

Gulf Coast Cooperative Ecosystem Studies Unit (GC-CESU)

Collaboration between Department of the Interior, National Park Service and Florida State University

Final Report for Task 2, November 2013

Oyster reef population and community dynamics at Canaveral National Seashore (CANAS), Cumberland Island National Seashore (CUIS), and Timucuan Ecological and Historic Preserve (TIMU)

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Population and community dynamics of oyster reefs at Canaveral National Seashore (CANA), Cumberland Island National Seashore (CUIS) and Timucuan Ecological and Historic Preserve (TIMU)

Task 2: To experimentally evaluate differences in growth, recruitment, and mortality that may underlie spatial trends in the condition of oyster reefs throughout National Seashores at Cumberland Island and Cape Canaveral as well as the Timucuan Ecological and Historic Preserve

Introduction/Rationale

For centuries, coastal economies and ecosystems depended on the services provided by oyster reefs. The benefits of oyster reefs include the enhancement of commercially important invertebrates and finfish, stabilization of shorelines, filtration of coastal water, and removal of excess nitrogen (Jackson *et al.* 2001; Grabowski *et al.* 2012). As a result of anthropogenic stressors, the global abundance of this habitat has declined by 85% (Kirby 2004; Beck *et al.* 2011). The majority of the remaining reef habitat is concentrated in six ecoregions; four of which are in the United States (Beck *et al.* 2011). Because of their important services, monitoring and preserving this remaining oyster habitat are key conservation goals.

Much of these remaining oyster reefs (*Crassostrea virginica*) can be found in the Florida ecoregion, which ranges from Jacksonville to Cape Canaveral, Florida. Unfortunately, there is little information on oyster reefs throughout this region that can be used to help guide conservation and restoration efforts. Much of this habitat occurs within the National Park Service boundaries: Cumberland Island, Timucuan, and Canaveral. Without updated and spatially explicit information on oyster populations and community structure, the National Park Service will be unable to efficiently direct conservation, eradication, or restoration resources to the appropriate oyster population(s). In collaboration with the NPS, we developed two objectives to address this knowledge gap:

- Task 1: identify the spatial extent of oyster reefs at each NPS unit, sub-sampling 25 representative reefs per unit and quantifying individual growth rates, population viability, and community structure
- Task 2: experimentally evaluate differences in growth, recruitment, and mortality that may underlie spatial trends in the condition of oyster reefs.

In this report, we summarize the results of Task 2.

Methods

Study sites

As discussed in the Final Report of Task 1, our preliminary survey of each park was conducted in October 2011. Following consultation with park managers, we selected 25 representative study reefs/park in January and February 2012.

Canaveral National Seashore (CANA)

On July 31st-August 1st 2012, October 17th – 18th 2012, and February 4th - 6th 2013, we visited CANA to monitor the survivorship experiment (see below for a description of the experiment) and replace recruitment collectors. Because we designed our study to avoid overlapping the configuration of reefs currently studied by Linda Walters of UCF, our survey reefs were not organized in discrete spatial areas as in the other park units. However, they differed by reef type (bar, point, or fringing; Fig. 1) and were distributed along a gradient from north to south that corresponds to the distribution and abundance of the predatory crown conch. As a result, we examined whether patterns of oyster recruitment, growth, or mortality varied by reef type or along this north-south gradient.

Timucuan Ecological and Historic Preserve (TIMU)

On August 16-17th 2012, November 8th-9th 2012, and Feb. 20th, 21st, and 25th 2013, we monitored the survivorship experiment at TIMU and replaced recruitment collectors. We divided TIMU into 5 areas across 2 creeks to examine spatial patterns in oyster recruitment, growth, and mortality (Fig. 2). Pumpkin Hill Creek contains 3 of the 5 areas (Areas 1,2,3) in the Northern region of the park and Clapboard Creek contains 2 of the 5 areas (Areas 4,5) in the Southern region of the park.

Cumberland Island National Seashore (CUIS)

On August 11-13th 2012, December 11th-13th 2012, and February 22nd - 24th 2013, we monitored the survivorship experiment and changed out recruitment collectors at CUIS. To evaluate spatial variation in oyster recruitment, growth, and mortality, we sampled 5 unique regions at CUIS (Fig. 3). Burbank Point (Area 1) is the most northern study area at the park unit and is directly exposed to the main channel on the west side of Cumberland Island. Brickhill Bluff (Area 2) is the most accessible to park visitors, with Malkintooth Creek (Area 3) and Mumford Creek (Area 4) occurring farther south along a channel. Beach Creek (Area 5) is the most southern area of the park and farthest from the main channel.

Oyster Recruitment

In April 2012, we deployed one recruitment collector per reef at each park (N=25 / park unit). For every monitoring trip to each park unit, we collected the existing recruitment collector and replaced it with a new collector (Fig. 4). All juvenile oysters ("spat") were quantified to assess spatial and temporal patterns in oyster recruitment.

Oyster Survival and Growth

In June 2012, we started an experiment to evaluate oyster survivorship and growth on each representative reef (N=25 / park unit). On each reef, we deployed three tiles with 12 juvenile oysters affixed to their surface; these juvenile oysters all came from a single Florida hatchery (Fig. 5; T. McCrudden Research Aquaculture). The three tiles per reef were randomly assigned to one of three treatments: predator enclosure ("cage"), enclosure control ("cage control"), and open tile ("no cage"; Fig. 6). Survivorship was quantified seasonally until March 2013, when we retrieved all tiles, and quantified final oyster survivorship and size (as a proxy for growth).

