2024 St. Andrew Bay Subtidal Oyster Mapping

Final Report completed June 30, 2025

Deliverable 1.2 for Florida Fish and Wildlife Conservation Commission (FWC) Contract #PR241565: St. Andrew Bay and Suwannee Sound Subtidal Oyster Reef Mapping 2023-2025

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This document is Deliverable 1.2, the final report on mapping subtidal oysters in St. Andrew Bay, Florida. The overall objective of the project, as stated in the contract, was to: "provide FWC managers and researchers with much needed information to improve oyster management and restoration on the Gulf Coast of Florida." Radabaugh et al. (2022) compiled in map form what was known with respect to location and types of the St. Andrew Bay oyster resources (**Figure 1**).

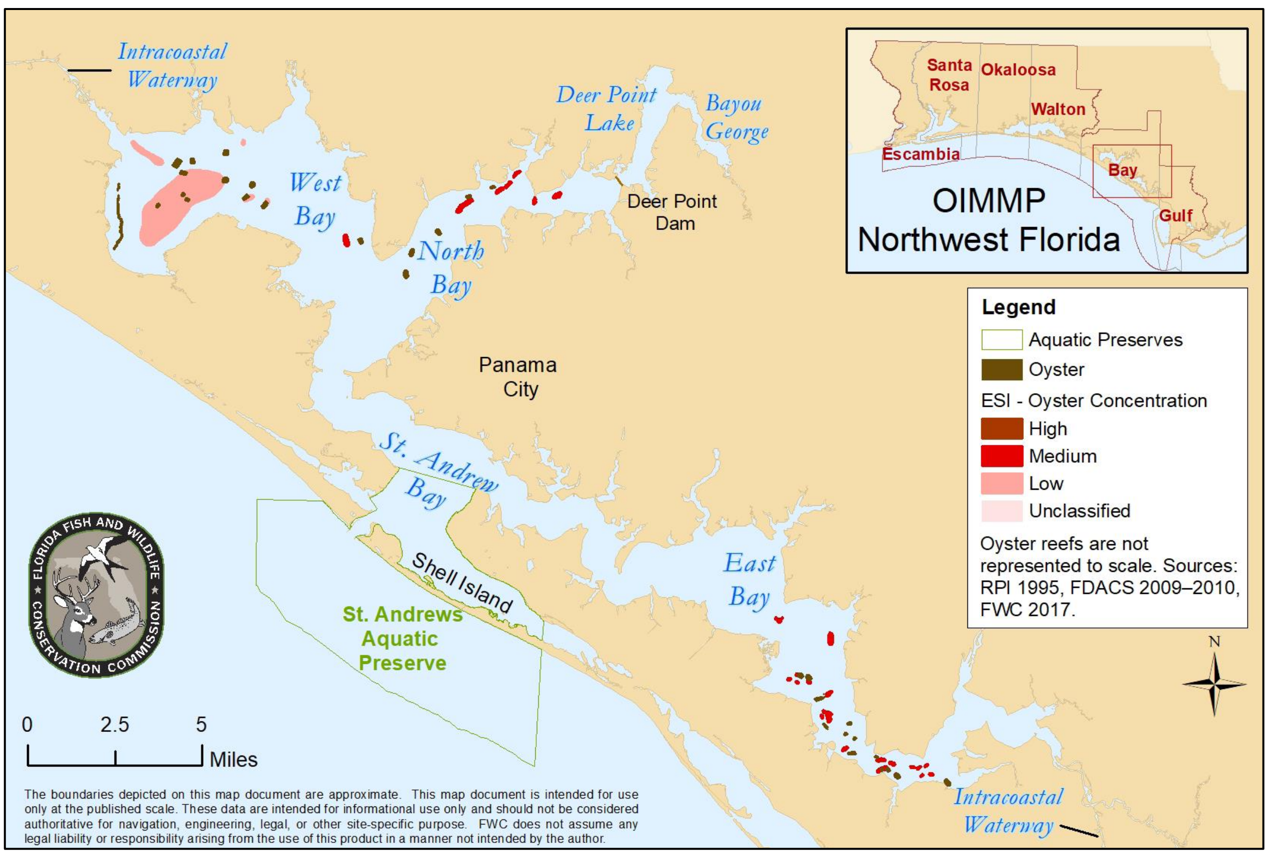

Figure 1. Historically mapped oyster extent in St. Andrew Bay based on data from a variety of sources (from Radabaugh et al. 2022).

Our mapping project focused on the subtidal reefs, natural and restored (i.e., cultched by addition of shell or rock). Intertidal oysters occur in many areas of St. Andrew Bay, but mainly only on hard substrates such as rock rip rap, pilings and other manmade structure. A recent large intertidal reef was constructed in southwestern West Bay (**Figure 1**; Hatchell et al. 2022), but no other intertidal reefs have been mapped. Thus, subtidal reefs likely represent most of the oyster resource in the Bay.

With respect to harvest potential, parts of East, North, and West bays are conditionally approved for shellfish harvesting (Radabaugh et al. 2022). Annual harvest yields for Bay County, nearly all of which comes from St. Andrew Bay, peaked in 1993 at 213 metric tons (470,000 pounds). In 2022, there were nine aquaculture leases in St. Andrew Bay, all in West Bay. Since the early 2000s, commercial harvest has been minimal. Reef restoration projects mainly consisting of adding rock or shell cultch onto a total of 50 ha (125 ac) of bottom area were conducted from 1987 through 2009. More recently, 17,000 yd^3 of crushed granite was placed over ~84 ac on nine debilitated reefs in 2016.

Our mapping effort included all three major geographic areas of the Bay (East, North, and West Bays), and included all major subtidal reef areas in **Figure 1**, but was restricted to a total of 53 "target polygons" (**Figure 2**). The target polygons were only considered approximations of reef shape and size because there had been no surveys designed to characterize spatial features of the reefs before the present project. Although there was no attempt at complete Bay-wide bottom areal coverage with respect to mapping, the target polygons were thought to represent most of the Bay's subtidal oyster resources. The only exceptions to this conclusion are two major areas in western West Bay that had been mapped as "low oyster concentrations" in **Figure 1**. These areas may warrant additional mapping, particularly when considering their total areal coverage.

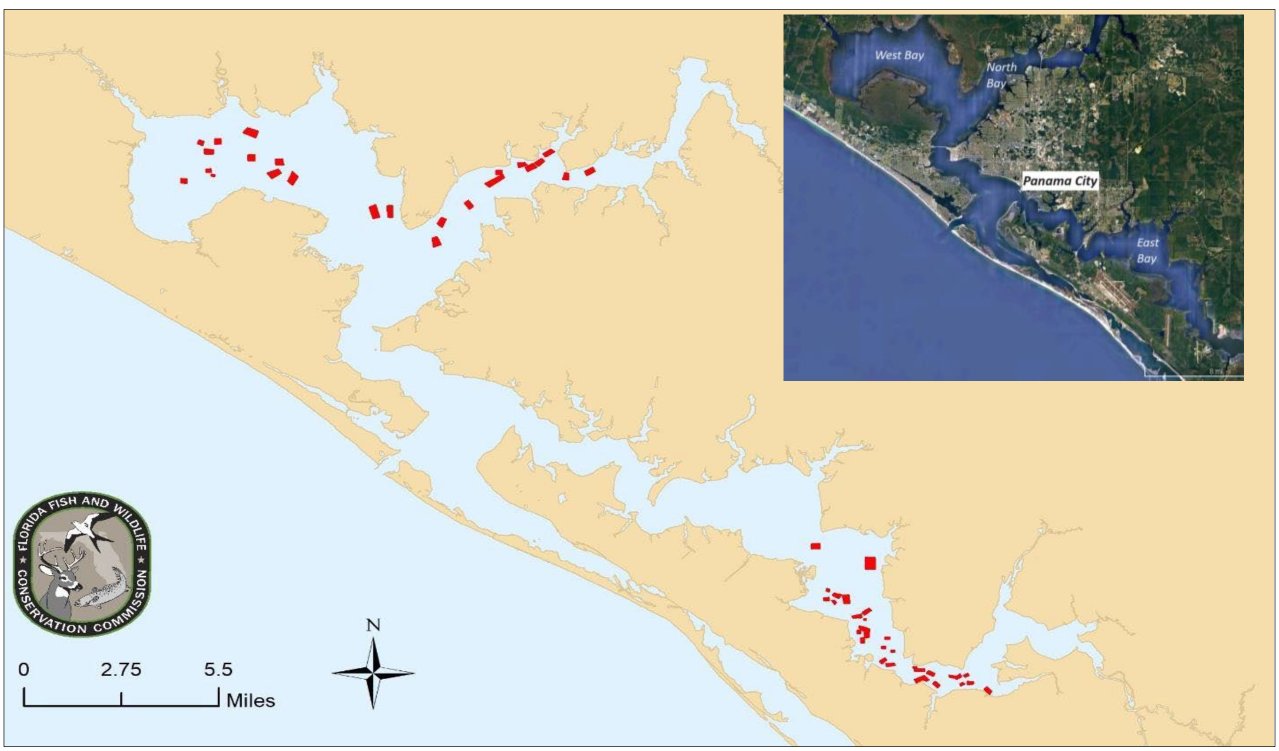

Figure 2. Locations of 53 subtidal oyster reefs (red polygons) in St. Andrew Bay that were the "target polygons" for the present mapping effort.

Mapping Methods

All surveys were conducted aboard Substructure's *Diversity*, a 26-ft Privateer (**Figure 3**). The sonar equipment consisted of a Ping DSP 3DSS-iDX-450-Pro multibeam echosounder, an SBG Systems Navsight Ekinox vessel position and motion reference unit (integrated in the 3DSS), an AML Oceanographic MicroX sound velocity sensor (SVS) mounted near the 3DSS, a YSI Castaway conductivity-temperature-depth (CTD) speed of sound profiler, and Hypack/Hysweep hydrographic data acquisition and processing software (see **Appendix B** for details on all acoustic equipment).

The methods used in the present project were similar to our previous work in Apalachicola Bay and recent studies in other areas. For example, Legare & Mace (2017) mapped subtidal oyster reefs in shallow waters (~3 m depth) of Copano Bay, Texas using side-scan sonar and a single-beam echosounder to produce preliminary maps that were later ground-truthed using a boat pole to probe the bottom. Our approach was essentially the same except we conducted ground-truthing concurrently in many areas with collection of the acoustic data. This allowed making notes in the field that facilitated initial acoustic image interpretation as well as identifying areas where extractive sampling with tongs or underwater photography would be needed. Thus, our approach in the field involved acoustic data acquisition and ground-truthing in an iterative manner.

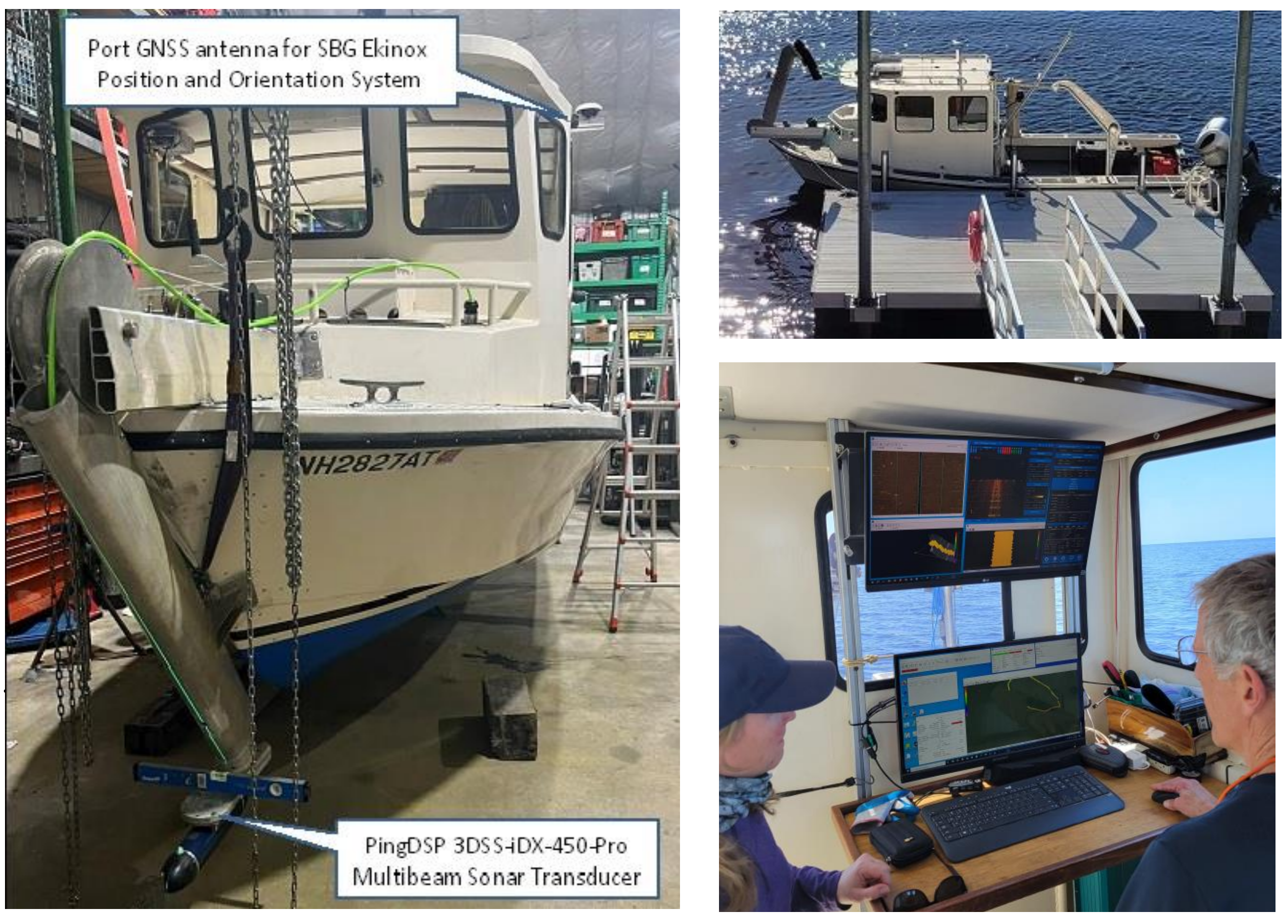

Figure 3. Left: Acoustic gear on Substructure's *Diversity* with bow-mount and towfish in deployment position. Top: *Diversity* dockside with bow-mount in raised position for transport. Lower: Sonar monitors in Wheelhouse.

The Ping unit provides simultaneous side-scan and bathymetric data outputs. It is a multibeam echosounder operating at 450 kHz with a nominal beamwidth of 0.4º. The system includes motion reference units (MRU) that are fully integrated into the sonar transducer package. It also includes a patented signal processing methodology that extends the single angle-of-arrival principle used in interferometric systems to accommodate multiple simultaneous backscatter arrivals (e.g., the seabed, sea surface, water-column, and multipath), resulting in improved wide-swath bathymetry, and both 2D and 3D imagery. The Ping towfish was mounted on a rigid bow-mount fairing about 50 cm below the water surface with known offsets to the SBG Navsight navigation reference point (**Figure 3**).

Figure 4 below illustrates the range of acoustic bottom coverage acquired for most of the target polygons. The target polygon was overlaid with multiple ship tracks spaced at 80 m intervals and covering an area slightly larger than the polygon. The range-scale for the Ping multibeam was set to 50 m for most surveys, yielding a useful 2D side-scan imagery swath width of about 100 m. Thus, the 80 m ship track spacing provided 100% 2D imagery (the brown colored areas in **Figure 4**) coverage over each target polygon, but <100% bottom coverage for bathymetry (the yellow to green colored areas) because its swath width typically was 8x to 10x ambient water depth. The bathymetric and 3D imagery coverage generally ranged from about a quarter to half that of the side-scan imagery.

