Final Report--Apalachicola Bay Subtidal Oyster Reef Mapping

Florida Fish and Wildlife Conservation Commission (FWC) Contract #19286
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Ray Grizzle and Krystin Ward
University of New Hampshire
Durham, NH 03824

Tom Waddington and Tom Reis
Substructure, Inc.
Portsmouth, NH 03801

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INTRODUCTION

The present mapping project (conducted from 2020-2022) is the initial major component of a larger, longer-term (2020-2024) effort to restore degraded subtidal oyster reefs in Apalachicola Bay, which was closed to commercial harvest on August 1, 2020. The closure was the most recent of several management actions resulting from the Deepwater Horizon oil spill in 2010 and subsequent collapse of the commercial oyster fishery in the Bay in 2012-2013 (Camp et al. 2015; Pine et al. 2015). Although mapping efforts focusing on selected areas had been done as part of a variety of restoration and other activities, no Bay-wide mapping had been conducted since surveys by the US Geological Survey in the mid-2000s (Twichell et al. 2007, 2010). *The overall aim of the present project was to provide current information on the spatial extent of live subtidal oyster reefs and bottom types potentially suitable for reef construction/restoration activities.*

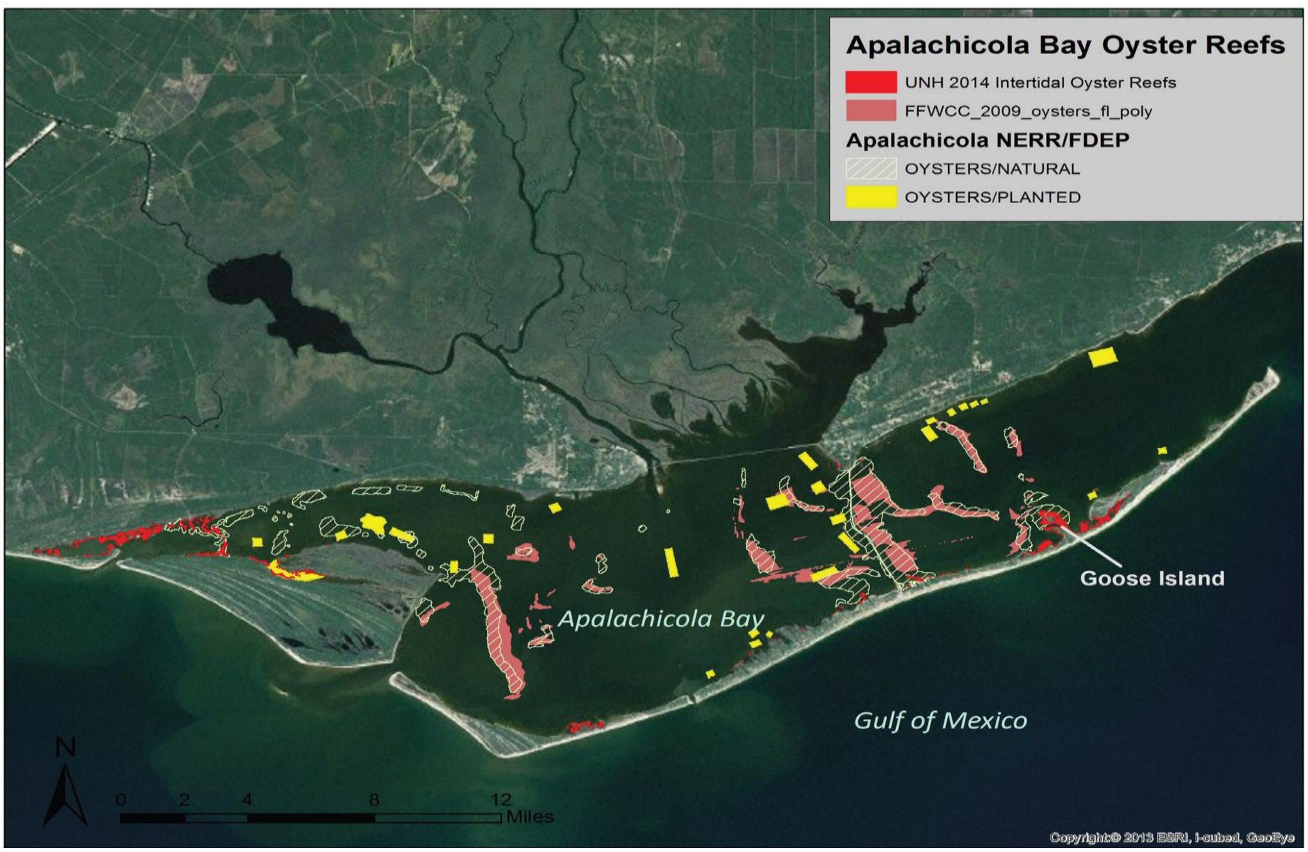

Figure 1. Composite of previously mapped subtidal and intertidal natural reefs, and recent restoration ("planted") sites in Apalachicola Bay (from Radabaugh et al. 2021).

Referring to **Figure 1** above, a major fact to note is that subtidal oyster reefs in Apalachicola Bay now consist of natural reefs and historical restoration ("planted," or "cultched") sites. Additionally, a substantial number of planted reefs were constructed on natural reefs as well as in areas where natural reefs had not historically occurred. All the subtidal oyster reefs (natural and planted) in **Figure 1** represented potential "target" reefs for re-surveying in the current project, and there was no attempt to find new subtidal reefs that had not been previously mapped.

METHODS

Study Design

The major initial challenge for study design was to determine how much of the ~10,000 acres of previously mapped subtidal reefs (natural and constructed) in the Bay (**Figure 1**) could be adequately re-surveyed. The contract set a target goal of 3,125 acres based on previous surveys in the Bay that used relatively close spacing (40 m) between ship tracks for acoustic surveying. Although it was decided early on that this goal could be increased by wider spacing of ship tracks, new data on how much firm bottom (i.e., oysters or bottom suitable for cultching) remained on the historically mapped reefs were needed to determine the potential final acoustic-based survey area. This figure would mainly control the distance between ship tracks needed. Thus, the overall project consisted of: (1) preliminary sampling of the bottom to determine how much of the historical reef areas could be re-surveyed; (2) Bay-wide acoustic surveys and ground-truthing; (3) preliminary map production; and (4) final map production.

Preliminary bottom sampling (2020)

The primary objective of preliminary sampling was to determine the current spatial extent of "firm" bottom on the 43 previously mapped subtidal oyster reefs in the Bay (**Figure 1**). This would provide information needed to determine ship-track width during the acoustic surveys, as discussed above. The resulting data were also used as ground-truthing for the subsequent acoustic survey data. Target preliminary sampling sites were determined by overlaying a 0.5-km grid over each of the ~40 previously mapped natural and planted subtidal reefs (**Figure 2**). Most sites were sampled by probing the bottom with a PVC pipe (**Figures 3B** and **5**) to determine the predominant composition of the bottom: mud, sand, shell hash, oysters, rock. This is essentially the method used by Swift (1897) in the initial survey of "oyster beds" and bottom areas "suitable for the planting of oysters" in Apalachicola Bay in 1895-1896 who used a wooden pole with a brass plate attached to the bottom. Most sites where the PVC probe indicated oysters or rock were sampled retroactively using patent or handheld tongs (**Figure 4B and C**).

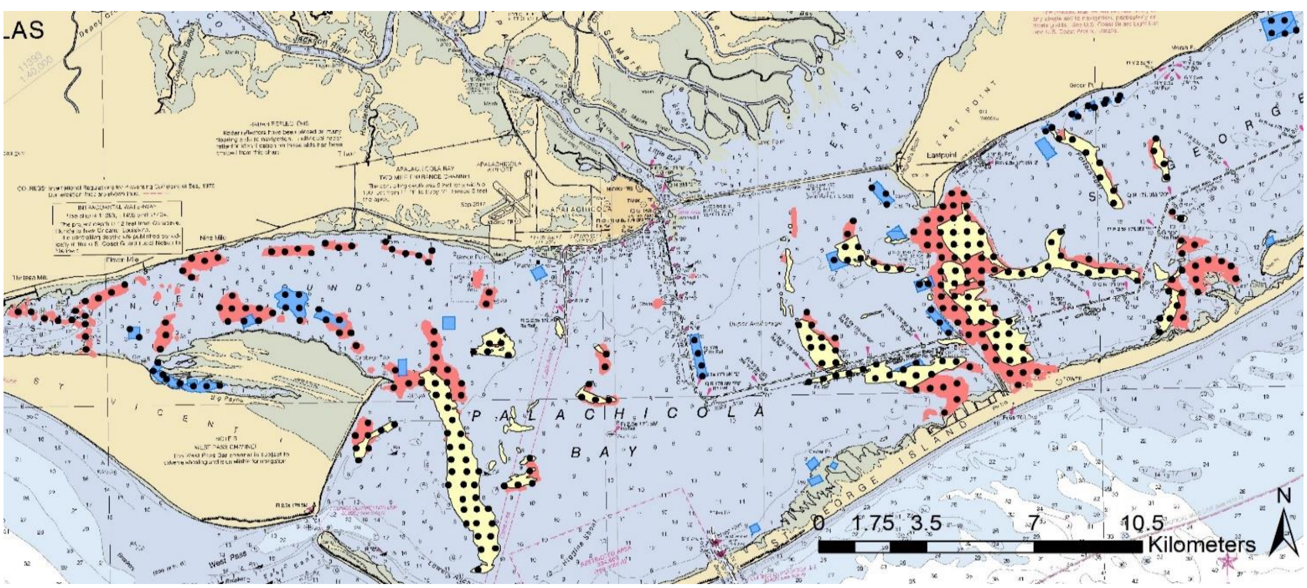

Figure 2. Proposed preliminary sampling sites at 0.5-km intervals on each of the ~40 previously mapped (**Figure 1**) subtidal reefs (natural and restoration sites). Blue = restoration reefs; Pink = natural reefs (FWC online data); Tan = Twichell et al. (USGS) natural reefs.

Acoustics and ground-truthing (2021)

Two acoustic systems and a primary vessel navigation and orientation system mounted on a 24-foot research vessel, *R/V Diversity (***Figure 3A***)*, were used to acquire data along multiple parallel ship tracks navigated across each of the final target reefs. The standard survey equipment on *Diversity* for this project included a bow-mounted Klein 3500 dual-frequency side-scan sonar system, a side-mounted Innomar SES-2000 dual-frequency, parametric sub-bottom profiler, an Applanix POSMV 320 vessel position and motion reference unit, a YSI Castaway conductivity-temperature-depth (CTD) speed of sound profiler, and Hypack hydrographic data acquisition and processing software package.