Data Analysis

We first used Analysis of Variance (ANOVA) to examine differences among park units and seasons in oyster recruitment and survival. When there were significant differences among parks, we then analyzed each park unit separately. At CANA, we conducted linear regressions on oyster recruitment and survival with season and reef type (fringing, bar, or point) as categorical variables and reef number (north to south) as a continuous variable. At TIMU and CUIS, we conducted ANOVAs with park area and season as categorical variables. In addition, at TIMU we conducted a separate analysis to determine if spatial patterns varied by creek (Pumpkin Hill or Clapboard). Because we only had size/growth data from a single time point (at the end of the experiment), we conducted ANOVAs as above without the seasonal factor.

Results

Oyster recruitment

The number of juvenile oysters recruiting to our collectors varied across park units and seasons ($F_{4,284} = 67.46$, $P < 0.001$; Fig. 7), so we then analyzed each park unit independently. Recruitment at CANA did not vary by reef type or along a north-south gradient within the park, but it was influenced by season ($F_{3,86} = 3.25$, $P = 0.02$; Fig. 7): the number of spat was higher in fall and winter than in spring and summer. Similarly, recruitment at TIMU was only affected by season ($F_{3,92} = 16.00$, $P < 0.001$; Fig. 7), with the greatest number of spat during the April-June sampling period. Neither creek nor park area explained significant variation in oyster recruitment at TIMU. Oyster recruitment was highest at CUIS (Fig. 7), and it varied both by park area and season ($F_{3,89} = 15.75$, $P < 0.001$; Fig. 8). Recruitment was negligible in the Beach Creek area except in the April to June sampling period. Among the other 4 park areas, recruitment was generally similar, except for higher numbers of spat at Brickhill Bluff between June and August 2012 (Fig. 8).

Oyster survival

The number of live oysters remaining in our predation experiment varied by park unit and season ($F_{4,646} = 8.25$, $P < 0.001$), by park unit and treatment ($F_{4,646} = 13.20$, $P < 0.001$), and by season and treatment ($F_{4,646} = 5.26$, $P < 0.001$; Fig. 9). In summer 2012, survival was lower in the cage treatments at CUIS than at the other park units, suggesting that the environment at CUIS is more stressful. Survival in the cage treatments remained higher at TIMU in fall and winter than at CANA and CUIS. Predation appeared lower at CANA and CUIS than TIMU in summer 2012, but this difference disappeared in fall and winter.

To gain a better understanding of spatial and seasonal trends in oyster survival, we analyzed each park unit independently. At CANA, season significantly explained oyster survival ($F_{2,171} = 80.54$, $P < 0.001$; Fig. 9): the number of live oysters remaining on our experimental tiles was highest in summer 2012 and declined over the course of the experiment. Survival also varied by treatment across the north-south spatial gradient, with a decline in the number of live oysters in the cage treatments from north to south ($y = -0.12x + 8.45$; $R^2 = 0.21$), but no change spatially in the cage control or no cage treatments ($F_{2,171} = 5.97$, $P = 0.003$; Fig. 10).

At TIMU, there were significant differences in oyster survival across seasons ($F_{2,204} = 16.06$, $P < 0.001$; Fig. 9), across treatments ($F_{2,204} = 184.67$, $P < 0.001$; Fig. 9), and across creeks ($F_{1,204} = 56.22$, $P < 0.001$; Fig. 11). Across seasons and treatments, survival was as expected: highest in the summer and declining over time, and highest in cages, intermediate in cage controls, and lowest in the absence of cages (Fig. 9). Survival was also higher overall in Clapboard Creek than in Pumpkinhill Creek (Fig. 11), predominantly due to lower survival in all treatments in area 1.

At CUIS, there were again significant differences in oyster survival across seasons ($F_{2,202} = 35.58$, $P < 0.001$), with highest survival in the summer (Fig. 9). There were also significant effects of treatment, but these varied depending on area of the park ($F_{2,202} = 16.39$, $P < 0.001$; Fig. 12). There were large differences in survival between cages and the other treatments at Beach Creek, suggesting both high predator abundances and favorable environmental conditions in this area. At the other areas, the reduced survival in cages suggest that factors other than predation (e.g., environmental stress) are causing substantial oyster mortality, particularly at Burbank Point.

Oyster growth

We also quantified oyster size at the end of our predation experiment, focusing on the oysters in the cages since they had the highest survival rates. Because all of the oysters came from the same stock at the beginning of the experiment, differences in final size reflect variation in growth. Average oyster size at the end of the experiment varied by park unit ($F_{2,66} = 4.98$, $P = 0.009$; Fig. 13), with larger oysters at TIMU and CANA than CUIS. When we analyzed the data for each park unit individually, there were no differences by reef type or reef area / creek at any of the sites. Thus, oyster growth is consistent among the different areas examined in each park unit, but varies across parks.