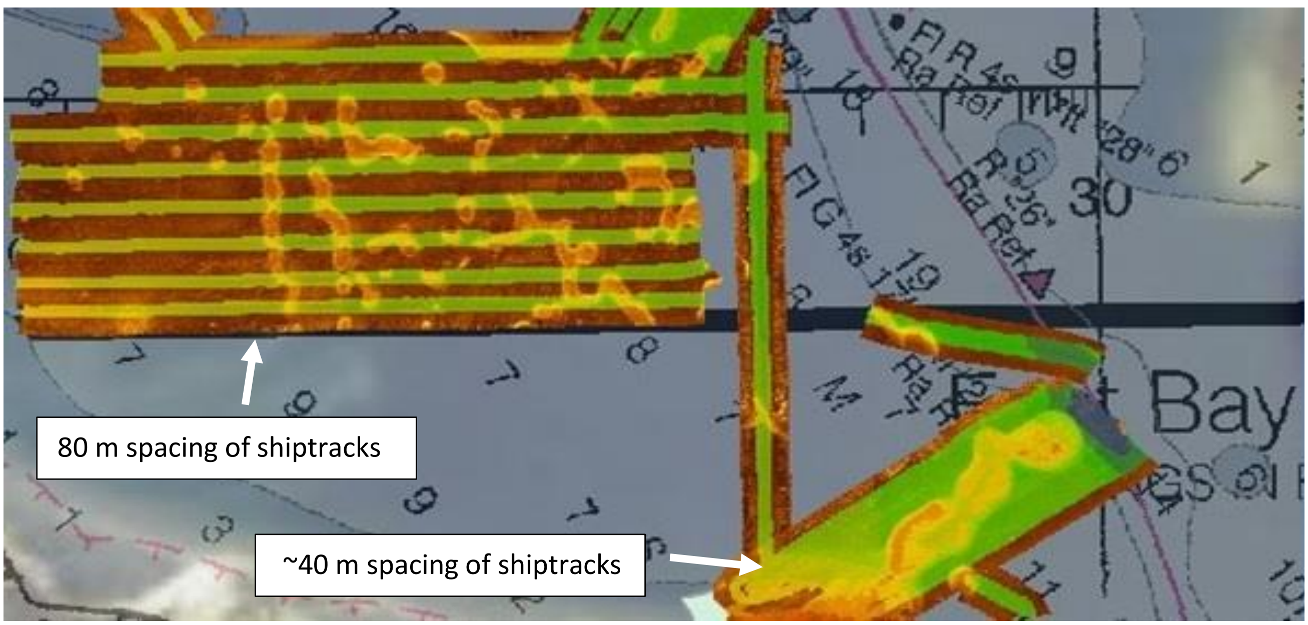

Figure 4. Acoustic imagery from two target polygons in East Bay illustrates how ship track spacing affected bottom coverage by the 2D side-scan imagery (shades of brown) and bathymetric data (green to yellow).

The Ping DSP provides remarkably high-resolution data. The 2D imagery for side-scan displays the relative amount of sound that is absorbed or reflected across the survey area, with complete areal coverage. Soft, muddy sediments absorb most of the soundwave while hard bottoms of rock or shell are highly reflective. For side-scan, high reflectance bottom types are lighter in color and low reflectance darker, both displayed herein in shades of tan to dark brown. The imagery for bathymetric data displays the sound wave return time from the surface sediments, thus reflecting bottom topography that is expressed as water depth. For bathymetry, water depths are displayed along a range of colors from red (shallow) to blue (deeper).

Acoustic data, however, are affected by environmental factors such as water density, waves, turbulence, and others as well as the accuracy of the position (navigation) data. Thus, extensive processing of the data is typically required (see **Appendix B** for details). In brief, all three data types: position and elevation, multibeam bathymetry, and side-scan required some level of processing. The real-time horizontal and vertical accuracy estimates were very strong throughout the survey period (generally in the 1-2 cm range), so minimal processing was required. The multibeam bathymetry and side-scan processing included reviewing all navigation data, applying speed of sound data, and extracting final soundings from the full datasets. Imagery mosaics were then produced at 1-meter resolution and exported as geoTIF or KMZ files, the latter particularly for use in GoogleEarth and comparison to other imagery.

Figure 5 below illustrates the level of detail typically provided by the side-scan imagery. At least some amount of highly reflective (i.e. hard) bottom types is visible in all 10 polygons (upper image), and the enlarged (lower image) of a restored reef (cultched with rock material) in 2016 clearly shows the "stringy" pattern of the deployed rock.

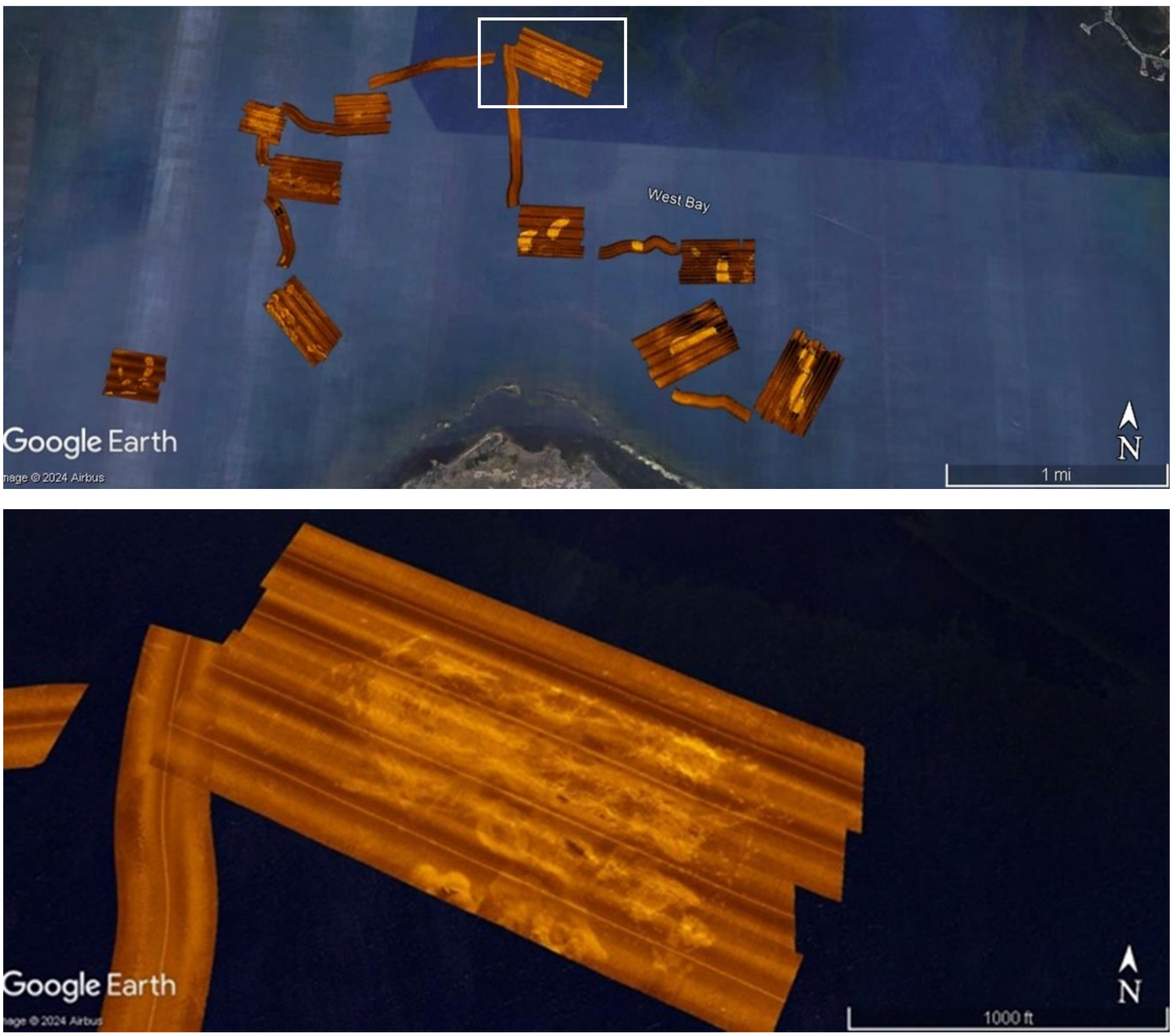

Figure 5. Side-scan imagery across 10 reefs in West Bay (upper image) with enlargement of a recent (2016) restoration site (white rectangle in upper image and lower image) that had been cultched with rock material.

The mapping focused on live oysters, but dead shell, rock, and sand were also mapped because all four are considered “hard” or “firm” bottom and they similarly result in high reflectance of acoustic signals. Sand, rock, and dead shell were of interest mainly because they represent potential restoration areas that might be improved by cultching with shell or rock. Hard bottom types covered by a thin layer of mud were also mapped in some areas because they might be suitable for cultching. All bottom types, however, require ground-truthing to assess the accuracy of the bottom type inferred from the acoustic data. The major method used in all areas was probing the bottom with an extendable aluminum pole (**Figure 6**). All hard bottom types are easily distinguishable from muddy sediments by probing, and although there are clear differences in “feel” among the bottom types, extractive sampling with handheld tongs and/or underwater photography was also used. In particular, if the acoustic data or probing indicated live oysters, their presence was confirmed (or refuted) in most cases with tongs and/or photography.

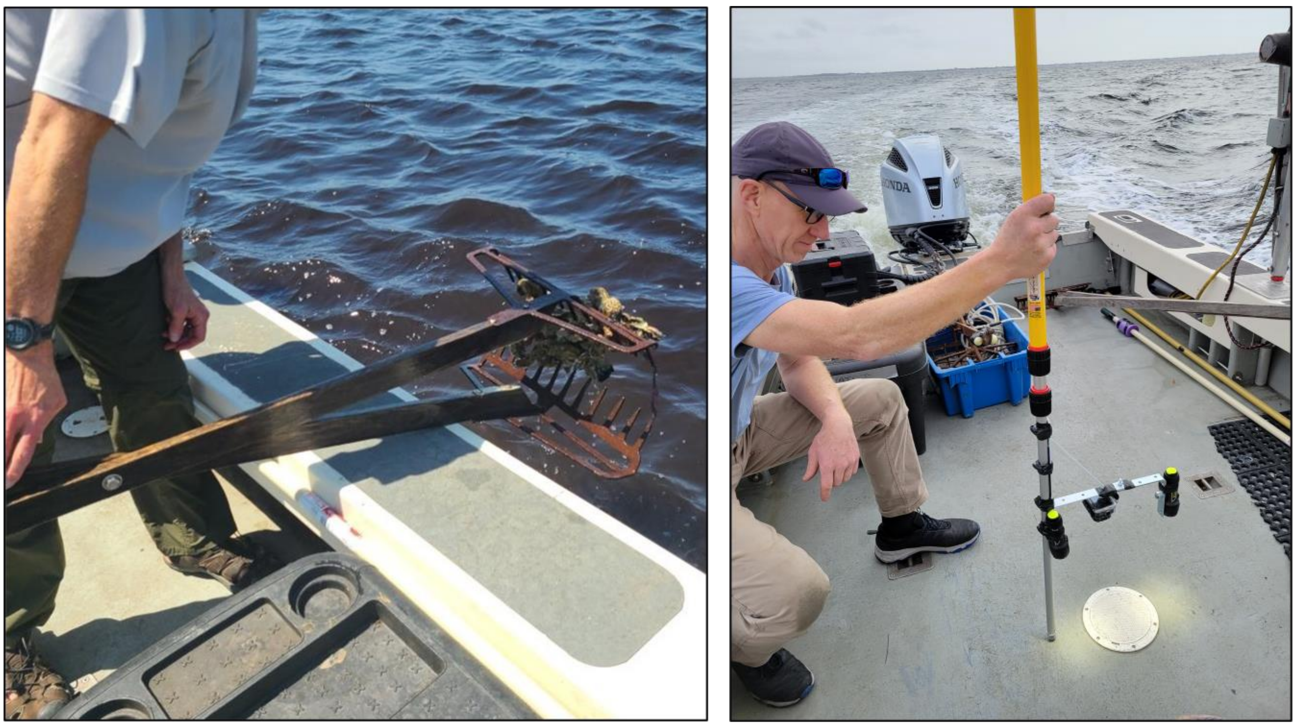

Figure 6. Handheld tongs containing several clusters of live oysters, and one of the extendable probes with GoPro camera and lights attached, used in ground-truthing the acoustics data.

Final map products were a synthesis of acoustic and ground-truthing data. Data from each of the 53 target polygons were processed individually. Note that although bathymetric and side-scan data were acquired in most areas, side-scan provided the major acoustic data used in final map production due to its complete bottom coverage in most target polygons and high-resolution 2D data (see above discussion and **Figures 4** and **5**). Side-scan data were converted into GeoTIFF files with 1-m pixel resolution that were analyzed to produce the final maps. **Figure 7** below illustrates the overall process involved in final map production by visual inspection and manual drawing of the polygons in ArcGIS software. Bottom areas with minimal surface features that absorbed much of the sonar signal mainly consisted of soft, muddy sediments and are shown as darker shades of brown. In contrast and as discussed above, ‘hard bottom’ (which could be live oysters, shell, sand, and/or rock) was identified by lighter shades of brown resulting from high reflectance of the sonar signal. Thus, the primary criterion for identifying hard bottom was color, shown as shades of brown ranging from tan to nearly white in the final map images.

The sonar signal, however, can be strongly affected by some environmental conditions (see Appendix A for details). For example, waves, boat wakes or sharp turns in the vessel can produce artifacts in the image that resemble high reflectance of bottom features. Additionally, the side-scan transducer sends out and receives signals in an arc extending outward on both sides of the transducer and it has a "dead zone" (nadir gap) directly underneath. The result is a swath of bottom under the transducer that typically resembles the low reflectance (dark brown in this report) of muddy sediments in the imagery. If high reflectance/hard bottom occurred on both sides of the dead zone, it was assumed that hard bottom was also in the dead zone.

The final step in map production involved incorporating ground-truthing data to differentiate as much as possible among the four types of hard bottom: live oysters, shell, rock, or sand. If live oysters were confirmed by one or more tong or GoPro photo samples, the entire polygon was designated as live oysters. If other ground-truthing sample(s) within that polygon indicated other hard bottom type(s), it(they) was also noted as present, but the area of the entire polygon was classified as live oysters. Thus, two final mapping datasets were produced as GIS shapefiles: hard bottom and live oysters. Finally, the total areal coverage of the hard bottom polygons and live oyster polygons in each target polygon were determined in ArcGIS, and the areal coverage of mud was determined as the difference between the overall mapped area and the total of the hard bottom polygon(s) in each target area.

