OCS Study
BOEM 2018-056

Developing Protocols for Reconstructing Submerged Paleocultural Landscapes and Identifying Ancient Native American Archaeological Sites in Submerged Environments

Field Report: 2013–2016

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DISCLAIMER

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ABOUT THE COVER

Cover photographs (Left image: John King and Brian Caccioppoli coring on Gorton Pond, Warwick, Rhode Island, photograph by Casey Hearn; Right image: Chali Machado examining submerged wood off West Beach, Block Island, Rhode Island, photograph by David Robinson).

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Acronyms and Abbreviations

AMI	Area of Mutual Interest
AMS	accelerator mass spectrometry
BOEM	Bureau of Ocean Energy Management
CHIRP	compressed high intensity radiated pulse
cm	centimeter
CRMC	Coastal Resource Management Council
DOI	Department of the Interior
DTU	dredge test units
ESPIS	Environmental Studies Program Information System
ft	foot
GNSS	Global Navigation Satellite System
in	inch
lb	pound
m	meter
mm	millimeter
NITHPO	Narragansett Indian Tribal Historic Preservation Office
nT	nanoTesla
OCS	Outer Continental Shelf
RIHPHC	Rhode Island Historical Preservation & Heritage Commission
s	second
USACE	US Army Corps of Engineers
VSP	visual sediment probe

1 Introduction

Project fieldwork conducted between 2013 and 2016 consisted of geophysical/remote sensing, geotechnical sediment sampling, and geoarchaeological investigations performed at interior and offshore areas in Rhode Island State waters and on the Outer Continental Shelf (OCS) offshore Rhode Island. Figure 1 illustrates the location of the four areas targeted as case studies for the project. The overall goals of these geological and geoarchaeological investigations were to:

- Assess the extent to which relict paleolandsapes survived post-glacial sea level rise in the study areas and whether or not they contained paleocultural deposits
- Understand the geologic processes associated with paleocultural landscape preservation
- Identify environmental proxies associated with preserved paleocultural landscapes that could be used to develop predictive models regarding the archaeological sensitivity of the seafloor
- Test the efficacy of existing and new survey equipment and methods for identifying and characterizing paleocultural landscapes

The purpose of this document is to summarize the field operations at each study area, and to provide an assessment of the field methodology and data acquisition procedures at each location. The discussion that follows is organized chronologically by year, with details describing each field effort presented according to study area location.