Discussion

Oyster recruitment at CANA was low overall, but as often observed for invertebrates at lower latitudes, this recruitment occurred even in winter, in contrast with TIMU and CUIS. Consistent with the results of our reef survey for task 1, oyster survival in our experiment at CANA decreased along a north to south gradient in our cage treatments. Interestingly, the same pattern did not hold for the open tiles, suggesting that environmental differences among northern and southern areas at CANA are as important as predators such as crown conchs in creating this spatial pattern in the survivorship of juvenile oysters. In order to rigorously link the spatial patterns of oyster survivorship with reef conditions, additional experiments are needed on the survivorship of adult oysters. High barnacle colonization, which can cause both competition for space and overgrowth of oysters, may have contributed to reduced oyster survival in cage treatments at CANA (Fig. 14). Competition with barnacles could also help to explain the reduced average oyster size at the end of the experiment compared to TIMU.

TIMU had intermediate levels of oyster recruitment throughout the spring, summer, and fall, and this recruitment was consistent across the park areas sampled. In contrast with our survey from Task 1 where we found greater live oyster abundance

in Pumpkinhill Creek compared to Clapboard Creek, we had greater survival of juvenile oysters in our experiment in Clapboard Creek. Taken with the higher condition index in Clapboard Creek, these results suggest that Clapboard Creek has more favorable environmental conditions for oysters than Pumpkinhill Creek. Clapboard Creek may also have lower predator abundances, as survival on the open tiles was greater in Clapboard than in Pumpkinhill. Oyster growth in our cage experiment was highest at TIMU but did not vary spatially within the park.

Oyster recruitment at CUIS was extremely high, particularly in spring of 2012. CUIS experienced another recruitment pulse in fall 2012, but there was no oyster recruitment in winter. Recruitment was generally consistent across all park areas sampled other than Beach Creek, which is the most southern area of the park and farthest from the main channel, suggesting recruits simply do not reach this area. However, oyster survival in our cages was highest at Beach Creek, consistent with the results from our Task 1 survey showing larger oysters in this area of the park. Thus, Beach Creek has favorable environmental conditions for adult oysters but currently experiences recruitment limitation. Oyster survival in the other areas of the park was relatively low even when oysters were protected from predators in cages, indicating that environmental conditions contribute to oyster mortality at CUIS. Average oyster size at the end of the experiment was also lower at CUIS than the other park units, again suggesting that environmental conditions are more stressful for oysters at CUIS.

The overall status of oyster populations across the three NPS park units reflects a combination of oyster recruitment, oyster growth, and oyster survivorship. Our study highlights substantial variation in these vital rates that is important to consider when interpreting the health of oyster reefs across NPS park units (i.e., Final Report on Task 1) and/or planning restoration activities. Based on our experiments over one year, the recruitment of oysters is relatively seasonal at all park units, occurs in higher numbers at the northern park (CUIS), and is spatially consistent throughout each park unit except for CUIS. With regards to growth, conditions appear more favorable toward the north (CUIS and TIMU) when compared to CANA. With regards to the survivorship of juvenile oysters, and as observed for most invertebrates, survivorship at all park units declined through time. Meanwhile, survivorship due to environmental conditions appeared lower toward the north (CUIS) and survivorship due to predation was lowest at TIMU. Finally, within each park unit, there is considerable spatial variation in the survivorship of juvenile oysters due to predation. Collectively, these results suggest that the oyster vital rates of recruitment and growth display relatively simple seasonal patterns that vary regionally, but that survivorship exhibits high local-scale variation within each park unit. However, it is important to point out that our studies only reflect a snap-shot of oyster population dynamics, and we recommend that these vital rate assessments be repeated in future years in order to discern whether regional patterns are stable or whether there is temporal variation within and across park units. In addition, we focused primarily on vital rates of juvenile oysters; future research should include a similar assessment for adult oysters. With these additional data, the NPS will be well positioned to conduct rigorous quantitative modeling of oyster population dynamics that can guide restoration and conservation activities.

References

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Figures

Figure 1. Study oyster reefs at Canaveral National Seashore. Reefs were numbered from north to south and classified by reef type: bar (circles), fringing (squares), or point (triangles). Crown conch surveys demonstrated that there was a sharp break between northern and southern reefs, with predatory crown conchs abundant in the southern region.

