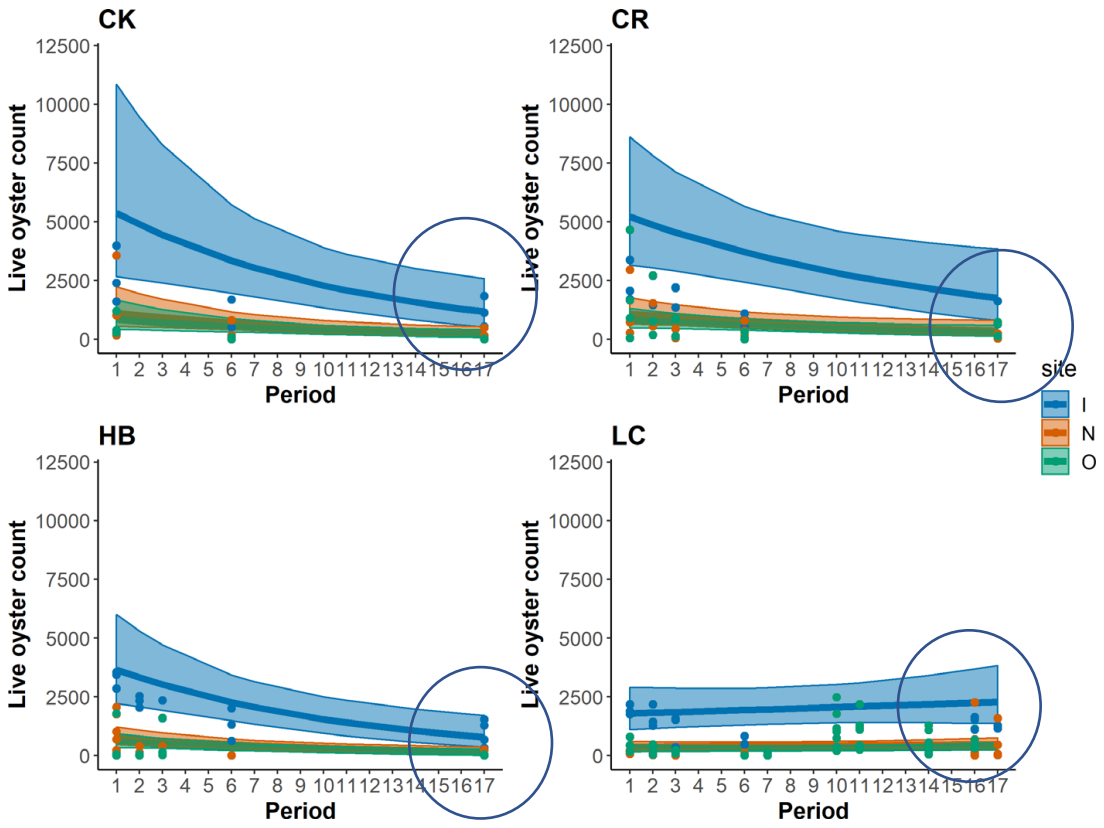


# What are we learning?




- Intertidal oyster resources are declining rapidly across the Big Bend
- 237% decline in counts of intertidal oysters since 2010
- Intertidal reefs are becoming more similar…

# What are we learning?




- Intertidal oyster resources are declining rapidly across the Big Bend
- 237% decline in counts of intertidal oysters since 2010
- Intertidal reefs are becoming more similar…
  - <u>But more similar AT LOWER NUMBERS OF OYSTERS</u>

# How can restoration be used to test hypotheses?

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- Reef decline a one-way trip
- Once reefs collapsed and shell material lost re-colonization not possible

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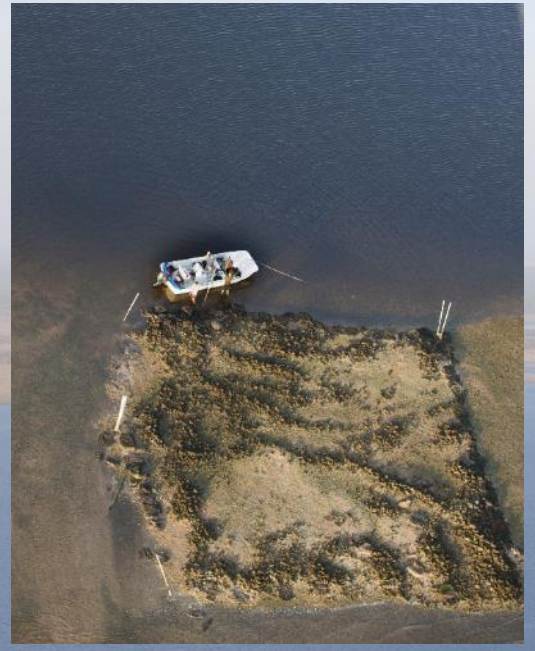
# How can restoration be used to test hypotheses?

- Reef decline a one-way trip
- Once reefs collapsed and shell material lost re-colonization not possible

- $H_o$ = Addition of durable substrate will allow oyster reef re-colonization and persistence
- Developed an experiment and monitoring program to test hypothesis –> *part of an adaptive management program*



## 2013 Pilot Restoration Project

Control

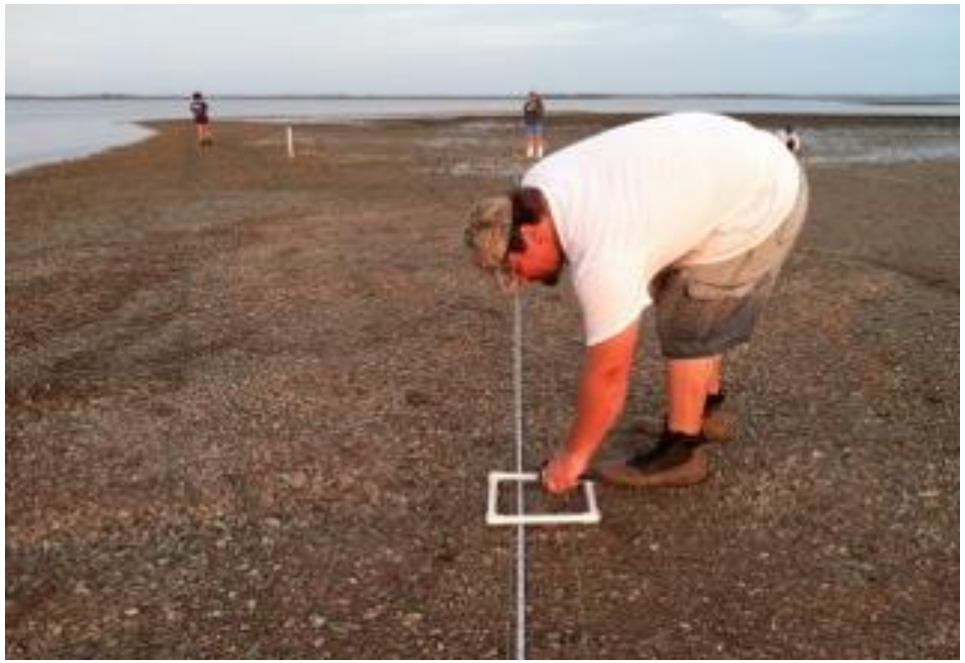
Restore

Control

Restore

*Journal of Shellfish Research*, Vol. 35, No. 2, 359–367, 2016.

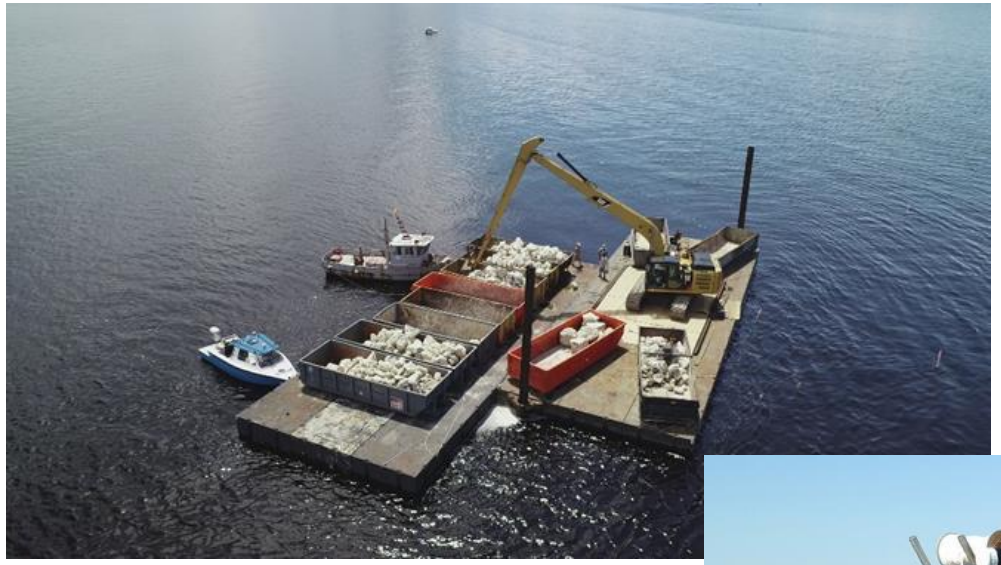
# REVERSING A RAPID DECLINE IN OYSTER REEFS: EFFECTS OF DURABLE SUBSTRATE ON OYSTER POPULATIONS, ELEVATIONS, AND AQUATIC BIRD COMMUNITY COMPOSITION

