

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 1, April 2013

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

Task Agreement No: P11AT51041

Cooperative Agreement No.: H5000 02 A271

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

Task 1: To quantify individual growth rates, population viability and community structure on oyster reefs throughout National Seashores at Cumberland Island and 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 National Park Service, 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 1.

Methods

Study sites

A preliminary survey of each park was accomplished in October 2011. Following consultation with park managers, we selected 25 representative study reefs/park in

January and February 2012. Data for Task 1 were collected in April 2012. For this sampling we used two different methods: 1) a point-estimate survey and 2) a grab sample. The point-estimate survey is a non-invasive method that provided surface cover information at multiple locations on each study reef. In contrast, the grab sample, which required the removal of reef structure, was collected less frequently per reef and provided more detailed information on the metrics of the oyster population (size-structure, ratio of dead to live adults, density, and condition index of adult oysters) and the reef's community structure (density and diversity of associated sessile and mobile invertebrates). We also quantified water temperature and salinity (N=5 measurements per park) during 5 visits to these sites between 2012 and 2013.

Canaveral National Seashore (CANA)

On April 4th-6th 2012, we sampled 25 study reefs at CANA (Fig. 1). Because we designed our study to avoid overlapping the configuration of reefs currently studied by Linda Walters of UCF, our survey reefs did not encompass a conspicuous spatial gradient. As a result, we analyzed the data from the point estimate survey and grab sample according to reef type at CANA (bar, point, fringing).

From our monitoring efforts at CANA, we have observed predatory crown conchs on a portion of our study reefs. Because of our research in St. Augustine, FL. showing that crown conch presence is associated with oyster mortality, on October 19th-21st 2012 we investigated the effects of crown conchs in CANA by sub-sampling 10 study reefs and completing walking surveys along with oyster quadrat harvests. The walking surveys produced the density and size range of crown conchs found on the study reef, while the quadrat gathered information on oyster population viability. We are currently analyzing these data.

Timucuan Ecological and Historic Preserve (TIMU)

On April 22nd-24th 2012, we sampled 25 reefs at TIMU (Fig. 2). Here the park is divided into 5 areas across 2 creeks. 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 (TIMU)

On April 13th-16th 2012, we sampled the 25 study reefs at CUIS (Fig. 3). We have focused our efforts into 5 unique focal areas in the park unit. The focal areas can be referenced by name or by area number. Area 1, also known as Burbank Point, 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. Area 2 (Brickhill Bluff) is the most accessible to park visitors, with Areas 3 (Malkintooth Creek) and 4 (Mumford Creek) occurring farther south along a channel. Area 5 (Beach Creek) is the most southern area of the park and farthest from the main channel.

Field Sampling:

Each reef was divided into 3 equal sections along the long axis of the reef parallel to the water line (left, middle, and right sections). The point-estimate survey was conducted by randomly placing a 0.25m² gridded quadrat around the midpoint of each of the three sections on every reef and then identifying what occurred beneath the grid

points (n=25; typically mud, live oyster, dead oyster). The quadrat used in the middle section of the point estimate survey served as the quadrat for the grab sample. The grab sample consisted of harvesting a 0.25m² area of the reef matrix including faunal community down to the substrate.

Grab Sample Processing:

An initial weight of the grab sample was measured before placing the sample in a 2mm sieve. All live oysters and all dead “gaping” oysters >20mm were measured for total length (longest distance from the umbo). A gaping oyster consists of a dead oyster with top-shell still intact. All live oysters were kept for a final live weight. Epifauna such as crabs, shrimp, fish and other bivalves were preserved for identification. From each grab sample, up to 10 oysters were quickly selected to cover a range of sizes for condition index and size-at-age analysis.

Lab analysis:

All oysters sampled from the harvested quadrat sample were measured for total length (defined as the longest measurement from the umbo), total weight, total top valve weight, top valve length and width, top valve shell thickness, and wet and dry tissue mass. Condition index was calculated by taking the weight of the entire oyster (total oyster biomass) and the dry weight of the oyster tissue (dry tissue biomass). Dry tissue biomass was measured by drying the inner oyster tissue (meat) at 70°C for 48 hours. The following relationship was used to estimate condition index (CI):

$$CI = \text{DRYTISSUEBIOMASS} / \text{TOTALBIOMASS}$$

Bottom valves from above were saved for age-at-size analysis. Oysters form perceptible growth bands and growth breaks in the umbo region (hinge of oyster) of the bottom valve that allows age to be estimated. The valves saved from the condition index analysis with umbo regions intact were used to determine the relative age of individual oysters. Each umbo was sectioned radially with a faceters saw. The growth bands and breaks in the cross section were counted to determine relative age.

Data Analysis

Population viability

We examined the following variables in one 0.25*0.25m quadrat harvested from each reef (N=25 per park): live oyster density, live oyster mass, average live oyster length, average condition index of individual oysters (dry mass of oyster tissue: total oyster mass), and the proportion of live oyster mass relative to the total sample mass. At CANA, we analyzed the data using a linear regression with reef number as a continuous variable and reef type (fringing, bar, or point) as a categorical variable. At TIMU, we analyzed the data using Analysis of Variance (ANOVA) with creek (Pumpkinhill Creek or Clapboard Creek) and area as additive, categorical variables. At CUIS, we analyzed the data using ANOVA with area as a categorical variable.