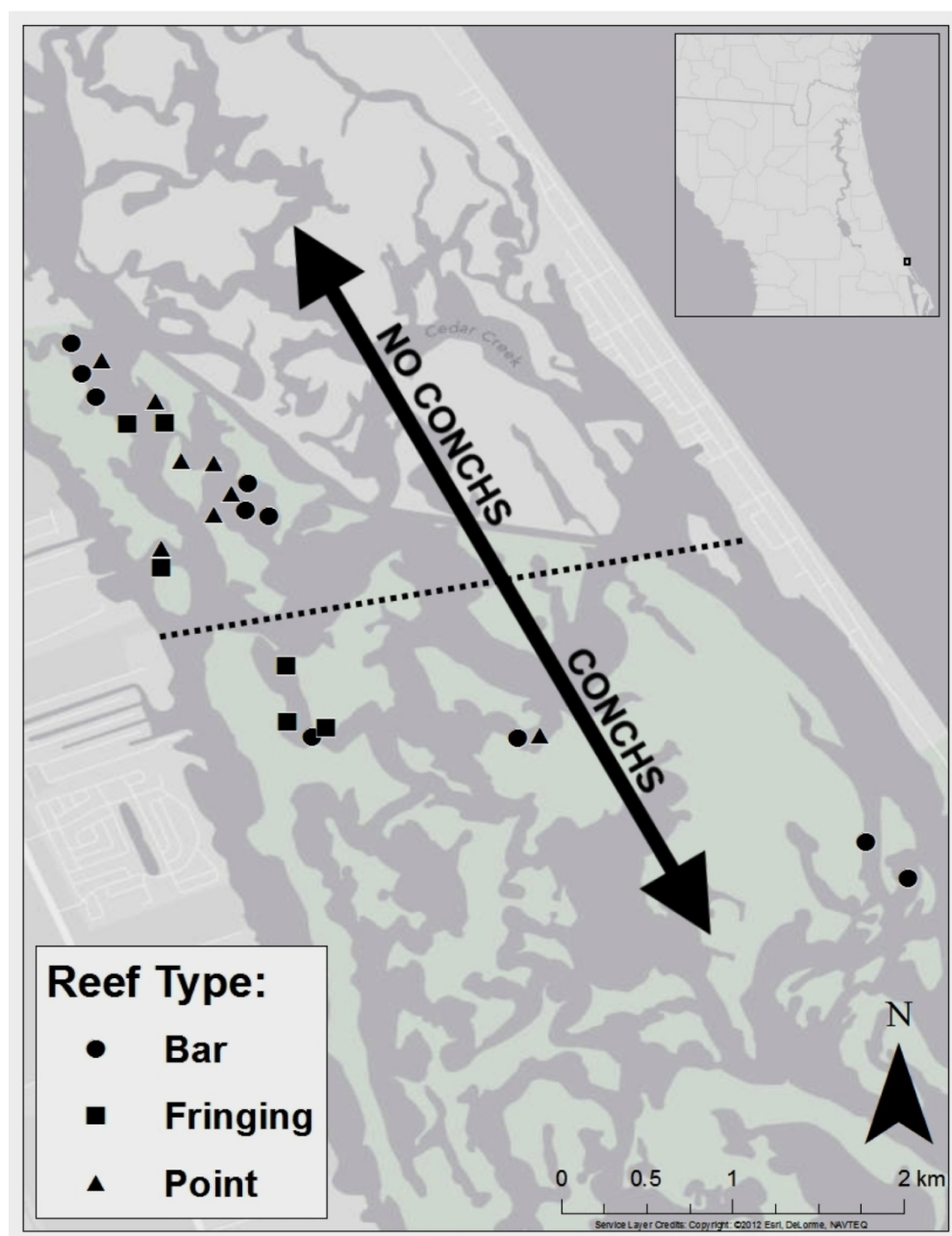


Figure 2. Study oysters reefs at Timucuan Ecological & Historic Preserve. Reefs were grouped into 5 areas with 5 reefs in each. Three areas were in Pumpkin Hill Creek, and two areas were in Clapboard Creek.

