Final Report

Marine Archaeological Investigation and Habitat Mapping of the Paleo-Suwannee River, Eastern Gulf of Mexico

NOAA Grant Number NA21OAR0110200

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1. Grant Number

   NA21OAR0110200

2. Principal Investigator

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3. Total Award from NOAA Ocean Exploration

   $460,455

4. Project Title

   Marine Archaeological Investigation and Habitat Mapping of the Paleo-Suwannee River, Eastern Gulf of Mexico

5. Area of Operation

   The study area is the hypothesized Paleo-Suwannee River Channel in the Eastern Gulf of Mexico, off the modern-day Suwannee River. A red dot indicates the study area's location on the map below (Figure 1), which shows the State of Florida, and the general bounding polygon for the study area is shown in yellow on the other map. The spatial relationship with Cedar Key, which was our "home port" and the location of some of our outreach and education activities, is shown on the map. The table below establishes the bounding polygon of our activities.

Table 1: Coordinates of the bounding rectangle of the area of operation.

	WGS 1984 UTM Zone 17N	WGS 1984
Top:	3,246,703.72 m	29.32787694°
Bottom:	3,189,443.92 m	28.81534222°
Left:	266,966.70 m	-83.39978667˚
Right:	289,165.76 m	-83.16051889°

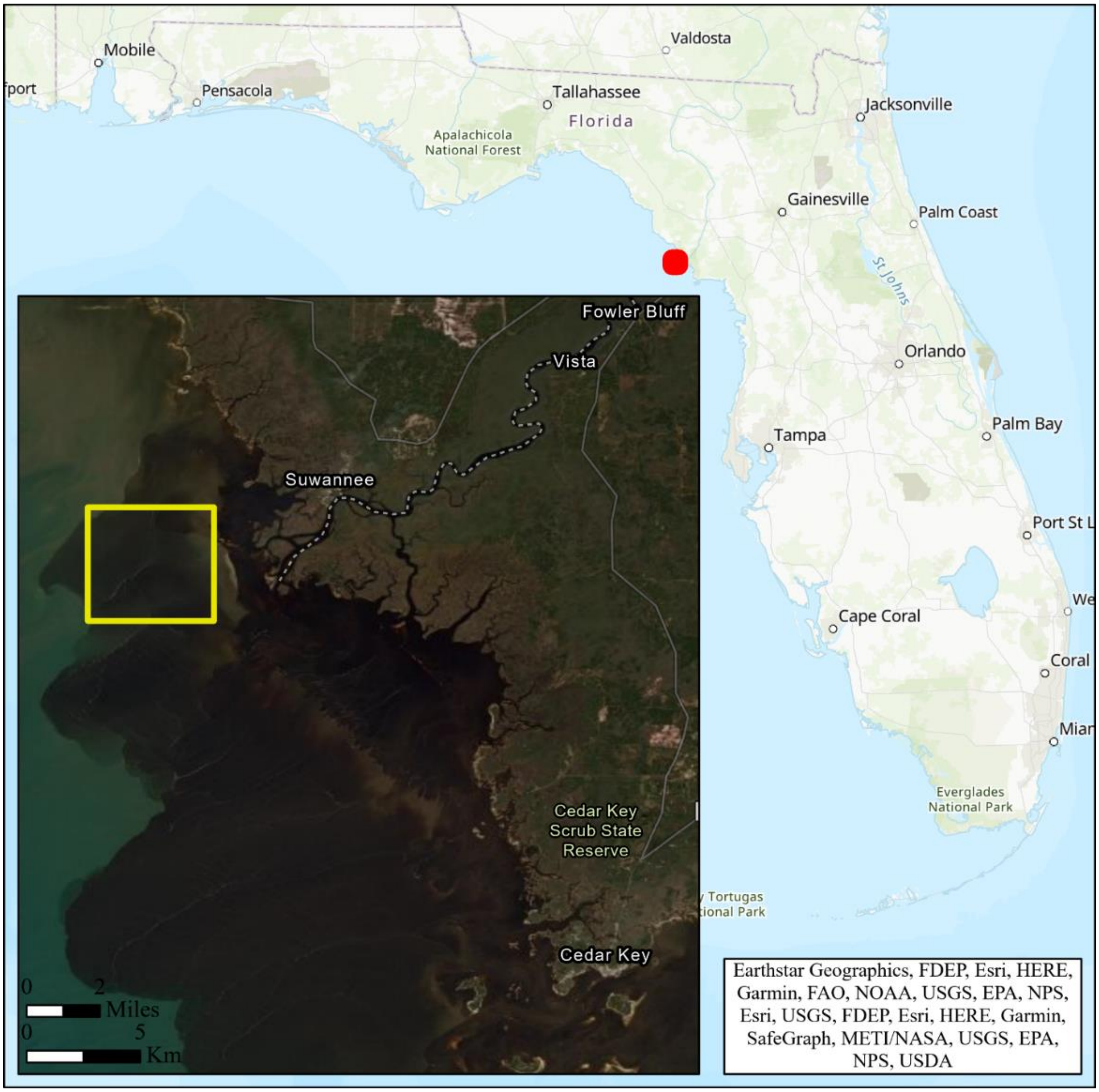

Figure 1: Area of operation

The relationship between the modern-day Suwannee River and the hypothesized Paleo-Suwannee River Channel is shown in the Sentinel-2 multi-temporal false-color composite satellite image below (Figure 2). The imagery dates from 2018 and was accessed through Google Earth Engine.

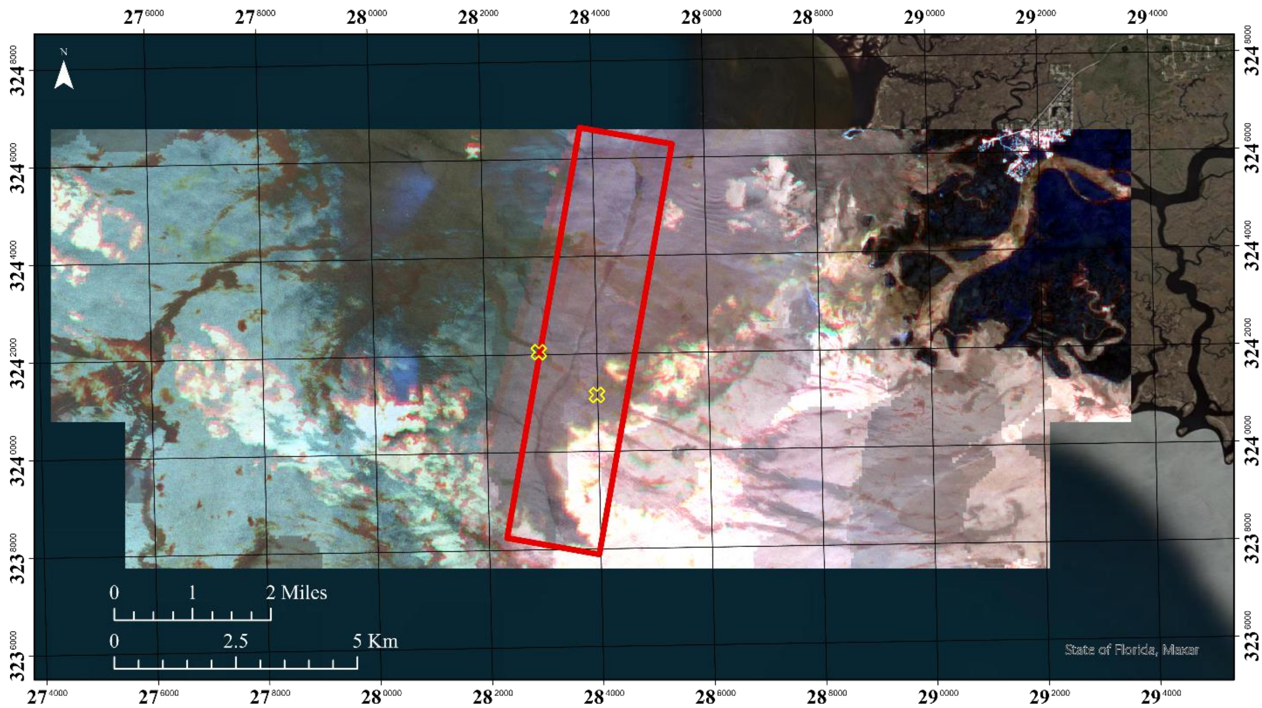

Figure 2: Location of the primary feature of interest for this project.

6. <u>Co-PIs, Participating Institutions, and Personnel</u>

-Benjamin Wilkinson, Associate Professor of Geomatics, University of Florida, Co-PI
-Kenneth Sassaman, Professor of Anthropology, University of Florida, Co-PI
-Matthew Newton, Ph.D. Student, Anthropology Department, University of Florida (Personnel)
-Arturo Chequer, M.S. Student, School of Natural Resources and the Environment, University of Florida (Personnel)
-Michael Faught, Archaeological Research Cooperative, Co-PI
-Anand Hiroji, Assistant Professor of Hydrography, The University of Southern Mississippi (Personnel)
-Brittany Adams, Graduate Student, University of Miami (Personnel)
-Eden Brazill, M.S. Student, University of Miami (Personnel)
-Davis Brown, Graduate Student, University of Florida (Personnel)
-Kevin Burnette, Student, Santa Fe College (Personnel)
-Julia Danielson, Graduate Student, University of Miami (Personnel)
-Devon Fogarty, Graduate Student, University of Miami (Personnel)
-Keianna Ford, Graduate Student, University of West Florida (Personnel)
-Casey Heffron, M.S. Student, University of West Florida (Personnel)
-Baker Herrin, Undergraduate Student, University of Florida (Personnel)
-Shea Husband, M.S. Student, University of Florida (Personnel)
-Jordan Jaundoo, Undergraduate Student, University of Florida (Personnel)
-Trevor Johnston, B.A. Student, Florida State University (Personnel)
-Hunter Kent, Student, University of Florida (Personnel)
-Evan Kornacki (Personnel)
-Emilee McGann, Ph.D. Student, University of Florida (Personnel)

-Tiffani Mendez, Graduated M.S. Student, Florida State University (Personnel)
-Kerri Mannino-Cuva, University of South Florida (Personnel)
-Connor O'Halloran, St. Johns River Management District (Personnel)
-Lily Orton, B.A. Student, University of South Florida (Personnel)
-John Sabin, Graduate Student, East Carolina University (Personnel)
-Matthew Taylor, Graduate Student, University of Miami (Personnel)
-Matthew Cole Tillman, Graduate Student, Florida Gulf Coast University (Personnel)
-Hunter Whitehead, Coastal Environments Inc. (Personnel)
-Sienna Williams, Graduate Student, University of West Florida (Personnel)

7. Award Period

From July 1st, 2021, to June 30th, 2024

II. Summary

1. Abstract

This project used acoustic and optical remote sensing to map the seafloor in a portion of the Gulf of Mexico along Florida's coastline, which was suspected to be the Paleo-Suwannee River Channel, to investigate potential cultural heritage sites. Geomorphological maps were produced at multiple spatial scales useful for stakeholders such as archaeologists, fisheries managers, and decision-makers in contexts like management and conservation. Archaeological scientific dives were performed throughout and around the study area to document seafloor characteristics, and sediment cores were extracted from the seabed. The produced geomorphological maps show a relatively flat seafloor with very little complexity. However, relict sand dunes were revealed, and regional bathymetry identified known oyster reef complexes. The sediment composition from the hypothesized Paleo-Suwannee channel was characteristically different from the cores extracted outside the channel zone. A total of 15 sediment cores contained a dense, humic deposition characteristic of marsh environments, located on top of bedrock and overlain with medium to coarse-grained sediments. These form dateable soil horizons that can be used to determine the relict course of the Paleo-Suwannee River. In many locations, an extensive oyster bioherm was covered with approximately 1 to 1.5 meters of marine sediment, which is significant because oyster bioherms would have supported human occupation in the area. Chert fragments were present in two sediment cores containing limestone bedrock. A moderately thick sediment sheet covers the foreshore zone out to approximately 10 miles seaward of the modern Suwannee Delta. Grouper Grounds yielded carbonate sediments of a very different composition than the Paleo-Suwannee River channel zone; this location is likely near an infilled spring. The karst dissolution in the area suggests that the location was likely a water body prior to its inundation during the last two stages of postglacial meltwater input. The sediments at the Port Paradise Spring appear to be consistent with the flow direction of the spring discharge. The cloudy discharge flowing out of the blue hole is suspected to be hydrogen sulfate. Sea life encountered during investigations includes sponges, clusters of living reefs, various reef fish, goliath groupers, snappers, snook, nurse sharks, arrow crabs, green sea turtles, and numerous invertebrates. No cultural materials nor human burials were located.

2. Purpose of Project

a. Topic Addressed

In the last 40 years, numerous sites dating as early as the Paleoindian and Early Archaic periods have been recorded off the Gulf Coast of Florida, where shallow-buried middens, exposed chert, and lithic tools were identified. Radiocarbon dating confirmed that some sites were occupied as early as 5.4 thousand years ago, and others are likely earlier. The modeled probability of finding offshore cultural heritage sites is thought to be driven by access to water, food, and lithics. Based on current archaeological and anthropological knowledge, it is highly likely that prehistoric people once inhabited the Paleo-Suwannee River's shores; the Suwannee River is one of four rivers that hold the most potential for Paleoindian site occurrences. Therefore, the topic that was addressed by this project was an underwater archaeological investigation of the Paleo-Suwannee River channel and its surroundings, which was deemed likely to yield critical new information about potential sites of cultural heritage. New information could contribute to the area being considered as a Florida Underwater Archaeological Preserve.

b. Project Objectives

This project aimed to map portions of the nearshore hypothesized Paleo-Suwannee River Channel, off Florida's Gulf of Mexico coast. Our first specific objective was to identify and characterize archaeological sites in the study area. In line with the "collect once and use many times" spirit that should guide most seafloor mapping efforts, our second objective was to produce geomorphological and habitat maps of the area at multiple spatial scales to evaluate their potential to act as proxies for sites of cultural heritage. Through these, we aimed to characterize the geomorphology and biota of the study area to inform management, sustainable use, and conservation of marine resources and to test different remote sensing approaches to characterize the seafloor.

3. Approach

a. Work Performed

Acoustic surveys were performed using an interferometric sidescan sonar mounted on an autonomous surface vehicle in September and October 2021 to map and image the seafloor in the study area. About 187 km of survey lines were followed (not including patch tests and repeated lines), and about 3 km^2 were mapped. More than thirty videos were collected from a small remotely-operated vehicle. The bathymetric data were processed and used as input for satellite-derived bathymetry derivation, testing three imagery sources (e.g., Planet, Sentinel-2, Landsat) at three different spatial resolutions. The bathymetric data were also used to conduct geomorphometric analyses and produce geomorphological maps. The sidescan sonar imagery was processed, and mosaics were produced at 10, 25, and 50 centimeters resolution. The data were visually analyzed to extract a total of 52 diving initial targets (Figure 11).

A total of 81 days of diving and snorkeling were held to conduct investigations in the study area (63 targets) and its surroundings (*e.g.*, Betty Castor Reef, Port Paradise Spring, Suwannee Reef). Our scientific diving protocol followed the American Academy of Underwater Sciences and the University of Florida guidelines. Activities were coordinated with Cheryl Thacker, the Dive Safety Officer at the University of Florida, including submissions of float plans for daily operations, all dive logs, and CPR, O_2, and dive certification records for all divers. Dive targets were investigated by alternating dive teams consisting of two divers per team. The topside team provided safety support while out of the water between dives. One diver remained fully equipped aboard the vessel, *i.e.*, with tank, fins, and the buoyancy compensator donned. The other topside personnel provided topside support to the divers. Dive teams performed circle searches and installed stationary buoys at each target investigation. Local bathymetry and geomorphology were observed, photographed, and recorded during each dive. Dive teams mapped features using the standard protocol outlined in the National Academy of Sciences Guide to Principles and Practice. Extensive diver-based video data were taken in these locations, looking for archaeological materials and seafloor features favorable for locating archaeological sites. Limestone, dolomite, oyster shells, and sediments were sampled depending on location.

A total of 33 sediment cores ranging from 0.6 to 2.41 meters in length were extracted in a cruciform pattern from our study area and its surroundings (*e.g.*, Port Paradise Spring). The sediment cores have been split and sampled by sedimentary strata. Ten samples were submitted for radiocarbon analysis of soil organics. Twenty of the sediment cores were taken from a segment of the Paleo-Suwannee Channel, which is evident in both the sidescan and satellite imagery and inspected by our dive teams. Sediment particle size analysis was conducted by nested mechanical sieving to determine the composition of the infilled channel zone, the surrounding marsh zones, and the transitional zones present along the margins between the river channel and the surrounding marsh. The Port Paradise Spring opening was measured from north to south and east to west, and sediments were hand-fanned around the spring up to 45 m from the lip of the opening. A total of ten sediment grab samples were collected along the eastern transect. Video data combined with underwater GPS data were collected in other locations (*e.g.*, Ten-Three Hole). A 3D photogrammetric model of the Port Paradise Spring was built from videos and photos collected during fieldwork.