Size-at-age analysis

We used the sclerochronology techniques developed by Kirby et al. (1998) to establish a relationship between oyster length and age. These data were then analyzed in two ways. First, we assessed whether the relationship between oyster length and age differed among the three parks. Second, we assessed whether the relationship between size and age differed within each park. For both analyses, we used the same model-selection approach. For each response, we created a series of nested linear models that ranged from simple to complex: (a) all possible single-factor models that included a null model of no relationship between size and age (i.e., intercept = 1), (b) the relationship does not differ among parks, and (c) the relationship depends on age and this differs among parks. This process was repeated for within Park analyses, except for (c) distinguishing among regions within a park. After constructing these nested models, we used AIC_c to identify the most parsimonious model (Burnham and Anderson 1998). Based on the model-selection results, we fitted a quadratic regression between age and length of oysters. In both model-selection processes, two models were declared significantly different if the same model-selection approach produced Δ AIC_c scores that differed by a value of 2.0 or more (Richards 2005). All data were analyzed with R 2.15.

Community structure

We analyzed the abundance of common reef taxa at each park (mud crabs, mussels, porcelain crabs) as well as the total abundance of fauna per reef using regression and ANOVA as described above in the "Population viability" section.

Environmental variables

We analyzed salinity and temperature variation by season and area in each park using individual ANOVAs.

Results

Population viability

The number of live oysters per quadrat (Fig. 4a; $R^2 = 0.32$; $y = -1.96x + 65.41$) as well as live oyster mass (Fig. 4b; $R^2 = 0.22$; $y = -0.04x + 1.57$) decreased from north to south at CANA, with no consistent effect of reef type on either variable ($P \geq 0.28$). In contrast, there was an interaction ($P = 0.003$) between reef type and reef location for oyster condition index (CI): CI increased from north to south on bar reefs (Fig. 4c; $R^2 = 0.84$; $y = 0.0004x + 0.009$) but decreased from north to south on fringing reefs ($R^2 = 0.33$; $y = -0.002x + 0.02$) and did not change for point reefs.

At TIMU, there were significant differences among creeks for live oyster mass, live oyster size, and CI (Fig. 5). Live oyster mass was marginally lower at Clapboard Creek than Pumpkin Hill Creek ($P = 0.06$; Fig. 5a), and live oyster size was significantly lower at Clapboard Creek ($P < 0.0001$; Fig. 5b). In contrast, CI ($P = 0.002$; Fig. 5c) was higher on average at Clapboard Creek. There were also significant differences in oyster size by area ($P = 0.02$; Fig. 5b).

At CUIS, live oyster size ($P = 0.002$; Fig. 6a) and the proportion of live oyster mass to total mass ($P = 0.04$; Fig. 6b) varied by area. Both measures were higher in area 4 than areas 1-3. Oyster size was also high at area 5, but the proportion of live oysters on the reefs in area 5 was comparable to areas 1-3.

Size-at-age

We found a significant relationship between oyster age and size, and these relationships differed among the three parks (AICc weight = 1.0, df = 8, Δ AICc = 29.1; Fig. 7). There was also significant variation in this relationship within areas at CANA (AICc weight = 0.99, df = 6, Δ AICc = 11.6; Fig. 8) and TIMU (AICc weight = 0.99, df = 6, Δ AICc = 8.5; Fig. 9), but not CUIS. In both CANA and TIMU, the areas in the north had size-age relationships that suggested higher growth rates and survivorship when compared to areas toward the south.

Community structure

Common taxa found in our grab samples included mud crabs (*Panopeus* spp., *Eurypanopeus* spp.), porcelain crabs (exotic), fiddler crabs, mussels, and the bivalve *Sphenia fragilis*. Overall, there were fewer taxa at CANA than TIMU and CUIS; fiddler crabs, porcelain crabs, and *Sphenia fragilis* were only found on reefs at the two northern parks.

At CANA, mud crab abundance varied by both reef location and reef type ($P = 0.08$; Fig. 10a): the number of mud crabs decreased from north to south, but only on fringing reefs ($R^2 = 0.95$; $y = -0.64x + 17.46$). In addition, there were differences in total faunal abundance among reef types ($P = 0.03$; Fig. 10b). We also found a significant gradient in crown conch abundance, with crown conchs present and abundant at southern but not northern reefs.

At TIMU, mussel abundance varied by creek ($P = 0.01$) and by area ($P = 0.02$; Fig. 11). In contrast, the abundance of mud crabs, porcelain crabs, and total fauna did not vary predictably by creek or area.

Despite high abundances of macrofauna at CUIS, reef faunal abundance did not vary predictably by area ($P > 0.05$).

Environmental variables

Temperature showed predictable seasonal variation, but it did not differ by area within the parks (ANOVA $P > 0.05$). Salinity, in contrast, varied by both season and location within the park at CANA and TIMU. Salinity was highest on average at CANA.

At CANA, there was a weak increase in salinity from north to south (reef 1 to reef 25; $R^2 = 0.22$; $y = 0.07x + 35.15$); salinity was highest in spring (mean=40.90) and lowest in fall (mean=34.02), with intermediate values in summer (mean=37.30) and winter (mean=36.60).

At TIMU, salinity decreased consistently from north to south (area 1 to area 5), regardless of creek ($R^2 = 0.95$; $y = -1.89x + 33.54$); it was also highest in spring (mean=34.88) and lowest in summer (mean=21.40), with intermediate values in fall (mean=28.37) and winter (mean=29.54).