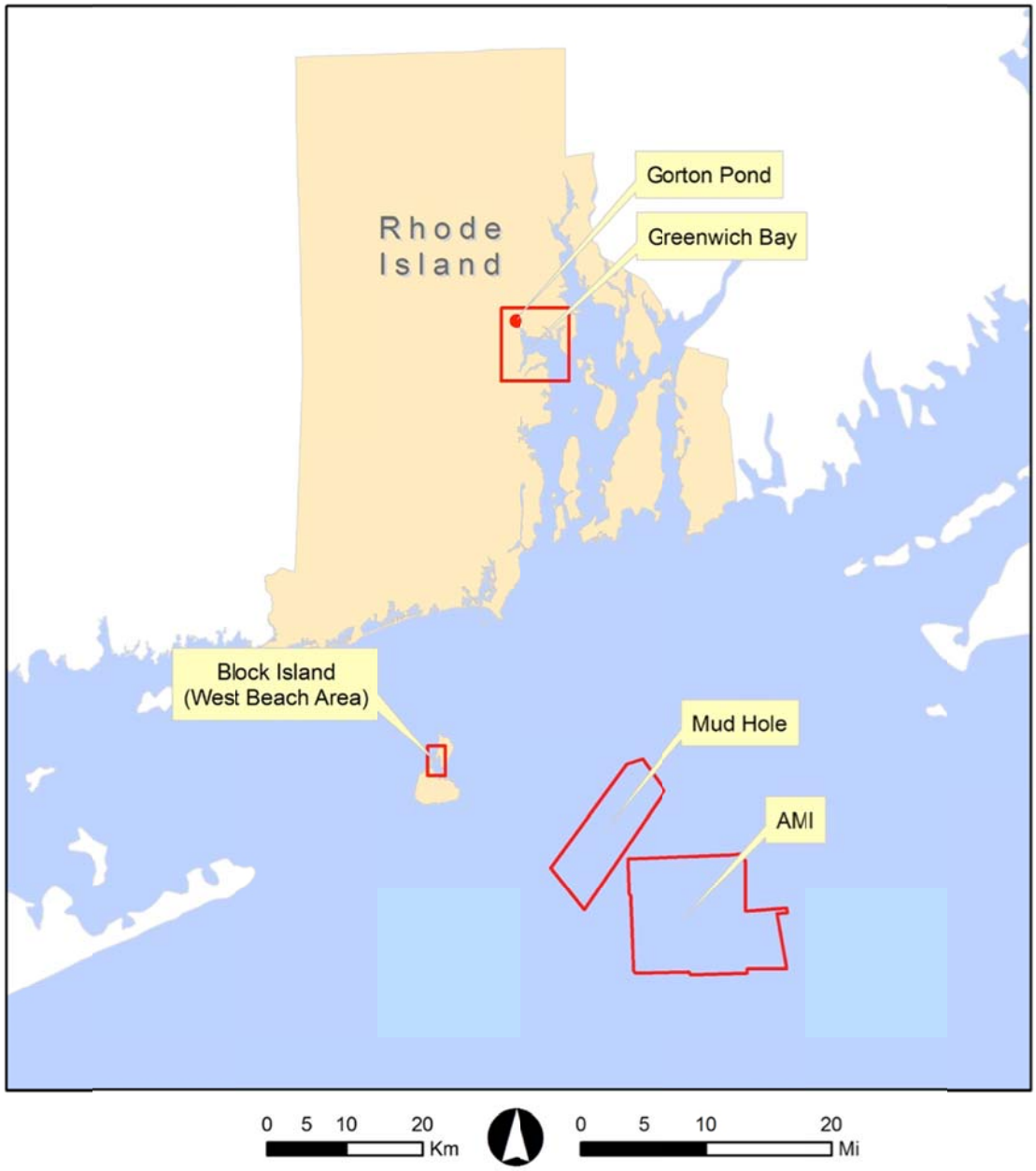

Figure 1. Project study area locations
The "interior" study area consists of Greenwich Bay and nearby Gorton Pond. The "offshore," and/or continental shelf areas, are represented by the Mud Hole, the Area of Mutual Interest (AMI), and the coastal northwestern portion of Block Island (West Beach and Great Salt Pond).

2 2013

Fieldwork for the project began in 2013 and was conducted by the University of Rhode Island's Graduate School of Oceanography (URI-GSO) and their Tribal research partner, the Narragansett Indian Tribal Historic Preservation Office (NITHPO). URI-GSO and NITHPO were assisted in their performance of the fieldwork by two of URI-GSO's project sub-consultants—the URS Corporation (URS) and CR Environmental, Inc. (CR).

The 2013 fieldwork focused exclusively on the two Narragansett Bay interior study areas: 1) Gorton Pond, in Warwick, Rhode Island and 2) the nearshore waters of Greenwich Bay off Cedar Tree Beach, also in Warwick, Rhode Island. Sediment core samples were collected at Gorton Pond, a small, fresh water, glacially formed "kettle pond" that drains into nearby Apponaug Cove. Gradiometric remote sensing, visual sediment probing, and geoarchaeological sub-surface sampling/excavation were conducted in the shallow waters of Cedar Tree Beach, situated in the northwestern corner of Greenwich Bay, at the mouth of Apponaug Cove (Figure 2). All fieldwork was performed in Rhode Island State waters following a Work Plan approved by the Bureau of Ocean Energy Management (BOEM) and NITHPO (Harris to Jordan, October 31, 2012). The Work Plan was executed under a Rhode Island Historical Preservation & Heritage Commission (RIHPHC) Phase I Intensive Archaeological Survey Permit (RIHPHC Permit No. 12-25), issued to URI-GSO's David Robinson (December 31, 2012). Fieldwork was also performed with authorization from the Rhode Island Coastal Resource Management Council (CRMC), provided on August 13, 2013 (CRMC Authorization No. 2013-08-038).