Table 2: Summary table of the work performed.

Number of dives with imagery	Photos: 59 (31 with ROV, 5 with dropped camera, 23 with divers) Videos: 97 (44 with ROV, 6 with dropped camera, 47 with divers)
Number of UxS deployments	23 ASV deployments, 10 ROV deployments
Number of days of UxS deployments	23 days of ASV, 10 days of ROV
Area mapped in the EEZ	0 km^2
Area mapped in Florida's territorial waters	3 km^2
Maximum depth of operations	15.25 m
Inventory of samples collected	399 lines surveyed with acoustics, 63 sites investigated by divers, 97 videos recorded, 59 photos captured, 255 sediment samples collected, 33 core samples extracted
Types of data collected	Bathymetric data, dual-frequency sidescan sonar data, seafloor video and photographic data, sediment samples, sediment cores.

b. Project Organization and Management, and Participants' Role and Responsibilities

The project was organized into two complementary components: mapping and archaeological investigation.

For the mapping, acoustic surveys were performed in September and October 2021. PI Vincent Lecours planned the logistical aspects of fieldwork (*e.g.*, designing the survey plan, reserving the platforms, dealing with the finances). Three project leaders shared the overall supervision and completion of fieldwork: Lecours, co-PI Matthew Newton, and Kevin Burnette. At least two project leaders were participating in the operations on most days. Their roles included field day planning, vessel piloting, ensuring the safety of all on board, collecting data, engaging with volunteers, data management, and vessel and platform maintenance. Finally, 45 volunteers participated in data collection. Volunteers were taught concepts of acoustic remote sensing, survey design, and data collection, helped with the deployment of instruments, and collected underwater video data.

Lecours, M.S. student Arturo Chequer, and personnel Anand Hiroji managed and performed the navigation and acoustic data processing. Chequer conducted satellite-derived bathymetry analyses, performed the geomorphometric analyses, and produced the geomorphological maps under the supervision of Lecours. Newton analyzed the sidescan sonar data to select dive targets.

The archaeological dives started in March 2022 and lasted until August 2024. Newton oversaw everything related to this fieldwork, including but not limited to planning dives and schedule management for divers (see list of personnel), monitoring weather forecasts and conditions, vessel and equipment maintenance, coordinating all activities through the University of Florida Dive Safety Office, submitting float plans for daily operations, filling dive logs and financial reports, digitizing field notes, and managing all divers and their CPR, O_2, and dive certification records.

Newton also led the analyses of cores and sediment samples and processed the video data to be georeferenced with underwater GPS data. Personnel Evan Kornacki produced the 3D photogrammetric model of the Port Paradise Spring, supported by Newton. Lecours and co-PI Kenneth Sassaman provided supervision when needed.

Lecours dealt with all project reporting and data management requirements, with support and validation from Newton. Co-PI Benjamin Wilkinson also assisted with grant management.

c. Data Organization, Processing, and Archiving

The project was organized into two complementary components: mapping and archaeological investigation.

The mapping component included raw acoustic data, raw navigation data from the autonomous surface vehicle, post-processed kinematic corrected inertial measurement unit and delayed heave data, processed bathymetry, and processed sidescan sonar data. The raw navigation data had to be post-processed in the Qinertia software to produce the post-processed kinematic inertial and delayed heave data. These data were used with raw acoustic data to produce the processed bathymetry (Figure 3) and sidescan sonar data. Overall, these data amount to more than 650 GB of data.

The analyses performed on the acoustic-based bathymetric data produced satellite-derived bathymetry (*e.g.*, Figure 4), and local (from acoustic bathymetry) and regional (from satellite-derived bathymetry; *e.g.*, Figure 4) geomorphometric analyses and geomorphological maps (*e.g.*, Figure 6).

The archaeological investigation component included sediment cores and samples, which are archived at the Laboratory of Southeastern Archaeology at the University of Florida, along with limestone, chert, dolomite, peat, and oyster samples. Other data include a point dataset with the locations and description of sediment cores and samples, photographs, video data, dive logs, and a 3D bathymetric model of the Port Paradise Spring. The video and photographic data (945 files) were assigned geographic coordinates when possible, totaling 205 GB of data.

All data and their complete metadata will be archived following NOAA data management requirements before May 2025.

4. Findings

a. *Actual Accomplishments and Findings*

Raw acoustic data were collected in the study area in September and October 2021 using an autonomous surface vehicle. Acoustic-based bathymetric data were produced at 0.25 (Figure 3) and 1.50 meters resolution, and sidescan sonar mosaics were produced at 10, 25, and 50 centimeters resolution. The targeted feature (cf. Figure 2) observed in satellite imagery did not appear in the acoustic bathymetry nor the sidescan sonar data. The bathymetry showed very little bathymetric variability, but three features of interest, likely relict sand dunes, were identified in the southernmost portion of the mapped area. However, changes in sidescan sonar intensity suggest spatial variations in sediment properties that may indicate an infilled channel. Debris on the seafloor, including crab traps, were observed in the sidescan sonar data.

The satellite-derived bathymetry produced a regional model of bathymetry (*e.g.*, Figure 4). It was clear from the quality of satellite imagery from different sensors and time that the area is highly challenging because of water turbidity. Relatively accurate bathymetric models were produced at 10 (*e.g.*, Figure 4) and 30 m resolution.

The geomorphological maps have revealed a very flat and non-complex environment in the study area, except for three large-scale ripples in the southern part of the study area that are hypothesized to be relict sand dunes. The satellite-derived bathymetry models confirmed that these features are part of a broader complex of ripples (Figure 5). The satellite-derived bathymetry also captured known features such as the Hedemon Reef and the Suwannee Reef complex (Figure 4). Ridges and channels were mapped and delineated across the modeled area from both the acoustic and satellite-derived bathymetric datasets (at different spatial scales – resolutions and extents; Figure 6).

Over a few weeks in September 2021, a massive fish mortality event spanning miles was observed near the study area. The event was reported to the Florida Fish and Wildlife Conservation Commission (FWC) Fish Kill Hotline, and we monitored the situation for their team throughout the event. On September 27th, 2021, we delayed the start of our survey to collect drone footage to document the extent of the fish mortality event, which a red tide would have caused.

In terms of archaeological investigations, a segment of the infilled Paleo-Suwannee channel of approximately 80 x 200 m has been observed in the low- and high-frequency sidescan sonar data, the satellite imagery, but not the bathymetric data. The channel feature is also visible to the scuba diver and identifiable by its sediment composition and the maximum depth of organic sediment. Margins surrounding the infilled river channel contain humic “fluff”, marls, and a dense concentration of marsh clams and other marine bivalves.

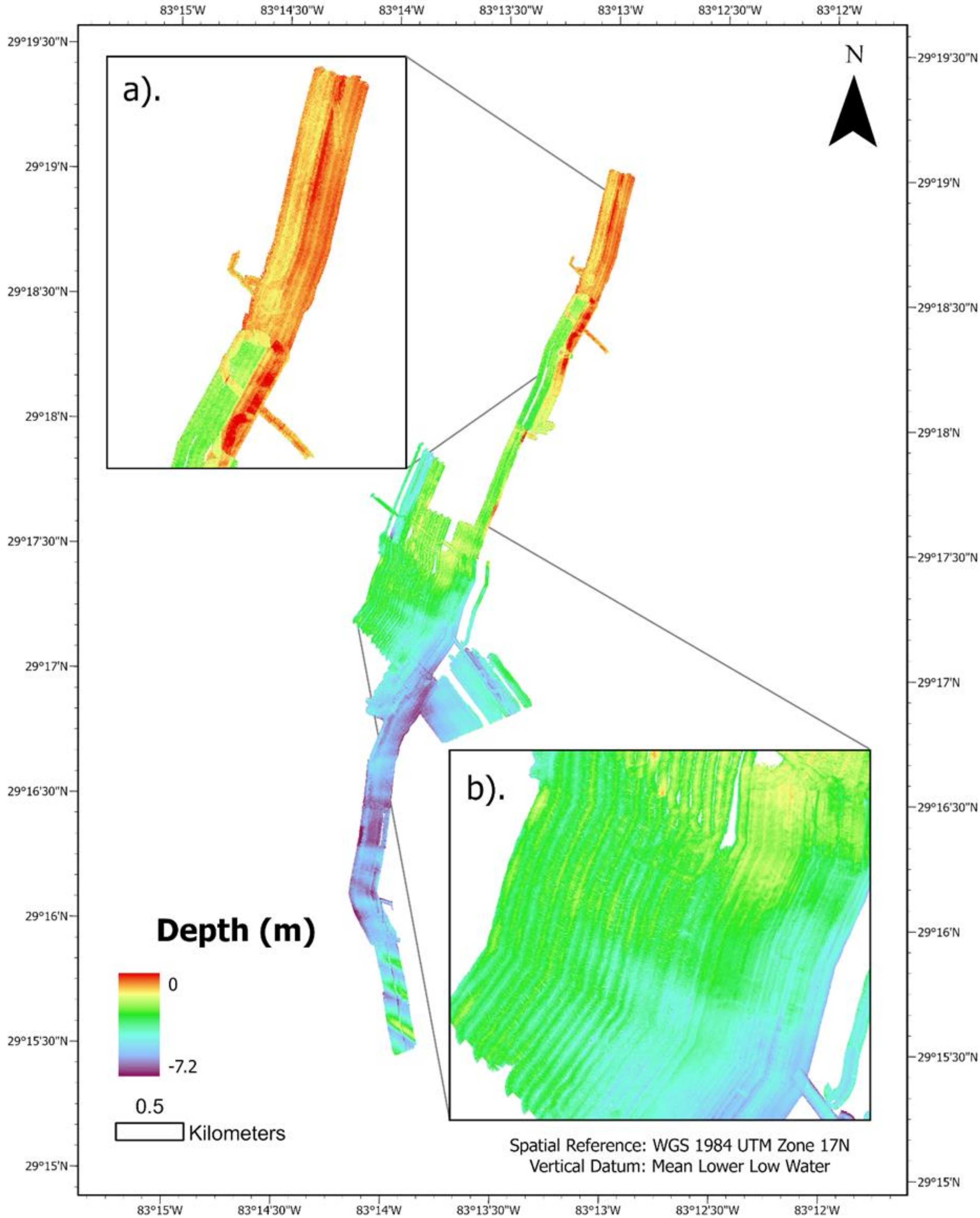

Figure 3: Processed acoustic bathymetry (25 cm resolution), with examples of errors and artifacts that could not be corrected in post-processing.

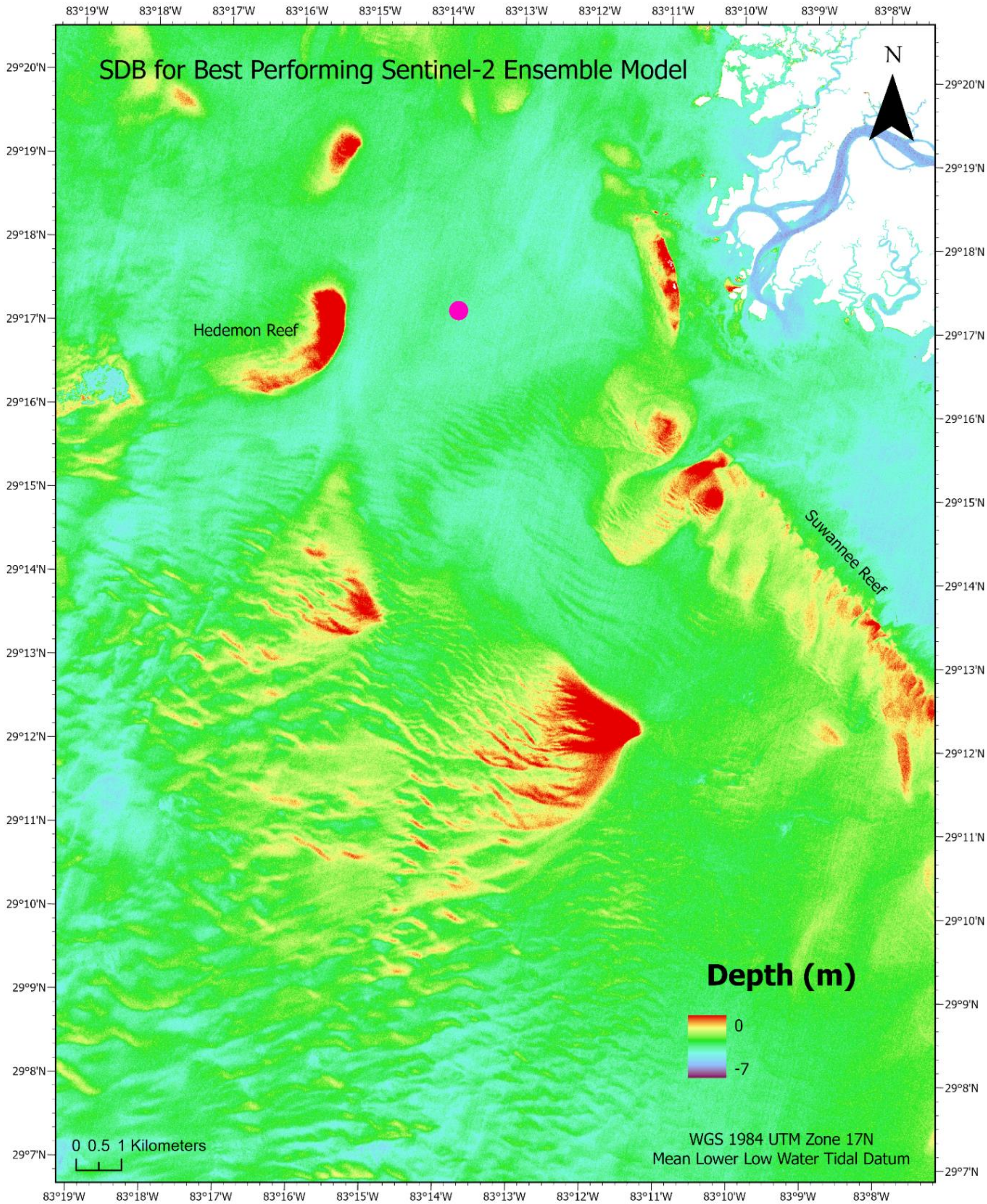

Figure 4: Example of regional bathymetry derived from satellite imagery; model trained with acoustic bathymetry.

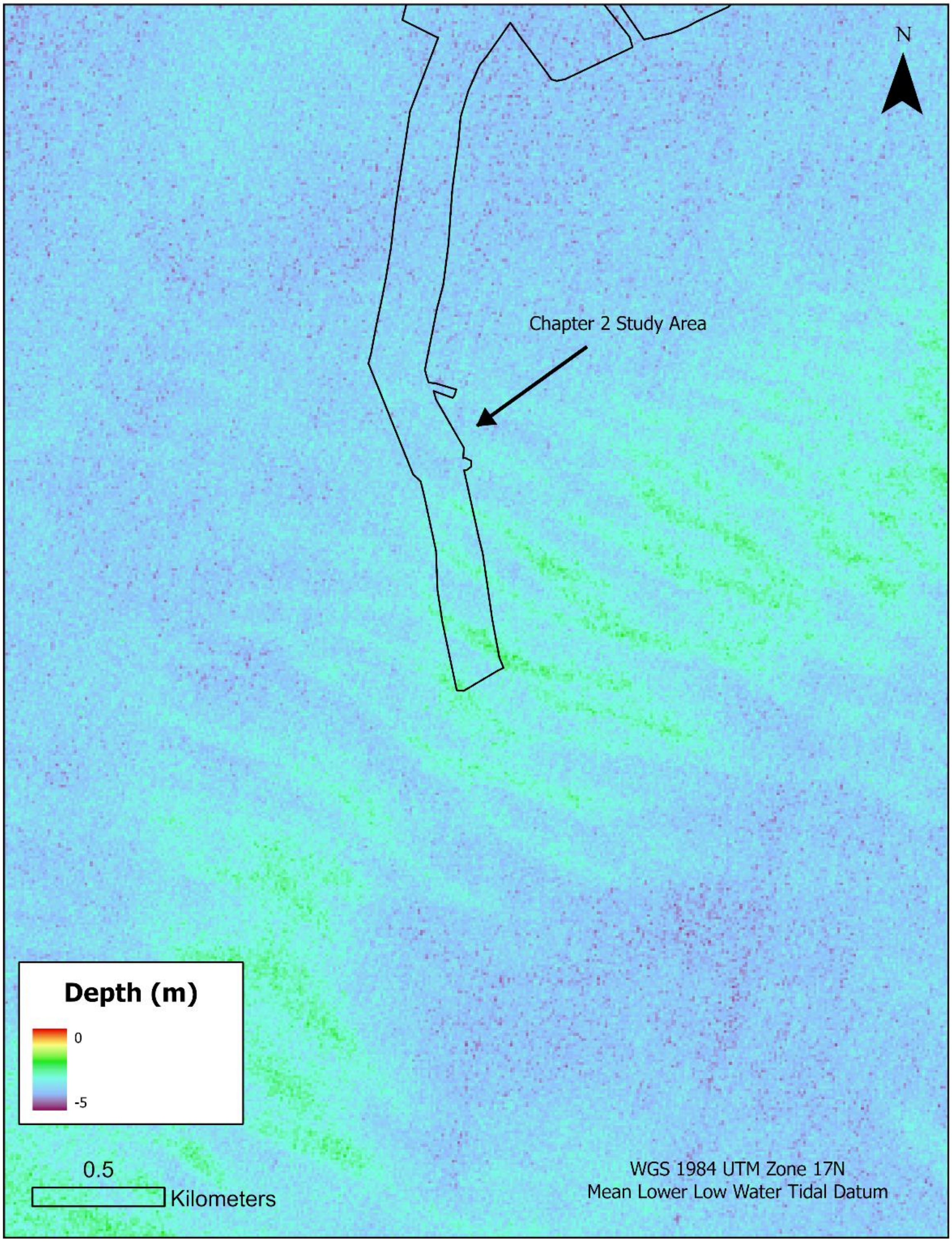

Figure 5: Hypothesized relict sand dunes found in the acoustic bathymetry and confirmed to be part of a larger complex by the satellite-derived bathymetry models..