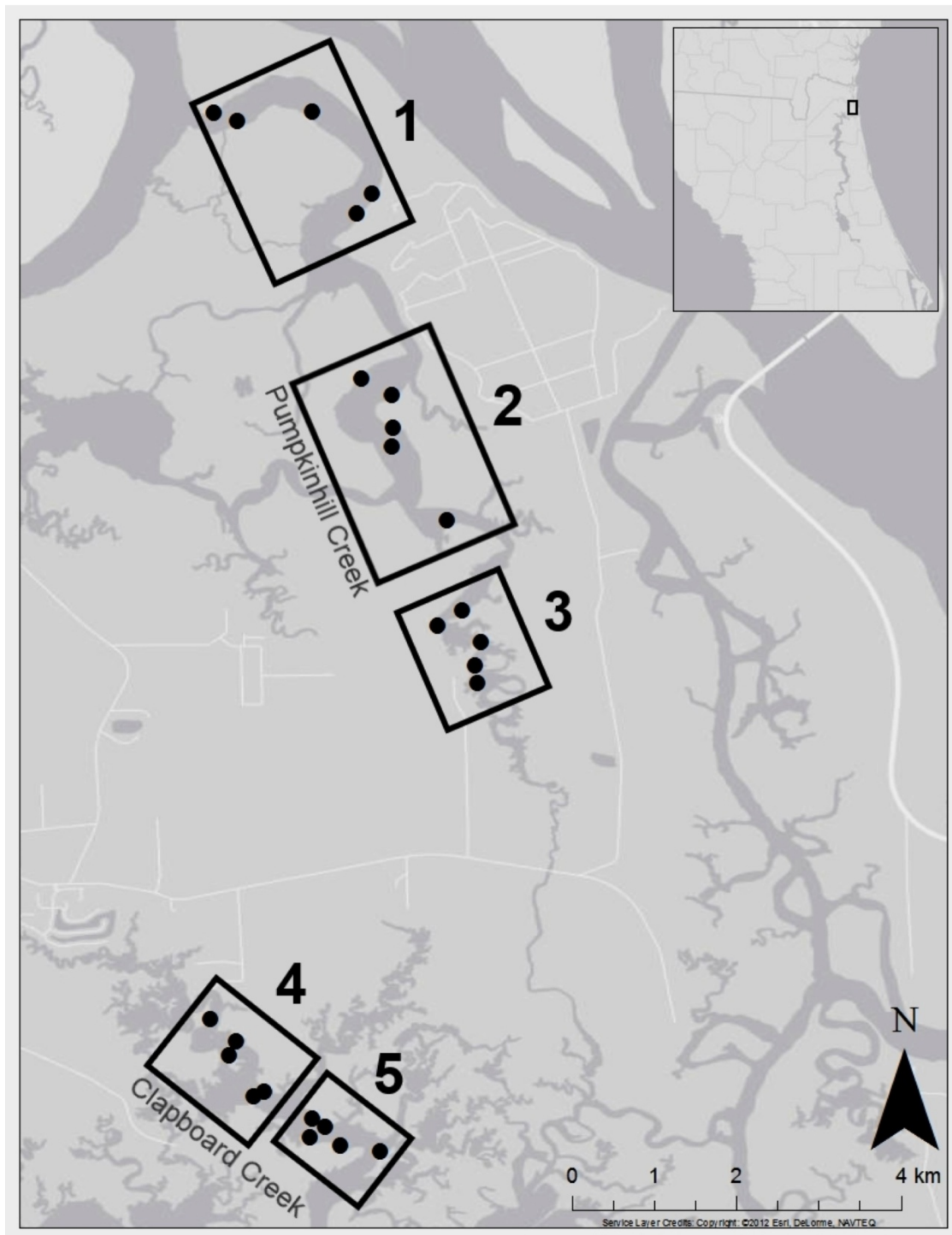


Figure 3. Study oyster reefs at Cumberland Island National Seashore. Reefs were grouped into 5 areas with 5 reefs in each.



Figure 4. Two recruitment collectors from TIMU. April 2012-June 2012 deployment.



Figure 5. 12 “spat” (juvenile oyster; outlined in white) were adhered to a tile for the tile experiment conducted at each park unit. The writing in bottom right corner allows identification of each individual spat tile (ex: T=Timucuan, tile #15).

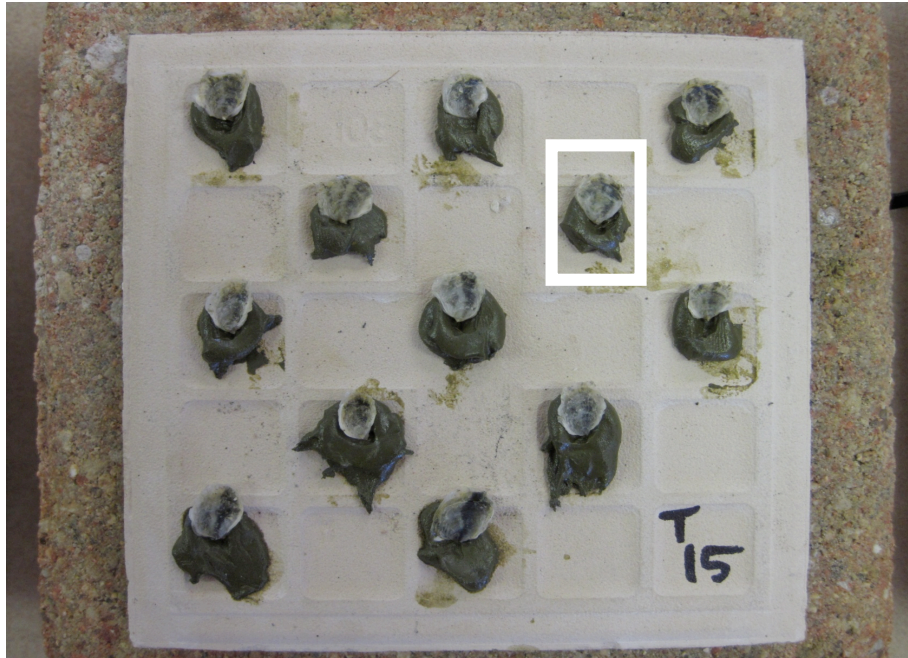


Figure 6. Reef with experimental treatments completely constructed (Cumberland Island, Area 5 Reef 2, June 2012).



Figure 7. Differences in oyster recruitment across park units and seasons. Error bars represent 1 S.E.

