Florida Oyster Cultch Placement Project
Year Three Monitoring Report

Introduction

The Florida Oyster Cultch Placement Project is a Natural Resource Damage Assessment (NRDA) Phase III *Deepwater Horizon* early restoration project. As a result of the *Deepwater Horizon* oil spill and associated response activities, oyster and benthic secondary productivity along Florida's Panhandle suffered adverse impacts. This project seeks to foster oyster reef habitat development, which would help compensate the public for Spill-related injuries and losses to oyster habitat and benthic secondary productivity. Monitoring for up to a 10-year period will be conducted to ensure project designs were correctly implemented and to evaluate project effectiveness, as budget allows. Performance criteria will be used to determine project success. Monitoring data and adaptive management principles will be used to evaluate the need for corrective actions and to correct deficiencies as funding allows. This monitoring plan will be implemented by the Central Panhandle Aquatic Preserves (CPAP), which is a division of the Office of Resilience and Coastal Protection (RCP) (formerly known as the Florida Coastal Office), part of the Florida Department of Environmental Protection (FDEP). The monitoring plan and activities conducted may be modified over time based on management needs for the Oyster Cultch Placement Project.

Project Overview

The objective of the Florida Oyster Cultch Placement Project is to promote reef development for oysters by restoring existing, degraded oyster reef habitats that have reached their productive lifespan. The restoration work included the placement of suitable cultch material on existing or previously constructed oyster bars by barge for the settling of native oyster larvae and oyster colonization. Approximately 61,943 cubic yards of oyster cultch has been placed over an estimated 296 acres of existing oyster bars. In particular, it included:

- Placing approximately 24,840 cubic yards of shell on 16 debilitated oyster reefs over an approximately 124-acre area in the Apalachicola Bay system in Franklin County.
- Placing approximately 17,000 cubic yards of crushed granite over an estimated 84 acres of debilitated oyster reefs in the St. Andrews Bay System in Bay County; and
- Placing approximately 20,103 cubic yards of a lime rock aggregate over an estimated 88 acres of debilitated oyster reefs in the Pensacola Bay System in Escambia and Santa Rosa Counties;

Cultch material consisted of combinations of oyster shells, either mined from existing sources or from active oyster shell collection sources, and/or limestone approved for use in these projects by Florida's Department of Agriculture and Consumer Services (FDACS). Placing substrate or "cultch" in bays where natural reproduction occurs, is the most effective technique used throughout the Gulf of Mexico (GOM) to 1) create three-dimensional reef structure, 2) stimulate spat setting, 3) sustain oyster fisheries, 4) enhance community functions, 5) increase natural productivity and 6) accelerate the recovery process. Florida has been involved in rehabilitating oyster reefs for more than sixty years and provides a multidimensional approach built on decades of experience. These restoration methods are established methods for this type of restoration project.

Cultch Sites to be Monitored

The FDEP acted as the administrator for the NRDA project in all three bays. As a subcontractor, FDACS was responsible for the administration, planning, implementation, management, and successful completion of all aspects of the barge cultch planting component. In all three bays, environmental conditions, as well as historical productivity and recruitment, were considered when selecting the oyster reefal complexes to be restored. The sites chosen by FDACS for cutch deposition were based on the aforementioned criteria and from input from FDEP, FWC, and local oyster harvesters.

Monitoring Protocols

1. Site Selection

   Prior to sampling, each reef site is divided into midpoints, the number of which depends on the size of the reef being sampled (i.e. a larger reef site contains more midpoints than a smaller site). Using ArcGIS, midpoints are determined to effectively assess the reef area. These midpoints are the exact location to be sampled.

   For each sampling day, four FDEP staff are needed: two divers, one safety diver, and a boat captain. All divers must be certified to dive for FDEP. Similarly, the boat captain must be certified to operate FDEP vessels. All diving is done in accordance to the FDEP's Underwater Operation Manual, which is available at http://www.dep.state.fl.us/admin/Safety/DsaB/files/Underwater_Ops_Manual.pdf.

   Based on weather, winds, and current conditions, the team selects an appropriate site(s) and/or midpoint(s) to sample. Once near the site, the boat captain "zeros out" the boat's position using GPS, getting as close to the designated midpoint's coordinates as possible.

2. Sample Collection

   Two divers enter the water on either side (starboard and port) of the boat. Each diver swims a weighted transect line out 10m from the side of the vessel. Each transect line has a mushroom anchor and dive flag with a float attached to the end. The diver then descends and places a 0.25 m^2 quadrat on the bottom in a haphazard manner near the transect line. Live oysters, shell, and associated fauna are removed to the depth of the sediment, placed in mesh collecting bags, and delivered to the survey vessel. This is repeated five times on each side of the boat, as well as off the bow of the boat. A total of 15 quadrats (5 starboard, 5 port, and 5 bow) are sampled for each midpoint.

   The boat captain and safety diver on the boat label sample bags as they are being collected. A sample ID is given to each sample (quadrat) that includes the site name, midpoint number, side of the boat, and the sample number. For example, the first quadrat from Cat Point, Midpoint 1, taken from the starboard side of the boat is given the ID: CP-MP1-S1.

   The team onboard records water quality observations at the surface and bottom of the water column, using a Yellow Springs Instrument (YSI) handheld datasonde. Parameters recorded include:

water temperature, dissolved oxygen, specific conductance, salinity, and pH. Weather conditions, wind, current, and latitude and longitude are also recorded.

3. Sample Processing

Samples are processed once all the quadrats have been collected for a midpoint. If it is not possible to process samples immediately after sampling, they are frozen until processing can be completed.

First, the sample is weighed using a digital hanging scale. If oysters are present in the collected sample, shell height of the first 100 live oysters is measured to the nearest millimeter (mm). Oyster shell height (Figure 1) is defined as the distance from the umbo to the distal margin of the shell (Bagget *et al*, 2014).

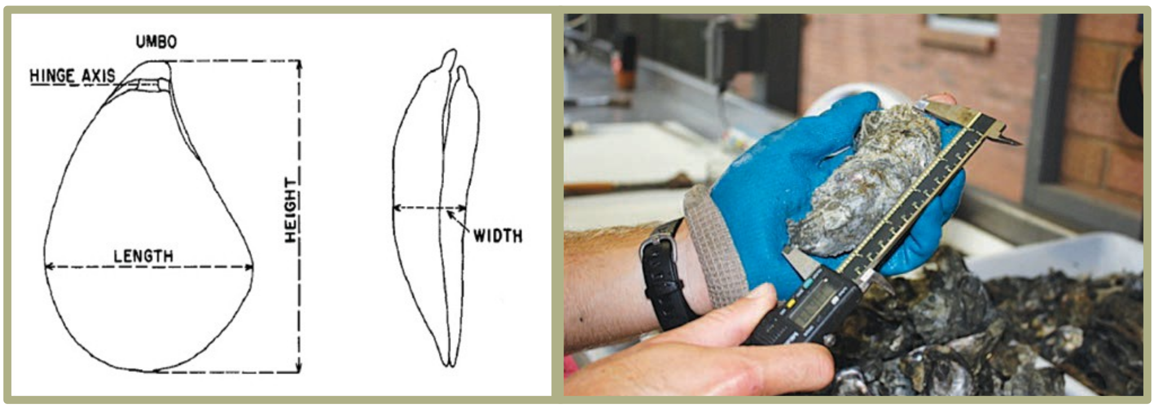


Figure 1: (left) Diagram of the height, length, and width measurements of an oyster shell, from Galtstoff 1964, Chapter 2. (right) An example of shell height measurement in a lab.

If the sample contains more than 100 live oysters, the remaining live oysters are counted. Live oysters are divided into one of three size classes (Table 1): spat (0-25 mm), seed (26-74 mm), and harvestable adult (75 mm and larger). The number of dead oysters in the sample is also counted.

Table 1: Oyster size classes

Size Class	**Oyster shell height (mm)**
Spat	0-25 mm
Seed	26-74 mm
Adult	≥75 mm

4. Data Entry

The oyster size data are entered in to an Excel spreadsheet and entries are separated into the size classes described above. Water quality parameters, weather conditions, wind, currents, and latitude and longitude are also entered into Excel. Next, all the data are proofed for quality control/quality assurance, and any errors are corrected. All Excel data and scanned copies of original data sheets are stored on the CPAP server.

5. Data Analysis
   Oyster populations are described in each bay by plotting parameters such as: total number of live vs. dead oysters, total number of oysters by size class, density of live oysters, average oyster size, etc.

   To determine the relative condition of oyster resources, an estimate of harvestable oysters is determined using FDACS' Standard Oyster Resource Management Protocol (see Appendix 1). This protocol has been used in Apalachicola Bay since 1982. FDACS uses a scale that states that 400 bags/acre could be harvested from productive artificially constructed reefs within two years of planting cultch. The scale is as follows:

   - More than 400 bags/acre = Healthy oyster reefs capable of sustaining commercial harvest.
   - More than 200 bags/acre = Oyster reefs capable of sustaining limited harvest.
   - Less than 200 bags/acre = Below level necessary to support commercial harvest.
   - Less than 100 bags/acre = Oyster reefs considered depleted.

   After the first two years of sampling, oyster populations will be compared using the Kruskal-Wallis test to determine significant differences between length-frequency distributions between reef sites.

6. Determining Spatial Extent of Cultched Areas
   Mapping of the cultched reefs will be conducted using high-resolution side scan sonar imagery collected using a Humminbird® side imaging system. Data will be imported and analyzed using spatial analysis software or another equivalent method as appropriate. Maps will be created depicting the extent of created or enhanced oyster reefs. At years 2, 4, 6, 8, and 10, the oyster cultch spatial extent will be analyzed to determine if reefal areas are equal to or greater than the design criteria for each bay.

7. Generation of Technical Reports
   CPAP submits an annual report to the DWH Project Manager detailing the recruitment, size, frequency of live oysters, frequency of recently dead oysters, and status of the shell material deployed. This report includes an estimate of harvestable oysters at each site, as well as the water quality and environmental parameters measured, and any recommendation for improving the enhanced site's productivity.

Monitoring Schedule

Safety is the top priority when determining sampling dates, as this type of monitoring is extremely weather dependent. Monitoring occurs twice a year (approximately every 6 months) during year 1 through 5 and annually during year 6 through 10. Bays are sampled in the same order that cultch material was placed; 1. Apalachicola Bay, which was shelled in October 2015; 2. St. Andrew Bay, which was cultched during June of 2016; and 3. Pensacola Bay; which was cultched in October 2016.

Note 1: During the Spring 2017 to Winter 2017/2018 sampling period, weather was a determining factor in sampling dates. Heavy rainfall and winds hampered sampling in Apalachicola Bay in Spring 2017, while windy weather coupled with frigid water temperatures delayed sampling in Winter 2017/2018. This resulted in a longer period than anticipated for rounds of sampling. Heavy rains along with Hurricane

Irma hitting the Panhandle area on September 11, 2017 delayed Summer/Fall 2017 sampling in Pensacola Bay.

Note 2: On October 10, 2018, Hurricane Michael impacted the Florida Panhandle as a Category 5 hurricane, causing major damage to Franklin County and surrounding areas. Monitoring efforts were delayed in Fall 2018 due to damaged equipment and poor water quality conditions caused by the storm.

Chapter 1: Apalachicola Bay

The Apalachicola Bay system (Figure 2) is a wide, shallow estuary that covers an area of approximately 210 square miles behind a chain of barrier islands (Gorsline, 1963). Its primary source of fresh water is the Apalachicola River. The estuarine system may be divided into four sections based on both natural bathymetry and man-made structural alterations; East Bay, St. Vincent Sound (which includes The Miles), Apalachicola Bay, and St. George Sound. Apalachicola Bay has over 4,000 acres of historically viable oyster reefs, with the bulk of the acreage included in the main bars of Cat Point, East Hole, and Dry Bar (FDACS, 2015). Approximately 24,840 cubic yards of fossilized oyster shell were placed on an estimated 124 acres of debilitated oyster reefs in the Apalachicola Bay system in Franklin County during October 2015. Figures 3-5 display maps of the cultched sites in Apalachicola Bay. GPS coordinates for each monitoring site's midpoint(s) are located in Table 2.

West Side (Figure 3)

- Eleven Mile: An unconsolidated natural oyster reefal complex. Reef is comprised primarily of a series of small natural oyster reefs (lumps/knobs), lying in a north-south configuration; each surrounded by a soupy-mud substrate. The reef is located in St. Vincent Sound in an Approved shellfish harvesting area. For monitoring purposes, this site was divided into two: Eleven Mile North and Eleven Mile South. Each site has one midpoint. These sites are located in the far western portion of Apalachicola Bay, in St. Vincent Sound, in an area commonly referred to as 'The Miles'.
- Bayou Flats: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching and relaying live oysters to the site. The reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located in St. Vincent Sound, near Big Bayou, in an Approved shellfish harvesting area. Bayou Flats has one midpoint for monitoring. This site is located in the far western portion of Apalachicola Bay, in St. Vincent Sound, in an area commonly referred to as 'The Miles'.
- Redfish Creek: An unconsolidated natural oyster reefal complex. Historically, portions of the reef received extensive restoration (1995 Job Training Partnership Act [JTPA] project). Reef is comprised primarily of a natural and planted oyster shell matrix. This reef is located north of St. Vincent Island, off Redfish Creek, in western Apalachicola Bay, in an Approved shellfish harvesting area. This site has been divided into two for monitoring: Redfish Creek Site #1 and Redfish Creek Site #2. Redfish Creek #1 has two midpoints, Redfish Creek #2 has one midpoint. These sites are located in the far western portion of Apalachicola Bay, in St. Vincent Sound, in an area commonly referred to as 'The Miles'.
- Cabbage Top: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. Reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located in St. Vincent Sound, north of St. Vincent Island, off of Cabbage Top, in a Conditionally Approved shellfish harvesting area. This site has two midpoints for monitoring.
- Cabbage Lumps: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. Reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located in St. Vincent Sound, north of St. Vincent Island, off of Cabbage Top, in a Conditionally Approved shellfish harvesting area. This site has one midpoint for monitoring.
- North Spur: Historically, portions of the reef have received extensive restoration by cultching. The substrate is primarily a natural and processed oyster shell matrix. The reef is located mid-bay, in Apalachicola Bay, in a Conditionally Approved shellfish harvesting area. North Spur has one monitoring midpoint.

- Green Point: Historically, portions of the reef have received extensive restoration by cultching. The substrate is primarily a natural and processed oyster shell matrix. Surrounding bottom is generally firm with sand shoals landward of the reef. The reef is located in Apalachicola Bay, in the vicinity of Green Point in a Conditionally Approved shellfish harvesting area. Green Point has one monitoring midpoint.
- Dry Bar: Large consolidated natural reefal complex; historically, portions of the reef have received extensive restoration by cultching. The reef is comprised primarily of a natural and planted oyster shell matrix. The surrounding bottom is generally firm. The reef is located offshore and northeast of the eastern end of St. Vincent Island, in a Conditionally Approved shellfish harvesting area. Dry Bar is divided into four midpoints for monitoring purposes.
- Little Gully: A consolidated natural reefal complex -an extension of Dry Bar; historically, portions of the reef have received restoration by cultching. The reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located northeast of the eastern end of St. Vincent Island, in a Conditionally Approved shellfish harvesting area. Little Gully is divided into two midpoints for monitoring purposes.

East Side (Figure 4)

- Norman's Bar: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. Reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located mid-bay, south of the John Gorrie Memorial Bridge, Apalachicola Bay, in a Conditionally Approved shellfish harvesting area. Norman's Bar is divided into two sites: Norman's Bar North and Norman's Bar Middle. Each site has two monitoring midpoints.
- Lighthouse Bar: An unconsolidated, natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. Reef is comprised primarily of a natural and planted oyster shell matrix. The reef is located in Apalachicola Bay, in a Conditionally Approved shellfish harvesting area. Lighthouse has two midpoints for monitoring.
- Cat Point: A large natural oyster reefal complex; portions of the reef have received restoration by cultching and relaying live oysters to the site. Cat Point bar is the prominent natural feature separating eastern Apalachicola Bay and St. George Sound. The reef is comprised primarily of a natural and planted oyster shell matrix. The surrounding bottom is generally firm with sand shoals landward of the reef. The reef is located in Apalachicola Bay, in the vicinity of Eastpoint, in a Conditionally Approved shellfish harvesting area. Cat Point has two midpoints for monitoring.
- Hotel Bar: Reef is a large, consolidated natural oyster complex; portions of the reef have received extensive restoration by cultching. The substrate is primarily a natural and processed oyster and clam shell matrix. The surrounding bottom is generally firm with sand shoals landward of the reef. The reef is located offshore of St. George Island, between the Intracoastal Waterway (ICWW) and the northern shoreline of St. George Island, in the vicinity of the Bryant Patton Bridge, in a Conditionally Approved shellfish harvesting area. Hotel Bar has three monitoring midpoints.

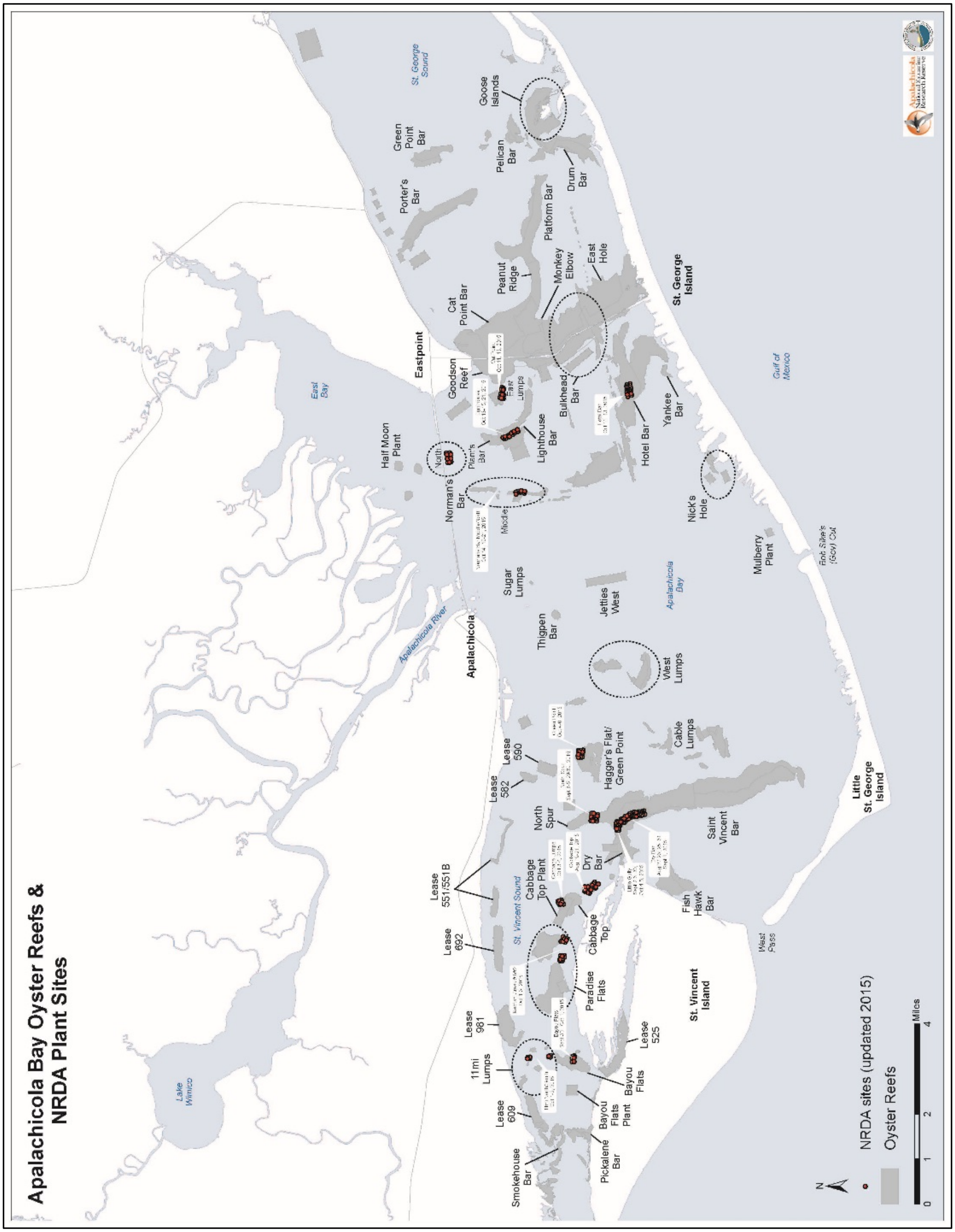


Figure 2: Map of oyster reefs for Apalachicola Bay. NRDA plant sites are indicated by a red dot.

Apalachicola NRDA Sites and Midpoints (West)

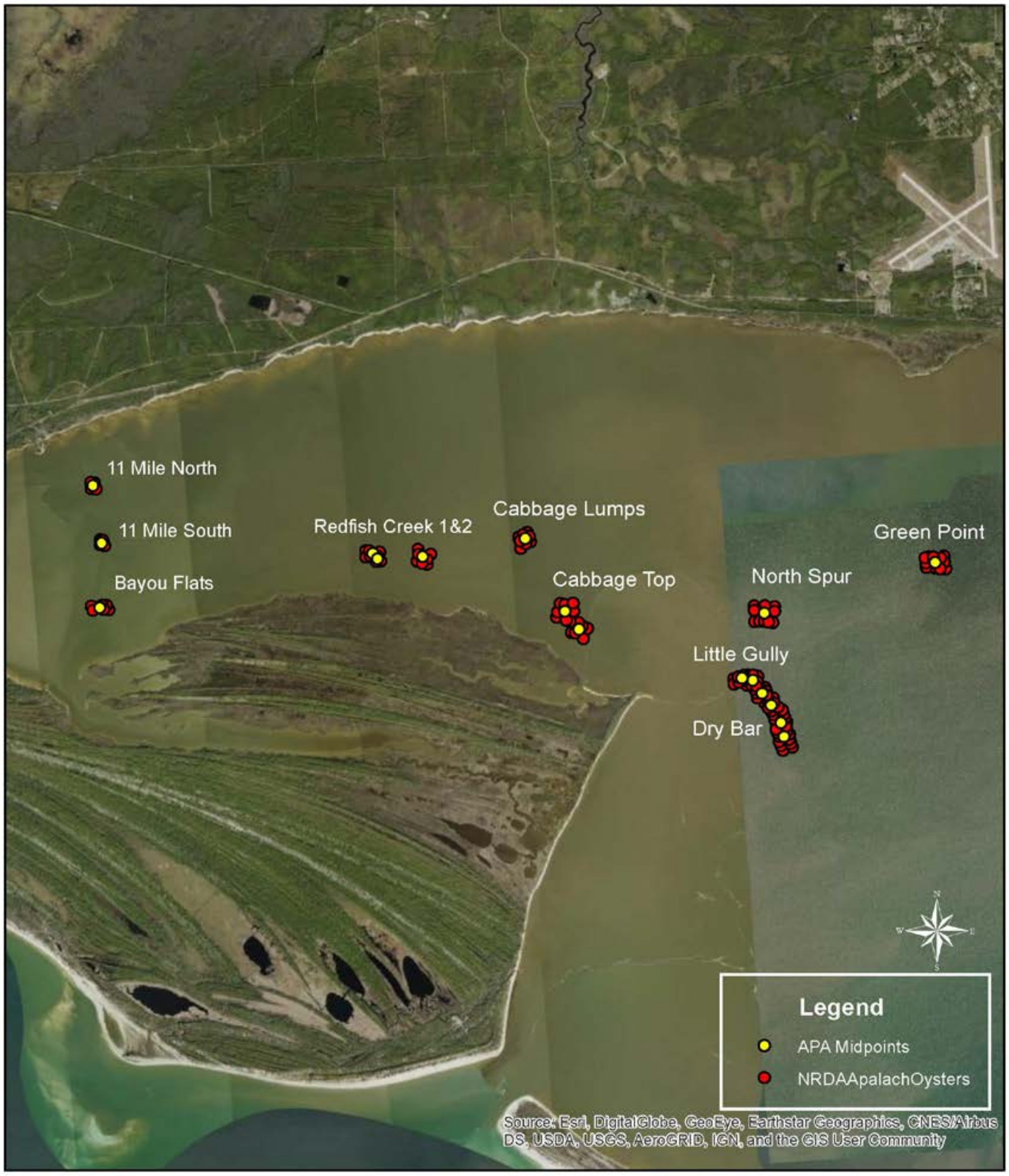


Figure 3. Apalachicola Sites with Midpoints in the West region of the bay. Eleven Mile North, Eleven Mile South, Bayou Flats, and Redfish Creek #1 & #2 are located in an area referred to as 'The Miles'.

Figure 4: Apalachicola Bay Sites with Midpoints in the East region of the bay.

Table 2: Coordinates for Apalachicola Bay Monitoring Sites.

Monitoring Site	Latitude	Longitude
West		
Eleven Mile North, Midpoint 1	29.70263	-85.14673
Eleven Mile South, Midpoint 1	29.69583	-85.14605
Bayou Flats, Midpoint 1	29.68821	-85.14692
Redfish Creek #1, Midpoint 1	29.69238	-85.10965
Redfish Creek #1, Midpoint 2	29.69173	-85.10903
Redfish Creek #2, Midpoint 1	29.69161	-85.1029
Cabbage Top, Midpoint 1	29.68405	-85.08428
Cabbage Top, Midpoint 2	29.68184	-85.08252
Cabbage Lumps, Midpoint 1	29.6929	-85.08897
North Spur, Midpoint 1	29.68219	-85.05745
Green Point, Midpoint 1	29.68675	-85.03391
Dry Bar, Midpoint 1	29.67278	-85.05849
Dry Bar, Midpoint 2	29.67133	-85.05734
Dry Bar, Midpoint 3	29.66919	-85.05614
Dry Bar, Midpoint 4	29.66754	-85.05592
Little Gully, Midpoint 1	29.67477	-85.06106
Little Gully, Midpoint 2	29.67443	-85.05958
East		
Norman's Bar North, Midpoint 1	29.72994	-84.92533
Norman's Bar North, Midpoint 2	29.73007	-84.92365
Norman's Bar Middle, Midpoint 1	29.70747	-84.93716
Norman's Bar Middle, Midpoint 2	29.70633	-84.9371
Lighthouse Bar, Midpoint 1	29.71107	-84.9167
Lighthouse Bar, Midpoint 2	29.70844	-84.91484
Cat Point, Midpoint 1	29.71296	-84.90185
Cat Point, Midpoint 2	29.71286	-84.89897
Hotel Bar, Midpoint 1	29.6721	-84.90031
Hotel Bar, Midpoint 2	29.67209	-84.89886
Hotel Bar, Midpoint 3	29.67224	-84.89768

Data Analysis for Apalachicola Bay 2017 - 2019

Apalachicola Bay NRDA Oyster Cultch Placement sites were sampled during April – July 2017 (Round 1), December 2017 – April 2018 (Round 2), and September – December 2019 (Round 3). A total of 16 reef sites consisting of 28 midpoints were sampled during each round (see Table 2 and Figures 3 & 4).

To date, a total of 2506.1 kilograms (5,525 pounds) of oyster/shell material has been collected in Apalachicola Bay, with an overall average sample weight of 1.99 kg (4.39 lbs.) among all sampling rounds. The average sample weight collected among sites sampled in Apalachicola Bay has continued to decrease each sampling round, from 2.39 kg in Round 1 to 1.55 kg in Round 3. For Round 3, Eleven Mile South had the largest average sample weight among all sites (3.12 kg) while Cabbage Top had the smallest (0.55 kg). The average sample weight per site for each sampling round is displayed in Table 3 below. Statistical analysis of weight per sample showed a significant decrease in the average sample weight in Apalachicola Bay from both Round 1 to Round 3 and from Round 2 to Round 3 ($p=6.82x10^{-14}$ and $p=2.37x10^{-7}$, respectively). When the oyster clutch is placed, it is not spread in a uniform way, which results in clusters and bare spots throughout the reef. This is supported by the variation in the average sample weight between sites and rounds.

Table 3: Average sample weights per site for Rounds 1-3.

Site	Round 1 Average Sample Weight (kg)	Round 2 Average Sample Weight (kg)	Round 3 Average Sample Weight (kg)
Bayou Flats	4.80	0.94	2.83
Cabbage Lumps	1.79	1.80	1.66
Cabbage Top	1.05	0.77	0.55
Cat Point	2.15	2.18	1.17
Dry Bar	2.58	1.76	0.91
Eleven Mile North	2.17	1.40	1.24
Eleven Mile South	4.95	3.26	3.12
Green Point	0.65	2.10	1.28
Hotel Bar	1.69	2.03	1.68
Lighthouse Bar	2.31	2.48	2.04
Little Gully	2.35	1.63	1.21
Norman's Bar Middle	2.00	2.70	1.47
Norman's Bar North	2.61	3.25	1.82
North Spur	1.24	2.17	2.52
Redfish Creek #1	3.52	1.56	1.63
Redfish Creek #2	3.95	2.78	2.34

Over the course of sampling, a total of 18,256 live oysters and 5,273 dead oysters have been collected in Apalachicola Bay (Figure 5). Approximately 10.29% of all live oysters collected in Apalachicola Bay during the project duration have come from Round 3 of sampling. The total number of live oysters collected in Round 3 (n=1879) decreased from both Rounds 1 (n=7479) and Round 2 (n=8898). A t-test analysis of live oysters collected per sample showed that the decrease in live oysters from Round 1 and Round 2 were both statistically significant ($p=3.79x10^{-18}$ and $p=2.81x10^{-13}$, respectively). A decrease in dead oysters sampled was also observed from Round 1 (n=3451) to Round 3 (n=191) and Round 2 (n=1631) to Round 3. The decreases in dead oysters observed per sample from Round 1 and Round 2 were also found to be statistically significant ($p=1.66x10^{-21}$ and $7.29x10^{-25}$, respectively).

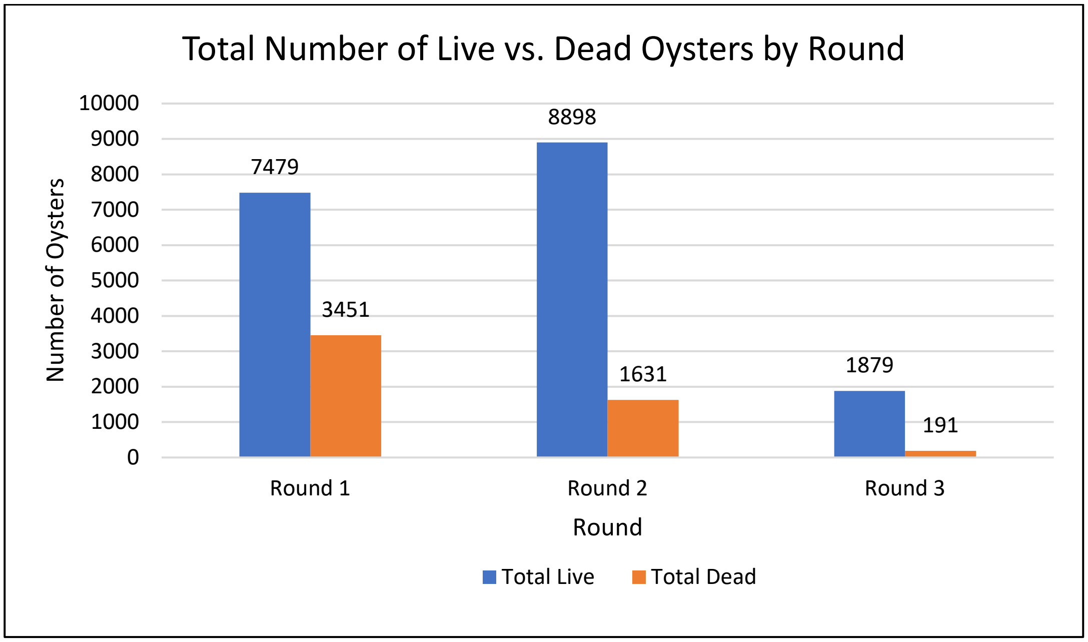


Figure 5: Total number of live vs. dead oysters by sampling round.