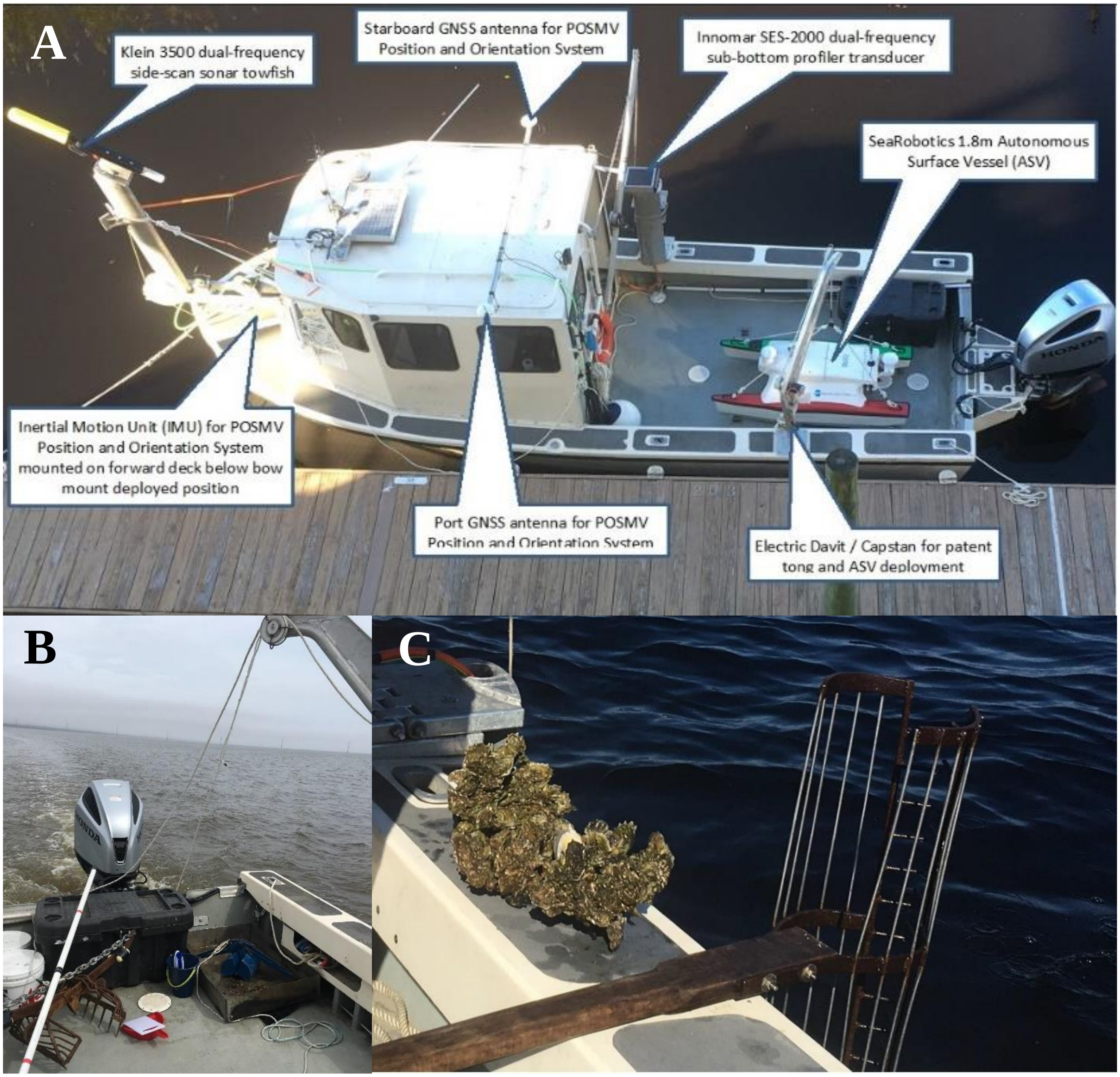

Figure 3. A: R/V *Diversity* (24-foot length, 8-foot beam) with major components used in acoustic surveys labeled: Klein 3500 side-scan sonar deployed from a bow mount; Innomar SES-2000 dual-frequency parametric sub-bottom profiler mounted amidships; Applanix POSMV GNSS antennae mounted on both sides of wheelhouse; SeaRobotics ASV; and davit for deployment of ASV and patent tongs. **B**: gear used for bottom sampling (ground-truthing); **C**: handheld tongs.

The POSMV Global Navigation Satellite System (GNSS) data was supplemented with real-time differential correctors from both a local base station and the Florida DOT Real-Time network, providing real-time horizontal and vertical error estimates (root mean square) generally less than 5 cm. Raw POSMV observables were recorded during all survey operations and POSPac Mobile Mapping Suite software was used to improve the real-time position and elevation data, especially during periods when there were issues with the real-time differential data link. During the survey, a NAD83 Universal Transverse Mercator (UTM-meters) coordinate system (Zone 16N) and a Mean Lower Low Water (MLLW-meters) vertical datum were used. NGS Geoid Model12B was used to transform the POSMV NAD83 GNSS ellipsoidal heights to NAVD88 orthometric heights, and the published NOAA VDatum offset (0.232 m in Apalachicola Bay) was used to convert from NAVD88 to MLLW. In addition to the continuous GNSS-derived water-level observations on the survey boat, the data from the NOAA Apalachicola tide station was also incorporated into the data processing review.

The Klein 3500 is a simultaneous dual-frequency, side-scan sonar operating at 445 and 900 kHz with a nominal horizontal beamwidth of 0.34º and a wideband frequency-modulated chirp pulse width of 1 to 8 msec. For this survey, the sonar towfish was mounted on a rigid bow-mount fairing at a fixed depth below the water surface and with known, fixed offsets to the primary POSMV navigation reference point. The side-scan sonar range-scale was set to 50-meters for most of the Apalachicola Bay work, though 25- and 75-meter range-scales were also used in a few instances. The biggest impediment to side-scan sonar data quality was shallow water and water-column refraction which was caused primarily by distinct water-column salinity boundaries. Processing of the side-scan sonar data included reviewing the raw sensor and navigation data, reviewing and updating the bottom-tracking, clipping any data as needed, applying a variety of gain adjustments, and creating imagery mosaics at various resolutions to assess data coverage, to compare overlap areas, and to integrate into the project geodatabase. Though both 455 and 900 kHz side-scan sonar data were acquired as separate files for each survey line, the processing effort focused almost entirely on the 900 kHz data because it provided higher-resolution imagery.

The Innomar SES-2000 dual-frequency parametric sub-bottom profiler was deployed on an over-the-side fairing tightly integrated with the primary POSMV reference point. The SES-2000 high-frequency channel was fixed at 100 kHz and was the primary source for tracking the initial bay bottom reflector and producing the single-beam bathymetry, while the SES-2000 low-frequency channel was user-selectable in the range of 4 - 20 kHz and was the primary source for tracking any sub-surface horizons or objects. The range resolution of the system is dependent on frequency and pulse length, with lower frequencies and longer pulse lengths resulting in lower resolution, but greater potential for imaging deeper below the seabed. For these operations when shallow penetration was the primary focus, the low-frequency channel was set to 12-15 kHz with a pulse length of one, resulting in a range resolution of approximately 10 cm. The range resolution for the high-frequency channel (and single-beam bathymetry) was around 4 cm.

Initial processing of the sub-bottom profile and single-beam data included reviewing the raw sensor and navigation data, reviewing and editing the RTK water-level data, reviewing and applying the speed of sound profile data, cleaning the raw acoustic data, and creating preliminary gridded products to assess data coverage and conduct cross-check comparisons. The primary final bathymetric products created from the 100 kHz single-beam data were along-track point files for each of the three survey areas with final gridded MLLW soundings spaced at both 1 and 3 m intervals. Additional processing of the lower frequency (12-15 kHz) sub-bottom profile data was focused primarily on bottom-tracking to digitize the initial bottom reflector, and then applying different gain settings to highlight any visible sub-bottom horizons (**Figure 8**). Any visible sub-bottom horizons were manually digitized so that the thickness and depths of these features could be extracted as needed.

The YSI Castaway CTD profiler was used to acquire water-column profile data before the start of daily survey operations and at routine intervals throughout each survey day. Speed of sound profiles were computed from the CTD data and entered directly into the data acquisition package for application to the single-beam bathymetry data. Despite the overall shallow survey depths (2-3 meters over most areas), there were still significant water-column speed of sound differences (up to 20 m/s) noted in several of CTD profiles that were closely correlated with large salinity differences, primarily associated with freshwater mixing from the Apalachicola River (**Figure 4**).

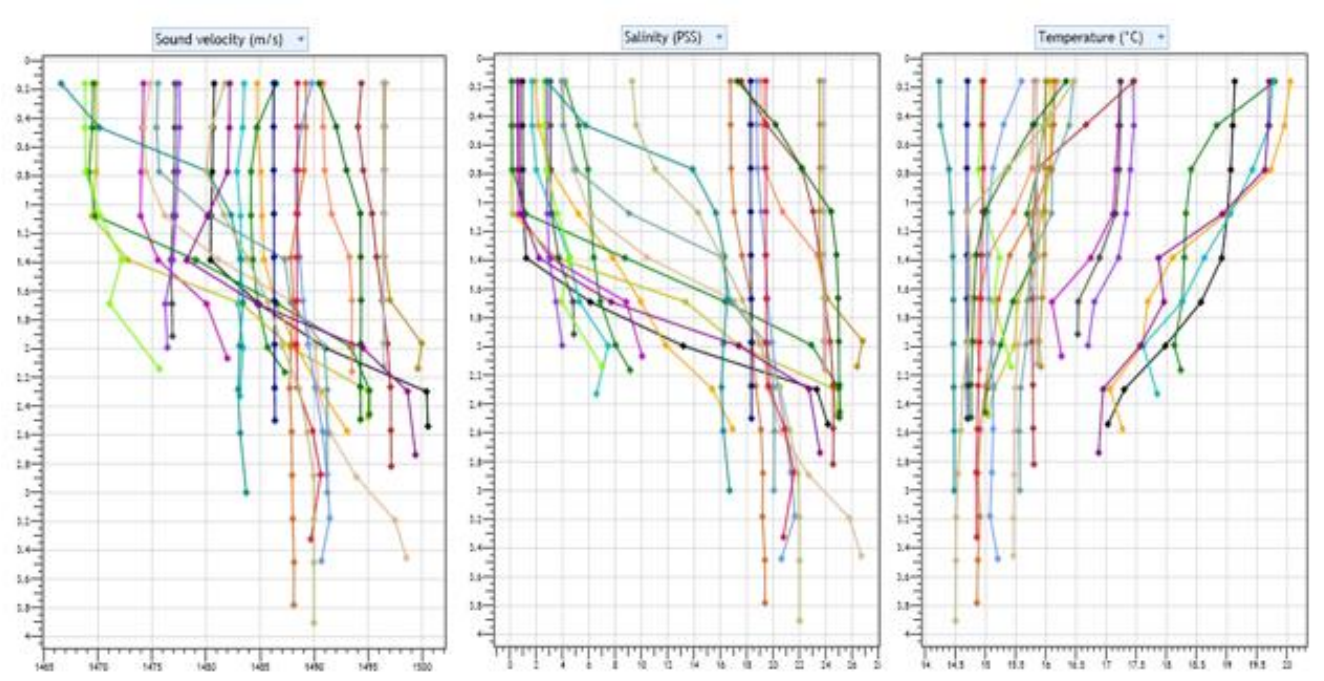

Figure 4. Overview of several of the shallow-water CTD casts that were taken in various areas of Apalachicola Bay during the period from 2/11/2021 through 2/28/2021. Most casts were consistent, significant differences (up to 20 m/s) were observed at certain times due to a notable halocline caused by freshwater mixing from either the Apalachicola River. Refraction caused by large water-column speed of sound differences negatively impacted the side-scan sonar data, but it was not practical to survey only in areas with a well-mixed water-column.

Ground-truthing included probing the bottom with a PVC pipe and extractive sampling with handheld tongs, patent tongs, and a van Veen grab (**Figures 3** and **5**). As noted above, the PVC pipe was essentially the same method used by Swift (1897) who produced the first map of oyster reefs in Apalachicola Bay based with a wooden pole. In the present study, the surficial sediments at each site were classed as *predominantly*: mud, sand, shell hash, rock, or live oysters. The classification was determined mainly by probing. No samples were extracted for quantitative analysis of textural characteristics, but handheld or patent tong samples were taken at most sites where classification by probing was ambiguous or to confirm the presence of live oysters. At some sites, the pipe was pushed into the bottom as much as 1 meter or until firm bottom was reached and notes were made on vertical variations in sediment type. Bottom sampling data obtained by others during 2019-2021 involving diver observations and extractive sampling (FWC and Apalachicola National Estuarine Research Reserve [ANERR]) and handheld tongs (Florida State University [FSU]), were also used in map production. Regardless of method, all ground-truthing data were qualitative, except FSU tong data in the final maps were presented in a relative abundance metric determined by assigning the total number of oysters collected in 6 tong “licks” to one of five classes: 1 – 50, 51 – 100, 101 – 300, 301 – 500, and >500.