Figure 2. Gorton Pond and Cedar Tree Point/Beach, in the Greenwich Bay area
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

2.1 Greenwich Bay – Cedar Tree Beach: Gradiometric Survey

2.1.1 Justification and Goals

Cedar Tree Beach forms the northwestern shoreline of Greenwich Bay, a major sub-embayment that drains into the larger Narragansett Bay estuary system. Hundreds of pre-contact period stone artifacts have been found by local residents in the exposed swash zone of Cedar Tree Beach. These artifacts do not exhibit significant marine growth or water-wear, suggesting that they originate from a nearby paleocultural landscape. Possible sources are archaeological deposits formerly situated in an ancient low-relief upland now being eroded by the northwardly migrating beach or in a partially eroded and buried submerged paleocultural landscape immediately offshore of the beach. The presence of a buried and submerged paleocultural landscape was suggested by detailed CHIRP (compressed high intensity radiated pulse) sub-bottom sonar survey data acquired previously by URI-GSO. The data depicted an acoustic reflector consistent with a marine bench or flat extending about 100 to 150 m off of Cedar Tree Beach out to the margin of a buried paleochannel near the current modern channel going across Greenwich Bay and into Apponaug Cove. This feature, combined with the large number of artifacts previously found and the protected environment within Greenwich Bay, presented a unique opportunity for conducting systematic, multi-phased geoarchaeological field investigations and field training. The primary goals of the field work at Cedar Tree Beach were to:

- Test the hypotheses that: a) an element of the paleolandscape is preserved submerged and buried off of Cedar Tree Beach; and b) that this paleolandscape may have been utilized by pre-contact period inhabitants and, therefore, could be a source of some of the pre-contact period stone artifacts appearing in Cedar Tree Beach's swash zone

- Test and evaluate the combination of close-interval (i.e., 1 m track line spacing) gradiometric survey, visual sediment probing, and excavation of 1x1 m underwater dredge test units (DTUs) for identifying submerged paleocultural landscapes

- Educate Tribal research partners in the application and use of geophysical survey equipment and non-disturbance marine remote sensing survey methods.

Fieldwork took into account comments and recommendations that were voiced by Tribal participants during the project's initial workshop in March of 2013. As such, the work progressed in phases involving the least-to-most invasive investigation techniques with an overall goal of minimizing the disturbance to the seafloor as much as possible during the performance of all phases of the field investigations.

The first phase involved performance of a close-interval (1-m spaced survey transects) gradiometric survey over a single 50x200 m study area, the northern edge of which was centered on the area where the greatest concentration of artifacts was found by Robin Cooney, long-time resident of the local community. Similar gradiometric surveys performed in terrestrial contexts onshore have proven effective at identifying buried cultural sites, particularly stone-oven, fire pit, and kiln features, where subtle, localized changes in the earth's magnetic field are detectable to gradiometers. The two main goals of this particular phase of survey were to:

- Acquire high-resolution magnetic data within the study area that could be processed and contoured to reveal subtle, low-amplitude, anomalous deflections (possibly associated with cultural features) in the earth's ambient magnetic field. Once located, these magnetic anomalies could then be targeted for focused, phased marine geoarchaeological

investigation consisting of visual ground-truthing and imaging using a visual sediment probe (VSP), and, if warranted, evaluated further through the excavation of 1x1 m underwater DTUs.