Salinity did not vary by park area at CUIS, although there was significant season variation, with highest salinities in spring (mean=34.49) and winter (mean=34.23), intermediate salinity in fall (mean=33.15), and lowest salinity in summer (mean=28.25).

Discussion

At CANA, live oyster abundance and biomass decreases along a north to south gradient, with the northern reefs having higher live coverage than the southern reefs.

Interestingly, mud crab abundance followed a similar pattern, with more mud crabs at northern than southern reefs. This positive relationship between live oyster and mud crab abundance suggests that the importance of oyster structure for mud crab habitat outweighs the negative influence of mud crab consumption on live oyster abundance. However, crown conch presence and abundance is negatively correlated with live oyster abundance: live oyster abundance declines in southern areas where crown conchs are abundant. Thus, consumption by crown conchs may be an important driver of live adult oyster abundance at CANA.

At TIMU, Pumpkin Hill Creek (areas 1-3) had greater live oyster abundance and larger oysters overall than Clapboard Creek (areas 4-5). However, on an individual basis, oysters from Clapboard Creek had higher condition index. Area 1 has a significantly higher proportion of live oyster weight compared to the total sample weight. In addition, Area 3 had the largest oysters and Area 5 had the smallest oysters. In both creeks, oyster size increases towards the source of the creek, corresponding to decreasing salinities. On average, Clapboard Creek has lower salinities than Pumpkin Hill Creek.

Area 5 (Beach Creek) at CUIS, the most southern area of the park and farthest from the main channel, had larger oysters on average than the other areas. Area 3 (Malkintooth Creek) had the smallest oysters, but also had a significantly higher percentage of live reef coverage. Area 2 (Brickhill Bluff), which is the most accessible to park visitors, had the least amount of live oyster coverage. Neither salinity nor faunal abundance varied predictably by area at CUIS.

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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.

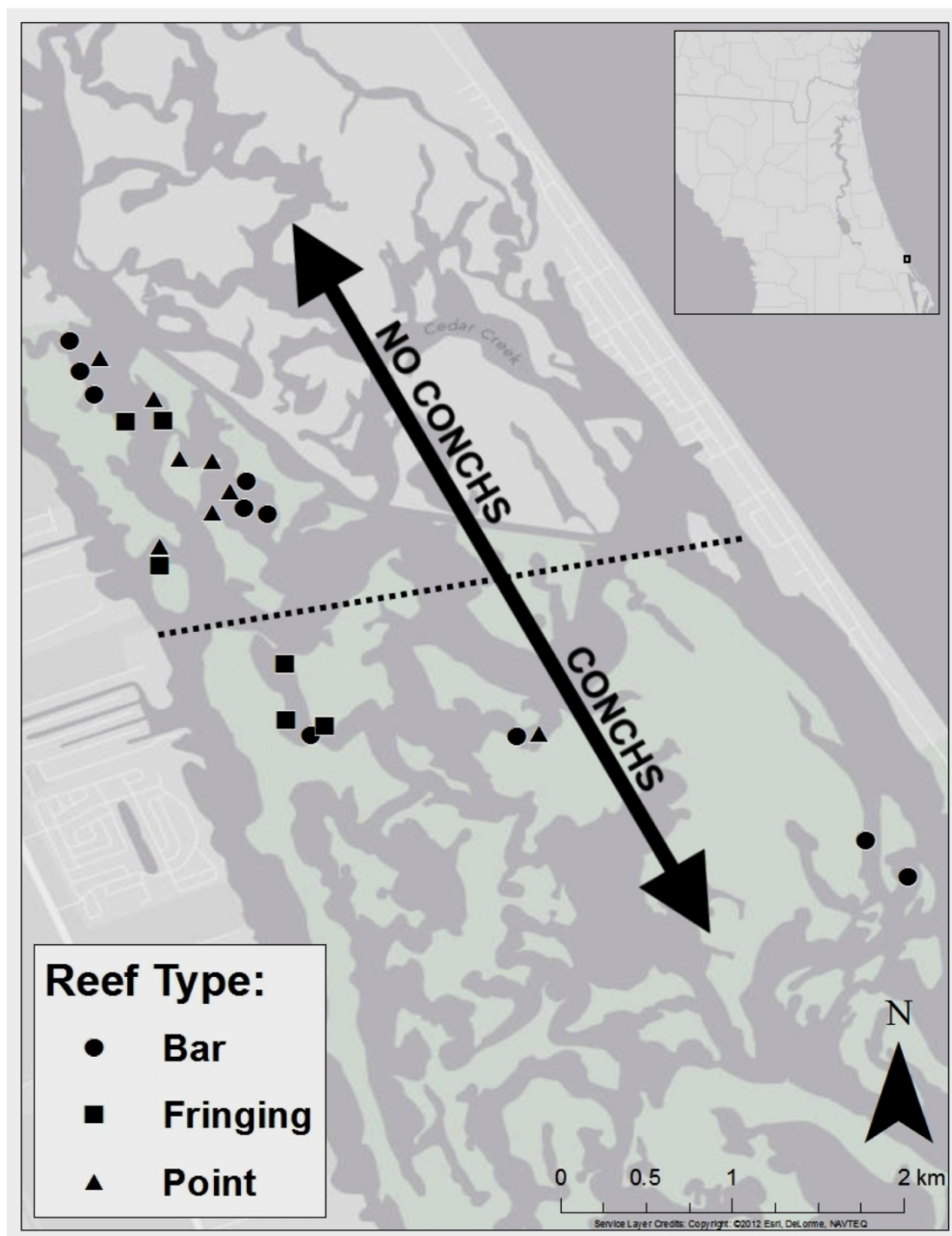


Figure 2. Study oysters reefs at Timucuan Ecological & Historic Preserve. Reefs were grouped into 5 areas with 5 reefs in each. Three areas were in Pumpkin Hill Creek, and two areas were in Clapboard Creek.