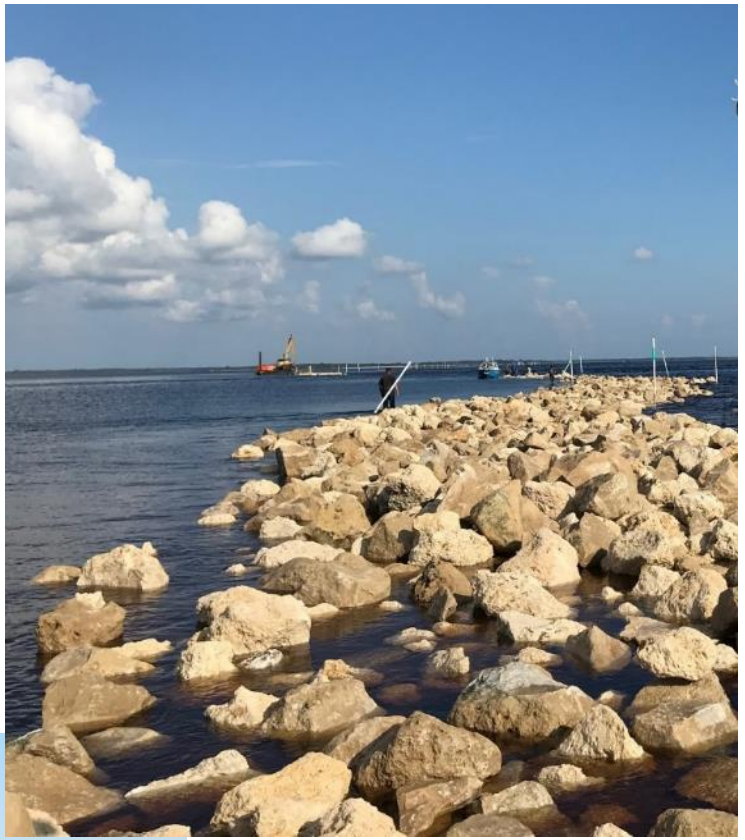


18 months

9x increase in oyster density on restored sites compared to control

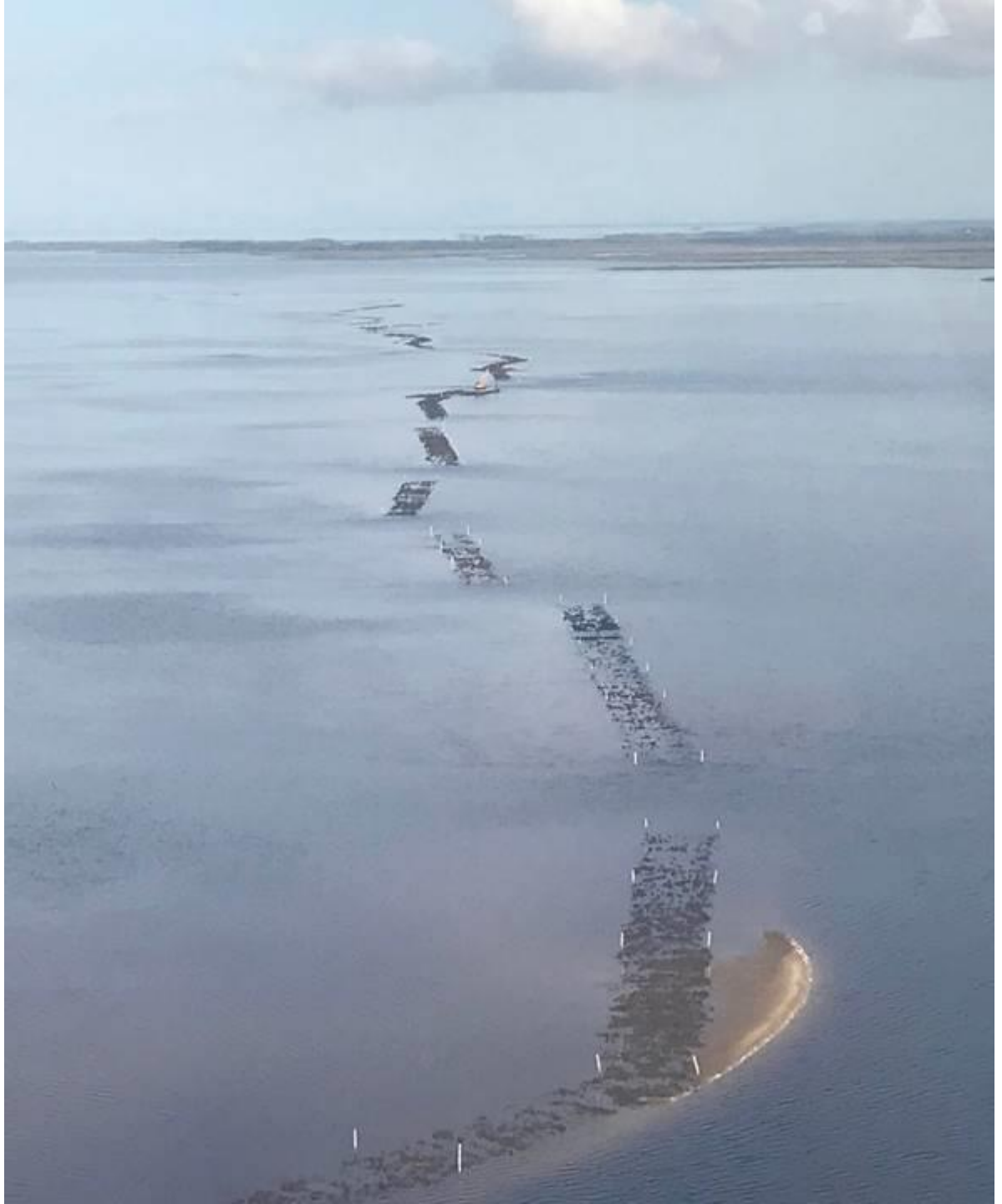
# 2018 Restore Lone Cabbage





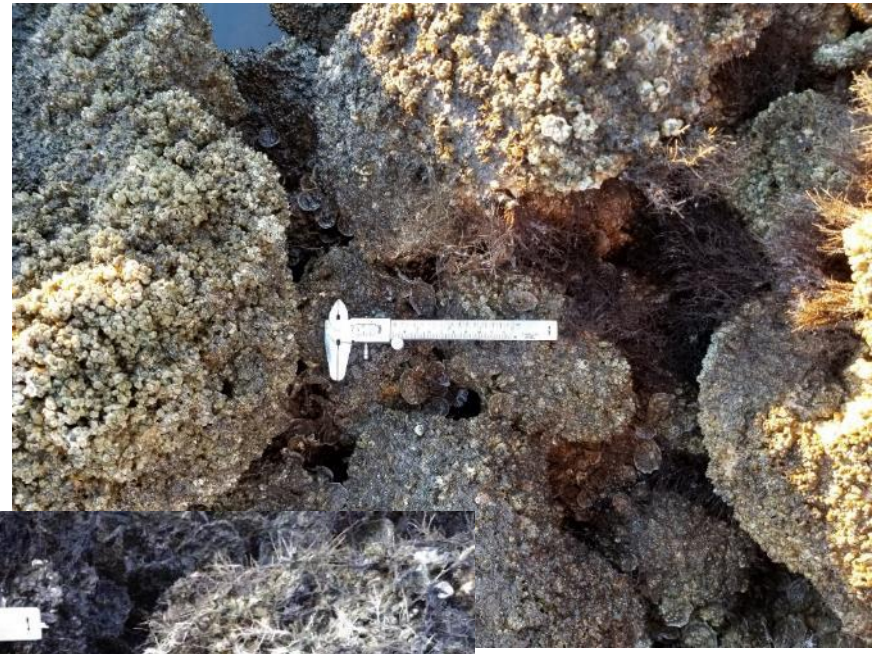
- NFWF-GEBF funded restoration of Lone Cabbage Reef
- Local sourced limestone placed on degraded chain of reefs
- 5-km in length x 10-m wide

- High-resolution, statistically robust monitoring program
  - ~3000-m of line transect
    - During winter
  - Allocated to restored/control & open/closed to fishing strata
  - Effort dynamically updated within season based on observed results



July 2018

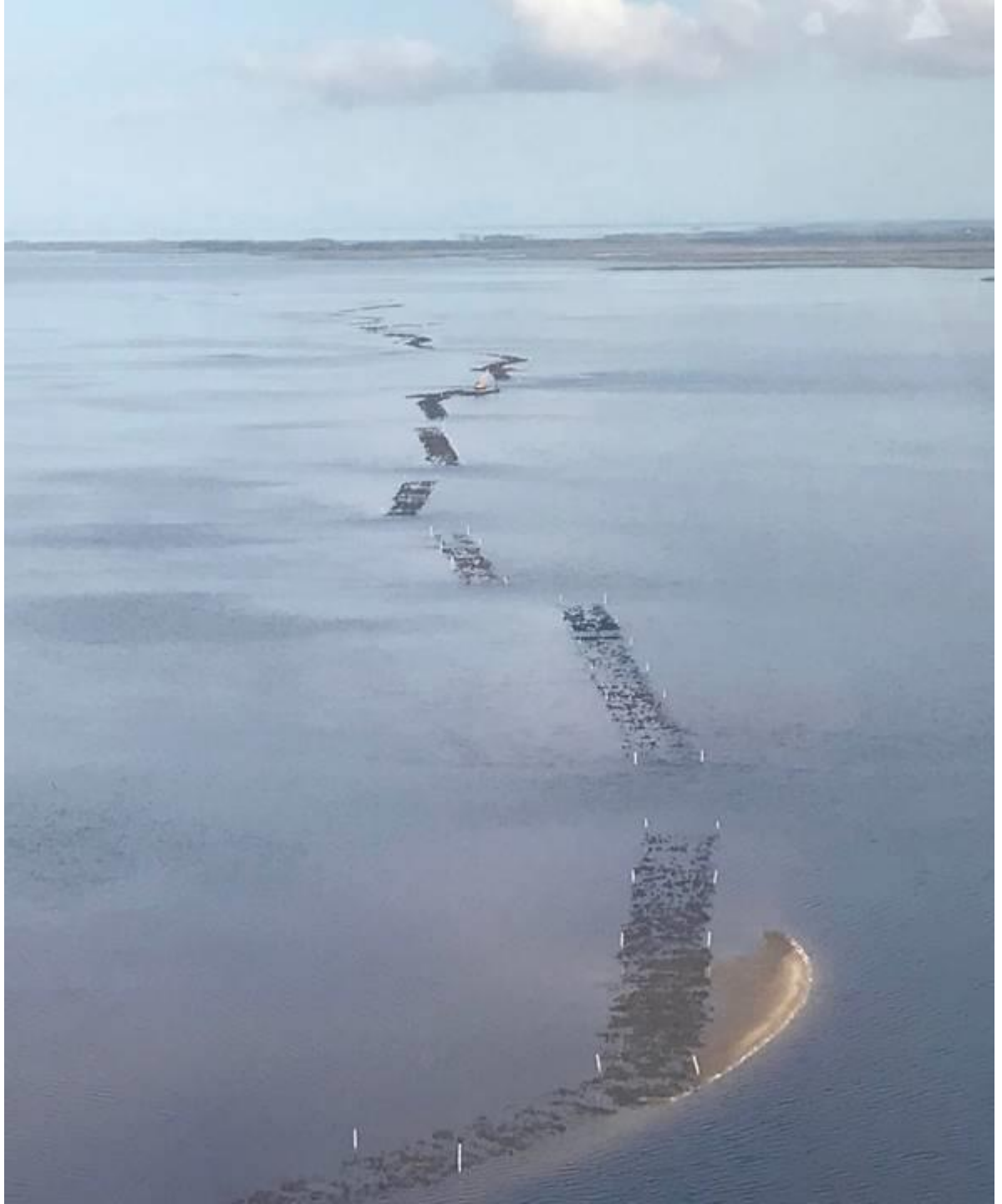
December 2018



July 2019

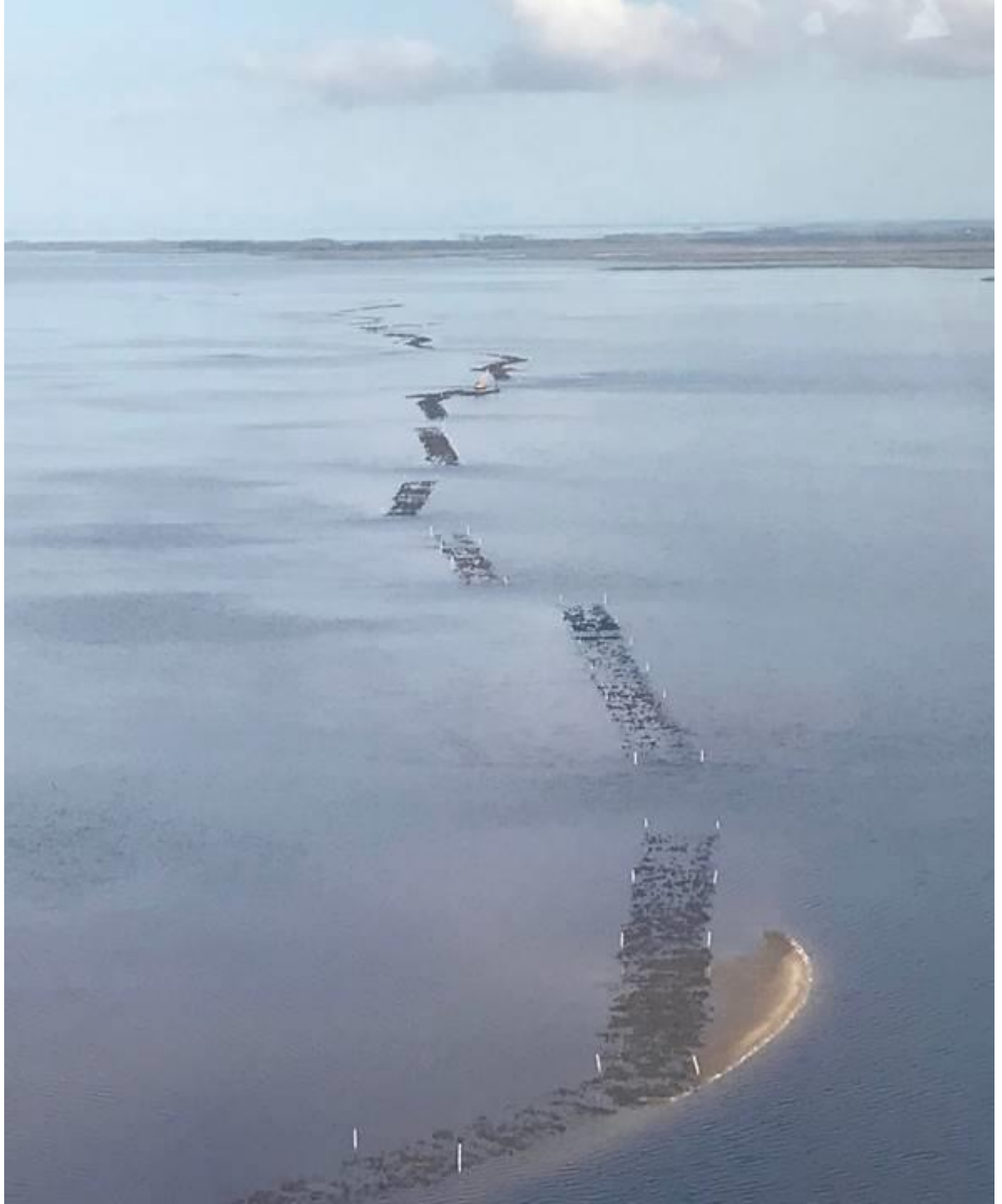
# Can restoration help?

- Local effect of oysters growing on rocks?  YES!
- But do these oysters persist?



# Can restoration help?

- Local effect of oysters growing on rocks?  YES!
- But do these oysters persist?
- Just finished fourth winter of monitoring