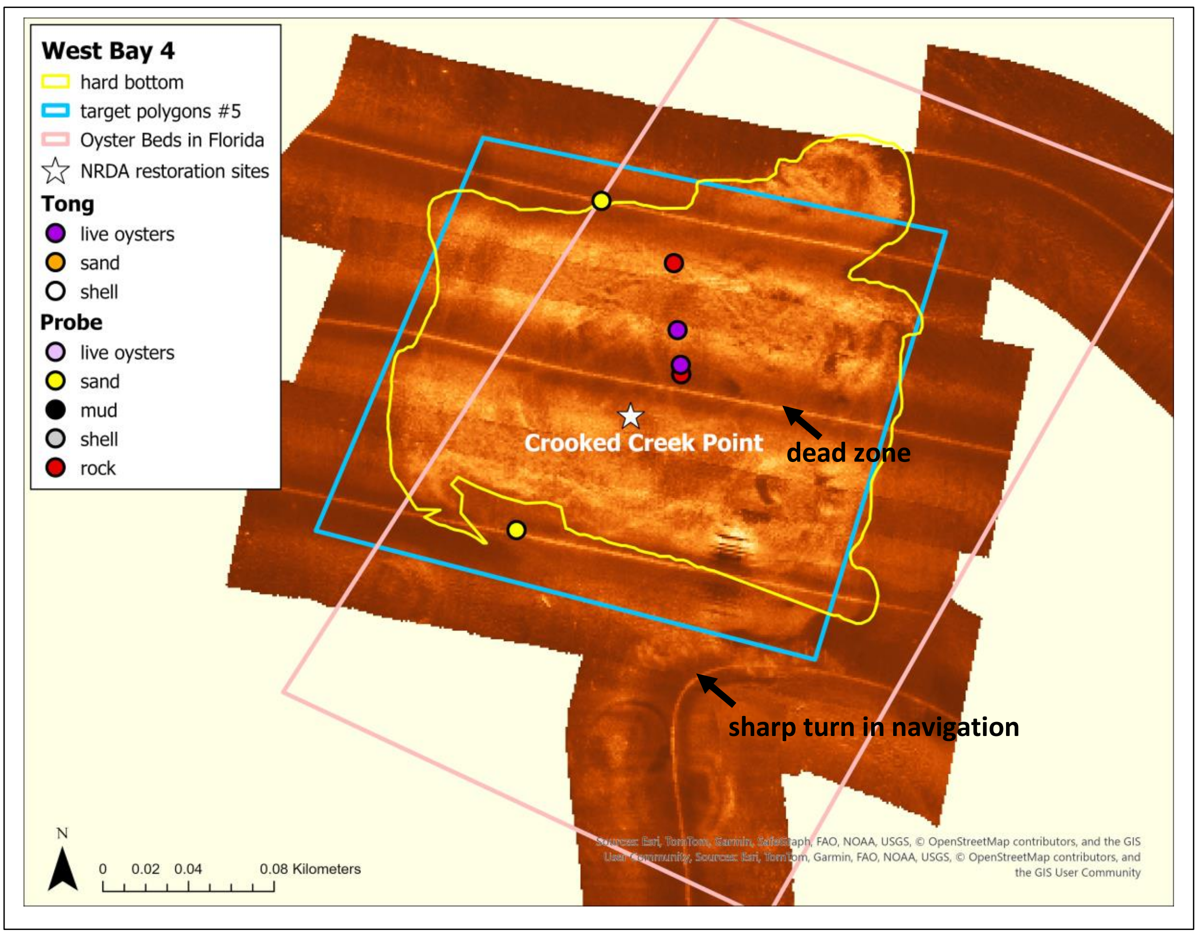

Figure 7. Target polygon 4 from West Bay illustrating "dead zone" in all 2D side-scan imagery and one potential artifact from navigation. Note linear patterns in some areas due to how rock cultch material was deployed.

Results

Acoustics and Ground-Truthing Overview

The 53 target polygons (**Figure 2**) were acoustically surveyed and ground-truth samples acquired during February 8 – 20, 2024 (**Figure 8**). Data were also acquired while navigating among some of the polygons and in nearby areas when hard bottom features were detected.

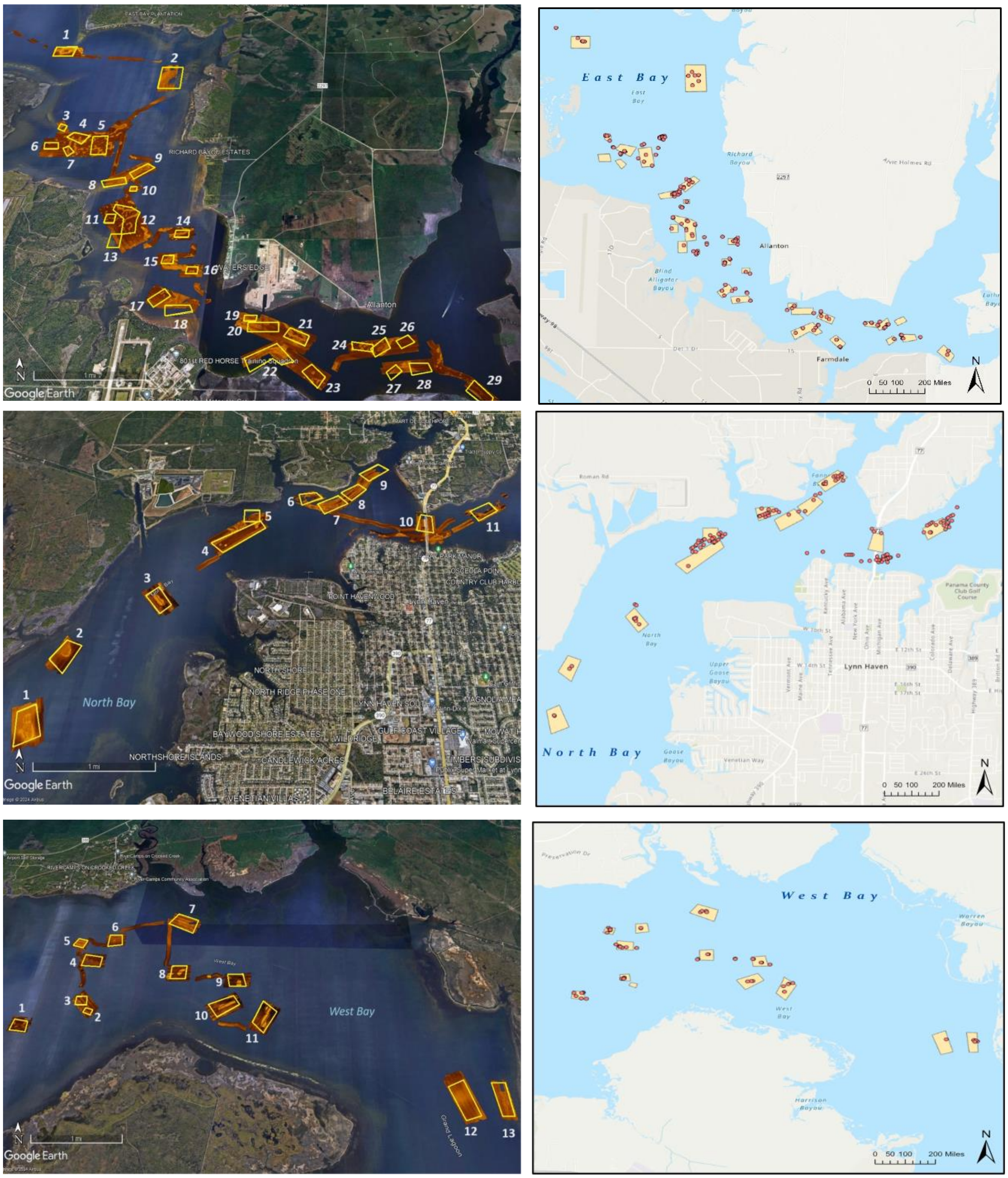

Figure 8. Left: Overview of acoustic imagery acquired across the 53 target polygons (each outlined in yellow) numbered consecutively from west to east in each map using side-scan imagery. Right: Overview of ground-truthing data points involving some combination of probe, handheld tongs, and underwater photography; note that most dots represent multiple samples.

Final Mapping Data Summaries

The 53 target polygons totaled 1,133 acres of bottom area compared to a total of 2,603 acres of bottom area that were surveyed during the present study (**Table 1**). Ground-truthing data were acquired at 355 locations: 241 probe samples, 96 handheld tong samples, and 18 underwater photography sites. Multiple ground-truth samples were acquired in most target polygons.

Table 1. Bottom type data summaries from the present study arranged by numbered target polygons (**Figure 7**), FWC 2022 sampling sites, and locations of 8 recent NRDA restoration sites. Latitude/longitude data indicate the approximate midpoint of each target polygon. LOBP = Little Oyster Bar Point, LOBR = Little Oyster Bar Ridge. Note that the total acreage for hard bottom polygons only included the area within the target polygons and immediately adjacent areas.

Target Polygon #	Lat_DD	Long_DD	Polygon Area (acres)	Surveyed Area (acres)	hard bottom (acres)	live oysters (acres)	FWC Station #	FWC Bottom Type	NRDA Name
East Bay 1	30.08610	-85.52639	28	117	33	32	1701	Oyster	
East Bay 2	30.07845	-85.50000	71	74	48		1483, 1442	Oyster, Sand	
East Bay 3-7	30.06013	-85.51714	73	316	53	18	1160	Mud	Goose Point
East Bay 8 and 9	30.05581	-85.50190	32	88	21	20			LOBP & Off LOBR
East Bay 10	30.05196	-85.50200	3	16	3	3	932	Oyster	
East Bay 11-13	30.04634	-85.50166	60	154	33	24	789, 791, 745, 651	Mud, Sand, Oyster	
East Bay 14	30.04329	-85.49201	8	38	8	7	707	Oyster	
East Bay 15	30.03884	-85.49348	7	30	17	18			
East Bay 16	30.03711	-85.48909	5	27	4		516	Oyster	
East Bay 17 and 18	30.03075	-85.49039	29	65	37	36	380, 330	Mud	
East Bay 19-23	30.02680	-85.47118	83	175	88	73	291, 249, 154, 80	Mud, Sand, Oyster	
East Bay 24-26	30.02534	-85.45845	32	74	12	8	205, 207, 209	Mud	
East Bay 27-28	30.02270	-85.45240	18	53	10	11	125, 127	Sand	
East Bay 29	30.01930	-85.44404	18	34	2		59	Sand	
North Bay 1	30.22787	-85.70737	35	66	15		3915	Oyster	
North Bay 2	30.23745	-85.70530	29	43	4		4274, 5000	Oyster, Mud	
North Bay 3	30.24591	-85.69226	24	50	9		4687	Oyster	
North Bay 4 and 5	30.26102	-85.67840	69	123	20	6	5383, 5802	Mud	East of Powerlines Ridge
North Bay 6	30.26533	-85.66800	19	34	12		6187	Mud	Newman Bayou Bar
North Bay 7-9	30.26631	-85.65942	77	118	14		6069, 6191, 6505	Oyster, Mud	
North Bay 10	30.25973	-85.64670	21	147	35		5682	Mud	
North Bay 11	30.26190	-85.63500	26	67	40	40	5959	Oyster	
West Bay 1	30.25540	-85.82720	18	37	5		5308	Oyster	
West Bay 2 and 3	30.26018	-85.81569	16	50	12		5454, 5735	Oyster	
West Bay 4	30.26931	-85.81570	26	50	12	10	6352	Oyster	
West Bay 5	30.27370	-85.81900	12	28	9	9			Crooked Creek Point
West Bay 6	30.27427	-85.81158	21	45	1	1	6637	Oyster	
West Bay 7	30.27851	-85.79583	50	78	22	21			2 Doyle Bayou's
West Bay 8	30.26658	-85.79573	26	60	8		6139	Oyster	
West Bay 9	30.26481	-85.78251	26	55	8		6020	Oyster	
West Bay 10	30.25944	-85.79182	42	71	8				South Chanel Ridge
West Bay 11	30.25693	-85.77576	44	71	12	11	5339	Oyster	
West Bay 12	30.24162	-85.73716	53	96	4		4492	Mud	
West Bay 13	30.24234	-85.72962	35	54	17	11			2 West Bay Points
		TOTAL:	**1133**	**2603**	**637**	**360**			

Hard bottom consisting of some combination of live oysters, shell, sand and/or rock was found in all 53 target polygons, but mud was the dominant bottom type in many areas (see **Figures 11 – 13** below). The 'snake-like' or sinuous pattern of some of the hard bottom polygons (**Figures 4** and **5**) is typical of oyster reefs in the region, mainly those in the intertidal zone but also some subtidal reefs. Live oysters, however, were found in only 19 of the 53 target polygons, 11 in East Bay, 2 in North Bay 6 in West Bay (**Table 1**). Although total bottom areal coverage of live oysters was estimated to be 360 acres, it should be noted that even if only one ground-truth sample indicated live oysters the entire polygon was mapped as live oysters. Thus, this figure is likely an over-estimate for live oyster areal coverage (see discussion above). An accurate estimate of the spatial extent of hard bottom and live oysters in St Andrew Bay will require additional mapping efforts that extends beyond the target polygons of the present study.

Finally, it should be noted that the 53 target polygons included most of the sampling sites visited in the 2022 FWC study (Davis 2023) and the 8 recent NRDA restoration sites (FDEP 2024). Although detailed comparisons of the new mapping data to data from the FWC and FDEP studies were outside the scope of the present project, general trends were evident. For example, live oysters were found at only 19/53 (=36%) or our target polygons compared to 21/43 (47%) of FWC sites, but most FWC oysters were <30 mm shell height (Davis 2023) and thus less detectable with our methods. These data are similar to recent data from the NRDA sites (FDEP 2024). Combining all data might reveal useful small spatial scale patterns. In sum, and regardless of the need for more data, the present study confirms that all three of the major Bays historically provided substantial oyster habitat that is now largely degraded.

Final Map Products

The maps of live oyster polygons will be available from https://geodata.myfwc.com/datasets/myfwc::oyster-beds-in-florida. For further information on hard bottom extent, ground truthing data, or associated metadata, contact GISLibrarian@MyFWC.com. The figures below provide examples of the kinds of map products that can be produced using the shapefiles and ground-truthing data from the present project.

All high reflectance areas in the side-scan imagery (see discussion above) were mapped as "hard bottom" and are shown as composite map images all areas surveyed in each of the three Bays individually in **Figure 9**. The ground-truthing data confirmed this overall classification (thematic accuracy) of hard bottom at >90% probability. The ground-truthing data, however, also indicated that live oysters, shell, rock, and in some cases sand had similar levels of high reflectance. Thus, the yellow-filled polygons in **Figure 9** are areas that consisted of some combination of live oysters, shell, rock, and/or sand. Because the major focus of the project was on live oysters, all hard bottom polygons that included one or more ground-truthing datapoints for live oysters were mapped as live oysters (**Figure 10**). The most obvious difference among the three Bays for live oysters, was the much greater number of polygons with live oysters in East Bay and North Bay compared to West Bay. It should be noted, however, that no information can be inferred about the overall density or spatial characteristics of live oysters within the green boundary.

The ground-truthing data also indicated that many "hard bottom" areas consisted of two or more of the four bottom classes of primary interest (live oysters, shell, sand, rock). The four different classes of hard bottom displayed discernable differences in some of the imagery but no consistent set of criteria could be developed to reliably discern their differences by visual inspection, with one exception. Rock, which was found only on previously cultched restoration sites, had a "stringy" pattern likely due to how it was deployed (see examples in **Figures 5** and **7** above, and **Figure 13D** below).