- Introduce and familiarize Tribal research partners in the methods of non-disturbance marine remote sensing geoarchaeological survey through active involvement in the field survey and data acquisition processes

2.1.2 Field Operations and Data Quality

The gradiometric survey was conducted over a four-day period between March 23 and March 26, 2013 in the area illustrated in Figure 3. Table 1 provides a summary of personnel involved with the field effort. No survey vessel was utilized. Instrumentation included a total field intensity Geometrics G-858 magnetometer operated in gradiometer mode (i.e., with two fixed magnetometer sensors oriented vertically on a boom and spaced about 1-m apart).

Table 1. Project personnel for Greenwich Bay – Cedar Tree Beach gradiometric survey

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Carol Gibson	URI-GSO	X	-	-	X
Doug Harris	NITHPO	X	X	-	-
Jean Pelletier	AE Com (URS)	X	X	-	X
Christopher Wright	CRE	X	-	X	X
Chali Machado	NITHPO	-	X	-	-
John Brown, IV	NITHPO	-	X	-	-
Muckquashim Hopkins	NITHPO	-	X	-	-

Access to the survey area was from shore via a public right-of-way extending across John Gallonio and Maryellen Hall's beach-front property. Performance of the survey involved walking across the exposed intertidal and submerged shallow sub-tidal portions of the nearshore mudflat off of Cedar Tree Beach. Prior to initiating the survey of each line, the end-points of planned survey tracklines were acquired using a handheld Garmin GPS and marked with flagged sticks, so that the surveyor could use the sticks for visual referencing while walking and collecting data along the transects. A digital left-right indicator on the gradiometer unit that tracked course heading along transects provided additional guidance to the surveyor during data acquisition. The 1-m interval of the planned survey tracklines optimized the density of coverage of the study area and increased the gradiometer's capacity to detect small features, such as might be caused by individual hearths. Gradiometer sensitivity was set at 0.01 nanoTesla (nT) or less, with data sampling set to 0.1 s. These settings yielded approximately one reading per 5 cm over-ground at normal walking/wading speeds of 1.5 m/s. Each magnetometer was fixed for gradiometric operation and was maintained at heights of 1 and 2 m above the harbor floor's surface. Positioning along surveyed lines was recorded in real time with the data from each magnetometer sensor. The quality of the acquired data was determined to be acceptable relative to the requirements of the survey, with minor magnetic noise typical of the Geometrics 858 system noted during data processing. None of the observed magnetic noise was significant enough to obscure magnetic features that were observable in the total field data or in the filtered data that was post-processed and plotted.