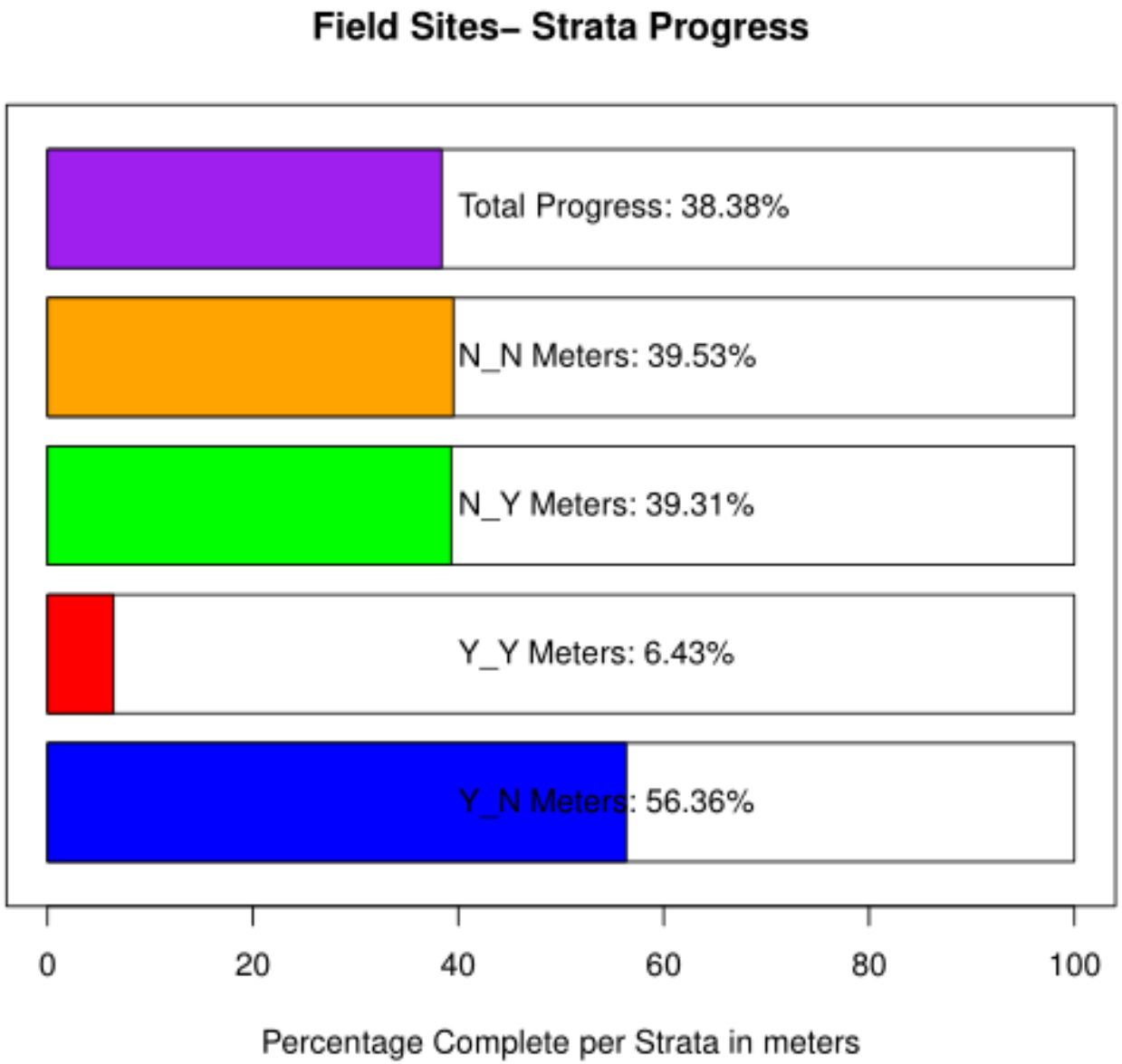
# Double data entry with built in error checking routine
# Data are entered and summarized within 3 days of field sampling…

# … to Github as repository for all data and standard code

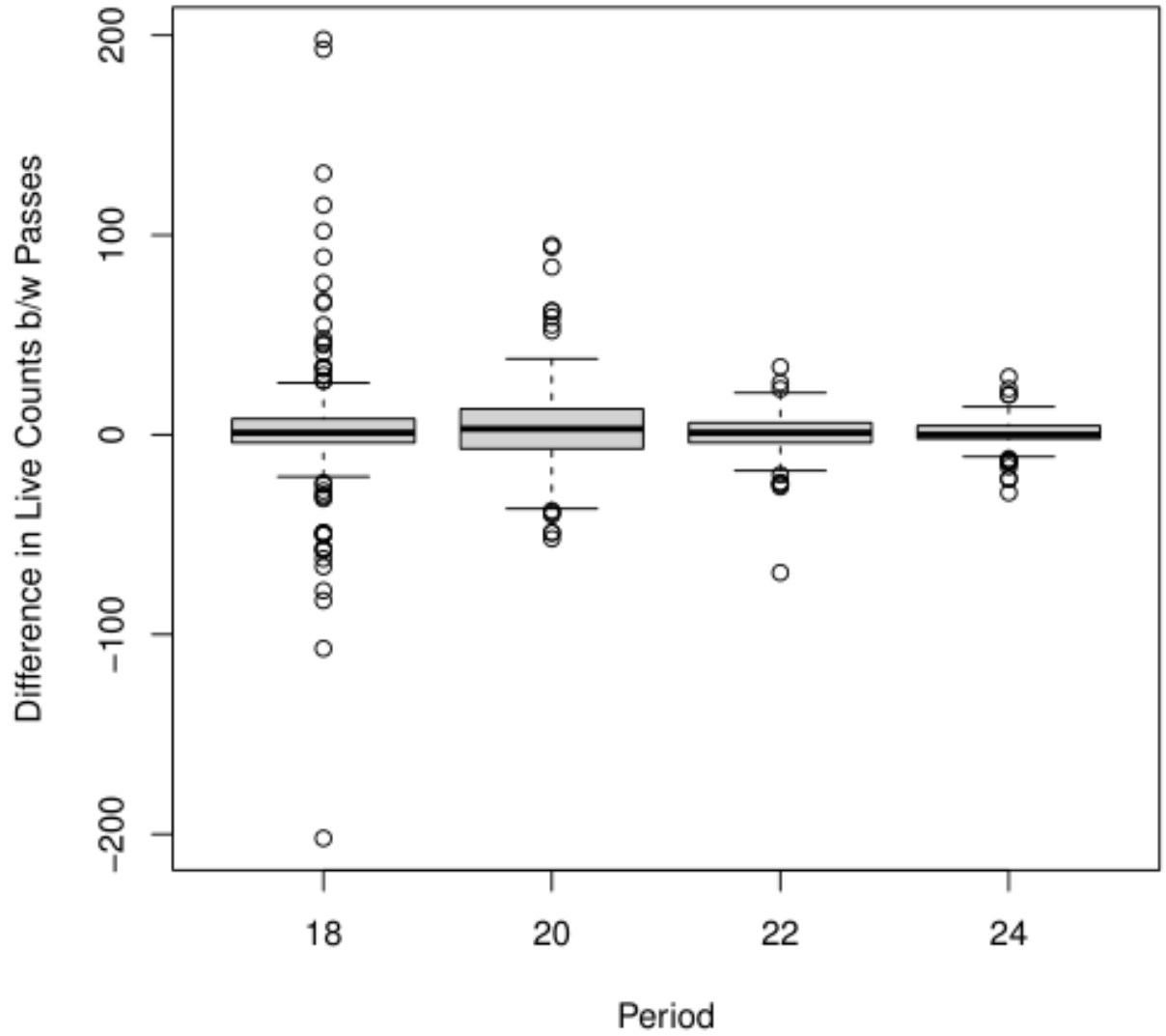
# … to weekly reports in RMarkdown

# What can we learn from the weekly reports?

# Progress


Field Sites– Strata Progress
Total Progress: 38.38%
N_N Meters: 39.53%
N_Y Meters: 39.31%
Y_Y Meters: 6.43%
Y_N Meters: 56.36%
0
20
40
60
80
100
Percentage Complete per Strata in meters

# Problems


Difference in Live Counts b/w Passes
200
100
0
−100
−200
18
20
22
24
Period

# Planning

## Sampling Protocols – Power Analyses

Before season starts, run power analyses based on previous years of data (period 18-22) and just last year (period 22)

Mid-season re-run power analyses using new data from period 24

R script – takes about 1 day to run

# Decision making

## How does period 24 compare to previous?

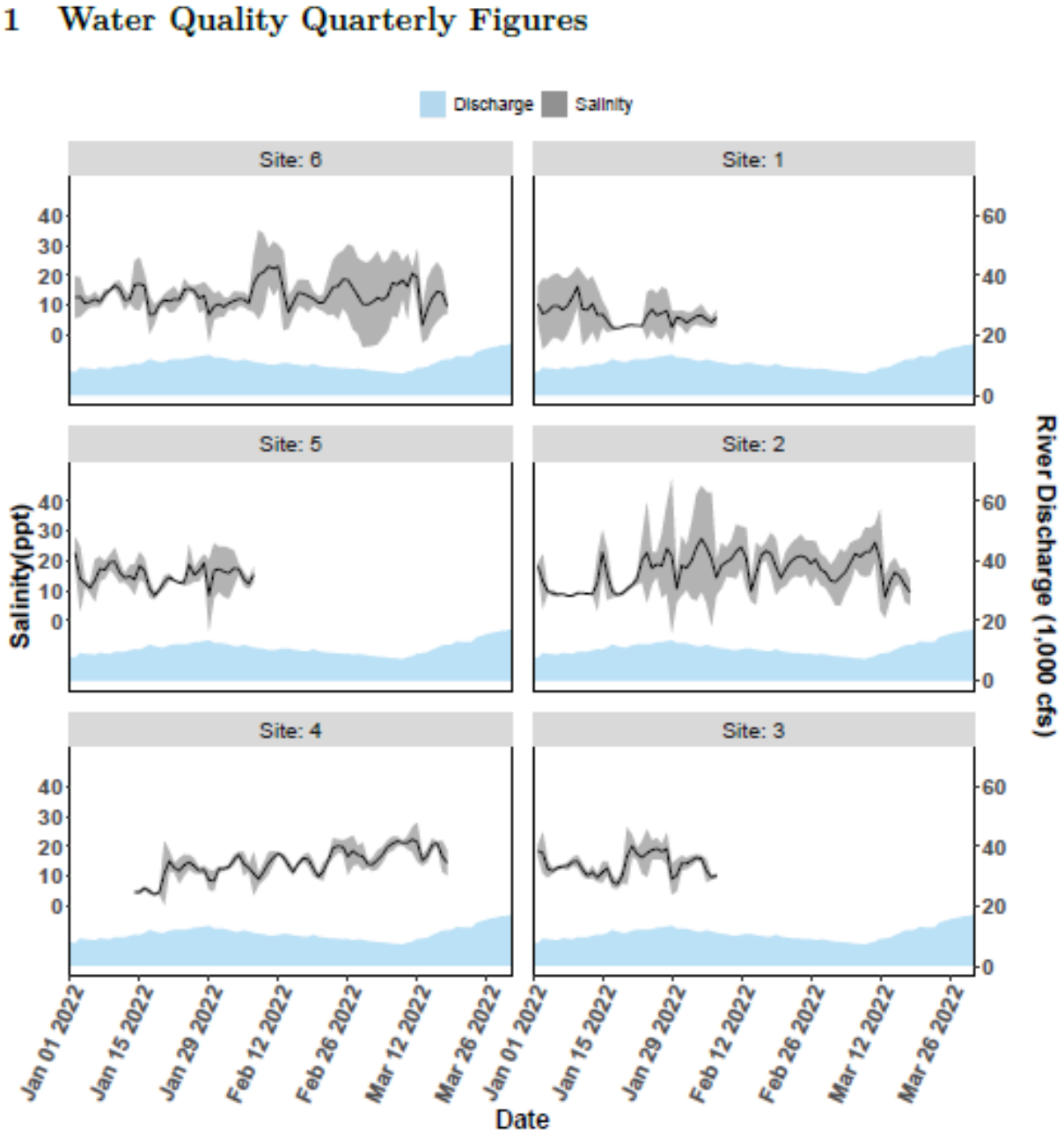
Live Oyster Counts by Period

| Period | Mean | Median | SD | Var | CV | SE | L95 | U95 | Bstrap_Mean | L95_Bstrap | U95_Bstrap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 982 | 695 | 935 | 874733 | 0.95 | 120 | 748 | 1217 | 982 | 751 | 1202 |
| 20 | 1844 | 1253 | 2125 | 4517189 | 1.15 | 310 | 1236 | 2451 | 1848 | 1321 | 2500 |
| 22 | 1334 | 702 | 1693 | 2867783 | 1.27 | 242 | 860 | 1808 | 1340 | 907 | 1870 |
| 24 | 1463 | 1102 | 1301 | 1693414 | 0.89 | 277 | 919 | 2007 | 1453 | 976 | 2050 |

Live Density by Period

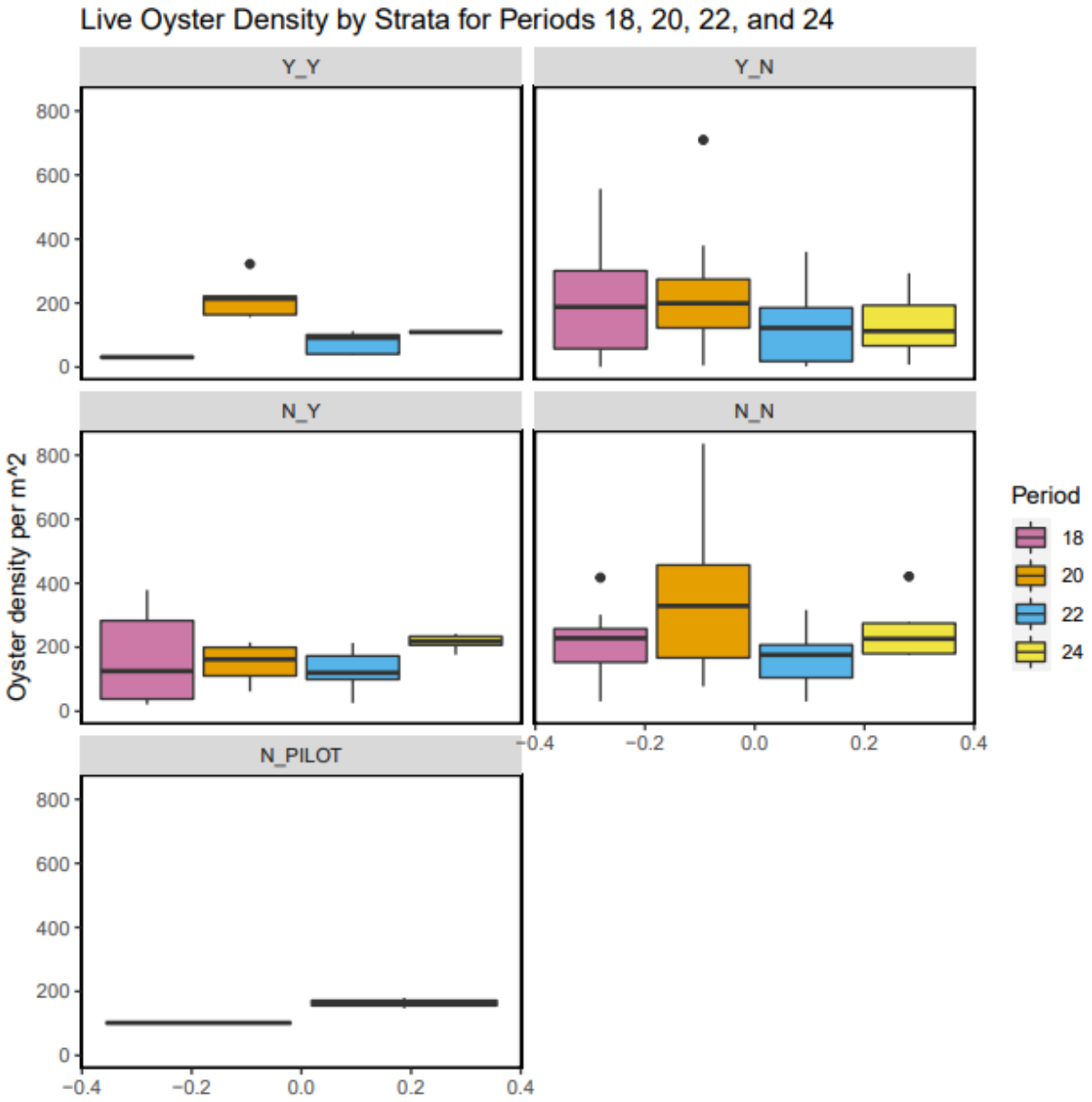
| Period | Mean | Median | SD | Var | CV | SE | L95 | U95 | Bstrap_Mean | L95_Bstrap | U95_Bstrap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 176 | 155 | 130 | 16945 | 0.74 | 17 | 144 | 209 | 177 | 145 | 209 |
| 20 | 256 | 203 | 187 | 35057 | 0.73 | 27 | 203 | 310 | 257 | 209 | 308 |
| 22 | 137 | 121 | 93 | 8638 | 0.68 | 13 | 111 | 163 | 137 | 112 | 162 |
| 24 | 187 | 178 | 94 | 8801 | 0.50 | 20 | 148 | 226 | 186 | 149 | 225 |