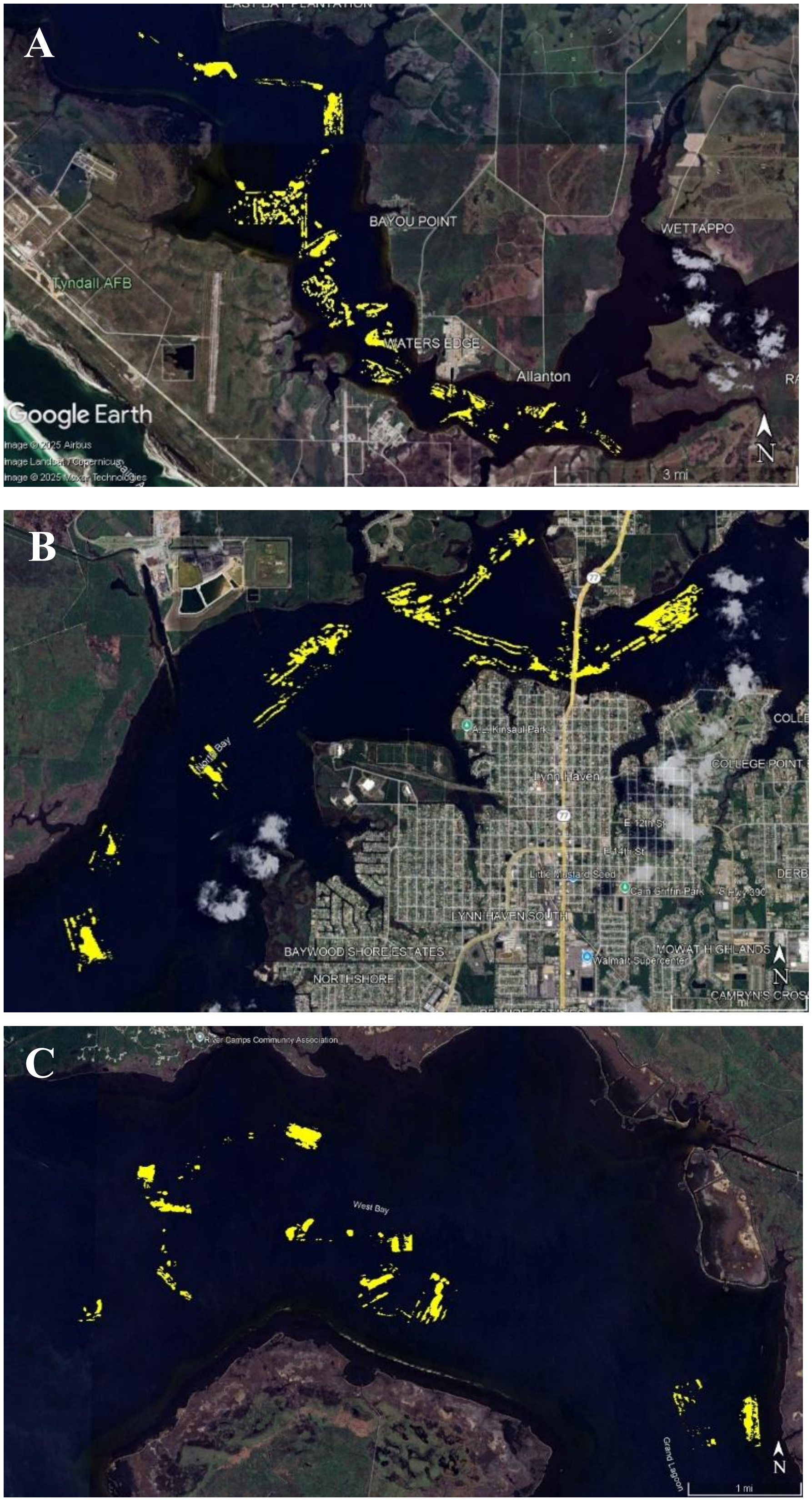

Figure 9. Overview of "hard bottom" (yellow-filled polygons) in each of the three Bays based on side-scan imagery and ground-truthing. A) East Bay, B) North Bay, C) West Bay.

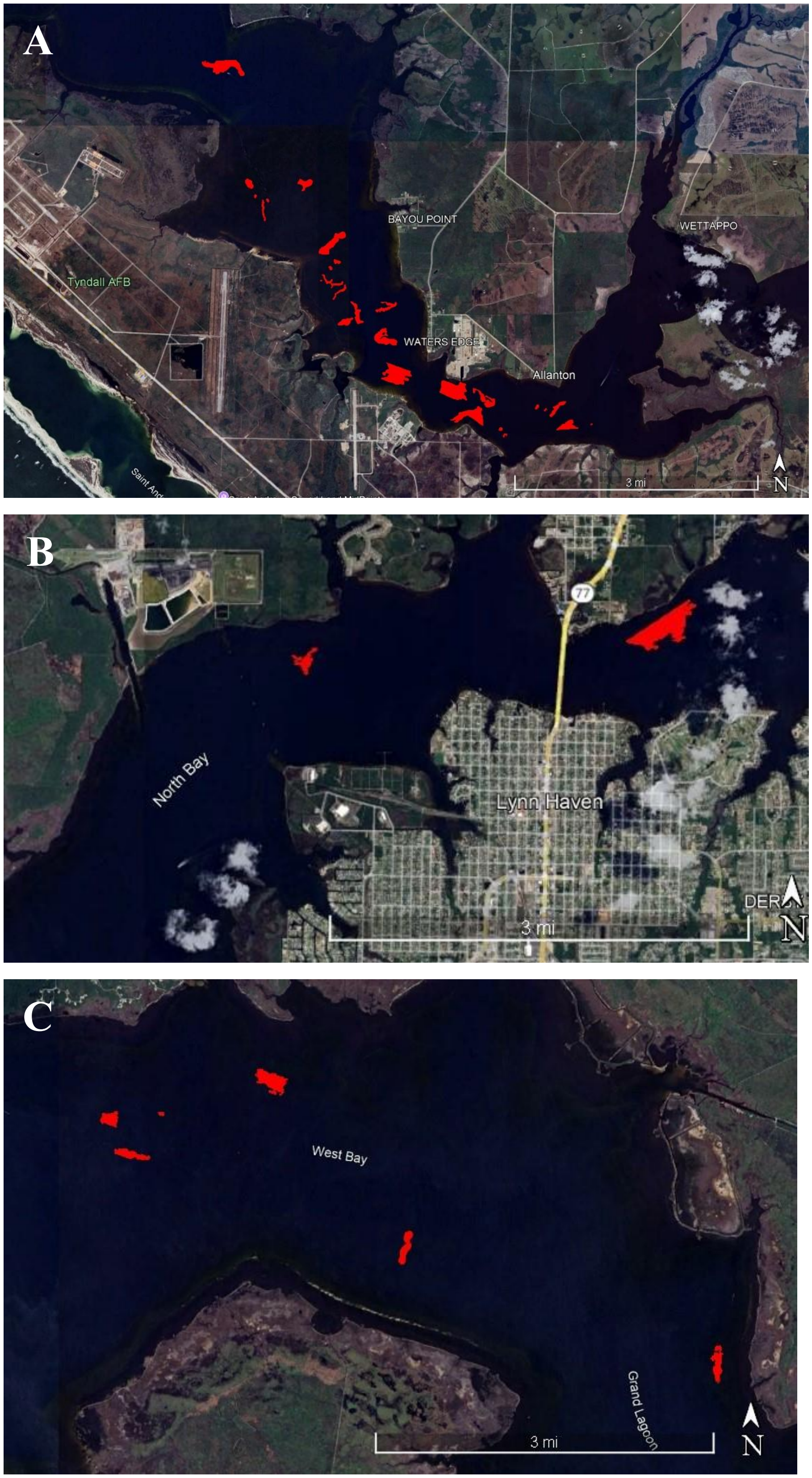

Figure 10. Overview of polygons where live oysters were found in each of the three Bays based on side-scan imagery and ground-truthing. A) East Bay, B) North Bay, C) West Bay.

Examples of how the final map products of the present study compare to the target polygons and to previous major mapping efforts are shown below. Several target polygons from each of East Bay, North Bay, and West Bay are grouped separately in **Figures 11, 12** and **13**, respectively. The boundaries of each target polygon are shown with blue lines, and the boundary data from the online Oysters Beds of Florida prior to the present study are shown with pink lines. The ground-truth data are shown as color-coded dots defined in the inset of each map. Note that the side-scan imagery (ranging from brown to near-white) delimits the total surveyed area, and in most cases substantially exceeds the target polygon (blue boundary lines) area.

The maps in **Figure 11** from East Bay illustrate target polygons where live oysters (dotted lines, purple ground-truthing points) were found. In all cases, live oysters were only found associated with some amount of hard bottom. These maps also illustrate the typical situation of only 1 or 2 ground-truthing points indicating live oysters in the entire polygon, except **Figure 11C** where multiple tong and probe samples were taken. Also note that these multiple samples indicated substantial areal coverage by live oyster and rocks on the two NRDA restoration sites.

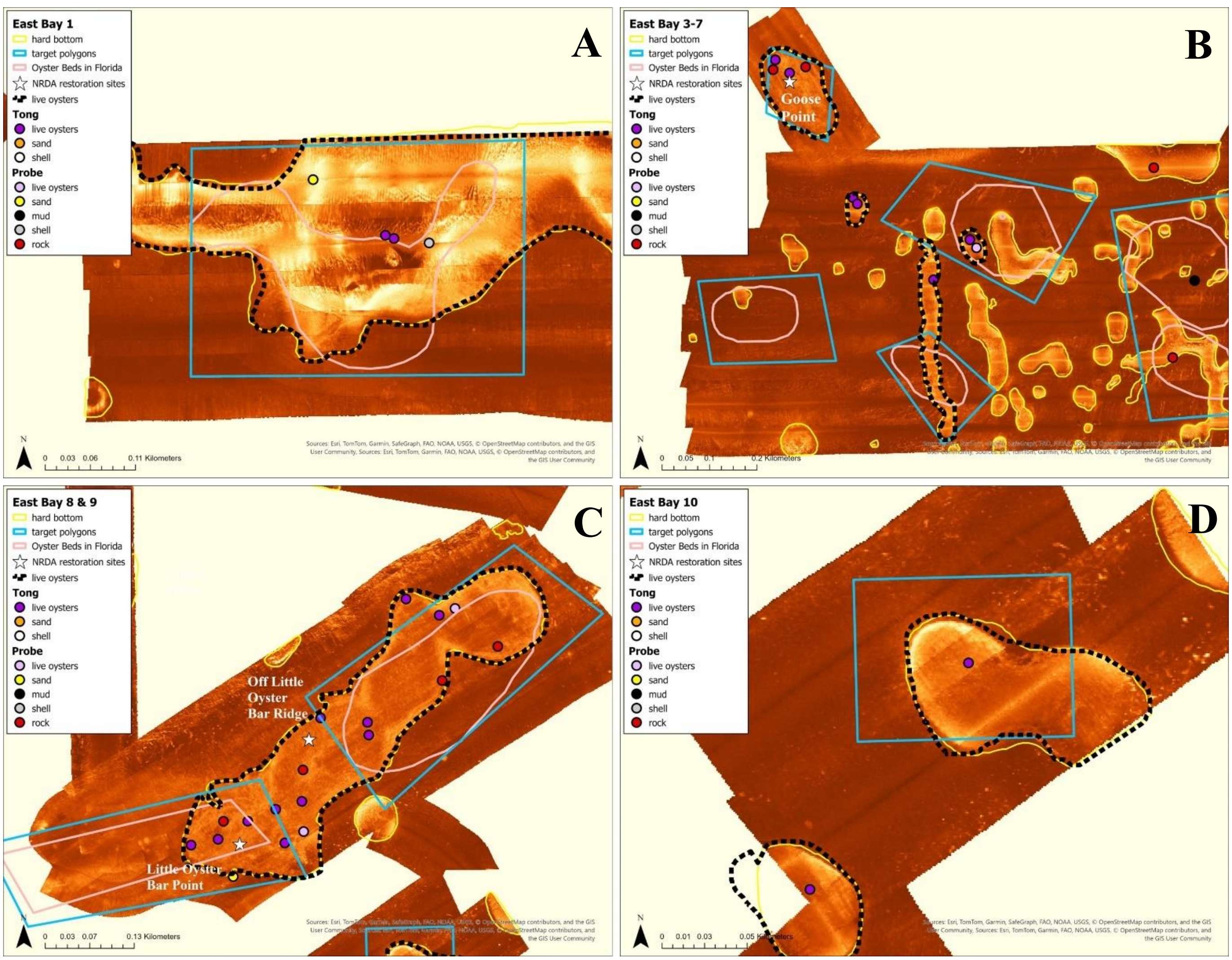

Figure 11. Examples of final maps from several target polygons in East Bay that illustrate typical side-scan base maps, ground-truthing data points, and manually drawn polygons for hard bottom and/or live oysters.

The maps from North Bay illustrate three target polygons (**Figures 12A**, **B** and **C**) where no live oysters were found, but rock was detected indicating they were apparently older cultched restoration areas. The hard bottom in these three also had rectangular or arc-like shapes. In contrast, hard bottom areas in the target polygons in **D** had a range of shapes including irregular and sinuous patterns typical of some natural reefs. The complex pattern of hard bottom and live oysters extended contiguously between and into both target polygons and included a NRDA cultched site as well as natural reef. Finally, note that 4 of the 5 probes indicating mud occurred outside the hard bottom polygons, and one was in a small dark brown patch indicating mud within the overall high-reflectance hard bottom area.

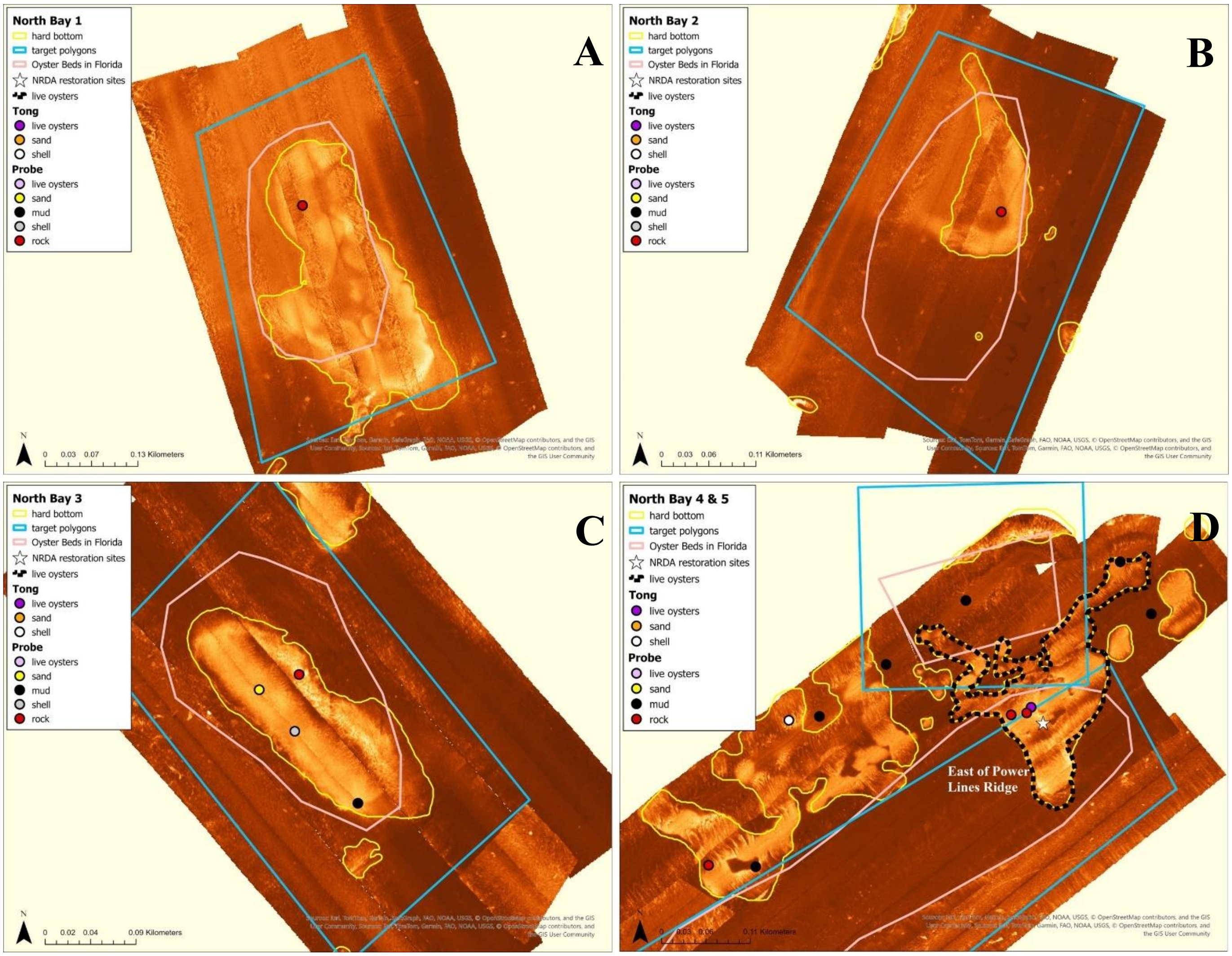

Figure 12. Examples of final maps from several target polygons in North Bay that illustrate typical side-scan base maps, ground-truthing data points, and manually drawn polygons for hard bottom and/or live oysters.