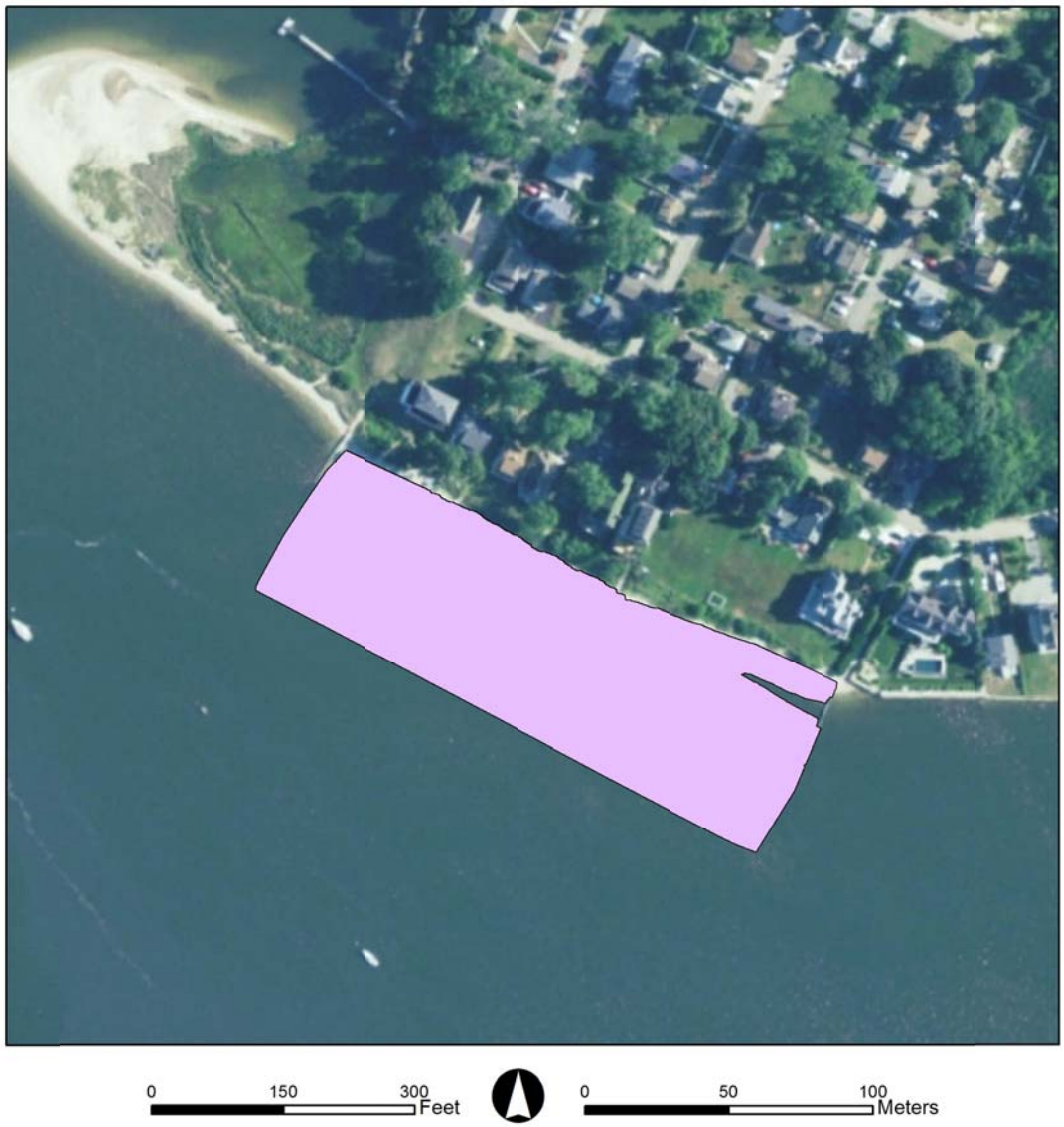

Figure 3. Area covered by gradiometric survey at Greenwich Bay's Cedar Tree Beach, Warwick, Rhode Island (water level shown at high tide)
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

2.1.3 Assessment of Field Operations and Data Acquisition Procedures

Field survey was completed successfully within the 50x200 m study area. Adequate coverage of the overall study area was attained, and the goals of this initial phase of the Cedar Tree Beach investigation were achieved. Three different Tribal representatives from NITHPO (Doug Harris, Muckquashim Hopkins, and Chali Machado) all gained new knowledge and experience in gradiometric survey methods. Acquired data were determined upon examination to be of acceptable quality for nearly all of the survey area with the exception of a narrow section at its southern edge, where data (that was collected along several transects after moisture compromised one of the data cables during survey) appeared to be muted in its range of recorded values as compared to the rest of the recorded data.