A comparison of size classes among live oysters showed that spat-sized oysters continued to be the most prevalent size class in all sampling rounds, representing approximately 79.91% of total live oysters processed to date and roughly 88.66% of total live oysters processed during Round 3 of sampling (Figure 6). Adult-sized, harvestable oysters continued to represent the least abundant size class. Statistically significant decreases in live oysters sampled were observed across all size classes (spat, seed, and adult) from Round 1 to Round 3 ($p=8.31x10^{-11}$, $p=2.09x10^{-12}$, and $p=1.81x10^{-9}$, respectively). Significant decreases were also observed across all size classes from Round 2 to Round 3 ($p=4.45x10^{-12}$, $p=6.05x10^{-9}$, and $p=7.09x10^{-6}$, respectively).

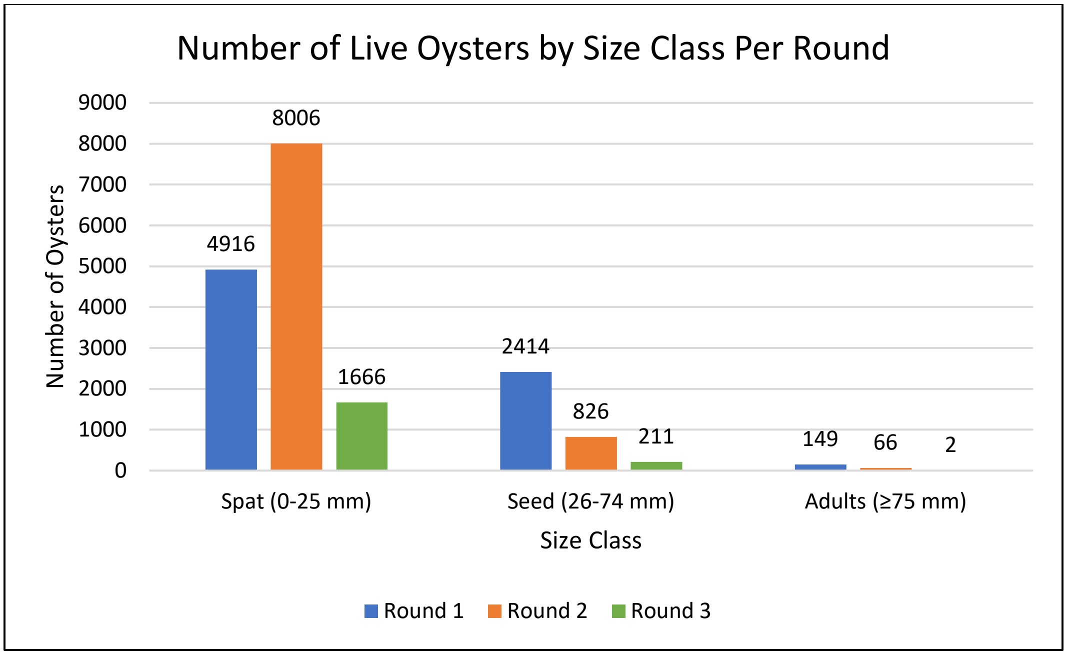


Figure 6: Number of live oysters by size class per sampling round.

Anecdotally, local oystermen have said that oyster populations on the west side of Apalachicola Bay have been declining more rapidly than those on the east side, particularly in the area referred to as 'The Miles'. To account for potential regional differences, , sites were separated by geographic location in Apalachicola Bay. Sites located to the east of the Apalachicola River (Cat Point, Hotel Bar, Lighthouse Bar, Norman's Bar Middle, and Norman's Bar North) were considered "East" sites, and those located to the west of the river (Bayou Flats, Cabbage Lumps, Cabbage Top, Dry Bar, Eleven Mile North, Eleven Mile South, Green Point, Little Gully, North Spur, Redfish Creek #1, and Redfish Creek #2) were considered "West".

For all rounds of sampling, the East side of the bay contained more live oysters across all size classes than the West side (Figure 7). The number of spat-sized oysters on the East side nearly doubled from Round 1 to Round 2, but drastically decreased from Round 2 to Round 3, with only 971 spat sampled. Both seed-sized and adult-sized oysters have continued to decline on the East side of the bay. The only adult-sized, harvestable oysters collected during Round 3 sampling were found on the East side of the bay, at Norman's Bar North (n=2). The number of spat-sized and seed-sized oysters increased slightly from Round 2 to Round 3 sampling on the West side of the bay. However, a decrease in adult-sized oysters was observed from Round 2 to Round 3, as no adult oysters were present in samples collected from the West side of the bay during Round 3. Decreases in number of live oysters across all size classes were observed on the West side when comparing Round 3 to Round 1.

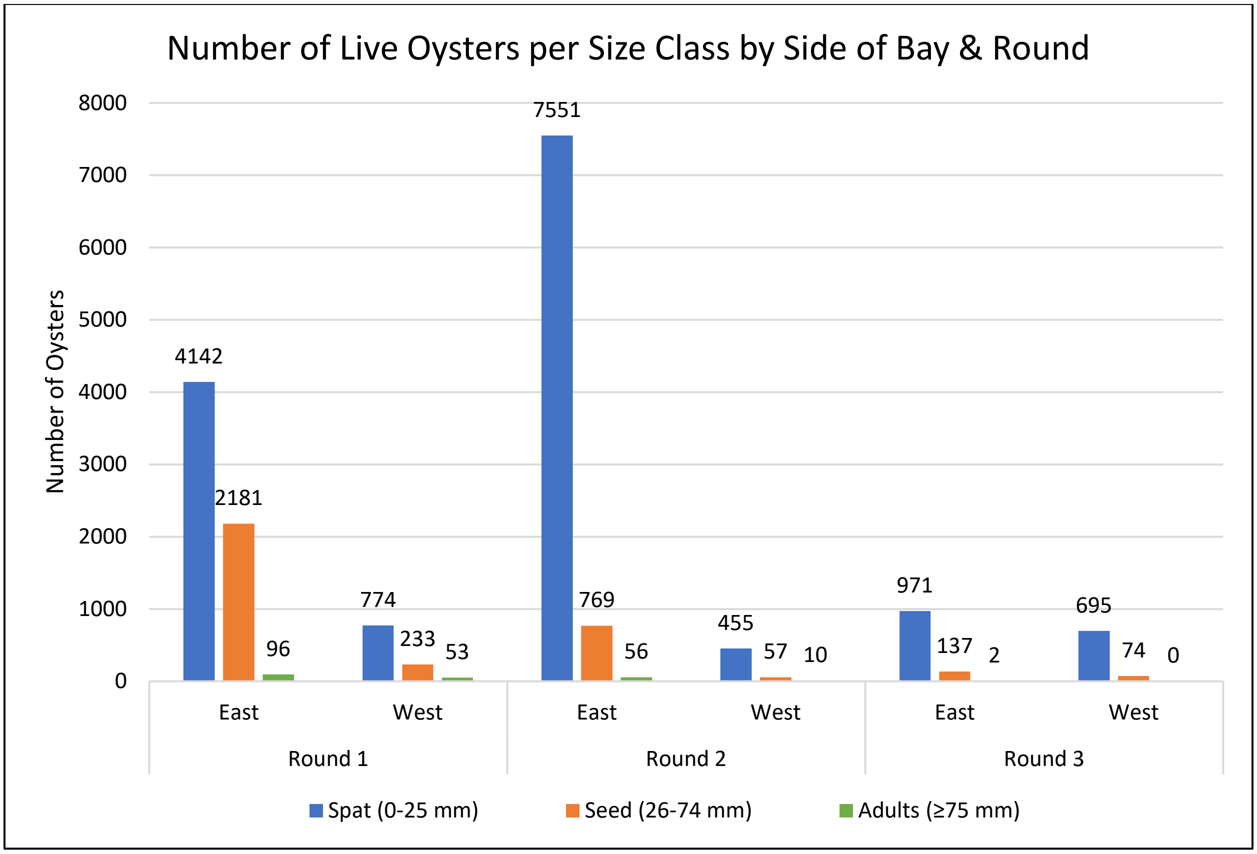


Figure 7: Number of live oysters per size class by side of bay and sampling round.

When analyzed by site, nine of the 16 sampling sites (Cabbage Lumps, Cabbage Top, Cat Point, Green Point, Hotel Bar, Lighthouse Bar, Norman's Bar Middle, Norman's Bar North, and North Spur) saw a decrease in the number of spat-sized oysters collected from Round 2 to Round 3, which includes all sites on the East side of the bay. The most notable decreases were observed at Hotel Bar, Lighthouse Bar, and Cat Point. (Figure 8).

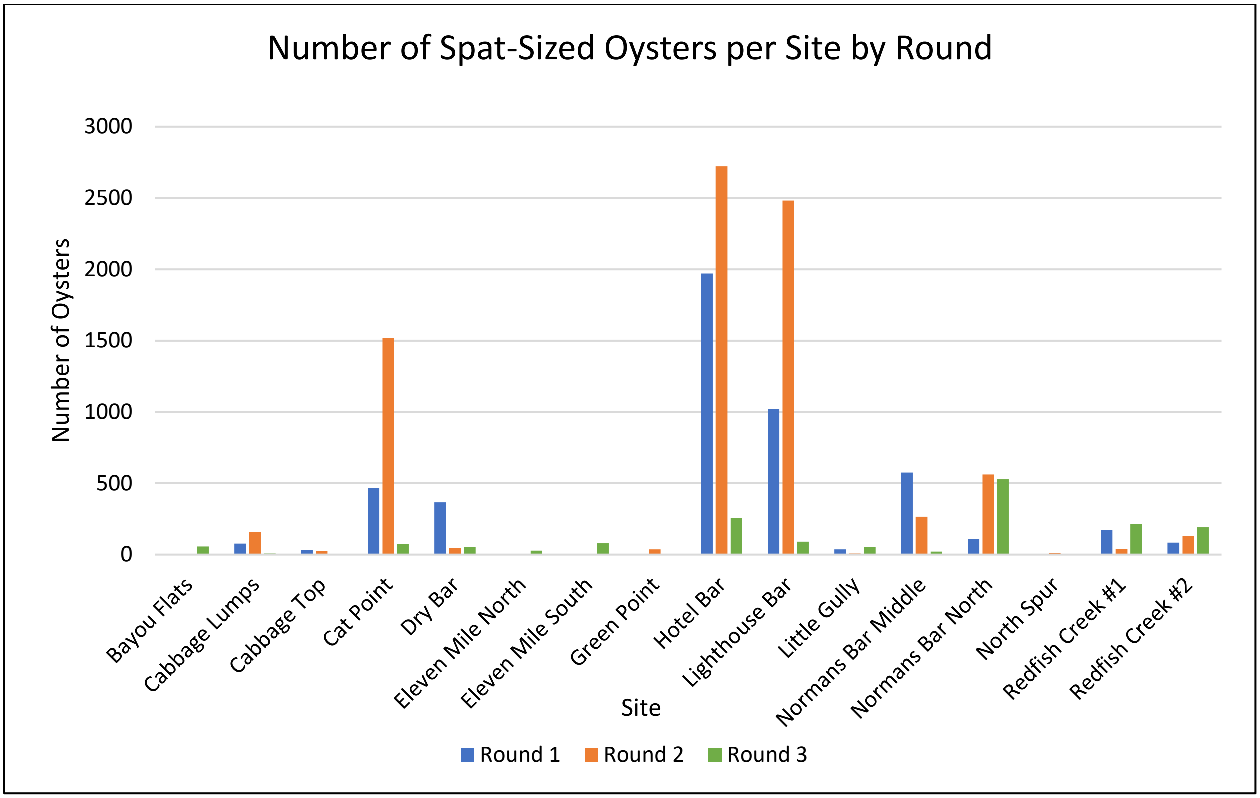


Figure 8: Number of spat-sized oysters per site by round.

The majority of sites in Apalachicola Bay saw a decrease in seed-sized oysters sampled from Round 2 to Round 3. (Figure 9). More than half (51.18%) of the total seed-sized oysters sampled during Round 3 were collected from one site, Norman's Bar North; however, the number of seed collected from this site decreased by 70% from Round 2 (n=360) to Round 3 (n=108). Five of the sites (Bayou Flats, Green Point, Little Gully, Norman's Bar Middle and North Spur) contained zero seed-sized oysters in Round 3 samples.

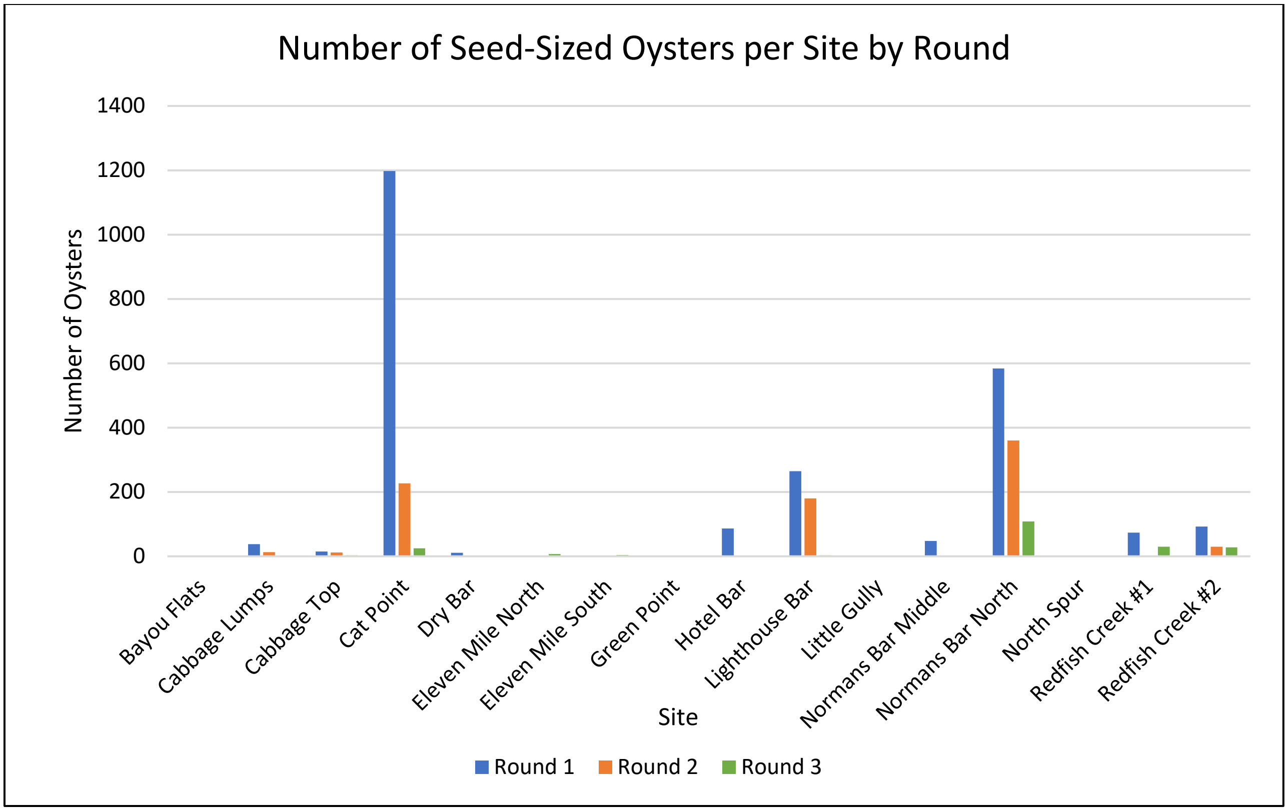


Figure 9: Number of seed-sized oysters per site by round.

Norman's Bar North was the only site that had adult-sized oysters present in Round 3 (n=2), which is less than the number of adult oysters sampled at Norman's Bar North in Round 1 (n=15) and in Round 2 (n=36).

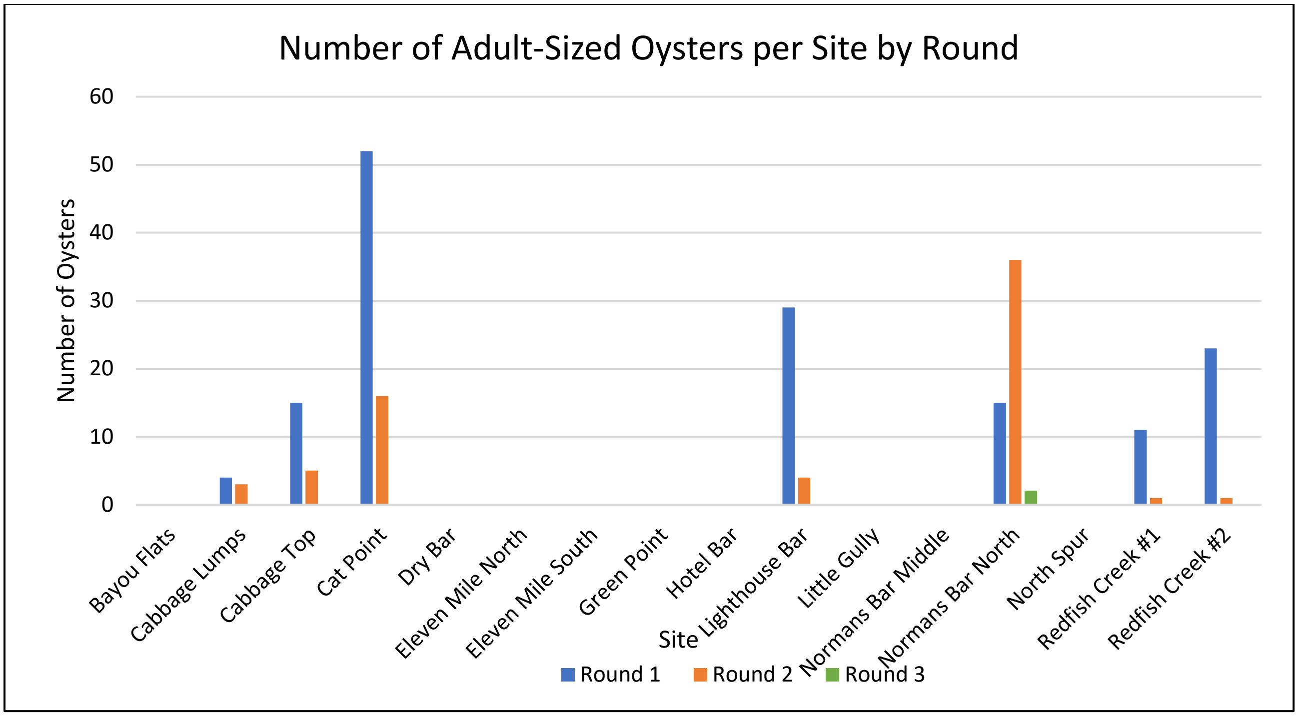


Figure 10: Number of adult-sized oysters per site by round.

The average shell height for oysters collected in Apalachicola Bay in Rounds 1, 2, and 3 of sampling was 23.52 mm, 15.73 mm and 16.34 mm, respectively. The decrease in average shell height from Round 1 to Round 3 was found to be statistically significant ($p=8.8x10^{-112}$), as was the increase in average shell height from Round 2 to Round 3 ($p=0.02$). All average shell heights are representative of the spat-sized oyster class (0-25mm). Shell height distribution of all measured oysters was plotted (Figure 10). A shell height of 11-15 mm was observed most frequently among live oysters collected in Apalachicola Bay in Round 3. Across all rounds, a shell height of 6-10 mm was most prevalent.

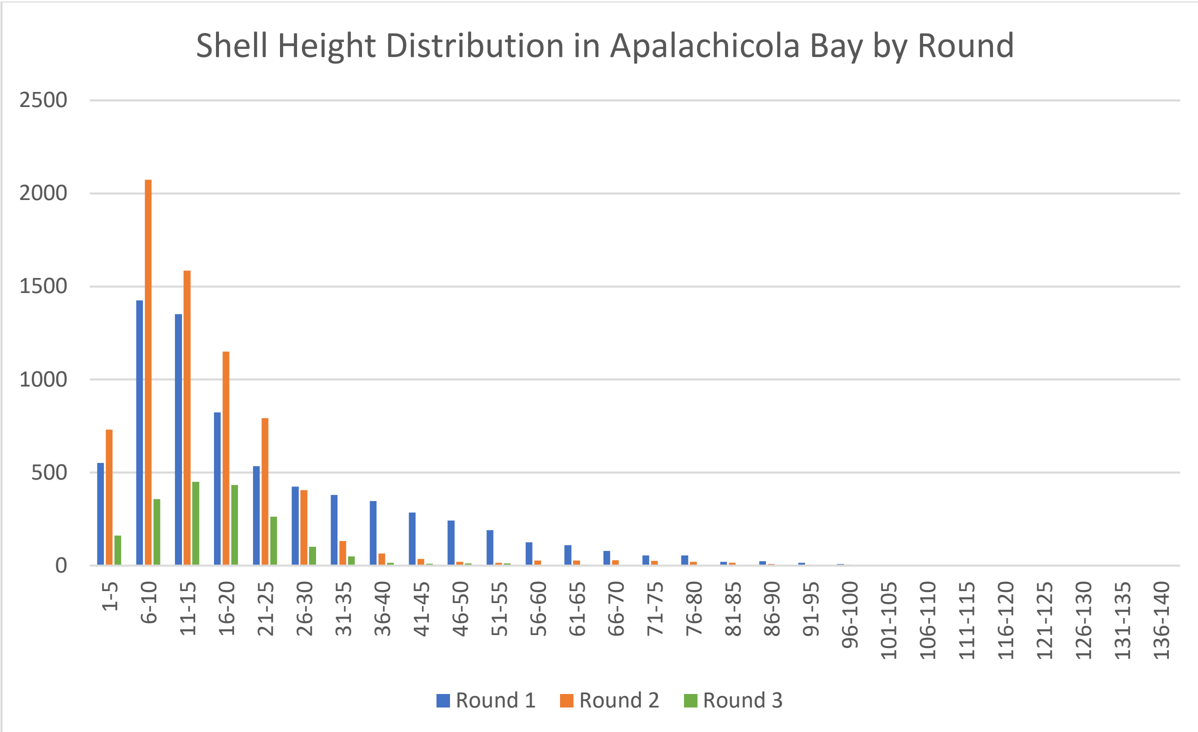


Figure 10: Shell height distribution by sampling round for the entire bay.

The shell height distributions of live oysters collected from both the West and East sides of Apalachicola Bay followed similar frequency distribution patterns to that of the entire bay (Figures 11 & 12). A shell height of 6-10 mm was observed most frequently among live oysters collected on the West side of the bay in Rounds 1 and 3, while oysters in the 16-20 mm shell height range were observed more frequently in Round 2 (Figure 11). To date, approximately 81.84% of all oysters measured on the West side of the bay have been in the spat size class. Oysters observed on the East side of the bay for Rounds 1 and 3 were most frequently observed in the 11-15 mm shell height range, while in Round 2 most live oysters occurred in the slightly smaller shell height range of 6-10 mm (Figure 12). The spat size class represents approximately 79.62% of all live oysters measured from the East side of the bay to date.

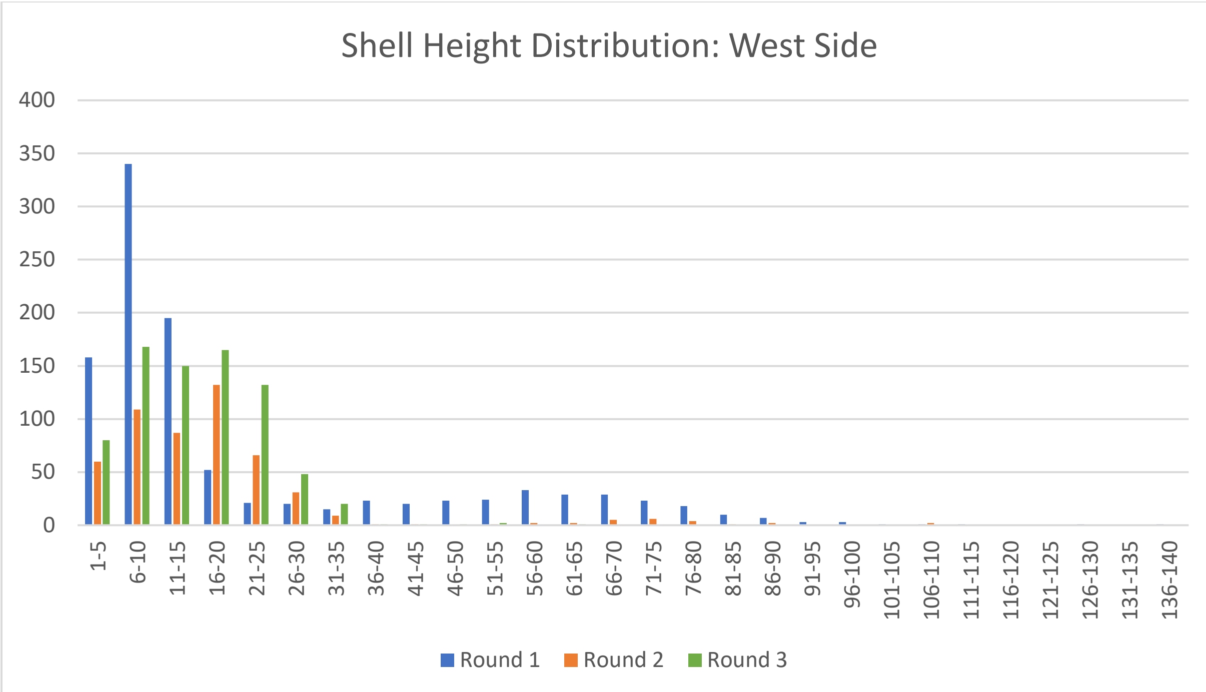


Figure 11: Shell height distribution by sampling round for the West side of the bay.

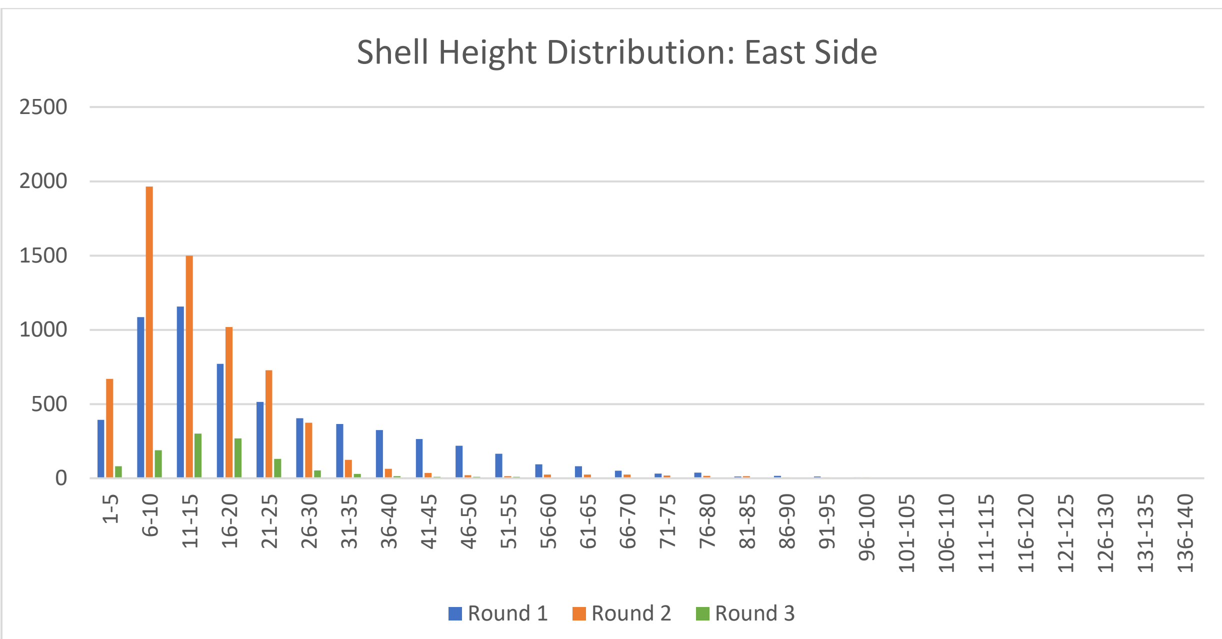
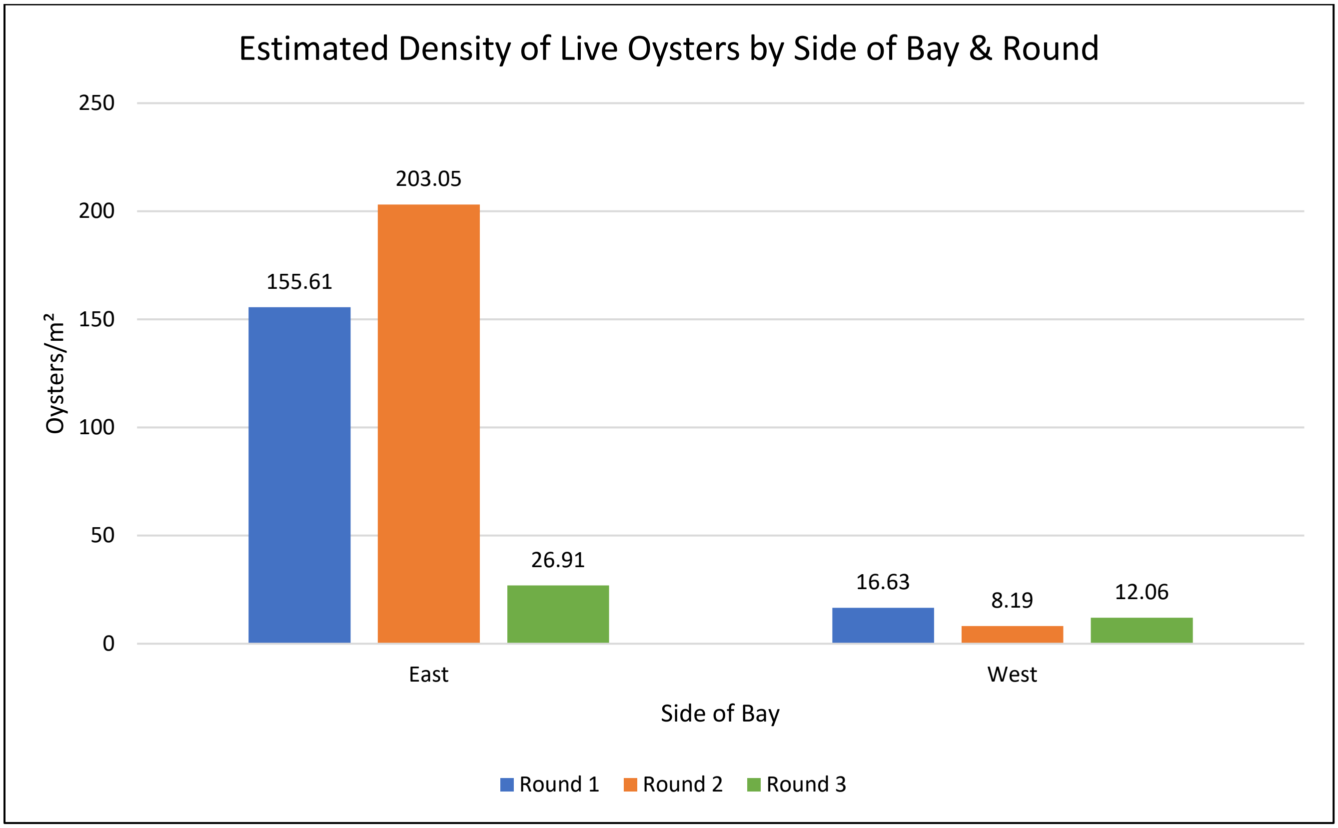


Figure 12: Shell height distribution by sampling round for the East side of bay.