# Similar process with water quality



# Can restoration help?

- Oysters persist on restored reefs (so far)
- Similar median density of oysters on rock reefs compared to wild reefs



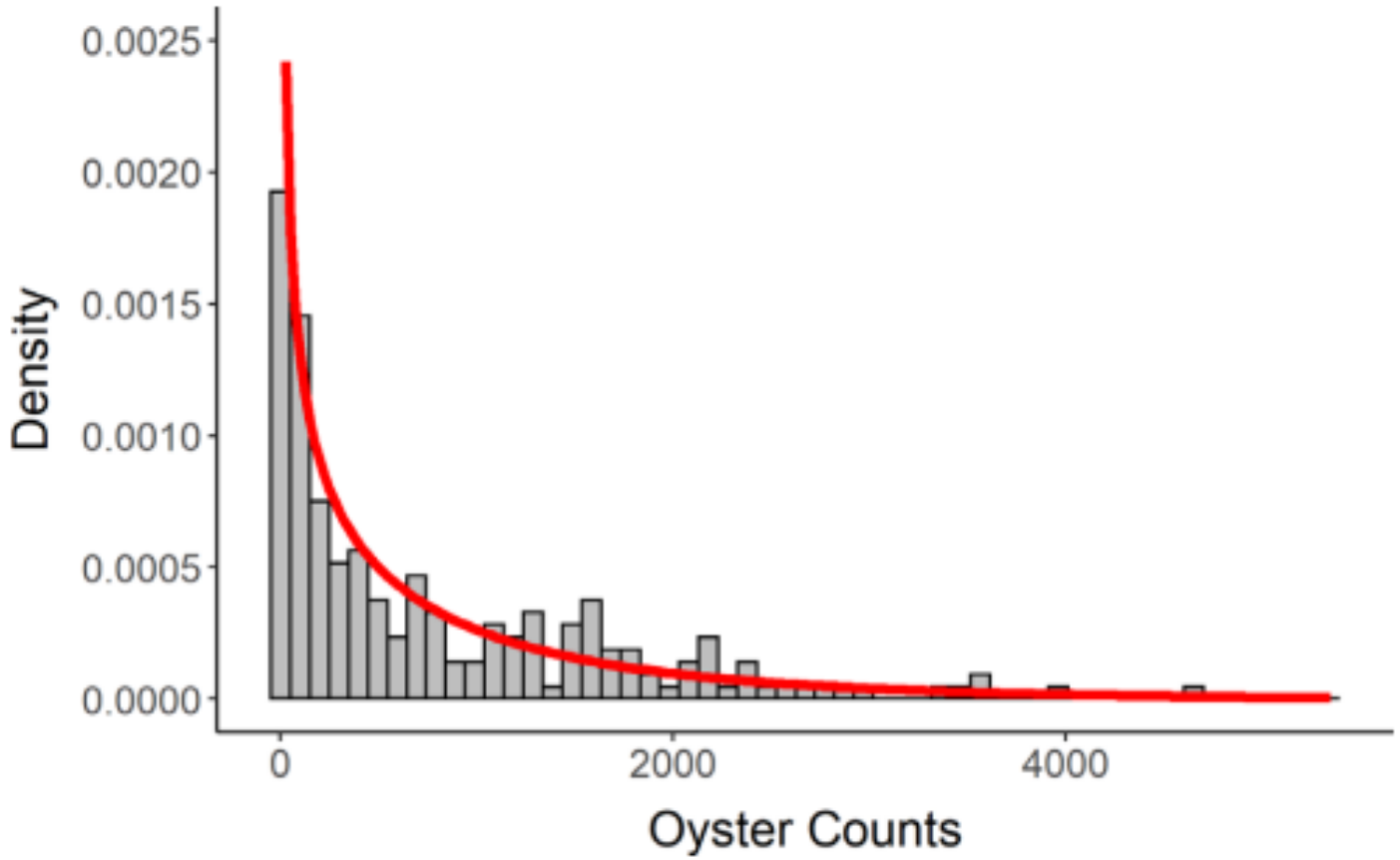
**Two lines of inference on oyster population trends and response to restoration**

**(1) Repeated measures fixed locations**
**(2) Random sampling restored and unrestored**

**Very high overdispersion**

**GLM count_live ~ period + offset(log(tran_length))**

**Can incorporate covariates salinity, open/closed harvest, elevation, etc.**



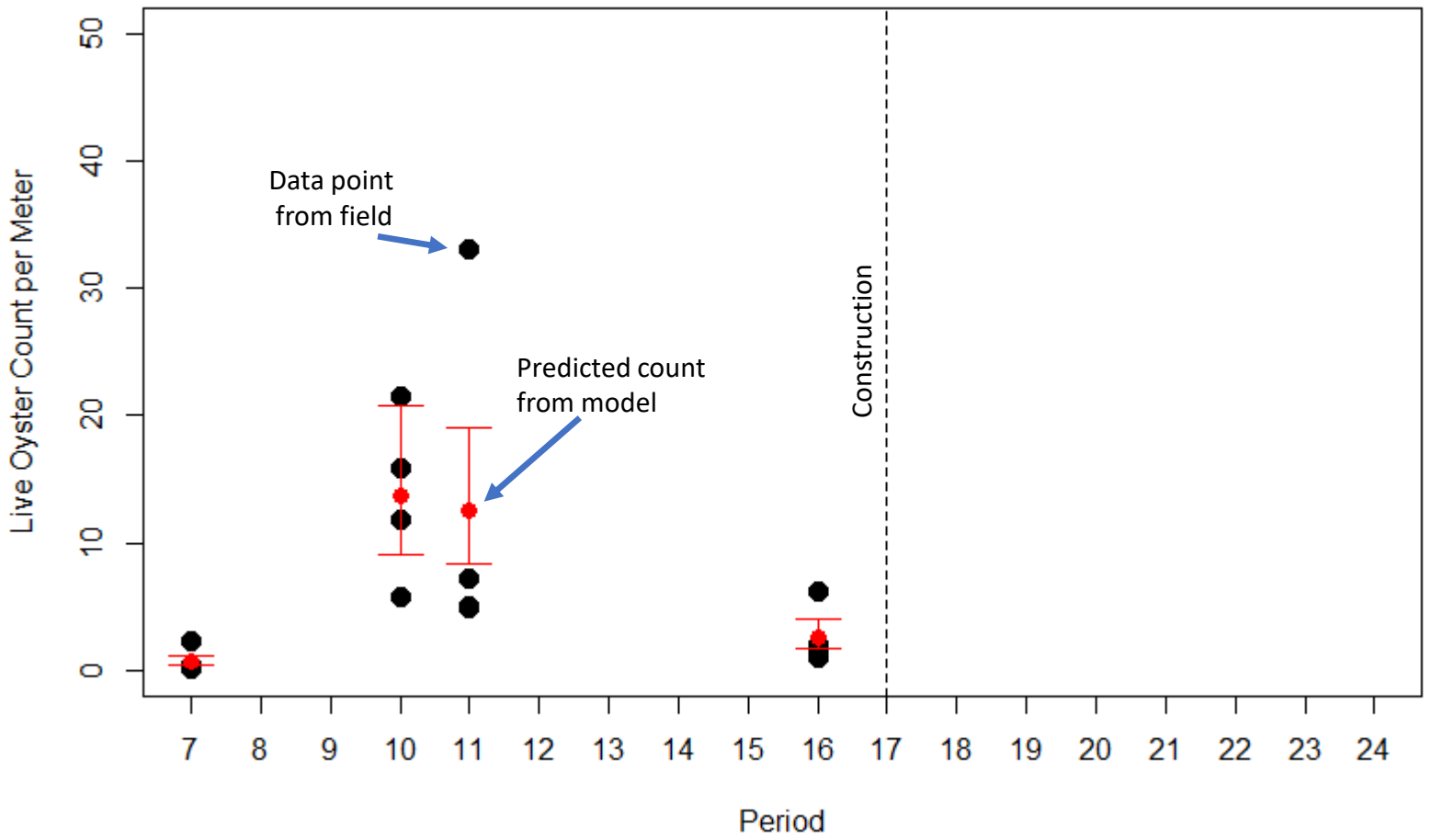
**(1) Repeated measures fixed locations**