2.2 Greenwich Bay – Cedar Tree Beach: Visual Sediment Probing

2.2.1 Justification and Goals

The gradiometric survey performed as the initial phase of fieldwork in the Cedar Tree Beach study area identified numerous magnetic anomalies. Some of these anomalies were clearly associated with visible modern, post-contact period ferrous metal cultural debris and structures (e.g., automobile parts and other debris, as well as the steel fasteners in the wooden groins extending into the water from the beach), while others were of the detectable size (i.e., approximately 0.5 to 3 m in duration) and intensity (i.e., 15 to 30 nT) that were suggestive of representing possible hearth or hearth-like paleocultural features, as indicated in reviewed literature on the subject (Jones and Munson 2005; Hamilton, et al. 2000). This second phase of the geoarchaeological field investigations performed in the Cedar Tree Beach study area involved the selective visual inspection of sub-surface sediments at the locations of all 10 of the magnetic anomalies identified as potential hearth or hearth-like cultural features, based on the visual examination of color-contour plots of the post-processed magnetic data depicting magnetic field strength and changes in the grade or slope between data, as well as the systematic visual examination and documentation of the nature of buried sediments, particularly the marine bench or flat, at 33 locations distributed on a 20-m grid across the entire study area. This visual inspection of the sub-surface sediments was achieved using a unique and minimally invasive technological approach termed "visual sediment probing." Visual investigation of the study area's sediments was justified based on: a) the results of the gradiometric survey; b) the presence of the submerged and buried marine bench or flat seen in the pre-existing sub-bottom profiler data; and c) the presence of hundreds of pre-contact period artifacts that were found at Cedar Tree Beach. The principal goals of the visual sediment probing phase of fieldwork were to:

- Determine the source of the magnetic anomalies identified during the gradiometric survey
- Determine whether or not the marine bench or flat had been previously a subaerially exposed paleocultural landscape with inherent archaeological sensitivity
- Determine whether or not excavation of 1x1 m sub-surface underwater archaeological DTUs was warranted, and, if so, where
- Introduce and provide experience to Tribal research partners in working with minimally invasive, sub-surface visual sediment probing technologies and field methods, data post-processing, and data interpretation

2.2.2 Field Operations and Data Quality

Between September 24 and September 27, 2013, a combined team of URI-GSO and NITHPO field personnel completed a systematic visual examination of sub-surface sediments across the Cedar Tree Beach study area using VSP technology. Table 2 provides a summary of personnel involved with the field effort, and Table 3 summarizes the instrumentation used.

Table 2. Project personnel for Greenwich Bay – Cedar Tree Beach visual sediment probing (2013)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Clifford Heil	URI-GSO	-	X	-	-
Monique LaFrance-Bartley	URI-GSO	-	X	-	-
Danielle Cares	URI-GSO	-	X	-	-
Cameron Morissette	URI-GSO	-	X	-	-
Chali Machado	NITHPO	-	X	X	-
John Brown, IV	NITHPO	-	X	X	-
Norman Machado	NITHPO	-	X	X	-

Table 3. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO Pontoon Boat	Survey vessel	9-m long custom surveying/coring barge
VSP System	Buried sediments imaging (in plan view); ground-truthing of magnetic anomalies	5-m long, 5-cm OD PVC pipe with smaller internal PVC pipe fitted with a color, digital, self-lit "snake-cam" at its lower end. Camera is connected to a vessel-based recording monitor via a video-signal cable for real-time monitoring by topside personnel and recording of video data; optimized for use by personnel wading in shallow water and imaging to a maximum depth of 3 m below the seafloor
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 2 m at the study area

The VSP was used to explore systematically a series of 33 probe-points distributed evenly across the study area on the 20-m nodes of a 10-m grid (Figure 4). An additional 10 selective probe-points centered on magnetic anomaly locations identified during the preceding gradiometric survey phase of the study also were examined using the VSP (Figure 4).

On each day of the VSP survey, the URI-GSO pontoon boat transited with the field team and equipment from Ponaug Marina in Apponaug Cove out to the Cedar Tree Beach study area and anchored. The various elements of the VSP system were then assembled, tested and deployed into the water for operation by two field personnel (co-project investigator Robinson and one of the NITHPO field specialists). Prior to beginning the investigation of each probe-point, an erasable white board with the probe-point's identification information and the date was video-recorded using the probe's camera. Doing so provided a convenient visual index for the VSP video footage. The two in-water field personnel then waded away from the pontoon boat out to the probe location