It should be noted that in 2021 acoustic surveying and ground-truthing were conducted *concurrently*. This was a departure from traditional seafloor mapping protocols where ground-truthing is conducted *after* preliminary maps are produced by acoustic (or other) methods in order to determine the “thematic accuracy” of the maps based only or mainly on remote sensing data. Our acoustic system provided real-time data for visual inspection, and due to the shallow water depths in most areas, we could quickly probe the bottom or take samples, thereby refining the interpretation process of the imagery as it was collected.

Figure 5. Top: Deploying patent tongs, and marked PVC pipe used to probe the bottom; note bottom penetration depth indicated by mud on the far end of the pipe. Bottom: Patent tong sample from Hotel Bar in southeastern Bay. Right: Handheld tong sample from restoration area in western Bay; note multiple size/age classes of live oysters and rock cultch.

Map production (2020-2022)

Map production occurred in all phases of the project but consisted of two major types: preliminary maps (2020 and 2021) based on one or two variables, and final maps (2022) focused on: (1) live oyster distribution, and (2) bottom types potentially suitable for restoration activities (cultching). All maps were produced using ArcGIS software, and are available online as shapefiles with metadata, georeferenced image files, and jpeg image files (see Appendices for complete list of all files).

Preliminary mapping was an iterative process that involved integration and comparisons of acoustic data (e.g., side-scan sonar imagery mosaics and trackline bathymetry) and ground-truthing data. Early on, the major task was to identify the combination of visible features in the acoustic imagery that corresponded to areas where live oysters were present. Side-scan sonar imagery provided wide swath coverage and qualitative data on the sediment surface characteristics. Thus, it was the major acoustic data used in map production, including detailed imagery of some of the restoration sites and the cultch material used in their construction (see more below).

For final map production, the five bottom types initially mapped (see above) were reduced to three: live oysters, firm (shell hash, rock, and oysters), and soft (mud, some sand). Side-scan imagery was used to determine the 2-dimensional shape of the reefs which were represented by manually constructed polygons. Firm bottom types potentially suitable for cultching were primarily mapped by manually constructing polygons that enclosed the firm bottom type datapoints but using the acoustic imagery (particularly side-scan sonar) to extend the boundaries in some cases.

RESULTS & DISCUSSION

Preliminary sampling (2020)

As noted in the Study Design subsection in Methods, a major challenge for the project was to determine how much of the ~10,000 acres of previously mapped subtidal oyster reefs (natural and constructed) in the Bay (**Figure 1**) should be re-surveyed. A total of 202 sites were visited over the period October 19 – 23, 2020 and the bottom probed and/or sampled with handheld or patent tongs. Data from these sites (**Figure 2**) were combined with ground-truthing data from an earlier study on Summer Bar east of Cat Point (Grizzle et al. 2020), yielding a total of ~320 data points where the bottom type had been classified.

A visual assessment of this combined dataset indicated that most of the oysters and bottom types (sand, shell, rock) that would likely be suitable for cultching mainly occurred on the historically mapped oyster reefs. Five major areas totaling ~6,700 acres were chosen as priority areas to be fully acoustically mapped (red outlined polygons in **Figure 6**). The six areas included the major oyster reefs in eastern areas (Cat Point and adjacent reefs), mid-Bay (Hotel bar), and western (Dry Bar and St. Vincent). All had been important harvest areas historically. These priority areas totaled more than double the original contract total of 3,125 acres to be surveyed. The major rationale for this decision was that acoustic surveying would be conducted with ship track spacing of >40 m between tracks but spacing would be adjusted as needed as the surveying progressed.

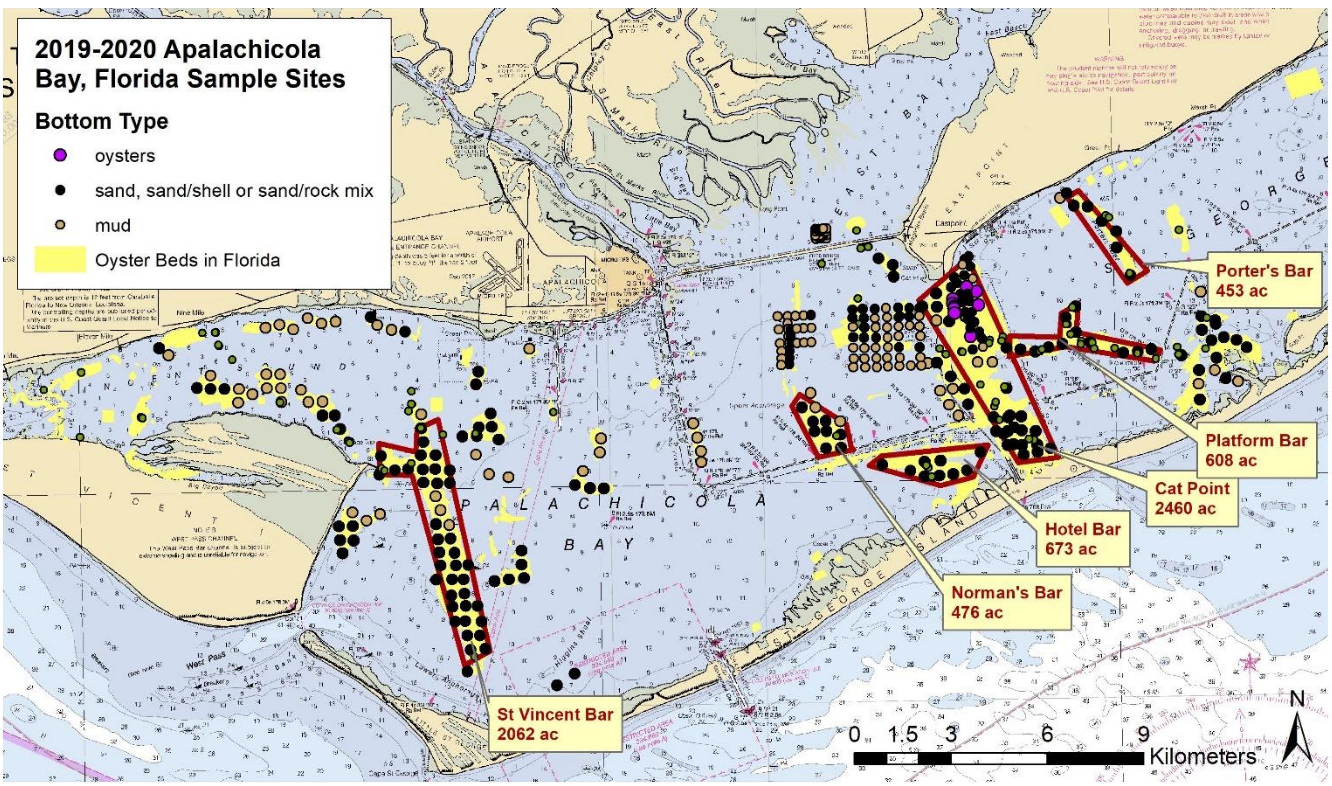

Figure 6. Bottom types (ground-truthing data) based on UNH and FWC sampling in 2019 (Grizzle et al. 2020) and 2020 in areas previously mapped as oyster reefs. Red polygons indicate the initial target areas for acoustic surveys.

Acoustics, ground-truthing, and preliminary maps (2021)

Based on the 6,700 acres of priority survey area (**Figure 6**), it was determined that acoustic survey lines (ship tracks) should be spaced at 80 to 160 m intervals, which was 2 to 4 times the spacing of 40 m used in our previous mapping in the Bay (**Figures 8** and **9** below show how all three spacing intervals affected side-scan imagery). The 80 to 160 m spacing did not provide full coverage ("insonification" of the bottom) by side-scan sonar but greatly increased the total bottom area surveyed.

Acoustic surveying and concurrent ground-truthing were conducted during January 17 - March 3, 2021. A total of ~15,000 acres were surveyed, far exceeding the contract goal and the priority areas goal developed during preliminary sampling, and including most of the natural and constructed oyster reefs in the Bay (compare **Figures 1** and **7**). Ground-truthing data collected during acoustic surveying were combined with data from our previous work in 2019 (Grizzle et al. 2020), our preliminary sampling in 2020 (see above), and data provided by FWC and FSU yielding a total of ~450 datapoints where the bottom was extractively sampled or probed. Extractive sampling with patent or handheld tongs was typically used after probing indicated live oysters or other hard substrate types were present.

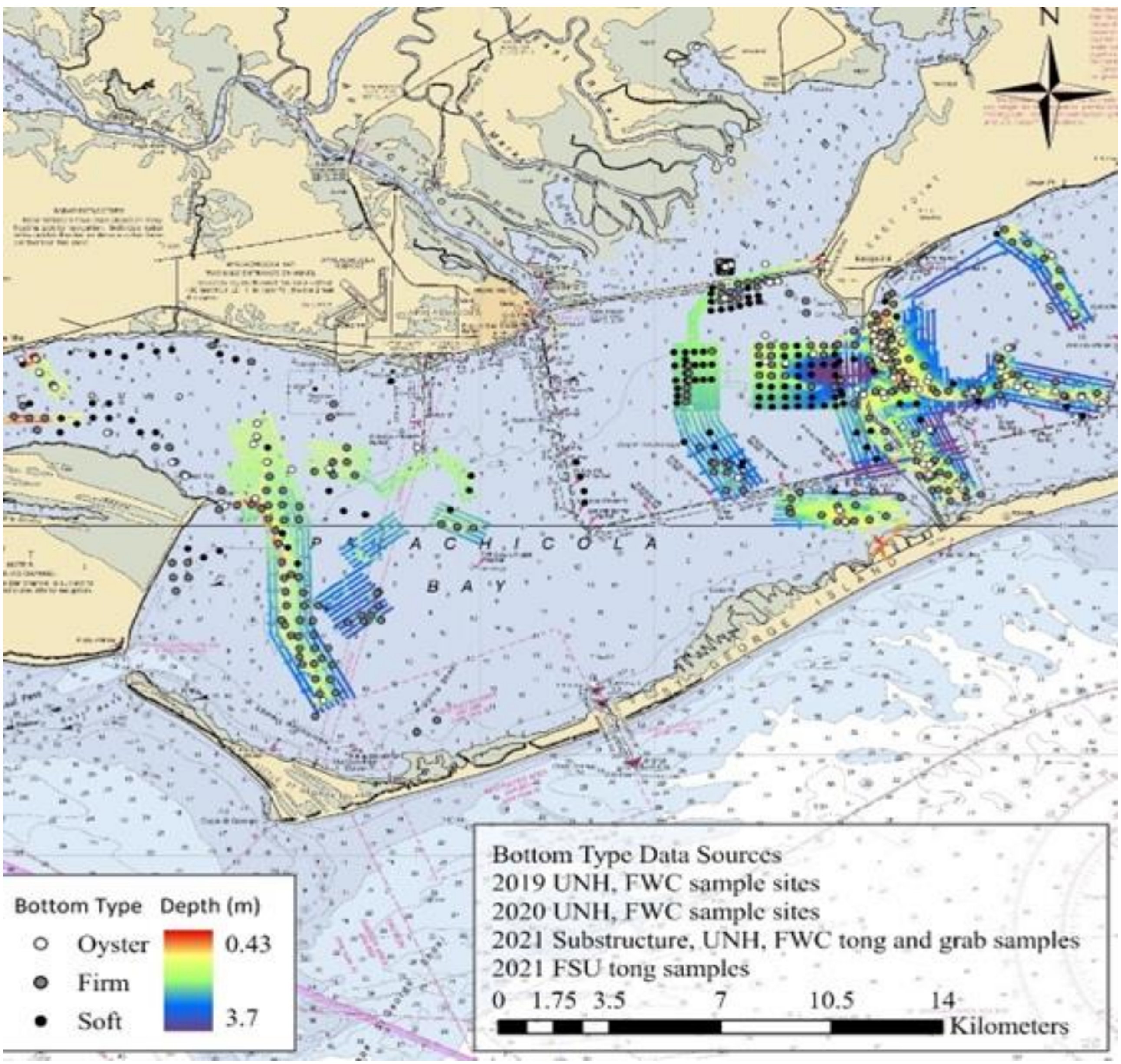

Figure 7. Bay-wide single-beam bathymetric data (water depth in meters) with ground-truthing data overlaid

Figure 8 is a comparison of side-scan imagery, sub-bottom profiling data, and ground-truthing samples combined. In sum, much is revealed about current conditions as well as the history of this area on Cat Point. Previous studies in the Bay described burial of oyster reefs during storms resulting in soft sediments overlying hard-bottom areas such as shell hash and probably live (before burial) oyster reefs (Livingston et al. 1999; Edmiston et al. 2008). Probing during our preliminary bottom sampling indicated multiple layers of bottom types (e.g., mud or sand overlying shell, or reversed) up to ~1 m below the surface in some areas, thus documenting a dynamic sedimentary environment. Oyster harvesters have voiced concern about loss of "oyster bottom" in the Bay over time: perhaps due to storms, over-harvest, or other factors. The lower left image of the sub-bottom profiling data in **Figure 8** makes it easy to imagine how muddy sediments could be eroded and re-deposited during storm events to result in dramatic changes in oyster reefs in the Bay. Although the sub-bottom data have not been comprehensively assessed to date, they have the potential to spatially characterize the extent of buried reefs that might be useful in assessing historical trends.