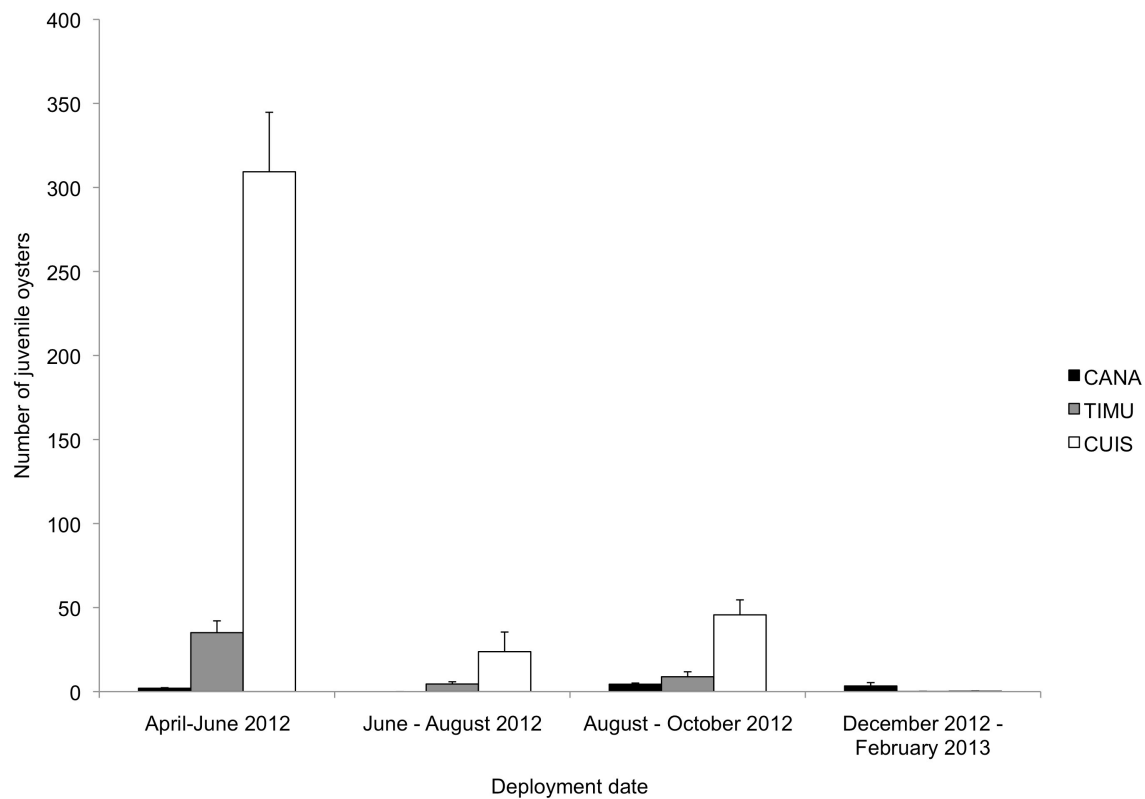


Figure 8. Oyster recruitment at CUIS by park area and season. Error bars represent 1 S.E.

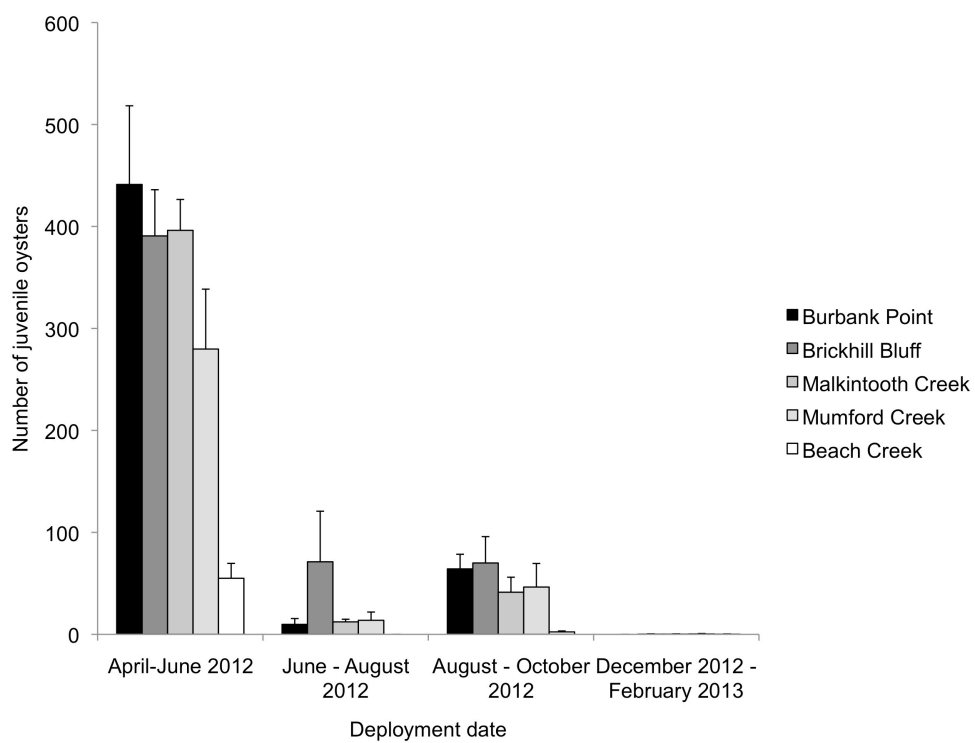


Figure 9. Differences in oyster survival across park units, seasons, and experimental treatments. Each experimental tile began with 12 oysters. Error bars represent 1 S.E.