using the handheld GPS to guide them to the probe-point. Once a probe-point location was occupied and a position fix confirmed, the in-water and topside project personnel coordinated verbally and video-documentation began. The VSP was oriented in a vertical position. Surface sediments on the seafloor were video-documented first with the probe held a short distance off of the bottom. Once the surface sediments were documented, the in-water team indicated to the topside personnel to throttle-up the water-pump delivering flow to the lower end of the VSP to enable it to work its way down into the sediments. The lower end of the VSP was then brought into contact with the seafloor and advanced downward into the sediments at 0.5-m increments. As each depth level was reached, the downward advancement of the VSP was paused long enough to allow the water flowing to its video-camera-equipped lower end to clear, so that sediments could be observed and described in field notes by topside personal watching the monitor and video-documented by the VSP's recording camera. Probing depths with the VSP did not exceed 2.75 m below the seafloor. Most probe depths ranged from 2.25 to 2.5 m below the surface. This depth range (i.e., ca. 2 m) was targeted as the realistic maximum depth limit for safely excavating underwater a 1x1 m dredge test unit in the event that additional sub-surface archaeological testing was warranted by the VSP survey's results. The VSP's probe depth below the seafloor was ascertained and controlled by the in-water personnel during the VSP's operation using the measured scale painted on the outside of the VSP for tracking and control. Probing operations were coordinated between the in-water personnel operating the VSP and the topside personnel viewing the probe's color-digital monitor and recording the VSP's video footage and field notes. Field notes recorded by topside personnel documented each probe-point's identification, the video-clock's start and end times for the overall probe documentation (as well as for each video-documented level), and preliminary observations about what was seen in the monitor. This process was repeated for all of the systematic and selective probe-points distributed across the study area.

Figure 4. Systematic visual sediment probing

Probing was conducted at 31 of the 33 probe-points distributed across the Cedar Tree Beach study area at a 20-m grid interval (represented by the yellow circles) and at 10 selective locations (represented by the pink crosses labeled S1, S2, S3, etc.) where magnetic anomalies were identified during the gradiometer survey. Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

2.2.3 Assessment of Field Operations and Data Acquisition Procedures

VSP survey operations proceeded smoothly and quickly, with between 7 and 12 probe-points completed each day. The efficiency of the process was somewhat surprising, because only one member of the field team (Robinson) had any previous experience working with the VSP technology, no similar type of combined selective and systematic VSP survey had ever been conducted, and this was the greatest number of probe-points that had ever been investigated.

Cavitation-induced, excessive bubbling of the water pumped to the lower end of the VSP, which initially interfered with its video camera's imaging capability, was eliminated by an in-field modification that was conceived of and applied by NITHPO's Norman Machado to the water-supply hose attached to the VSP's outer PVC pipe.

The VSP's imaging system performed efficiently as a minimally invasive, expedient, first-pass approach to imaging sediments in the study area. The VSP provides a view and information about the sediments that is completely different from that which is obtained using coring technologies. The VSP provided a plan view of the sediments and their various strata, which enabled the physical characteristics of the sediments to be observed dynamically as flow of the VSP's water eroded them and allowed for the identification and imaging of the surfaces of formerly subaerial, desiccated, and dessication-cracked sediment strata (i.e., archaeologically sensitive, submerged paleo-landsurfaces), neither of which is attainable from observing split core samples. All but two of the systematic probe-points targeted for investigation using the VSP, one of which was at a groin location and the other of which was located onshore, were explored. Thus, a total of 41 VSP points was explored during this phase of the Cedar Tree Beach geoarchaeological investigation.

2.3 Gorton Pond: Sediment Coring

2.3.1 Justification and Goals

Gorton Pond is a freshwater glacial kettle lake that drains into Apponaug Cove in the northwestern portion of Greenwich Bay (Figure 5). It is located approximately 2.4 km from the Cedar Tree Beach study area. Sediment cores collected at Gorton Pond prior the initiation of this project provided a preliminary age model and paleoenvironmental record of this area (Morissette 2014). The purpose of the field effort at Gorton Pond was to obtain additional longer cores that would be analyzed for a variety of proxies in order to assist in the creation of a more detailed paleoenvironmental reconstruction of the Greenwich Bay area. Two coring systems were employed to recover the most complete sedimentary record: biological-type coring, which excels at preserving the sediment-water interface, and Livingston-type coring, which allows for the recovery of long, continuous sediment cores through multiple drives in the same cased hole.