To account for any bias based on the difference in sampling effort among sites, estimates of the density of live oysters (live oysters/m²) were calculated. The estimated overall density (live oysters/m²) in Apalachicola Bay increased from Round 1 to Round 2 (71.23 to 84.74 oysters/m^2, respectively) but estimated overall density drastically decreased to 17.90 live oysters/m^2 in Round 3.

When comparing sides of the bay, the estimated density of live oysters was greater on the East side than the for than the West side for all sampling rounds. A notable decrease in the estimated density of live oysters was observed in Round 3 (n=26.91 live oysters/m^2) from Rounds 1 and 2 (n= 155.61 live oysters/m^2 and n=203.05 live oysters/m^2, respectively). Estimated density of live oysters on the West side of the bay increased slightly from Round 2 to Round 3 sampling (8.19 to 12.06 live oysters/m^2, respectively), but still remains low. The estimated density of live oysters on the West side decreased slightly overall from Round 1 (n=16.63 live oysters/m^2) to Round 3.



The estimated density of live oysters varied greatly by site (Figure 13). Cat Point had the highest estimated oyster density during the first round of sampling (228.80 live oysters/m^2), while Lighthouse Bar had the highest for Round 2 (355.60 oysters/m^2). Norman's Bar North had the highest estimated oyster density (85.07 live oysters/m^2) for Round 3 of sampling, which is considerably less than the highest densities of previous rounds. A decline in estimated oyster density was observed at more than half of the sampling sites (Cabbage Lumps, Cabbage Top, Cat Point, Green Point, Hotel Bar, Lighthouse, Norman's Bar Middle, Norman's Bar North and North Spur) from Round 2 to Round 3. The greatest decline was observed at Lighthouse Bar, which decreased from 355.60 to 12.53 live oysters/m^2 from Round 2 to Round 3.

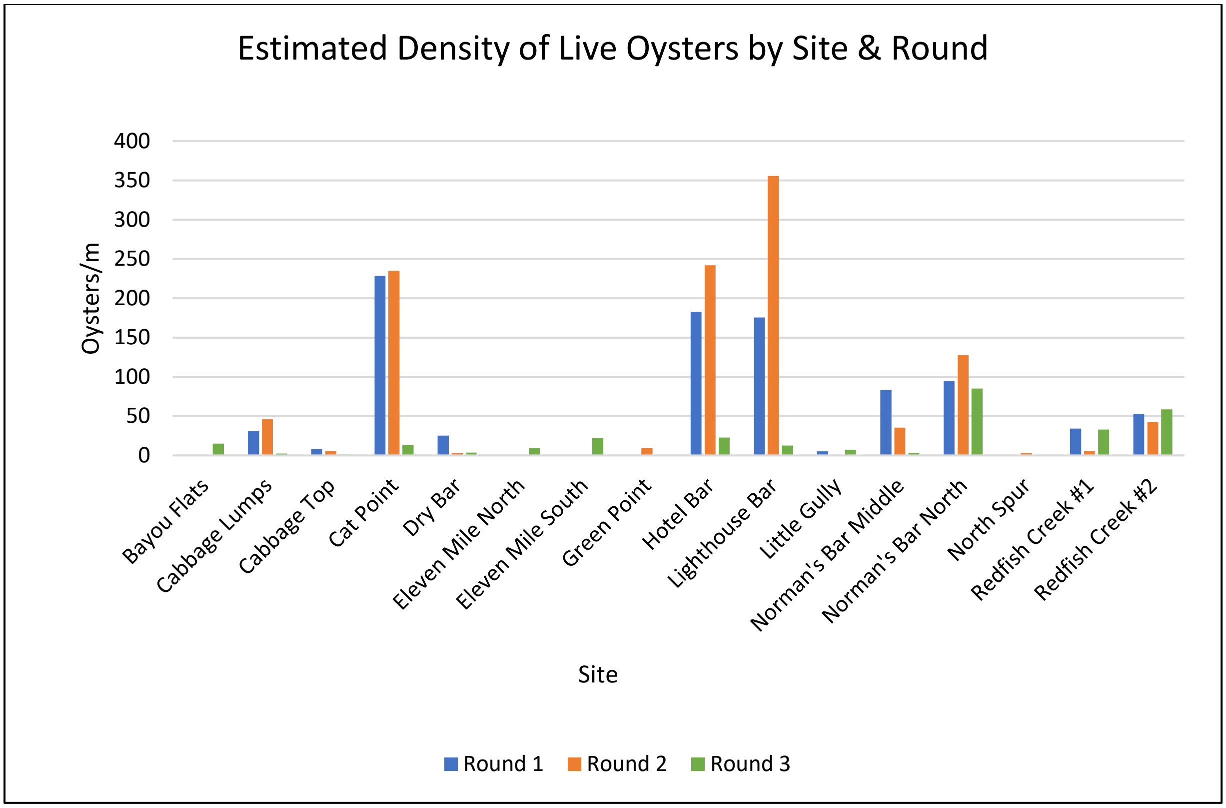


Figure 13: Estimated density of live oysters (oysters/m²) by site and sampling round.

FDACS Standard Oyster Resource Management Protocol

FDACS protocols were used to estimate the number of bags of harvestable oysters per site (see Appendix 1). Table 4 compares the estimated bags per acre per site by sampling round. The only site observed in Round 3 with an estimated bags/acre of harvestable oysters above 0.00 was Norman's Bar North (4.80 bags/acre). None of the sites sampled in Apalachicola Bay in Round 3 were capable of sustaining commercial harvest, and all are considered depleted.

Table 4: Estimated bags/acre per site by sampling round.

Site	Bags per acre Round 1	Bags per acre Round 2	Bags per acre Round 3
Bayou Flats	0.00	0.00	0.00
Cabbage Lumps	19.19	14.39	0.00
Cabbage Top	35.97	11.99	0.00
Cat Point	124.71	38.37	0.00
Dry Bar	0.00	0.00	0.00
Eleven Mile North	0.00	0.00	0.00
Eleven Mile South	0.00	0.00	0.00
Green Point	0.00	0.00	0.00

Hotel Bar	0.00	0.00	0.00
Lighthouse	69.55	9.59	0.00
Little Gully	0.00	0.00	0.00
Norman's Bar Middle	0.00	0.00	0.00
Norman's Bar North	35.97	86.34	4.80
North Spur	0.00	0.00	0.00
Redfish Creek #1	26.38	2.40	0.00
Redfish Creek #2	110.32	4.80	0.00

For reference, FDACS uses the following scale:

- More than 400 bags/acre = Healthy oyster reefs capable of sustaining commercial harvest.
- More than 200 bags/acre = Oyster reefs capable of sustaining limited harvest.
- Less than 200 bags/acre = Below level necessary to support commercial harvest.
- Less than 100 bags/acre = Oyster reefs considered depleted.

It is evident that neither the East nor West side of the bay are capable of producing enough adult oysters to sustain commercial harvest (Figure 14). The number of bags per acre of harvestable oysters has decreased over time on both sides of the bay. The estimated number of harvestable oysters on the East side of the bay, which has historically been more productive, has decreased by approximately 98% at cultched sites since the beginning of project sampling.

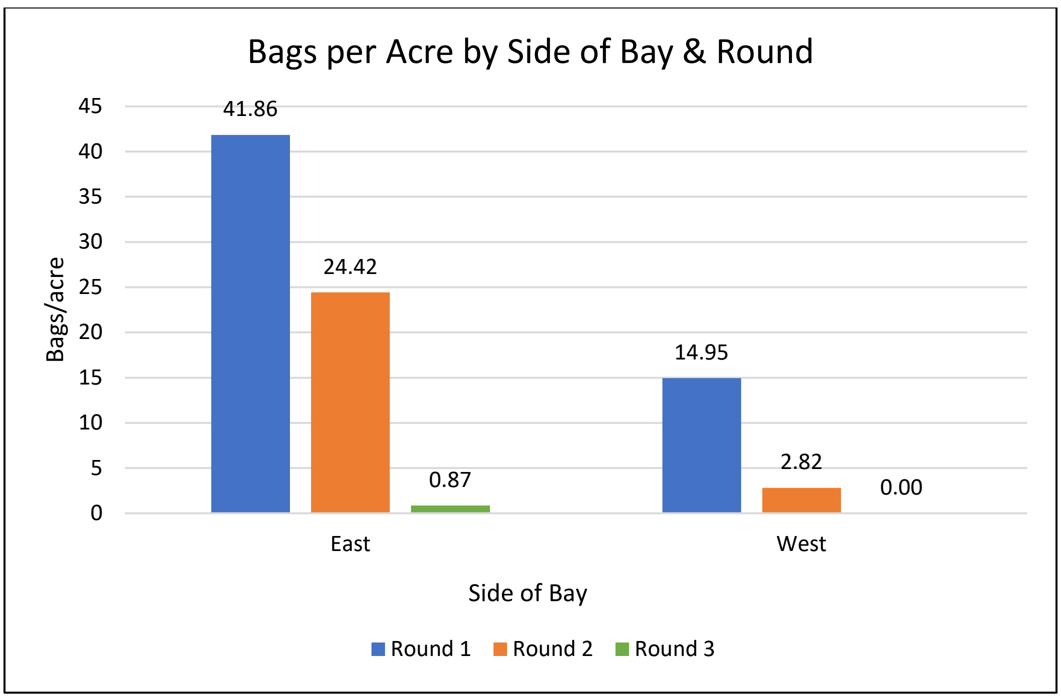


Figure 14: Estimated average bags per acre by side of bay and round.

Discussion

The Florida Oyster Cultch Placement Project seeks to foster oyster reef habitat development by restoring existing, degraded oyster reefs that have reached their productive lifespan. In October 2015, approximately 24,840 cubic yards of fossilized oyster shell was deposited on an estimated 124 acres (16 sites) of debilitated oyster reef in the Apalachicola Bay system. Monitoring of all cultched sites will occur annually for a period of 10 years to evaluate project success.

In optimal conditions, oysters can reach market size in 12 to 18 months after settling (Ingle and Dawson, 1952). However, some reefs may take two to five years to become productive due to variable recruitment and survival. Monitoring results indicate that conditions are not optimal, as limited adult oysters have been observed on the east side of the bay, and no adults were collected on the west side in Round 3. As previously mentioned, the decline in adult-sized, harvestable oysters in Apalachicola Bay was considered statistically significant when compared to Round 1 and Round 2. Spat-sized (0-25 mm) oysters have been most frequently observed in all sampling rounds; it is expected that as those oysters continue to grow, a sufficient number of oysters collected in subsequent rounds would have a larger shell height range (seed or adult-sized). Overall, this shift in shell height distribution has not been observed. Natural mortality (disease, predation, etc.) can account for decreased survivorship of individual oysters over time; however, it appears that oysters of sub-adult size are not surviving to adulthood sufficiently to sustain commercial harvest in Apalachicola Bay.

Round 2 sampling occurred in late 2017/early 2018, and CPAP planned to sample Apalachicola Bay reefs for Round 3 in the Fall of 2018. However, on October 10, 2018, Hurricane Michael greatly impacted coastal regions along Florida's Panhandle. Due to Hurricane Michael and other unforeseen circumstances (staff medical issues, staffing issues, boat repairs, etc.), staff was not able to complete Round 3 sampling in Apalachicola Bay until the Fall of 2019. Total numbers of live and dead oysters observed significantly decreased between Round 2 and 3; overall live oyster density estimates sharply decreased on the east side of the bay, while the west side of the bay exhibited a slight increase in oyster density, although it remains low. Many factors contribute to oyster survival, and post-hurricane conditions (i.e. altered salinity regimes, algal blooms, etc.) may have caused oyster populations to suffer losses. It is unfortunate that one year elapsed between Round 2 and 3; immediate impacts to oyster reef populations by Hurricane Michael remains unknown. Immediate post-hurricane data could have indicated direct impacts to oyster populations, as well as provided insight into how major tropical events impact Apalachicola Bay as a whole.

It seems very possible that oyster reefs and/or cultch material may have been displaced because of the hurricane. Many reefs (~81%) have seen a decrease in sample weight since the beginning of project monitoring. The five sites with the largest decrease in average sample weight from Round 1 to Round 3 can be found on the West side of the bay (Bayou Flats, Dry Bar, Eleven Mile South, Redfish Creek #1, and Redfish Creek #2), possibly indicating differences in sediment transport regionally in Apalachicola Bay. During sampling, CPAP observed that some reefs were silted over; cultch material could be felt under a layer of silt and mud (i.e. Cabbage Top). Some of the reefs, such as Dry Bar, did not have much material present; much of the cultch material had been covered by sand. It is unfortunate mapping of the cultched reefs did not occur after initial cultch deposition to record a baseline footprint of each reef area. It would have been ideal to compare initial cultched area versus the current reef area for a more accurate comparison of change in reef extent over time. Based on samples of cultch material collected throughout the course of sampling, it is anticipated that reef area will have declined from original clutched reef footprint on some reefs, specifically in 'The Miles' on the west side of the bay. Mapping the reefal area of all reefs in the Spring and Summer of 2020 will enable CPAP to estimate reef area loss or gains.

Water Quality Monitoring

As sessile, benthic filter feeders, oysters are heavily dependent on and influential of the water they inhabit. Multiple water quality parameters (temperature, dissolved oxygen (DO), salinity, and pH) for each site were recorded at both bottom and surface depths (Table 5). This data provides a 'snapshot' of the conditions at the time of sampling; as additional sampling occurs, water quality data will be analyzed to investigate long-term trends in water quality at each site and across the bay.

Table 5: Water quality parameter measurements in Apalachicola Bay.

Site	Midpoint	Round	Sample Position	Temperature (Celcius)	DO (mg/L)	Salinity (ppt)	pH
Bayou Flats	1	1	Surface	31.4	6.71	31.07	8.04
Bayou Flats	1	1	Bottom	31.6	6.62	30.96	8.13
Cabbage Lumps	1	1	Surface	28.4	8.68	5.68	8.27
Cabbage Lumps	1	1	Bottom	28.5	6.33	9.32	7.94
Cabbage Top	2	1	Surface	28.4	8.21	6.57	8.22
Cabbage Top	2	1	Bottom	28.9	6.40	9.50	7.97
Cabbage Top	1	1	Surface	28.4	8.21	6.57	8.22
Cabbage Top	1	1	Bottom	28.9	6.40	9.50	7.97
Cat Point	1	1	Surface	24.6	6.18	28.42	7.73
Cat Point	1	1	Bottom	24.6	6.05	28.43	7.75
Cat Point	2	1	Surface	24.6	6.18	28.42	7.73
Cat Point	2	1	Bottom	24.6	6.05	28.43	7.75
Dry Bar	2	1	Surface	27.1	5.89	23.45	8.02
Dry Bar	2	1	Bottom	27.1	4.75	24.73	7.93
Dry Bar	1	1	Surface	27.1	5.89	23.45	8.02
Dry Bar	1	1	Bottom	27.1	4.75	24.73	7.93
Dry Bar	3	1	Surface	27.3	6.04	2.07	7.44
Dry Bar	3	1	Bottom	29.0	4.69	23.09	7.91
Dry Bar	4	1	Surface	27.3	6.04	2.07	7.44
Dry Bar	4	1	Bottom	29.0	4.69	23.09	7.91
Eleven Mile North	1	1	Surface	21.8	7.04	23.64	7.83
Eleven Mile North	1	1	Bottom	22.2	5.93	28.22	7.78
Eleven Mile South	1	1	Surface	22.1	7.28	25.11	7.90
Eleven Mile South	1	1	Bottom	22.0	6.70	27.00	7.88
Green Point	1	1	Surface	26.0	7.46	22.14	8.26
Green Point	1	1	Bottom	26.1	6.20	29.36	8.38
Hotel Bar	1	1	Surface	23.0	7.76	15.77	7.89
Hotel Bar	1	1	Bottom	22.8	6.65	28.41	7.67
Hotel Bar	2	1	Surface	23.3	7.67	16.04	7.95

Hotel Bar	2	1	Bottom	23.3	6.59	28.51	7.82
Hotel Bar	3	1	Surface	23.3	7.67	16.04	7.95
Hotel Bar	3	1	Bottom	23.3	6.59	28.51	7.82
Lighthouse	1	1	Surface	26.0	6.69	16.54	8.04
Lighthouse	1	1	Bottom	26.5	5.79	22.35	7.96
Lighthouse	2	1	Surface	26.0	6.69	16.54	8.04
Lighthouse	2	1	Bottom	26.5	5.79	22.35	7.96
Little Gully	1	1	Surface	28.8	6.96	17.99	8.13
Little Gully	1	1	Bottom	29.0	4.63	21.82	7.98
Little Gully	2	1	Surface	28.2	7.20	5.59	7.84
Little Gully	2	1	Bottom	28.8	5.15	13.72	7.77
Normans Bar Middle	1	1	Surface	24.5	7.66	11.44	7.80
Normans Bar Middle	1	1	Bottom	26.2	4.66	26.39	7.60
Normans Bar Middle	2	1	Surface	26.1	7.96	14.88	8.23
Normans Bar Middle	2	1	Bottom	26.9	5.66	22.11	8.02
Normans Bar North	1	1	Surface	26.4	6.70	20.73	8.25
Normans Bar North	1	1	Bottom	26.4	6.51	20.73	8.33
Normans Bar North	2	1	Surface	26.4	6.70	20.73	8.25
Normans Bar North	2	1	Bottom	26.4	6.51	20.73	8.33
North Spur	1	1	Surface	25.7	7.55	21.39	8.46
North Spur	1	1	Bottom	26.2	5.83	31.42	8.44
Redfish Creek #1	1	1	Surface	31.2	6.97	19.05	8.29
Redfish Creek #1	1	1	Bottom	30.8	4.09	25.26	7.98
Redfish Creek #1	2	1	Surface	30.7	7.71	12.84	8.37
Redfish Creek #1	2	1	Bottom	30.7	5.92	22.75	8.11
Redfish Creek #2	1	1	Surface	31.4	8.28	8.31	8.36
Redfish Creek #2	1	1	Bottom	31.1	3.95	26.29	7.90
Bayou Flats	1	2	Surface	17.9	8.87	15.48	8.06
Bayou Flats	1	2	Bottom	17.9	8.88	15.50	8.05
Cabbage Lumps	1	2	Surface	19.6	8.45	21.96	8.08
Cabbage Lumps	1	2	Bottom	20.0	7.65	24.71	8.02
Cabbage Top	1	2	Surface	21.2	9.43	15.50	8.14
Cabbage Top	1	2	Bottom	21.2	8.93	16.90	8.09
Cabbage Top	2	2	Surface	21.2	9.43	15.50	8.14
Cabbage Top	2	2	Bottom	21.2	8.93	16.90	8.09
Cat Point	1	2	Surface	18.8	8.14	31.61	7.94
Cat Point	1	2	Bottom	18.3	7.75	32.91	7.92
Cat Point	2	2	Surface	18.8	8.14	31.16	7.94
Cat Point	2	2	Bottom	18.3	7.75	32.91	7.92

Dry Bar	1	2	Surface	17.3	8.78	18.87	8.02
Dry Bar	1	2	Bottom	17.3	8.73	19.95	8.09
Dry Bar	2	2	Surface	17.3	8.78	18.87	8.02
Dry Bar	2	2	Bottom	17.3	8.73	19.95	8.09
Dry Bar	3	2	Surface	17.3	8.78	18.87	8.02
Dry Bar	3	2	Bottom	17.3	8.73	19.95	8.09
Dry Bar	4	2	Surface	21.0	8.85	18.27	8.04
Dry Bar	4	2	Bottom	21.0	8.62	18.57	8.01
Eleven Mile North	1	2	Surface	18.8	8.43	15.52	8.02
Eleven Mile North	1	2	Bottom	18.7	8.38	15.54	8.02
Eleven Mile South	1	2	Surface	18.1	8.62	15.81	8.03
Eleven Mile South	1	2	Bottom	18.1	8.57	15.82	8.03
Green Point	1	2	Surface	18.2	8.85	20.17	7.97
Green Point	1	2	Bottom	17.3	9.31	26.65	8.00
Hotel Bar	1	2	Surface	18.6	8.03	33.56	7.97
Hotel Bar	1	2	Bottom	18.5	8.05	33.56	7.95
Hotel Bar	2	2	Surface	15.3	9.42	12.38	8.06
Hotel Bar	2	2	Bottom	15.2	9.47	12.38	8.04
Hotel Bar	3	2	Surface	15.3	9.42	12.38	8.06
Hotel Bar	3	2	Bottom	15.2	9.47	12.38	8.04
Lighthouse	2	2	Surface	15.4	9.27	8.76	7.93
Lighthouse	2	2	Bottom	15.8	8.92	16.12	7.90
Lighthouse	1	2	Surface	15.4	9.27	8.76	7.93
Lighthouse	1	2	Bottom	15.8	8.92	16.12	7.90
Little Gully	1	2	Surface	20.8	8.96	16.25	8.10
Little Gully	1	2	Bottom	20.7	8.58	17.71	8.06
Little Gully	2	2	Surface	20.8	8.96	16.25	8.10
Little Gully	2	2	Bottom	20.7	8.58	17.71	8.06
Norman's Bar Middle	2	2	Surface	14.9	9.26	5.97	7.89
Norman's Bar Middle	2	2	Bottom	16.1	8.06	20.72	7.89
Norman's Bar Middle	1	2	Surface	14.9	9.26	5.97	7.89
Norman's Bar Middle	1	2	Bottom	16.1	8.06	20.72	7.89
Norman's Bar North	1	2	Surface	15.2	8.94	1.70	8.03
Norman's Bar North	1	2	Bottom	16.0	9.18	6.83	7.90
Norman's Bar North	2	2	Surface	15.2	8.94	1.70	8.03
Norman's Bar North	2	2	Bottom	16.0	9.18	6.83	7.90
North Spur	1	2	Surface	18.9	8.79	20.43	8.04
North Spur	1	2	Bottom	17.6	8.35	28.80	7.96
Redfish Creek #1	2	2	Surface	18.7	9.27	16.72	8.09

Redfish Creek #1	2	2	Bottom	18.7	9.31	16.72	8.09
Redfish Creek #1	1	2	Surface	18.7	9.27	16.72	8.09
Redfish Creek #1	1	2	Bottom	18.7	9.31	16.72	8.09
Redfish Creek #2	1	2	Surface	18.6	9.13	16.79	8.11
Redfish Creek #2	1	2	Bottom	18.5	9.19	16.79	8.12
Bayou Flats	1	3	Surface	20.1	9.00	19.17	8.26
Bayou Flats	1	3	Bottom	19.7	8.98	19.65	8.25
Cabbage Lumps	1	3	Surface	28.3	7.47	15.90	7.90
Cabbage Lumps	1	3	Bottom	28.3	7.53	15.92	7.99
Cabbage Top	1	3	Surface	28.2	7.63	16.36	7.99
Cabbage Top	1	3	Bottom	28.2	7.67	16.36	8.00
Cabbage Top	2	3	Surface	28.2	7.63	16.36	7.99
Cabbage Top	2	3	Bottom	28.2	7.67	16.36	8.00
Cat Point	2	3	Surface	17.9	8.86	19.55	7.98
Cat Point	2	3	Bottom	17.2	8.08	27.40	7.91
Cat Point	1	3	Surface	17.9	8.86	19.55	7.98
Cat Point	1	3	Bottom	17.2	8.08	27.40	7.91
Dry Bar	1	3	Surface	22.7	7.48	22.99	7.93
Dry Bar	1	3	Bottom	22.7	7.41	23.41	7.95
Dry Bar	2	3	Surface	22.7	7.48	22.99	7.93
Dry Bar	2	3	Bottom	22.7	7.41	23.41	7.95
Dry Bar	3	3	Surface	22.7	7.48	22.99	7.93
Dry Bar	3	3	Bottom	22.7	7.41	23.41	7.95
Dry Bar	4	3	Surface	22.7	7.48	22.99	7.93
Dry Bar	4	3	Bottom	22.7	7.41	23.41	7.95
Eleven Mile North	1	3	Surface	20.0	9.34	17.26	8.35
Eleven Mile North	1	3	Bottom	19.7	9.31	17.66	8.32
Eleven Mile South	1	3	Surface	19.7	9.27	18.09	8.37
Eleven Mile South	1	3	Bottom	19.2	9.02	19.24	8.33
Green Point	1	3	Surface	29.2	7.09	22.64	7.86
Green Point	1	3	Bottom	28.8	7.02	25.80	7.84
Hotel Bar	1	3	Surface	25.0	6.38	30.99	7.85
Hotel Bar	1	3	Bottom	25.0	6.25	31.04	7.91
Hotel Bar	2	3	Surface	25.0	6.38	30.99	7.85
Hotel Bar	2	3	Bottom	25.0	6.25	31.04	7.91
Hotel Bar	3	3	Surface	25.0	6.38	30.99	7.85
Hotel Bar	3	3	Bottom	25.0	6.25	31.04	7.91
Lighthouse	1	3	Surface	19.2	7.98	28.16	8.04
Lighthouse	1	3	Bottom	19.1	7.40	31.69	8.03
Lighthouse	2	3	Surface	19.2	7.98	28.16	8.04
Lighthouse	2	3	Bottom	19.1	7.40	31.69	8.03

Little Gully	1	3	Surface	17.1	8.97	18.15	7.95
Little Gully	1	3	Bottom	17.1	8.79	20.55	7.97
Little Gully	2	3	Surface	17.1	8.97	18.15	7.95
Little Gully	2	3	Bottom	17.1	8.79	20.55	7.97
Norman's Bar Middle	1	3	Surface	18.8	8.44	17.54	8.08
Norman's Bar Middle	1	3	Bottom	18.8	8.07	24.32	8.03
Norman's Bar Middle	2	3	Surface	18.8	8.44	17.54	8.08
Norman's Bar Middle	2	3	Bottom	18.8	8.07	24.32	8.03
Norman's Bar North	1	3	Surface	17.7	8.69	16.45	8.18
Norman's Bar North	1	3	Bottom	19.1	7.45	28.09	7.98
Norman's Bar North	2	3	Surface	17.7	8.69	16.45	8.18
Norman's Bar North	2	3	Bottom	19.1	7.45	28.09	7.98
North Spur	1	3	Surface	28.9	7.67	17.38	7.96
North Spur	1	3	Bottom	28.8	4.96	26.97	7.81
Redfish Creek #1	1	3	Surface	20.3	9.41	16.91	8.35
Redfish Creek #1	1	3	Bottom	19.4	9.36	19.94	8.28
Redfish Creek #1	2	3	Surface	20.3	9.41	16.91	8.35
Redfish Creek #1	2	3	Bottom	19.4	9.36	19.94	8.28
Redfish Creek #2	1	3	Surface	24.1	7.19	20.69	7.98
Redfish Creek #2	1	3	Bottom	23.8	7.08	20.74	7.98

Chapter 2: St. Andrews Bay

The St. Andrews Bay watershed spans approximately 740,000 acres of the central Florida Panhandle adjacent to the Gulf of Mexico. The watershed includes Econfina Creek and the groundwater contribution area for springs discharging into the creek, the interconnected estuarine system of St. Andrew, West, North, and East bays, and St. Joseph Bay. The watershed also includes Deer Point Lake Reservoir, Lake Powell and other coastal dune lakes, and contributing basins and tributaries of all these waterbodies (NWFWMD, 2017).

Approximately 17,000 cubic yards of crushed granite was placed on an estimated 84 acres of debilitated oyster reefs in the St. Andrews Bay System in Bay County during June 2016 (FDACS, 2016). The crushed granite was placed in West Bay, North Bay, and East Bay within the St. Andrews Bay System (Figure 15).

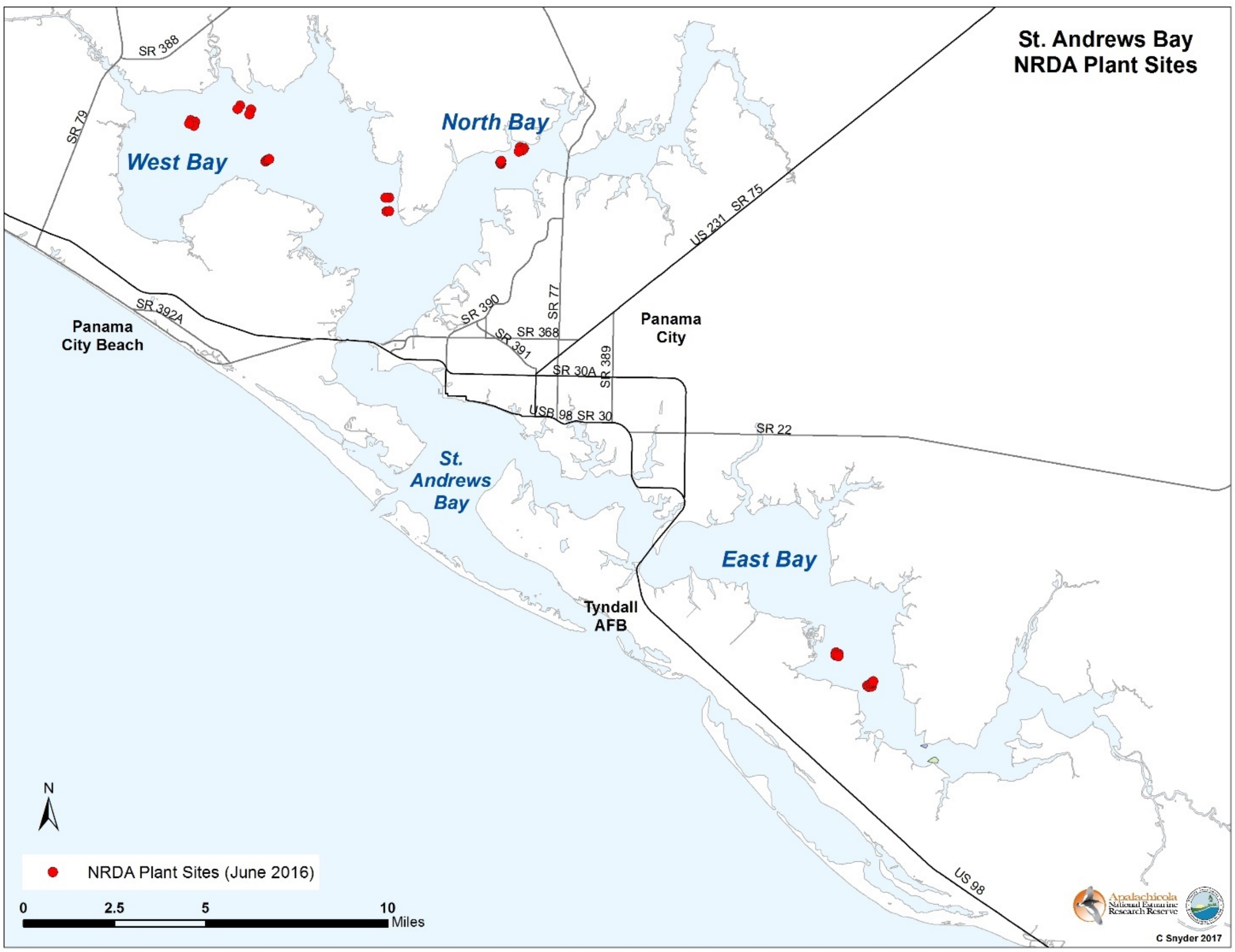


Figure 15: Map of St. Andrews Bay.