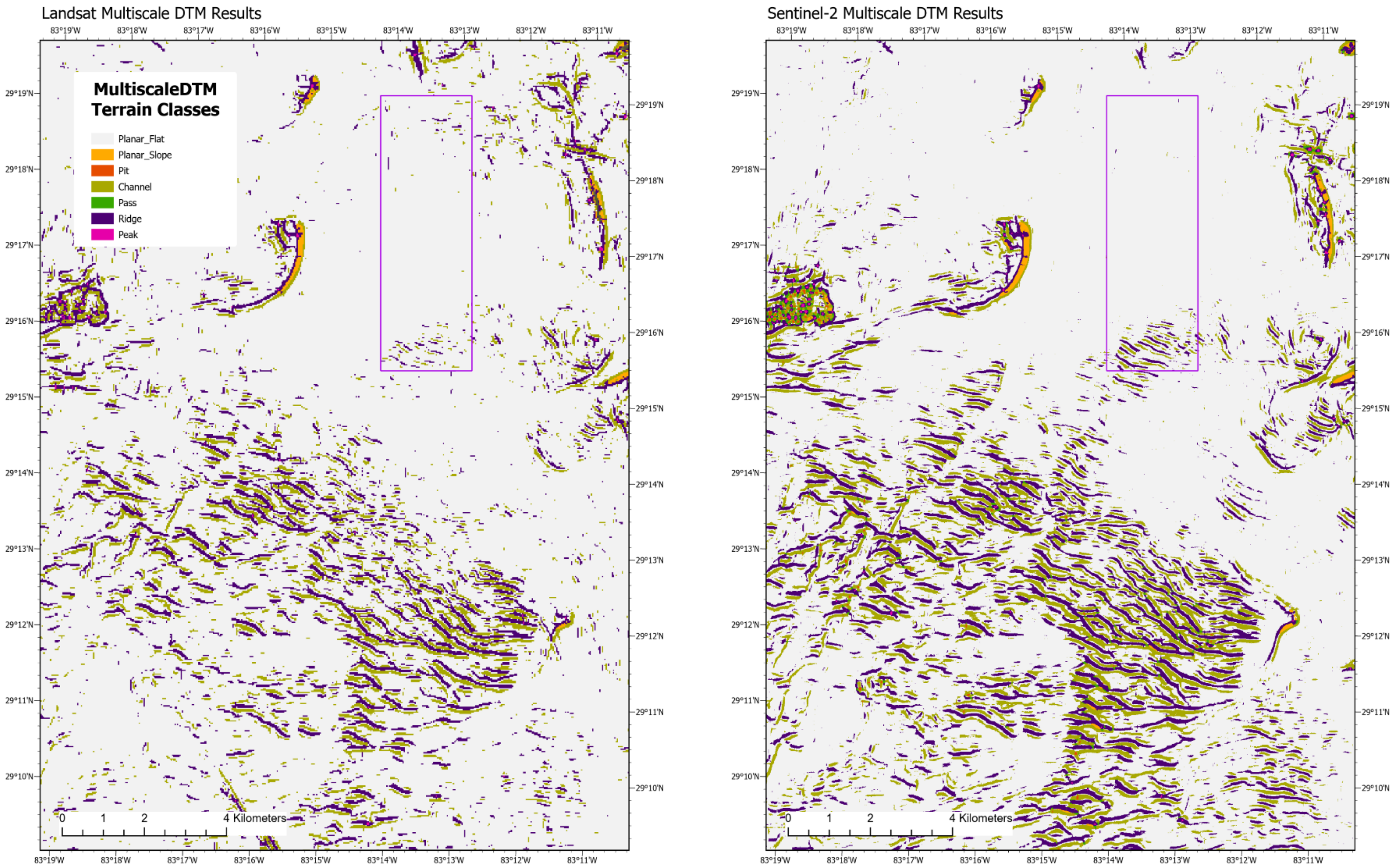

Figure 6: Classified landform features from the satellite-derived regional bathymetry for Landsat (30 m resolution) and Sentinel-2 (10 m resolution) bathymetry.

The structure documented at the "Linear Scatter" site was investigated as a potential shipwreck since the sonar image showed protruding wood and rope. A search continued in the vicinity until an identical structure was located, photographed, and mapped approximately 29 m to the east of the target. These were hand-built crab traps weighed down by concrete and crushed shells. The rope connecting the two traps together was nylon and, therefore, post-World War II. No other materials were located near Target 16 within a search area of 400 square meters.

Sediment cores were collected by dive teams, then sealed, measured, wrapped, and labelled while underwater, and finally transported in an upright position to be stored at the Laboratory of Southeastern Archaeology at the University of Florida. The first 26 of 33 have been split, with one half of each core wet screened through nested sieves ranging from 1/16'' to 1/14." The other half of the samples were separated by sediment composition, grain size, color, and oyster composition. A total of 30 sediment cores ranging from 0.6 to 2.41 m in length were extracted from our study area (

Table 8). A batch of ten radiocarbon assays was conducted from the sediment cores by the University of Georgia's Stable Isotope Laboratory (Table 3).

Analyses of sediment cores revealed that the hypothesized Paleo-Suwannee channel is infilled with open marine sediment beyond a depth of 2.5 meters. The sediment composition taken from the segment of the Paleo-Suwannee channel present in both the side-scan sonar imagery and the satellite data is different from the cores extracted outside of the channel zone. Sediment particle size analysis will determine the compositions of the infilled channel zone, the surrounding marsh zones, and the transitional zones present along the margins between the river channel. We located a marsh zone adjacent to the infilled channel, also visible in satellite imagery (Sentinel-2) and acoustic data. It also appears that seagrass shows a signature in the Sentinel-2 data. A moderately thick sediment sheet covers the foreshore zone out to approximately 10 miles seaward of the modern Suwannee Delta. This is positive in the sense that any prehistoric archaeological deposits in the area that might exist are protected by a moderately thick layer of sediment. On the other hand, these potential deposits remain elusive to the archaeologists without first conducting a sub-bottom survey and then truthing the targets by dredging. These efforts would require access to a larger, live-aboard research vessel.

Areas of diffused boundaries are present in the upper 15 centimeters of the sediment profile as dark, humic, sandy soils. Target 50, approximately 2.5 kilometers northwest of the Channel Target, also exhibits a similar sediment composition and cover pattern, so this area was targeted intensively with line searches, sediment probe surveys, and sediment coring after the features in the acoustic and satellite images were found to match on the seafloor. The data from this area will be used to increase resolution across 2.5 km of the seafloor in a southeast-to-northwest orientation. We hope to connect the two locations and add them to previous studies conducted in the region, further documenting the relict course of the now-submerged Suwannee River.

A total of 15 sediment cores contain a dense, humic deposition characteristic of marsh environments, and these are all overlain with medium to coarse-grained sediments. In many locations, an extensive relict oyster bioherm is covered with approximately 1 to 1.5 meters of marine sediment. Other locations exhibit at least two discrete layers of oyster shells. These findings are significant for three reasons: the marsh sediments are dateable soil horizons, the oyster bioherms would have supported human occupations in the area, and the marsh zones can be used to determine the relict course of the Paleo Suwannee River. The marsh layer in three sediment cores appears intact, with sharp contact boundaries between the terrestrial and marine layers. This is important because the marsh/peat layer is most conducive to the favorable preservation of archaeological materials. We found a layer of oyster material at core 15 beneath restricted marine sediments in approximately 15 feet of water. Radiocarbon analyses have dated the samples (Table 3).

Table 3: Dating of core samples from radiocarbon analyses.

Sample ID	RC Age BP	Median (Years BC)	YBP
C6 118-120	4680+/- 20	3441	5464
C6 218-220	6480 +/- 30	5422	7445
C3168-170	6100 +/- 25	5017	7040
C3 196-198	6250 +/- 25	5262	7285
C10 145-150	5030 +/- 25	3874	5897
C10 165-16	4830 +/- 25	3580	5603
C11 51-70	3540 +/- 20	1883	3906
C11 185-180	7410 +/- 25	6313	8336
C15 61-76	5980 +/- 25	4869	6892
C16 100-110	5790 +/- 25	4645	6668

Within the Paleo-Suwannee project area are bedded chert fragments in limestone bedrock. This is significant because we had not recorded any exposed bedrock at this water depth, and radiocarbon analyses have produced absolute dating of the samples immediately above the chert fragments. While we may not be able to confidently say that we collected prehistoric ground surfaces above the chert and limestone bedrock, we can say that we certainly hit bedrock. The sediments above the bedrock appear to be swamp/marsh sediments, macroscopically. Analysis of the sediment and microfaunal contents will determine the type of sediment, then we can ascertain when the terrestrial sediments were overlain with marine deposits, thus reconstructing the timing of sea level transgression in the specific area.

The two sediment cores extracted from Grouper Grounds yielded carbonate sediments of a very different composition than the Paleo-Suwannee River channel zone. This was the only location exhibiting classic karst features such as solution features, dolostone, and limestone. The Grouper Grounds location is likely an infilled spring or near one, and is a sediment-starved location that contains rocks on the surface and very small amounts of sand cover. The karst dissolution present in the area suggests that the location was likely a water body prior to its inundation during the last two stages of postglacial meltwater input.

The Port Paradise Spring was officially relocated after about 30 years, and accurate geographic coordinates were recorded. It was located in approximately 40 feet of water and was approximately 15 meters at the widest point. No cultural materials were located. Modern fishhooks, fishing lines, and debris were found at the opening, as well as a detached anchor. Abundant wildlife was filmed, including sponges, reef fish, snappers, snooks, nurse sharks, arrow crabs, green sea turtles, goliath groupers, and numerous invertebrates. There appeared to be very little living coral. The cloudy discharge flowing out of the blue hole is suspected to be hydrogen sulfate. The sediments appeared to be consistent with the flow direction of the spring discharge. The cloudiness of the discharging water and the darkness that begins at 60 feet from the water surface prevented us from collecting video data. The Paradise Spring is an important location due to the prevalence of prehistoric artifacts often found at springs. The spring is perhaps more “sediment-starved” than other blue holes, such as Ray Hole Spring in the Big Bend, which could potentially limit our chances of finding artifacts in a stratigraphic position.

The Ten Three Hole location exhibited karst features and abundant reef life, including sponges and clusters of living reef, but we found no cultural materials or spring features. The bottom experienced a high amount of dissolution.

Ultimately, we did not encounter any human burials or materials of cultural importance. The Seminole and Miccosukee Tribes do not want any burials to be disturbed whatsoever, and we were successful in keeping with their wishes.

b. Inventory of Activities

Acoustic surveys were performed from September 14th, 2021, to October 12th, 2021. Each day of surveying, the SR-Surveyor M1.8 autonomous surface vehicle (Figure 7) rented from SeaRobotics Corp. was launched from the CK Roses vessel (FL4632RF, Figure 8), which is property of the Nature Coast Biological Station of the Institute of Food and Agricultural Sciences of the University of Florida. The vehicle was equipped with an EdgeTech 2205 sonar; acoustic data were collected on the lines shown in the map below. The survey was designed to ensure at least 150% coverage between adjacent lines, assuming a three-meter water depth. About 187 kilometers of survey lines were followed (not including patch tests and repeated lines), and about 3 km^2 were mapped (Figure 9). The coordinates of the bounding polygon of the area surveyed are listed in Table 4. The area mapped corresponds to the feature of interest shown within the red box in Figure 2. Volunteers also recorded some *ad hoc* video data using a Trident remotely-operated vehicle (Figure 10), but they were not georeferenced due to a lack of instruments to do so at the time.

Figure 7: SR-Surveyor M1.8 autonomous surface vehicle used for the acoustic surveys.

Figure 8: The CK Roses, the vessel that was used to monitor the autonomous surface vehicle.

Photo provided by Emily Colson, Nature Coast Biological Station.

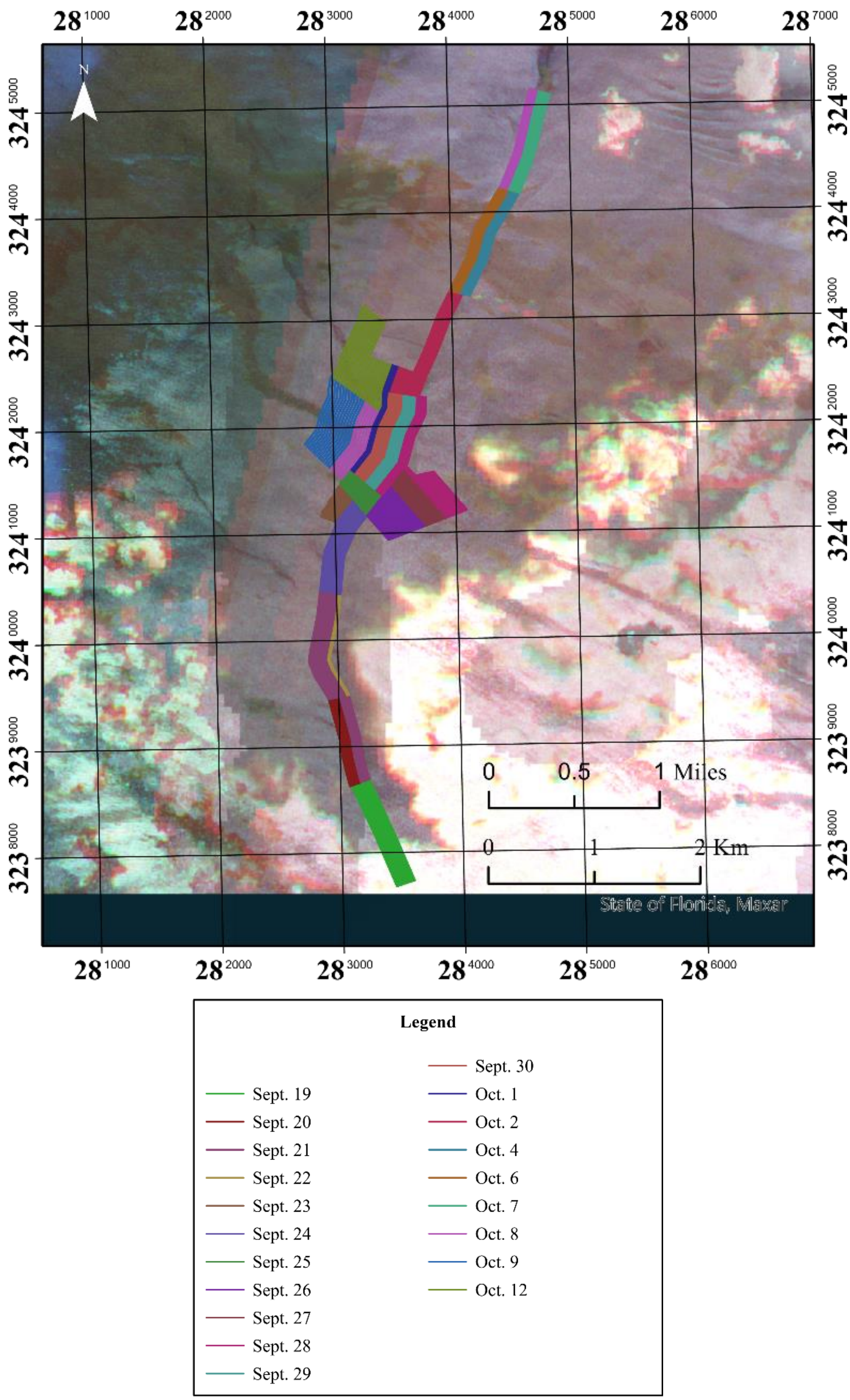

Figure 9: Survey lines followed by the autonomous surface vehicle, per day.