***Strong positive response to restoration, then → *k*?**

**(2) Unrestored and restored sites**

***Positive response on restored**
***Unrestored continue to decline**
***Unrestored and restored similar counts**

Example inference from fixed-location repeated measures sites



**(1) Repeated measures fixed locations**

***Strong positive response to restoration, then → *k*?**

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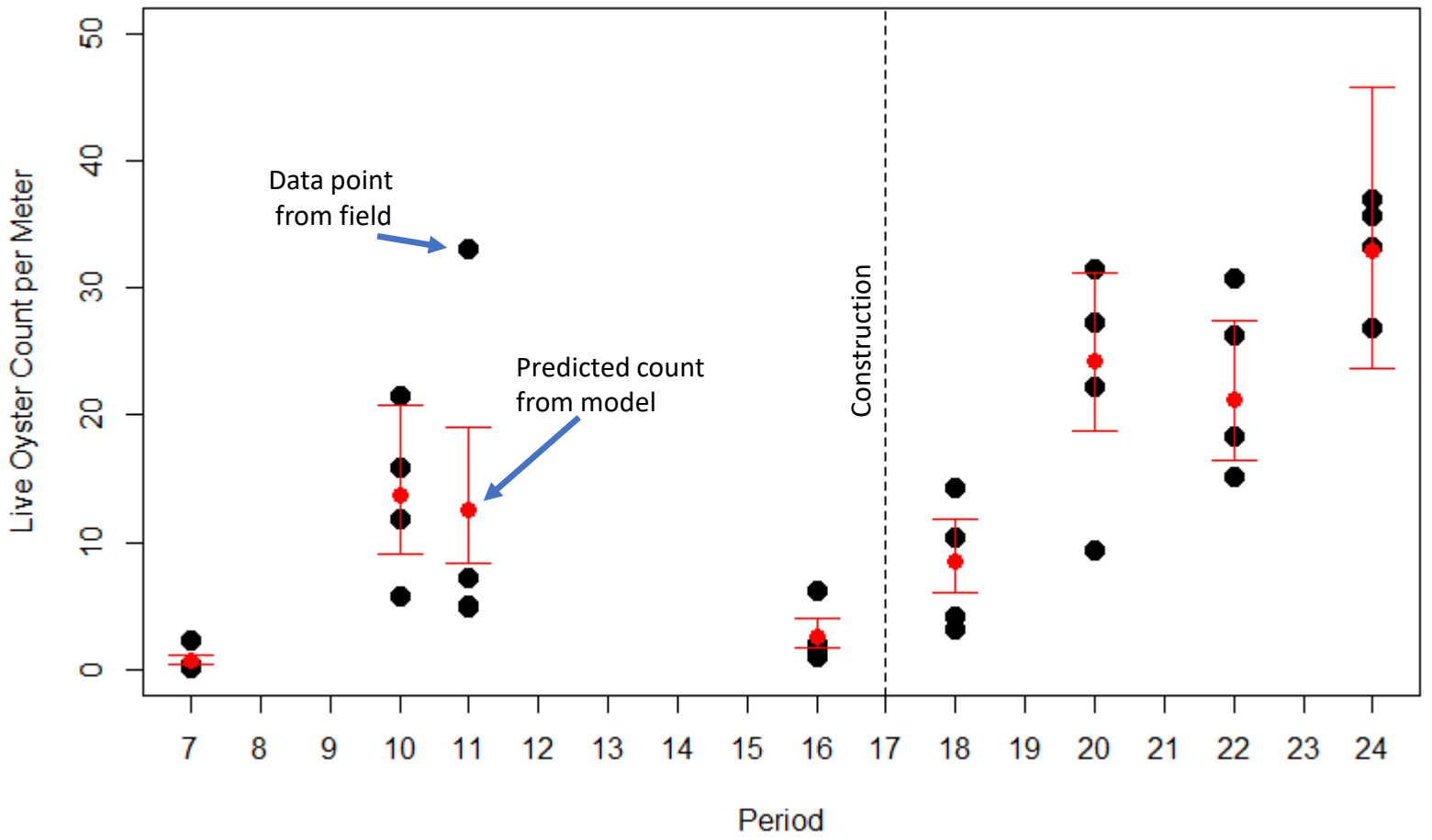
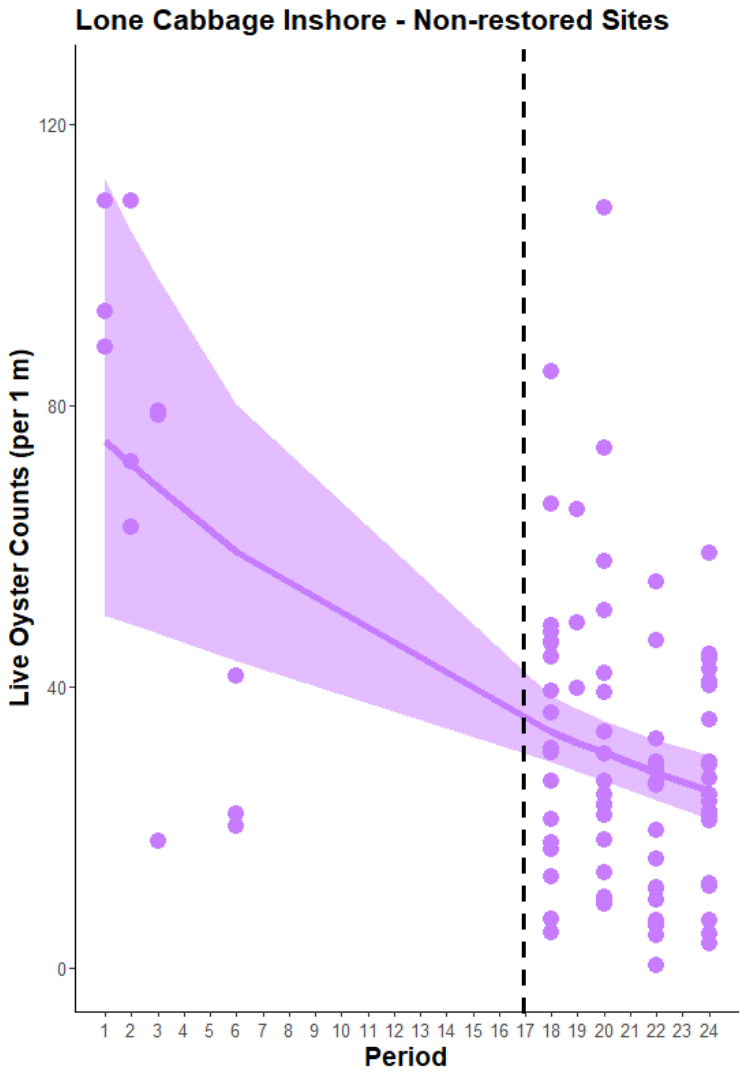
Example inference from fixed-location repeated measures sites

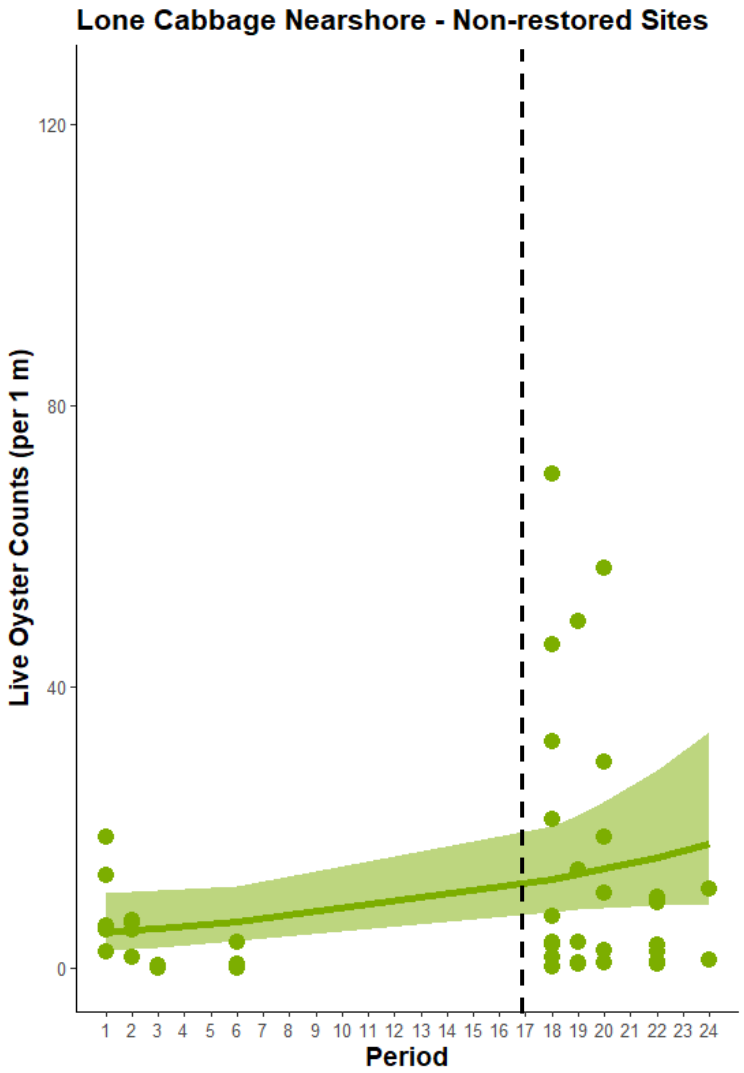


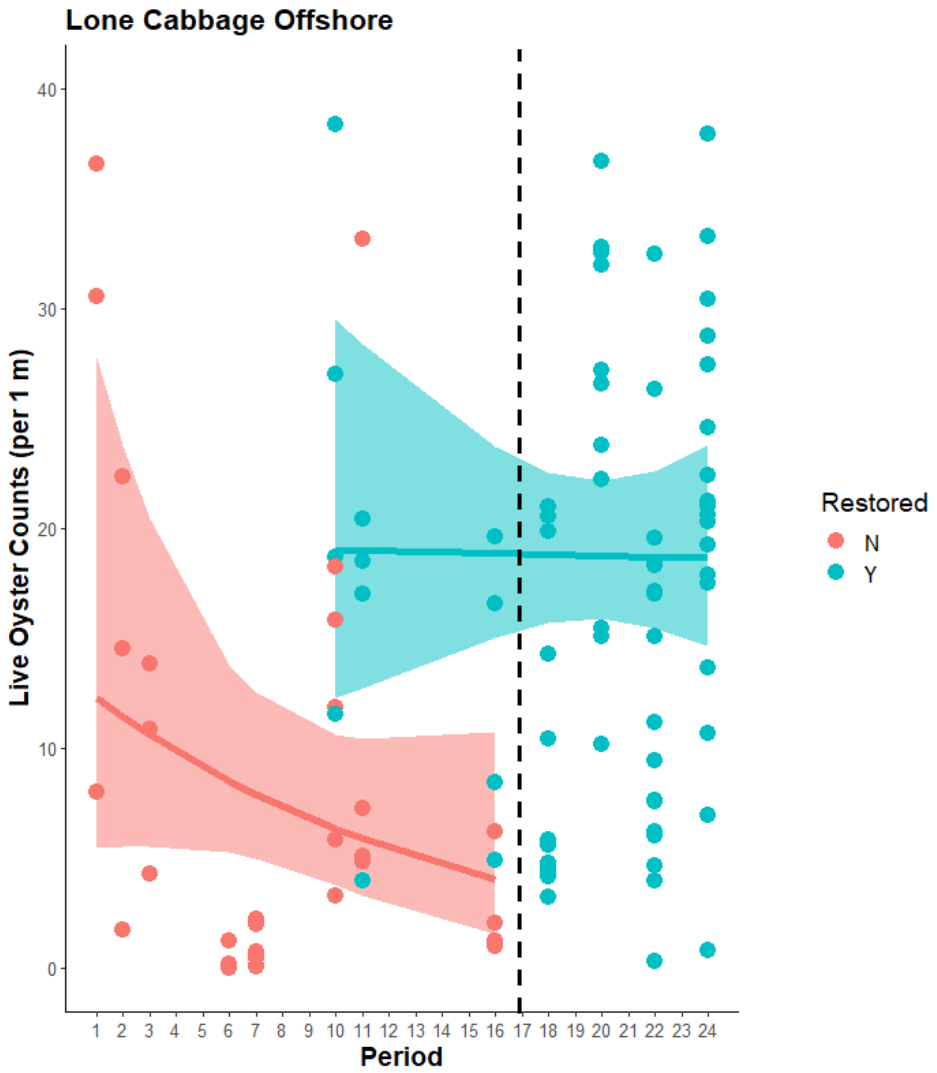
# Can restoration help?

- **Benefits beyond the ribbon of rock?**

# Key result from winter 2021/2022



# Not likely to be spurious – supported by resampling

PeerJ Life & Environment

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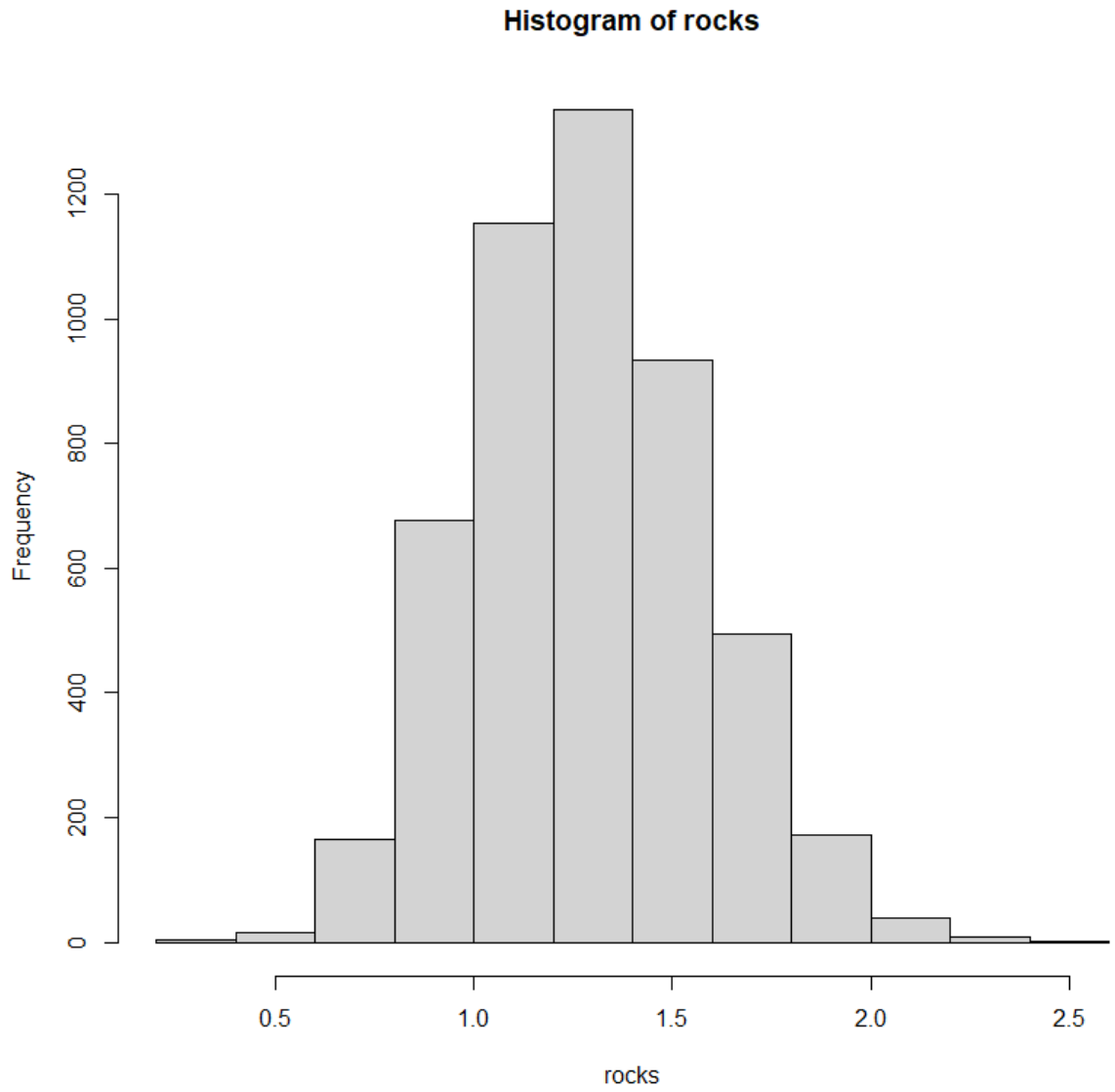
‹ BIODIVERSITY AND CONSERVATION

Bootstrap methods can help evaluate monitoring program performance to inform restoration as part of an adaptive management program