West Bay (Figure 16):

- Crooked Creek Point: An unconsolidated natural oyster reefal complex. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals landward of reef. This reef is improved habitat constructed on sand shoals and spoil in the middle of West

Bay along the North side of the Gulf Intracoastal Waterway (ICWW), in a Conditionally Approved shellfish harvesting area. This site has one midpoint for monitoring.

- Doyle Bayou: A natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix and the surrounding bottom is generally sand shoals. The reef is located on the north side of West Bay, south of Doyle Point, in a Conditionally Approved shellfish harvesting area. Doyle Bayou was separated into two midpoints for monitoring.
- West Bay Point: A natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals. The reef is located on the north side of West Bay, west of West Bay Point, in a Conditionally Approved shellfish harvesting area. This site was separated into two midpoints for monitoring.
- South Channel Ridge: A natural oyster reef ridge on the south side of the ICWW, West Bay, north of Breakfast Point; the existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. South Channel has one midpoint for monitoring.

St. Andrews NRDA Sites & Midpoints (West Bay)

Figure 16: NRDA sites and midpoints in West Bay.

North Bay (Figure 17):

- Newman Bayou Bar: An unconsolidated natural oyster reefal complex. Historically portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located in the vicinity of Newman Bayou, in a Conditionally Approved shellfish harvesting area. Newman Bayou Bar has one midpoint for monitoring.
- East of Power Lines Ridge: A natural oyster reef ridge on the east side of the power lines in North Bay, west of Long Beach Point; the existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. This site has one midpoint for monitoring.

St. Andrews NRDA Sites & Midpoints (North Bay)

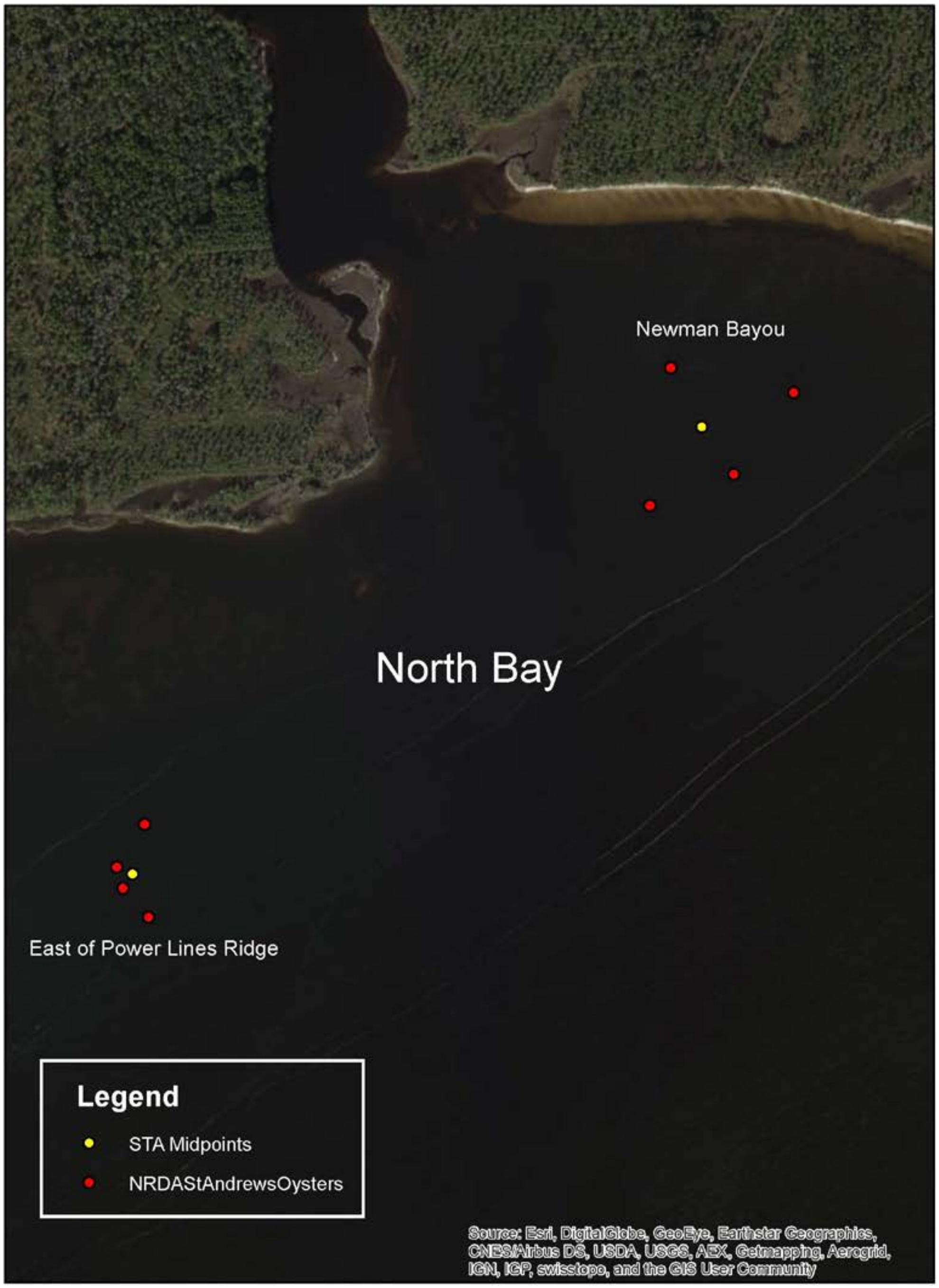


Figure 17: NRDA sites and midpoints in North Bay.

East Bay (Figure 18):

- Goose Point: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals. The reef is located in proximity to Goose Point in East Bay, in a Conditionally Approved shellfish harvesting area. Goose Point has one midpoint for monitoring.
- Little Oyster Bar Point: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located offshore of Little Oyster Bar Point in the southwestern vicinity of East Bay, in a Conditionally Approved shellfish harvesting area. This site has one midpoint to monitor.
- Off Little Oyster Bar Ridge: A natural oyster reef ridge to the north and east of Little Oyster Bar Point in East Bay. The surrounding bottom is generally muddy. This site has one midpoint to monitor.

Figure 18: NRDA sites and midpoints in East Bay.

Table 6: Midpoint Coordinates for St. Andrews Bay Monitoring Sites

Monitoring Site	Latitude	Longitude
West Bay		
Crooked Creek Point, Midpoint 1	30.2734	-85.81961
Doyle Bayou, Midpoint 1	30.27948	-85.7967
Doyle Bayou, Midpoint 2	30.27889	-85.79476
West Bay Point, Midpoint 1	30.24304	-85.7294
West Bay Point, Midpoint 2	30.24118	-85.72944
South Channel Ridge, Midpoint 1	30.25925	-85.78476
North Bay		
Newman Bayou Bar, Midpoint 1	30.26501	-85.66839
East of Power Lines Ridge, Midpoint 1	30.25957	-85.67753
East Bay		
Goose Point, Midpoint 1	30.06591	-85.52038
Little Oyster Bar Point, Midpoint 1	30.05354	-85.50507
Off Little Oyster Bar Ridge, Midpoint 1	30.05491	-85.504

Data Analysis for St. Andrews Bay 2017-2020

St. Andrews Bay NRDA Oyster Clutch Placement sites were sampled during August 2017 (Round 1), April - May 2018 (Round 2), and December 2019 - January 2020 (Round 3). St. Andrews Bay has a total of 9 reef sites consisting of 11 midpoints(as seen in Figures 15-18).

To date, 1,290.35 kilograms (2,844.73 pounds) of cultch material and oysters have been collected in St. Andrews Bay. A total of 325.77 kg of sample material was collected during Round 3, with an overall average sample weight of 1.97 kg. A per sample statistical analysis showed that the average sample weight in Round 3 was significantly less than in both Round 1 ($p=.0038$) and in Round 2 ($p=3.70\times10^{-9}$). The highest average sample weights for Round 1 and 2 were observed at West Bay Point (n=4.37 kg and n=4.56 kg, respectively), while East of Power Lines Ridge provided the largest average sample weight for Round 3 (n=3.92 kg). (Table 7). It should be noted that a large sample weight does not necessarily correlate to a large density of live oysters. When the oyster clutch is placed, it is not spread in a uniform way, but rather results in clusters and bare spots throughout the reef. This is supported by the variation in the average sample weight between sites and rounds.

Table 7: Average sample weight of material collected during all rounds in St. Andrews Bay.

Site	Round 1 Average Sample Weight (kg)	Round 2 Average Sample Weight (kg)	Round 3 Average Sample Weight (kg)
Crooked Creek Point	1.50	1.93	0.0
Doyle Bayou	3.86	1.68	1.08
East of Power Lines Ridge	0.79	2.96	3.92
Goose Point	2.68	4.30	2.37
Little Oyster Bar Point	1.06	2.82	1.73

Newman Bayou Bar	1.03	2.34	0.02
Off Little Oyster Ridge	2.17	5.59	2.23
South Channel Ridge	3.85	2.56	3.62
West Bay Point	4.37	4.56	2.84

To date, a total of 37,042 live oysters and 5,524 dead oysters have been sampled from St. Andrews Bay. In Round 3, 15,120 live oysters and 1379 dead oysters were observed. The increase in number of live oysters and decrease in dead oysters from Round 1 to Round 3 were found to be statistically significant ($p=6.00x10^{-5}$ and $p=6.80x10^{-6}$, respectively.) Although a decrease in live oysters and increase in dead oysters was observed from Round 2 to Round 3, these differences were not found to be statistically significant ($p=0.68$ and $p=0.25$, respectively). The number of live and dead oysters sampled by round can be seen in Figure 19.

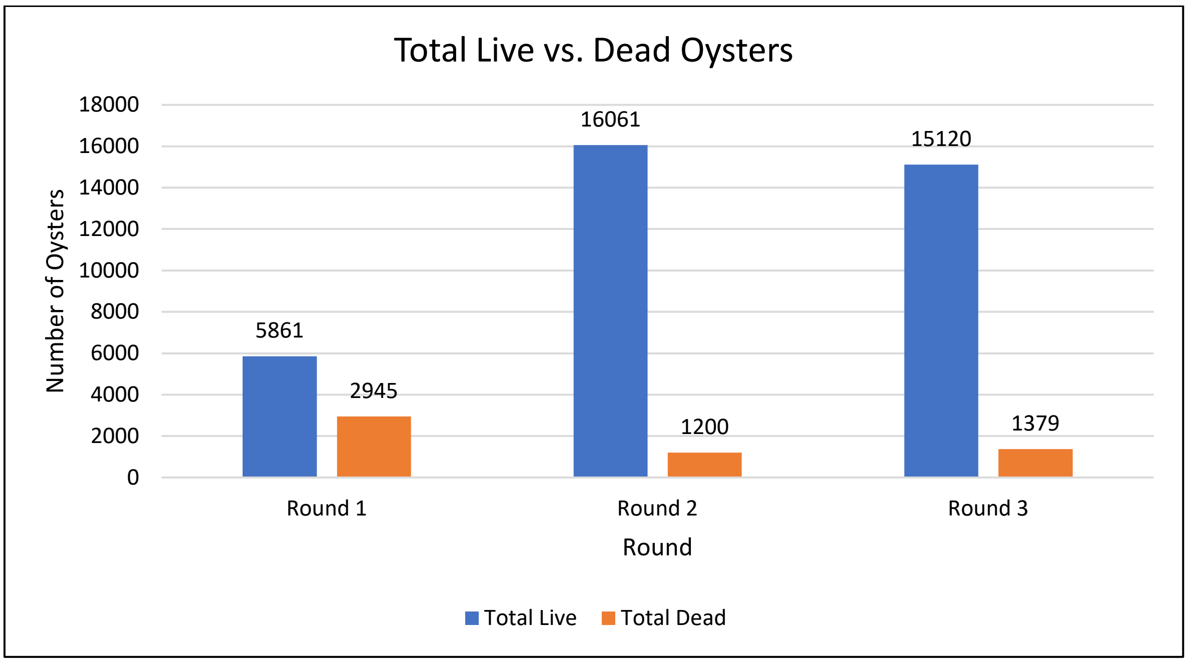


Figure 19: Total live and dead oysters collected in St. Andrews Bay system.

A comparison of oyster abundance by size-class shows that in Round 3, spat sized oysters continued to be the most abundant (n=13,075), followed by seed-sized oysters (n=1,986) and adult-sized, harvestable oysters (n=59). An increase in spat-sized oysters was observed from Round 1 (n=4,855) to Round 3 and from Round 2 (n=11,314) to Round 3. When analyzed on a per sample basis, the increase in number of spat from Round 1 to Round 3 was found to be statistically significant ($p=0.0002$), but the increase from Round 2 to Round 3 was not ($p=0.41$). An increase in the number of seed-sized oysters was observed from Round 1 (n=968) to Round 3, but a decrease in the same size class was observed from Round 2 (n=4,628) to Round 3. Both the increase from Round 1 to Round 3 and the decrease from Round 2 to Round 3 were found to be statistically significant ($p=1.2x10^{-5}$ and $4.5x10^{-8}$, respectively). The same pattern was observed in oysters of the adult size class; an increase in adult-sized oysters was observed from Round 1 (n=38) to Round 3, but a decrease was observed from Round 2 (n=119) to Round 3. The increase in adult oysters from Round 1 to Round 3 was not found to be statistically significant (p=0.31), but the decrease from Round 2 to Round 3 was considered significant (p=0.02) (Figure 20).

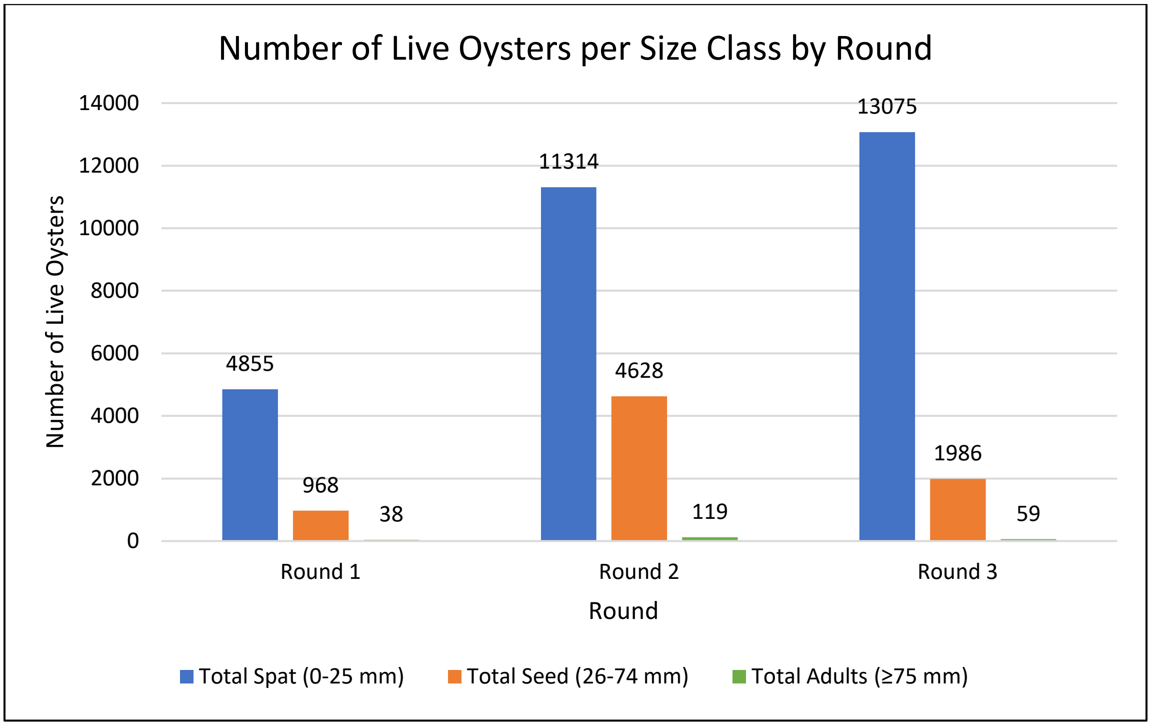


Figure 20: Size class distribution for St. Andrews Bay.

The St. Andrews Bay system contains four geographically distinct bays: St. Andrew Bay, West Bay, North Bay, and East Bay (Figure 15). Sample sites in West Bay include Crooked Creek Point, Doyle Bayou, South Channel Ridge, and West Bay Point. East of Power Lines and Newman Bayou Bar are the only monitoring sites in North Bay. East Bay contains three sampling sites: Off Little Oyster Bar Ridge, Little Oyster Bar Point and Goose Point. There are no oyster cultch sites in St. Andrew Bay proper. Data was analyzed by geographic region (i.e. Bay) to account for regional differences in oyster populations. To date, West Bay has continued to produce the highest total number of live oysters, as well as the highest number of spat-sized oysters. In West Bay, an increase in the number of spat sampled was observed from Round 1 (n=4,602) to Round 3 (n=10,339) and from Round 2 (n=6,124) to Round 3. However, decreases in seed-sized and adult-sized oysters were observed from Round 1 to Round 3 and Round 2 to Round 3 in West Bay. In East Bay, increases in live oysters were observed across all size classes from Round 1 to Round 3, but decreases across all size classes were observed from Round 2 to Round 3. In North Bay, increases in spat- and seed-sized oysters were observed from Round 1 (n=53 spat and n=17 seed) to Round 3 (n=652 spat and n=86 seed), and a decrease in adult-sized oysters was observed (n=4 and n=0, respectively). North Bay has historically produced fewer live oysters than the rest of the geographic regions sampled in St. Andrews Bay. From Round 2 to Round 3, decreases in number of live oysters were observed across all size classes in North Bay (Figure 21).

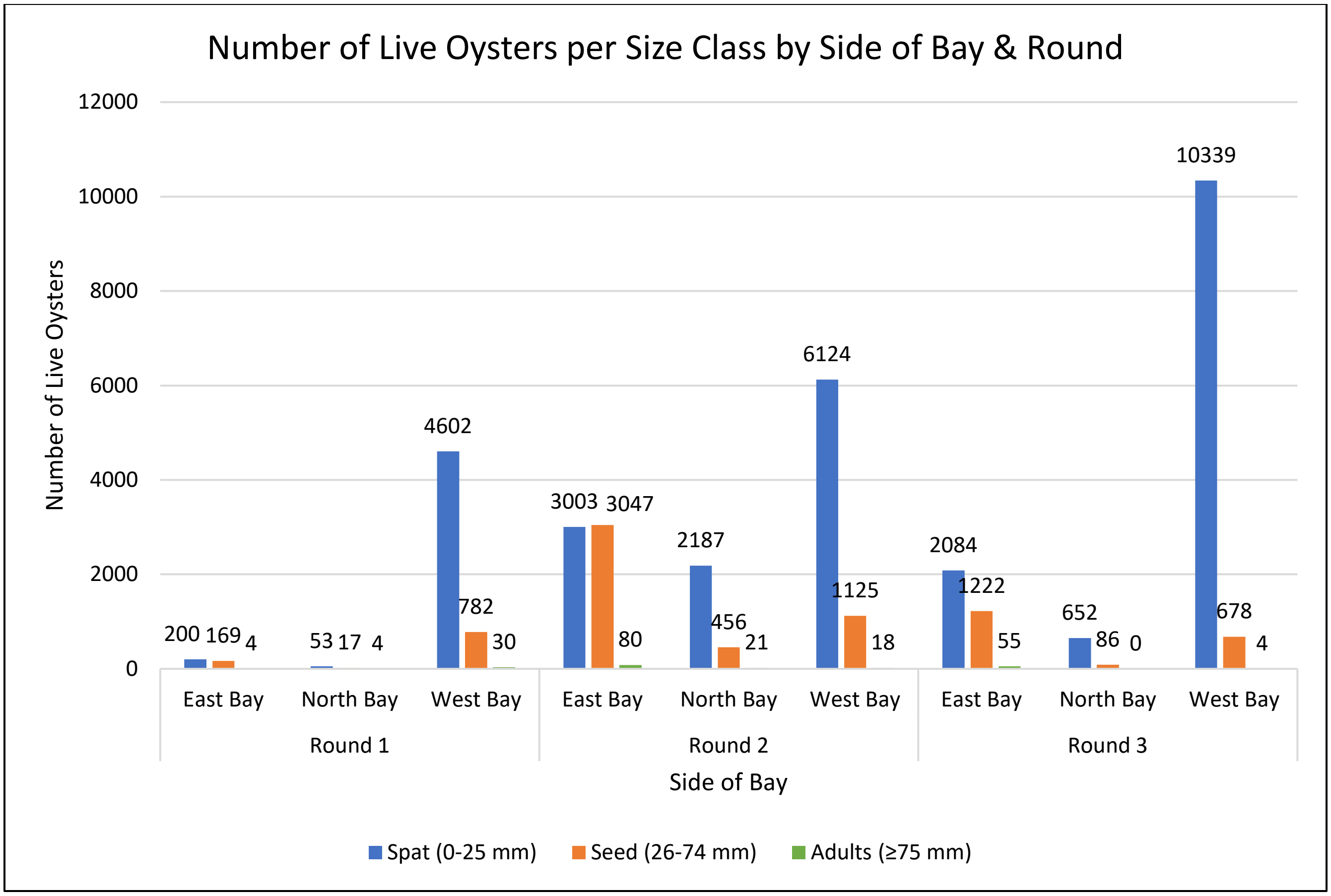


Figure 21: Size class distribution of live oysters within the three geographically distinct bays.

When comparing size class distribution by site, a decrease in the number of spat-sized oysters was observed from Round 2 to Round 3 at all sites except for Doyle Bayou and South Channel Ridge. South Channel Ridge experienced a dramatic increase in the number of spat sampled from Round 2 to Round 3 (n=1,465 and n=8,204, respectively). The number of spat observed at South Channel Ridge accounted for approximately 62.75% of the total spat sampled during Round 3. From Round 1 to Round 3, approximately half of all sites experienced a decrease in spat-sized oysters sampled, and half experienced an increase. Zero spat-sized oysters were observed at Crooked Creek Point in Round 3, and only one was observed at Newman Bayou Bar (Figure 22).

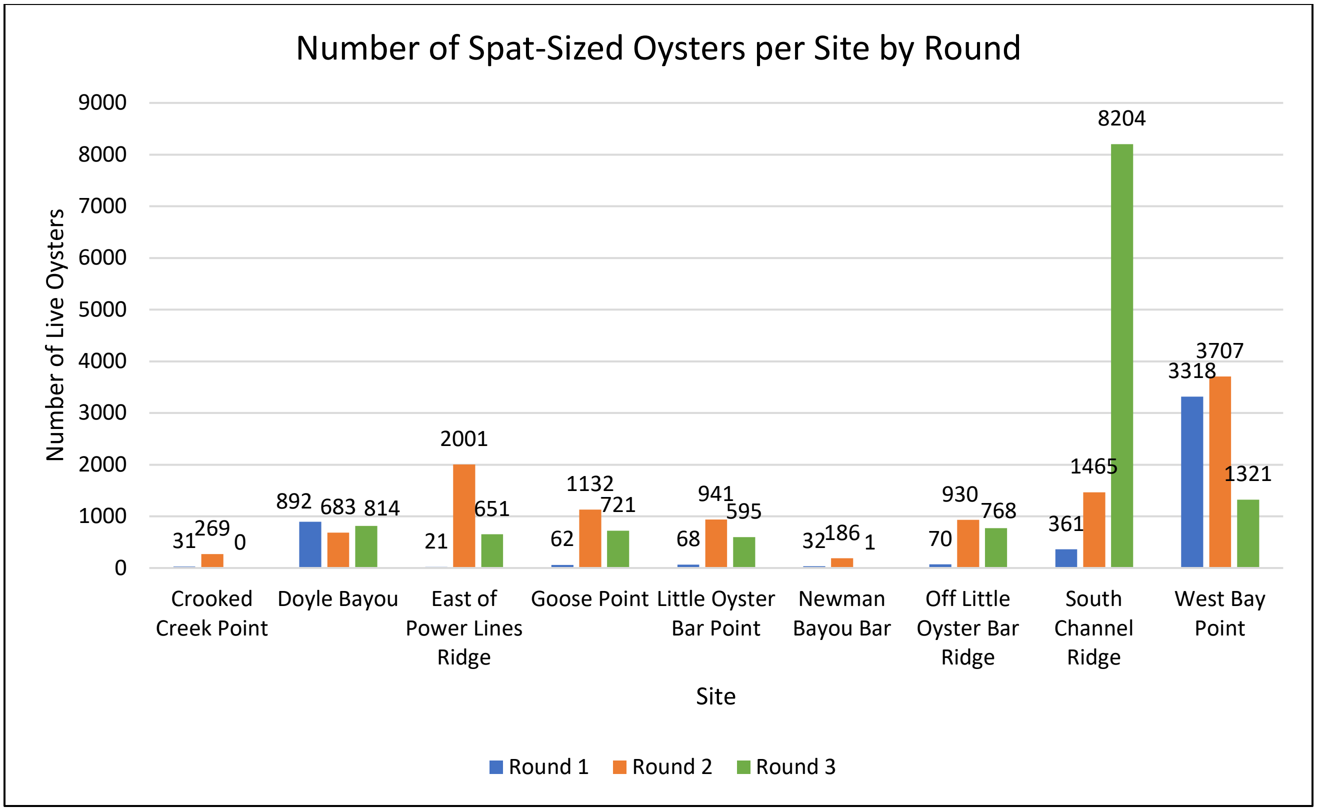


Figure 22: Spat size class distribution by site and round of sampling.

Except for Doyle Bayou, all sites experienced a decrease in the number of seed-sized oysters sampled from Round 2 to Round 3. The highest number of seed-sized oysters observed during Round 3 was at Little Oyster Bar Point (n=414), which is a dramatic decrease in the highest number of seed observed in Round 2 (Off Little Oyster Bar Ridge, n=1,640). Zero seed-sized oysters were observed at Crooked Creek Point and at Newman Bayou Bar in Round 3. As was seen in spat-sized oysters, approximately half of sites experienced a decrease from Round 1 to Round 3 in the number of seed-sized oysters sampled, and approximately half experienced an increase. (Figure 23).

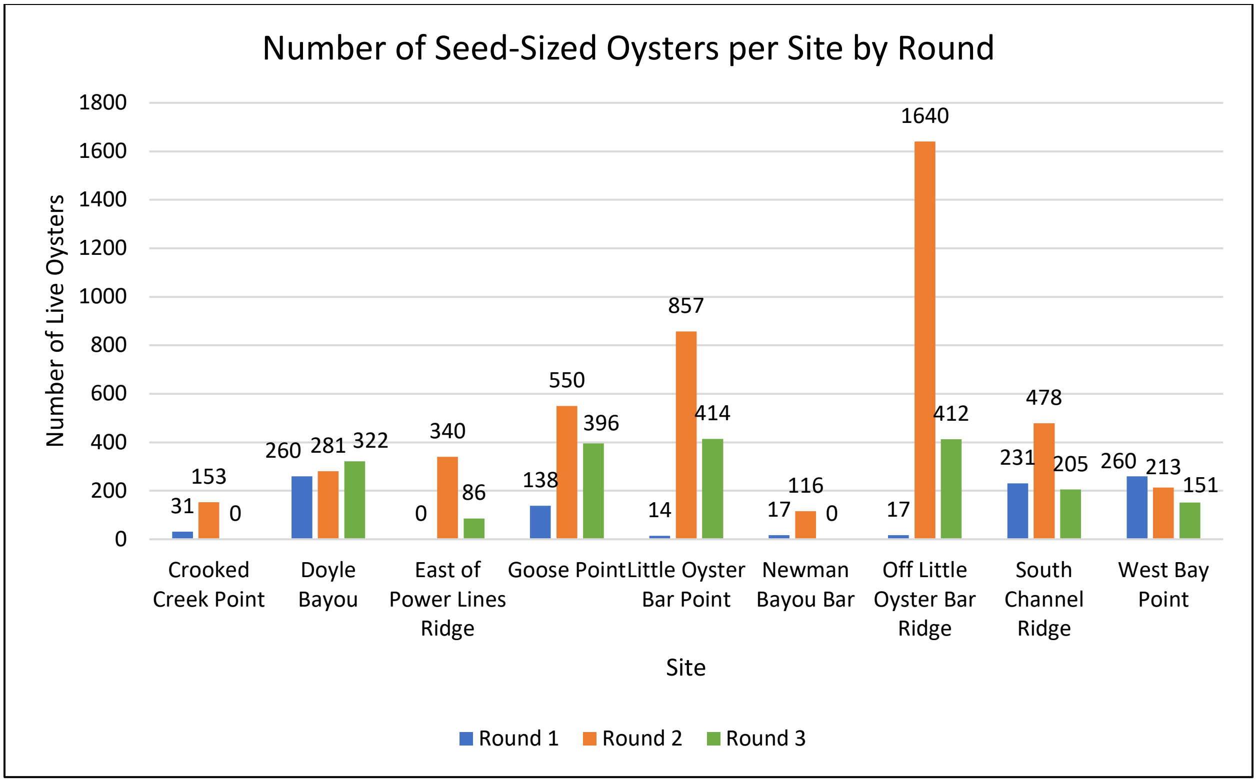


Figure 23: Seed size class distribution by site and round of sampling.

While the number of adult-sized oysters has remained relatively low throughout all rounds of sampling, increases in adult-sized oysters were only observed at three sites from Round 2 to Round 3: Doyle Bayou (n=1), Goose Point (n=21), and Little Oyster Bar Point (n=12). West Bay Point had zero adult oysters present in both Round 2 and Round 3, and all other sites experienced a decrease in the number of adult oysters from Round 2 to Round 3. As was noted in other size classes, approximately half of the sites in St. Andrews Bay experienced an increase in the number of adult-sized oysters sampled, while approximately half saw a decrease. Zero adult-sized oysters were observed at East of Power Lines Ridge in both Round 1 and Round 3 (Figure 24).