Table 4: Coordinates of the bounding polygon of the area surveyed with the autonomous surface vehicle.

	WGS 1984 UTM Zone 17N	WGS 1984
Top:	3,245,149.696132 m	29.31668639°
Bottom:	3,237,682.0811503 m	29.24969472°
Left:	282,759.233484 m	-83.236955°
Right:	284,840.738076 m	-83.21408167°

Figure 10: Trident ROV.

Image courtesy of Sofar Ocean.

Most days of surveying, team members left the Millhopper Fisheries & Aquatic Sciences Campus of the University of Florida located in Gainesville, Florida, at 7:30 AM, which resulted in the arrival at the Nature Coast Biological Station in Cedar Key, Florida, around 8:50 AM. Volunteers were then taken in charge by a team member who explained the plan for the day and what to expect. Loading of equipment followed. We would be ready to leave the marina between 9:45 and 10:30 AM, depending on how busy the boat ramp was. Depending on water conditions and the location of surveys, transit would take between 45 minutes and almost two hours (surveys were between 15 and 20 miles from the marina). Data collection would begin following calibration of the navigation instruments and stop when the battery would be close to empty, if technical issues arose, or if the weather turned or we would be getting close to sunset. Upon return to the marina, the vessel was removed from the water and cleaned. The equipment was then unloaded and set up to charge overnight. The team would usually return to Gainesville between 7 and 9 PM.

As mentioned above, 51 targets were identified in the sidescan sonar data. Their coordinates are listed in Table 3, and their geographic distribution within the acoustic survey area is shown in Figure 11. Archaeological diving surveys began on February 22nd, 2022. Completion of the initial 15 target anomalies acquired from raw acoustic data and two additional judgemental targets at Hedemon Reef and Red Bank Reef were completed by March 27th, 2022. During sonar anomaly target investigation, concentric circles were searched until a 12 to 18-meter radius had been reached, usually in 1 to 2-meter increments per circle. In some cases, multiple searches were conducted near the targeted anomaly, resulting in multiple overlapping circles of coverage. Only circle searches were conducted during this time since water clarity was most often very poor due to the prevailing surface wind currents.

A systematic sediment push-probe survey was conducted at “Channel Target” (see Table 1) on March 28th and 29th, 2022. A surface marker buoy was deployed from the vessel and used as a center point for a 75-meter north-to-south baseline. Transect lines 25 meters long were surveyed by dive teams from east to west while recording the results of the sediment probe survey every 5 meters along the transect line. The transect line was moved northward along the baseline at 5-meter increments. The push probe survey allowed documenting the uppermost 15 centimeters of sediment cover and ground-truth data present in both satellite imagery (Figure 2) and the acoustic bathymetry collected during the survey phase of the project (Figure 3).

Investigation of 34 more targets was completed between April 3rd, 2022, and May 5th, 2022. During these months, water clarity was often much clearer, allowing for video recordation in many areas under investigation. On May 14th, 2022, an intensive line search began at the Channel Target to maximize diver coverage and investigate the extent of the channel feature identified in satellite and sonar data. A surface marker buoy was deployed each day at a new UTM coordinate that corresponded to the end of the previous day’s investigation. The first dive team would install a 50-meter baseline with survey chaining pins and then conduct 20-meter transect line surveys at every 5 meters mark on the baseline, including 0 and 50 meters. Each diver swam in opposite directions, covering approximately 2.5 meters of the bottom. When each diver reached the end of the transect line, a signal was given to move the transect line 5 meters along the baseline, and then another signal was given to begin swimming the line. This method proved to be effective when diver visibility was favorable. When visibility was poor, 10-meter transects were swum on either side of the baseline using the same technique as the 20-meter transect swim, enabling better precision of the position of the transect line. Divers would fan shallow (< 20 centimeters) holes along the baseline and transect lines, then record the composition of the sediments and note the presence or absence of humic soil and marine bivalves. The systematic line search at the Channel Target continued until June 2nd, 2022. A total of 28 baselines (1400 x 20 meters) were surveyed within the Channel Target location.

Table 5: Coordinates of the targets for diving extracted from identified anomalies in the sidescan sonar data.

Location	Latitude (WGS 1984, DD)	Longitude (WGS 1984, DD)
Target 1	29.26327947	-83.23370472
Target 2	29.26484460	-83.23398570
Target 3	29.26515141	-83.23398208
Target 4	29.26689585	-83.23540909
Target 5	29.26761205	-83.23466326
Target 6	29.26297749	-83.23234001
Target 7	29.26368670	-83.23255091
Target 8	29.26567297	-83.23300565
Target 9	29.27058051	-83.23411046
Target 10	29.28067303	-83.23483433
Target 11	29.28059651	-83.23455481
Target 12	29.28121401	-83.23377586
Target 13	29.29335454	-83.22801928
Target 14	29.29296794	-83.22793884
Target 15	29.28213781	-83.22762141
Channel Target	29.26224359	-83.23359515
Target 16	29.31627448	-83.21672559
Target 17	29.31247967	-83.21864582
Target 18	29.31104226	-83.21893537
Target 19	29.28174342	-83.23351148
Target 20	29.28343139	-83.22870267
Target 21	29.28479739	-83.22914717
Target 22	29.28577724	-83.23108840
Target 23	29.25137904	-83.22727960
Target 24	29.25413660	-83.22964555
Target 25	29.25819276	-83.23051909
Target 26	29.25872128	-83.23162033
Target 27	29.25920745	-83.23184912
Target 28	29.25974914	-83.23230227
Target 29	29.26164760	-83.23200234
Target 30	29.26189557	-83.23313364
Target 31	29.26259070	-83.23335021
Target 32	29.26444494	-83.23373686
Target 33	29.26618322	-83.23510610
Target 34	29.26788917	-83.23601309
Target 35	29.27102337	-83.23580011
Target 36	29.27121790	-83.23559433
Target 37	29.27563808	-83.23348321
Target 38	29.28018323	-83.22714338
Target 39	29.29147592	-83.22886091
Target 40	29.29441704	-83.23085685
Target 41	29.29487791	-83.23035864
Target 42	29.29631188	-83.22386209
Target 43	29.29748798	-83.22375975
Target 44	29.29748535	-83.22376556
Target 45	29.30498155	-83.22093688
Target 46	29.30601132	-83.22157133
Target 47	29.30712200	-83.22079703
Target 48	29.30986599	-83.21852132
Target 49	29.31025543	-83.21941913
Target 50	29.31503379	-83.21568703
Target 51	29.26582261	-83.23260279

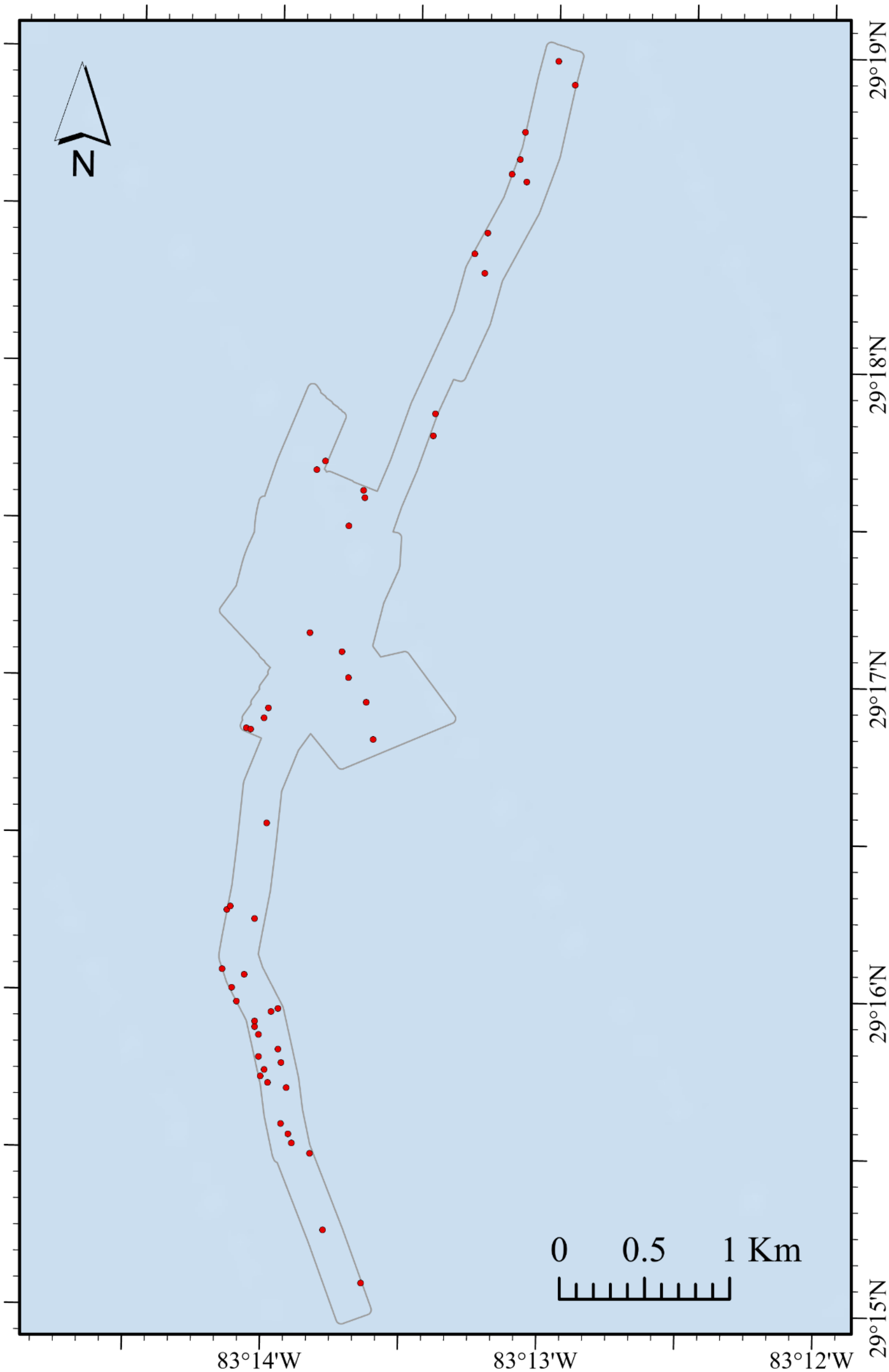

Figure 11: Location of diving targets, identified from anomalies in the sidescan sonar imagery.

A line search at Target 16 (Linear Scatter Target) was conducted on June 7th, 2022. On the second dive, the target was identified and mapped. Line searches continued near the structure until June 15th, 2022. An identical structure was located and mapped approximately 29 meters to the east. No other materials were located near Target 16 within a search area of 200 square meters.

Between June 16th and 21st, 2022, we extended our search to other judgemental targets acquired from local informants and fishing forums, listed in Table 6 and mapped in Figure 12: Grouper Grounds, Ten Three Hole, and SeaHorse Reef (Table 6) were acquired from fishing forums, Sandbar and Delta were determined from satellite imagery (Figure 2), and SeaMount Grasses was chosen because it exhibited anomalous bathymetry. The other targets listed in Table 6 were investigated between June 27th and 30th, 2022, along with a revisit to Grouper Grounds.

Table 6: Coordinates of additional targets investigated (not identified from acoustic surveys).

Location	Latitude (WGS 1984, DD)	Longitude (WGS 1984, DD)
Delta	29.29131	-83.30505
Grouper Grounds	28.82650	-83.23723
Hedemon	29.31706	-83.25943
Hedemon 2	29.29167	-83.26000
Linear Scatter	29.28186	-83.22725
Red Bank	29.32433	-83.22833
Sand Bars	29.31479	-83.20359
SeaHorse Reef	29.03576	-83.03481
SeaMount Grasses	29.16650	-83.23087
Ten Three Hole	29.05767	-83.30317
Wrong Reef	29.28386	-83.25962

Sediment coring operations began on July 9th, 2022, after receiving the permits from the U.S. Army Corps of Engineers and the Florida Department of Environmental Protection Agency, and were completed on December 8th, 2022. The sediment coring locations were selected from processed sidescan sonar data, diver inspection surveys, and satellite imagery. Twenty sediment cores were taken from a segment of the hypothesized Paleo-Suwannee Channel visible in both the sidescan data and satellite imagery and previously inspected by our dive teams.

Two-person dive teams use a three-inch aluminum core tube of eight feet in length to collect the cores. The core tubes were driven into the seafloor using a ten-pound kettlebell. The divers took turns hammering the core tube until the exposed portion was approximately 30 centimeters from the seafloor. Next, a pipe cutter tool was used to cut the deformed portion of the aluminum tube. With the clean cut, a plumber’s cap was installed to pressurize the content of the core and keep sediments in place while the tube was removed. The first dive team then exited the water, and the second team came in to remove the core tubes. To do so, they wrapped the pipe with duct tape and tied a rope around it using a Prusik knot (or triple-sliding hitch). The rope was looped around the end of a high lift farm jack placed on top of a wooden board to keep the jack from sinking into the seafloor. The jack was positioned parallel to the core tube to keep it upright as the core tube was cranked up from the seabed. Once the core breached the seafloor, it was capped with a rubber-fitted cap and taped to keep the content from falling out of the bottom during transport. The divers ascended with the core sample and swam it back to the boat. The topside crew then strapped the core upright, removed the plumber's cap, and siphoned the water off the top of the sample before recapping the core and labeling it with an arrow indicating up (in case the sample were to topple over accidentally) and a provenience number. During that time, the second dive team brought up the farm jack and the rest of the equipment before exiting the water.

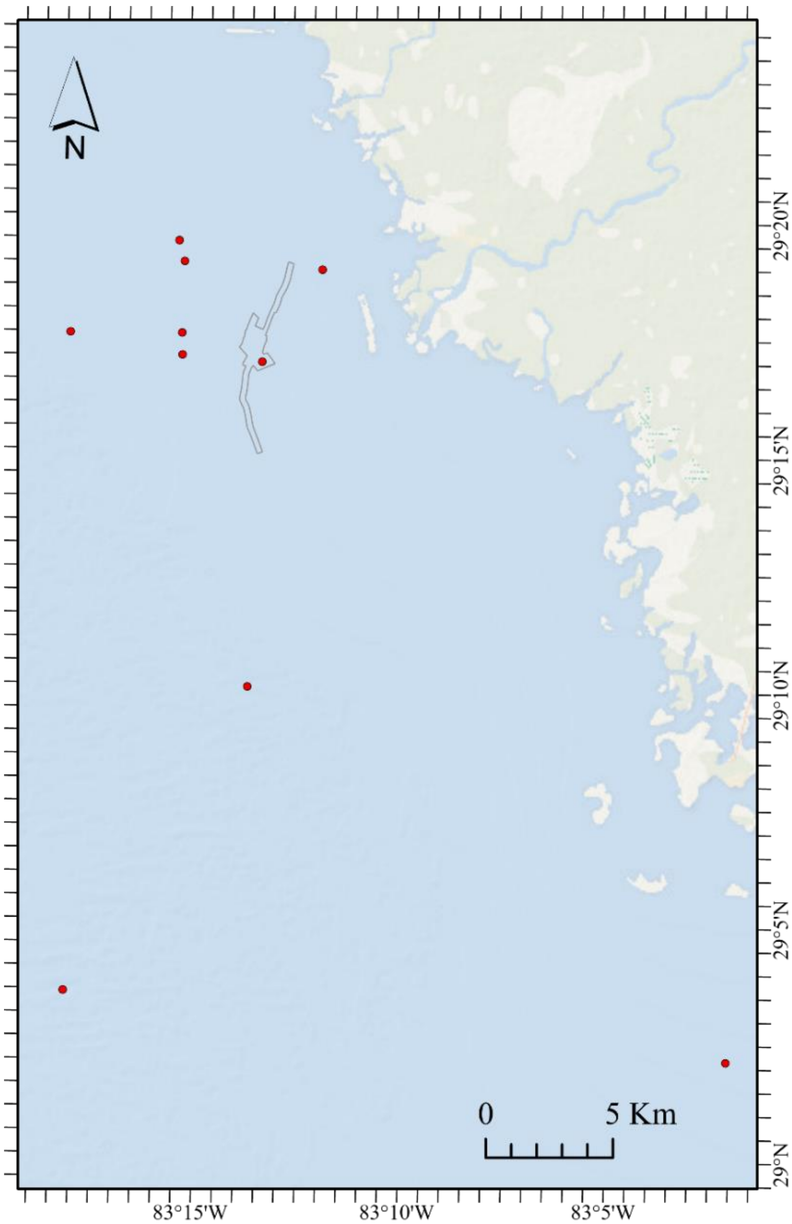

Figure 12: Location of additional targets (not identified from acoustic data).

The core samples were transported back to the Laboratory of Southeastern Archaeology of the University of Florida at a 45-degree angle, where they were stored upright until processed. On several occasions, the cores required multiple dives to impact and for removal. On at least two occasions, removing the cores took eight to ten dives due to the core tube being lodged in dense humic muck or limestone bedrock. No sediment cores were left in the seabed.