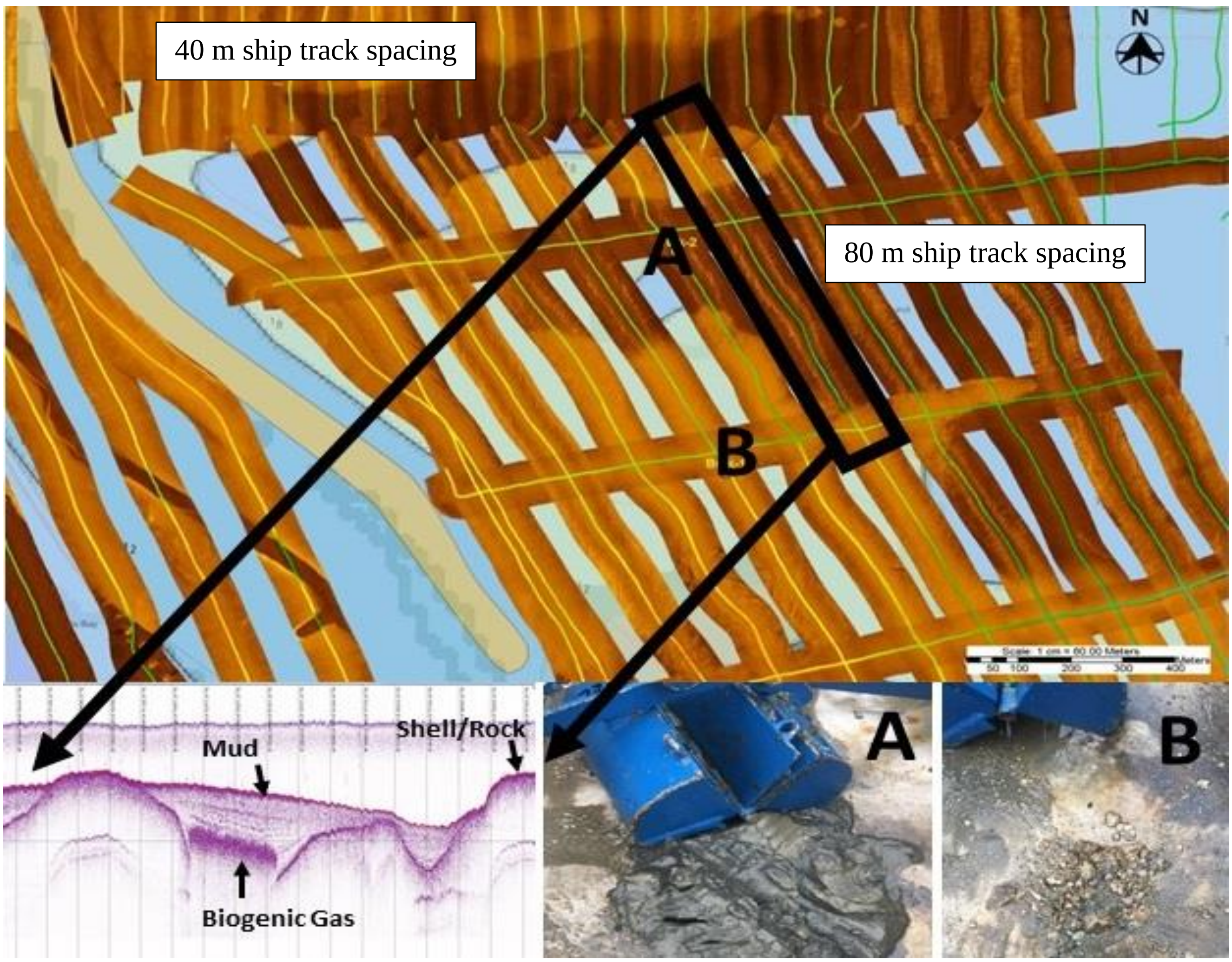

Figure 8. The upper image shows side-scan sonar data (shades of brown) and single-beam bathymetry (yellow-to-green lines indicating trackline depths) in the Bulkhead Bar area. Lower row of three images shows sub-bottom profile data along track in rectangular box and vanVeen grab samples takes at sites "A" and "B" in upper image adjacent to the ship track. Note the general east-west orientation of hard bottom (sand/shell/rock) ridges (light-colored areas in side-scan image) and muddy sediments (dark areas) between the ridges.

As noted above, it became evident early on in map production that side-scan imagery would be most useful for discerning and describing the spatial extent of oyster reefs and other relevant bottom features. Thus, side-scan data were most effective in final map production for live oyster reefs. Oyster reefs and other firm bottom types (shell and rock) provide a strong return of the sound wave, appearing lighter in color than muddy bottoms (see cultched area in **Figure 9**), which also were typically in deeper waters. Live oysters also increase the rugosity (bottom roughness) due to their vertical and irregular growth form. Single-beam data, however, showed that the variation typically was only several centimeters in most cases, indicating relatively low relief compared to mature oyster reefs (perhaps 5 or more years to develop with no harvesting) that might extend 0.1 to 0.5 m above the bottom. Cultched areas, regardless of whether live oysters are present, also have a roughness element determined by the material used in construction.

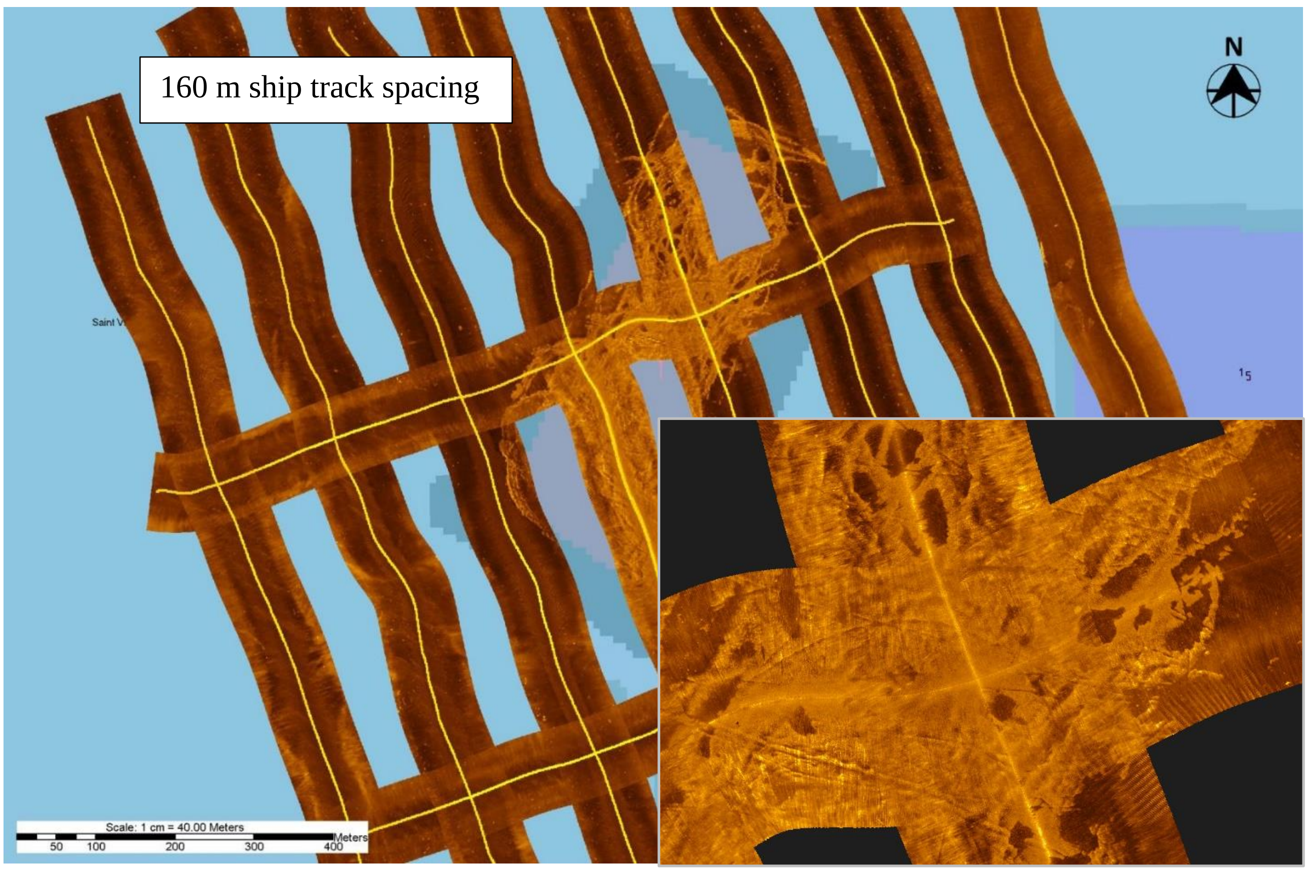

Figure 9. Side-scan sonar mosaic and single-beam trackline bathymetry from northern St. Vincent Bar area. Note details of cultch material on the bottom of restoration area indicated by faint jagged-edged rectangle on base map. The inset zoomed-in view around a crossline junction illustrates the sporadic nature of the rock placement and also highlights the stark acoustic contrast between the high-reflectance rock and oysters and the underlying low reflectance muddy sediment.

Figure 10 below shows four examples of how side-scan imagery was combined with ground-truthing data for final map production. At least one ground-truthing datapoint indicating live oysters were found in all seven polygons (yellow boundaries) shown, and this was the typical case for the mapped reefs (see below). In cases where gound-truthing indicated live oysters but the acoustic data were ambiguous, a small round or oval polygon was drawn.