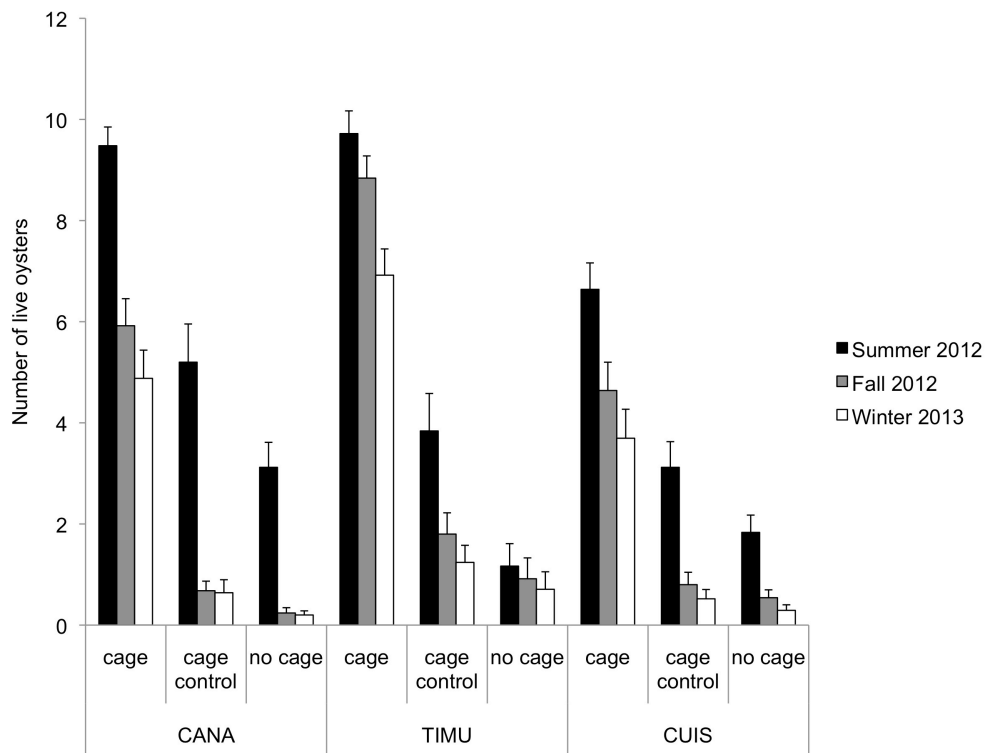


Figure 10. Differences in oyster survival at CANA across treatments and a spatial gradient from north to south. Each experimental tile began with 12 oysters.

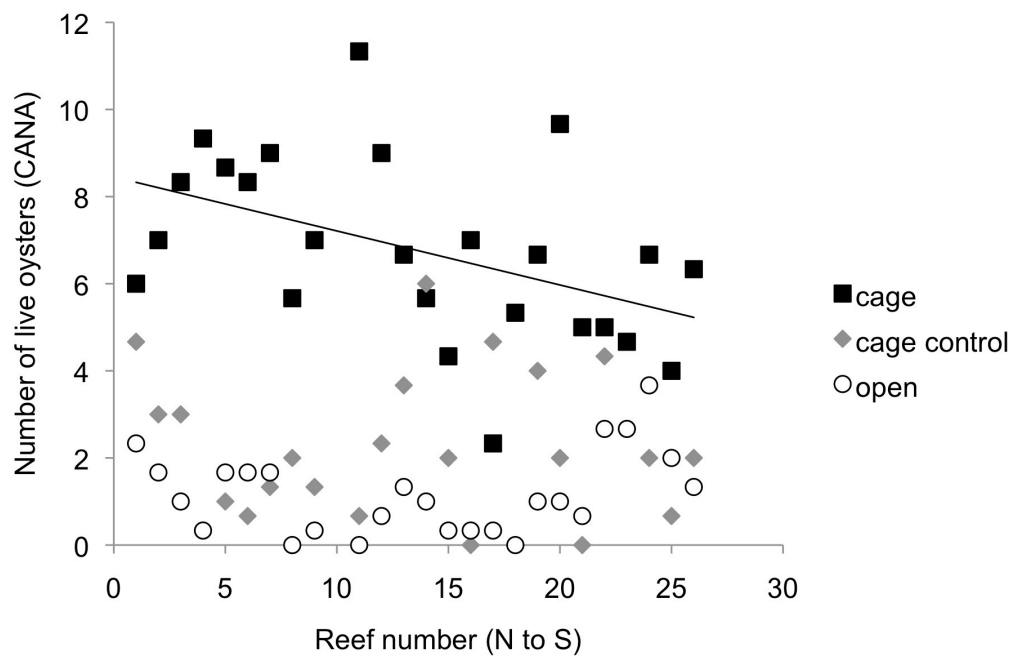


Figure 11. Oyster survival at TIMU by experimental treatment, park area (1-5), and creek (Pumpkinhill vs. Clapboard). Each experimental tile began with 12 oysters. Error bars represent 1 S.E.