Our dive team then visited Betty Castor Reef, an artificial reef, on May 8th and 9th, 2023, to inspect the reef's condition and search for archaeological materials. More specifically, the reef was examined for signs of comet scour created by objects used to create artificial reefs, such as sunken blocks and other large objects. These scours can aid in discovering submerged archaeological and paleontological sites by scouring the ephemeral marine and restricted marine sediments that overlay the former terrestrial soils. The "natural" scouring process created by "unnatural" sunken materials can expose bedrock and relict landforms, including in situ root systems of "ancient" or submerged terrestrial forests. Seven dives were conducted during the two days. We collected one limestone sample for analysis. Several hand-fanned test units were dug to record the depth to limestone. GoPro video footage and photos were recorded during the two days.

On May 10th, 2023, we attempted to locate the Port Paradise Spring using coordinates provided by Dr. Jim Cutler from the Mote Marine Laboratory. We inspected the bottom during two dives but could not find the spring. Most of the day was spent trying to locate the spring using our fish finder. On May 11th, 2023, our dive team attempted to find Chris Spring, another spring locale with coordinates provided by Dr. Cutler. The area is a popular fishing location due to the expansive seagrass in the area. We spent half a day searching for the spring from our boat and the other half in the water. The coordinates brought us to the center of the Suwannee Fishing Reef (not to be confused with the Suwannee Reef, an oyster complex). The coordinates brought us along a line of bathymetric rise from approximately 10 to 18 feet over approximately 100 feet of linear distance. We conducted circle searches for two dives. On May 20th, 2023, we revisited the location of sediment core 15 (cf.

Table 8) and dug a small (20 centimeters wide) and 60 centimeters deep test pit to examine the buried oyster bioherm and surrounding sediments. We collected two one-gallon bags of whole oyster shells for analysis and potential dating. We could not dig our pit beyond 60 centimeters due to the dense shell and sticky sediments; thus, we could not reach the limestone bedrock present in the sediment cores of the area. Video data and photos were collected. On May 21st, 2023, four dives were conducted at Paradise Spring after locating the spring depression using a fish finder and a stationary buoy marker. The examination was challenging due to the decreased water clarity within the discharge zone, and the 20-mile open ocean voyage to the spring location further complicated fieldwork logistics; our crew could only travel to the area when boating conditions were less than 1 foot. We placed a surface marker buoy to lessen the time required to locate the spring in the future. Video and photos were taken at the location. On May 22nd, 2023, we conducted dives at Ten Three Hole. We conducted a 30-meter circle search of the area.

On July 19th and 20th, 2023, our dive team visited Port Paradise Spring to inspect the condition of the surrounding seafloor and search for archaeological materials. Seven dives were conducted during the two days. We measured the spring opening from north to south and east to west and hand-fanned surrounding sediments up to 45 meters from the lip of the opening. Videos were recorded on these days. On July 26th and 27th, we revisited Port Paradise Spring using our updated coordinates. Relocating the spring was difficult because the surface marker buoy had been removed since our last visit. We suspect a dive charter team frequents the blue hole as we witnessed a dive boat pass us on our way out. Most of the first day was spent trying to locate the spring, but we were able to conduct three dives, during which we collected sediment along a 45-meter baseline. We sampled limestone and dolomite and took sediment samples from the western margin, which appeared consistent with the spring discharge's flow direction. On the second day, we were unsuccessful in collecting a water sample before being chased off the water by impending thunderstorms. On August 2nd and 3rd, 2023, our dive team again relocated Port Paradise Spring after the surface marker buoy had been removed. Two dives were conducted on the first day using the underwater GPS and a GoPro to record video data. Videos were recorded at depths of 39, 45, and 50 feet. Personnel Newton and Brown deployed the tethered underwater camera from the vessel while the dive team guided it into the spring opening. During these two field days, we circled the spring opening with the underwater GPS unit while recording underwater videos. On August 13th and 14th, our team continued to record video data of bottom features using the underwater GPS unit. We mapped the uppermost ledges at Port Paradise Spring approximately 55 feet from the water surface on the first field day. It is important to note that there was still sunlight reflecting on the ledges without any overhead obstructions, and therefore, it was an open water dive rather than a cavern or cave dive. The second field day was spent recording sponges and clusters of living reefs at Ten Three Hole. No sediment samples were collected from this site due to poor diving conditions. Another eight shallow water locations (< 5 feet) were logged with the underwater GPS along with video data, although visibility again proved to be an issue in shallow waters. Then, the team moved to record the bottom on video along with underwater GPS at five of our previously visited targets (T9, T16, T21, T26, T45; cf. Table 5). The decision to deploy the unit from the boat's deck was made due to the shallow location (< 3 feet) and a concern for water temperatures, which were exceeding 90 degrees Fahrenheit. By staying on the boat, the crew avoided any potential cuts from the sharp oyster debris, lowering the likelihood of bacterial infections. On August 15th, 2023, a team of three personnel snorkeled in shallow waters to attempt to record video data and underwater GPS coordinates near the Suwannee Oyster Reef. The coordinates were recorded, but the videos were challenging to collect due to turbidity and other water conditions. Still, we collected shell samples at all five locations. On August 16th, 2023, Newton deployed the underwater GPS and GoPro pole-mounted unit from the vessel's deck at four locations near the Suwannee Oyster Reef complex; the high water temperature and presence of flesh-eating bacteria elsewhere in the Gulf cautioned the dive team away from entering the water to collect shell samples.

c. Inventory of samples collected

Details on the data collected during acoustic surveys for each day are presented in Table 7. Figure 11 and Figure 12 show the locations of the dives where seafloor characteristics were documented, with their coordinates in Table 5 and Table 6. Finally, the location of the core samples is shown in Figure 13 (coordinates listed in

Table 8).

Table 7: Inventory of acoustic data collected during acoustic surveys.

Days	Dates	Leads	Assistants	Volunt.	Start – End Times Total Time	Lines Completed	Notes
Monday	9/13/2021	Newton	None	1			Mobilization, picked up instruments in Stuart, FL
Tuesday	9/14/2021	Lecours, Burnette	None	1			Navigated to patch test area, deployment failed due to communication antenna issues.
Wednesday	9/15/2021	Lecours, Newton, Burnette	None	0			Stayed onshore to fix communication antenna; wire had come loose during mobilization. Performed tests onshore to ensure no further issues. Could not connect to RTK base station.
Thursday	9/16/2021	Newton, Burnette	Herrin	0			Put vessel in the water but stayed at the marina; heavy rains and risk of thunderstorms. No data were collected.
Friday	9/17/2021	Lecours, Newton, Burnette	None	3	10:22 AM - 2:02 PM 3 h 40 min	12 (2.25 GB)	Morning troubleshooting of RTK with SeaRobotics. No solution found; not enough cell signal in the area. Ran patch test.
Saturday	9/18/2021	Lecours, Newton	None	1	1:19 PM – 3:27 PM 2 h 8 min	10 (3.67 GB)	Ran patch test. Issues with alignment caused by survey lines being longer than 1 km.
Sunday	9/19/2021	Lecours, Newton, Burnette	None	3	12:15 PM – 4:51 PM 4 h 36 min	15 (6.68 GB)	
Monday	9/20/2021	Lecours	Espriella	2	12:50 PM – 2:28 PM 1 h 38 min	8 (2.59 GB)	
Tuesday	9/21/2021	Lecours, Newton	Hintenlang	0	12:15 PM – 3:37 PM 3 h 22 min	19 (6.26 GB)	
Wednesday	9/22/2021	Newton, Burnette	Atchia	2	12:25 PM – 3:26 PM 3 h 1 min	11 (5.33 GB)	ASV propeller had to be repaired due to drop. Clear weather, choppy seas.

Thursday	9/23/2021	Lecours	Herrin	2	1:20 PM – 5:22 PM 4 h 2 min	24 (5.72 GB)	Delayed start as vessel was needed early morning. Ran patch test.
Friday	9/24/2021	Lecours, Newton	Jaundoo	1	12:14 PM – 5:33 PM 5 h 19 min	16 (9.31 GB)	Met with SeaRobotics in the morning to figure out RTK solution. Clear weather, light winds (3-7 kts). Completed 13 lines.
Saturday	9/25/2021	Lecours, Burnette	Jaundoo	2	2:45 PM – 4:46 PM 2 h 1 min	31 (3.77 GB)	
Sunday	9/26/2021	Newton, Burnette	None	2	11:30 AM – 3:05 PM 3 h 35 min	27 (6.56 GB)	Problems with antenna alignment. Overcast weather, choppy seas (9 kts).
Monday	9/27/2021	Lecours, Newton	None	3	11:44 AM – 2:56 PM 3 h 12 min	15 (6.33 GB)	Documented fish kill for FWC.
Tuesday	9/28/2021	Lecours, Newton	Hintenlang	0	11:30 AM – 5:06 PM 5 h 36 min	24 (9.56 GB)	
Wednesday	9/29/2021	Newton, Burnette	Rodofili	1	11:10 AM – 4:51 PM 5 h 41 min	12 (6.82 GB)	
Thursday	9/30/2021	Lecours, Burnette	Herrin	1	11:20 AM – 4:49 PM 5 h 29 min	22 (8.10 GB)	Rope got caught in propeller, had to fix and remove ropes.
Friday	10/01/2021	Newton	None	2	12:25 PM – 4:20 PM 3 h 55 min	15 (7.05 GB)	
Saturday	10/02/2021	Newton	Jaundoo	1	11:30 AM – 3:46 PM 4 h 16 min	21 (7.84 GB)	Shipwreck observed in sidescan sonar.
Sunday	10/03/2021	Newton, Burnette	None	2			Reached patch test area, ASV would not go to lines. Dongle housing for Hypack key license had gotten wet, which corroded the connection. Repairs, no data collected.
Monday	10/04/2021	Newton	Espriella	3	11:25 AM – 4:00 PM 4 h 35 min	15 (5.53 GB)	Ran patch test. Clear weather, wind less than 5 kts. Issues with propellers getting out of casing.
Tuesday	10/05/2021	Newton	Hintenlang	3	11:15 AM – 2:53 PM 3 h 38 min	21 (5.30 GB)	Issues with propellers getting out of casing.
Wednesday	10/06/2021	Newton, Burnette	Atchia	1	11:55 AM – 3:25 PM 3 h 30 min	11 (4.34 GB)	Weather rainy and choppy seas (over 3 ft waves). Communication antenna short-circuited.

Thursday	10/07/2021	Lecours, Burnette	Herrin	3	11:10 AM – 3:52 PM 4 h 42 min	14 (7.21 GB)	Issues with propellers getting out of casing.
Friday	10/08/2021	Lecours	Jaundoo	2	11:25 AM – 5:07 PM 5 h 42 min	24 (7.11 GB)	Issues with propellers getting out of casing.
Saturday	10/09/2021	Leours, Burnette	Jaundoo	2	10:55 AM – 3:00 PM 4 h 5 min	14 (7.76 GB)	Issues with propellers blocking and getting out of casing. Lost antenna and communication. Surveys aborted mid-day.
Sunday	10/10/2021	Lecours, Burnette	None	3			Tried to fixed antenna. Factory reset. No data collected.
Monday	10/11/2021	Lecours	None	0			Drove to SeaRobotics to fix antenna and propeller. No data collected.
Tuesday	10/12/2021	Lecours	Hintenlang	0	10:10 AM – 2:09 PM 3 h 59 min	18 (7.60 GB)	Ran patch test.
10/13/2021-10/25/2021		Lecours, Newton, Burnette	Rodofili, Atchia, Jaundoo, Espriella	23			Oyster reef surveys for unrelated sponsored project.
Tuesday	10/26/2021	Lecours	None	0			Demobilization. Drove equipment back to Stuart, FL.

Table 8: Location and characteristics of core samples.

Core	Date	Latitude (WGS 1984, DD)	Longitude (WGS 1984, DD)	Number of Bags	Sample Length (cm)	Length of Tube (cm)
C1	24-Jul-22	29.280597°	-83.234556°	6	61	90
C2	26-Jul-22	29.262592°	-83.233339°	14	199	240
C3	07-Aug-22	29.262000°	-83.231453°	16	198	250
C4	07-Aug-22	29.262000°	-83.231453°	6	65	75
C5	07-Aug-22	29.262000°	-83.231453°	6	82	110
C6	26-Aug-22	29.262444°	-83.231017°	21	241	255
C6.2	25-Aug-22	29.262444°	-83.231017°	6	62	106
C6.3	25-Aug-22	29.262444°	-83.231017°	10	90	113
C7	26-Aug-22	29.262036°	-83.233364°	15	195	230
C7.2	26-Aug-22	29.262036°	-83.233364°	7	66	97
C7.3	26-Aug-22	29.262036°	-83.233364°	screened	screened	screened
C8	27-Aug-22	29.262125°	-83.232072°	6	68	111.5
C8.2	27-Aug-22	29.262125°	-83.232072°	8	83	120
C9	03-Sep-22	29.263050°	-83.232728°	10	109	140
C10	06-Sep-22	29.263825°	-83.232864°	14	165	254
C11	06-Sep-22	29.261911°	-83.232536°	screened	screened	screened
C12	07-Sep-22	29.263828°	-83.231550°	7	205	240
C13	07-Sep-22	29.263147°	-83.231358°	15	160	238
C14	10-Oct-22	29.263758°	-83.234664°	8	149	234
C15	11-Oct-22	29.285728°	-83.230981°	10	126	240
C15.2	10-Oct-22	29.285728°	-83.230981°	8	174	262
C16	08-Oct-22	29.287189°	-83.230917°	8	139	238
C17	09-Oct-22	29.284328°	-83.231067°	10	142	248
C18	09-Oct-22	29.285725°	-83.230128°	11	145	229
C19	09-Oct-22	29.254244°	-83.229642°	8	156	247
C20	09-Oct-22	29.275667°	-83.233472°	6	130	243
C21	11-Nov-23	29.215832°	-83.191700°	9	178	243
C22	08-Dec-23	28.825611°	-83.192711°	4	48	103
C23	08-Dec-23	28.825611°	-83.192711°	3	40	90
C24	08-Dec-23	28.826494°	-83.193000°	3	42	95
C25	14-Aug-23	29.057664°	-83.303169°	9	111	150
C26	15-Aug-23	29.057664°	-83.303169°	4	96	150
C27	15-Aug-23	29.057664°	-83.303169°	9	130	150

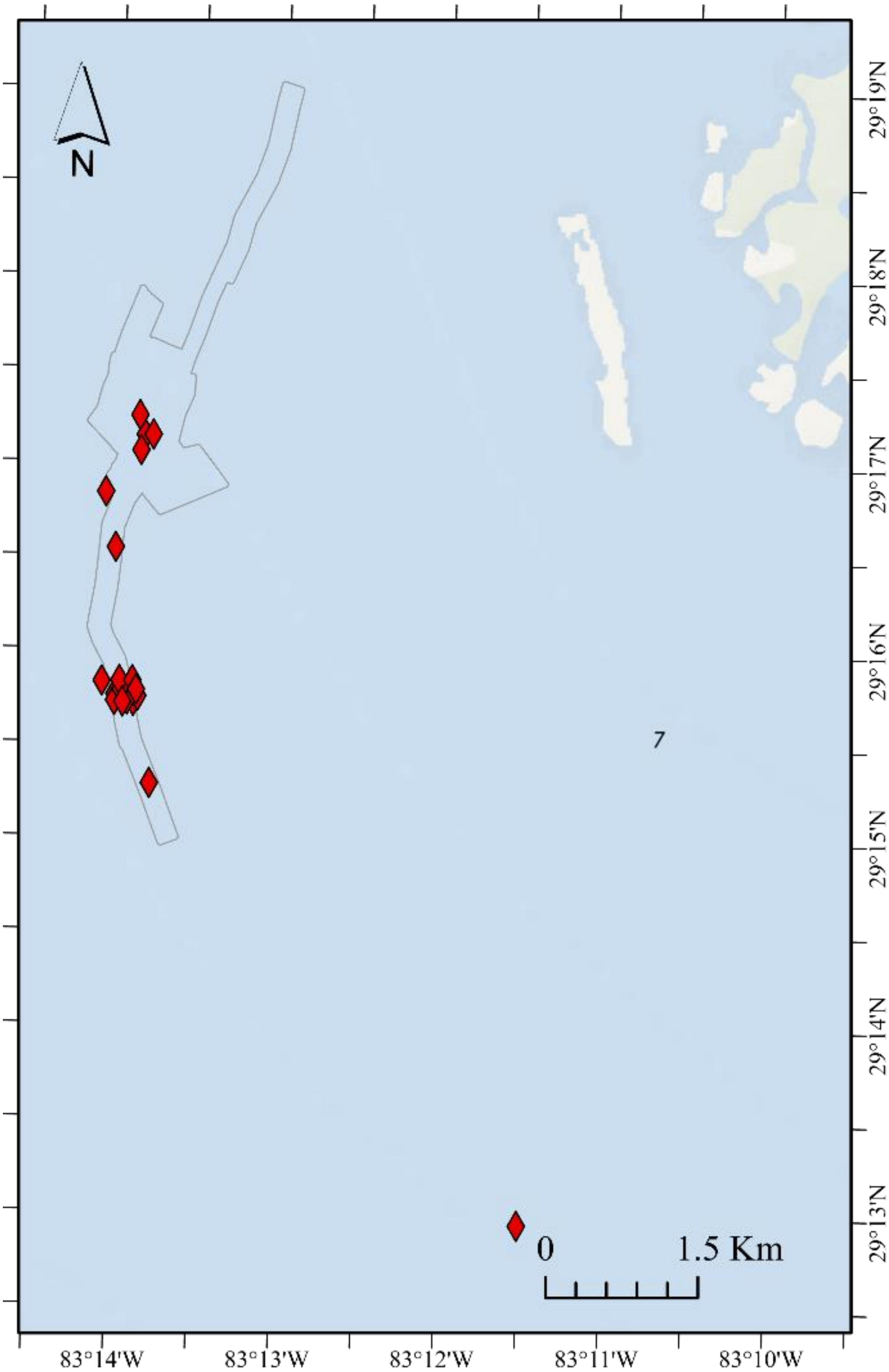

Figure 13: Location of the core samples extracted from the seabed in the primary study area.