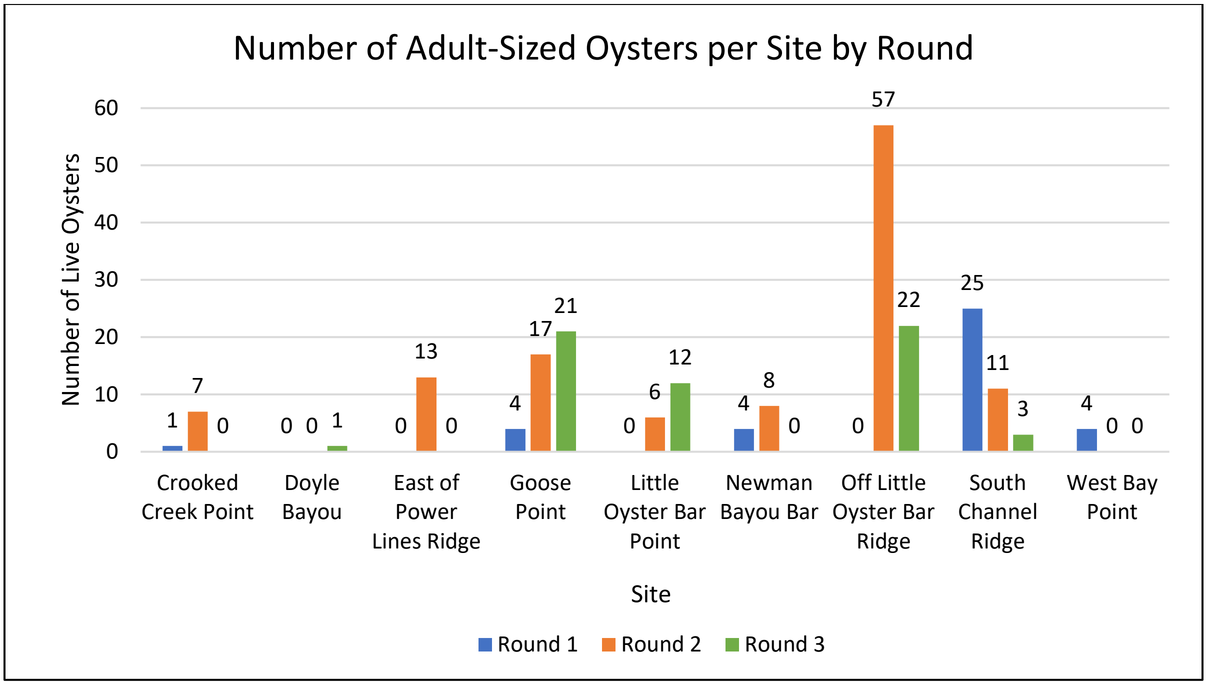


Figure 24: Adult size class distribution by site and round of sampling.

Average shell height of all oysters sampled in St. Andrews Bay during Round 3 was 19.01 mm (Figure 25). Statistical analysis showed that the average shell height observed in Round 3 was not significantly less than that of Round 1 (n=19.37mm, p=0.22), but was considered significantly less than the average shell height in Round 2 (n=22.92, $p=5.9\times10^{-76}$).

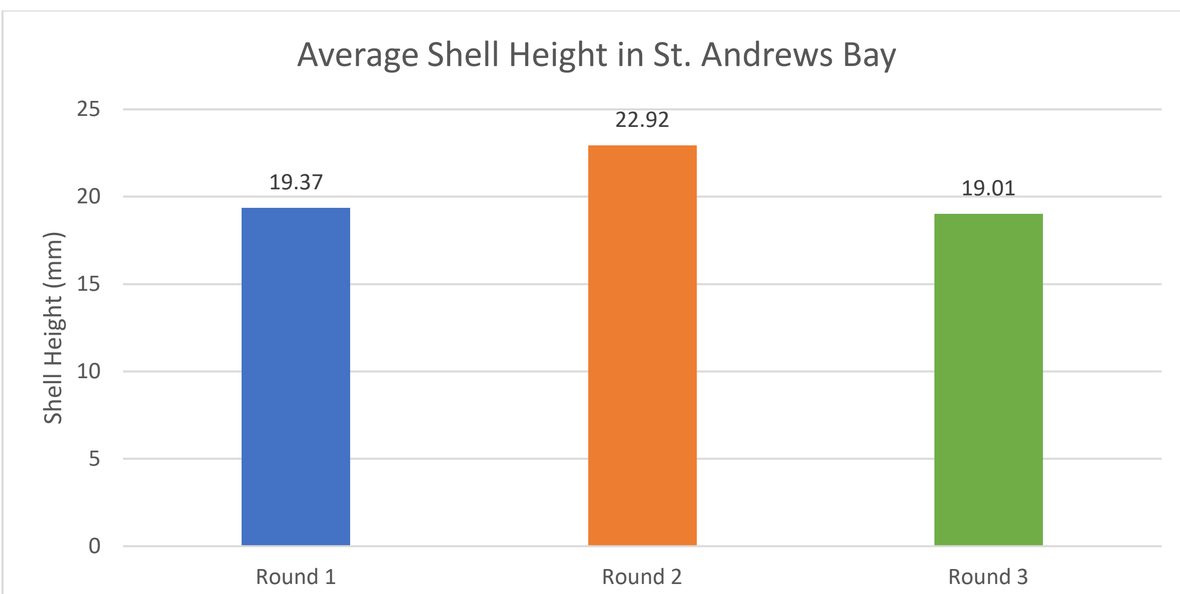


Figure 25: Average shell height of live oysters collected in the St. Andrews Bay system.

An analysis of shell height distribution throughout the entire St. Andrews Bay system showed that the majority of live oysters collected during all rounds of sampling occurred in the 6-25 mm range (spat-sized); the most prevalent shell height range was 6-15mm in Rounds 1 and 3, and 11-20 mm in Round 2 (Figure 26). The size frequency distribution was similar across all rounds, with a higher frequency of oysters in the spat- and seed-sized ranges, although Round 2 contained a greater number of oysters in the 11-25 mm range than Rounds 1 and 3.

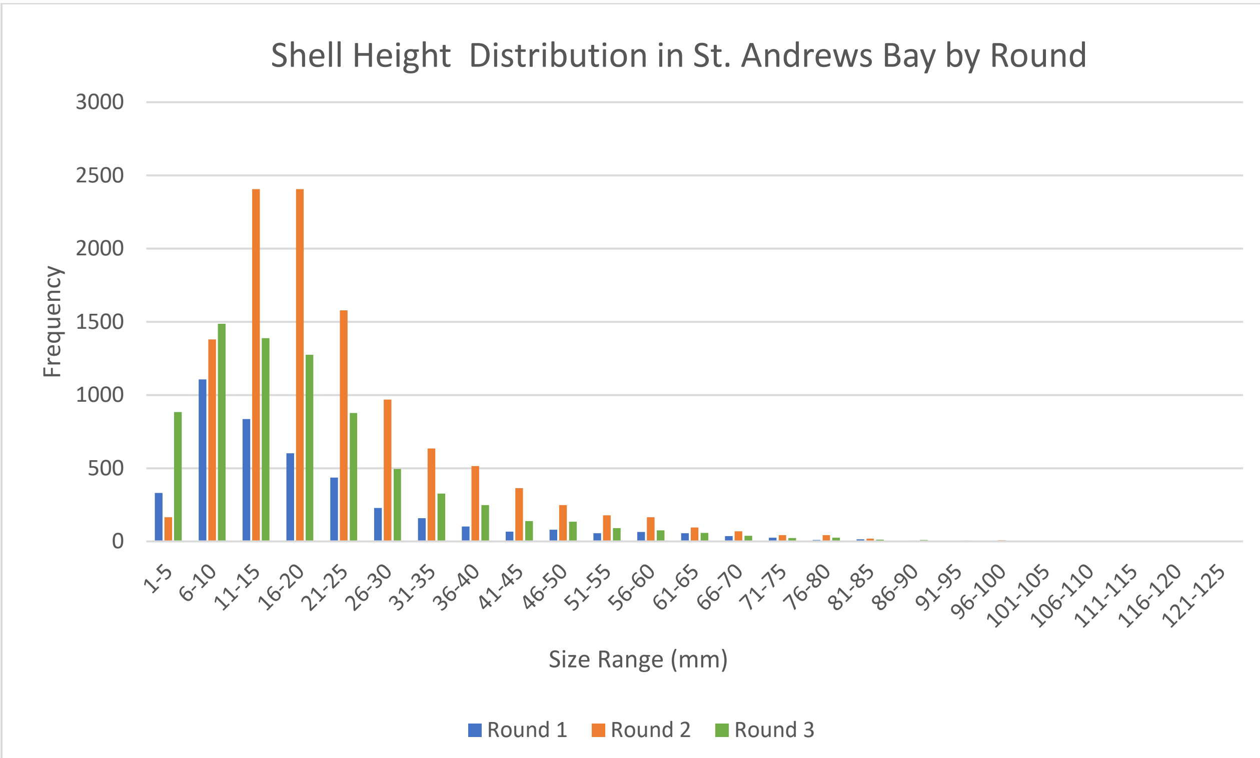


Figure 26: Shell height distribution throughout the entire bay system.

Shell height distribution in each individual bay was similar to that of the entire St. Andrews Bay system. In East Bay, the most prevalent size range in Round 3 was 6-20mm, whereas the most prevalent size range in Round 2 was 11-25mm. In West Bay, the most frequently observed size range was slightly smaller than that of East Bay; the most prevalent size range in Round 3 was 1-15mm in West Bay. This is also slightly smaller than previous rounds, with 6-20mm as the most prevalent size range in Round 1 and Round 2 in West Bay. Although drastically fewer oysters were sampled in North Bay from Round 2 to Round 3, oysters of the 6-25mm range remained the most prevalent. Shell height measurements from North Bay in Round 1 also trended toward a smaller size range (6-15mm), with very few observations made in Round 1 compared to Rounds 2 and 3 (Figures 27-29).

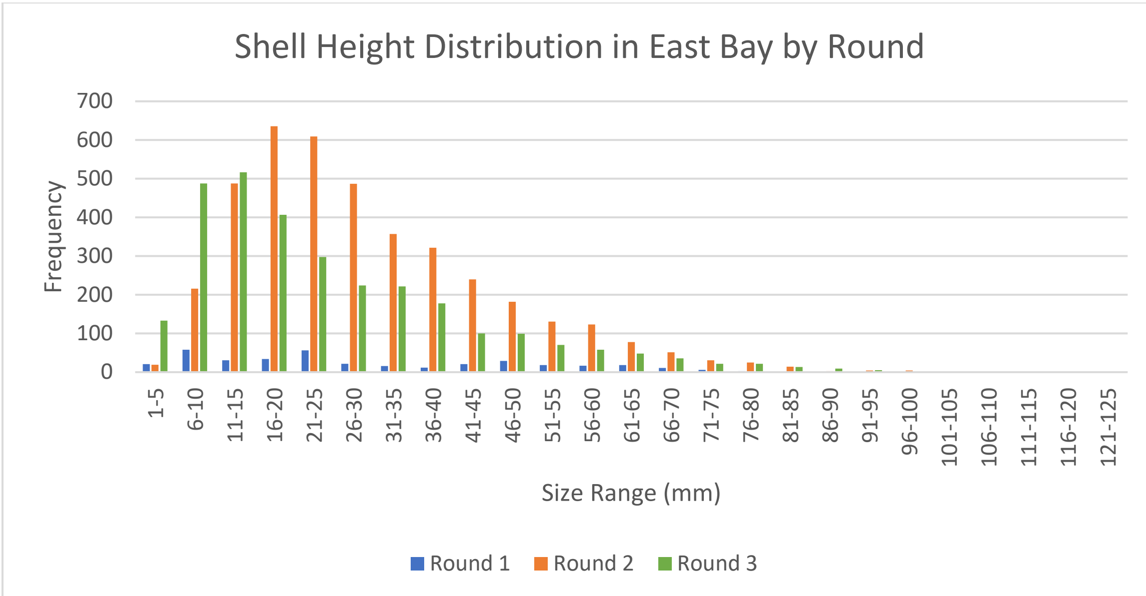


Figure 27: Shell height distribution in East Bay.

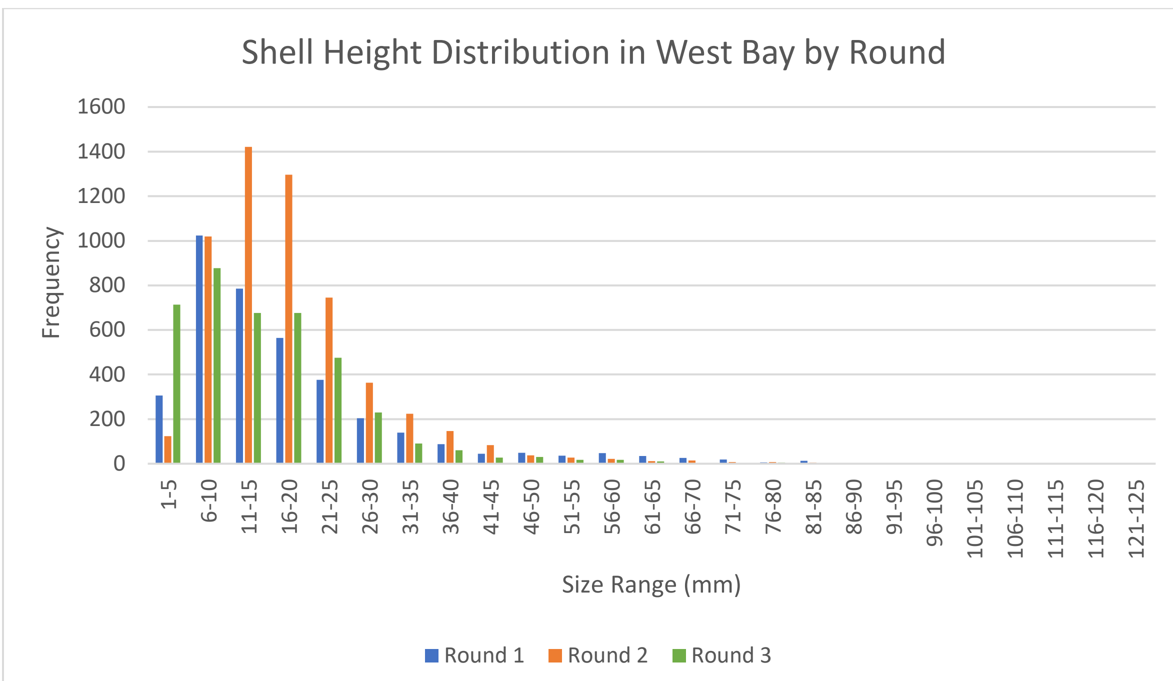


Figure 28: Shell height distribution in West Bay.

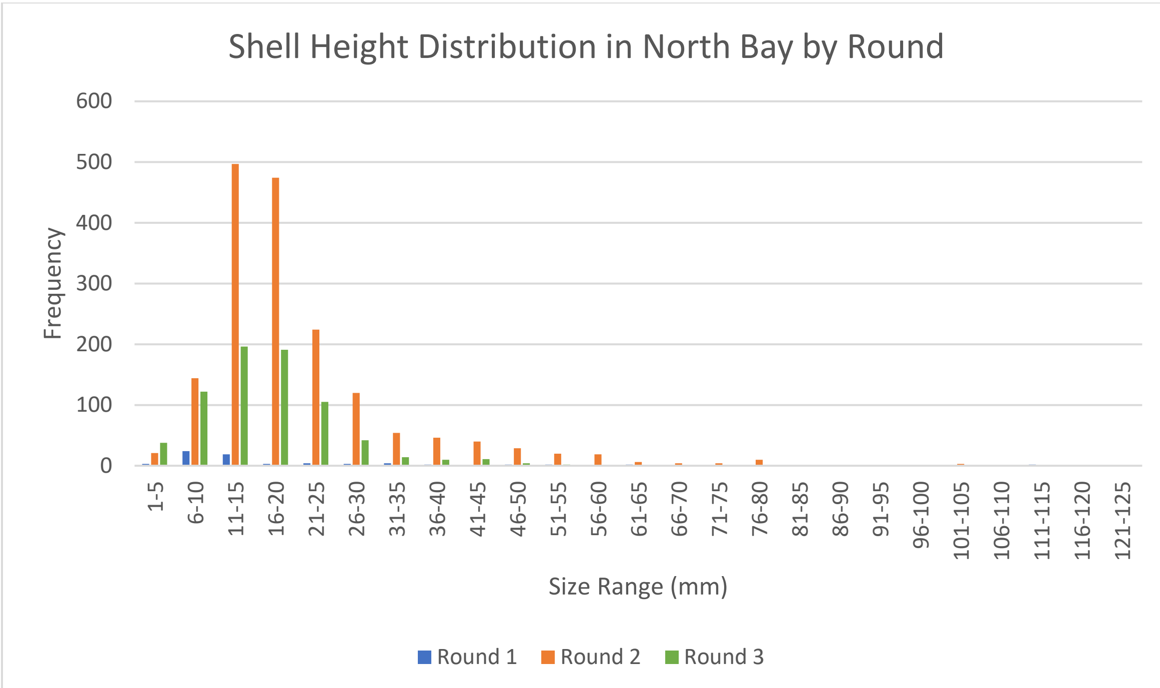


Figure 29: Shell height distribution in North Bay.

The estimated density of live oysters for all restored reefs in the St. Andrews Bay system was 366.55 live oysters/m^2 in Round 3. This is more than double the estimated density of Round 1 (n=144.72 live oysters/m^2), and slightly less than the estimated density of Round 2 (n=389.36 live oysters/m^2) (Figure 30).

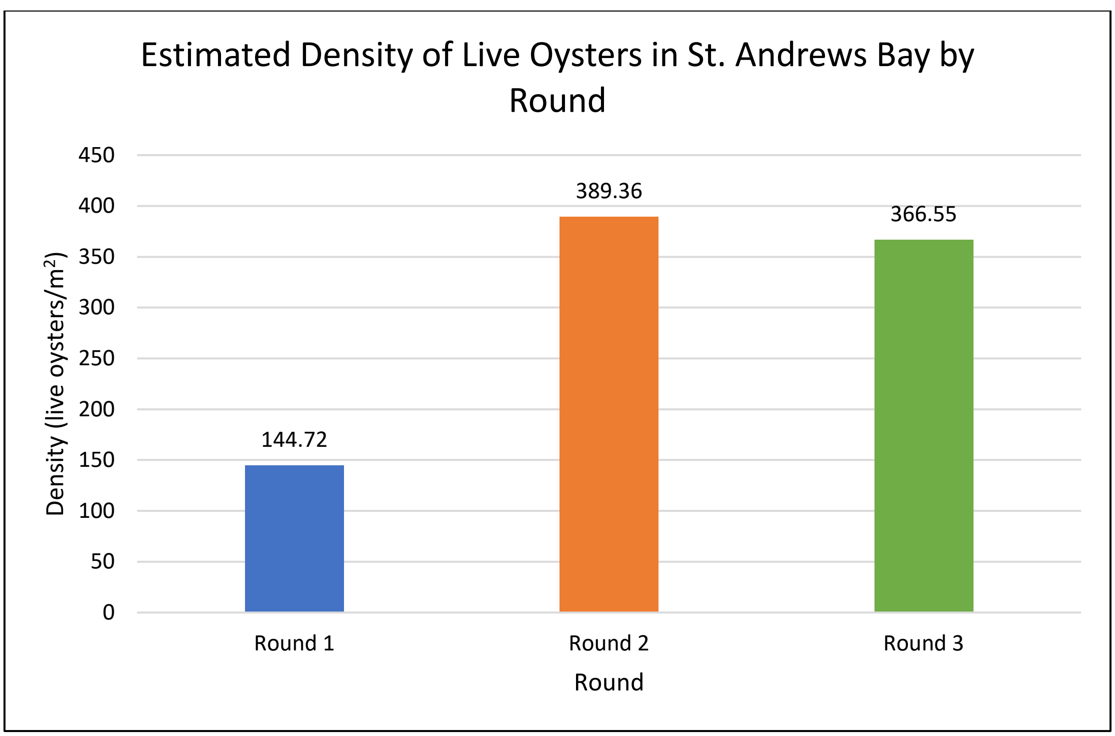


Figure 30: Density of live oysters in St. Andrews Bay by round.

When compared by side of bay, the estimated density of live oysters increased from Round 1 to Round 2 but decreased from Round 2 to Round 3 in both North Bay and East Bay. A steady increase in estimated live oyster density was observed from Round 1 and Round 2 to Round 3 in West Bay, with an increase of approximately 150% from Round 2 (n=322.98) to Round 3 (n=489.82) (Figure 31).

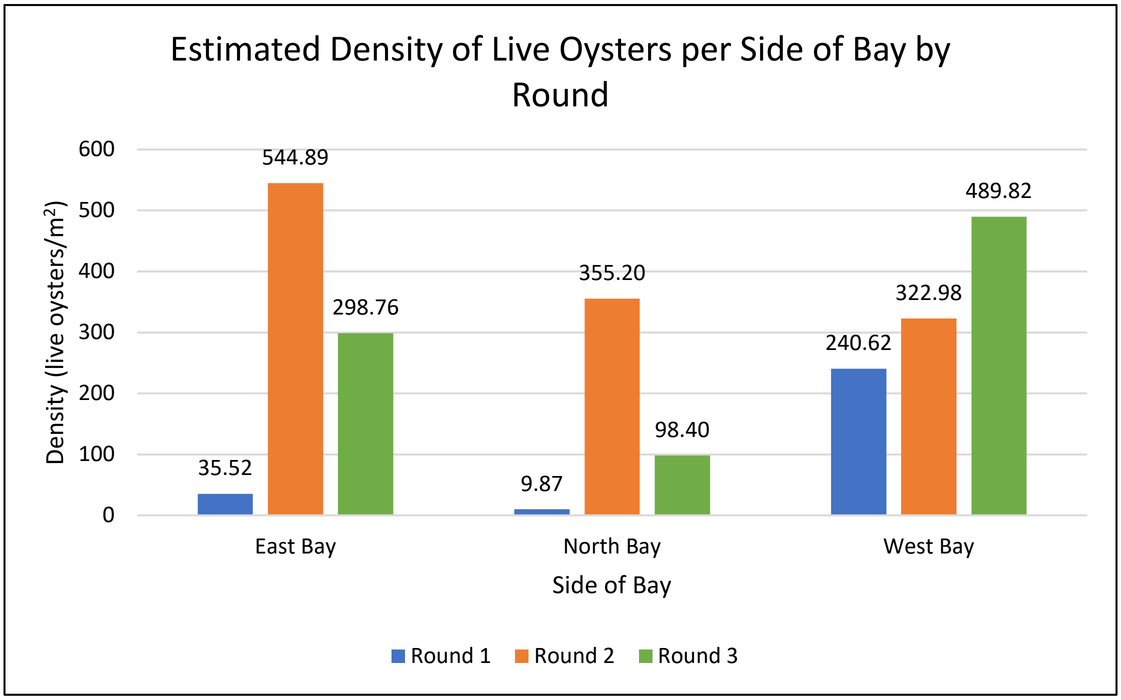


Figure 31: Density of live oysters in St. Andrews Bay by round of sampling.

Decreases in live oyster density were observed at all sites from Round 2 to Round 3, with the exceptions of Doyle Bayou and South Channel Ridge. South Channel Ridge had the highest estimated live oyster density in Round 3 (n=2,243.20 live oysters/m^2). From Round 1 to Round 3, approximately half of sites experienced a decrease in estimated live oyster density, while half experienced an increase (Figure 32).

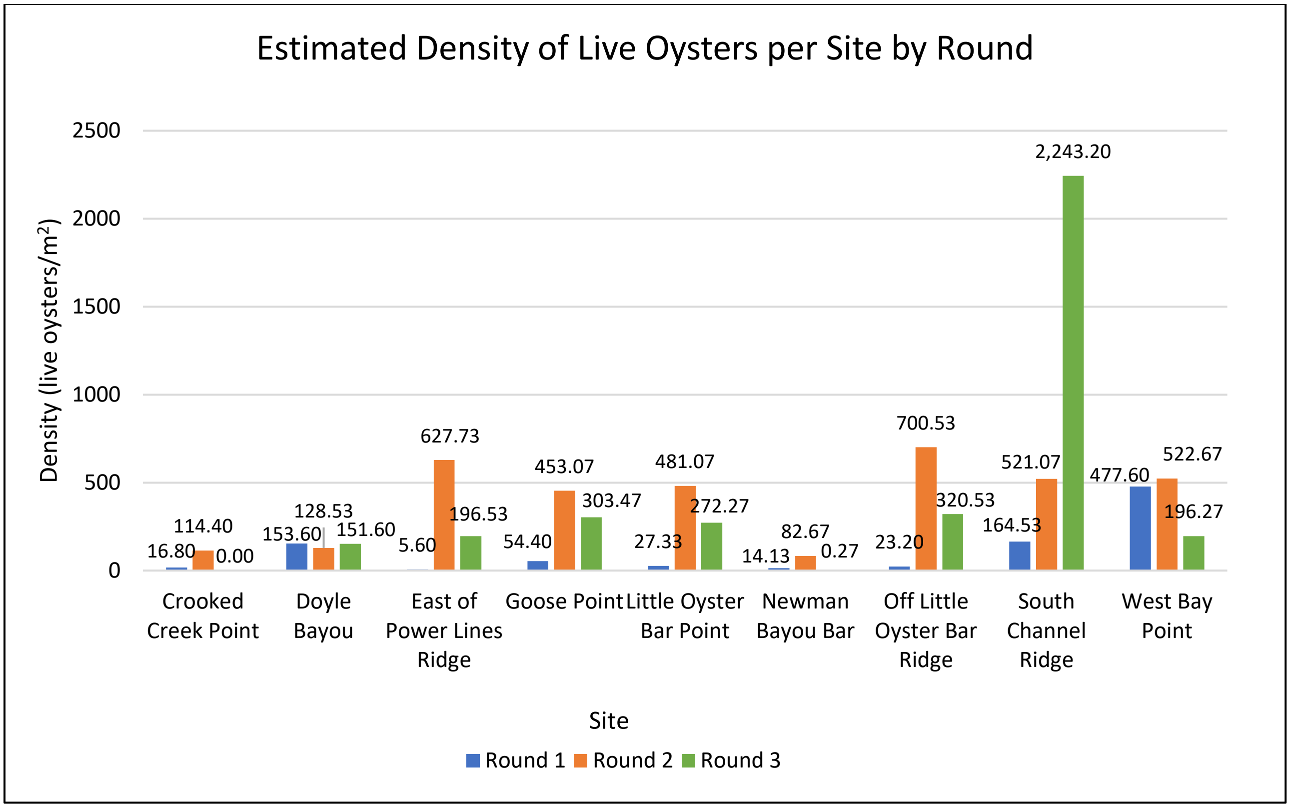


Figure 32: Density of live oysters collected throughout the bay during each round of sampling.

FDACS Standard Oyster Resource Management Protocol

FDACS protocols were used to estimate the number of bags of harvestable oysters per site (see Appendix 1). The calculations that were performed to estimate the number of bags per acre of legal harvest-sized (adult) oysters are shown in Table 8.

In Round 3, the highest estimated bags per acre of harvestable oysters was found at Off Little Oyster Bar Ridge (n=105.52 bags/acre). This was also the site with the highest estimate in Round 2 (n=273.40). Four of the nine sites had estimates of zero bags per acre of harvestable oysters in Round 3. Increases in estimated bags per acre of harvestable oysters were seen at Doyle Bayou, Goose Point, and Little Oyster Bar Point from Round 2 to Round 3. In Round 3, none of the sites had estimates capable of sustaining limited commercial harvest (>200 bags/acre), and all but two sites (Goose Point and Off Little Oyster Bar Ridge) had estimates considered depleted (<100 bags/acre) (Table 8).

Table 8: Comparison between Round 1 and Round 2 of calculated bags per acre of harvestable oysters.

Site	Round 1	Round 2	Round 3
Crooked Creek Point	4.80	33.58	0.00
Doyle Bayou	0.00	0.00	2.40
East of Power Lines Ridge	0.00	62.35	0.00
Goose Point	19.19	81.54	100.73

Little Oyster Bar Point	0.00	28.78	57.56
Newman Bayou	19.19	38.37	0.00
Off Little Oyster Bar Ridge	0.00	273.40	105.52
South Channel	119.91	52.76	14.39
West Bay Point	9.59	0.00	0.00

For reference, FDACS uses the following scale:

- More than 400 bags/acre = Healthy oyster reefs capable of sustaining commercial harvest.
- More than 200 bags/acre = Oyster reefs capable of sustaining limited harvest.
- Less than 200 bags/acre = Below level necessary to support commercial harvest.
- Less than 100 bags/acre = Oyster reefs considered depleted.

It is evident that all reefs have estimates that would be considered below the level necessary to support commercial harvest (<200 bags per acre) or depleted (<100 bags/acre). All bays experienced a decrease in estimated bags per acre of harvestable oysters from Round 2 to Round 3. Overall decreases from Round 1 to Round 3 were also observed in North Bay and West Bay. Zero bags per acre were estimated in North Bay in Round 3. However, an increase was seen in East Bay from Round 1 to Round 3 (Figure 33).

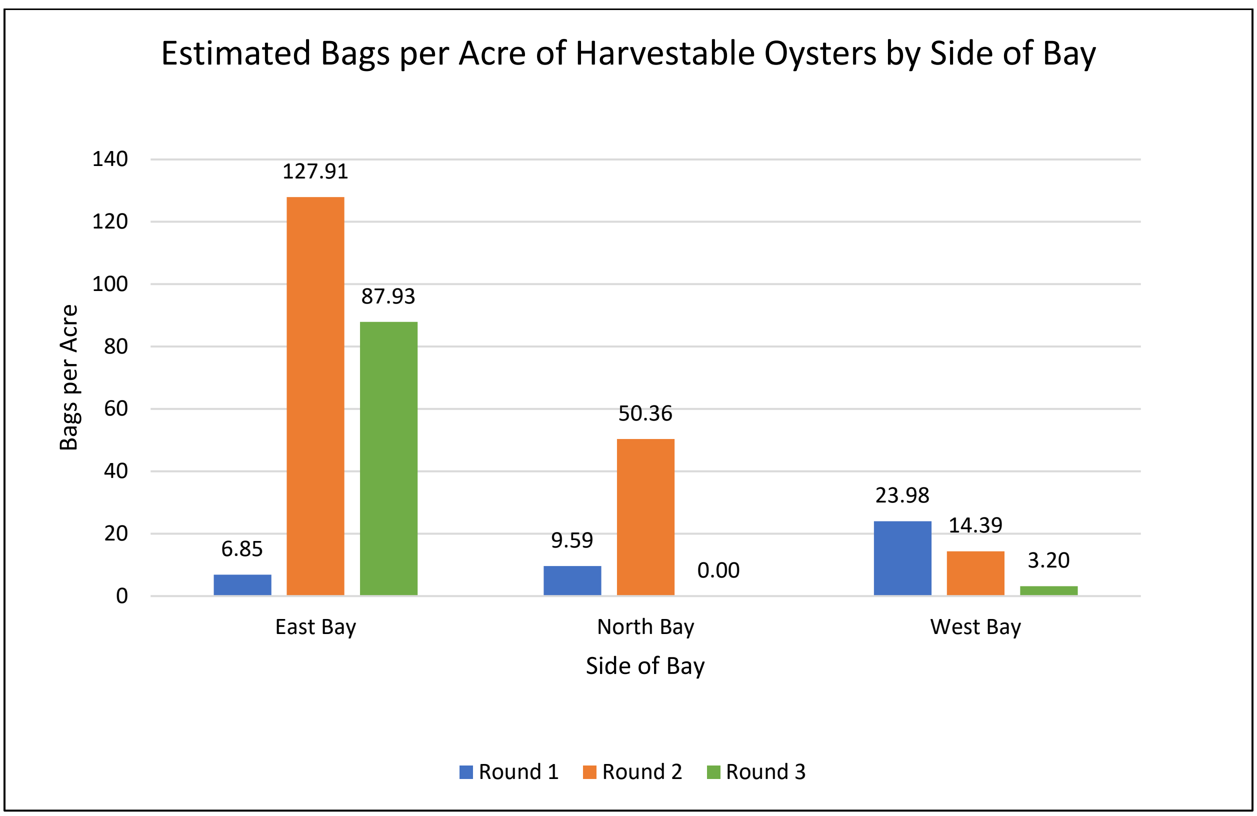


Figure 33: Estimated average bags per acre of harvestable oysters by side of bay.