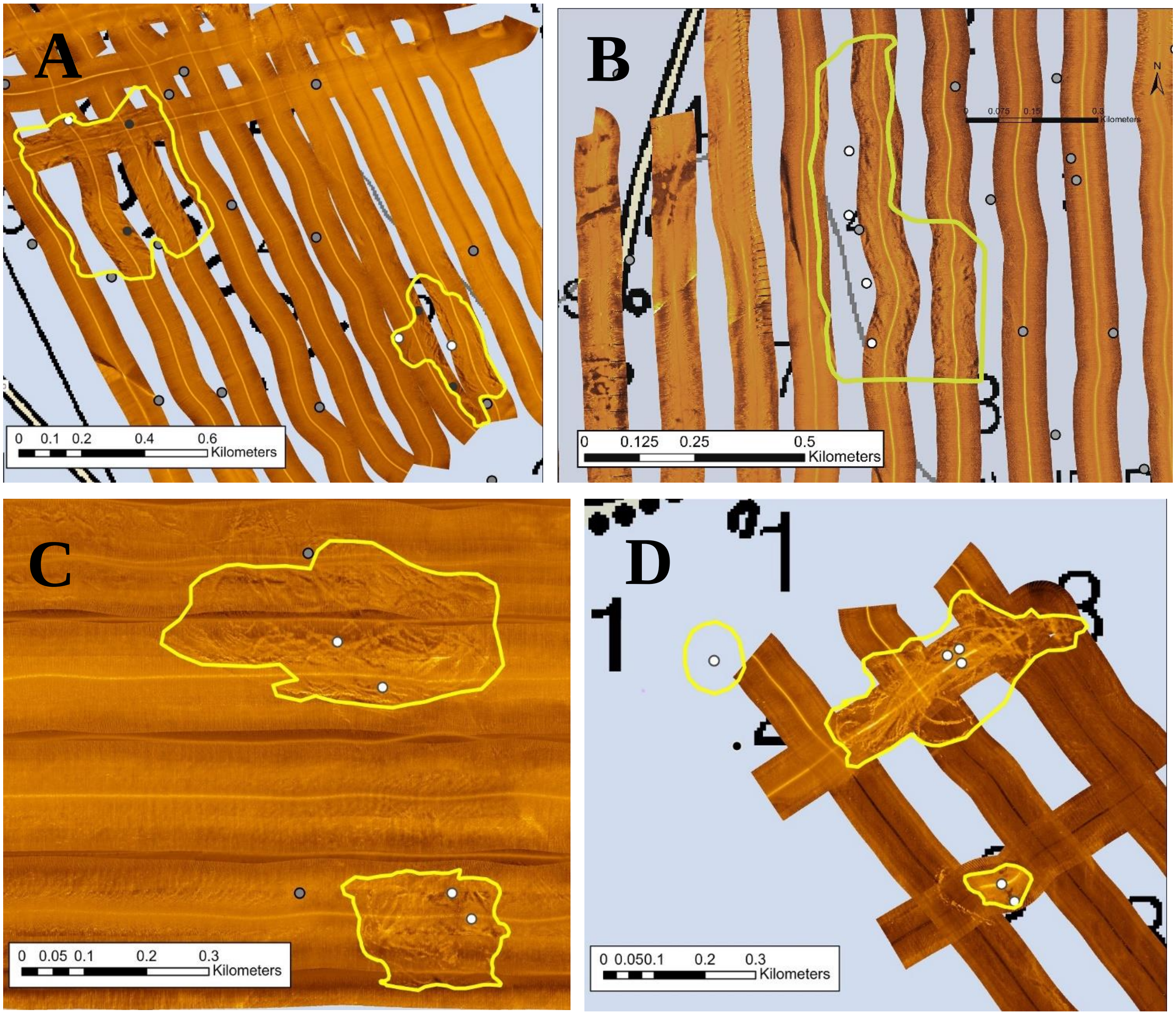

Figure 10. Composite of images illustrating how side-scan imagery was used in combination with ground-truthing data to determine spatial extent of live oyster reefs. A: Bulkhead bar area; B: Cat Point bar; C: Hotel bar; and D: restoration site in St. Vincent Sound.

Final maps: live oyster reefs and bottom types suitable for cultching (2022)

The final stage in map production was to combine the appropriate acoustic spatial data with ground-truthing point data to produces maps showing: (1) the spatial extent of live oyster reefs, and (2) the spatial extent of firm bottom types potentially suitable for restoration by cultching. Live oyster reefs are discussed first, followed by areas suitable for cultching. For both, Bay-wide patterns are considered first, then close-up presentations for eastern and western areas of the Bay. As introduction, **Figures 11** and **12** show historic oyster reef (bar) names, 16 NRDA restoration sites constructed in 2015, 14 RESTORE sites constructed in 2017, and USGS oyster reef data (Twichell et al. 2007), which will be referenced in discussion below of the new maps.

The RESTORE (Oyster Reef Restoration Project) restoration sites were constructed in November 2017 on 14 degraded natural reefs using ~95,500 yd^3 of lime rock aggregate covering a total area of 317 acres (FDEP 2021). Most of the sites had been cultched previously using a variety of materials. RESTORE sites were Bay-wide but focused in eastern areas, particularly the Cat Point area (**Figure 11**). Annual sampling during 2018-2020 indicated much better reef development (i.e., increases in mean oyster size, density of adult oysters, and consistent annual spat sets) compared to the NRDA sites (FDEP 2021).

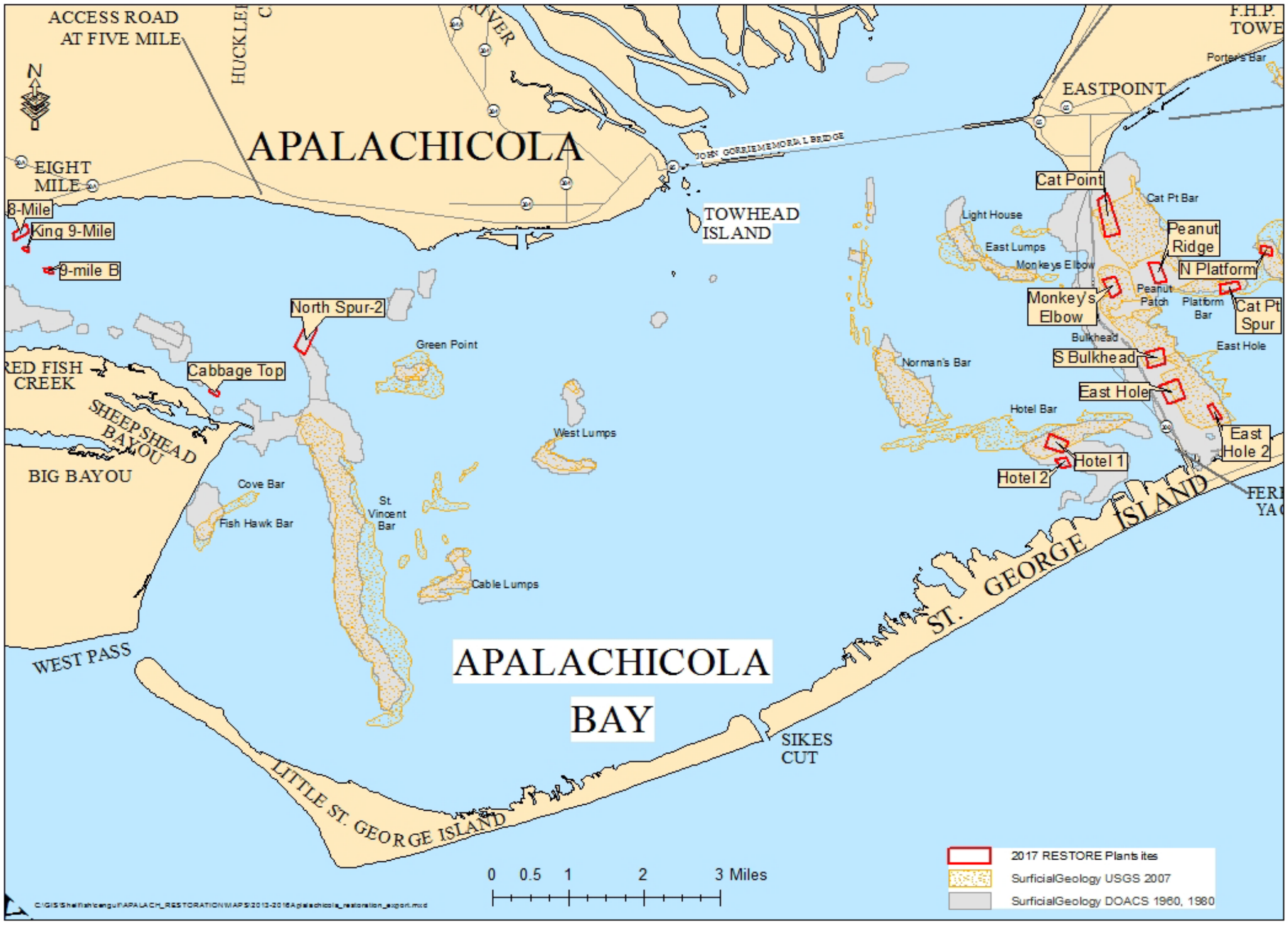

Figure 11. RESTORE 2017 restoration sites (from FDEP 2021).

The NRDA (Natural Resource Damage Assessment) restoration sites were constructed using ~24,840 yd^3 of oyster shell on 16 debilitated oyster reefs covering a total area of 124 acres in October 2015 (FDEP 2019). Most of the NRDA sites were in western areas of the Bay (**Figure 12**). Most also were on natural reefs, and many had been cultched previously using a variety of materials. Live oyster total densities varied widely (means ranged from <10 to 203/m^2) among the sites all 3 years of annual sampling (2017-2019) and were much higher on sites in the eastern Bay. Spat set was greatest during 2018 but did occur on sites on both sides of the Bay all 3 years (FDEP 2019).

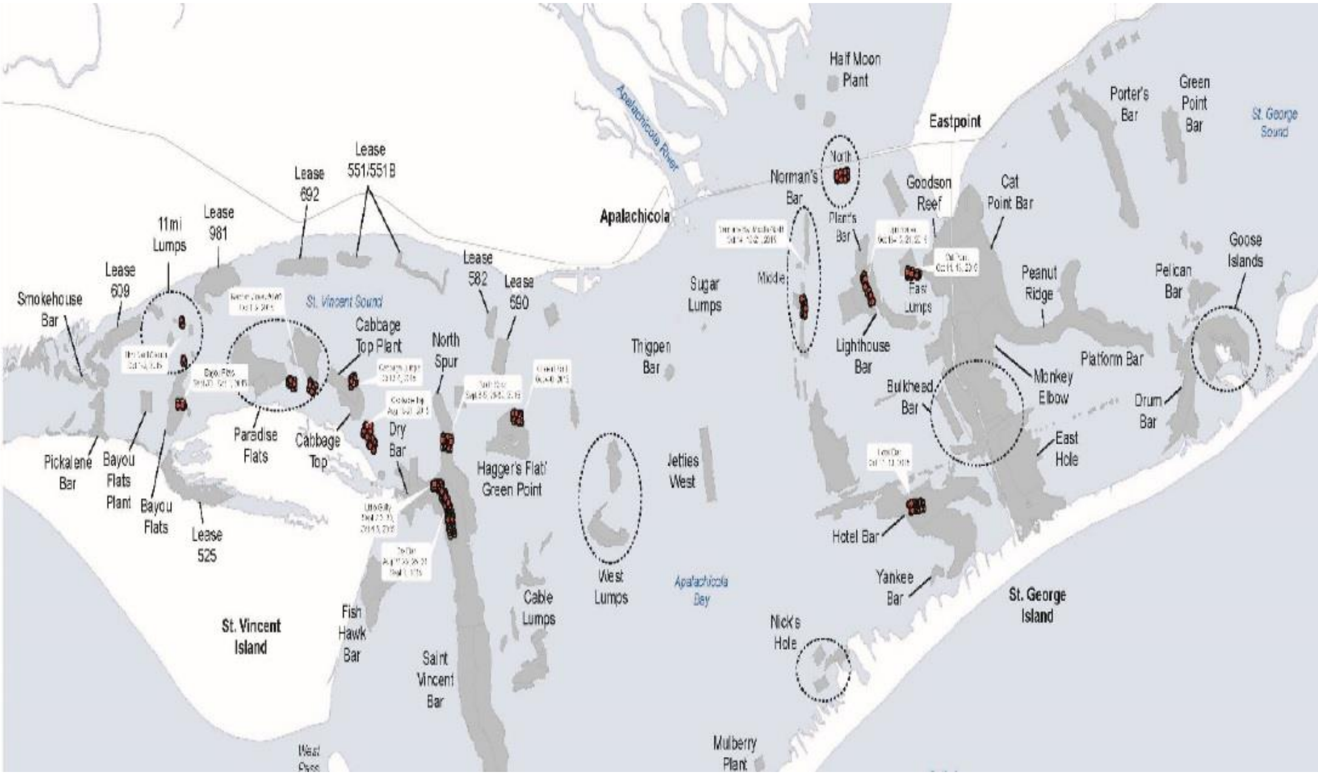

Figure 12. NRDA 2015 restoration sites (from FDEP 2019).