d. Resulting Publications, Presentations, and Website

Chequer A (2024) Multiscale geomorphological characterization of the hypothesized Paleo-Suwannee River, Eastern Gulf of Mexico. *Thesis presented to the University of Florida*, 85 p. *(M.S. thesis)*

Newton M, Lecours V & Kornacki E (2024) Archaeological investigations of Port Paradise Spring, Eastern Gulf of Mexico. *American Academy for Underwater Sciences Annual Symposium*, Fort Pierce, Florida, USA, April 14th – 20th. *(Presentation with abstract)*

Lecours V (2023) La géomatique au service des aires marines protégées. *Les aires marines protégées : Enjeux et défis actuels*, Aix-Marseille Université, France, June 19th - 23rd. *(Keynote presentation at a summer school; no abstract)*

Newton MA & Lecours V (2023) Suwannee offshore: Underwater archaeological investigation of a paleo-river channel. *Florida Anthropological Society 75th Annual Meeting*, St. Augustine, Florida, USA, May 12th - 14th. *(Presentation with abstract)*

Lecours V & Hiroji A (2023) Where has the Suwannee Reef gone? Mapping historically significant subtidal oyster habitats in Florida at multiple scales. *International GeoHab Symposium 2023*, St-Gilles-les-Bains, La Réunion, May 8th - 12th. *(Presentation with abstract)*

Chequer A, Newton MA, Lecours V & Hiroji A (2023) Marine habitat mapping and archaeological investigation of the submerged Paleo-Suwannee River, eastern Gulf of Mexico, United States. *International GeoHab Symposium 2023*, St-Gilles-les-Bains, La Réunion, May 8th - 12th. *(Presentation with abstract)*

Newton MA & Lecours V (2023) The Paleo-Suwannee Project: Offshore research in the Eastern Gulf of Mexico. *Society for American Archaeology 88th Annual Meeting*, Portland, Oregon, USA, March 29th - April 2nd. *(Presentation with abstract)*

Lecours V, Abd-Elrahman A & Wilkinson BE (2022) Beyond hydrography: Marine geomatics at the University of Florida. *International Hydrographic Review*, 27, 133-141. *(Editor-reviewed invited article)*

Newton M, Lecours V & Sassaman K (2022) The Paleo-Suwannee Project. *East Carolina University's Maritime Studies Student Scholar Symposium*, Greenville, North Carolina, USA, April 9th. *(Invited seminar presentation; no abstract)*

Lecours V (2022) Habitat mapping from reefs to rift: selected projects from the University of Florida Marine Geomatics Lab. *Oceanography Seminar Series*, Dalhousie University, Halifax, Canada, March 15th. *(Invited seminar presentation; no abstract)*

Lecours V (2022) La géomatique au service des sciences de la mer. *Webinaire du Centre de Recherche en Données et Intelligence Géospatiales de l'Université Laval*, Québec, Canada, February 3rd. *(Invited seminar presentation; no abstract)*

Lecours V (2021) Using geomatics to advance coastal and marine sciences. *School of Forest, Fisheries, & Geomatics Sciences Advisory Board Meeting*, Gainesville, Florida, USA, December 10th. *(Invited presentation; no abstract)*

Lecours V (2021) University of Florida benthic habitat mapping updates. *Florida Coastal Mapping Program 2021 Summit*, online, December 7th. *(Invited presentation; no abstract)*

Newton M (2021-now) Paleo-Suwannee Education Outreach. https://paleosuwanneeeducationaloutreach.org/ *(Website)*

e. Final Data Inventory

All raw acoustic and navigation data total about 650 GB and have been stored on two hard drives and in the cloud, together with about 205 GB of photographs and video data. All raw data will be provided in their native format with appropriate metadata documentation to be archived and made publicly available through the NOAA National Centers for Environmental Information no later than May 2025. We are unaware of any reasons that might prohibit sharing and re-using the data associated with this project. We expect all our data and research outputs to be fully accessible to the public and stakeholders. All data and their complete metadata will be archived following NOAA data management requirements before May 2025.

f. Previously-Submitted Major Adjustments to Project

During the acoustic surveys in September and October 2021, some changes to the planned fieldwork had to be made. First, mobilization of the autonomous surface vehicle had to be delayed from August 30th,2021, to September 13th, 2021, due to Hurricane Ida that made landfall in Louisiana on August 29th, 2021. The renter's (Okeanus) offices and warehouses are located in Houma, Louisiana, and sustained major damage from the hurricane. This situation only shifted the start and end of data collection by one day but did not allow time for technical troubleshooting before the start of data collection, which explains the issues encountered during the first week of surveying (cf. Table 7). Daily departures from the marina were later than planned because tides usually prevented us from leaving the vessel in the water. Putting it in and taking it out of the water daily lengthened the typical schedule. A couple of days (September 21st and 25th, 2021) were delayed because of the tides that were too low to get out of the marina, and one day was delayed because the supporting vessel was needed early morning by the Nature Coast Biological Station crew.

Personnel-wise, the team was stretched thinner than expected, as we lost one project leader early in fieldwork due to seasickness and a primary assistant who moved away. In addition, it was decided that at least two team leaders, instead of one, would be present at all times due to the challenges associated with departing from a busy marina with many commercial and recreational vessels and having many inexperienced volunteers to manage during maneuvers that require focus and safety.

While we expected at least five hours of surveying per day, the water conditions and the battery life did not allow for this. The water conditions were often rougher than expected, thus requiring more power to adjust and follow the survey lines and reducing the overall speed of the autonomous surface vehicle. As a result, we covered fewer linear kilometers per day than expected. On average, we surveyed close to four hours per day (92 hours total). The patch test was not performed every day as intended due to the time required to transit to and from the patch test area and the time required to put the autonomous surface vehicle in the water and retrieve it back in the boat. Only one day had to be fully canceled because of the weather (September 16th, 2021). A few other days started later than expected due to early morning storms but had minimal impact on the amount of data collected since we were limited by battery life regardless (see below). We note that on days with rougher seas (e.g., September 22nd and 26th, October 6th, 2021), the autonomous surface vehicle needed more battery power to navigate and follow survey lines, thus moving slower and reducing the total amount of data that could be collected.

We also encountered technical difficulties during fieldwork, significantly limiting the data we could collect. First, the antennas enabling communication between the supporting vessel and the autonomous surface vehicle caused problems on three occasions. On September 14th, 2021, communication could not be established. Inspection on the following day showed that the ethernet connector within the antenna of the supporting vessel had come loose during mobilization, and it was fixed. This issue resulted in two days of data collection lost. Then, on October 6th, 2021, data collection was underway under heavy rain and in choppy waters. Water got into the antenna of the supporting vessel and short-circuited it. Smoke was observed, and the ethernet connector was burnt and unusable. The autonomous surface vehicle had to be retrieved manually, and data collection was aborted. Finally, on October 9th, 2021, we lost communication with the autonomous surface vehicle. Once we retrieved it, the communication antenna mounted on the vehicle was blinking in a previously unobserved pattern. Since it was a Saturday, we could not get support from SeaRobotics Corp., but an internet search indicated that water had likely gotten into the antenna, causing it to go into a factory reset mode. We tried rebooting the antenna on October 10th, 2021, without success. We finally got ahold of SeaRobotics Corp. and drove the autonomous surface vehicle to Stuart, Florida, on Monday, October 11th, 2021, to replace the antenna. This issue resulted in two and a half days of data collection lost. Second, the real-time kinematic (RTK) solution for positioning and navigation of the autonomous surface vehicle did not function. The vehicle connects with the local shore base stations to get NTRIP corrections through a cellular connection. However, the study area is located within a region with a significantly low cellular service, preventing the connection with the local base stations. We attempted to use the cellular booster kit to increase the signal, but there was not enough signal to start with to enable the booster to work. We tried different approaches to connect to the cellular network and to get an RTK solution, including using a mobile base station, but could not resolve it. We got support from SeaRobotics Corp. on September 17th, 2021, and after trying different things, concluded that we would not be able to get RTK solutions. We thus performed all surveys based on a differential GPS solution, which is less accurate but accurate enough to ensure navigation along survey lines. We increased the accuracy of the data in post-processing using a post-processed kinematic (PPK) solution in the software Qinertia, which brought the accuracy of the data on par with RTK. The third technical issue was that on September 18th, 2021, after conducting a patch test, the autonomous surface vehicle drifted in transit due to a compass error. Attempting to bring it back on track consumed the entire battery. Troubleshooting showed that the gyro sensor becomes uncalibrated if it follows the same heading for more than one kilometer. Due to this issue, we lost one day of data collection and needed to redraw all survey lines to make them shorter than one kilometer. Other minor issues with antenna alignment occurred throughout fieldwork, sometimes shortening field days. Another technical issue had to do with propellers. On September 22nd, 2021, the autonomous surface vehicle (more than 125 lbs) was dropped on the ground while loading the vessel, bending the shroud. Repairs delayed the start of data collection that day, but damages were limited. On September 30th, 2021, one of the ropes tied to the vehicle for transport came untied and got caught in the propeller. The vehicle struggled to follow the survey lines, which likely impacted the data. A couple of hours of data collection were lost that day to clean the propeller from the ropes and untie all ropes from the vehicle to prevent this from happening again. Starting on October 2nd, 2021, one of the propellers would sometimes come out of its casing and stop working, leading the vehicle to struggle to follow the lines. Every time, the vehicle had to be turned off, brought back onboard the supporting vessel, and the propeller reinserted into its casing. Every time this happened (about every second day), we would lose about one hour of data collection. While at SeaRobotics Corp. on October 11th, 2021, they disassembled the propeller and realized that a small ring holding components in place was broken. They replaced it, and no further issues were observed with the propellers. Finally, on October 3rd, 2021, the surveying software Hypack would not launch the surveys. An assessment back onshore highlighted corrosion in the USB connection of the software dongle onboard the ASV. The connector was thoroughly cleaned and sealed, which solved the issue.

We also had issues with batteries for the autonomous surface vehicle. The manufacturer indicated a battery life of six hours. In the rougher sea conditions of the Gulf, we found that the batteries would usually give us about four hours of survey time, but less in really rough conditions. While the vehicle rental usually comes with only one battery, we were able to get a second one from SeaRobotics Corp., hoping to get between six to eight hours of survey time per day. Unfortunately, SeaRobotics Corp. only provided us with one charger, and charging one battery takes between 12 and 15 hours. For most days, we could not optimize battery use and charging time to enable us to use both batteries. In addition, starting on September 26th, 2021, one of the two batteries started showing a communication error, and we could no longer monitor its voltage, current, and fuel level. Despite this, we attempted to use it a few times, but when the battery died, we lost communication and control of the autonomous surface vehicle, and the survey system shut down suddenly without properly saving data. When we finally were able to get a second charger from SeaRobotics Corp., the defective battery stopped working, and they did not replace it. While it is difficult to estimate the amount of data that could not be collected because of this issue, we estimate that we could have increased our coverage by at least an additional 25 to 50% if we had had two fully functional batteries, although the longer days might have been challenging to manage for the small crew.

The Trident ROV could not be deployed every day. Wave conditions often prevented us from safely deploying and retrieving it. In addition, the supporting vessel had to stay in relative proximity to the moving autonomous surface vehicle to ensure constant and strong communication between the antenna mounted on the autonomous surface vehicle and the antenna on the supporting vessel; the remotely-operated vehicle could not be deployed when the vessel was not anchored due to the risk of getting the tether in the vessel engine. In addition, early in the fieldwork, one of the volunteers got the controller wet, which broke the touch screen. We could still launch the remotely-operated vehicle but could not record nor tilt down the camera. The controller could not be replaced as this vehicle was not manufactured anymore. The GoPro HERO9 was also not deployed as we were relying on the tether of the underwater GPS to attach it to, which was delivered too late. Despite ordering the WaterLinked underwater GPS and accessories on July 28th, 2021, it was not delivered until very late in the fieldwork. In addition, it was not ready to be used upon arrival as it needed to be adapted to North American wiring conventions. We judged that it would not have been a good use of time to go back over the already surveyed areas to collect video data as it would have jeopardized the amount of acoustic data collected. Given how turbid the water was, it was decided that it would be better to postpone video data collection until winter before the archaeological dives. This resulted in the fact that we could not assess habitat use and habitat type by collecting underwater video data of species occurrences and surficial geology.

In terms of the education and outreach activities planned, we could not have a live feed with the Florida Public Archaeology Network and their partner school classrooms due to the lack of cellular signal, even with the signal booster. We also could not meet with K12 school groups visiting the Nature Coast Biological Station since these tours were canceled due to health concerns with the global pandemic of Covid-19.

In terms of archaeological fieldwork (2022-2024), access to appropriate vessels delayed the start of fieldwork. The Nature Coast Biological Station of the University of Florida decided to stop renting its vessels due to financial constraints. We thus relied on vessels from the Fisheries & Aquatic Sciences program of the School of Forest, Fisheries, and Geomatics Sciences of the University of Florida. However, the vessels required critical maintenance to be done to ensure the safety of our divers. Due to these delays in starting fieldwork and lousy weather preventing us from conducting fieldwork, the field season began in March 2022 instead of January 2022 and lasted until the end of the year, despite hurricane season. Finally, there were unexpected delays in getting approval from the U.S. Army Corps of Engineers for coring. It took almost a month longer than they announced to give us the permits, adding further delays to fieldwork by preventing us from conducting our coring operations. During dive investigations, the divers could not georeference observations accurately using a locator U1 and a WaterLinked Underwater GPS G2. The GPS unit had an electrical issue in the first days of fieldwork that fried the motherboard, and a replacement had to be ordered. Unfortunately, we could not wait for the replacement to arrive to avoid further delays in conducting the dive investigations. Observations were thus georeferenced based on a surface GPS unit (instead of an underwater GPS unit), resulting in a lower positional accuracy for the observations.

Weather conditions and scheduling issues – with divers coming from all over the State of Florida to conduct this fieldwork – often impacted dives in 2023 and 2024. Wind and weather conditions were largely uncooperative in this area of the Gulf during the late summer of 2023. When boating conditions were fair, diver visibility was limited due to rain fallen during the preceding week. Also, Ten-Three Hole and Port Paradise Spring were 18 and 20 miles seaward of Cedar Key, respectively. As safety was paramount, the crew decided against several days of pleasant diving conditions due to unpredictable storms along the coast, limiting the risks of getting stuck far away from the marina in unsafe weather conditions; the size of our vessel and our long voyage to safety limited our eligible workdays. We also picked out the calmest days to attempt to record video data within the acoustically surveyed area. Finally, we also occasionnally experienced shortages of divers and volunteers during this period.

Changes in the way video data were collected occurred. Volunteers broke the Trident remotely-operated vehicle during the acoustic surveys of 2021, and no replacement could be found. Therefore, we acquired two GoPro cameras and built a PVC frame to lower the cameras to the seafloor and run the transects. Unfortunately, the underwater currents in the study area were too strong for the system. An alternative frame with metal posts was built, but the currents were too strong again, and the tension on the frame risked damaging the vessel and the underwater GPS antenna. We evaluated several other options, including borrowing remotely-operated vehicles, but these solutions were sub-optimal as most available remotely-operated vehicles do not have downward-looking cameras. In addition, the potential collaboration with another professor at the University of Florida to use his small ROVs to explore the spring and other areas fell through due to a lack of availability of his team. Divers ran some video transects, but not as long as planned, as it would have been too dangerous for divers to run such long transects. An Aqua-Vu HD7i Pro underwater camera was purchased to collect some observations, but weather and water conditions have limited the amount of data that could be collected.

g. Equipment Inventory

The only piece of equipment purchased with the funds granted for this project is a Waterlinked Underwater GPS G2 (version R100 with no topside) with locator U-1 for ROV and diver and an antenna. It is currently stored in the Marine Geomatics Laboratory at the University of Florida.