- **Repeat restoration 5000 times**



# Not likely to be spurious – supported by resampling

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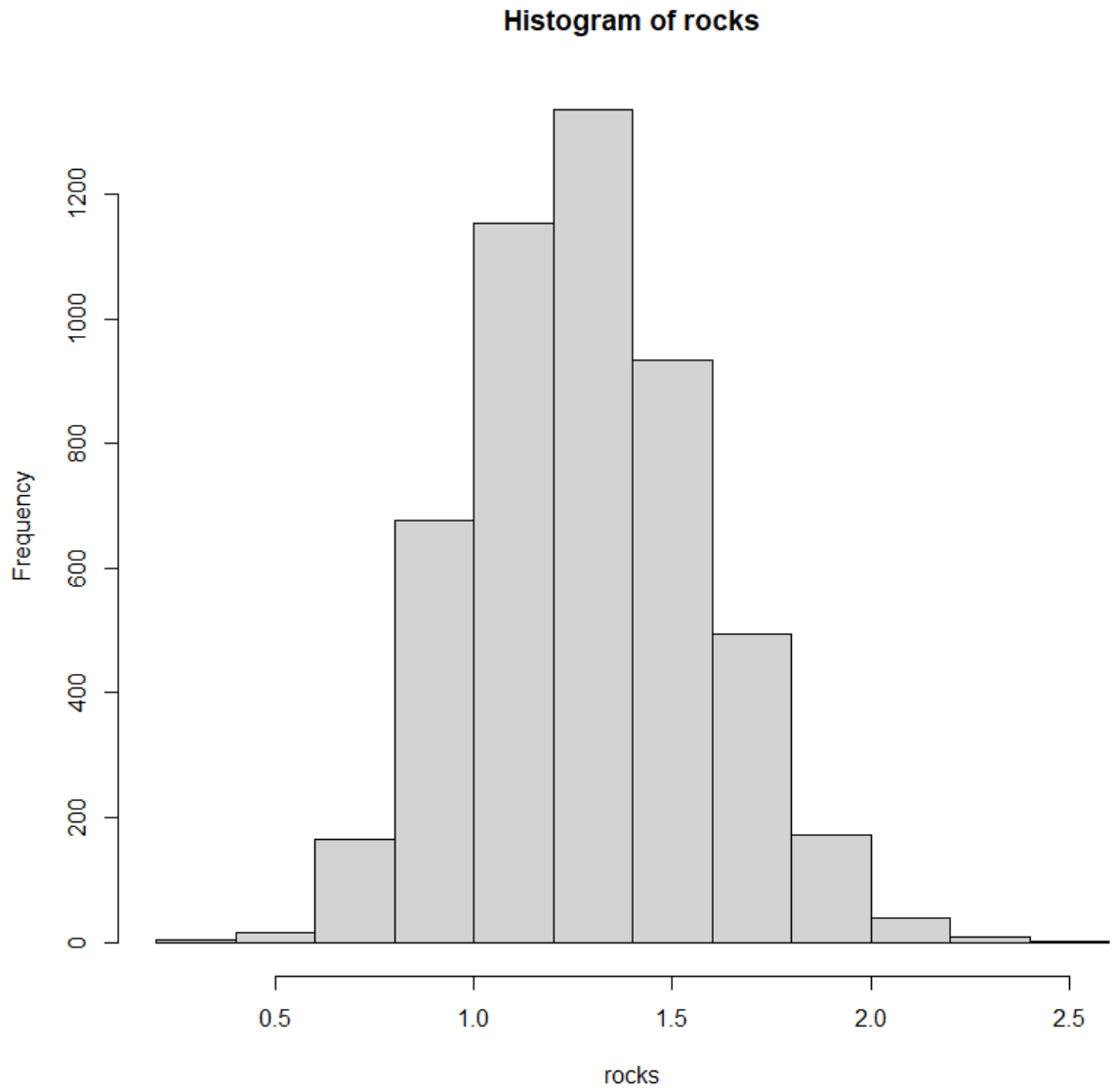
‹ BIODIVERSITY AND CONSERVATION

Bootstrap methods can help evaluate monitoring program performance to inform restoration as part of an adaptive management program

- **Repeat restoration 5000 times**
- **Same result → positive response for restoration 100% of the time**
- **Type of power analyses**

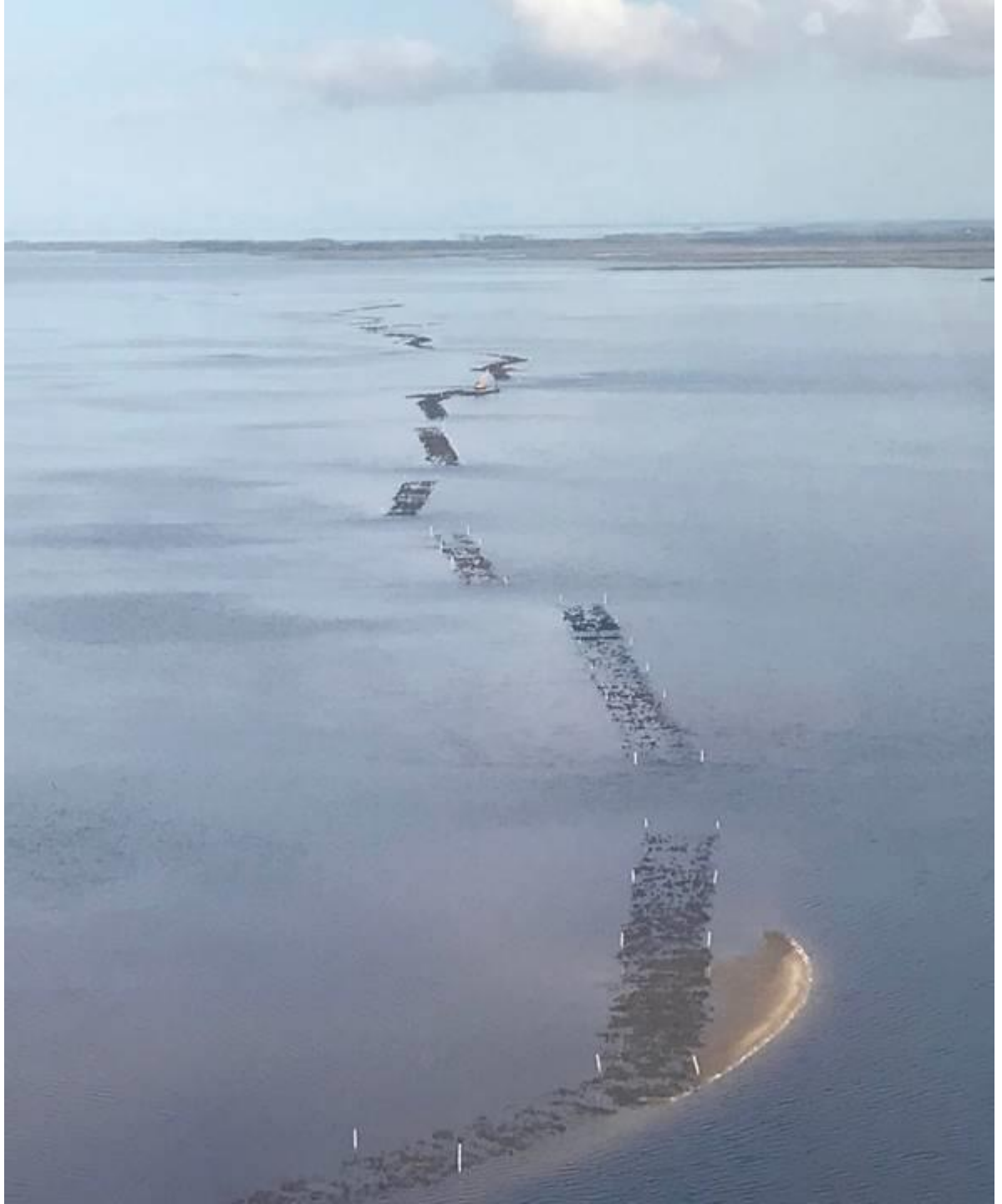


# Can restoration help?

- **Overall continued declines in unrestored oyster reefs**
- **Very wide range in counts of oysters across unrestored reefs**
- **Restored reefs similar counts and size structure of unrestored**
  - **<2% of 23,000+ oysters measured intertidal bars since 2010 legal size**

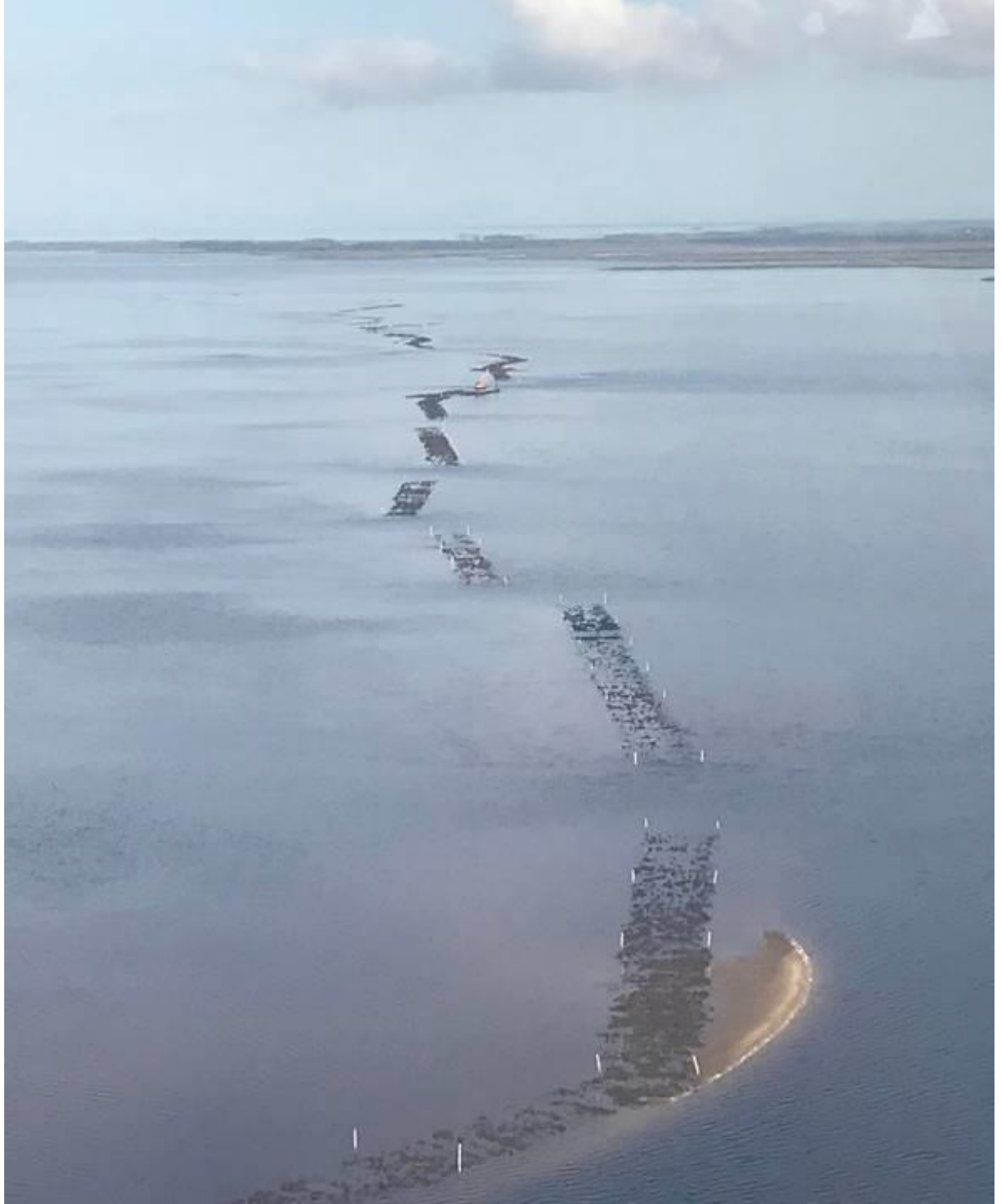
# Going forward

- **Treat restoration projects as experiments not solutions**



# Going forward

- **Treat restoration projects as experiments not solutions**
- **Focus research efforts on promoting resilience in existing wild reefs**
  - **Why are wild reefs declining?**



# Is Lone Cabbage a “success”?

# Is Lone Cabbage a "success"?

- **We have demonstrated an AM process that has resulted in significant learning about restoring oyster resources in Suwannee Sound**
- **We feel strongly that the project offers a framework to advance learning beyond the project scale**

# Is Lone Cabbage a "success"?

- **Lone Cabbage project monitoring phase  < 2 years remaining**
- **Learn faster & improve outcomes by not always starting at zero**
  - **Existing modern data workflow and analyses framework**
  - **Rigorous oyster and water quality monitoring framework**
  - **More time learning, less time launching**

ARTICLE

# Trends in Oyster Populations in the Northeastern Gulf of Mexico: An Assessment of River Discharge and Fishing Effects over Time and Space

PeerJ Life & Environment

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‹ BIODIVERSITY AND CONSERVATION

# Bootstrap methods can help evaluate monitoring program performance to inform restoration as part of an adaptive management program

Canadian Science Publishing | **Canadian Journal of Fisheries and Aquatic Sciences**

# A Cautionary Tale: Management Implications of Critical Transitions in Oyster Fisheries

zenodo

rmarkdown

*Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 14:e10192, 2022
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ISSN: 1942-5120 online
DOI: 10.1002/mcf2.10192

FEATURED PAPER

# Adaptive Management in Practice and the Problem of Application at Multiple Scales—Insights from Oyster Reef Restoration on Florida's Gulf Coast

**W. E. Pine III,* F. A. Johnson, and P. C. Frederick**
*Department of Wildlife Ecology and Conservation, University of Florida, 110 Newins-Ziegler Hall, Gainesville, Florida 32611, USA*