Figure 13 below shows the disappointing but expected Bay-wide distribution of live oysters based on ground-truthing datapoints collected from 2019-2021 that were expanded spatially in most cases using side-scan sonar data to infer the boundaries of each reef area. We note, however, that for datapoints where acoustic imagery was not available or ambiguous, a small circle or oval was drawn around the ground-truthing datapoint(s). Thus, this map likely under-represents the total areal coverage but not substantially. Live oysters only covered ~515 acres of bottom, compared to ~10,000 acres of oyster beds in online database for Apalachicola Bay (also see Pine et al. 2015).

The above comparison indicates that current bottom areal coverage by live oysters in the Bay is only ~5% of historical coverage by oyster beds. We caution, however, that “live oysters” and “oyster beds” are not the same metric. All mapping efforts since Swift (1897) used different methods, and none to our knowledge provided live oyster density data *combined with* areal coverage data; see Pine et al. (2015) for further discussion and a similar conclusion. For the present study, however, we suggest it is reasonable to combine live oyster data from recent sampling of the NRDA (FDEP 2019) and RESTORE (FDEP 2021) restored reefs with our areal coverage data because most of the live oyster reefs mapped herein were on the restored reefs.

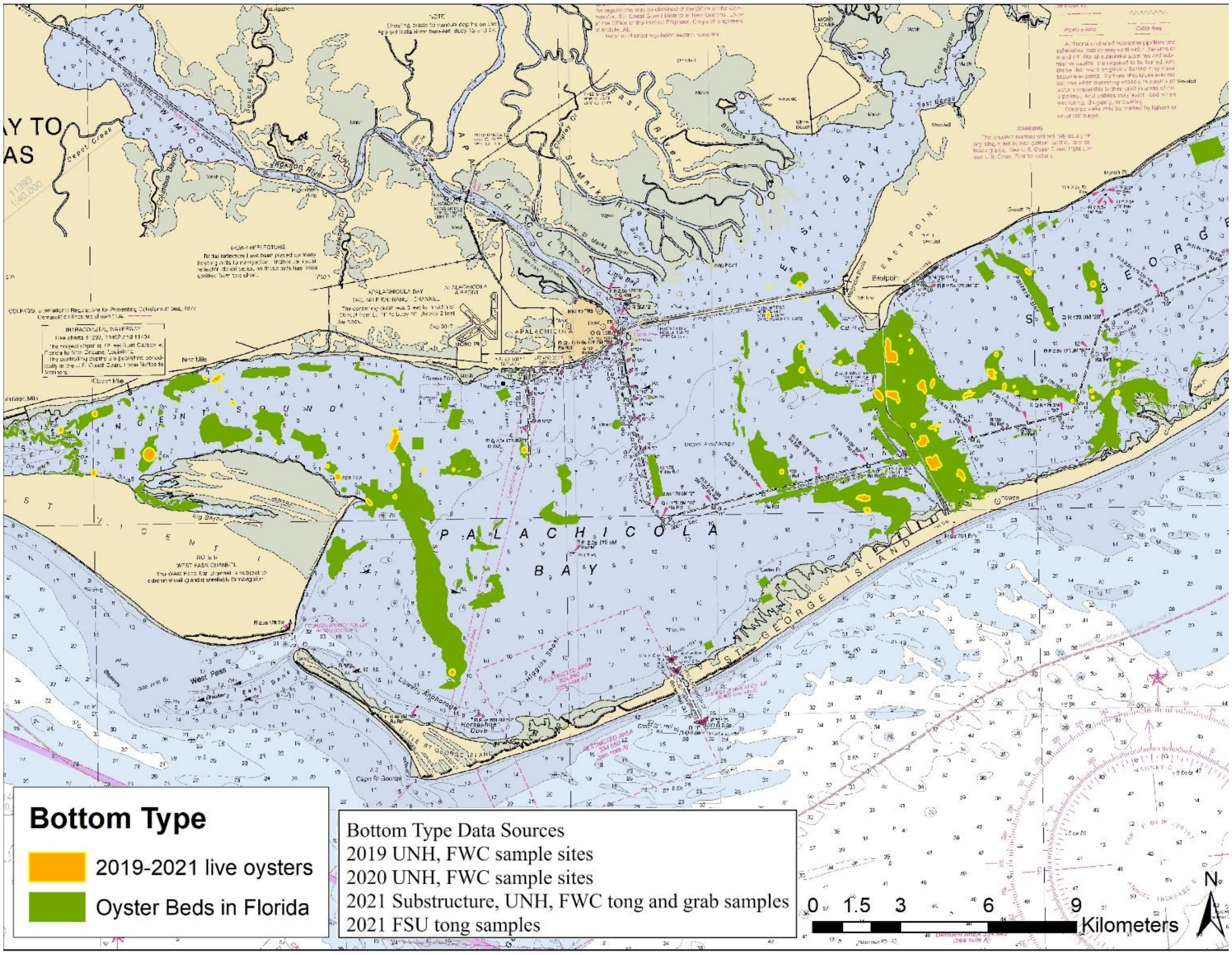

Figure 13. Bay-wide distribution of live oysters based on side-scan sonar imagery and ground-truthing point data from the present study (yellow polygons) compared to “oyster beds in Florida” online database (green polygons), and Twichell et al. (2007) natural reefs.

Turning to details on current (2019-2021) live oyster distributions, on both the eastern and western sides of the Bay live oysters showed two prominent spatial patterns (**Figures 13** and **14**). Nearly all occurred on firm bottom types (shell or rock) in shallow (<3 m) water depths, and perhaps most importantly, nearly all were on NRDA and RESTORE restoration sites (**Figures 11** and **12**).

In contrast to the paucity of live oysters in the Bay, there is substantial areal coverage by firm bottom types potentially suitable for cultching. In the eastern Bay, our mapping data indicate a total of ~7,000 acres of firm (shell, rock, and oysters combined) bottom types. In the western Bay, our data indicate ~3,225 acres of firm bottom. The sum of both areas (~10,225 acres) is essentially the same as the coverage by oyster beds on historical maps (see discussion in Pine et al. 2015). Additionally, our areal coverage polygons for firm bottom types on the major reefs on both sides of the Bay (Cat Point, Bulkhead, Hotel, and St. Vincent) are similar to the historic reefs in size and shape. The major changes appear to have been in St. Vincent Sound where several historically mapped oyster beds are now largely covered with soft sediments.

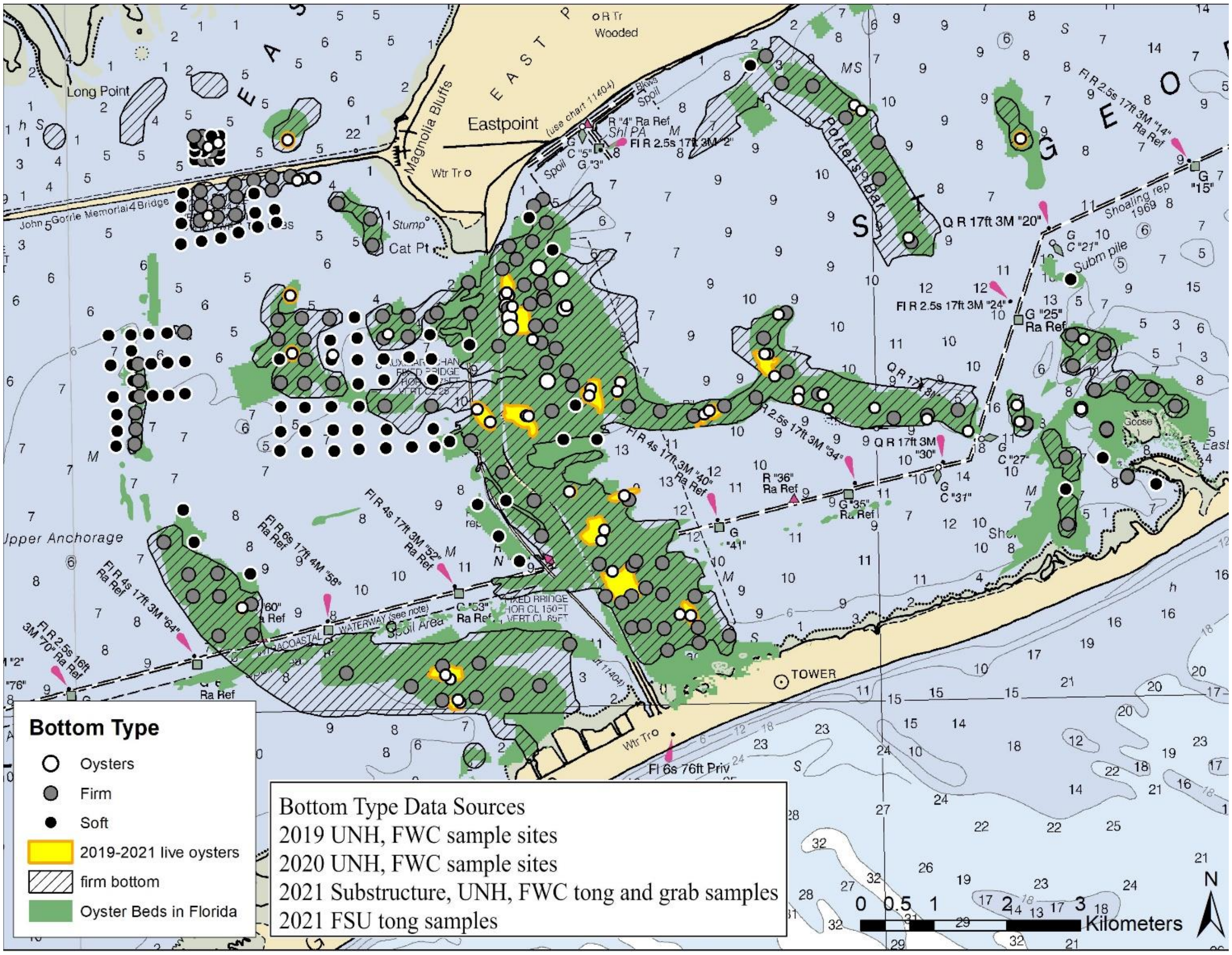

Figure 13. Current live oyster reefs (yellow polygons), firm bottom types suitable for cultching (cross-hatched areas) and historic oyster reefs (green polygons) on Cat Point and nearby areas.