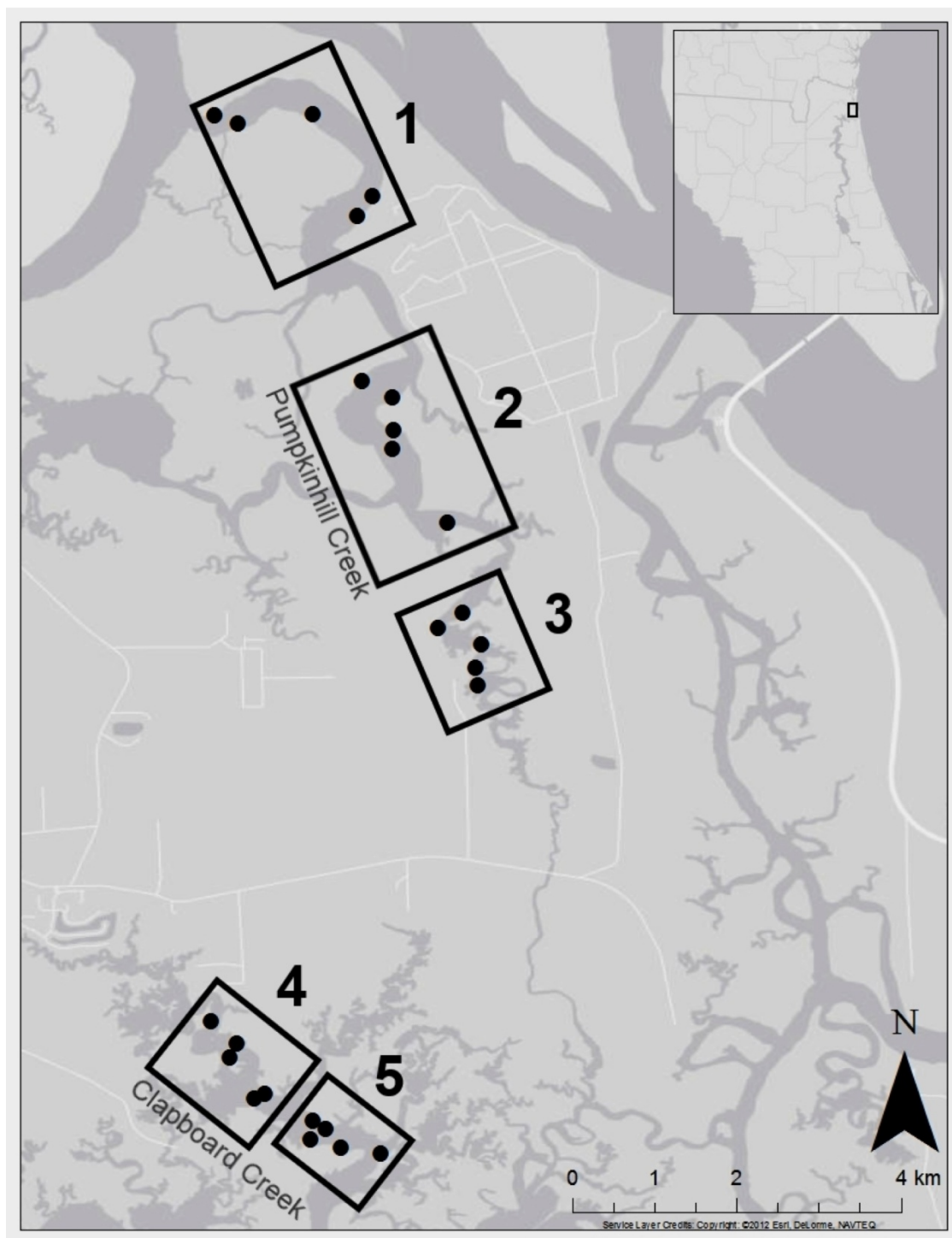


Figure 3. Study oyster reefs at Cumberland Island National Seashore. Reefs were grouped into 5 areas with 5 reefs in each.



Figure 4. Metrics of population viability for CANA oyster reefs. (a) The number of live oysters per reef declined from north to south at CANA. (b) Live oyster mass also decreased from north to south. (c) Condition index, or the ratio of tissue dry mass to total tissue and shell mass, decreased from north to south for fringing reefs, but it increased from north to south for bar reefs.