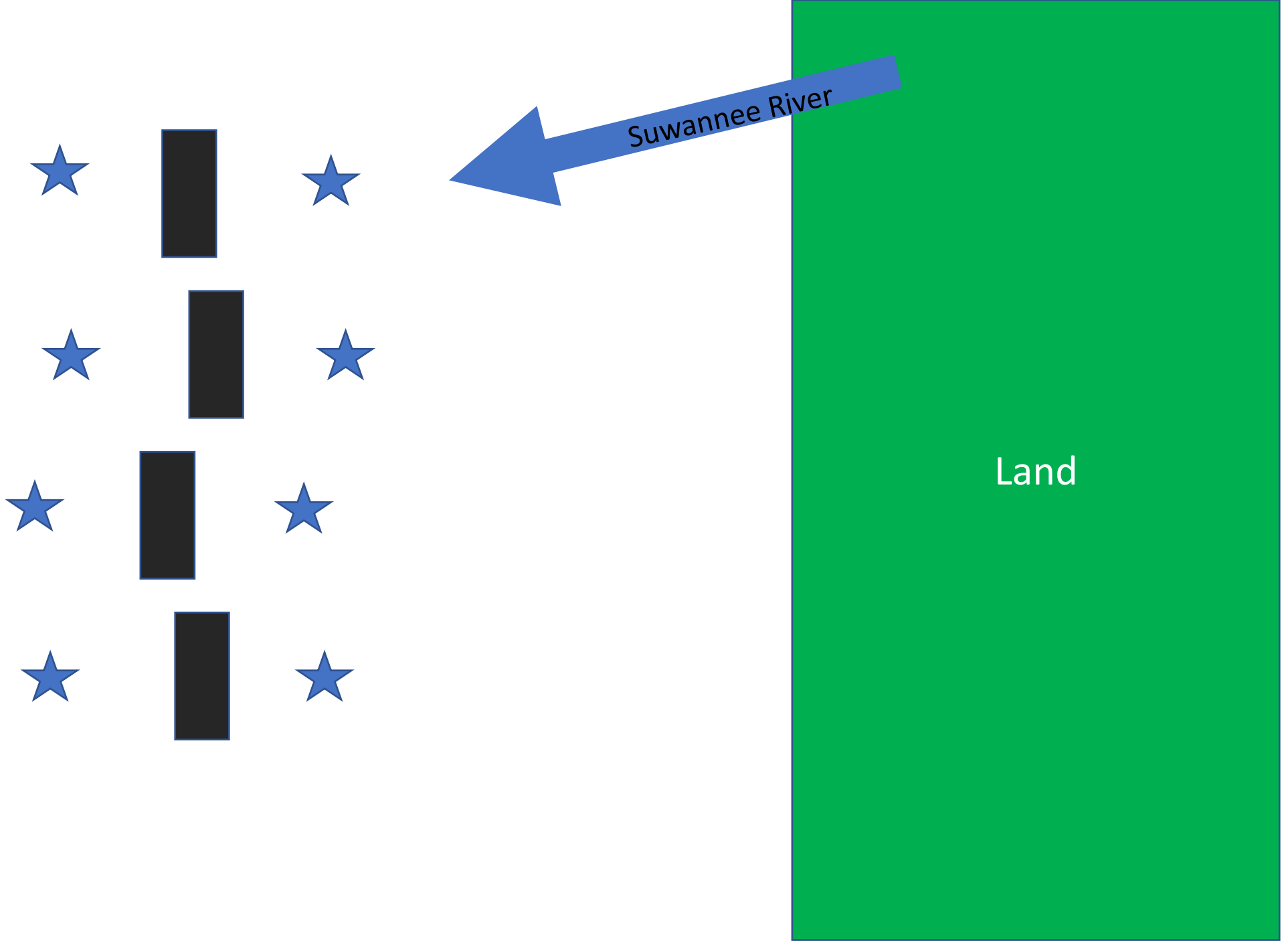
**L. G. Coggins**
*U.S. Fish and Wildlife Service, Post Office Box 346, Bethel, Alaska 99559, USA*

*Journal of Shellfish Research*, Vol. 35, No. 2, 359–367, 2016.

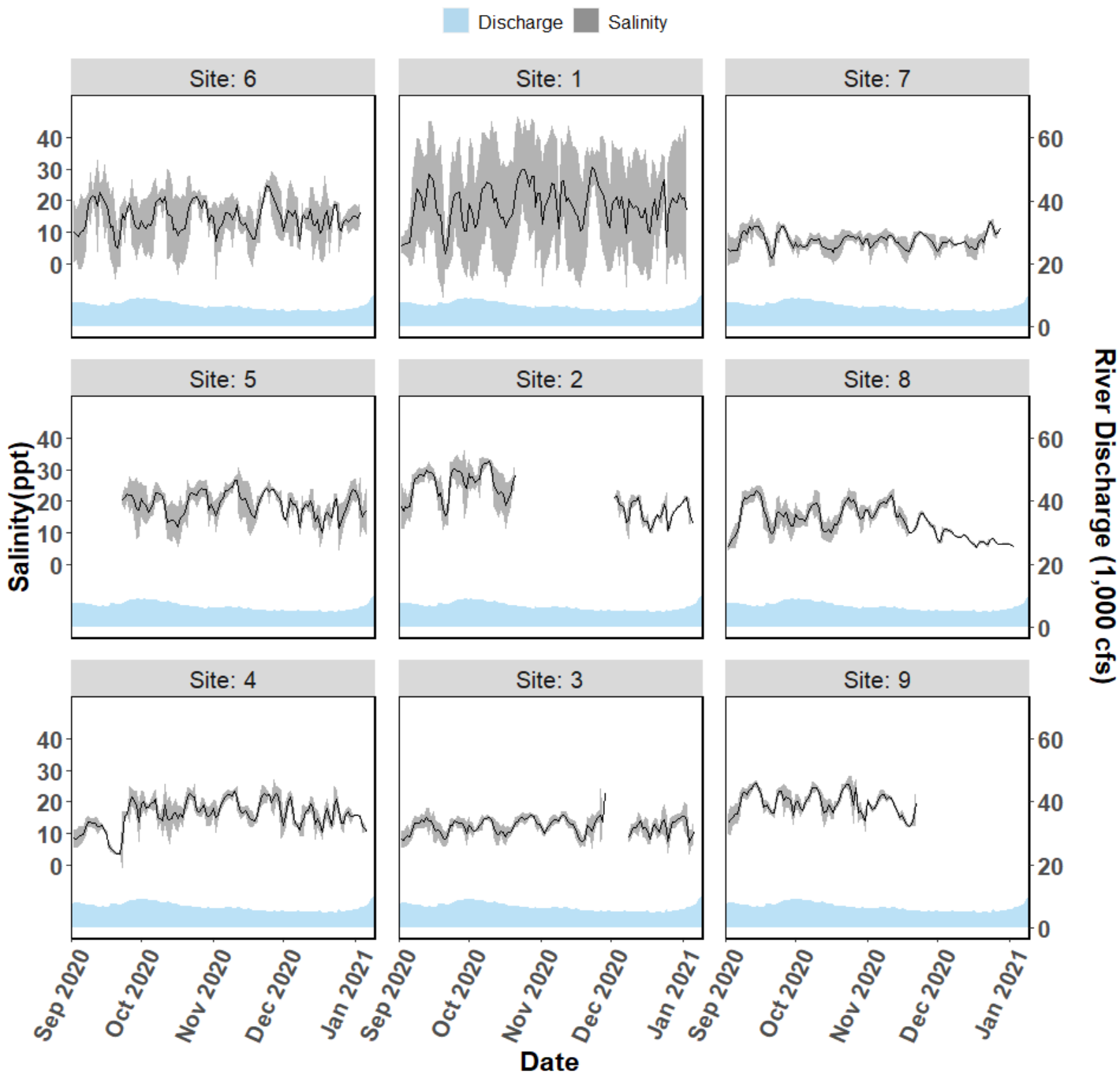
# REVERSING A RAPID DECLINE IN OYSTER REEFS: EFFECTS OF DURABLE SUBSTRATE ON OYSTER POPULATIONS, ELEVATIONS, AND AQUATIC BIRD COMMUNITY COMPOSITION

RStudio

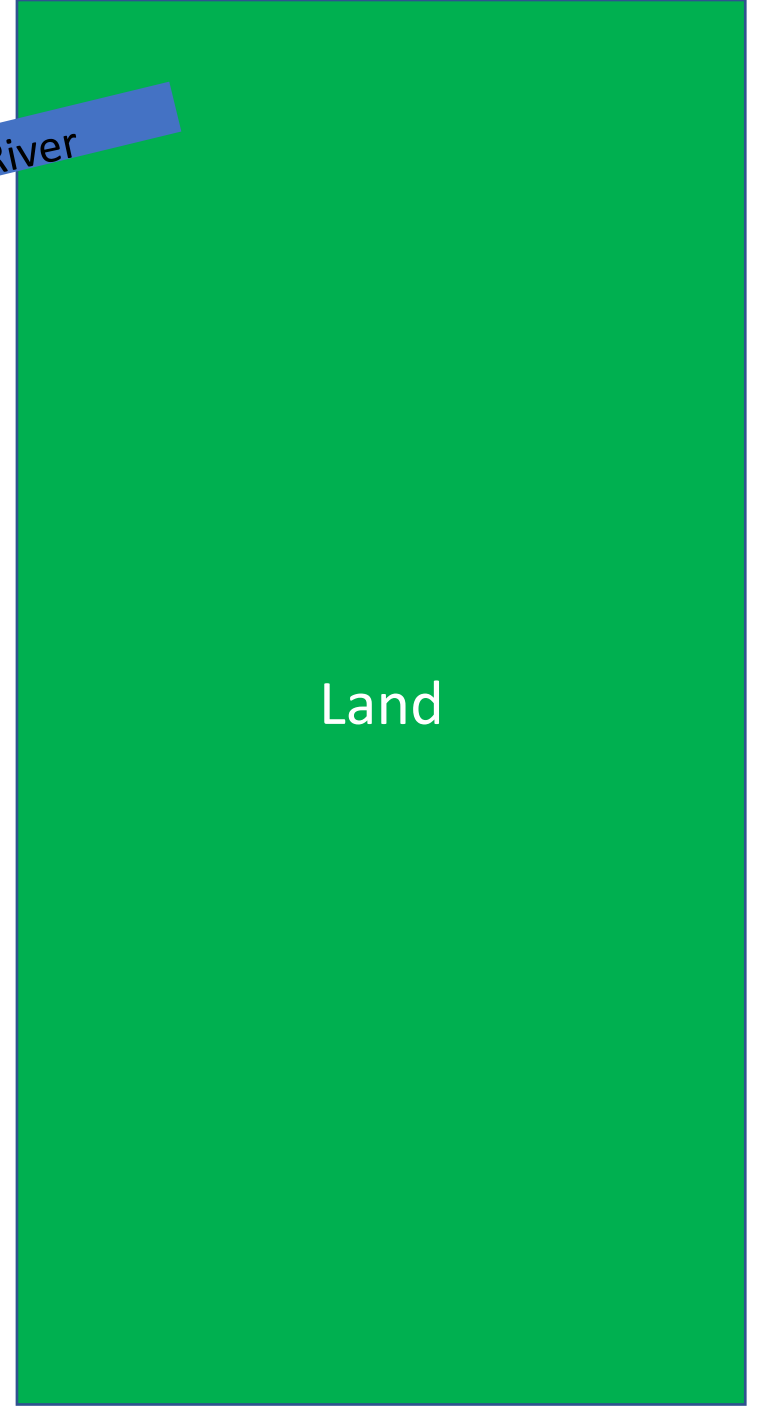
GitHub

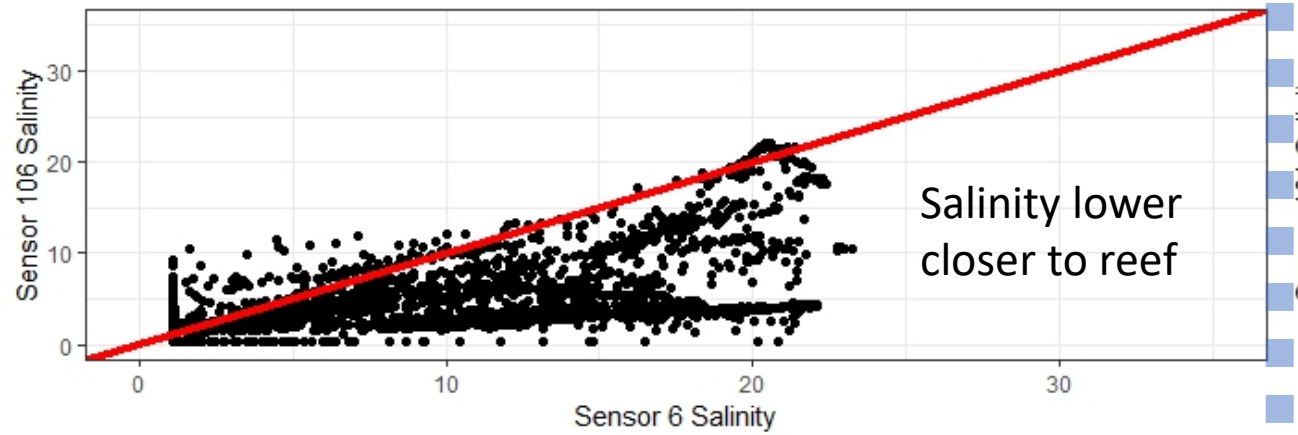

Suwannee River
Land

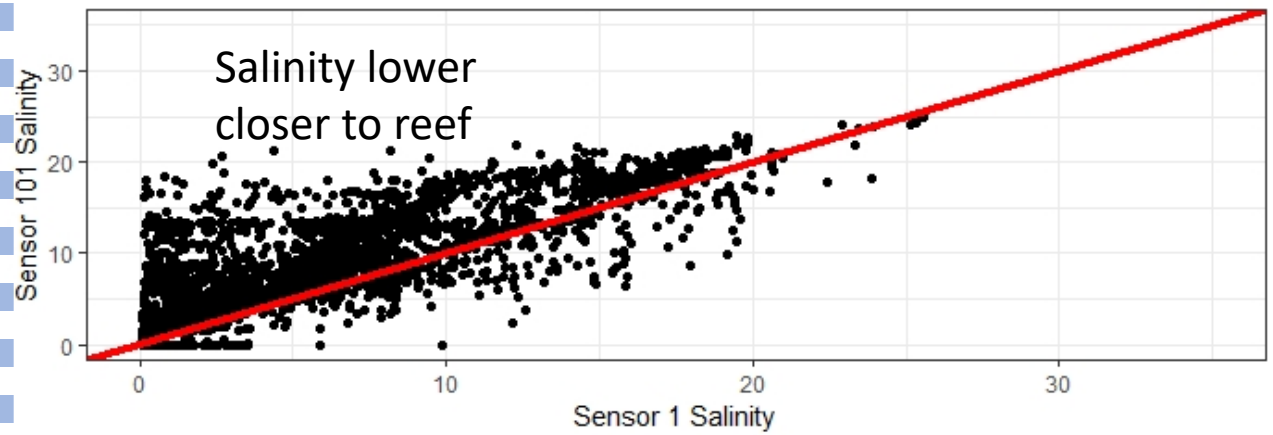
- Unclear whether construction of reef has changed salinity patterns at river discharge levels observed since summer 2017