The maps from West Bay (**Figure 13**) include small irregularly shaped hard bottom areas that apparently were natural reefs but no live oysters (**A**) and two polygons that included an old rectangular cultched area as well as irregularly shaped hard bottom, but no live oysters (**B**). Map **C** shows a linear hard bottom area with irregular edges and live oysters as well as sand and shell ground-truthing data points. Also note the much lighter area where the live oysters were found, suggesting that the live oysters could be detected by the acoustic data but as noted above this was not consistently the case with the acoustic data. The **D** map shows a NRDA site with live oysters and a geometric shape.

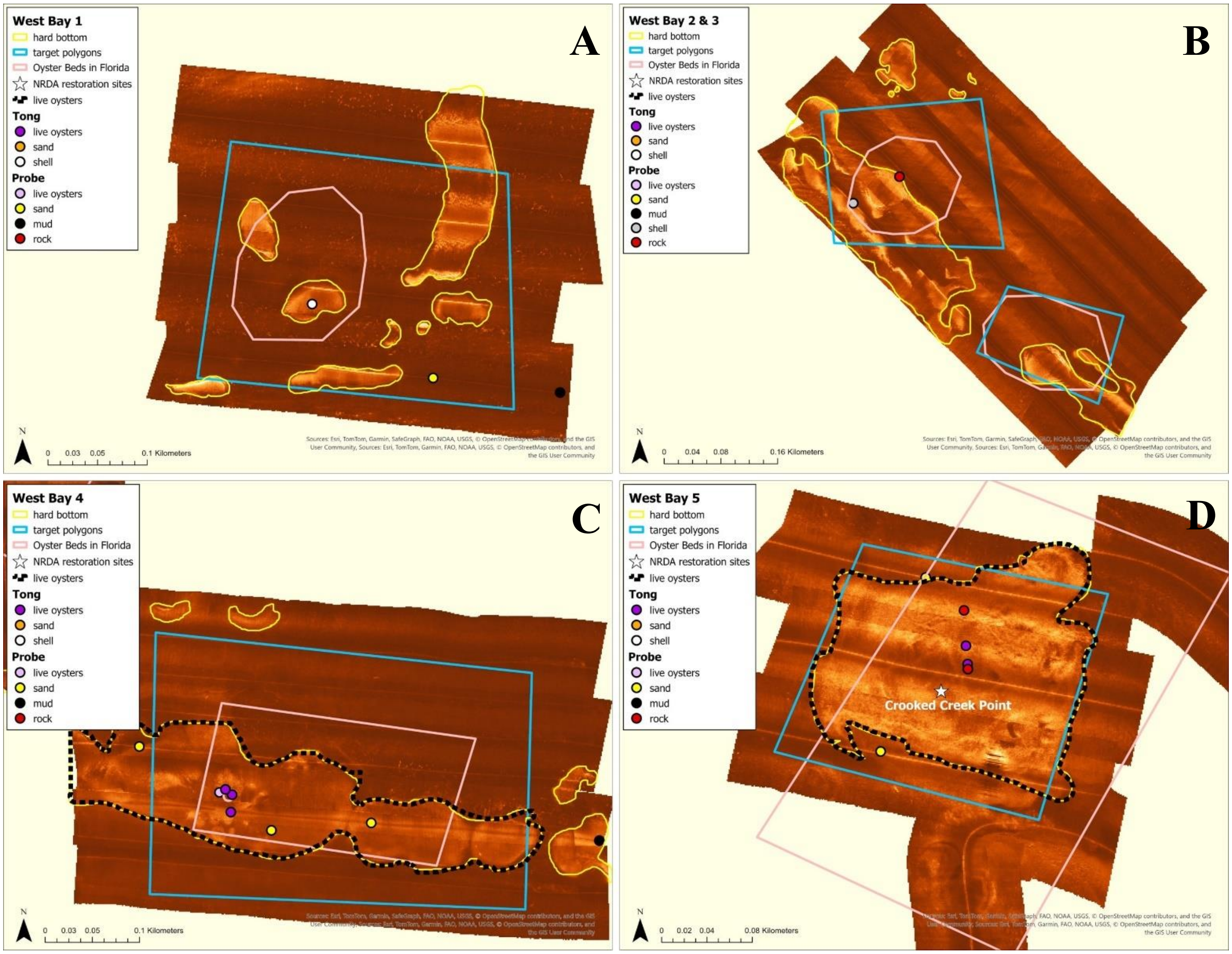

Figure 13. Examples of final maps from several target polygons in West Bay that illustrate typical side-scan base maps, ground-truthing data points, and manually drawn polygons for hard bottom and/or live oysters.

The most obvious overall difference between the new maps of live oysters (above figures) and online Oyster Beds of Florida maps before the present study (pink polygon boundary lines in above) is the more realistic morphology of the oyster reefs revealed by the acoustic data. This was expected because nearly all previous maps were not meant to represent realistic shapes, rather just the general location of where oysters had been reported (**Appendix B**). Nonetheless, some amount of hard bottom was found within the boundaries of most previously mapped reefs. Thus, the earlier maps were reasonably accurate at a useful spatial scale but not in small-scale details. And in most cases, hard bottom mapped in the present study extended well outside the earlier boundaries, indicating a more extensive amount of historical oyster habitat than previous mapping efforts showed.

Conclusions

The overall objective of the present project was to "provide FWC managers and researchers with much needed information to improve oyster management and restoration on the Gulf Coast of Florida." With respect to management, the new data confirm that all three of St. Andrew's major Bays historically provided substantial oyster habitat that is now largely degraded. The new mapping also provided data that indicate more survey work will be required to characterize the full spatial extent of the St. Andrew Bay oyster resources. Although live oyster densities cannot be inferred from the new mapping data, the presence of live oysters did compare well with ongoing FWC sampling data and data from FDEP assessment of the recent NRDA restoration sites. The spatially detailed data from the present project might be combined with FWC and FDEP existing data in some areas on oyster density and other metrics to yield more information on the spatial extent and condition of the oyster resource. Data from this project might also be useful for designing future quantitative sampling efforts.

With respect to restoration, the present project yielded high-resolution shapefiles of "hard bottom" and live oysters that might be useful in designing future projects to complement the recent NRDA (FDEP 2024) and Hatchell et al (2022) restoration efforts. Ongoing FWC monitoring of some of these cultched areas is providing assessment data as well as new information on recruitment potential (Davis 2025). These data will be particularly useful in identifying high recruitment areas likely to result in the most successful long-term restoration. And the new "hard bottom" data herein could provide the basis for designing cultching projects that better reflect the historical shape and size of the Bay's natural oyster reefs compared to typical cultching that occurs in regular geometric shapes such as circular or square. A "more natural" cultching design would also likely be more efficient with respect to the volume of cultch deployed per unit area coverage due to less loss of cultch on muddy bottoms. Finally, the ongoing FWC monitoring of oyster restoration in Apalachicola Bay was designed to yield information on potential relationships between various existing reef metrics and restoration success that might be useful in designing restoration sites in St. Andrew Bay.

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Appendix A - St. Andrew Bay Survey Methods

Acoustic surveys and ground-truthing for the 53 target polygons in St. Andrew Bay were conducted in February 2024 (**Table 1**). All survey operations were conducted aboard Substructure's survey vessel *Diversity* (**Figure 1**). *Diversity* was trailered to Panama City, FL at the beginning of the project and stored at local marinas for the duration of the project. During operations in West and North Bays the boat was docked at Bayside Marina, and during operations in East Bay the boat was docked at Pier 98 Marina. Most of the main study areas were characterized as shallow-water habitat, and in many cases, the primary areas of interest (previously identified oyster habitat) were in some of the shallowest areas. After confirmation of adequate water depths at each of the sites, follow-on multibeam sonar surveys were conducted to delineate the primary bottom features. Due to the wintertime survey period, there were some minor weather delays over the course of the project, but they did not impact the overall planned survey and sampling schedule

Table 1. Chronological summary of major survey activities.

Date	Day	Daily Activity Type	Daily Operations Overview
1/14 - 2/2		Off-site Mob / Testing	Off-site mob focused primarily on fabricating, installing, and testing PingDSP bow-mount on *Diversity,* measuring precise offsets between all survey sensors, and extensive maintenance on all boat and trailer mechanical systems.
2/3 -2/5		Travel	Depart Portsmouth, NH with *Diversity,* arrive Panama City, FL.
2/6		On-site Mob / Testing	On site mob around Panama City, including establishing local docking options, setting up local accomodations, and mobilizing gear on survey boat.
2/7	038	Launch / Multibeam Survey	Launch boat and complete on-water mob and testing. Conduct patch test in St. Andrews Bay, and begin initial coverage in West Bay survey areas. Docking at Bayside Marina for West and North Bay survey opeations.
2/8	039	Multibeam Survey	Conduct multibeam survey in West Bay survey areas. Complete initial coverage with 80m lines using 50m range setting on Ping. Refraction due to halocline had minor impact on outer imagery range.
2/9	040	Multibeam Survey	Conduct multibeam survey in North Bay survey areas. Complete initial coverage with 80m lines using 50m range setting on Ping. Refraction due to halocline had minor impact on outer imagery range.
2/10	041	Sampling	Begin bottom sampling in high reflectance acoustic areas using pole mounted GoPro camera, hand tongs, and probe. Start in West Bay and move to North Bay due to increasing SE winds.
2/11-2/13	042-044	Weather / Process	In due to strong SE winds and thunderstorms, followed by strong NW winds. Processed data and perfomed boat maintenance.
2/14	045	Sampling	Continue bottom sampling in high reflectance acoustic areas in West Bay and North Bay using pole mounted GoPro camera, hand tongs, and probe.
2/15	046	Multibeam Survey	Transit to East Bay and begin multibeam survey operations in East Bay survey areas. Some issues with internal Ping / SBG connection, but data were fine. Begin docking boat at Pier98 Marina.
2/16	047	Multibeam Survey / Sampling	Complete initial multibeam coverage in East Bay with 80m lines using 50m range setting on Ping. Some nearshore areas were not covered due to shallow depths. Also did some tong samples in the upper parts of East Bay.
2/17-2/18	048-049	Weather / Process	In due to strong NE winds and thunderstorms, followed by strong NW winds. Processed data and perfomed boat maintenance.
2/19	050	Sampling	Continue bottom sampling (tongs, probes, and u/w video) in high reflectance acoustic areas throughout East Bay. Matt Davis form FWC was on board today.
2/20	051	Multibeam Survey / Sampling	Conduct fill-in multibeam coverage in two areas (Little Oyster Bar Pt and transit area) to provide full-bottom bathymetry coverage. Also completed additional tong samples and video captures in these same two areas.
2/21	052	Demob	Retrieve *Diversity* at public boat ramp in Parker, perform basic boat and engine maintenance, and demob survey components for transit and storage.
2/22	053	Travel	Transport *Diversity* to short-term storage area in Branford, FL where it will remain until it is remobbed for the Suwannee Sound survey operations in early April.

Acoustic Equipment

Hydrographic survey equipment on *Diversity* included a bow-mounted PingDSP 3DSS-iDX-450-Pro multibeam echosounder, an SBG Navsight Ekinox vessel position and motion reference unit (integrated in the 3DSS), an AML MicroX sound velocity sensor (SVS) mounted near the 3DSS, a YSI Castaway conductivity-temperature-depth (CTD) speed of sound profiler, and Hypack/Hysweep hydrographic data acquisition and processing software package (**Figure 1**). The PingDSP bow-mount was custom designed and built to provide a stable and ruggedized mounting platform that could be quickly and safely deployed and recovered by a single person. The mounting system features were critical for being able to safely conduct survey operations in both main study areas which were characterized by generally shallow depths and limited prior survey data. Before the start of this survey, the horizontal and vertical offsets between the locations of the various critical sensors (e.g., PingDSP sonar phase center, SBG IMU phase center, and the SBG GNSS antennas) were precisely measured using survey laser measuring instruments over short ranges. These precise physical measurements were used to create an accurate vessel reference frame for the survey platform and were entered into the survey hardware configuration files and applied during data acquisition.

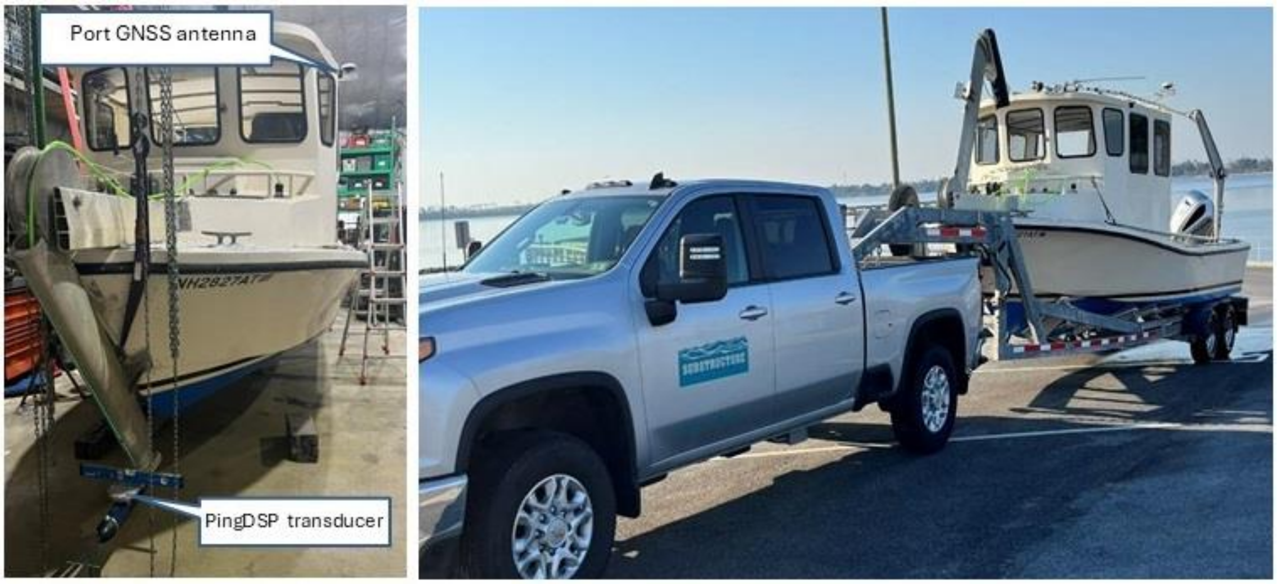


Figure 1. Left: *Diversity* in the Substructure shop during initial mob as the PingDSP sonar was being leveled on the bow mount and precise offsets were being measured between the sonar phase center and the SBG Navsight primary GNSS antenna. Right: *Diversity* on the trailer just after it was retrieved at the public boat ramp in Parker, FL.

The PingDSP 3DSS-iDX is a multibeam echosounder operating at 450 kHz with a nominal beamwidth of 0.4º. The system includes an AML SVS and SBG motion reference unit (MRU) that is fully integrated into the subsea sonar transducer package. The 3DSS-iDX incorporates a patented signal processing methodology that extends the single angle-of-arrival principle used in interferometric systems to accommodate multiple simultaneous backscatter arrivals (e.g., the seabed, sea surface, water-column, and multipath), resulting in improved wide-swath bathymetry, and both 2D and 3D acoustic imagery. For this survey, the sonar towfish was mounted on a rigid bow-mount fairing about 50 cm below the water surface with known, fixed offsets to the primary SBG Navsight navigation reference point.