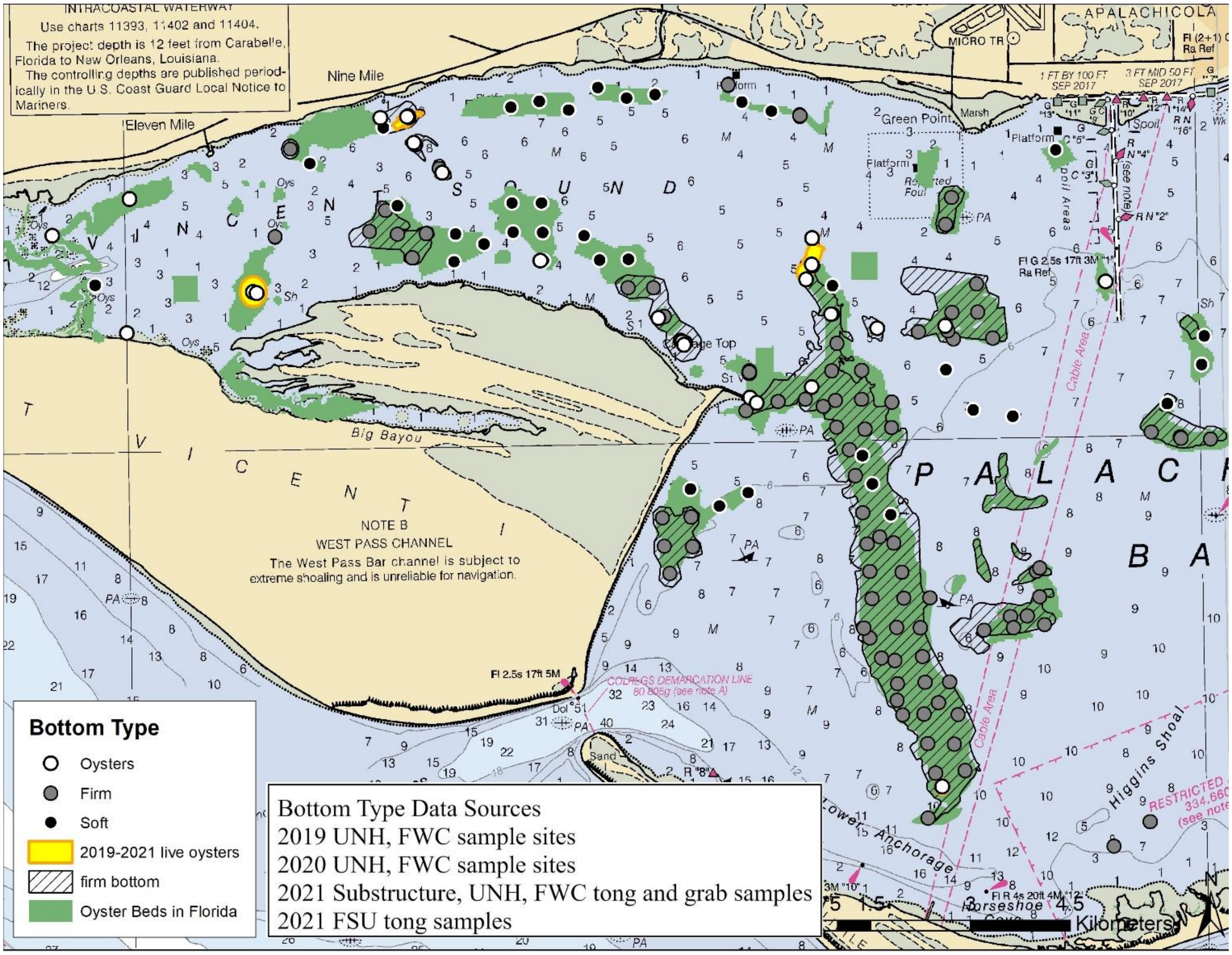

Figure 14. Current live oyster reefs (yellow polygons), firm bottom types suitable for cultching (cross-hatched areas) and historic oyster reefs (green polygons) on St. Vincent bar and nearby areas and St. Vincent Sound.

ACKNOWLEDGMENTS

The following individuals provided maps, datasets, or other information on Apalachicola Bay, and some were involved with the project from start to finish. We are grateful for their help. Marissa Gast, University of New Hampshire, did much of the GIS work during the last year or so of the project. We very much appreciate her mapping skills. Rolf Bremer with Substructure, Inc. maintained and captained the *Diversity* for all the acoustic surveys. His skills and attitude greatly improved the quality of mapping products and made the work more enjoyable. Matt Davis, Sarah Cahill, and colleagues at FWC's Apalachicola Bay Shellfish Laboratory provided boat time, excellent assistance and advice, and good company on several days on the water collecting data. Sandra Brooke and Shannon Hartsfield, Florida State University, and the Apalachicola Bay Science Initiative, kindly provided their data on live oyster distributions. Jennifer Harper and Jonathan Brucker, Apalachicola National Estuarine Research Reserve, provided reports on their sampling of NRDA and RESTORE restoration sites. Katie Davis, FDACS, Apalachicola, provided data and maps for shellfish leases and plant sites from 2013-2017. We thank Bill Pine, University of Florida, for sharing his extensive knowledge of the Bay with us on several occasions. Finally, Melanie Parker, Jim Estes, Mike Norberg, Ryan Gandy, and Devin Resko were our FWC partners for the project. We appreciate their help in many ways.

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APPENDICES

Ground truthing (bottom sampling) 2019-2021

Each ground truthing event is included in separate shapefiles (listed below). In addition to these files, each of the ground truthing files are also combined in to one shapefile with metadata. These shapefiles include ground truthing points taken 2019-2021 from FWC, UNH, and Substructure. Samples were collected using patent tongs and by probing the bottom. Samples were taken to determine bottom type (mud, sand, shell/sand, rock, and live oysters) in restoration areas and in areas where Substructure conducted multibeam bathymetry and side-scan sonar 2019-2021.

Files included:
Cat Point area_sand_shell_rock_oysters_hard bottom (.shp)
Mud_sand and mud_soft_bottom (.shp)
St Vincent Island area_hard bottom_sand_sandshell_rock_oysters (.shp)

Notes on Bottom Type sampling shapefiles

2019 UNH, FWC sample sites
2020 UNH, FWC sample sites
2021 Substructure, UNH, FWC, tong and grab samples sites
2021 FSU tong sample sites

Additional Shapefiles

Apalachicola Contours 3-29-2022 (.shp)
2021 Live Oysters Apalachicola (.shp)

Bathymetry (Substructure)

2021_all-export_3m_avg_mllw (xyz)
2021_all-export_3m_avg_mllw_sort50 (xyz)
2021_all-export_1m_avg_mllw
2019_summer_bar_3m_cell-ctr_mllw (xyz)

Side-scan_sonar_mosaics (Substructure)

These side-scan sonar mosaics were created by Tom Waddington at Substructure. The data were collected in 2021 and processed using Hypack.

Files included:
mid-bay_a_50cm (.tif)
cat-point_north_50cm_rev1 (.tif)
apalach_west-lumps_50cm (.tif)
apalach_sv-sound_50cm (.tif)
apalach_sv-sound_50cm (.tif).tif)
apalach_st_vincent_50cm (.tif)
apalach_mid-bay_b_50cm (.tif)
apalach_cat-pt_lower_50cm (.tif)
apalach_cat-east_50cm (.tif)
apalach_2019_area6_lf_50cm (.tif)
apalach_2019_area2_lf_50cm (.tif)
apalach_2019_area1_lf_all_50cm (.tif)

Finished map jpegs

All maps include legend, sources text box, scale bar and north arrow.

Figure 1: Full extent Apalachicola Bay, USA Topo Maps, Bathymetry showing water depth, point data showing ground truthing bottom type 2019 and 2021, including ‘Class FSU data’

Figure 2: Full extent Apalachicola Bay, USA Topo Maps, Side scan sonar, Ground truthing bottom type point file including ‘Class FSU data’

Figure 3.1: Full extent Apalachicola Bay, USA Topo Maps, point file (shapefile) showing substrate from (bottom type) sampling, ArcGIS polygons (contour shapefiles created from bathymetric data) indicating water depth

Figure 3: Full extent Apalachicola Bay, USA Topo Maps, ArcGIS shapefile (created from bottom sampling points) indicating live oysters from 2019 through 2021 (yellow and orange polygons) including ‘Class FSU data’, 2006 Florida Fish and Wildlife Conservation Commission natural, planted and cultched reefs (green polygons)

Figure 4: Cat Point area, US Topo Map, Side scan sonar, ArcGIS shapefile (created from bottom sampling points) indicating live oysters from 2019 through 2021 (yellow outline polygons), 2019-2021 ground truthing point shapefile including ‘Class FSU data’

Figure 5: Cat Point area, US Topo Map, firm and soft bottom polygons, ArcGIS shapefile (created from bottom sampling points) indicating live oysters from 2019 through 2021 (yellow and orange polygons), 2006 Florida Fish and Wildlife Conservation Commission natural, planted and cultched reefs (green polygons), 2019-2021 ground truthing point shapefile not including ‘Class FSU data’

Figure 6: Cat Point area, US Topo Map, ArcGIS polygons (contour shapefiles created from bathymetric data) indicating water depth, ground truthing point shapefile including ‘Class FSU data’

Figure 7: St Vincent Island area, US Topo Map, side scan sonar, 2019-2011 ground truthing point shapefile including ‘Class FSU data’ (green circles), 2019-2021 live oyster polygons, ArcGIS shapefile (created from bottom sampling points) indicating live oysters from 2019 through 2021 (yellow outline polygons)

Figure 8: St Vincent Island area, US Topo Map, 2006 Florida Fish and Wildlife Conservation Commission natural, planted and cultched reefs (purple polygons), 2019-2021 ground truthing point shapefile including ‘Class FSU data’

Figure 9: St Vincent Island area, USA Topo Map, point data indicating substrate (bottom type) sampling 2019-2021, ArcGIS contour polygons (created from bathymetric data) indicating water depth

Figure 10.1, 10.2, 10.3, 10.4: US Topo Map, side scan sonar, point shapefile indicating live oysters from substrate (bottom type) sampling, polygons (yellow) indicating live oysters found through 2019-2021 bottom sampling with ‘Class FSU data’

Figure 10: St Vincent Island area, US Topo Map, side scan sonar, point shapefile indicating substrate (bottom type) sampling, polygons (yellow) indicating live oysters found through 2019-2021 bottom sampling with 'Class FSU data' (green)

Figure 11: St Vincent Island area, US Topo Map, ArcGis shapefile (yellow polygons) indicating live oysters found through 2019-2021 bottom sampling, point shapefile indicating substrate (bottom type) sampling 2019-2021 including 'Class FSU data'

Figure 12 final report_figure 3: Apalachicola Bay with live oysters (polygons) shapefile with "Oyster Beds in Florida" shapfile created in 2006, also showing planted and cultched reefs
Figure 12: St Vincent Island area, US Topo Map, ArcGIS polygons (contour shapefiles created from bathymetric data) indicating water depth, point shapefile indicating substrate (bottom type) sampling 2019-2021 including 'Class FSU data'

Figure 13: St Vincent Island area, USA Topo Map, point data indicating substrate (bottom type) sampling 2019-2021, bathymetric data indicating water depth

Figure 14: St Vincent Island area, USA Topo Map ArcGIS point shapefile indicating live oysters, firm bottom, and soft bottom from 2019 through 2021 bottom type sampling with side scan sonar

Figure 15.1: St. Vincent Island area, US Topo Map, ArcGIS polygons (contour shapefiles created from bathymetric data) indicating water depth, point shapefile indicating substrate (bottom type) sampling 2019-2021 including 'Class FSU data'

Figure 15: St Vincent Island area, USA Topo Map, ArcGIS polygons (shapefile created from bottom sampling points) indicating live oysters from 2019 through 2021

Figure 16.1: Full extent Apalachicola Bay (grey basemap), point data indicating substrate (bottom type) sampling in areas with side scan sonar and bathymetric data (Substructure, 2019-2021)

Figure 16.2 & 16: Full extent Apalachicola Bay (color basemap), point data indicating substrate (bottom type) sampling in areas with side scan sonar and bathymetric data (Substructure, 2019-2021)

Bathymetry

Change coordinate system from default Geographic Coordinate System (GCS_WGS_1984) to XY Projected Coordinate System (NAD 1983 UTM Zone 16N for XY) and Z Vertical Coordinate System (NAD 1983)

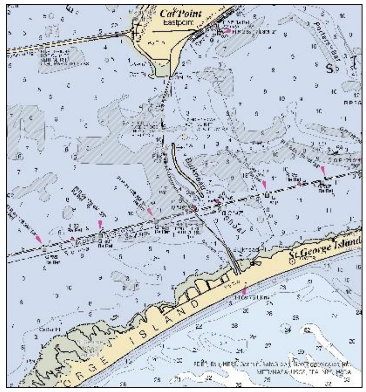
Additional Files Included in Dropbox (non UNH/Substructure)

2021 FSU tong samples (.shp)
Florida Fish and Wildlife Conservation Commission Historical Oysters (.shp) (2006 Oyster Beds in Florida)

Metadata for Shapefiles (UNH, Grizzle)

mud_sand and mud_soft_bottom

Shapefile



Tags

Florida, Apalachicola Bay, Cat Point, 2019, Soft Substrate, Polygons, side scan Sonar, Ground-Truthing

Summary

This shapefile consists of manually drawn polygons that delimit soft bottom areas consisting of mud near Cat Point in Apalachicola Bay, FL. This "mud," ranged from very soft mixtures of silt and clay to mixed soft sediments that were firmer and included sand but typically with no or very little shell that could be detected by probing.

A major aim of the overall project was to determine the amount of firm bottom (mainly shell but also sand/shell mixtures and rock) and live oysters in the study areas. These firm bottom types, in general, represent areas that should be further assessed for future oyster restoration sites while the soft bottom types would not be favorable for restoration.