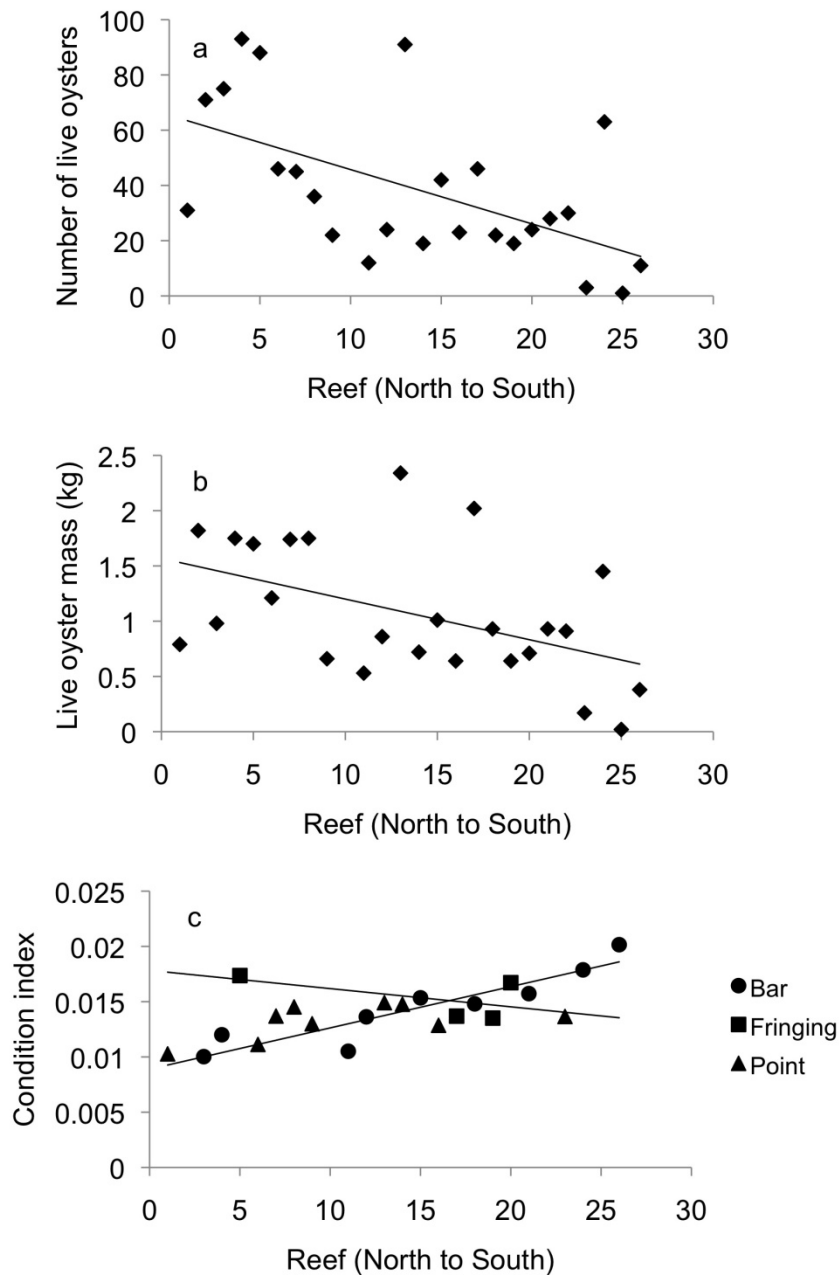


Figure 5. Metrics of population viability for TIMU oyster reefs. (a) Live oyster mass was higher in Pumpkin Hill Creek than in Clapboard Creek. (b) Live oyster length (mm) was also higher in Pumpkin Hill Creek, with the largest oysters in areas 2 and 3. (c) Condition index was higher in Clapboard Creek than in Pumpkin Hill Creek.