The range-scale for the Ping was set to 50-meters for all St Andrews survey operations which means that the 2D imagery swath (side-scan) was typically around 100 m (with some outer range reduction in softer sediments due to refraction). The bathymetry and 3D imagery swath were dependent on the water-depth and were generally maintained at eight to ten times the water depth. Primary line-spacing for all of the survey operations was set to 80 m and was intended to provide at least 100% 2D imagery coverage over all of the required survey areas. Depending on the survey depths, the resulting bathymetry and 3D imagery coverage generally ranged from about a quarter to a half of the 2D.

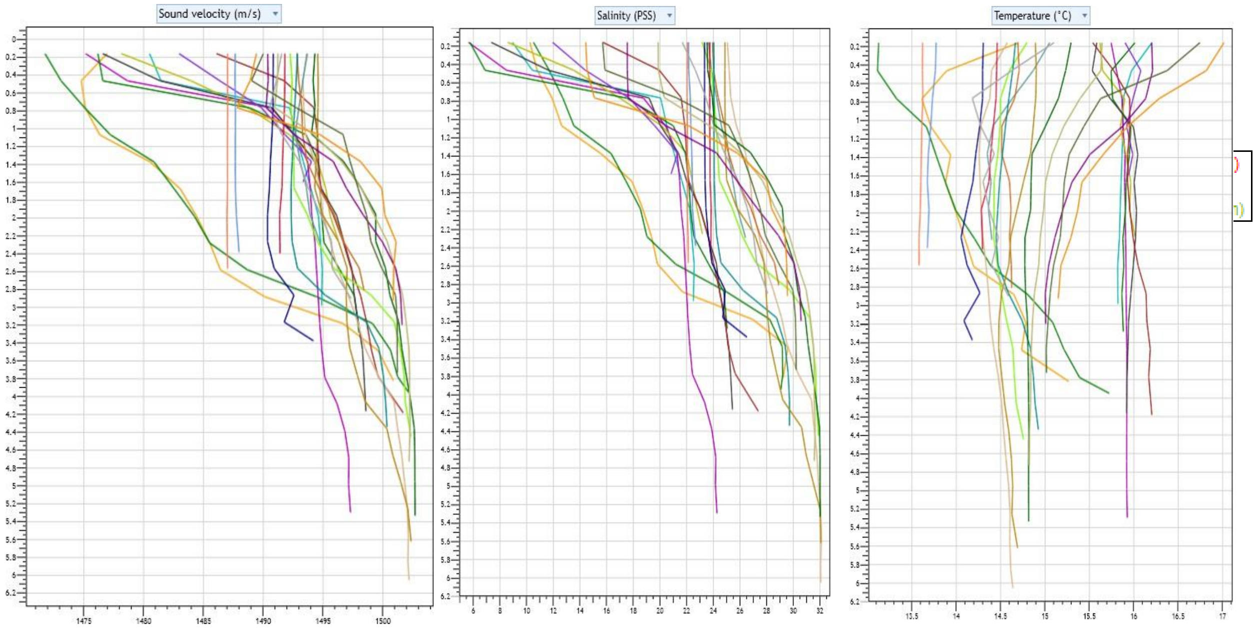
Survey Horizontal and Vertical Positioning

To ensure accurate real-time positioning, the SBG primary Septentrio Global Navigation Satellite System (GNSS) receiver was configured to receive real-time kinematic (RTK) differential correctors from the Florida Department of Transportation's (FDOT) Florida Permanent Reference Network (FPRN) broadcast service. The cellular broadband connection was reliable on the survey vessel throughout the survey period, and the FPRN provided continuous RTK DGNSS correctors to the SBG's primary navigation source that were used as part of the tightly coupled vessel navigation and orientation solution. During the survey, a NAD83 Universal Transverse Mercator (UTM-meters) coordinate system Zone 16N and a NAVD88 vertical datum were used. NGS Geoid Model18 was used to transform the NAD83 GNSS ellipsoidal heights to NAVD88 orthometric heights. In addition to the continuous GNSS-derived water-level observations on the survey boat, the data from the NOAA Panama City tide station was also incorporated into the data processing review.

Based on DGNSS correctors received from the FPRN, the SBG operated in the Fixed Narrow Lane RTK mode throughout almost all of the survey operations, with position and elevation root mean square (RMS) error estimates that were consistently at the few-centimeter level. The only brief period when the SBG operated in the non-fixed mode occurred when operating in the immediate vicinity of the Lynnhaven Bridge in North Bay. Because of the greater uncertainty in the GNSS elevations, the real-time DGNSS vertical reference data was only updated when the SBG was operating in the Fixed-Narrow Lane mode. Throughout the survey period, the SBG raw observable data were always recorded to enable post- processing with the SBG Qinertia software as needed.

Speed of Sound

A YSI Castaway CTD profiler was used to acquire periodic speed of sound profiles during the survey operations. In addition, the AML MicroX SVS included on the 3DSS provided continuous near-surface speed of sound readings that were recorded with the raw sonar data. Before the start of daily survey operations and at routine intervals throughout each survey day, water column speed of sound profiles were acquired with the Castaway and entered directly into the Hypack data acquisition package. Comparisons between the MicroX near-surface speed of sound values and the near-surface speed of sound values from the periodic Castaway CTD profiles showed strong agreement throughout the survey period. Despite the generally shallow survey depths (2-4 meters over most areas), there were still significant water-column speed of sound differences (up to 25 m/s) noted in several of CTD profiles that were closely correlated with large salinity differences between the upper and lower water-column (**Figure 3**).



	Symbol	Device	Cast time (local)	Min conductivity	Max conductivity	Min temperature	Max temperature	Min pressure	Max pressure	Location source	Sample type
		CC2351002	2024-02-20 15:50:57	14556.360	35974.610	13.87	15.28	0.150	4.264	GPS	Cast
		CC2351002	2024-02-20 13:46:05	13875.970	36730.400	13.61	15.26	0.150	3.790	GPS	Cast
		CC2351002	2024-02-20 11:18:56	13685.260	36927.480	13.11	15.72	0.150	3.920	GPS	Cast
		CC2351002	2024-02-16 13:33:38	12655.150	29417.110	15.82	16.20	0.150	2.958	GPS	Cast
		CC2351002	2024-02-16 11:35:51	8152.592	31523.350	15.74	15.92	0.150	5.262	GPS	Cast
		CC2351002	2024-02-16 09:59:52	12022.220	30286.480	15.62	16.01	0.150	2.228	GPS	Cast
		CC2351002	2024-02-15 17:10:06	8351.150	32385.060	15.74	16.01	0.150	3.256	GPS	Cast
		CC2351002	2024-02-15 14:21:57	10387.230	32874.270	15.53	16.04	0.150	4.139	GPS	Cast
		CC2351002	2024-02-15 12:50:52	16447.500	28051.520	15.90	16.08	0.150	1.575	GPS	Cast
		CC2351002	2024-02-15 10:28:09	20985.090	35370.790	15.53	16.20	0.150	4.163	GPS	Cast
		CC2351002	2024-02-09 15:22:36	20090.000	36995.250	15.15	17.01	0.150	2.912	GPS	Cast
		CC2351002	2024-02-09 14:10:56	21567.640	37621.470	15.01	16.74	0.150	3.720	GPS	Cast
		CC2351002	2024-02-09 12:31:20	23597.470	38024.870	15.00	16.21	0.150	3.185	GPS	Cast
		CC2351002	2024-02-09 11:16:43	26088.760	39041.850	14.82	15.64	0.150	4.722	GPS	Cast
		CC2351002	2024-02-09 10:37:21	30197.380	39449.630	14.77	15.29	0.150	5.337	GPS	Cast
		CC2351002	2024-02-08 16:59:06	27890.920	34868.140	14.18	15.10	0.150	2.889	GPS	Cast
		CC2351002	2024-02-08 15:58:05	31462.470	39388.140	14.47	14.90	0.150	5.620	GPS	Cast
		CC2351002	2024-02-08 15:24:26	30257.880	36975.680	14.45	14.92	0.150	4.330	GPS	Cast
		CC2351002	2024-02-08 13:25:20	29258.950	32816.390	14.05	14.30	0.150	3.361	GPS	Cast
		CC2351002	2024-02-08 12:46:02	29815.050	29847.410	14.28	14.46	0.150	2.382	GPS	Cast
		CC2351002	2024-02-08 10:57:21	27577.460	28115.630	13.67	13.77	0.150	2.368	GPS	Cast
		CC2351002	2024-02-08 09:56:36	27352.630	27434.750	13.58	13.62	0.150	2.552	GPS	Cast
		CC2351002	2024-02-07 17:51:22	30255.230	35832.610	14.51	14.71	0.150	2.801	GPS	Cast
		CC2351002	2024-02-07 16:26:45	29413.710	39258.120	14.42	14.79	0.150	4.439	GPS	Cast
		CC2351002	2024-02-07 14:56:25	30142.930	32857.720	14.35	15.05	0.150	2.280	GPS	Cast
		CC2351002	2024-02-07 14:20:26	31437.190	39365.310	14.25	14.63	0.150	6.056	GPS	Cast

Figure 3. Overview of the CTD casts that were taken in West Bay, North Bay, and East Bay during the various phases of the St Andrews Bay acoustic survey from 2/7/2024 through 2/20/2024. Significant differences (up to 25 m/s) in the speed of sound profiles were observed at certain times due to a notable low salinity layer in the upper water-column. These stratified conditions were most noticeable in East and North Bays, while the shallower waters in western West Bay were generally well mixed. Refraction caused by large water-column speed of sound differences had some impact on the acoustic imagery data quality but did not limit the ability to delineate hard bottom features across the full swath. The temperature profiles were generally consistent through the water column for most of the survey period, with a gradual warming trend in the upper water column observed later in the survey period.

Survey Data Processing

To ensure the accuracy and consistency of the navigation and elevation solution, Qinertia software was used to review and assess the real-time SBG Navsight solution. The primary reason for re-processing the SBG solution was to improve the vertical resolution so that the needed water-level reductions could be computed and applied to the bathymetric data. Qinertia utilized the raw observable data from the SBG Navsight, as well as static GNSS data from the relevant continuously operating reference stations (CORS) throughout the region, to re-compute the complete Navsight solution on the survey vessel using both forward and backward processing. The resulting Smoothed Best Estimate of Trajectory (SBET) file was then re-applied to the multibeam data to improve the accuracy and consistency of the final horizontal and vertical measurements. The real-time horizontal and vertical RMS accuracy estimates were very strong throughout the survey period (generally in the 1-2 cm range), so Qinertia was often only used to evaluate and confirm the real-time results.

Multibeam Bathymetric Processing

After application of the SBET file if necessary, initial processing of the multibeam bathymetry 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. Processing of the multibeam data for bathymetry focused on evaluating coverage across the swath and trimming any outer beam areas as needed. The primary preliminary bathymetric products created from the multibeam data were coarsely gridded (3m) datasets that could be used during the sampling operations to help determine the sampling plan and technique. The final gridded soundings were extracted from the full dataset using two different selection methods: 1) average of all soundings in the 1-m cell assigned to the cell center and 2) sounding nearest to the center of the 3-m grid cell assigned to its true position. Initial overview figures have been created for each of the two main survey regions showing the general bathymetric coverage and data range (**Figures 4** and **5**). An additional figure was created to illustrate the differences in coverage between the 3D acoustic bathymetry and the 2D acoustic imagery, and also to provide an example of full-bottom bathymetric coverage (**Figure 6**).

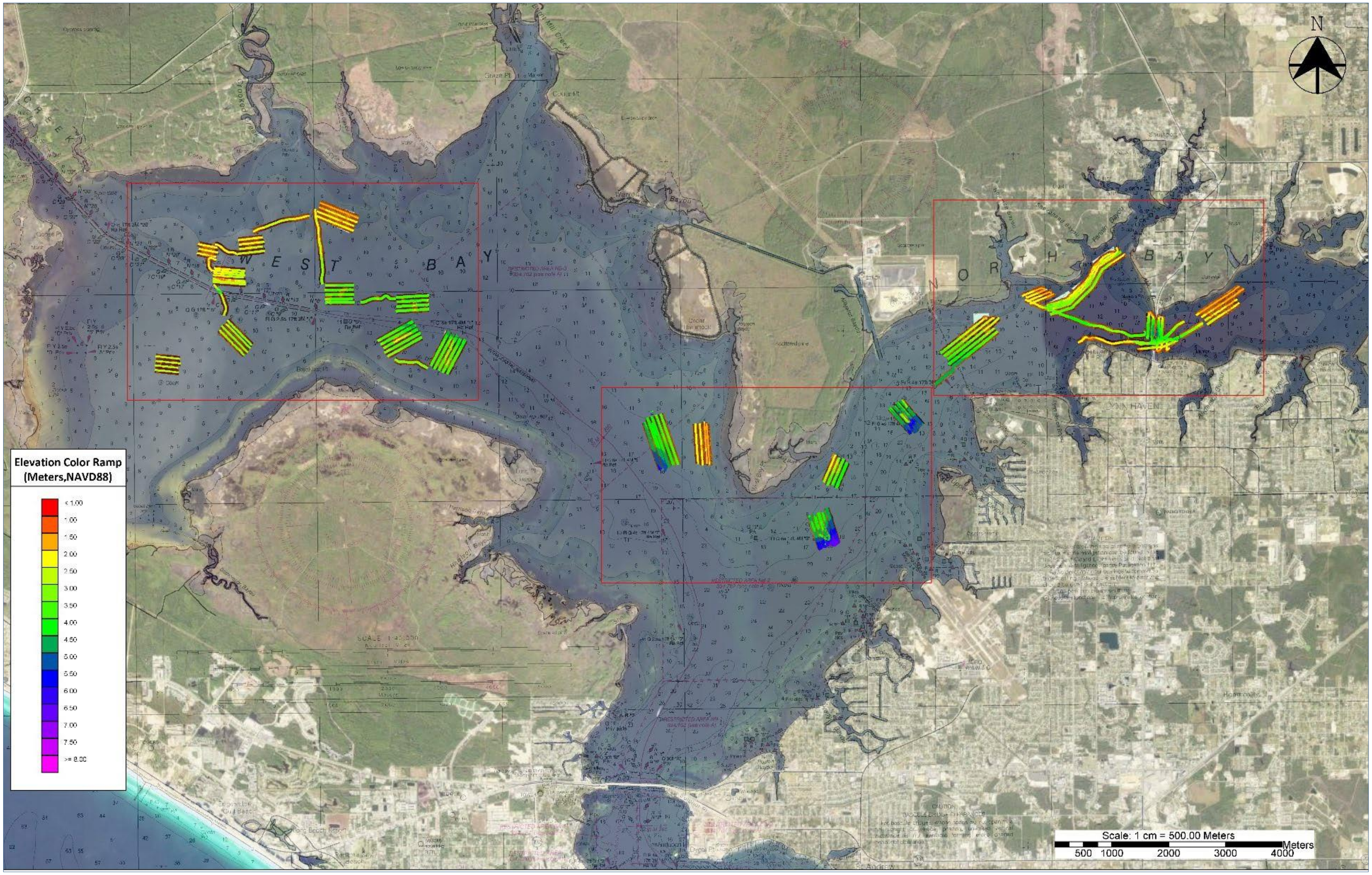


Figure 4. Depiction of the overall acoustic survey coverage in West and North Bays through the multibeam bathymetry matrix data and the 2D imagery mosaics. At this display scale, the multibeam imagery mosaics are mostly covered up by the gridded bathymetry data, even though the bathymetry data provides only partial coverage.