Discussion

The Florida Oyster Cultch Placement Project seeks to foster oyster reef habitat development by restoring existing, degraded oyster reefs that have reached their productive lifespan. In June 2016, 17,000 cubic yards of crushed granite over an estimated 84 acres of debilitated oyster reefs in the St. Andrews Bay System in Bay County. Monitoring of all cultched sites will occur annually for 10 years to evaluate project success.

In optimal conditions, oysters can reach market size in 12 to 18 months after settling (Ingle and Dawson, 1952). However, some reefs may take two to five years to become productive due to variable recruitment and survival. Monitoring results indicate that oysters are growing, but most likely not in optimal conditions. Adult oysters have been observed in all three rounds of sampling; however, no adults were collected in North Bay in Round 3. Spat-sized (0-25 mm) oysters have been most frequently observed in all sampling rounds; it is expected that those oysters would continue to grow, such that oysters collected in subsequent rounds would have a larger shell height range (seed- or adult-sized). Overall, this shift in shell height distribution has not been observed.

Round 2 sampling occurred in Spring 2018, and CPAP planned to sample St. Andrews reefs in the Fall of 2018. However, on October 10, 2018, Hurricane Michael greatly impacted coastal regions along Florida's Panhandle. As a result of Hurricane Michael and other unforeseen circumstances (staff medical issues, staffing issues, boat repairs, etc.), staff did not sample St. Andrews reefs until the Winter of 2019/2020.. Many factors contribute to oyster survival, and post-hurricane conditions (i.e. altered salinity regimes, algal blooms, etc.) may have caused shifts in oyster populations. It is unfortunate that one year elapsed between Round 2 and 3; immediate impacts to oyster reef populations remains unknown. Data during that period could have indicated direct post-hurricane impacts to populations, as well as provided insight into how major tropical events impact St. Andrews Bay as a whole.

It seems very possible that oyster reefs and/or cultch material may have been displaced because of the hurricane. Many reefs have seen a decrease in sample weight; this was most evident in West Bay. CPAP has noted that some reefs were missing; many areas were just sandy bottom while cultch material could be felt under a layer of mud at others. Crooked Creek Point did not have any cultch material present in Round 3; it is hypothesized that this site was silted over or cultch material was deposited elsewhere as a result of Hurricane Michael. At Doyle Bayou, Midpoint #2 had very little material collected in Round 1 and has had near-zero to zero material collected in Rounds 2 and 3. While this monitoring point is located inside the reef perimeter, cultch material is absent. Since this has been noted prior to Hurricane Michael, it is hypothesized that material was not correctly placed at this location or settled very rapidly after deposition. Settlement seems less likely because at Midpoint #1 at Doyle Bayou, cultch material has been collected during all rounds, and oysters of all size classes have been observed. It is unfortunate that mapping of the cultched reefs did not occur after initial cultch deposition to record an accurate baseline footprint of each reef. It would have been ideal to compare initial cultched area versus the current reef area. Based on samples collected, it is anticipated that reef area will have declined from original clutched reef footprint on some reefs. Mapping the area of the reefs in the Spring and Summer of 2020 should enable CPAP to estimate reef area loss or gains.

Water Quality Monitoring

Water quality parameters (temperature, dissolved oxygen (DO), salinity, and pH) were recorded at each site midpoint, both at the surface and on the bottom of the water column (Table 9). This data provides a 'snapshot' of the conditions at the time of sampling; as additional sampling occurs, water quality data will be analyzed to investigate long-term trends in water quality at each site and across the bay.

Table 9: Water quality parameters at NRDA Oyster Clutch sites in St Andrews Bay for Rounds 1-3 (Fall 2017- Winter 2020).

Site	Midpoint	Round	Sample Position	Temperature (Celcius)	DO (mg/L)	Salinity (ppt)	pH
Newman Bayou Bar	MP1	1	surface	20.5	6.55	8.47	7.26
Newman Bayou Bar	MP1	1	bottom	28.9	2.25	26.2	7.46
East of Power Lines Ridge	MP1	1	surface	28.6	6.71	9	7.44
East of Power Lines Ridge	MP1	1	bottom	28.7	2.24	27.84	7.58
West Bay Point	MP1	1	surface	29.4	6.71	18.03	7.76
West Bay Point	MP1	1	bottom	28.6	4.46	23.38	7.74
West Bay Point	MP2	1	surface	29.4	6.71	18.03	7.76
West Bay Point	MP2	1	bottom	28.6	4.46	23.38	7.74
Crooked Creek Point	MP1	1	surface	30	6.56	12.61	7.26
Crooked Creek Point	MP1	1	bottom	29.3	5.22	20.23	7.56
Doyle Bayou	MP1	1	surface	30.6	6.67	15.81	7.58
Doyle Bayou	MP1	1	bottom	29.6	5.2	20.1	7.63
Doyle Bayou	MP2	1	surface	30.6	6.67	15.81	7.58
Doyle Bayou	MP2	1	bottom	29.6	5.2	20.1	7.63
South Channel Ridge	MP1	1	surface	29.9	6.69	18.43	7.46
South Channel Ridge	MP1	1	bottom	29	0.36	30.24	7.48
Little Oyster Bar Point	MP1	1	surface	30	6.14	8.78	7.34
Little Oyster Bar Point	MP1	1	bottom	29.1	1.78	24.8	7.45
Off Little Oyster Bar Ridge	MP1	1	surface	30.5	6.3	10.22	7.24
Off Little Oyster Bar Ridge	MP1	1	bottom	29	1.25	25.64	7.42
Goose Point	MP1	1	surface	30.1	6.33	10.45	7.24
Goose Point	MP1	1	bottom	29.2	2.14	23.59	7.36
Off Little Oyster Bar Ridge	MP1	2	surface	27.2	7.13	25.02	8
Off Little Oyster Bar Ridge	MP1	2	bottom	28.2	6.27	28.46	7.87
Little Oyster Bar Point	MP1	2	surface	27.9	7.12	25.17	8.04
Little Oyster Bar Point	MP1	2	bottom	28	6.21	28.42	7.87
Goose Point	MP1	2	surface	27.5	7.13	23.82	7.94
Goose Point	MP1	2	bottom	27.9	6.22	26.6	7.9
Crooked Creek Point	MP1	2	surface	24.4	7.33	23.67	7.93
Crooked Creek Point	MP1	2	bottom	25	7.04	32.25	7.93
Doyle Bayou	MP1	2	surface	25.4	7.45	26.55	8.07
Doyle Bayou	MP1	2	bottom	24.8	7.4	27.4	8.08
Doyle Bayou	MP2	2	surface	25.4	7.45	26.55	8.07

Doyle Bayou	MP2	2	bottom	24.8	7.4	27.4	8.08
South Channel Ridge	MP1	2	surface	25.4	7.33	24.91	7.97
South Channel Ridge	MP1	2	bottom	24.2	6.8	33.21	7.92
Newman Bayou	MP1	2	surface	20.1	7.88	20.77	8
Newman Bayou	MP1	2	bottom	21.7	7.58	27.3	7.98
East of Power Lines Ridge	MP1	2	surface	20.9	7.77	25.3	7.98
East of Power Lines Ridge	MP1	2	bottom	21.1	7.99	26.96	8.01
West Bay Point	MP1	2	surface	21	7.61	26.67	7.96
West Bay Point	MP1	2	bottom	20.8	7.7	26.71	7.93
West Bay Point	MP2	2	surface	21	7.61	26.67	7.96
West Bay Point	MP2	2	bottom	20.8	7.7	26.71	7.93
Crooked Creek Point	MP1	3	surface	14.6	9.15	26.75	8.04
Crooked Creek Point	MP1	3	bottom	14.5	9.1	26.97	8.05
Doyle Bayou	MP1	3	surface	15.3	8.45	27.21	7.92
Doyle Bayou	MP1	3	bottom	15.2	9.2	27.51	7.93
Doyle Bayou	MP2	3	surface	15.3	8.45	27.21	7.92
Doyle Bayou	MP2	3	bottom	15.2	9.2	27.51	7.93
South Channel Ridge	MP1	3	surface	15.1	8.9	27.06	7.99
South Channel Ridge	MP1	3	bottom	15	8.8	28	7.97
West Bay Point	MP1	3	surface	15.8	8.41	28.01	8.01
West Bay Point	MP1	3	bottom	15.6	8.33	29.66	7.99
West Bay Point	MP2	3	surface	15.8	8.41	28.01	8.01
West Bay Point	MP2	3	bottom	15.6	8.33	29.66	7.99
Little Oyster Bar Point	MP1	3	surface	16.5	8.15	25.32	8
Little Oyster Bar Point	MP1	3	bottom	16.5	8.23	26.24	7.97
Off Little Oyster Bar Ridge	MP1	3	surface	16.7	8.25	24.79	7.92
Off Little Oyster Bar Ridge	MP1	3	bottom	16.4	8.08	26.03	7.92
Goose Point	MP1	3	surface	17	8.48	25.49	7.95
Goose Point	MP1	3	bottom	16.9	8.49	25.59	7.96
Newman Bayou Bar	MP1	3	surface	21.1	8.23	15.9	8.18
Newman Bayou Bar	MP1	3	bottom	19.6	7.93	26.64	8.04
East of Power Lines Ridge	MP1	3	surface	20.9	8.07	17.19	8.19
East of Power Lines Ridge	MP1	3	bottom	20.4	7.72	25.3	8.07

Chapter 3: Pensacola Bay

The Pensacola Bay watershed is an interconnected system of estuaries encompassing nearly 7,000 square miles in northwest Florida and southern Alabama, with approximately one third of the watershed residing within the state of Florida. The system is comprised of Escambia Bay, Pensacola Bay, Blackwater Bay, East Bay, and Santa Rosa Sound. Feeding into this series of embayments are three major rivers: the Escambia, Blackwater, and Yellow rivers. The East Bay River also contributes a small amount of freshwater to the system. The entirety of the Pensacola Bay watershed system eventually discharges into the Gulf of Mexico, south of Pensacola, Florida (Lewis, 2010). In October 2016, 20,103 cubic yards of a lime rock aggregate over an estimated 88 acres of debilitated oyster reefs in the Pensacola Bay System in Escambia and Santa Rosa Counties (FDACS, 2016). The following sites were selected for restoration, with monitoring conducted at the predetermined midpoints of each site (see Figure 34 and Table 10). Four of the sites sampled lie in the Escambia Bay region, with the remaining thirteen sites located within the East Bay region (refer to Figures 35 & 36 and Table 10).

Escambia Bay (Figure 35)

- <u>Trout Bayou #1:</u> An unconsolidated natural oyster reefal complex. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals landward of reef. Reef is improved habitat constructed on sand shoals and spoil off the northeastern mainland shoreline of Escambia Bar, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- <u>Trout Bayou #2:</u> An unconsolidated natural oyster reefal complex. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals landward of reef. Reef is improved habitat constructed on sand shoals and spoil off the northeastern mainland shoreline of Escambia Bar, in a Conditionally Approved shellfish harvesting area. This site consists of two monitoring midpoints.
- <u>Boathouse Lumps #1:</u> A natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sandy shoals. The reef is located north of Hernandez Point on the west side of Garcon Peninsula, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- <u>Boathouse Lumps #2:</u> A natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sandy shoals. The reef is located north of Hernandez Point on the west side of Garcon Peninsula, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.

East Bay (Figure 36)

- <u>White Point Bar #1:</u> An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located in the vicinity of White Point on the eastern side of the Garcon Peninsula, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- <u>White Point Bar #2:</u> An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located in the vicinity of White Point on

the eastern side of the Garcon Peninsula, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.

- Square Bar: A natural oyster reef. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located southeast of the southeastern most point of the Garcon Peninsula, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- Escribano Point #1: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals. The reef is located in proximity to Escribano Point in East Bay, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- Escribano Point #2: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally sand shoals. The reef is located in proximity to Escribano Point in East Bay, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- Mussel Beds: An unconsolidated natural oyster reefal complex. The existing substrate is an oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located offshore of the northeast mainland shoreline of East Bay, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- No Name Bar: A natural oyster reef. The existing substrate is an oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located off Long Branch, northwest of the East River, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- Point, No Point Bar: A natural oyster reef. The existing substrate is an oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located offshore of the northeast mainland shoreline of East Bay, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- East River #1: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located west of the mouth of the East River, in a Conditionally Approved shellfish harvesting area. This site consists of two monitoring midpoints.
- East River #2: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located west of the mouth of the East River, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- East River #3: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located west of the mouth of the East River, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.
- Big John Bar: An unconsolidated natural oyster reefal complex. The existing substrate is an oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located half of a mile due west of the East River #2 site, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.

- Half Moon Bar: An unconsolidated natural oyster reefal complex. Historically, portions of the reef have received restoration by cultching. The existing substrate is clam and oyster shell matrix, and the surrounding bottom is generally muddy. The reef is located north of the southern mainland shoreline of East Bay, in a Conditionally Approved shellfish harvesting area. This site consists of one monitoring midpoint.

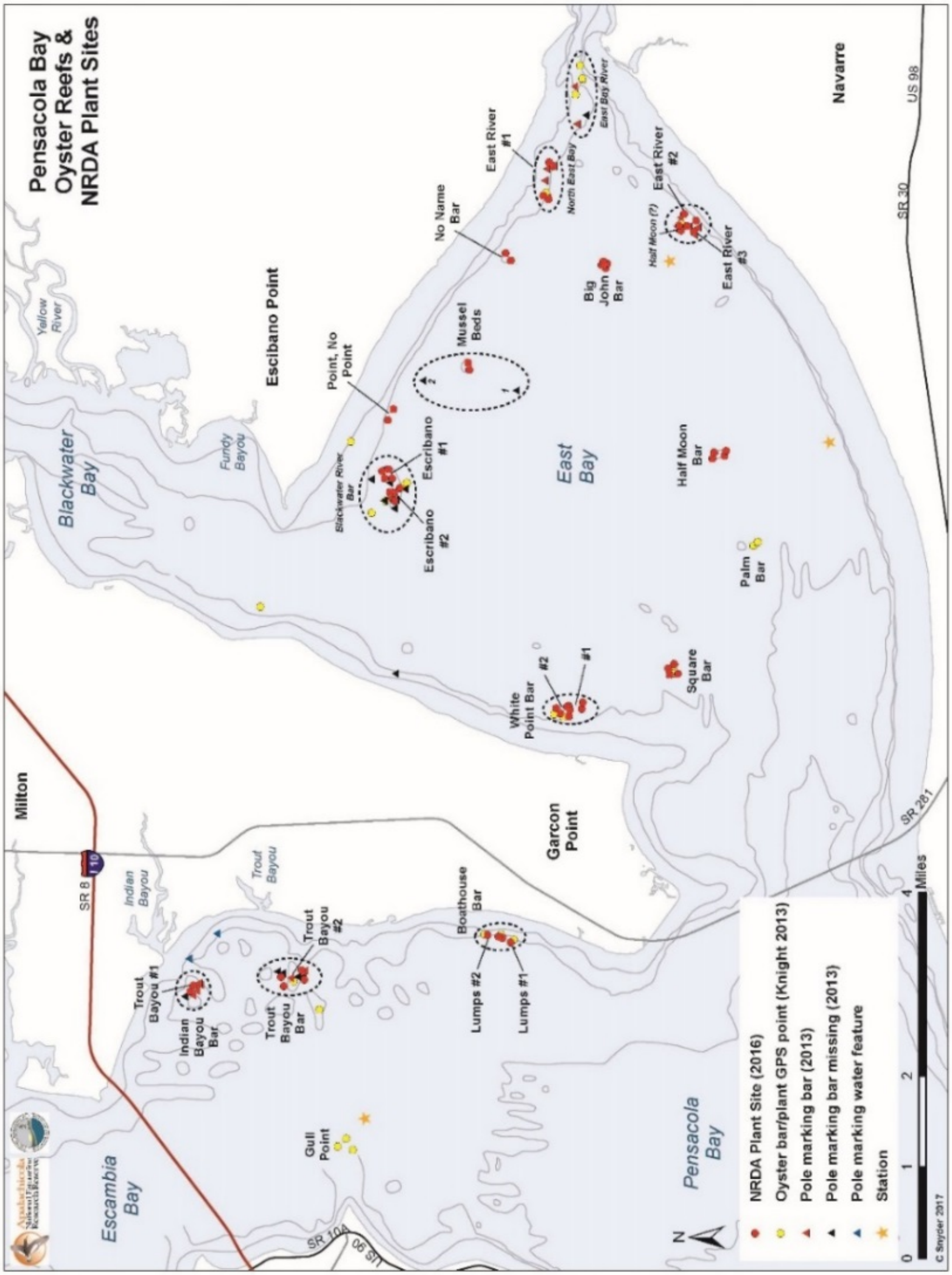


Figure 34: Map of Sample Sites for Pensacola Bay.

Pensacola NRDA Sites & Midpoints (West)

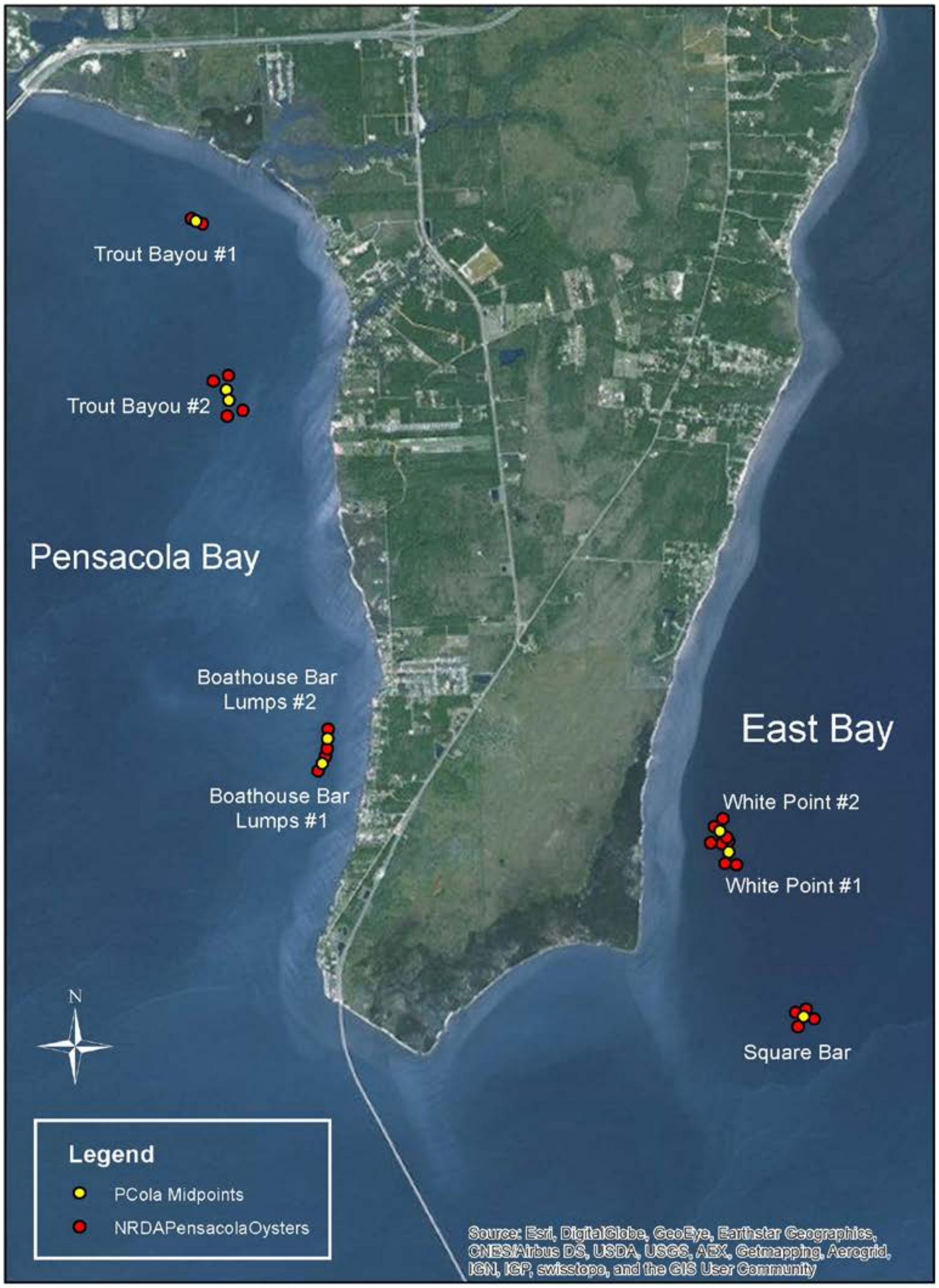


Figure 35: Map of Sample Sites in Escambia Bay (western) region of Pensacola Bay.

Figure 36: Map of Sample Sites in East Bay region of Pensacola Bay.

Table 10: Coordinates for Pensacola Bay Monitoring Sites

Monitoring Site	Latitude	Longitude
Escambia Bay		
Trout Bayou #1, Midpoint 1	30.51744	-87.1116
Trout Bayou #2, Midpoint 1	30.50153	-87.1093
Trout Bayou #2, Midpoint 2	30.50056	-87.10905
Boathouse Lumps #1, Midpoint 1	30.46626	-87.10106
Boathouse Lumps #2, Midpoint 1	30.46858	-87.10038
East Bay		
White Point Bar #1, Midpoint 1	30.45606	-87.05789
White Point Bar #2, Midpoint 1	30.45806	-87.05869
Square Bar, Midpoint 1	30.44034	-87.05079
Escribano Point #1, Midpoint 1	30.48627	-87.0192
Escribano Point #2, Midpoint 1	30.48774	-87.01618
Mussel Beds, Midpoint 1	30.47475	-86.99598
No Name Bar, Midpoint 1	30.46872	-86.9757
Point, No Point Bar, Midpoint 1	30.48724	-87.00527
East River #1, Midpoint 1	30.46243	-86.9605
East River #1, Midpoint 2	30.46265	-86.9628
East River #2, Midpoint 1	30.44044	-86.96892
East River #3, Midpoint 1	30.43842	-86.96919
Big John Bar, Midpoint 1	30.453	-86.97669
Half Moon Bar, Midpoint 1	30.43362	-87.01099

Data Analysis for Pensacola Bay 2017 - 2019

Pensacola Bay NRDA Oyster Cultch Placement sites were sampled during September/October 2017 (Round 1), July 2018 (Round 2), and November 2019 (Round 3). A total of 17 sites consisting of 19 midpoints) were sampled each round.

As cultch placement is not uniform, sample size may vary both within and between sites/regions, both within and between rounds. The total weight of samples collected to date is 1952.18 kg (4303.82 lbs.), with an average sample weight of 2.28 kg (5.03 lbs.). The largest average sample weight in Round 3 was found at Escribano Point #2 (n=3.81 kg). Average sample weight has remained relatively consistent across all three rounds, and when analyzed on a per sample basis, Round 3 sample weights did not differ significantly from Round 1 and Round 2 sample weights.

Table 11: Average sample weight of material collected during all rounds in Pensacola Bay.

Site	Round 1 Average Sample Weight (kg)	Round 2 Average Sample Weight (kg)	Round 3 Average Sample Weight (kg)
Big John Bar	4.21	2.25	2.46
Boathouse Lumps #1	3.30	2.35	2.62
Boathouse Lumps #2	1.51	1.01	0.97
East River #1	1.02	2.28	1.63
East River #2	5.72	3.30	3.75
East River #3	0.17	2.38	2.02
Escribano Point #1	1.79	3.32	3.32
Escribano Point #2	2.36	4.29	3.81
Half Moon Bar	2.73	3.21	3.19
Mussel Beds	0.96	0.47	1.85
No Name Bar	1.81	2.44	2.37
Point No Point Bar	0.56	0.81	0.38
Square Bar	2.10	3.08	2.47
Trout Bayou #1	0.43	0.68	0.04
Trout Bayou #2	3.06	2.33	3.21
White Point Bar #1	2.66	2.63	2.97
White Point Bar #2	2.31	3.34	2.72

To date, 18,118 live and 3,008 dead oysters have been sampled from Pensacola Bay. In Round 3, 7,557 live oysters and 600 dead oysters were collected, with the number of live oysters increasing from Rounds 1 and 2 and the number of dead oysters decreasing from Rounds 1 and 2. The increase in live oysters from Round 1 (n=5,572) to Round 3 and Round 2 (n=4,989) to Round 3 were both found to be statistically significant when analyzed on a per sample basis ($p=0.002$ and $p=2.92x10^{-7}$, respectively). The decrease in dead oysters sampled from Round 1 (n=1,770) to Round 3 was found to be statistically significant ($p=3.34x10^{-9}$), but the decrease from Round 2 (n=638) to Round 3 was not (p=.705).

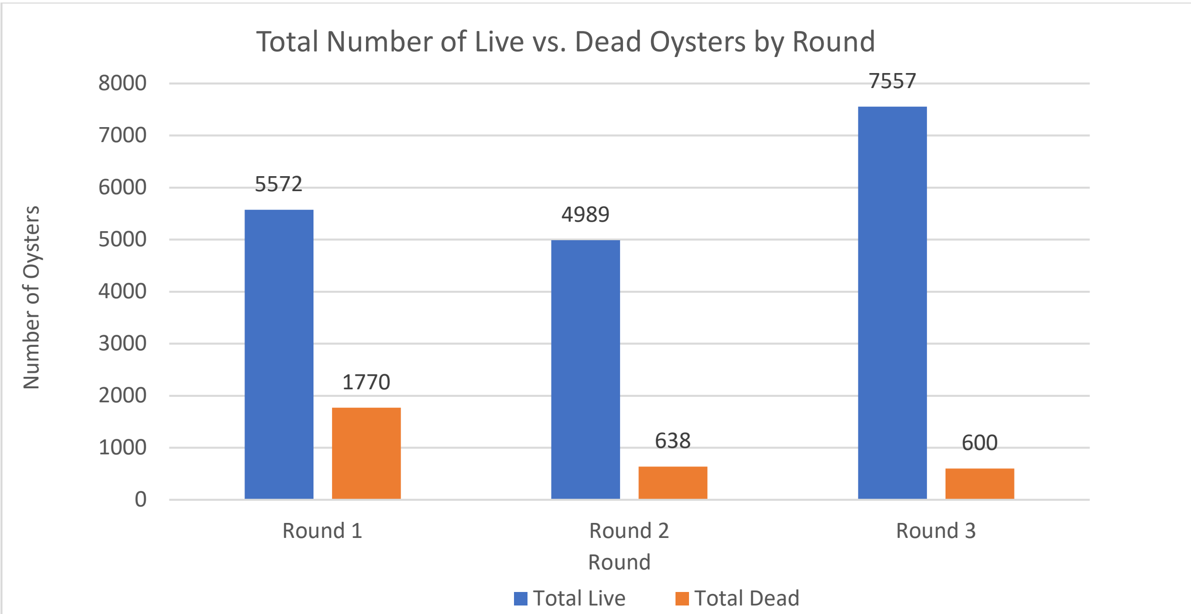


Figure 37: Total number of live vs. dead oysters sampled in Pensacola Bay by round.

Spat-sized oysters continued to be the most abundant size class across all rounds of sampling. In Round 3, approximately 53.83% of all live oysters sampled were in the spat size class (n=4,068). Seed-sized oysters represented the next most abundant size class at 45.72% of all oysters sampled (n=3,455). Adult-sized oysters represented the least abundant size class in Round 3 (n=34), with only 0.45% of the oysters sampled in Round 3. This general pattern of size-class abundance was observed in all rounds. Increases in the number of live oysters were observed across all size classes from both Round 1 to Round 3 and from Round 2 to Round 3. The increase in spat per sample from Round 1 (n=3,486) to Round 3 was not found to be statistically significant (p=0.21). However, the increase in spat from Round 2 (n=2,695) to Round 3 was considered statistically significant ($p=1.31x10^{-5}$). Increases in seed per sample were found to be statistically significant from both Round 1 (n=2,070) to Round 3 ($p=1.65x10^{-5}$) and from Round 2 (n=2,292) to Round 3 ($p=2.58x10^{-5}$). The increase in number of adult-sized oysters from Round 1 (n=16) to Round 3 was not found to be statistically significant (p=0.06), but the increase from Round 2 (n=2) to Round 3 was considered statistically significant ($p=7.32x10^{-7}$) (Figure 38).

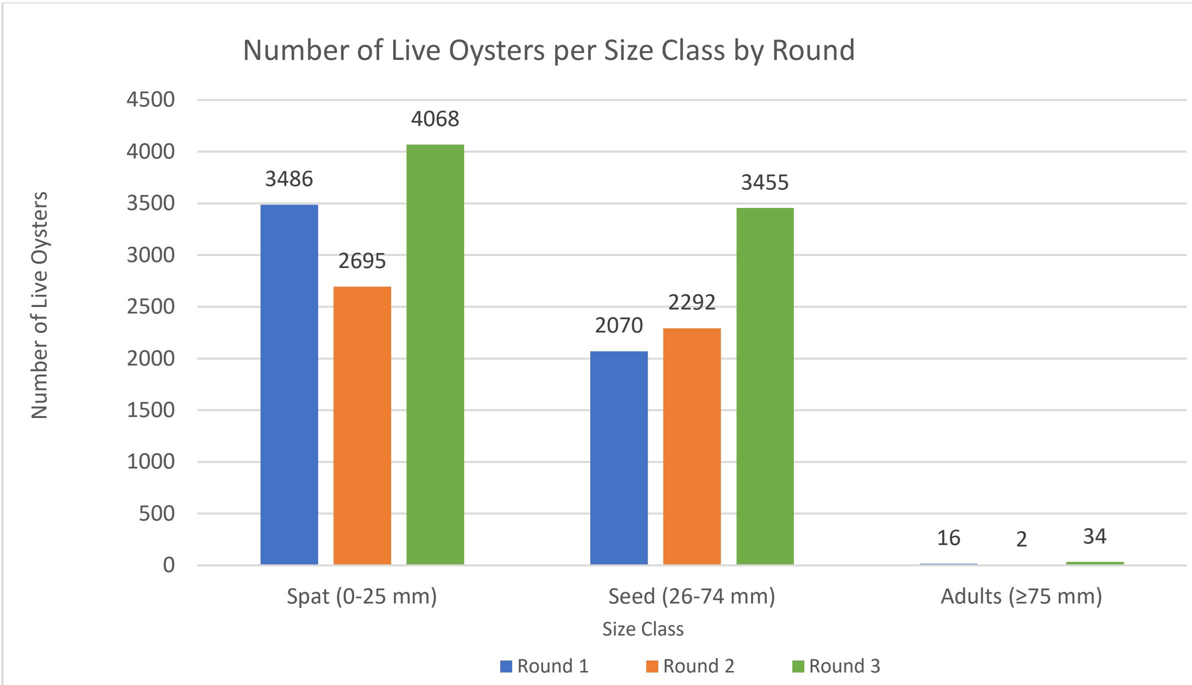


Figure 38: Total number of live oysters sampled in Pensacola Bay by size class.