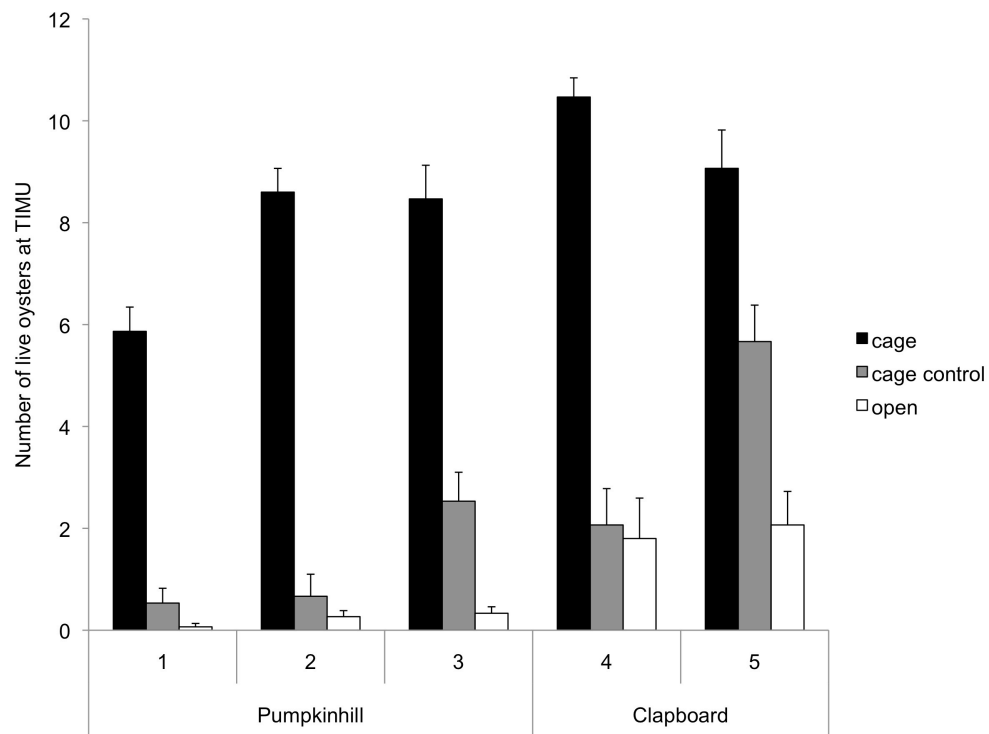


Figure 12. Oyster survival at CUIS by experimental treatment and park area. Each experimental tile began with 12 oysters. Error bars represent 1 S.E.

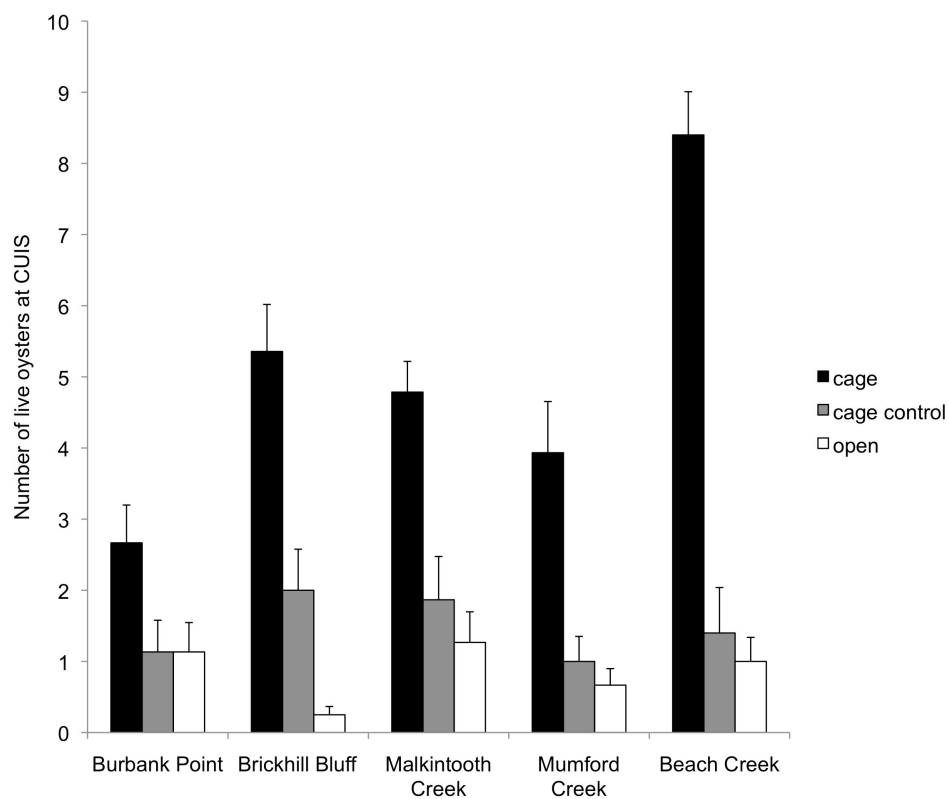


Figure 13. Oyster growth (represented by the average size of oysters at the end of the experiment) varied across park units. Error bars represent 1 S.E.

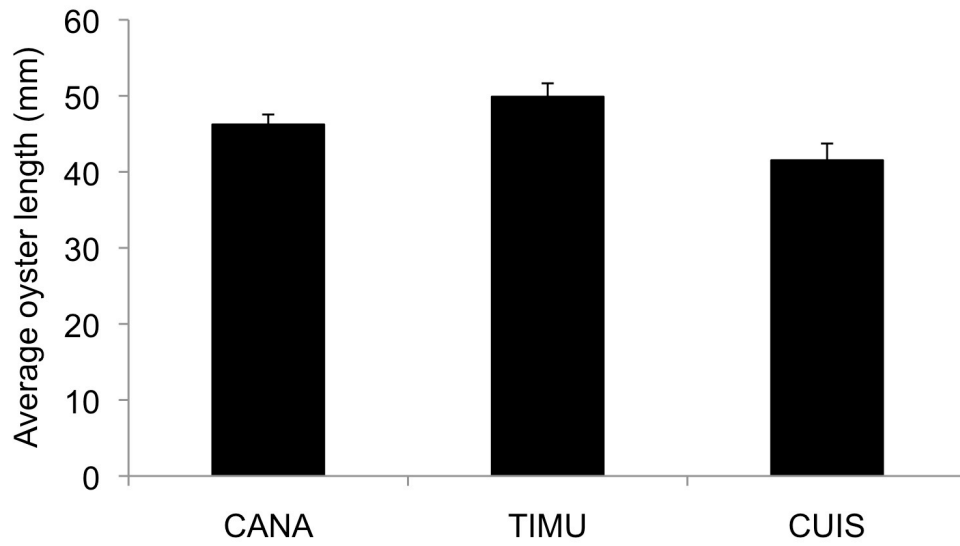


Figure 14. Tiles from Canaveral National Seashore showing heavy overgrowth by barnacles.