5. Highlights from Outreach, Education, Diversity, and Inclusion Activities

During the acoustic fieldwork in September and October 2021, more than 100 individuals expressed interest in participating in fieldwork (about 90% students, 5% state agency employees, and 5% members of the public). However, due to space and scheduling constraints, a total of 45 different volunteers came with us on the boat to experience the technologies used first-hand. Many came more than once; two volunteers even joined as many as nine times! Volunteers were given the opportunity to “drive” the autonomous surface vehicle before launching its autonomous mode, were given complete control of the remotely-operated vehicle when weather and sea conditions allowed, and participated in monitoring activities (cf. Figure 14). Volunteers included undergraduate and graduate students from tens of departments at the University of Florida (*e.g.*, biology, civil engineering, marine sciences, environmental engineering, environment and global health, geomatics, interdisciplinary ecology, transportation engineering, forestry, biochemistry, medicine, coastal engineering, geography, biotechnology), members of the general public, and employees of the University of Florida and the Florida Fish & Wildlife Conservation Commission.

Figure 14: Volunteers were hands-on with the equipment during acoustic surveys.

During this 2021 fieldwork, we also took the time to interact with the local community. Many mornings, while docked at the marina, we had the opportunity to interact with local commercial fishers and explain the importance of this work. On the water, it was most often recreational fishers that would be curious about the autonomous surface vehicle and that we would be able to educate about the work performed and the technologies used. Finally, we had several interactions with residents of Cedar Key who would see us carry the equipment between the marina and the Nature Coast Biological Station, where we stored it.

In terms of diving investigations, a middle school teacher participated in them on February 26th, 2022. Students from Eastern Carolina University and the University of Florida Scientific Diver Training Program participated in three days of diving operations between March 2nd and 7th, 2022. Overall, more than 25 students from a total of seven universities participated as scientific divers to conduct the archaeological dives and investigations.

On October 15th, 2021, we participated in two events associated with the Nature Coast Biological Station Open House in Cedar Key. We set up a table during the day with visuals and the Trident ROV so local school groups and visitors could learn about this project. Three team members were present to engage and answer questions. Then, in the evening, the guests of the Nature Coast Biological Station, which included local business owners, captains, fishers, guides, and members of the public, in addition to donors and leaders of the University of Florida, had the opportunity to interact with five team members and explore the SR-Surveyor M1.8 autonomous surface vehicle. We participated again in the Nature Coast Biological Station Open House in October 2022.

Two employees of the main communications office at the University of Florida joined us for a couple of days and documented our fieldwork. They also performed interviews with team members. They intend to create a multimedia series with photos, videos, and quotes to highlight this research as part of a broader series of strategic communications. Social media coverage was relatively frequent during fieldwork and posts were made on the University of Florida Marine Geomatics Lab's Twitter account, with tags to the School of Forest, Fisheries, and Geomatics Sciences and other relevant groups within the University of Florida, and to NOAA's Office of Ocean Exploration. The Florida Marine Data Hub account retweeted the information. A description of the project and fieldwork was also included in the Center for Coastal Solutions of the University of Florida newsletter. SeaRobotics, the company building the SR-Surveyor M1.8 autonomous surface vehicle, also published some of our footage of the vehicle collecting data surrounded by dolphins on their LinkedIn page.

We have also created several web pages and blog posts for the Florida Public Archaeology Network (FPAN; https://paleosuwanneeeducationaloutreach.org/), providing an overview of the project, technical specifications, anticipated outputs, a description of volunteers' experience, a "meet the crew" section, a description of what a typical day on the water is like, and other topics.

III. Evaluation

1. Accomplishments

In terms of acoustic surveys, no backscatter data were generated due to the nature of the system available for rental: the EdgeTech 2205 is an interferometric phase differencing bathymetry system that only produces bathymetry and sidescan sonar imagery. We were expecting to be able to function with two batteries for the autonomous surface vehicle; however, the battery life and charging time of the rented system limited us to using only one battery per day, halving our survey time. On the other hand, we were able to double the number of survey days, which compensated partly for this limitation. Also, the lack of a base station on the coastline prevented us from collecting real-time kinematic data, causing some quality issues with the data. We were able to use post-processed kinematics to correct the navigation data to a certain level. Patch tests could not be performed daily due to the time required to navigate to the patch test area. There were also issues to access that area at low tides.

We could not collect georeferenced remotely-operated vehicle video data due to delays with instrument acquisition and equipment breaks. We compensated with other camera systems, but the video data were not collected simultaneously with the acoustic data. In addition, the videos show the limited visibility in the study area throughout the year, limiting our ability to identify biota and surficial geology. These elements were characterized by diver investigations when possible but without highly accurate georeferencing. Too few biological observations were present in the data to produce species distribution models, which additionally would have been largely impacted by the artifacts in the bathymetric data.

Prevailing poor weather conditions delayed the archaeological diving portion of the project on many occasions (*e.g.*, February to April 2022, June 2023). During the first interval, winds over 11kts blew from the west constantly, creating poor boating conditions and severely limiting visibility. The dive team quickly realized these conditions were unfavorable for line searches and switched to circle searches with smaller intervals. During the second interval of poor weather, the wind again prevailed from the west, but this time along with daily rain showers. A few core dive team members used this downtime period to acquire their cavern certifications.

Our project bounds were expanded in an effort to explore exposed karst environments and to observe changes in sediment cover across the seafloor at a greater distance. During this time, we relocated a spring, searched all accessible ledges, and took multiple samples. In doing so, the area was expanded to include areas of lesser sedimentation (< 1 meter) and carbonate structures. For example, Port Paradise Spring is approximately 30 miles outside our initial project boundaries. During the diver investigations, the area was deemed to contain the highest potential to yield archaeological materials. It was thus determined that efforts should be concentrated there for a segment of diving operations.

Sediment particle analysis was not done by laser diffractometry using a Malvern Mastersizer 3000 because the expert cost analysis revealed that the costs and time needed to do so would exceed the benefits unless the composition was complex, which was not the case. Sediment particle size analysis was therefore conducted by nested mechanical sieving.

Due to not finding any discrete evidence, such as objects or burials, of cultural heritage, we could not produce predictive models based on seafloor characteristics.

2. Expenditures

a. Describe original planned expenditures

The original planned expenditures are listed in Table 9.

In terms of personnel, a total of $19,200 over the duration of the project was planned for the PI to ensure successful project completion, including overall project direction and coordination and oversight of data collection, analysis, and interpretation, among other responsibilities. A total of $94,294 for two years was planned as a stipend for one PhD and one master's student. Finally, $50,400 was planned for the scientific divers' salary. With the different fringe rates for these categories of personnel, the fringe benefits amounted to $20,009.

Regarding travel, $21,719 was planned for fieldwork expenses (*i.e.*, mileage, per diem, and accommodations when needed), $1,344 was planned to attend a training on the autonomous surface vehicle in Stuart, Florida, $5,900 was planned to send the master's student to an international multibeam training in New Orleans, Louisiana, $114 for outreach activities in Cedar Key, Florida, $2,159 to send the PhD student to the Society for American Archaeology Annual Meeting, and $3,369 to the master's student to the annual International GeoHab Symposium.

For equipment, $6,234 was reserved for acquiring a Waterlinked underwater GPS. For supplies, $8,788 was planned for diving supplies (*i.e.*, tanks, oxygen kits, air refills), $1,767 to produce outreach material, and $452 to purchase hard drives for local data management.

Other planned expenses included tuition for the PhD and master's students ($60,210), acoustic data processing software licenses ($2,000), and rental costs for the autonomous surface vehicle and the supporting vessel ($37,800).

Table 9: Original planned expenditures.

	Item	Year 1	Year 2	Total
A.	Personnel	$106,308.00	$ 57,586.00	$163,894.00
B.	Fringe Benefits	$ 11,775.00	$ 8,234.00	$ 20,009.00
C.	Travel	$ 29,020.00	$ 5,585.00	$ 34,605.00
D.	Equipment	$ 6,234.00	$ -	$ 6,234.00
E.	Supplies	$ 10,748.00	$ 259.00	$ 11,007.00
F.	Contractual	$ -	$ -	$ -
G.	Construction	$ -	$ -	$ -
H.	Other	$ 66,472.00	$ 33,538.00	$100,010.00
I.	Total Direct Charges	$230,557.00	$105,202.00	$335,759.00
J.	Indirect Charges	$ 86,022.00	$ 38,674.00	$124,696.00
K.	TOTALS (sum of I and J)	$316,579.00	$143,876.00	$460,455.00

These planned direct costs amounted to $335,759, which were added to the indirect costs of $124,696, for a total of $460,455.

b. *Describe actual expenditures*

The actual expenditures are listed in Table 10.

In terms of personnel, a total of $180,747 was spent on personnel, including PIs ($28,619), graduate students ($95,153), and divers and other supporting crew ($56,976). With the different fringe rates for these categories of personnel, the fringe benefits amounted to $23,490.

Regarding travel, $9,840 was spent on fieldwork expenses (*i.e.*, mileage and accommodations when needed), $2,125 was spent to attend a training on the autonomous surface vehicle in Stuart, Florida, $5,929 was spent to send the master's student to an international multibeam training in St. Petersburg, Florida, $114 for outreach activities in Cedar Key, Florida, $1,490 to send the PhD student to the Society for American Archaeology Annual Meeting, and $4,640 to the master's student to the annual International GeoHab Symposium. These total $24,135.

For equipment, $8,972 was spent on the acquisition of a Waterlinked underwater GPS. For supplies, $3,722 was spent on diving supplies (*e.g.*, air refills), $1,214 to produce outreach material, and $612 to purchase hard drives for local data management, totaling $5,548.

Other expenses include tuition for the PhD and master's students ($38,522), software licenses ($1,242), and rental costs for the autonomous surface vehicle and the supporting vessel ($35,487).

These direct costs amounted to $318,139, which were added to the indirect costs of $142,293, for a total of $460,435.

Table 10: Actual expenditures.

	Item	Total
A.	Personnel	$180,746.38
B.	Fringe Benefits	$ 23,489.43
C.	Travel	$ 24,134.42
D.	Equipment	$ 8,971.33
E.	Supplies	$ 5,547.05
F.	Contractual	$ -
G.	Construction	$ -
H.	Other	$ 75,250.06
I.	Total Direct Charges	$318,138.67
J.	Indirect Charges	$142,295.62
K.	TOTALS (sum of I and J)	$460,434.29

c. Final Budget Expenditures Table

Table 11: Final budget expenditures table per NOAA Ocean Exploration's template.

BUDGET EXPENDITURES REPORT			
NOAA Grant No.:	**NA21OAR0110200**		
Institution Name:	**University of Florida**		
Lead PI Name:	**Vincent Lecours**		
Award Period:	**7/1/2021 to 6/30/2024**		
Reporting Period:	**7/1/2021 to 6/30/2024**		
Total Award Amount:	**$460,455**		
	*** Funds Available**	**Actual Expenditures**	
	For This Reporting Period	**For This Reporting Period**	**Balance Remaining**
Salaries & Wages	$ 163,894.00	$ 180,746.38	$ (16,852.38)
Staff Benefits	$ 20,009.00	$ 23,489.43	$ (3,480.43)
Travel	$ 34,605.00	$ 24,134.42	$ 10,470.58
Services	$ -	$ -	$ -
Supplies	$ 11,007.00	$ 5,547.05	$ 5,459.95
Equipment	$ 6,234.00	$ 8,971.33	$ (2,737.33)
Other	$ 100,010.00	$ 75,250.06	$ 24,759.94
Indirect Cost	$ 124,696.00	$ 142,295.62	$ (17,599.62)
		$ -	
Total	$ 460,455.00	$ 460,434.29	$ 20.71

d. Discrepancies between Planned and Actual Expenditures

Overall, this project cost precisely $20.71 less than was planned.

More funds were expended on salaries and wages for two reasons. First, the administrative change of PI mid-grant led to effort, and therefore salary, to be distributed to a different co-PI that had a higher base salary at the time. The same effort, therefore, cost more ($9,419). Second, we completed more days of fieldwork than planned, resulting in more work for divers and crew and, consequently, more funds spent on their salaries ($6,576). About $859 extra was spent on graduate student stipends due to the increase in minimum stipend by the university. These extra salaries and wages resulted in more fringe benefits spent ($3,481) than initially planned.

Fewer funds than initially planned were spent on travel. This is mainly caused by the fact that per diem was planned for all divers and crew for all days of fieldwork; however, the university does not pay per diem for day trips, which we ended up doing instead of spending funds on accommodations. Also, for some longer stretches of good and safe conditions for diving, co-PI Sassaman provided independent funds to allow divers to camp close to the study area, thus reducing fatigue and increasing diver safety. Overall, this saved about $11,880 of funds, which compensated other travel categories where costs exceeded what was planned. This is the case for travels to Stuart, Florida, for the training on the autonomous surface vehicle, which ended up costing $781 more due to the cost of the hotel closest to the training facility. Travels to the International Multibeam Training for the master's student cost $29 more than planned, and their attendance at the International GeoHab Symposium cost $1,271 more than planned due to the remote location of that year's conference. However, the participation of the PhD student in the Society for American Archaeology Annual Meeting cost $670 less than planned. Overall, this left more than $10,470 unspent for the travel category, which allowed compensating for other categories where more money had to be spent than initially planned.

Equipment cost about $2,738 more than initially planned due to the failure of a component of the Waterlinked underwater GPS, which had to be replaced. Supplies ended up significantly cheaper than planned ($5,548) as the cellular booster kit and router for outreach purposes were cheaper than planned ($554 less), although the hard drives were more expensive ($160 more). Most funds dedicated to outreach material were not spent because the PI had free printing access. Most importantly, other programs at the University of Florida allowed us to use their diving equipment (*e.g.*, oxygen kits, tanks) and other materials for free, saving us significant money (more than $5,000). We only had to pay for maintenance, repairs, and air refills.

In the "other" category, tuition fees were significantly cheaper than planned due to in-state waivers granted to our two graduate students. Funds were also lower for some of the boats' rental as other programs at the University of Florida allowed us to use them for free, except for maintenance, repairs, and fuel. That saved enough funds to increase the number of days we could rent the autonomous surface vehicle and compensate for other categories that were more expensive than initially planned.

To complete the work, the total direct charges thus ended up being over $17,600 cheaper than we had planned. However, the indirect costs ended up being about the same amount more expensive than initially planned. This is due to the IDC being applied to more elements: tuition and rental costs were exempted from IDC, but in the end, this category was $24,760 cheaper than planned. This amount was used to compensate for higher expenses in other categories on which IDC was applied. These variations eventually evened out, leaving $20.71 unspent to complete the planned work.

Table 12: Discrepancies between planned and actual expenditures.

	Item	Planned	Actual	Difference
A.	Personnel	$163,894.00	$180,746.38	-$ 16,852.38
B.	Fringe Benefits	$ 20,009.00	$ 23,489.43	-$ 3,480.43
C.	Travel	$ 34,605.00	$ 24,134.42	$ 10,470.58
D.	Equipment	$ 6,234.00	$ 8,971.33	-$ 2,737.33
E.	Supplies	$ 11,007.00	$ 5,547.05	$ 5,459.95
F.	Contractual	$ -	$ -	$ -
G.	Construction	$ -	$ -	$ -
H.	Other	$100,010.00	$ 75,250.06	$ 24,759.94
I.	Total Direct Charges	$335,759.00	$318,138.67	$ 17,620.33
J.	Indirect Charges	$124,696.00	$142,295.62	-$ 17,599.62
K.	TOTALS (sum of I and J)	$460,455.00	$460,434.29	$ 20.71

3. Next steps

a. Planned or Expected Outcomes

The data acquired under the grant are being used as part of Matthew Newton's PhD dissertation, titled "Paleoenvironmental Reconstruction of an Underwater Archaeological Landscape off the Northern Gulf Coast of Florida". This expected outcome is scheduled for completion in the summer of 2025.

Four peer-reviewed publications are planned: one led by PI Lecours describing the acoustic dataset that was produced, one by MS student Arturo Chequer on the satellite-derived bathymetry datasets that were produced, and two led by PhD student Matthew Newton, one focused on the Paleo-Suwannee channel and another one on Port Paradise Spring.

Finally, data analyses from the project are scheduled to be presented during the upcoming Society for American Archaeology Conference in Denver, Colorado, in April 2025.

b. Contributions to Societal and Ecosystem Well-Being

The urgency to improve prehistoric archaeological prospection models has been amplified by increased activity in the offshore minerals and green energy sectors. Protecting culturally sensitive areas from the wake of industrial activities is an ever-growing concern for Tribal representatives and federal agencies. One problem is that historically, shipwrecks dating to the onset of European occupations and onwards have garnered more attention than submerged indigenous archaeological sites due to their likelihood of discovery via their large size and distinct, ship-shaped remote sensing signatures. Conversely, submerged indigenous sites that most often consist of comparatively smaller features, such as shell midden and lithic scatters, lack definitive remote sensing signatures. The outcome of this has been an uneven distribution of marine surveying efforts that has hindered our understanding of underwater cultural heritage.