Abundance of oysters sampled varied with geographic region, with more live oysters collected in East Bay than in Escambia Bay in all three rounds. Increases in all three size classes were observed from Round 1 to Round 3 and from Round 2 to Round 3 in East Bay. East Bay had a large number of both spat and seed-sized oysters, but the dominant size class for East Bay was seed in both Round 1 (n=1960) and Round 2 (n=1799); however, in Round 3, the dominant size class was spat (n=3633). The dominant size class for Escambia Bay in Round 1 and 2 was spat (n=1937 and n=1204, respectively) while in Round 3, seed size oysters were the dominant size class (n=998). A continuing decrease in spat-sized oysters has been observed in Escambia Bay since Round 1; however, an increase in seed-sized and adult-sized oysters was observed from both Round 1 to Round 3 and from Round 2 to Round 3. In Escambia Bay, the number of seed size oysters observed in Round 3 was more than double that of Round 2 and nearly ten times more than the number of seed-sized oysters collected in Round 1 (Figure 39).

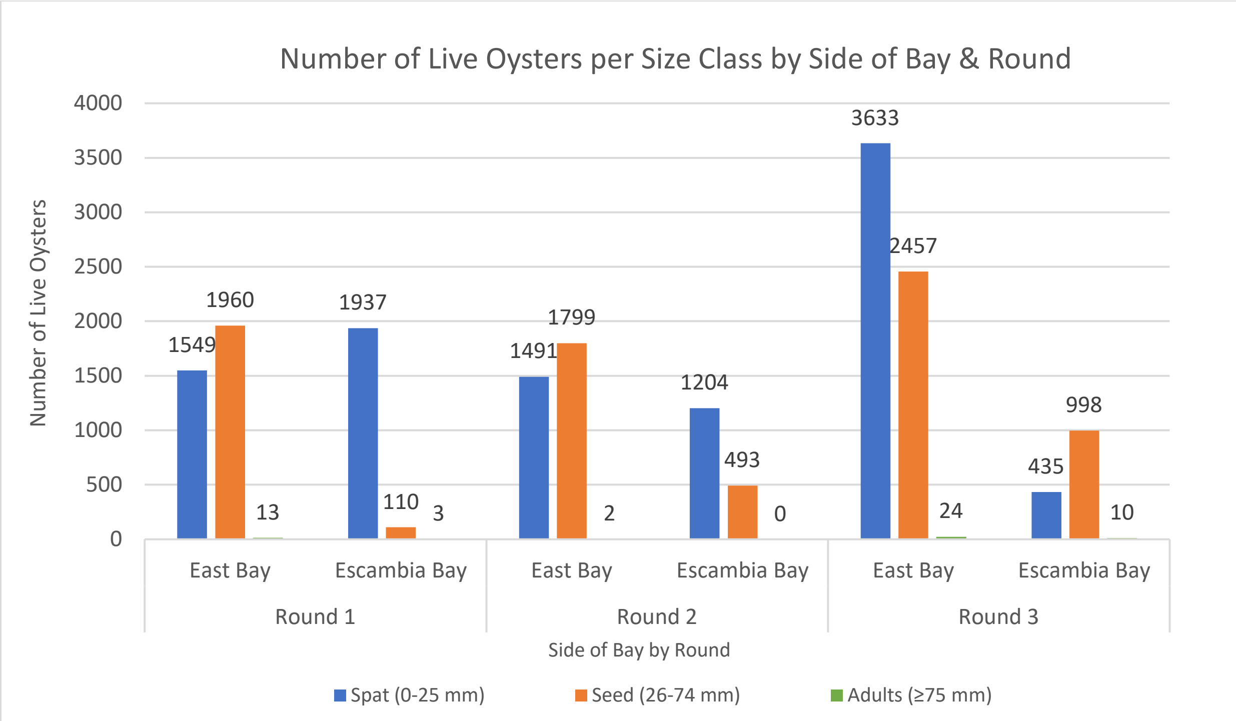


Figure 39: Live oysters per size class by side of bay and round.

The greatest number of spat observed in Round 3 was at East River #2 (n=651). This is similar to the highest number of spat in Round 2 (n=668) found at Trout Bayou #2. These amounts are both far less than the highest number of spat found in Round 1, which was also at Trout Bayou #2 (n=1507). Both Square Bar and Trout Bayou #1 had zero spat present in Round 3. Although the overall number of spat-sized oysters increase from Rounds 1 and 2 to Round 3, no discernable pattern was noted in overall changes in spat abundance across sites. During Round 1, Trout Bayou #2 had the greatest number of spat (n=1507), followed by East River #2 (n=425) and Half Moon Bar (n=391). Trout Bayou #2 also had the highest number of spat in Round 2 (n=668), followed by Half Moon Bar (n=331) and Escribano Point #2 (n=299). East River #2 had the greatest number of spat observed in Round 3 (n=651). During Round 1, zero spat were sampled at East River #3 and Escribano Point #2, and only one spat was sampled at Trout Bayou #1. All sites sampled during Round 2 had spat present. Trout Bayou #1 and Square Bar did not have any spat on samples collected in Round 3 (Figure 40). Some reefs possessed very few spat sized oysters: Boathouse Lumps #1 (n=96), Boathouse Lumps #2 (n=12), and Point No Point Bar (n=30); additionally, zero seed or adult sized oysters were encountered at these reefs.

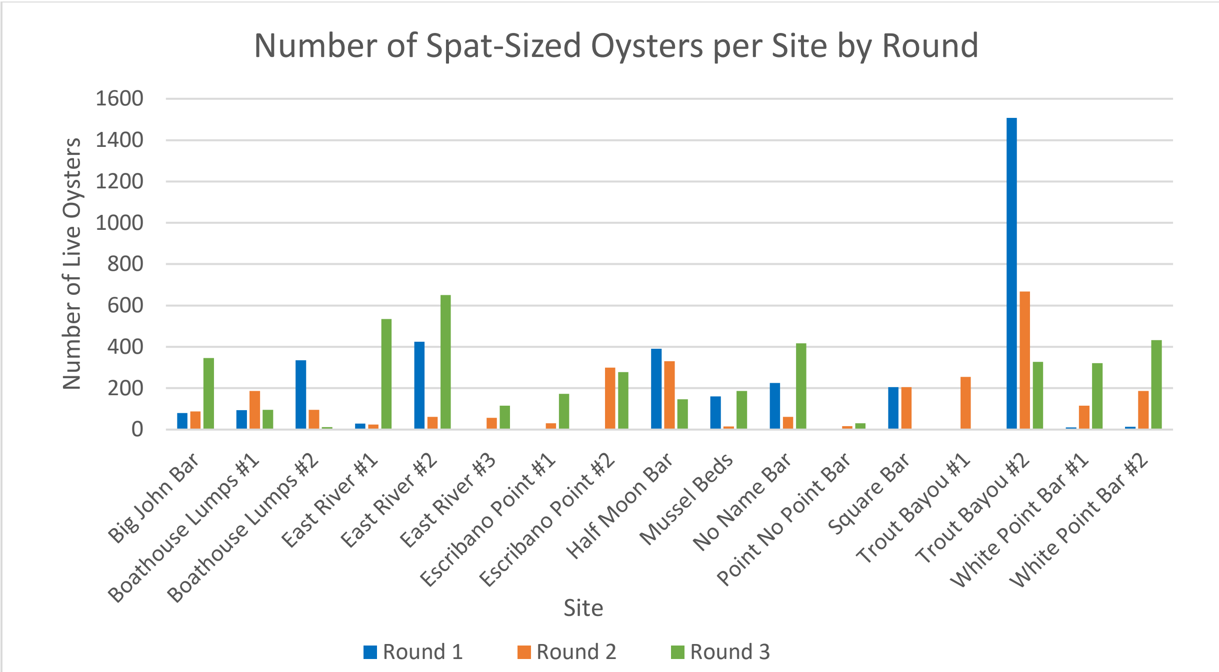


Figure 40: Spat-sized oysters per site by round in Pensacola Bay.

The greatest number of seed-sized oysters was observed at Trout Bayou #2 in Round 3 (n=998), which is more than three times the amount of seed-sized oysters measured at any other reef. In both Round 1 and Round 2, the greatest number of seed-sized oysters were observed at East River #2 (n=745 and n=418, respectively). Zero seed-sized oysters were observed at Boathouse Lumps #1, Boathouse Lumps #2, Half Moon Bar, Square Bar, and Trout Bayou #1 in Round 3. Again, no discernable pattern was noted in overall changes in seed abundance across sites when compared to previous rounds (Figure 41).

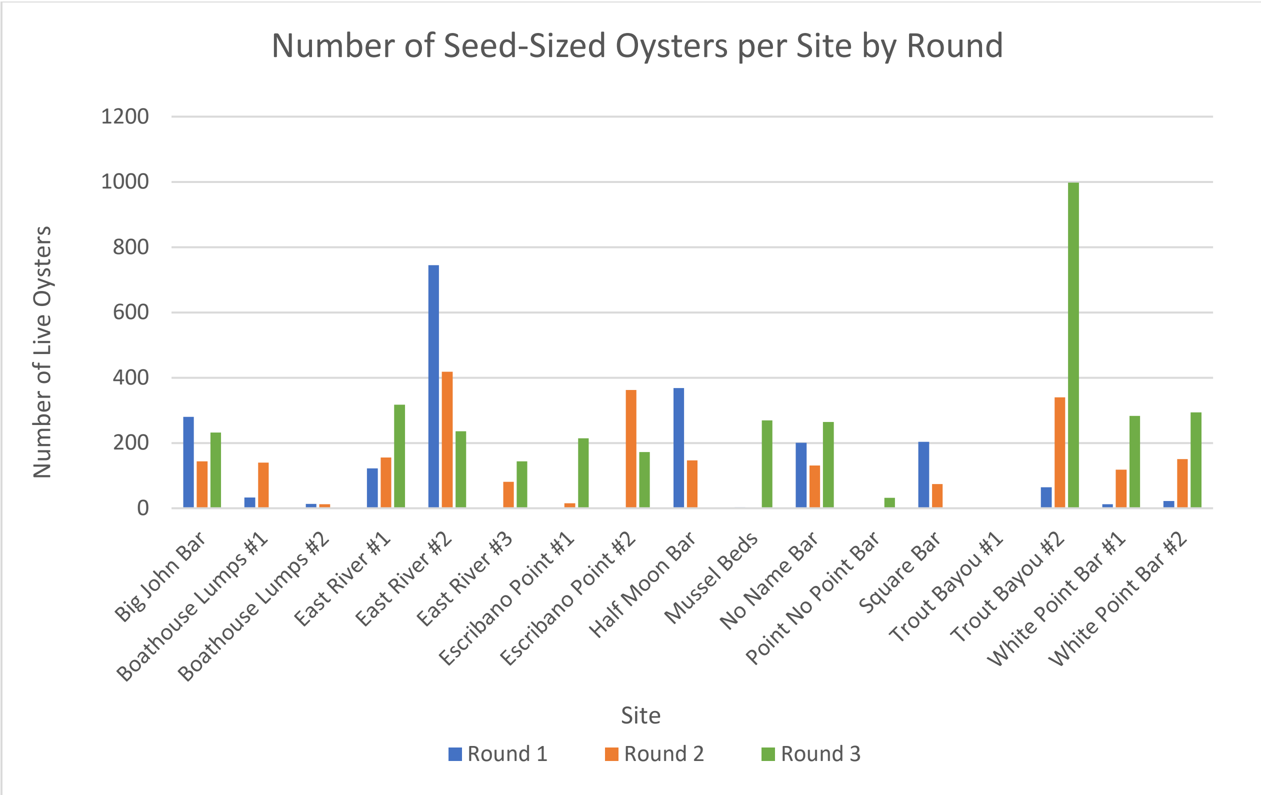


Figure 41: Seed sized oysters per site by round in Pensacola Bay.

Eight of the sites sampled in Round 3 had adult-sized, harvestable oysters present, which is considerably more than in previous rounds; in Round 1 only three sites had adult oysters present, and in Round 2 only sites had adult oysters present. In Round 3, the greatest number of adult-sized oysters was found at Trout Bayou #2 (n=10), which also had the highest number of seed-sized oysters in Round 3. Trout Bayou #2 was also one of the only sites in Round 2 to have adult-sized oyster present. This suggests that more oysters are capable of surviving to adult, harvestable size at this location in comparison to other sites. Zero adult oysters were sampled in Round 3 at Boathouse Lumps #1, Boathouse Lumps #2, Escribano Point #1, Escribano Point #2, Half Moon Bar, No Name Bar, Point No Point Bar, Square Bar, Trout Bayou #1, and White Point Bar #1.

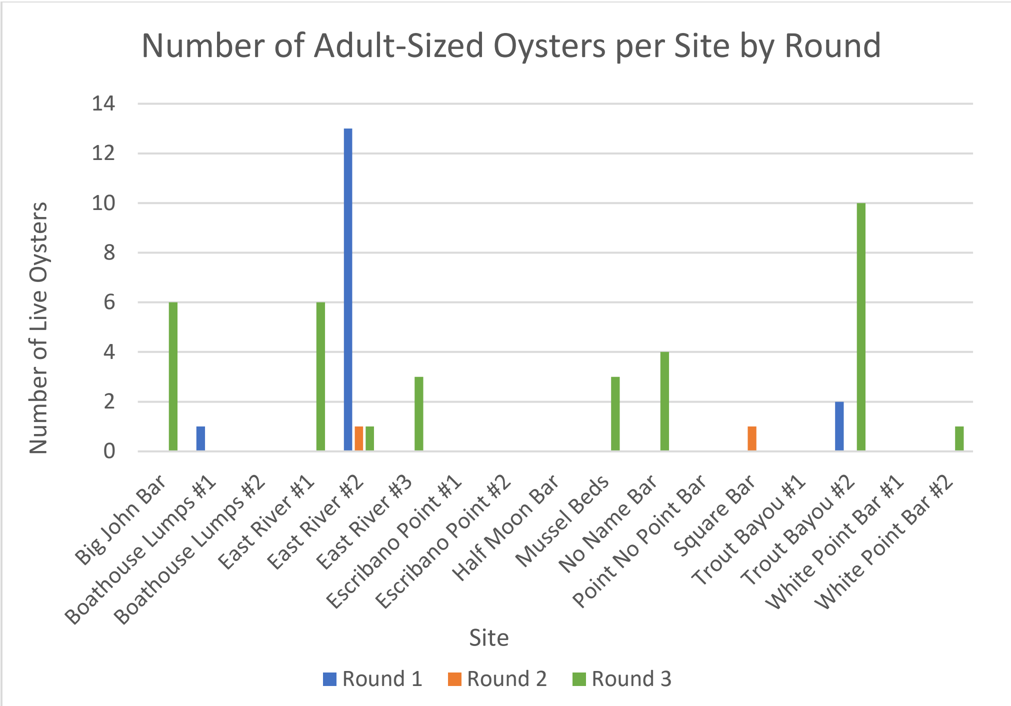


Figure 42: Adult sized oysters per site by round in Pensacola Bay.

Average shell height in Pensacola Bay was 24.62 mm in Round 3 and did not differ significantly from that of Round 1 (n=24.27mm) or Round 2 (n=25.10mm) (p=0.055 and p=0.067, respectively).

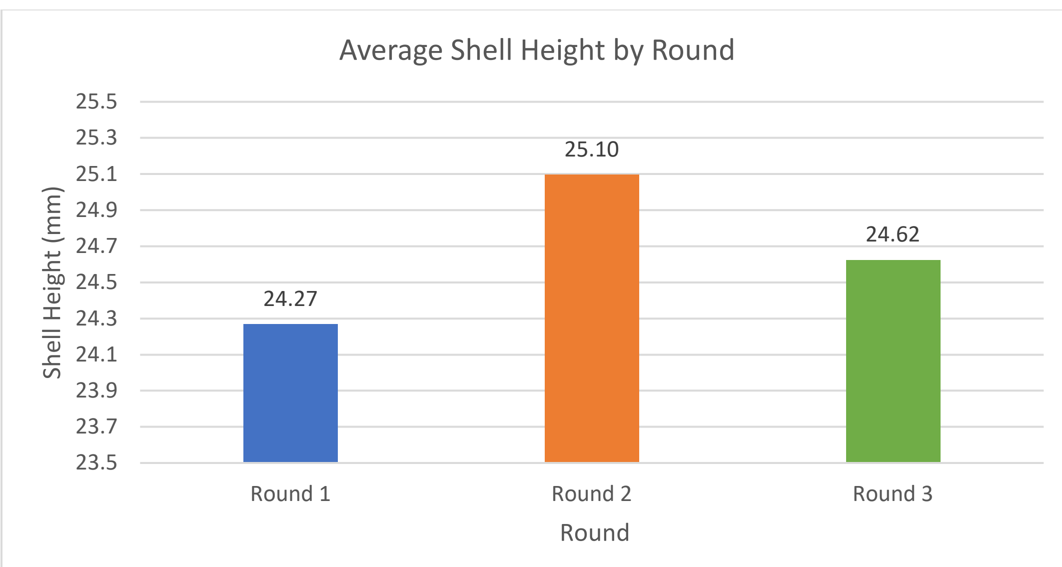


Figure 43: Average shell height by round.

Distribution of shell height measurements throughout Pensacola Bay varied slightly between rounds, as is expected with the slight differences in average shell height.. A general trend toward smaller size measurements was noted in all rounds, as is to be expected with a larger number of spat- and seed-sized oysters and very few adults sampled in all rounds. Shell height measurements were most frequently observed in the 21-35mm (larger spat to seed-sized) range in Round 3. In Round 1, the most dominant shell height range was from 16-30mm, and in Round 2 shell heights of 6-15mm were most prevalent, followed by oyster in the 26-30mm size range. The distribution curve of overall shell height in Pensacola Bay as continued to shift slightly toward larger dominant size ranges since Round 1 (Figure 44).

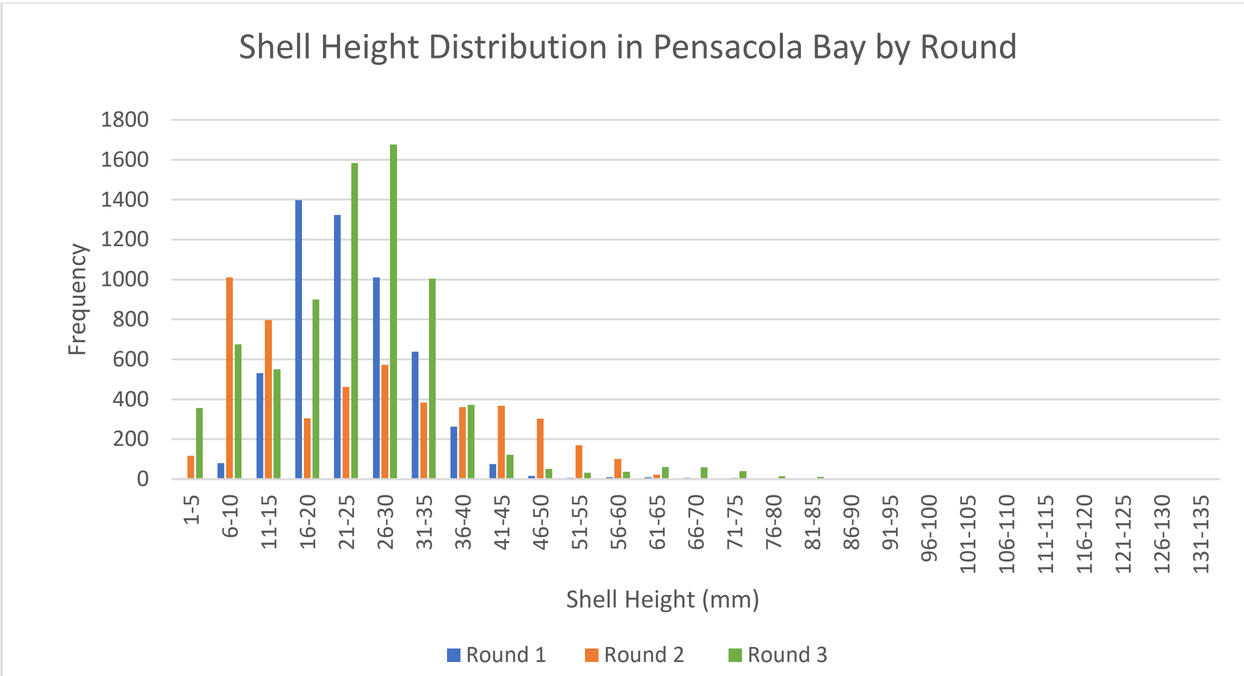


Figure 44: Shell height distribution per round in Pensacola Bay.

Distribution of shell height measurements in East Bay closely resembled that of the entire Pensacola Bay system. This is to be expected, as most of the oysters sampled were from East Bay, and therefore would provide the majority of the data for the entire bay. Although the overall number of oysters sampled in Round 3 increased from previous rounds, the general distribution of shell height frequencies has remained relatively consistent. Oysters in the 16-35mm range were most prevalent in both Rounds 1 and 3. Round 2 shell heights most frequently fell into the 6-15mm and 21-30mm ranges (Figure 45).

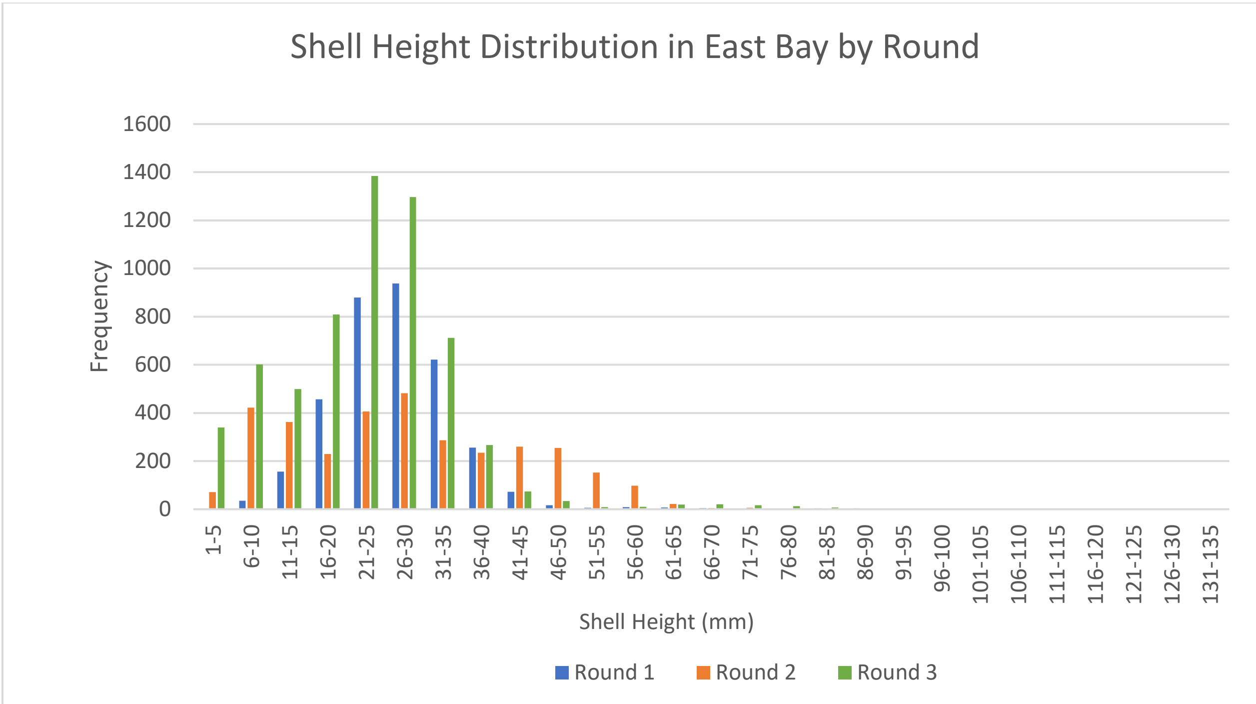


Figure 45: Shell height distribution by round in the East Bay region of Pensacola Bay.

Although slightly different in overall distribution from East Bay, oysters sampled from Escambia Bay still trended toward smaller oyster sizes in all rounds. In Round 3, shell height measurements occurred most frequently in the 26-35mm range, which is considered seed-sized and is slightly larger in size than previous rounds. In Round 1, measured oysters largely fell into the size range of 16--25mm. In Round 2, the majority of oysters fell into the 6-15mm range (Figure 46).

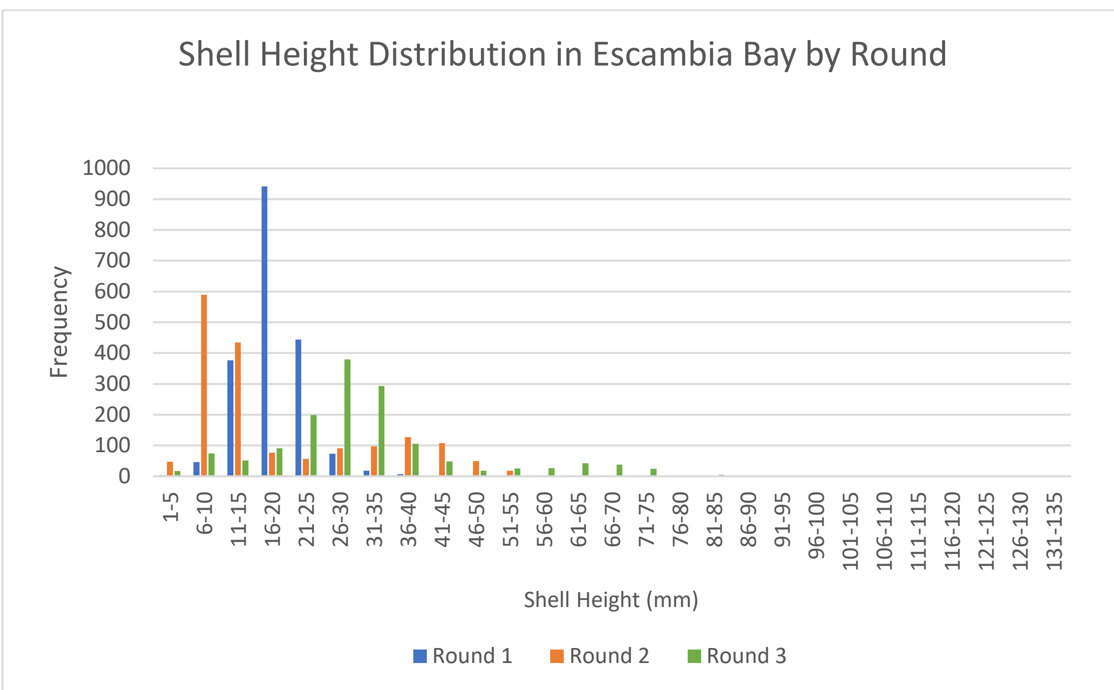


Figure 46: Shell height distribution by round in the Escambia Bay region of Pensacola Bay.

Estimated density provides a better understanding of the general distribution of the oyster population present within a standardized area and accounts for differences in sampling efforts (i.e. larger number of samples per site). Estimated live oyster density increased from Round 1 (n=78.20 live oysters/m^2) and Round 2 (n=70.02 live oysters/m^2) to Round 3 (n=106.06 live oysters/m^2) (Figure 47).

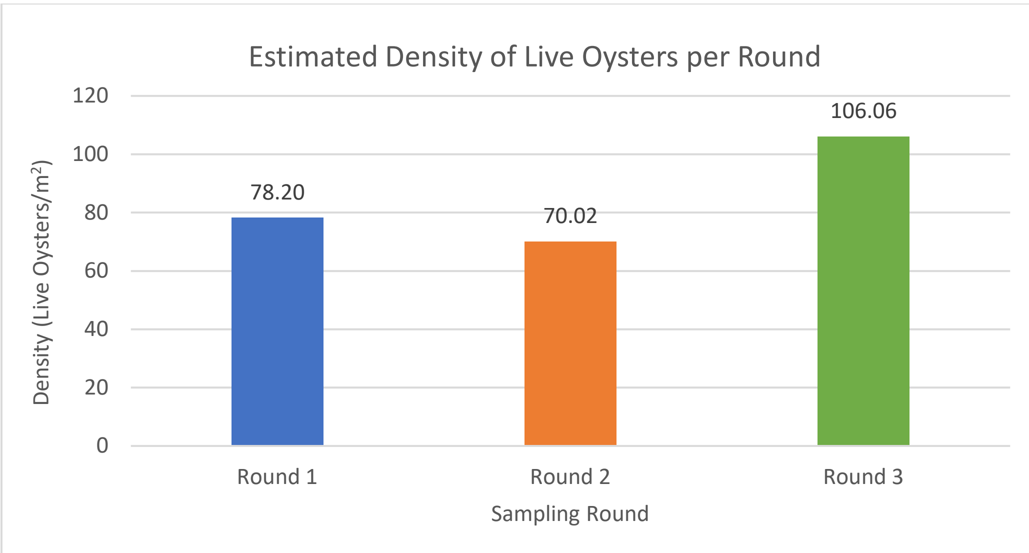


Figure 47: Estimated oyster density per round in Pensacola Bay.

Density allows for a stronger comparison of oyster productivity between different regions of the bay, while eliminating the factor of differences in the amount of material sampled, as larger sites consisting of multiple midpoints would have more samples taken than those with only a single midpoint. Estimated density of live oysters in the East Bay region of Pensacola Bay nearly doubled from Round 1 (n=67.09 live oysters/m^2) and Round 2 (62.70 live oysters/m^2) to Round 3, (n=116.46 live oysters/m^2). Estimated live oyster density in Escambia Bay has steadily declined since Round 1 (Figure 48).