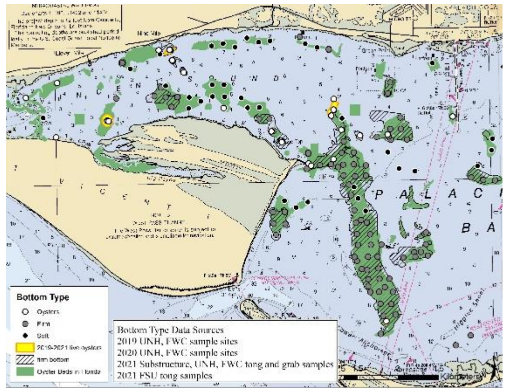
Description

The overall design of the ground-truthing effort was a systematic sampling program with samples spaced at ~500-m intervals. This level of spacing insured multiple samples in each of several different potential bottom types indicated in the acoustic imagery. Ground-truthing field work, conducted in collaboration with FWC staff on 15 – 18 May 2019, consisted of a combination of sampling of the bottom with patent tongs and probing the bottom with a PVC pipe. This file was created for Florida Fish and Wildlife Conservation Commission under contract no. 18184 and no, 19286.

The side-scan imagery clearly showed several distinct bottom features, including remarkable detail on the boundaries of the natural reef, oriented east-west in the bottom central portion of the study area. And ground-truthing data collected at 0.5-km intervals was sufficient to at least coarsely delimit the different bottom types so that potential cultching areas (defined as 'hard' bottom types: sand, shell, or live oysters) could be determined. Manually drawn polygons included all the soft bottom types based on bottom sampling. There were 4051.67 acres of soft bottom in the surveyed area of Apalachicola Bay near Cat Point

St Vincent Island area_hard bottom_sand_sandshell_rock_oysters

Shapefile



Tags

Florida, Apalachicola Bay, Cat Point, 2019, Hard Substrate, Soft Substrate, Polygons, side scan Sonar, Ground-Truthing

Summary

This shapefile consists of manually drawn polygons that delimit firm bottom areas consisting mainly of sand, rock, shell, or live oysters near St Vincent Island in Apalachicola Bay, FL.

A major aim of the overall project was to determine the amount of firm bottom (mainly shell but also sand/shell mixtures and rock) and live oysters in the study areas. These firm bottom types, in general, represent areas that should be further assessed for future oyster restoration sites.
Polygons in this shapefile add up to approximately 3225.0 acres

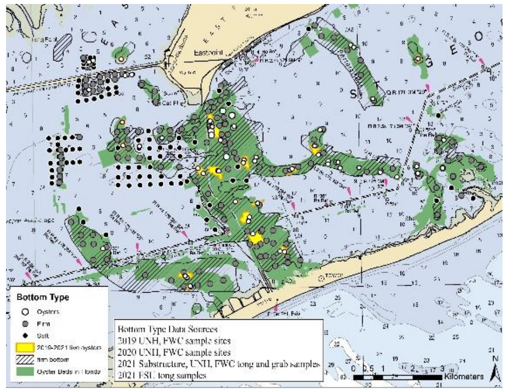
Description

The overall design of the ground-truthing effort was a systematic sampling program with samples spaced at ~500-m intervals. This level of spacing insured multiple samples in each of several different potential bottom types indicated in the acoustic imagery. Ground-truthing field work, conducted in collaboration with FWC staff, consisted of a combination of sampling of the bottom with patent tongs and probing the bottom with a PVC pipe. This file was created for Florida Fish and Wildlife Conservation Commission under contract no. 18184 and no, 19286.

The side-scan imagery clearly showed several distinct bottom features, including remarkable detail on the boundaries of the natural reef oriented east-west in the bottom central portion of the study area. And ground-truthing data collected at 0.5-km intervals was sufficient to at least coarsely delimit the different bottom types so that potential cultching areas (defined as ‘hard’ bottom types: sand, shell, or live oysters) could be determined. Manually drawn polygons that included all the hard bottom types based on bottom sampling indicated that essentially all the higher reflectance areas would be potentially suitable for cultching.

Cat Point area_Apalach Bay_sand_shell_rock_oysters_hard bottom

Shapefile



Tags

Florida, Apalachicola Bay, Cat Point, 2019, Hard Substrate, Soft Substrate, Polygons, side scan Sonar, Ground-Truthing

Summary

This shapefile consists of manually drawn polygons that delimit firm bottom areas consisting mainly of sand, rock, shell, or live oysters near Cat Point in Apalachicola Bay, FL.

A major aim of the overall project was to determine the amount of firm bottom (mainly shell but also sand/shell mixtures and rock) and live oysters in the study areas. These firm bottom types, in general, represent areas that should be further assessed for future oyster restoration sites.
Polygons in this shapefile add up to approximately 6985.0 acres

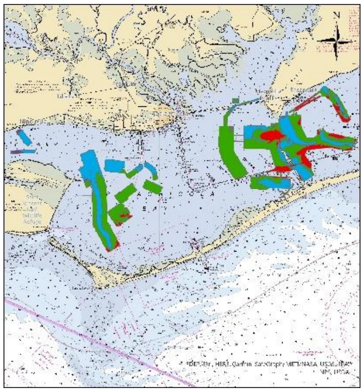
Description

The overall design of the ground-truthing effort was a systematic sampling program with samples spaced at ~500-m intervals. This level of spacing insured multiple samples in each of several different potential bottom types indicated in the acoustic imagery. Ground-truthing field work, conducted in collaboration with FWC staff on 15 – 18 May 2019, consisted of a combination of sampling of the bottom with patent tongs and probing the bottom with a PVC pipe. This file was created for Florida Fish and Wildlife Conservation Commission under contract no. 18184 and no, 19286.

The side-scan imagery clearly showed several distinct bottom features, including remarkable detail on the boundaries of the natural reef oriented east-west in the bottom central portion of the study area. And ground-truthing data collected at 0.5-km intervals was sufficient to at least coarsely delimit the different bottom types so that potential cultching areas (defined as 'hard' bottom types: sand, shell, or live oysters) could be determined. Manually drawn polygons that included all the higher reflectance areas would be potentially suitable for cultching.

Apalachicola Contours 3-29-2022

Shapefile



Tags

Florida, Apalachicola, Cat Point, Depth Contour, Polygon, 1m, 2019-2021

Summary

These polygons are depth contours (less than 1m=purple, 1-2m=blue, 2-3m=green, and more than 4m=red) of Apalachicola Bay based on the 2019-2021 bathymetric data.

A major aim of the overall project is to determine the amount of firm bottom (mainly shell but also sand/shell mixtures and rock) and live oysters in the study areas.

The ground-truthing findings overall confirmed the expected relationship between bathymetry and bottom type: firm bottom types (sand, shell, rock, live oysters) typically are elevated to a discernable (by acoustic methods) extent above adjacent softer, muddy bottoms. Muddy, soft bottom areas based on probe and tong sampling correlated mainly with the deeper areas (water depths >1.5 m) on the bathymetric maps and the lighter areas on the side-scan maps. The firm bottom types (sand, rock, shell, live oysters) correlated mainly with shallow water depths and darker areas in side-scan imagery. Historically oyster bottom has been mapped in areas with water depths less than 5 ft. The bathymetric data was particularly useful in the 1,000-acre target area of Cat Point, but also to some degree in the other two study areas of Cat Point. The multibeam data were particularly effective in detecting hard bottom in the 60-acre northern area.

Description

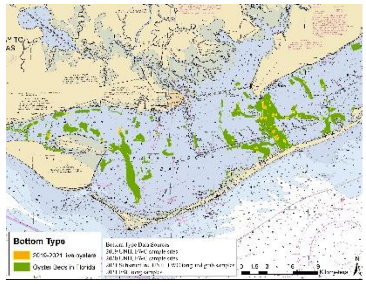
A bathymetric grid with a 3m swath was recorded using an Edgetech 6205 mutibeam transducer. It was decided that the surveying would begin on Cat Point and adjacent reefs, then move to St. Vincent bar and adjacent reefs. The overall aim was to survey as much of the major reefs as possible in the eastern and western portions of the Bay. This file was created for Florida Fish and Wildlife Conservation Commission under contract no. 18184 and no, 19286.

Depth 'contour polygons' were created from the 2019-2021 bathymetry data, using the ArcGIS Contour tool. The cell size of the raster was left on 'default' and the contour interval was 1. The depth classes were set to less than 1m, 1-2m, 2-3m, and greater than 3m. The ArcGis union tool was used to combine the 2019 and 2021 datasets and the overlaps were removed. The contour polygons were grid-like, so the interior holes within each class polygon were manually removed and then the ArcGis smoothing tool was applied to each class polygon (poynomial approximation with exponential kernal, smoothing tolerance=12m) to smooth the edges.

Within the surveyed area, 176.8967 acres were less than 1m, 5361.145 acres were 1-2m, 8071.919 acres were 2-3m, and 1924.311 acres were greater than 3m deep.

2021 Live Oysters Apalachicola

Shapefile



Tags

Florida, Apalachicola Bay, 2019-2021, Live oyster beds, Polygons, Ground-truthing, side scan sonar

Summary

These polygons were manually drawn in ArcGIS to show areas of Apalachicola Bay, FL that contain live oysters (hard substrate) as of 2019-2021. Polygons were manually drawn around UNH/Substructure/FWC tong and grab ground truthing samples and 2019-2021 detailed sonar imagery in areas where live oysters were found.

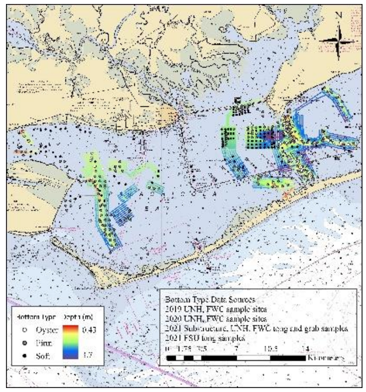
Description

Major bottom types (mud, sand, shell, rock, and oysters) are typically visually discernable in much of the side-scan imagery and are confirmed by the extensive ground-truthing data which include using a PVC pipe to probe the bottom in order to determine predominant gross bottom type and patent tongs that were used to confirm the probe classification. Side-scan, bathymetric, and ground-truthing data were used in combination to manually drawn polygons and indicate size and location of “live oyster” bottom. This file was created for Florida Fish and Wildlife Conservation Commission under contract no. 18184 and no. 19286.

Each live oyster ground-truthing point was outlined. The side scan sonar was used as a guide to differentiate the edges of the oyster bed. Live oyster bed points outside of the side-scan sonar where encircled by a standard-sized circle (r=100m). Standard circles were also used to outline live oyster bed points that lacked a discernable border on the side scan sonar. There were ~515 acres of live oysters in the surveyed area of Apalachicola Bay

2019_2021_UNH_Substructure_FWC_Bottom_Type_Sampling

Shapefile



Tags

Florida, Apalachicola Bay, 2019-2021, Hard Substrate, Soft Substrate, Polygons, side scan Sonar, Bathymetry, Ground-Truthing, oyster tongs, Bottom Sampling

Summary

Ground-truthing field work, conducted by UNH & Substructure in collaboration with FWC staff, consisted of a combination of sampling of the bottom with patent tongs and probing the bottom with a PVC pipe. This file was created for Florida Fish and Wildlife Conservation Commission. The side-scan imagery and bathymetry (shown in image with bottom type sampling overlay) clearly showed several distinct bottom features, including remarkable detail on the boundaries of the natural reefs throughout the Bay and ground-truthing data collected at 0.5-km intervals was sufficient to at least coarsely delimit the different bottom types so that potential cultching areas (defined as 'hard' bottom types: sand, shell, or live oysters) could be determined.

Description

A major aim of the overall project was to determine the amount of firm bottom (mainly shell but also sand/shell mixtures and rock) and live oysters in the study areas. These firm bottom types, in general, represent areas that should be further assessed for future oyster restoration sites while the soft bottom types would not be favorable for restoration