In this context, our project has contributed a wealth of data to be used in environmental reconstructions of the seafloor in the study area and beyond. The documentation of karst features at the Port Paradise Spring, Ten Three Hole, and Grouper Grounds locations is substantial because it will help refine predictive models in the region at water depths less than 60 feet. In addition, these karst sites are situated along what we believe to be the Paleo-Homosassa River. The presence of chert outcrops is also significant because the location of chert resources is an input for models of human occupation areas. Since we have reached the bottom of the current sedimentary sequence beneath the seafloor, and given that an organic-rich horizon overlies both the chert and limestone present in the cores, we will be able to establish the *terminus ante quem* for the deposition of the humic layer.

The findings from the sediment cores are significant for many reasons. First, the marsh sediments are dateable soil horizons. Then, the oyster bioherms would have supported human occupations in the area. Finally, the marsh zones can be used to determine the relict course of the Paleo-Suwannee River. The marsh layer appears intact, with sharp contact boundaries between the terrestrial and marine layers. This is important because the marsh/peat layer is most conducive to the favorable preservation of archaeological materials. In addition, bedded chert fragments in limestone bedrock were found in the primary study area. This is significant because no exposed bedrock was ever recorded at this water depth, and radiocarbon analyses have produced absolute dating of the samples immediately above the chert fragments.

If the Grouper Grounds are confirmed to be an infilled spring, it would prove to be a significant finding since humans have often frequented springs since the initial Peopling of the Americas. The Port Paradise Spring was also officially relocated after about 30 years, and accurate geographic coordinates were recorded. The documentation and characterization of Port Paradise Spring is the first of a blue hole in the area, highlighting its tourism potential.

The methods used enabled continuing to develop protocols for locating submerged archaeological sites in relatively shallow waters (less than 100 feet) in areas with high sedimentation (*i.e.*, two meters or more overlying sediment).

Finally, the sidescan sonar dataset and the local and regional bathymetric datasets that were produced highlighted seafloor biogenic and geologic features. They informed us of the dynamic nature of the seafloor in this area, which is influenced by natural phenomena coming from the Gulf of Mexico as well as by river input and anthropogenic activities.

Overall, while no cultural materials were located, our project provided a deeper historical context to the towns of Cedar Key and Suwannee, Florida. The local populations were very interested in understanding the cultural value of their respective town, and they often engaged our field crew at the boat docks. We feel strongly that our project bolstered the cultural capital of Cedar Key and the Nature Coast as a whole. This research and the data collected are relevant to coastal scientists, engineers, biologists, wildlife ecologists, archaeologists, and geologists for coastal planning, protection, and cultural resource management.

Although buried and exposed river channels are invaluable features to guide research efforts, the areas adjacent to paleo-rivers hold the key to understanding the lifeways of the persons that frequented the banks, and if a paleo-river channel has been identified previously, the essential foreground has already been laid. Then, it follows that mapping springs, lithic outcroppings, and shellfish deposits onto the paleolandscape increases the likelihood of discovering submerged sites. We hope to continue working towards these aims. Underwater research is painstakingly slow, yet research in this location now stands on more footing than ever.

c. Needs and Plans for Additional Work

In the short-term, data on hand from sediment cores, radiocarbon assays, and sub-bottom surveys conducted by Wright *et al.* in 2005 will serve as a baseline for comparison of sediments and geological features collected and observed during fieldwork. Sedimentary analysis of all thirty cores collected from the Paleo-Suwannee, three cores from Grouper Grounds, and ten grab samples collected along the eastern perimeter of Port Paradise Spring will be conducted during the first trimester of 2025, together with shell fractions analysis. Sedimentary analysis will be conducted primarily with nested sieves ranging from 1/16’’ to ¼’’ unless ambiguity arises between taxonomical end members. In other words, using sieves is justified except in cases when macroscopic analysis cannot discern between, for example, muddy sand and sandy mud. In these cases, the pipette or diffractometer methods will be used. Graphic results of the cores will be generated using SedLog, an open-sourced program. Finally, the sediment sequences and ten radiocarbon dates acquired from the Paleo-Suwannee channel zone will be combined with the cores and radiocarbon assays collected by Wright *et al.* (2005). From these, a table will be created and imported into a geographic information system to show sediment cover along with relative and radiometric dates across vertical and horizontal axes so that all future endeavors can map features onto a pre-modeled landscape.

We confirmed that the hypothesized Paleo-Suwannee channel is infilled with open marine sediment and located a marsh zone adjacent to the infilled channel. We also found that the sediments exhibit a similar composition and cover pattern at Target 50, approximately 2.5 kilometers northwest of the Channel Target. We hope to connect the two locations next and add them to previous studies conducted in the region, further documenting the relict course of the now-submerged Suwannee River.

Our work demonstrated that the characteristics of the study area are suitable for yielding prehistoric archaeological deposits, being protected by a moderately thick sediment sheet. In addition, a dense concentration of large, disarticulated oyster and clam shells between 10 to 50 centimeters deep beneath the seafloor was found in chert-bearing sites, which warrants more investigations due to the rare occurrences of submerged archaeological middens across the globe. This information will be used as input for a model of human occupation areas in the future. That said, these potential deposits and buried layer of whole shells remain elusive to the archaeologists without first conducting a sub-bottom survey and then truthing the targets by dredging, which would require access to a larger, live-aboard research vessel. Future work should integrate these methods into the current study design to push the boundaries of what was accomplished in this project. We note that arrangements are being discussed with the University of Bradford (United Kingdom) for using an interferometric sub-bottom profiler over the summer of 2025. Access to the Florida Institute of Oceanography research vessels should also be explored.

The karst sites documented during this project (*i.e.*, Port Paradise Spring, Ten Three Hole, Grouper Grounds) are situated along what we now believe to be the Paleo-Homosassa River. Looking further into the future, a similar project as the one conducted here on the Pale-Suwannee River could be conducted on the Paleo-Homasassa River to evaluate its potential to yield archaeological materials and be integrated into models of past human occupation. In the meantime, these sites need to be further investigated; although archaeologists surveyed Port Paradise Spring for two days in the late 1980s, the rare nature of a blue hole accessible in shallow water depths warranted a more thorough examination. Divers with specialized training are needed to retrieve core samples from the bottom of the sediment cone. Additional radiocarbon dating of oyster shells is planned, but additional sediment samples are needed from Grouper Grounds and Ten-Three Hole.

Appendix: Abstracts, Publications, and Other Materials

Authors: Chequer A

Title: Multiscale geomorphological characterization of the hypothesized Paleo-Suwanne River, eastern Gulf of Mexico.

Type of publication: Thesis presented to the graduate school of the University of Florida in partial fulfillment of the requirements for the degree of Master of Science.

Date: August 2024.

Abstract: Although the Floridian economy relies on the spatial distribution of marine resources, significant gaps in mapping coverage and spatial resolution hinder decision-making in resource management. This thesis focuses on semi-automated geomorphometric analyses of bathymetric data from the nearshore coastal waters of the Big Bend of Florida to investigate the presence of an inundated hypothesized paleochannel of the Suwannee River along the seabed and to develop a cost-effective and rapidly reproducible methodology for monitoring short-term changes in the seabed.

Multiscale geomorphometric analyses were used to test the spatial scale at which the inherent properties of the seafloor would be captured. Results from geomorphometric classification of acoustic bathymetry did not confirm that a paleochannel was present in the study site but did reveal rippling bedforms (alternating between ridges and channels) in the south, possibly underwater dunes. Optical remote sensing techniques integrated with acoustic bathymetry produced satellite-derived bathymetry (SDB) that provided regional context for the hypothesized paleochannel. SDB results captured known features and similar dunes extending beyond the study site. Ensemble model-inspired methods were not successful at increasing the accuracy of estimated SDB depths, which was likely impacted by the turbid nature of the Big Bend Coast.

The results from this study demonstrate the use of multiscale geomorphological analyses semi-automated methods for nearshore coastal areas and provide the first high-resolution bathymetry for this study area, which can be used to inform potential archaeological site exploration and marine resource management, as well as train other automated toolsets to derive broader bathymetric coverage for critical areas.

Authors: Newton M, Lecours V & Kornacki E

Title: Archaeological investigations of Port Paradise Spring, Eastern Gulf of Mexico.

Conference: American Academy for Underwater Sciences Annual Symposium, Fort Pierce, Florida, USA.

Date: April 14th –20th, 2024.

Abstract: An investigation of Port Paradise Spring, a shallow blue hole in the eastern Gulf of Mexico, consisted of 10 days of diving investigations during the summer of 2023. The research was a portion of the first author's dissertation research funded by the National Oceanic and Atmospheric Administration (NOAA) Ocean Exploration Research (OER) initiative. The spring was first published in the Florida Anthropologist by Don Serbousek in 1988 following limited explorations by Jim Dunbar of the Florida Bureau of Archaeological Research (FBAR), and volunteers. The blue hole is approximately 20 nautical miles seaward of Crystal River and opens from the seafloor at a depth of approximately 38 feet. The relatively shallow depth of Port Paradise Spring, the low occurrences of sedimentation at the site, and its position on the continental shelf within the 40-60ft bathymetric slope speak to the potential of former human habitations at the locale. Operations consisted of 2-3 AAUS divers performing line and circle searches and hand fanning along the spring opening and under shallow (<6ft) ledges at 40ft and 50ft water depths. Over two hours of underwater video was recorded at the site in tandem with a WaterLinked Underwater GPS locator. We present here the preliminary findings of the visual survey and discuss ongoing plans for future research at this unique karst feature.

Authors: Newton MA & Lecours V

Title: Suwannee offshore: Underwater archaeological investigation of a paleo-river channel.

Conference: Florida Anthropological Society 75th Annual Meeting, St. Augustine, Florida, USA.

Date: May 12th-14th, 2023.

Abstract: Global sea level rise since the end of the Younger Dryas (approximately 11,700 years before the present) has hindered our understanding of coastal settlements dating to the Late Pleistocene to Middle Holocene periods (*i.e.*, coastal settlement predating 4,500 years ago). This is especially true for the eastern Gulf of Mexico, where shorelines have moved landward from their Pleistocene positions by as much as 300 km. As a result, all evidence for the first 10,000 years of coastal dwelling along the northern Gulf Coast of Florida is underwater. Locating submerged archaeological sites in marine environments remains a challenge for coastal research, yet work conducted over the last forty years has demonstrated that evidence of early coastal peoples can be recovered from primary depositional contexts, and while we have learned that marine processes surely play a role in archaeological site formation and destruction, they can also preserve archaeological deposits.

Authors: Lecours V & Hiroji A

Title: Where has the Suwannee Reef gone? Mapping historically significant subtidal oyster habitats in Florida at multiple scales.

Conference: International GeoHab Symposium 2023, St-Gilles-les-Bains, La Réunion, France.

Date: May 8th-12th, 2023.

Abstract: Eastern oysters (*Crassotrea virginica*) provide numerous ecosystem services to coastal ecosystems and human communities and are considered a Species of Greatest Conservation Need in Florida. Along the central and northwestern Florida coastline, offshore subtidal oyster reefs have experienced an estimated net loss of 88% since 1982 because of a combination of environmental and anthropogenic stressors. This loss highlights the importance of frequent and comprehensive monitoring of these critical habitats to inform management and restoration, yet there is currently a lack of spatially-continuous baseline data.

The Suwannee Reef was so extensive over 50 years ago that it created an enclosed bay. Today, however, the reef is mostly subtidal and only fragments remain. This work aimed to update the information we have on the distribution and extent of the reef by mapping oyster habitats along the historical footprint of the Suwannee Reef. In October 2021, bathymetric and sidescan data were collected using an EdgeTech 2205 echosounder mounted on an uncrewed surface vehicle. The surveys were designed to follow the latest available data on oyster beds along the reef, which were recorded in 2001. The processed bathymetric grid, produced at a 25 cm resolution, covered an area spanning about 1.7 km2 in depths ranging from about +0.49 m to -4.41 m relative to the lowest astronomical tide datum. Vertical uncertainty on the bathymetry averaged 8 cm.

The 2001 data showed 20 individual beds distributed along a six-kilometre stretch and covering about 47,000 m2. These beds were not visible anymore in the 2021 bathymetry and sidescan data, and no clear evidence of oysters could be found except in one particular area where the data suggest that there may have been a 45 m migration of shell material toward the coastline. However, this will need to be validated with upcoming ground-truthing.

The broader-scale morphology of the seafloor suggests that the former oyster beds played a key role in shaping the seafloor. To confirm this, the bathymetric data were used to inform an empirical satellite-derived bathymetry process using Sentinel-2 data (10 m resolution). The resulting regional bathymetry, which had an R^2 value of 0.59 and a standard error of 4 cm, highlighted the important contribution of oyster resources, past and present, in shaping the seafloor in the area. Current work tests semi-automated classification methods to characterize the area's geomorphology quantitatively and will add to the story about the role of the Suwannee Reef in shaping its environment.

Authors: Chequer A, Newton MA, Leocurs V & Hiroji A

Title: Marine habitat mapping and archaeological investigation of the submerged Paleo-Suwannee River, eastern Gulf of Mexico, United States.

Conference: International GeoHab Symposium 2023, St-Gilles-les-Bains, La Réunion, France.

Date: May 8th-12th, 2023.

Abstract: The coastal waters of Florida are highly valuable areas for economic and recreational use but are also highly threatened by anthropogenic pressures and the effects of climate change. As such, there is a need to produce benthic habitat maps that can assist with the identification and monitoring of economic, cultural, and environmental resources in contexts such as management and conservation. The goal of this project is to create geomorphological and habitat maps of the nearshore submerged Paleo-Suwannee River channel and tidal flats off Florida's Gulf of Mexico coast derived from acoustic remote sensing technologies to enable habitat identification and map habitat distribution and extent while also detecting potential cultural heritage targets given the high archaeological potential of this area.

In September and October 2021, bathymetric data were collected using an EdgeTech 2205 echosounder mounted on an uncrewed surface vehicle. About 187 km of survey lines were run over an area identified from satellite imagery and hypothesized to be part of former tidal flats of the Paleo-Suwannee River before its submersion by the Gulf of Mexico thousands of years ago. A total of 29 sediment cores were collected as ground-truthing data. The bathymetric data were cleaned and referenced to a vertical datum using RTK tide, and a bathymetric grid at 1.5 m spatial resolution was generated. Subsequently, the bathymetry was analysed using two predeveloped models. First, the "MultiscaleDTM" R package was used to extract seven morphometric features defined from the slope and several types of curvatures. Then, the Bathymetric and Reflectivity-based Segments (BRESS) software was used to segment the area into different morphometric features using three different classification schemes. Results from the different techniques were compared.

The processed bathymetric grid covered about 2.4 km2, with depths ranging between 0 and 5 m (average of 3.8 m deep). Depending on the scale and type of analyses, results showed that most of the study area is relatively flat (>60%) with some ridges (≈14%), channels (≈10%), and slopes (≈9%). However, motion artifacts in the bathymetric data impacted the relative proportion of morphometric features captured in the area. Two main morphological features were identified in the southernmost portion of the study area. The sediment cores suggest that these features have a different sediment composition than surrounding habitats. The presence of chert outcrops and oyster bioherms, known to act as surrogates of early human occupation in the area, were noted in the cores.

Authors: Newton MA & Lecours V

Title: The Paleo-Suwannee Project: Offshore research in the Eastern Gulf of Mexico.

Conference: Society for American Archaeology 88th Annual Meeting, Portland, Oregon, USA.

Date: March 29th - April 2nd, 2023.

Abstract: The goal of the project is to find and map a portion of the submerged Paleo-Suwannee River in the Eastern Gulf of Mexico. The main goals of our research are to find the Suwannee River channel offshore and map any archaeological sites encountered, and produce geological (sedimentological) and habitat (species and landscape) maps of the area at multiple scales. We will use this information to evaluate submerged sites of cultural heritage, and natural resources, to inform management and foster responsible stewardship. In line with the “collect once and use many times” spirit that guides most seafloor mapping efforts, our second objective ties into other priorities outside of archaeological science, since we aim to document the sediments and biota to inform management, sustainable use, and conservation of marine resources in this area. In the process, we are testing new and innovative remote sensing approaches.

Authors: Lecours V, Abd-Elrahman A & Wilkinson BE

Title: Beyond hydrography: Marine geomatics at the University of Florida.

Journal: International Hydrographic Review.

Date: May 2022.

Abstract: Florida depends on the oceans, yet its waters have not been extensively mapped to the highest standards. While there is a need for marine spatial data for a wide range of applications and issues, there is also a need to develop data acquisition, processing, and analytical workflows and to integrate different surveying instruments that can capture the complex and extensive coastal environment – both above and below the waterline. This note provides an overview of the research performed by scientists at the School of Forest, Fisheries, and Geomatics Sciences, University of Florida, in the field of hydrography and marine geomatics.