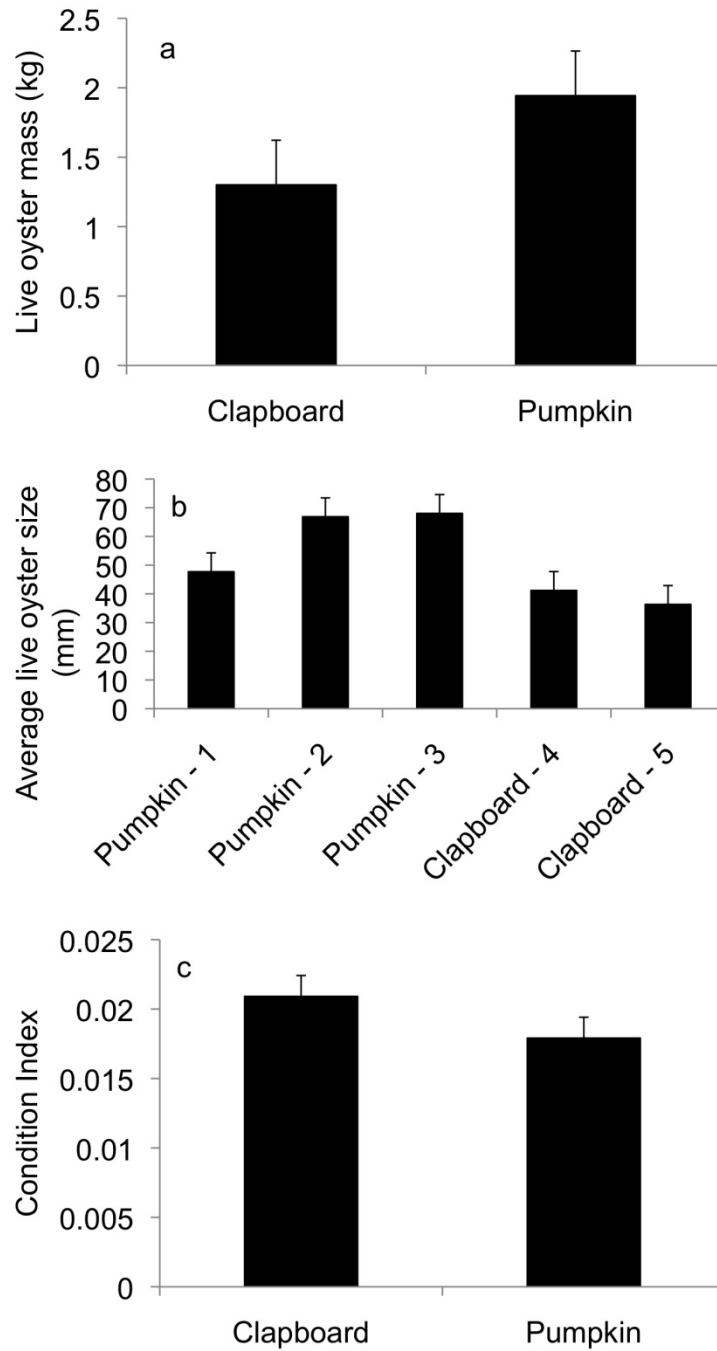


Figure 6. Metrics of population viability for CUIS oyster reefs. (a) Live oyster length (mm) varied by area, with largest oysters in areas 4 and 5. (b) The proportion of reef that was made of live oyster mass also varied by area and was highest in area 4.

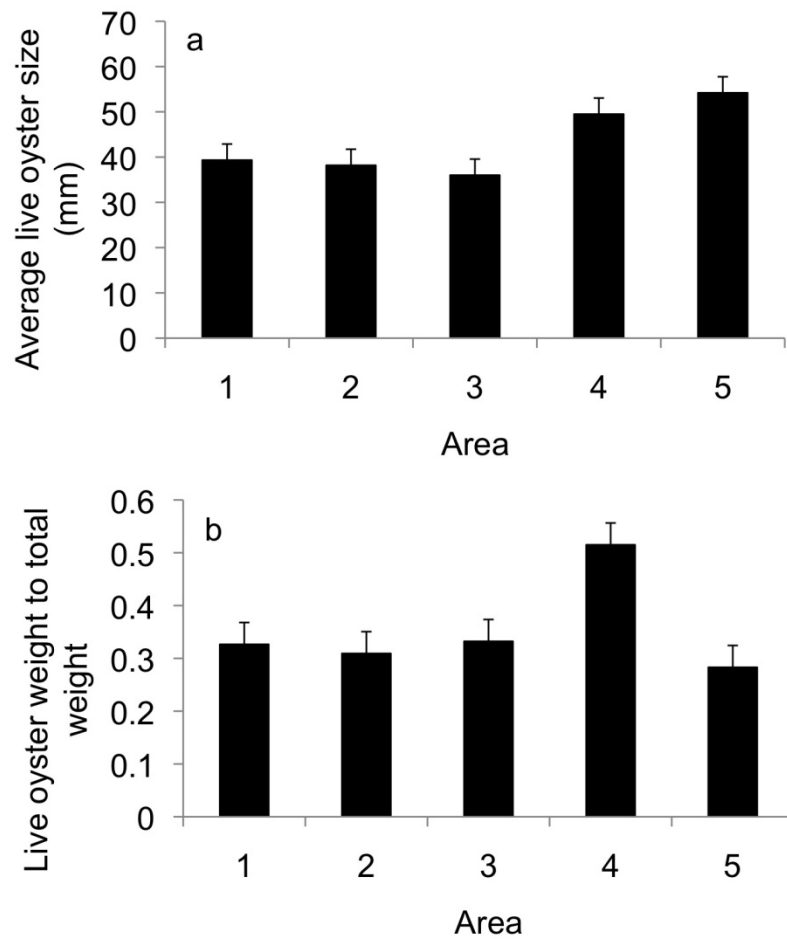


Figure 7. Size-age relationships across the three NPS sites examined in this study: CANA (closed circles), TIMU (gray circles), CUIS (open circles). TIMU and CUIS show very similar relationships, but CANA oysters asymptote at a smaller size.

