• Bill Pine
• billpine@ufl.edu

• Massive team effort
Objective: 2009 Peter Frederick and I were interested in helping people 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...
  - But more similar AT LOWER NUMBERS OF OYSTERS
How can restoration be used to test hypotheses?
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
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
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

• \( H_0 = \) Addition of durable substrate will allow oyster reef re-colonization and persistence
• Developed an experiment and monitoring program to test hypothesis — \textit{part of an adaptive management program}
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
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%

Percentage Complete per Strata in meters
Problems
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
How does period 24 compare to previous?

### Live Oyster Counts by Period

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Var</th>
<th>CV</th>
<th>SE</th>
<th>L95</th>
<th>U95</th>
<th>Bstrap_Mean</th>
<th>L95_Bstrap</th>
<th>U95_Bstrap</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>982</td>
<td>695</td>
<td>935</td>
<td>874733</td>
<td>0.95</td>
<td>120</td>
<td>748</td>
<td>1217</td>
<td>982</td>
<td>751</td>
<td>1202</td>
</tr>
<tr>
<td>20</td>
<td>1844</td>
<td>1253</td>
<td>2125</td>
<td>4517189</td>
<td>1.15</td>
<td>310</td>
<td>1236</td>
<td>2451</td>
<td>1848</td>
<td>1321</td>
<td>2500</td>
</tr>
<tr>
<td>22</td>
<td>1334</td>
<td>702</td>
<td>1693</td>
<td>2686783</td>
<td>1.27</td>
<td>242</td>
<td>860</td>
<td>1808</td>
<td>1340</td>
<td>907</td>
<td>1870</td>
</tr>
<tr>
<td>24</td>
<td>1463</td>
<td>1102</td>
<td>1301</td>
<td>1693414</td>
<td>0.89</td>
<td>277</td>
<td>919</td>
<td>2007</td>
<td>1453</td>
<td>976</td>
<td>2050</td>
</tr>
</tbody>
</table>

### Live Density by Period

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

Decision making
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 $\rightarrow k$?

(2) Unrestored and restored sites

*Positive response on restored
*Unrestored continue to decline
*Unrestored and restored similar counts
(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
Can restoration help?

• Benefits beyond the ribbon of rock?
Key result from winter 2021/2022

Lone Cabbage Inshore - Non-restored Sites

Lone Cabbage Nearshore - Non-restored Sites

Lone Cabbage Offshore

Live Oyster Counts (per 1 m)

Period

Restored: N, Y
Not likely to be spurious – supported by resampling

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

- Repeat restoration 5000 times
- Same result $\rightarrow$ 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
Trends in Oyster Populations in the Northeastern Gulf of Mexico: An Assessment of River Discharge and Fishing Effects over Time and Space

BOOTSTRAP METHODS CAN HELP EVALUATE MONITORING PROGRAM PERFORMANCE TO INFORM RESTORATION AS PART OF AN ADAPTIVE MANAGEMENT PROGRAM

Canadian Journal of Fisheries and Aquatic Sciences

A CAUTIONARY TALE: MANAGEMENT IMPLICATIONS OF CRITICAL TRANSITIONS IN OYSTER FISHERIES

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 Nevin-Ziegler Hall, Gainesville, Florida 32611, USA

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


REVERSING A RAPID DECLINE IN OYSTER REEFSS: EFFECTS OF DURABLE SUBSTRATE ON OYSTER POPULATIONS, ELEVATIONS, AND AQUATIC BIRD COMMUNITY COMPOSITION
• Unclear whether construction of reef has changed salinity patterns at river discharge levels observed since summer 2017
Salinity lower closer to reef

Salinity lower closer to reef

Salinity lower closer to reef

Salinity lower closer to reef

Salinity lower closer to reef

Salinity lower close to reef
Land

Higher salinity

Lower salinity

Higher salinity

Suwannee River

Land
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.