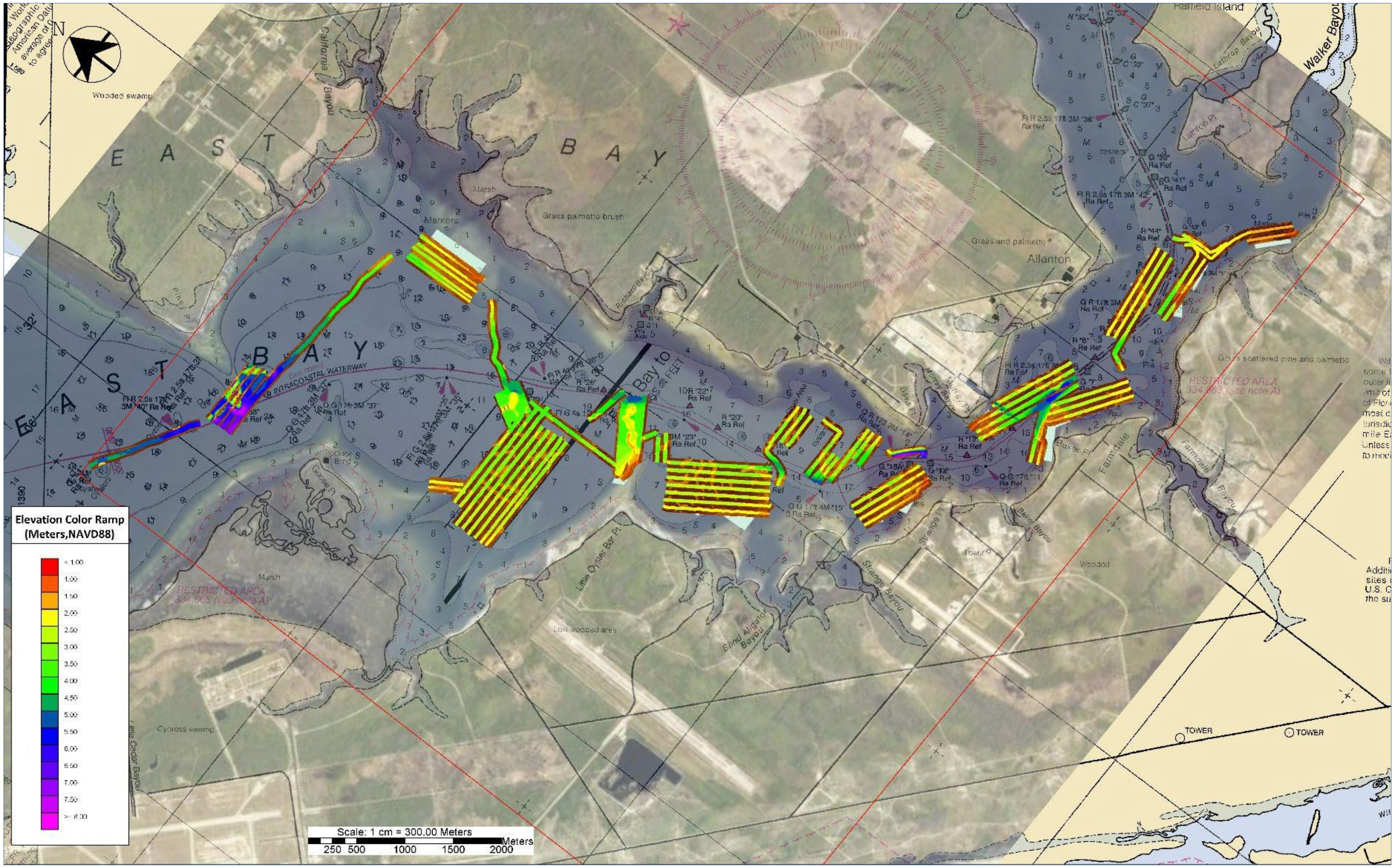


Figure 5. Depiction of the overall acoustic survey coverage in East Bay through the multibeam bathymetry matrix data and the multibeam imagery mosaics. At this display scale, the multibeam imagery mosaics are mostly covered by the gridded bathymetry data, even though the bathymetry data provides only partial coverage.

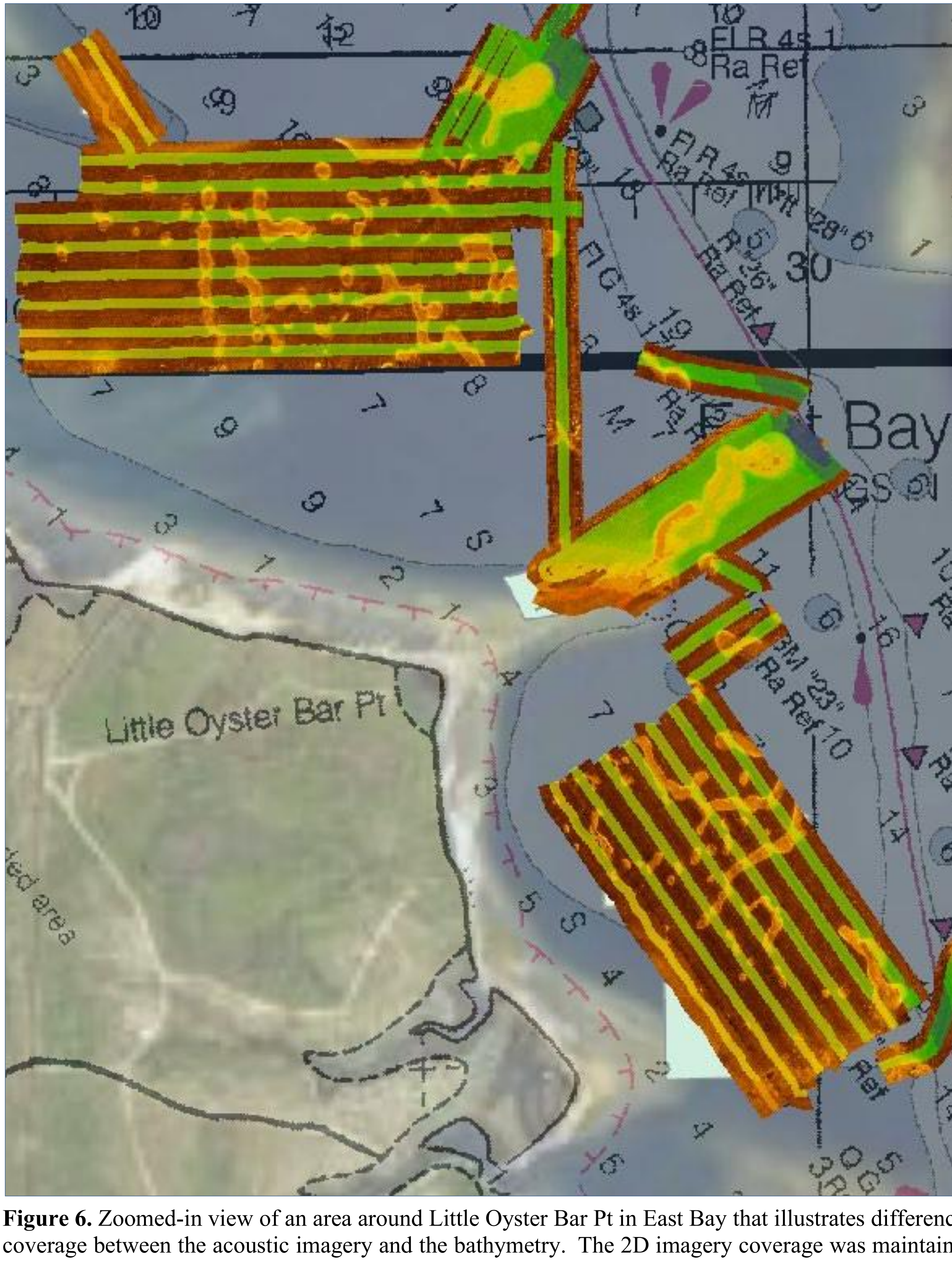


Figure 6. Zoomed-in view of an area around Little Oyster Bar Pt in East Bay that illustrates differences in coverage between the acoustic imagery and the bathymetry. The 2D imagery coverage was maintained at 100-m (with some occasional reduction due to refraction), while the bathymetric coverage was generally limited to eight times the water depth. This figure also shows the two sample areas where full-bottom bathymetry was obtained, requiring a much greater density of survey line coverage. In the shallowest areas, survey lines had to be spaced at less than 10m.

Multibeam Imagery Processing

After application of the SBET file if necessary, initial processing of the multibeam imagery 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 preliminary imagery mosaic data products to assess data coverage. All of the acoustic imagery data processing was conducted in Chesapeake Technology SonarWiz. For these operations, the 50-m imagery range setting was used during all data acquisition, primarily because there were definitive survey goals that enabled the application of a systematic survey plan designed to provide at least 100% imagery coverage over all of the identified "oyster" polygons (**Figure 7**). Preliminary imagery mosaics for the different survey areas were initially exported as geoTIFs and KMZs at a 1-meter resolution. The geoTIFs were then used within Hypack during the physical sampling operations to help plan and select specific target locations. The acoustic imagery KMZs were viewed in GoogleEarth to help assess the overall coverage and also to compare the acoustic imagery results against the aerial imagery, particularly in the nearshore areas (**Figure 8**).

Figure 7. A view of the western parts of West Bay provides a representative example of how the initial acoustic imagery coverage was focused on obtaining at least 100% imagery coverage over all of the defined "oyster" polygons. In this figure, the imagery mosaics are partially transparent so the underlying polygons are visible. Additional acoustic data were also acquired during transits between the primary areas.

Figure 8. Examples of exported 1-m resolution 2D (side-scan) imagery mosaics from several of the target polygons in East Bay as viewed in GoogleEarth. The hard bottom (light brown) areas showing high-reflectance of the sonar signal clearly constrast in most areas with the darker brown muddy sediments. The GoogleEarth interface was helpful to step through images from different time periods to best characterize the shallow nearshore areas. This aerial image from 2019 provided the best view of the immediate nearshore areas showing extensive sand bar features that sometimes extended into the survey areas.

Ground-Truthing of Sonar Data

Ground-truthing involved sampling the bottom using three methods: probes, handheld oyster tongs, and underwater video. At most sites, an extensible fiberglass or aluminum pole with threaded aluminum tip (a "roller brush extension pole" for painters) was used as a probe (**Figure 9C**). Probing or "poling" the bottom was the major method used by Swift in the 1890s to determine the bottom type at ~80,000 sites resulting in the first (and still the most geographically extensive) map of oysters in Apalachicola Bay. Swift used a wooden pole with a brass plate attached to the bottom. A recent survey by Legare and Mace (*Journal of Coastal Research*, 33:286-294, 2017) in Texas used probe sampling and bottom grabs for ground-truthing sonar data. Probe sampling can accurately differentiate between muddy sediments and more firm sand and shell. Live oysters, however, could be confused with shell and required additional sampling with tongs or video. Probes could be used effectively in water up to ~5 m deep.

In most cases, ground-truthing was conducted concurrently with the acoustic surveys but post-survey ground-truthing using probes, tongs, and video were also used. Concurrent ground-truthing and sonar surveying mainly involved quickly probing the bottom and recording data so a reasonably consistent acoustic survey speed of several knots could be maintained. The probe data was initially used to refine interpretation of the acoustic survey data and to help characterize the sediments and the potential presence of oysters. The probing provided both an initial indication of surface sediment type and also a periodic quality check on the real-time multibeam acoustic data.

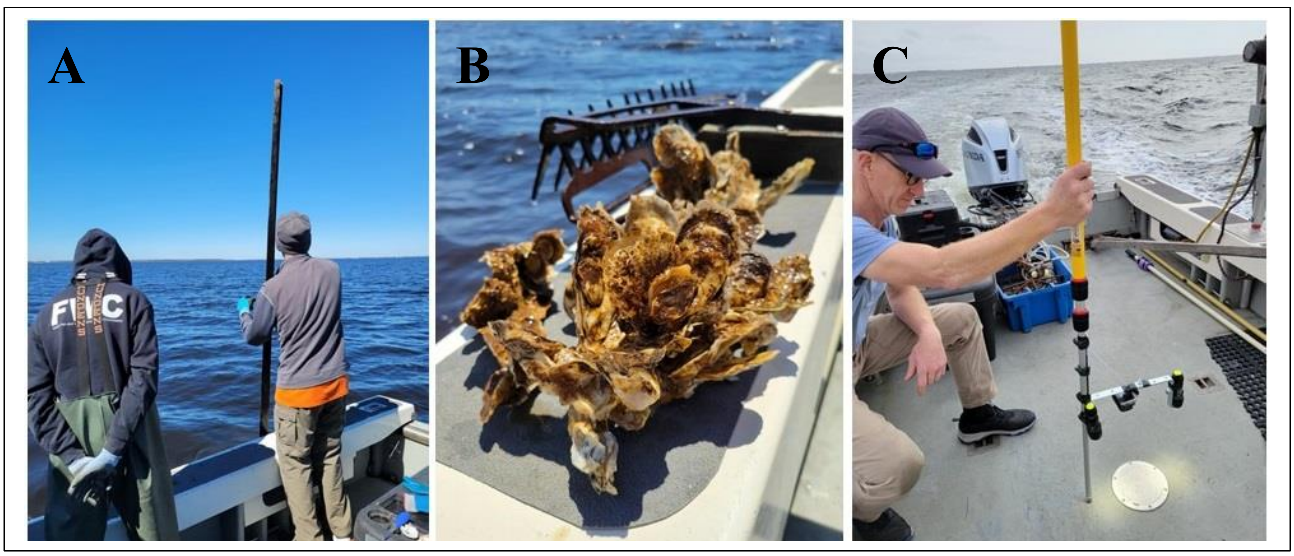


Figure 9. Methods used in ground-truthing. **A**) Handheld tongs; **B**) Live oysters collected with tongs; **C**) Extensible pole used to probe the bottom, with GoPro and lights attached for video.

For areas where live oysters were indicated by the probe, additional ground-truthing was typically conducted post-survey, using handheld tongs and/or underwater video (**Figures 9** and **10**). The underwater imagery data were collected with a downward-looking GoPro camera mounted on a telescoping pole that also included supplemental lighting. Water visibility was generally good throughout the sampling period, so the GoPro images provided a useful qualitative view of the seafloor conditions. In areas where oysters were suspected (usually through a combination of the acoustic data, probing, and images), 12-foot hand tongs were used to sample the bottom. All oyster samples that were collected were removed from the tongs, photographed, characterized on deck, and returned overboard. **Figure 10** illustrates the typical finding of multiple "hard bottom" classes (sand, shell, live oysters) in many areas.