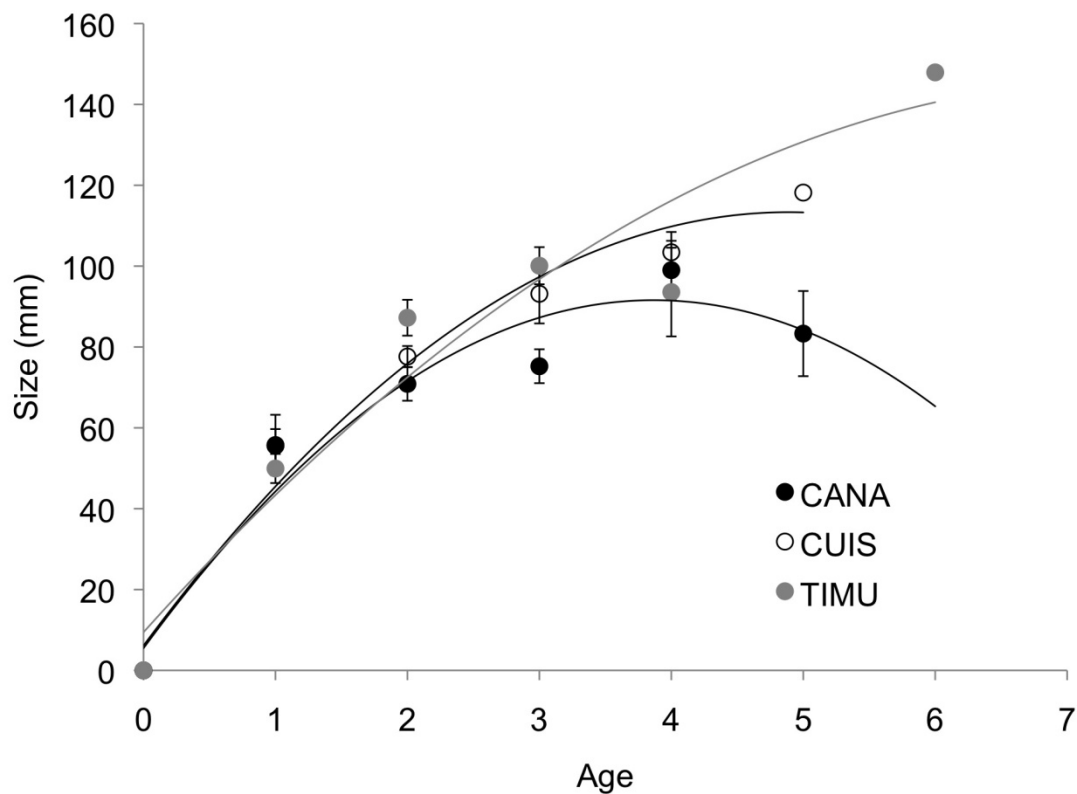


Figure 8. Size-age relationships differ between northern (no crown conchs; open circles) and southern (crown conchs; closed circles) reefs at CANA. The slope of the relationship is very similar, but oysters from northern CANA sites are larger for a given age than oysters from southern CANA sites.

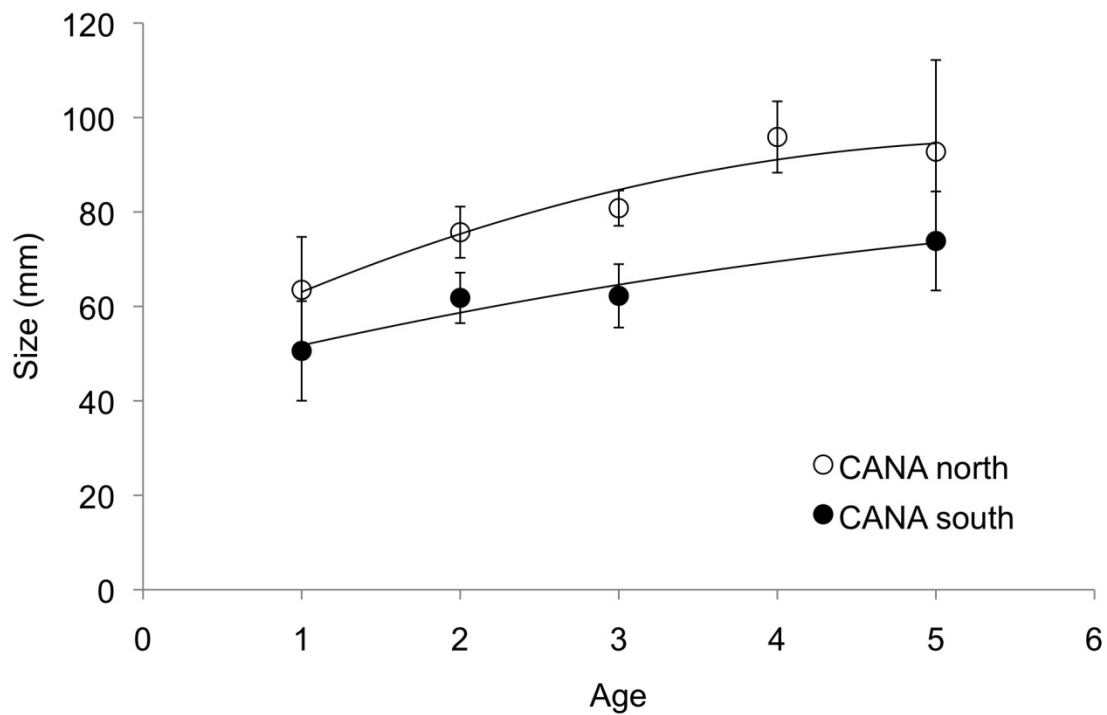


Figure 9. Size-age relationships differ slightly between TIMU sites in Pumpkin Hill Creek (open circles) and Clapboard Creek (closed circles), particularly for older individuals.