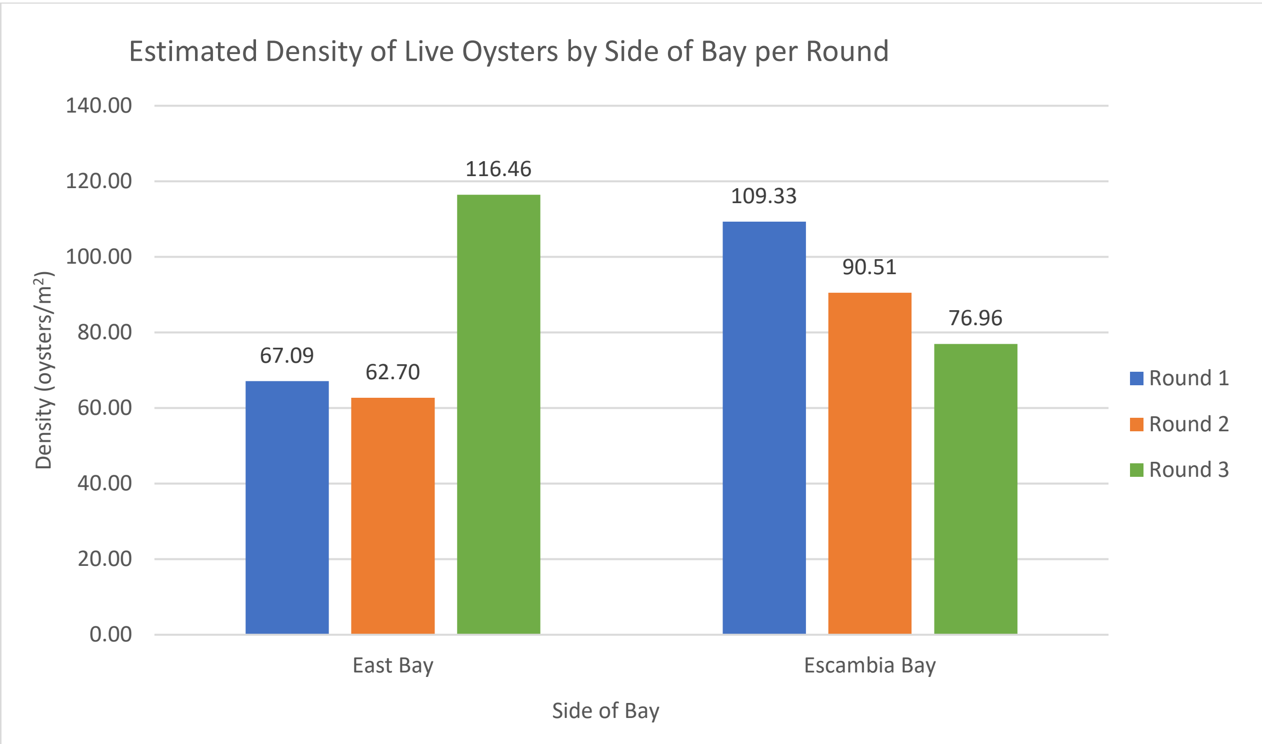


Figure 48: Estimated density (oysters/m^2) of live oysters by side of bay per round.

The highest estimated density of live oysters in Round 3 was at East River #2 (n=236.80 live oysters/m^2), which also had the highest density in Round 1 (n=315.47 live oysters/m^2). Both Square Bar and Trout Bayou #1 had no live oysters present in Round 3 samples and therefore had an estimated live oyster density of 0. As oysters were present in previous rounds at these sites, a noticeable decrease is present in their respective live oyster density. Across the majority of sites sampled, a general decrease in estimated live oyster density was seen from Round 1 to Round 2 (Figure 49). In Round 3, most reefs saw a substantial increase in estimated oyster density; however, Boathouse Lumps #1 and #2, Escribano Point #2, Half Moon Bar, Square Bar, and Trout Bayou #1 exhibited significant decreases in estimated oyster density. No discernable pattern is present in overall live oyster density changes among sites between the three rounds.

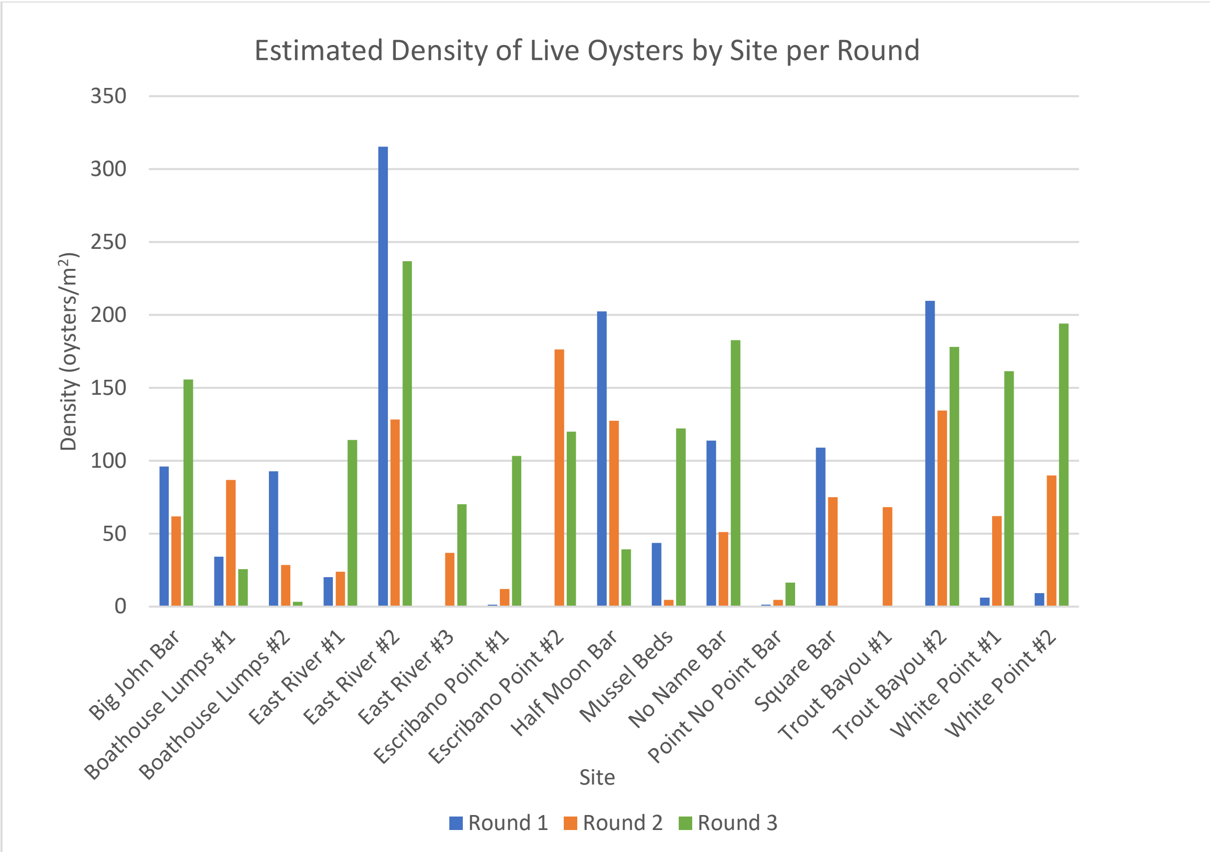


Figure 49: Estimated density of live oysters per site by round in Pensacola Bay.

FDACS Standard Oyster Resource Management Protocol

Bags per acre of harvestable oysters is the standard utilized by the Florida Department of Agriculture and Consumer Services (FDACS) to evaluate overall productivity for a shellfish harvesting area and determine whether a particular area is suitable for commercial harvest (see Attachment 1). A minimum of 200 bags/acre of harvestable oysters is required to sustain limited commercial harvest, and below 100 bags/acre is considered a depleted resource. Although more sites yielded harvestable oysters in Round 3 than in previous rounds, and many sites saw an increase in estimated bags per acre of harvestable oysters, no sites sampled in Round 3 had estimates considered capable of sustaining commercial harvest. All sites were below the threshold for a 'depleted resource' (<100 bags/acre) in Round 3.

Table 12: Estimated bags per acre of harvestable oysters per site by round.

Site	Bags Per Acre Round 1	Bags Per Acre Round 2	Bags Per Acre Round 3
Big John Bar	0.00	0.00	28.78
Boathouse Lumps #1	4.80	0.00	0
Boathouse Lumps #2	0.00	0.00	0
East River #1	0.00	0.00	14.39
East River #2	62.35	4.80	4.80
East River #3	0.00	0.00	14.39
Escribano Point #1	0.00	0.00	0
Escribano Point #2	0.00	0.00	0
Half Moon Bar	0.00	0.00	0
Mussel Beds	0.00	0.00	14.39
No Name Bar	0.00	0.00	19.19
Point No Point Bar	0.00	0.00	0
Square Bar	0.00	4.80	0
Trout Bayou #1	0.00	0.00	0
Trout Bayou #2	4.80	0.00	23.98
White Point Bar #1	0.00	0.00	0
White Point Bar #2	0.00	0.00	4.80

Increases in estimated bags per acre of harvestable oysters were seen in both East Bay and in Escambia Bay from previous rounds. Escambia Bay (n=9.59 bags/acre) had a slightly higher estimated number of bags per acre than East Bay (n=8.22) in Round 3 (Figure 50). However, as entire regions, both East Bay and Escambia Bay had estimates well below the threshold for sustaining limited commercial harvest, and current estimates consider the resource in these regions 'depleted'.

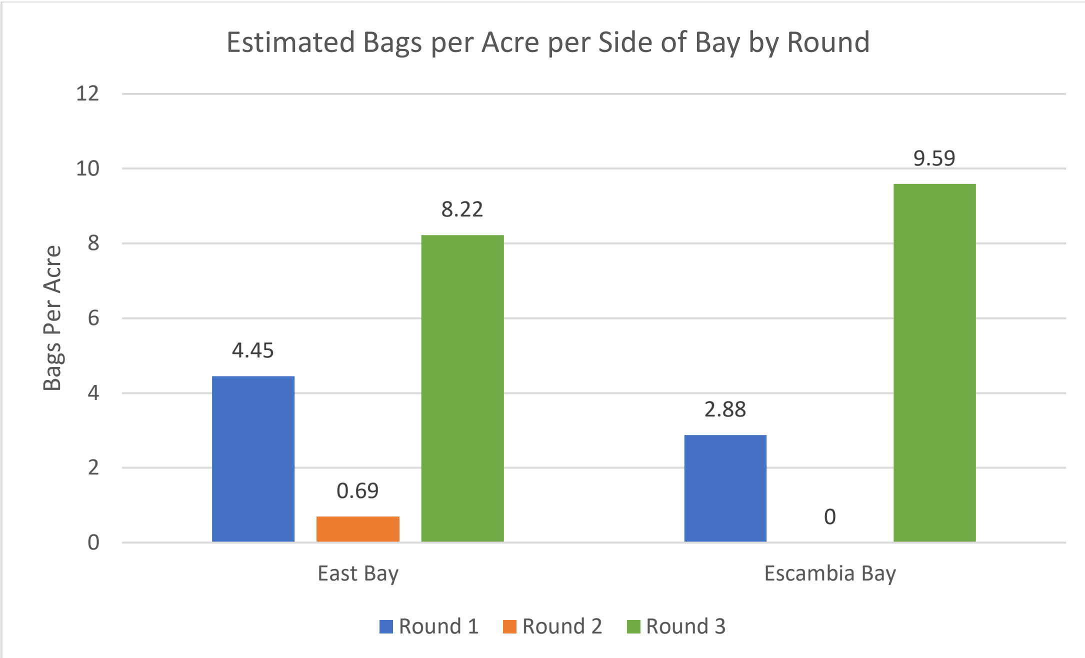


Figure 50: Bags per acre of harvestable (adult-sized) oysters per side of bay by round.

Discussion

The Florida Oyster Cultch Placement Project seeks to foster oyster reef habitat development by restoring existing, degraded oyster reefs that have reached their productive lifespan. In October 2016, 20,103 cubic yards of a lime rock aggregate over an estimated 88 acres of debilitated oyster reefs in the Pensacola Bay System in Escambia and Santa Rosa Counties. Monitoring of all cultched sites will occur annually for 10 years to evaluate project success.

In optimal conditions, oysters can reach market size in 12 to 18 months after settling (Ingle and Dawson, 1952). However, some reefs may take two to five years to become productive due to variable recruitment and survival. Monitoring results indicate that conditions are not optimal, as limited adult oysters have been observed throughout Pensacola Bay across all rounds. Spat size (0-25 mm) oysters were the most frequently observed in Rounds 1 and 2, while seed size (26-75 mm) were the most common size range for oysters in Round 3.

It is discouraging that very little spat was observed on the Escambia Bay sites in Round 3. Current oyster populations will not be able to recover if unable successfully reproduce. Spat was more prevalent in East Bay, and it is expected that those oysters will continue to grow, such that the majority of oysters collected in subsequent rounds would have a larger shell height range (seed or adult size); however, overall, this shift in shell height distribution has not been observed. Thirty-four adults were collected during Round 3, which is more than the other rounds combined.

Round 2 sampling occurred in the Summer 2018, and Round 3 sampling was anticipated in the Spring of 2019. However, on October 10, 2018, Hurricane Michael made landfall impacting coastal regions along Florida's Panhandle. As a result of Hurricane Michael and other unforeseen circumstances (staff medical issues, staffing issues, boat repairs, etc.), staff did not sample Pensacola Bay until the late Fall of 2019. The total number of live oysters was the highest recorded in Round 3; additionally, total dead in Round 3 were the lowest recorded across all sampling rounds. Overall oyster density estimates have decreased for Escambia Bay since Round 1; however, East Bay has seen a considerable increase in estimated oyster densities. Many factors contribute to oyster survival, and post-hurricane conditions (i.e. altered salinity regimes, algal blooms, etc.) may contribute to shifts in oyster population dynamics. It is unfortunate that one year elapsed between Round 2 and 3; immediate impacts to oyster reef populations remains unknown. Data during that period could have indicated direct post-tropical event impacts to populations, as well as provided insight into how major tropical events impact Pensacola Bay as a whole.

It seems very possible that oyster reefs and/or cultch material may have been displaced over time. Several reefs have seen a decrease in average sample weight since Round 1. CPAP noted during sampling that some reefs were silted over; cultch material could be felt under a layer of silt and mud. Some reefs, such as Trout Bayou #1 and Point No Point Bar, did not have much material present. It is unfortunate that mapping of the cultched reefs did not occur after initial cultch deposition to record a baseline footprint of each reef. It would have been ideal to compare initial cultched area versus the current reef area. Based on samples of cultch material collected, it is anticipated that reef area will have declined from original clutched reef footprint on reefs experiencing a decline in sample weight.. Mapping the reefal area of all the reefs in the Spring and Summer of 2020 should enable CPAP to estimate reef area loss or gains.

Water Quality Monitoring

As sessile, benthic filter feeders, oysters are heavily dependent on and influential of the water they inhabit. Multiple water quality parameters (temperature, dissolved oxygen (DO), salinity, and pH) for each site were recorded at both bottom and surface depths (Table 13). This data provides a 'snapshot'of the conditions at the time of sampling; as additional sampling occurs, water quality data will be analyzed to investigate long-term trends in water quality at each site and across the bay. Water quality data for each site can be viewed on Table 4.

Table 13: Bottom and surface water quality data for each NRDA site in Pensacola Bay by round.

Site	Round	Sample Position	Depth (m)	Temperature (Celsius)	DO (%)	DO (mg/L)	Salinity (ppt)	pH
Big John Bar	1	Surface	0.1	17.2	96.8	8.69	12.86	7.95
Big John Bar	1	Bottom	2.2	17	96.7	8.68	13.35	7.86
Boathouse Lumps #1	1	Surface	0.1	28.2	102.7	7.32	16.49	8.04
Boathouse Lumps #1	1	Bottom	2.5	28.1	89.8	6.38	16.77	7.95
Boathouse Lumps #2	1	Surface	0.1	28.3	100.2	7.14	16.79	8.03
Boathouse Lumps #2	1	Bottom	2.3	28.1	88.3	6.34	17.83	7.94
East River #1	1	Surface	0.1	18.7	92.7	8.14	11.14	7.73
East River #1	1	Bottom	1.9	18.2	90.7	7.91	15.27	7.61
East River #2	1	Surface	0.1	17.7	97.9	8.67	12.98	7.84
East River #2	1	Bottom	1.8	17.4	92.7	8.16	15.46	7.81
East River #3	1	Surface	0.1	17.7	97.9	8.67	12.98	7.84
East River #3	1	Bottom	2.4	17.4	92.7	8.16	15.46	7.81
Escribano Point #1	1	Surface	0.1	28.5	103.1	7.4	14.68	7.98

Escribano Point #1	1	Bottom	2.5	27.9	94.8	6.78	16.42	7.87
Escribano Point #2	1	Surface	0.1	28.7	103.5	7.39	15.04	7.96
Escribano Point #2	1	Bottom	2.4	28	99.7	7.16	15.86	7.9
Half Moon Bar	1	Surface	0.1	18.3	98	8.62	11.92	7.78
Half Moon Bar	1	Bottom	1.8	17.1	95.5	8.41	15.44	7.82
Mussel Beds	1	Surface	0.1	29.1	97.6	6.9	14.97	7.83
Mussel Beds	1	Bottom	2.3	28	95.6	6.83	16.4	7.88
No Name Bar	1	Surface	0.1	29.4	94.5	6.64	15.24	7.81
No Name Bar	1	Bottom	2.2	28.4	84.9	6.02	16.17	7.71
Point No Point Bar	1	Surface	0.1	29	101.1	7.15	15.63	7.9
Point No Point Bar	1	Bottom	2.7	28.3	99.2	7.08	16.01	7.91
Square Bar	1	Surface	0.1	18.1	95.8	8.53	10.47	7.65
Square Bar	1	Bottom	1.7	17.3	97.4	8.59	15.04	7.85
Trout Bayou #1	1	Surface	0.1	30.1	107.2	7.56	12.4	8.07
Trout Bayou #1	1	Bottom	2.2	28.8	68.7	4.87	16.36	7.84
Trout Bayou #2	1	Surface	0.1	29.5	103.5	7.46	10.66	8.04
Trout Bayou #2	1	Bottom	2.2	28.2	93.5	6.64	17.45	7.96
White Point Bar #1	1	Surface	0.1	17.8	90.5	8.56	1.45	8.14
White Point Bar #1	1	Bottom	2.1	18.2	88.5	7.6	16.16	7.54
White Point Bar #2	1	Surface	0.1	18.1	90.6	8.49	1.69	7.85
White Point Bar #2	1	Bottom	2.1	18.1	91.7	7.91	15.95	7.58
Big John Bar	2	Surface	0.1	30.1	102.7	7.22	13.58	9.12
Big John Bar	2	Bottom	2.5	29.8	60.8	4.2	17.86	8.83
Boathouse Lumps #1	2	Surface	0.1	30.9	146	10.37	10.79	9.94
Boathouse Lumps #1	2	Bottom	2.1	29.4	64.5	4.37	20.26	9.63
Boathouse Lumps #2	2	Surface	0.1	31.4	162	11.46	10.71	10.55
Boathouse Lumps #2	2	Bottom	1.9	29.5	60.7	4.11	19.92	9.51
East River #1	2	Surface	0.1	30.6	91.2	6.41	12.84	10.08
East River #1	2	Bottom	2.3	30.4	35.2	2.44	14.7	9.42
East River #2	2	Surface	0.1	30.8	96.8	6.71	14.08	10.03
East River #2	2	Bottom	2.2	30.2	77.9	5.42	15.19	9.8
East River #3	2	Surface	0.1	30.2	80.1	5.58	14.03	9.84
East River #3	2	Bottom	2.8	29.8	54.7	3.74	19.38	9.39
Escribano Point #1	2	Surface	0.1	29.6	102	7.36	11	9.24
Escribano Point #1	2	Bottom	2.6	29.5	100.4	7.13	14.12	8.92
Escribano Point #2	2	Surface	0.1	30.1	101.6	7.27	11.14	10.42
Escribano Point #2	2	Bottom	2	29.9	106.2	7.54	12.88	10.11
Half Moon Bar	2	Surface	0.1	29.7	106.1	7.53	12.66	9.42
Half Moon Bar	2	Bottom	2.4	29.2	98.3	6.98	14.3	9.21
Mussel Beds	2	Surface	0.1	29.9	107.7	7.57	14.12	11.1
Mussel Beds	2	Bottom	2.3	29.6	104.8	7.41	14.3	10.89
No Name Bar	2	Surface	0.1	30.4	105.2	7.33	14.66	10.67
No Name Bar	2	Bottom	2.4	30.4	103.5	7.2	14.58	10.03

Point No Point Bar	2	Surface	0.1	30.1	112.4	7.89	14.49	11
Point No Point Bar	2	Bottom	2.4	29.9	91.4	6.14	15.36	10.9
Square Bar	2	Surface	0.1	29.9	103.1	7.27	13.35	9.63
Square Bar	2	Bottom	2.2	29.3	89.5	6.32	14.28	9.11
Trout Bayou #1	2	Surface	0.1	31.2	124.9	8.78	10.61	10.07
Trout Bayou #1	2	Bottom	2.4	30.8	74.2	5.13	14.6	9.49
Trout Bayou #2	2	Surface	0.1	31.6	118.7	8.44	7.83	10.35
Trout Bayou #2	2	Bottom	1.9	29.7	64.1	4.44	15.81	9.51
White Point Bar #1	2	Surface	0.1	29.6	105	7.6	9.86	9.21
White Point Bar #1	2	Bottom	2.5	29.5	86.8	6.4	11.75	8.81
White Point Bar #2	2	Surface	0.1	29.3	104.5	7.59	9.74	9.06
White Point Bar #2	2	Bottom	2.5	29.4	46.4	3.25	15.37	8.51
Big John Bar	3	Surface	0.1	15	98.7	8.87	20.6	8.24
Big John Bar	3	Bottom	2.5	14.3	104.9	9.41	22.79	8.15
Boathouse Lumps #1	3	Surface	0.1	13.8	102.4	9.25	21.8	7.92
Boathouse Lumps #1	3	Bottom	1.9	14.9	104.5	8.97	26.17	7.93
Boathouse Lumps #2	3	Surface	0.1	14	102.9	9.26	21.85	7.99
Boathouse Lumps #2	3	Bottom	1.6	15	107.3	9.21	25.98	8.03
East River #1	3	Surface	0.1	15.3	101.5	9.03	20.83	8.26
East River #1	3	Bottom	2.4	15.2	103.8	9.22	21.42	8.2
East River #2	3	Surface	0.1	15	98.6	8.68	23.64	8.14
East River #2	3	Bottom	2.3	14.9	98.9	8.73	23.47	8.08
East River #3	3	Surface	0.1	14.8	95.6	8.47	23.1	8.01
East River #3	3	Bottom	2.8	15.5	97.5	8.33	26.73	7.98
Escribano Point #1	3	Surface	0.1	14.1	102	9.13	22.35	8.07
Escribano Point #1	3	Bottom	2.5	13.9	110.9	9.92	24.06	8
Escribano Point #2	3	Surface	0.1	14	101.8	9.17	22.38	7.69
Escribano Point #2	3	Bottom	2.5	13.8	109.1	9.72	23.69	7.8
Half Moon Bar	3	Surface	0.1	14.1	102.6	9.3	22.18	8.09
Half Moon Bar	3	Bottom	2.2	13.8	104.7	9.47	23.17	8.06
Mussel Beds	3	Surface	0.1	14.1	104.3	9.46	20.21	7.89
Mussel Beds	3	Bottom	2.3	14.1	105.1	9.4	22.78	7.87
No Name Bar	3	Surface	0.1	14.1	100.8	9.21	19.85	7.87
No Name Bar	3	Bottom	2.2	14.2	101.1	9.03	22.3	7.85
Point No Point Bar	3	Surface	0.1	14.5	101.1	9.03	21.4	7.88
Point No Point Bar	3	Bottom	2.3	14.3	103	9.18	23.27	7.87
Square Bar	3	Surface	0.1	14.2	101.9	9.29	21.15	8
Square Bar	3	Bottom	1.9	13.8	105.5	9.62	22.49	8.01
Trout Bayou #1	3	Surface	0.1	14.6	106.8	9.36	23.84	8.04
Trout Bayou #1	3	Bottom	2.0	15.6	108.2	9.15	26.21	8.01
Trout Bayou #2	3	Surface	0.1	13.8	104.3	9.37	22.36	8.03
Trout Bayou #2	3	Bottom	1.7	15	108.7	9.33	26.09	8.02
White Point Bar #1	3	Surface	0.1	13.5	94.8	9.08	15.95	8.04

White Point Bar #1	3	Bottom	2.4	13.3	99.2	9.3	19.9	7.98
White Point Bar #2	3	Surface	0.1	13.2	94.8	9.16	15.24	7.79
White Point Bar #2	3	Bottom	2.2	13.2	98.8	9.32	18.51	7.81

Appendix 1 – FDACS Standard Oyster Resource Management Protocol

Introduction: The Florida Department of Agriculture and Consumer Services (FDACS) shares responsibility for managing oyster resources in Apalachicola Bay with the Florida Fish and Wildlife Conservation Commission (FWC); more specifically, the Division of Aquaculture manages oysters from both resource development and public health protection perspectives.

Oyster Resource Assessments: The Division has conducted oyster resource surveys on the principle oyster-producing reefs in Apalachicola Bay since 1982. This information is used by resource managers to reliably predict trends in oyster production; to monitor oyster population dynamics, including recruitment, growth, natural mortality, standing stocks; and to determine the impacts of climatic events such as hurricanes, floods, and droughts.

Continuous monitoring and data analyses have allowed resource managers to develop a scale using defined sampling protocol to determine the relative condition of oyster resources based on estimated production parameters. Estimated production exceeding 400 bags of oysters per acre is applied as an indicator of healthy oyster reefs capable of sustaining commercial harvesting. Accordingly, oyster populations are 1) capable of supporting limited commercial harvesting when stocks exceed 200 bags/acre, 2) below levels necessary to support commercial harvesting when stocks fall below 200 bags/acre, and 3) considered depleted when marketable stocks are below 100 bags/acre. Generally, production from Cat Point Bar has been the most accurate indicator of oyster production in Apalachicola Bay, but East Hole Bar and St. Vincent Bar are also reliable indicators of the condition of oyster resources throughout the Bay. This scale forms the basis for the Standard Resource Management Protocol provided in Subsection 68B-27.017, Florida Administrative Code (FAC), which is used as the criteria for setting the number of harvesting days in the Winter Harvesting Season in Apalachicola Bay. Subsection 68B-27.017(2)(a), FAC, provides that oysters may be harvested for commercial purposes on any day of the week from November 16 to May 31 of each year when the Bay is not closed for public health purposes and when the oyster resources on Cat Point Bar and East Hole Bar can sustain a harvest of 300 bags of oysters per acre.

CREATION OF POPULATION ESTIMATES

Background: In 1985, hurricanes Kate and Elena devastated a majority of the oyster reefal complexes in Apalachicola Bay. In 1986, comprehensive management programs and regulatory restrictions were implemented to foster resource recovery and facilitate restoration. During this period, a massive oyster reefal complex refurbishment project was undertaken wherein; 385 acres were planted, using 96,230 cubic yards of clam shell.

Evaluating: Oyster populations were compared using the Kruskal-Wallis test to determine significant differences between length-frequency distributions among replicate samples and between successive sampling intervals.

Transects were established across the restored reef and quadrats were selected along transects by tossing a PVC grid from the survey vessel.

Specifics: a weighted 0.25m^2 PVC grid was used to delineate sample quadrats. Samples were collected by divers; live oysters, shell and associated fauna were removed to a depth of 15cm, placed in mesh collecting bags and delivered to the survey vessel. Live oysters were measured to the nearest lower 0.5cm length.

Oysters ≥75mm were used to provide estimates of marketable oysters/m^2 and densities were extrapolated to calculate potential production levels.

Ingle and Whitfield (1968 & 1973) estimated that about 400bu/acre could be harvested from productive artificially constructed reefs within two years of planting cultch. A scale was developed using field surveys of natural and constructed bars in Apalachicola Bay to determine the relative condition of oyster resources based on production estimates.

Production:
Estimates:

- >400 bags/acre – healthy oyster reefs capable of sustaining commercial harvest
- >200 bags/acre – capable of sustaining limited commercial harvest.
- <200 bags/acre – below level necessary to support commercial harvest
- <100 bags/acre – considered depleted

CALCULATIONS FOR ASSESSING POPULATION ESTIMATES FROM FIELD SURVEYS

Example from Cat Point 09/08 data set:

	Quadrats (Total #)	**Live Oysters (Total #)**	**Mean Length (mm)**	**Density (live oysters/ m^2)**		**Oysters ≥75mm (dec)**	**(Harvestable Oysters/m^2)**	**Harvestable Oysters/acre**	**Bags of Harvestable Oysters/Acre**
	20 [1]	616 [2]	55.2 [3]	123.2 [4]		.1721 [5]	21.2 [6]	85.8 [7]	381 [8]

[1] Total # of quadrats sampled
[2] Total # of all live oysters in all quadrats
[3] Mean Length derived from Statistical Analysis Software programs
[4] Total Oysters [2]/No. of Quadrats [1] x 4; Oysters/0.25m^2 x 4 = Oysters/m^2
[5] Proportion of oysters ≥75mm ; Total # of Oysters ≥75mm/Total # of Live Oysters [2]
[6] Proportion of oysters≥75mmmm [6] x Density [4] = Oysters ≥75/m^2
Example: 0.1721 [5] x 123.2 [4] = 21.20 harvestable oysters/m^2
[7] Proportion of oysters≥75mm [6] x Density [4] x 4,047 = oyster ≥75mm/acre
Example: 0.1721 x 123.2 x 4,047 = 85,807.4 harvestable oysters/acre)
[8] Oysters/Acre divided by 225 oysters/bag

Example: 85,807.4 /225 = 381.36 bags/acre

Explanations:

[1] Total # of quadrats sampled:

The total number of quadrats collected per site varies by site size.

[2] Total # of all live oysters in all quadrats

As with variations in quadrats per site vary with site size, number of live oysters may also vary with difference in sampling effort at different sites.

[3] Mean Length

Calculated as average shell height (mm) of oysters sampled.

[4] Total Oysters/No. of Quadrats; Oysters/0.25m^2 x 4 = Oysters/m^2

Intuitively, the total number of oysters per quarter-meter square quadrat is multiplied by 4 in order to acquire total number of oysters per meter square.

[5] Number of oysters ≥75mm/Total oysters [2]

The number of harvestable sized oysters divided by the total number of live oysters sampled yields a decimal proportion of oysters ≥75mm.

[6] Proportion of oysters ≥75mm [5] x Density [4] = Oysters ≥75/m^2

The percentage of oysters greater than 75 mm (~3 inches; standard legally harvestable-sized) multiplied by the density yields the number of harvestable-sized oysters per meter. This information is key for assessing population trends and assessing the productivity of a given oyster reefal complex.

[7] Proportion of oysters ≥75mm [5] x Density [4] x 4,047 = oyster ≥75mm / acre

The percentage of oysters greater than 70 mm (~ 3 inches; standard legal-size oyster) multiplied by the density, and then multiplied by 4,047 (no. of square meters in an acre) yields the total number of oysters per acre.

[8] Oysters/Acre divided by 225 oysters per bag

Through historical sampling of oyster catch volumes it has been determined that the average 60 lb. bag contains approximately 225 legal sized (3 inches or greater) oysters or the approximate number of legal sized oysters which could be contained in two (2) five-gallon buckets. The value of legal sized oysters per acre total is the most important result from our calculations as it allows us to make management decisions related to the oyster fishery.

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