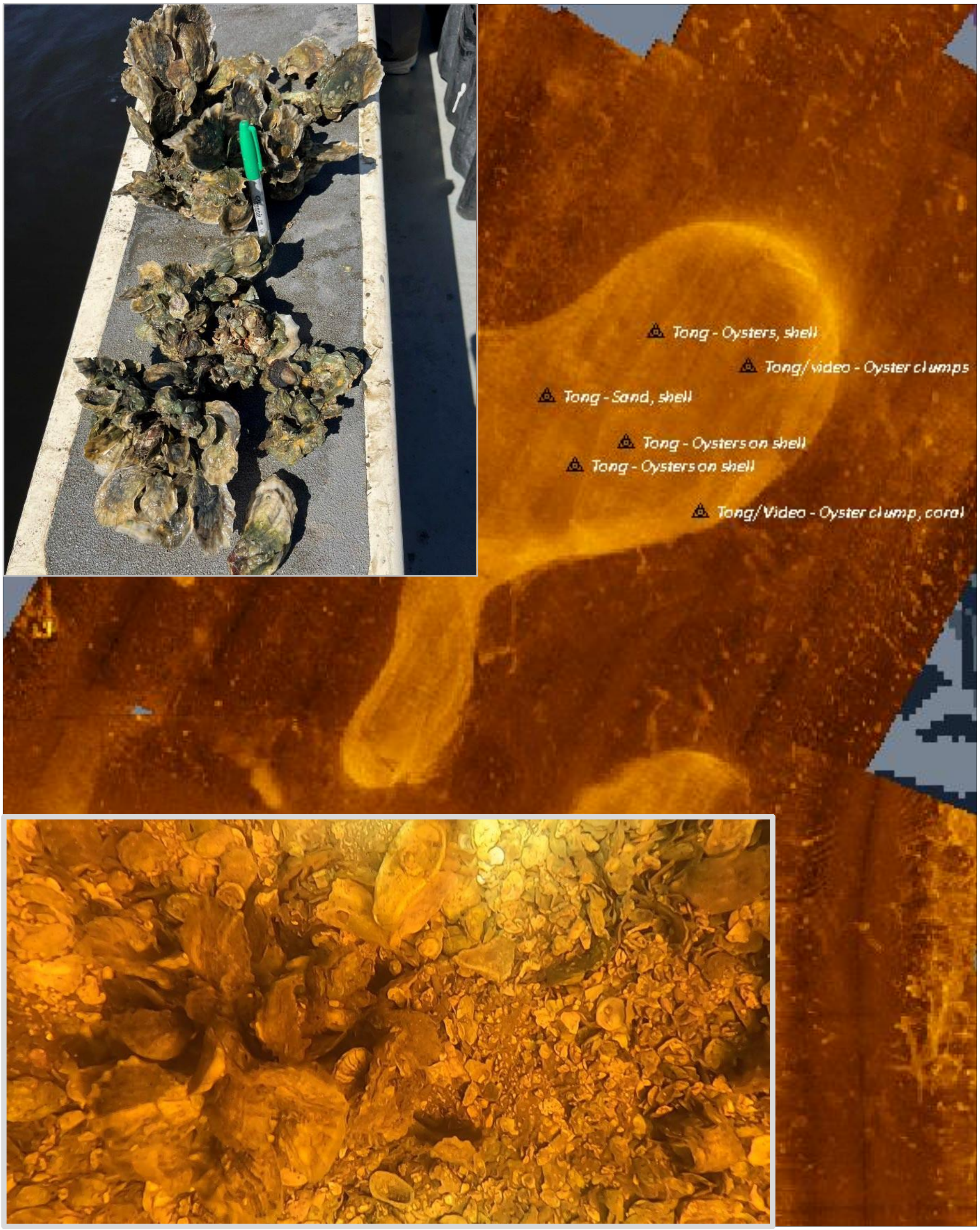


Figure 10. An area in East Bay between Goose Point and Richard Bayou where multiple tong and video samples (labelled triangles) were taken. The upper left inset shows the contents from one of the tong samples and the lower left is a video still of an oyster clump on shell bottom. Note the high-reflectance (light colored) hard bottom in the side-scan imagery compared to surrounding muddy sediment (darker brown).

APPENDIX B - Previous Oyster Mapping in St. Andrew Bay

<u>RPI (1995), from the 1995 Environmental Sensitivity Index</u>

Erma.noaa.gov—Gulf of Mexico—Restoration—DWH Gulf Spill Restoration—NRDA Workgroup Data—Oysters—

> Subtidal Oyster Recruitment Sampling Results

> Nearshore & Subtidal Oyster Quadrat Abundance Sampling Results

> Abundance Sampling Results—2010-2024 Quadrat Abundance: Market Size Live Oysters, Seed Size, Spat Size, Market Size Dead Oysters, Seed Size Dead Oysters, Spat Size Dead Oysters

> ADCIRC

> 2013 Oyster Resource Mapping Plan Seafloor Substrate Mapping/Classification

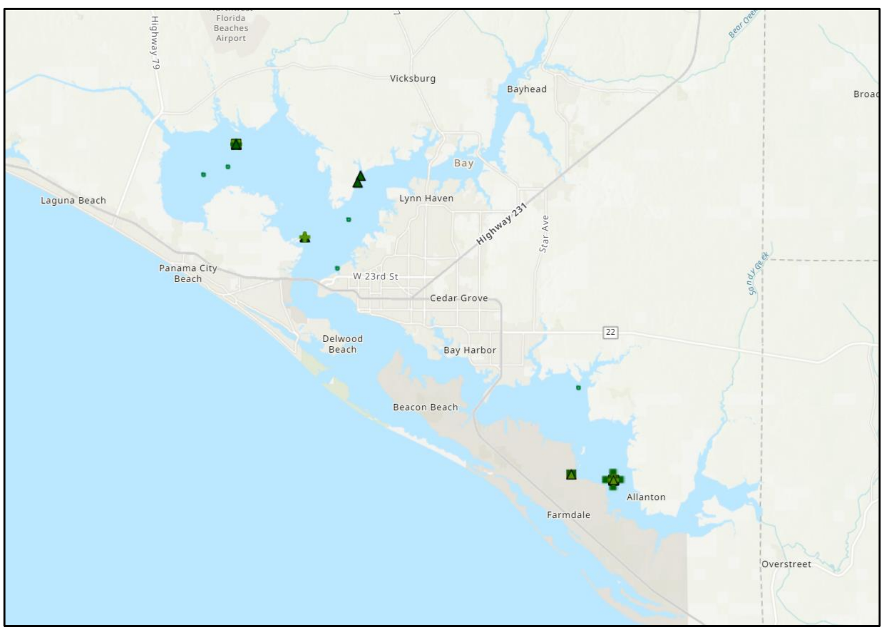
> Oyster Sampling Transition Plan Seafloor Substrate Mapping/Classification

> Estimation of Subtidal Oyster Habitat in the Northern Gulf of Mexico

> Percent Cover--Site Boundaries for Oyster Sampling Transition Plan and 2013 Oyster Resource Mapping Plan Sites (NOAA)(PDARP)

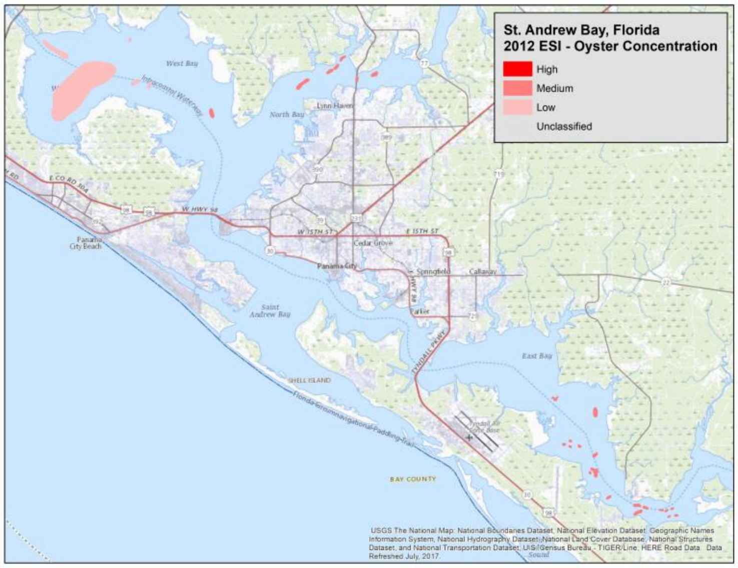
> Oyster Percent Cover Strata for Recruitment Technical Memorandum

*ALL ESI MAPS AVAILABLE FOR THIS AREA SHOWED SUBSTRATE POLYGONS ALONG SHORE BUT NO OYSTER DATA. ABOVE FLES (RED) COULDN'T BE DOWNLOADED AS A SHAPEFILE.

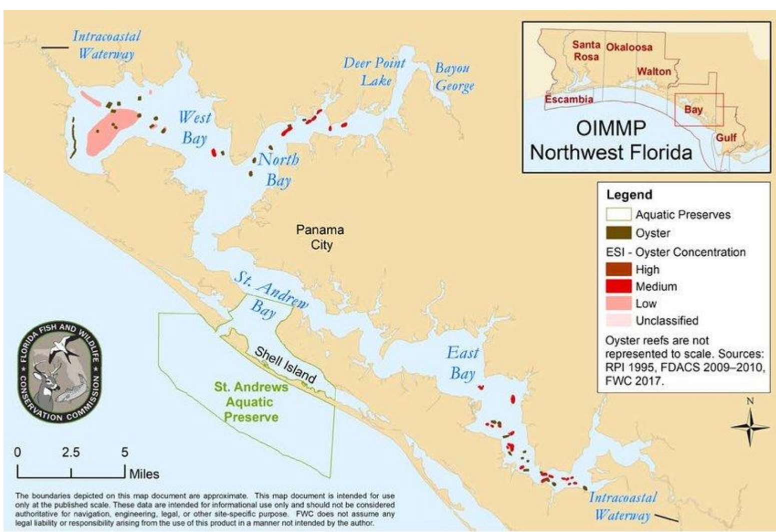


*The following maps were produced from shapefiles from the FWC "Index of Oyster Maps in Florida".

Compiled by the Oyster Integrated Mapping and Monitoring Program. These files are not included in the "Oyster Beds in Florida" shapefile. https://geodata.myfwc.com/datasets/oyster-beds-in-florida
SHAPEFILES:
https://www.arcgis.com/home/item.html?id=74a183566bd1430bbe5a55c47e6e191d
2012 ESI_RPI_2012_Oyster Concentration

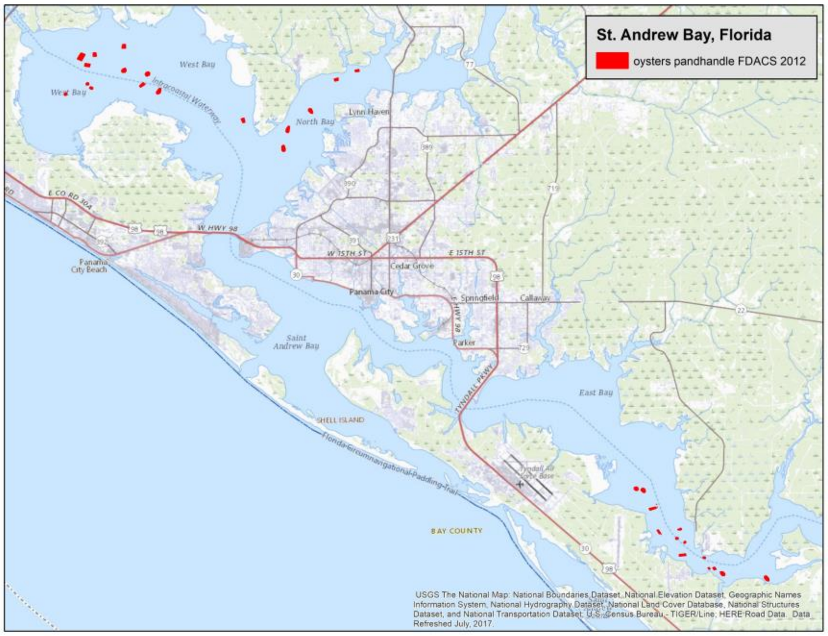


FDACS (2009-2010), from navigational charts and local knowledge
https://www.researchgate.net/figure/Mapped-oyster-extent-in-St-Andrew-Bay-Oyster-mapping-sources-RPI-1995-from-1995_fig20_336197190

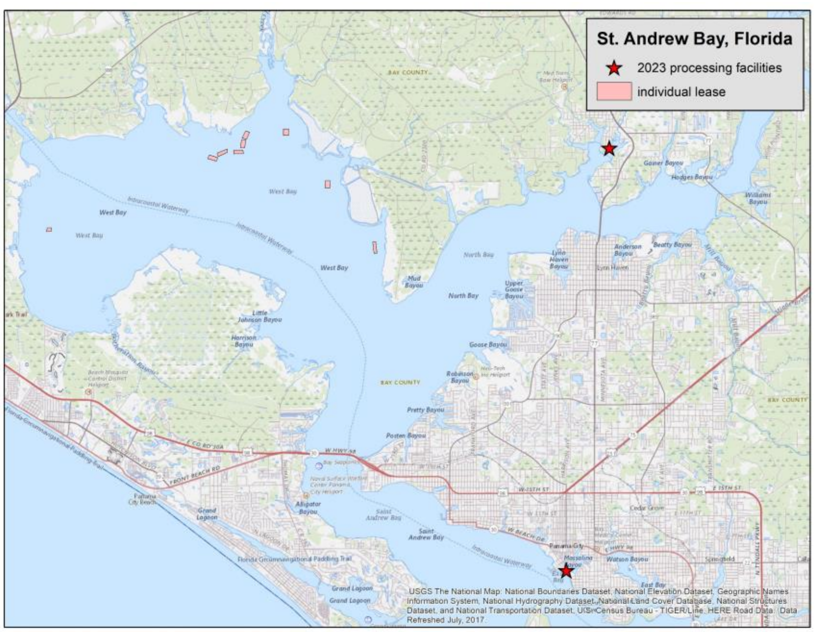


7. Mapped oyster extent in St. Andrew Bay. Oyster mapping sources: RPI 1995 (from 1995 Environmental Sensitivity Index), FDACS 2009-2010 (from navigation charts and local knowledge), and FWC 2017 (from 2017 side-scan sonar).

SHAPEFILES
https://www.arcgis.com/home/item.html?id=403ca311ee0f4d2b98fc45a1f0ce9f17
oysters_panhandle_FDACS_GSMFC_2012



Emailed from Harrell, Jackie Jacquelin.Harrell@fdacs.gov
Individual_lease_2023
2023_processing_facilities



FWC (2017), from 2017 side-scan-sonar

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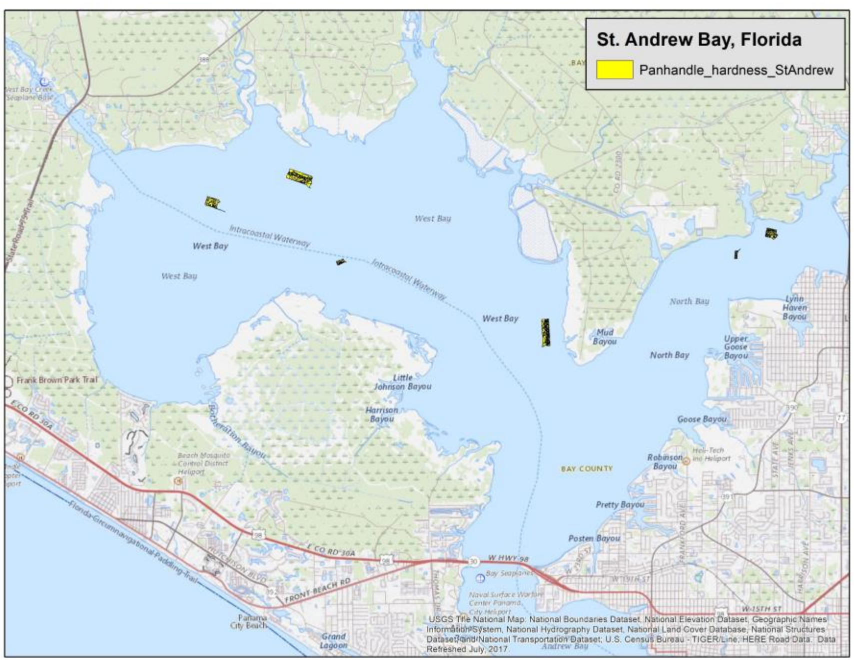
FWC (Florida Fish and Wildlife Conservation Commission). 2017. Side scan sonar of oyster reef habitat restoration in St. Andrew Bay, FL

https://services2.arcgis.com/z6TmTIyYXEYhuNM0/arcgis/rest/services/hardness_StAndrew_FDEP_2021/FeatureServer

Panhandle_hardness_StAndrew



Description

Hardness maps of cultched areas in St. Andrew Bay from side scan sonar. Not included in FWC's Oyster Beds in Florida layer. For layer file, contact GISLibrarian@MyFWC.com