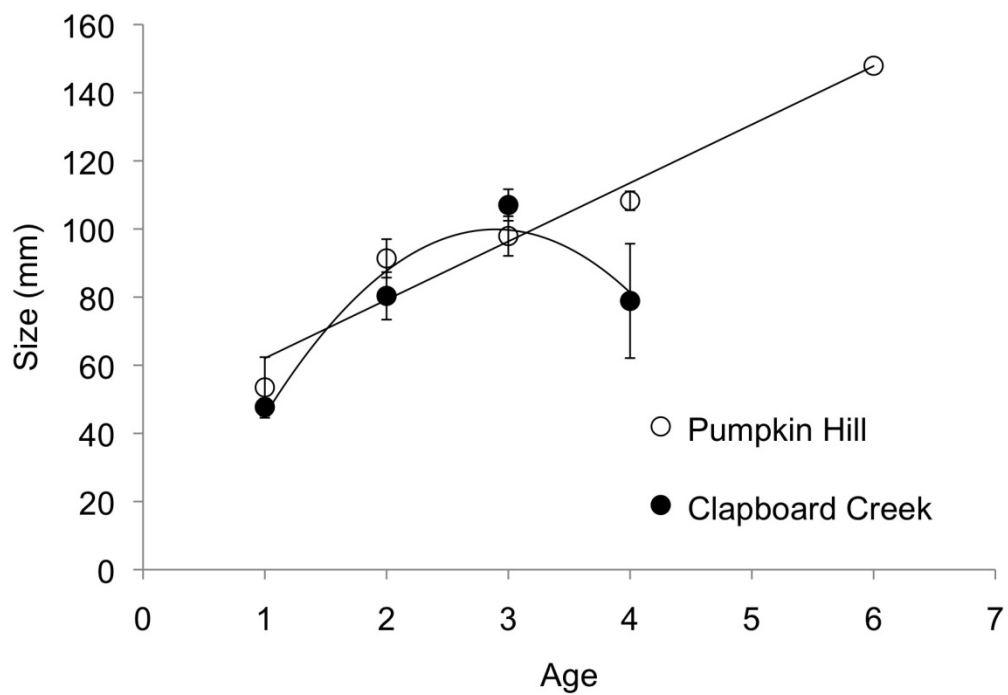


Figure 10. Oyster reef community structure at CANA. (a) Mud crab abundance decreased from north to south on fringing reefs but did not change with reef position for bar or point reefs. (b) Bar and fringing reefs had higher total faunal abundance than point reefs.

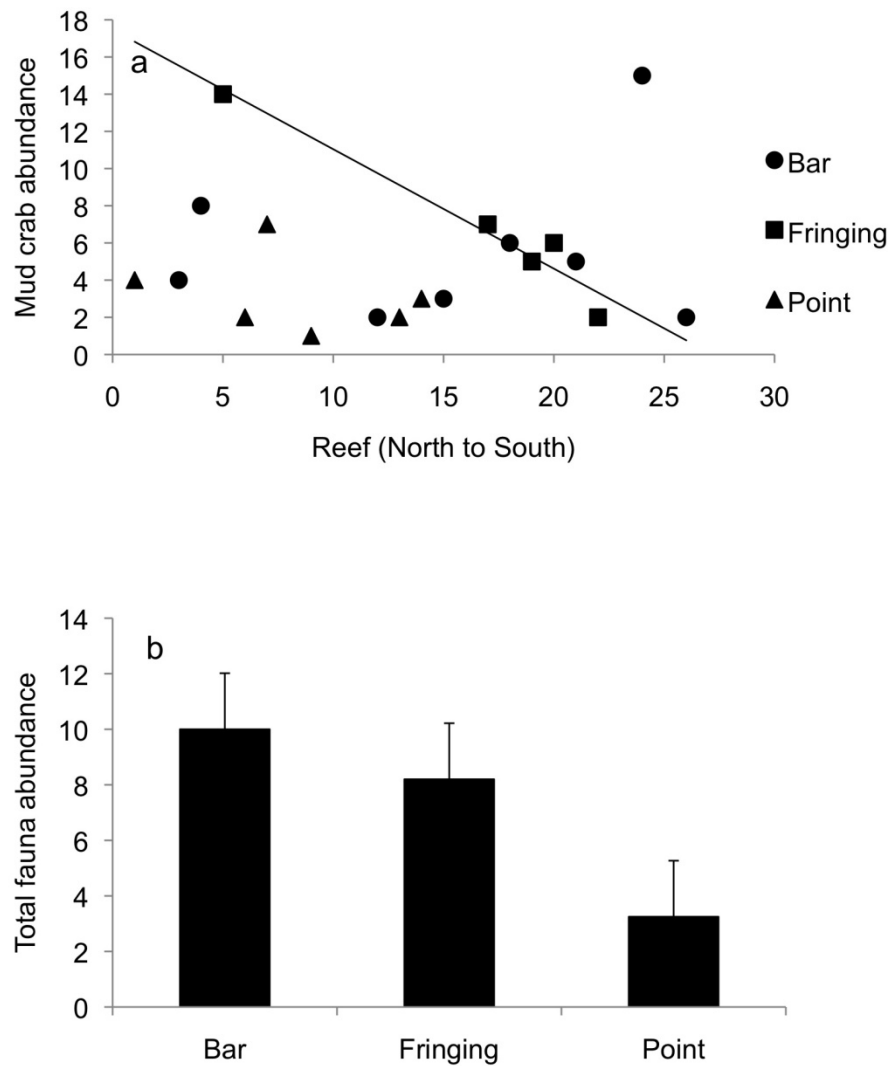


Figure 11. Oyster reef community structure at TIMU. The number of live mussels per reef was higher on average in Pumpkin Hill Creek than in Clapboard Creek. Within Pumpkin Hill Creek, the number of live mussels increased from area 1 to area 3 (north to south).