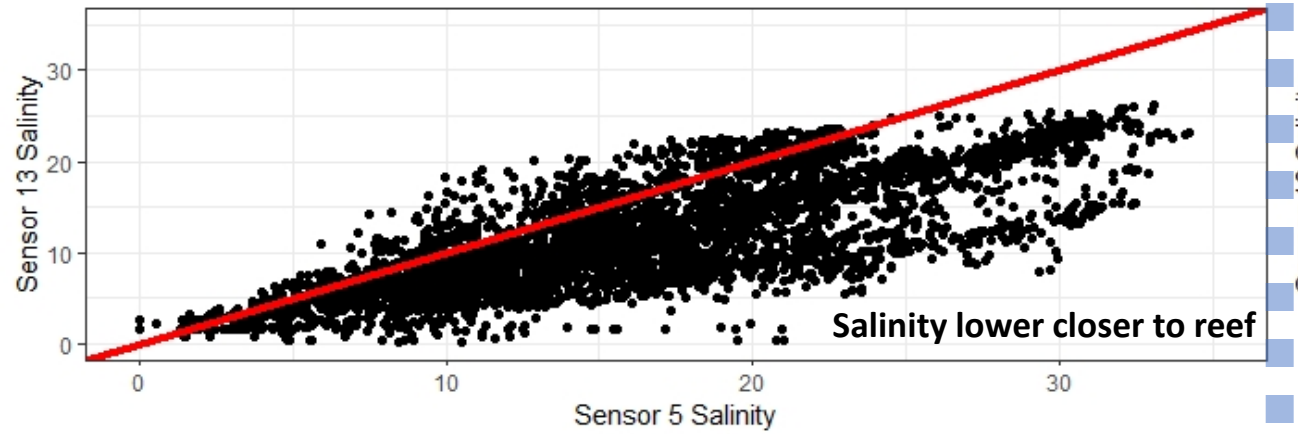


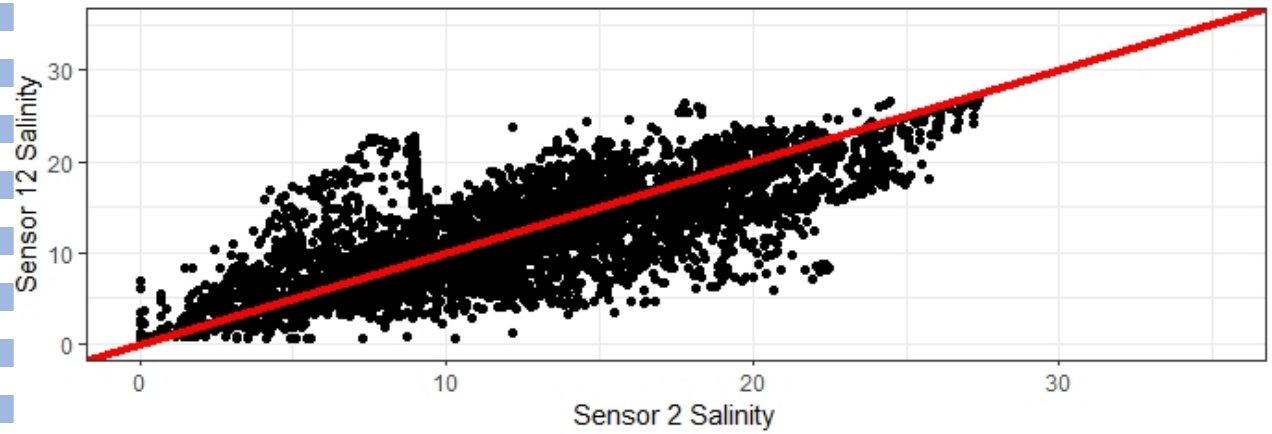
Suwannee River

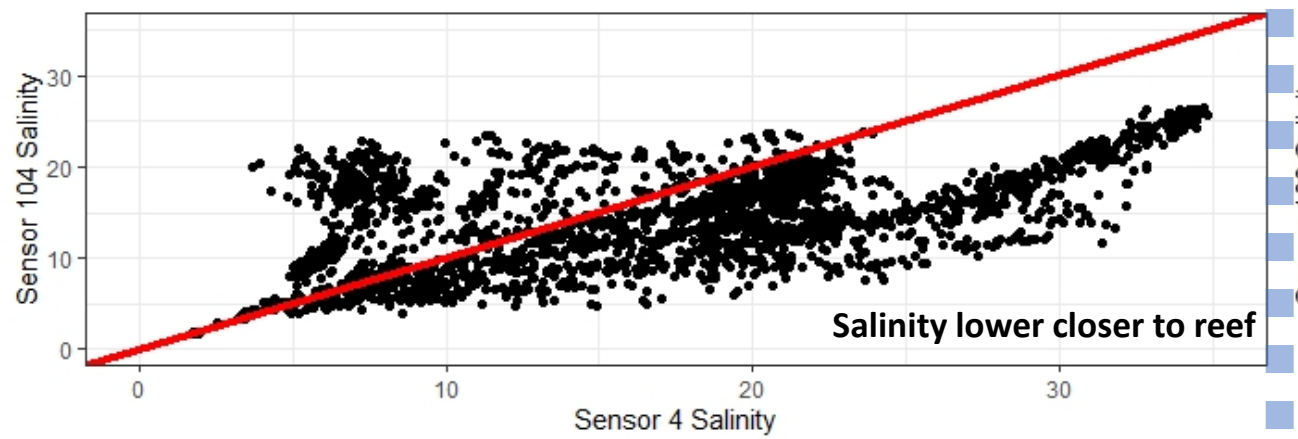

Land

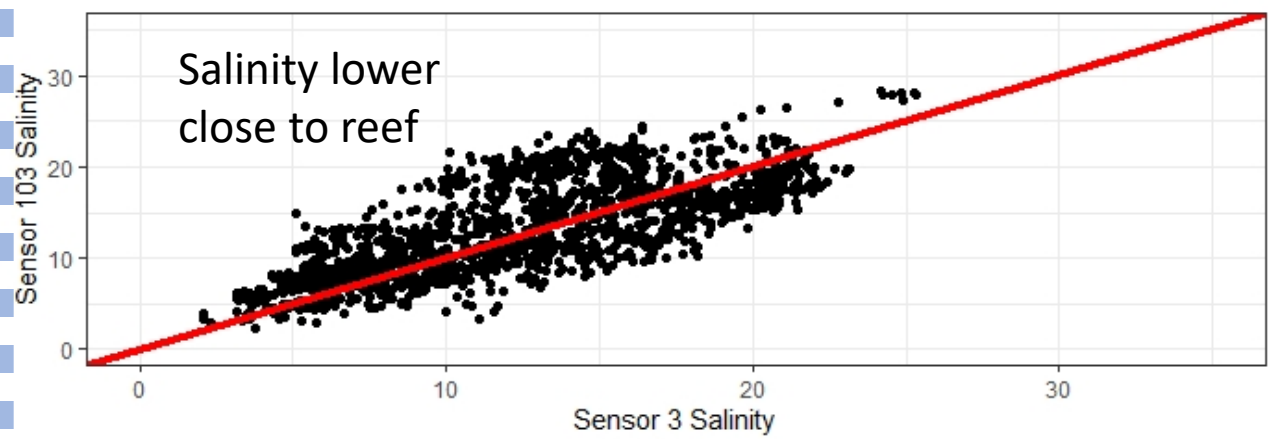

Sensor 106 Salinity
Sensor 6 Salinity
Salinity lower
closer to reef


Sensor 101 Salinity
Sensor 1 Salinity
Salinity lower
closer to reef


Sensor 13 Salinity
Sensor 5 Salinity
Salinity lower closer to reef


Sensor 12 Salinity
Sensor 2 Salinity


Sensor 104 Salinity
Sensor 4 Salinity
Salinity lower closer to reef


Sensor 103 Salinity
Sensor 3 Salinity
Salinity lower
close to reef

Suwannee River

Land

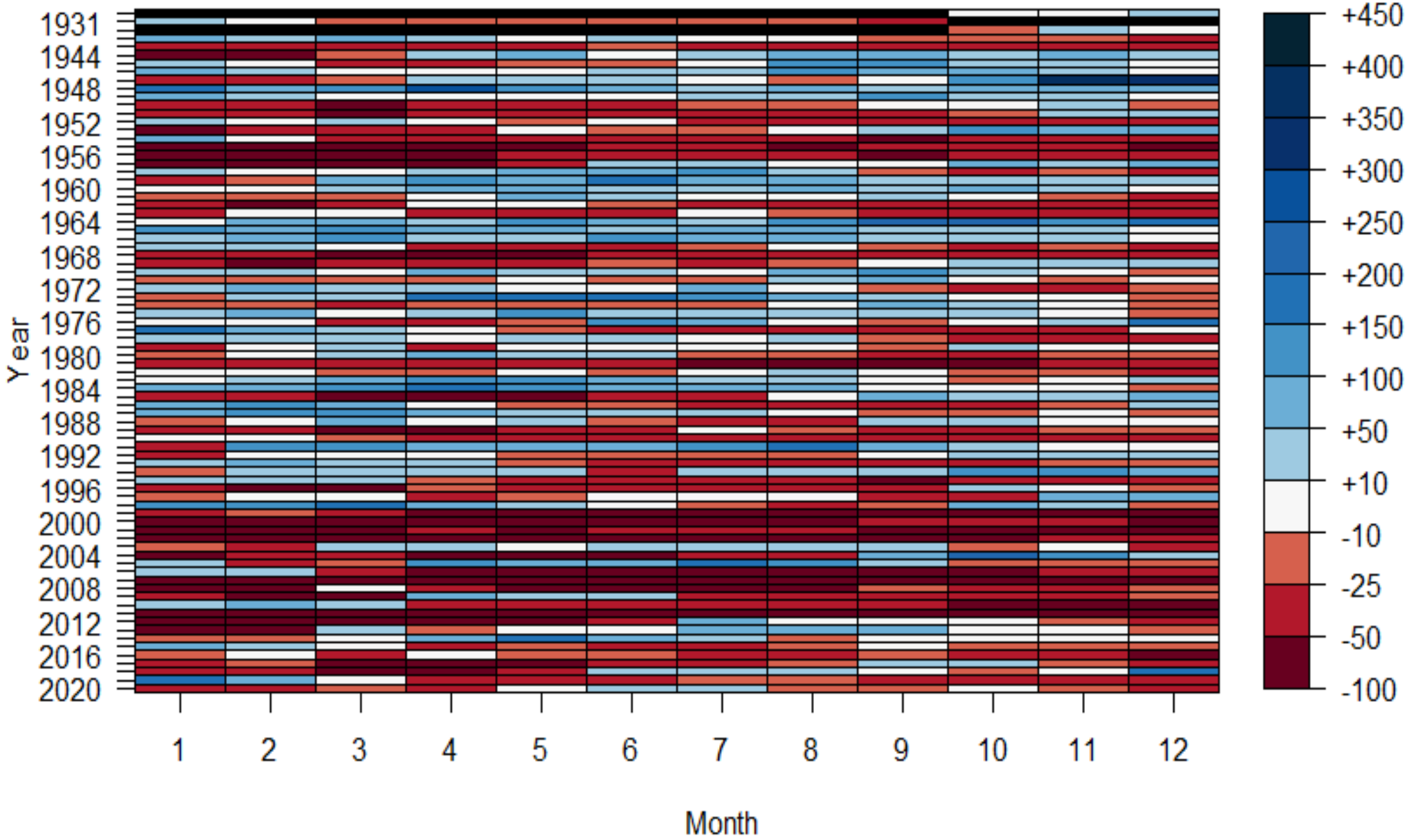
Higher salinity

Lower salinity

Lower salinity

Higher salinity

# Is Lone Cabbage a "success"?

- To be successful elsewhere AM programs will require **stronger, more decisive leadership** and **commitment to the process** to tackle these complex issues

# Deviations in Discharge from Period of Record