Figure 5. Location of sediment cores (GP13BC1 and GP13LC2) obtained in Gorton Pond, Warwick, Rhode Island
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

2.3.2 Field Operations and Data Quality

Prior to initiating field operations at Gorton Pond, the URI-GSO project team requested authorization from the Rhode Island CRMC and the US Army Corps of Engineers (USACE) to conduct coring. URI-GSO was informed that as long as all cores were removed from the lake for analysis (i.e., no side-casting of sediments), then a USACE permit for coring was not required. Coring was conducted under CRMC authorization (No. 2013-08-038). Field operations occurred on August 16, 2013.

Table 4 provides a summary of personnel involved with the field effort, and Table 5 summarizes the instrumentation used. Personnel for small vessel/inshore coring operations were chosen based on availability and experience.

Table 4. Project personnel for Gorton Pond sediment coring (2013)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
John King	URI-GSO	X	X	X	X
Chip Heil	URI-GSO	X	X	-	-
Cameron Morissette	URI-GSO	X	X	X	X
Brian Caccioppoli	URI-GSO	X	X	X	X

Table 5. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Livingston-type coring system	Sediment coring	Optimized for use in lakes containing up to 25 m of post-glacial sediment; obtains continuous 1–1.5 m core sections through a cased hole
Biological-type coring system	Sediment coring	<2 m coring capacity; 2.4 m polycarbonate liner; optimized for use in flocculent or loosely compacted sediments
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 9 ft at the study area

Coring at Gorton Pond was centered in the deepest part of pond in water depth of approximately 13 m (Figure 5). Because high-resolution bathymetric data was not available for Gorton Pond, the latitude/longitude of the targeted "deep hole" was obtained prior to the field expedition by using ArcGIS software to digitize and georegister a paper bathymetric map available through the Rhode Island Department of Environmental Management (RI DEM, 2013), which represented the best available data for the area.

The survey vessel was trailered from URI-GSO to an easily accessible location at Gorton Pond and launched successfully, and the coring team motored to the study location. A handheld Garmin GPS unit was used to navigate to the target location. Once the vessel was on station, it was anchored using two Danforth anchors cleated to the bow and a zinc weight cleated to the stern, after which coring operations commenced.

The goal of the coring effort was to maximize the length of the recovered sediment record while insuring that the sediment-water interface and the upper part of the sediment record was recovered intact; therefore, the two cores were taken at the same location. A "biological-type" coring system was deployed first to recover the sediment/water interface and upper sediment section with minimal disturbance. This system consists of a 2.4 m polycarbonate core liner, square threaded pushrods, and an internal piston deployed through the vessel's "moon pool" (a square hatch in the middle of the vessel's deck). Biological coring is initiated by setting the internal piston into its starting position and lowering the core barrel to the seafloor. The sediment core is collected by a single drive of core barrel until refusal is met. Coring operations proceeded smoothly, and core "GP13BC1," representing 0–115 cm of the sediment section, was successfully recovered. In order to

ensure that the sediment/water interface and internal stratigraphy of the core were preserved, the core was filled with seawater and strapped upright on the boat and allowed to settle before the excess core liner was cut down and the core was capped.

After the recovery of the biological core, coring operations switched to the Livingstone system. Livingstone coring was implemented with successive 1-m coring drives, allowing for the collection of long, continuous sediment cores. This was achieved by guiding the Livingstone core barrel, piston, and drive rods through steel casing, which simultaneously keeps the core hole open, directs each successive drive through the original hole, and prevents the push rods from bending under force.

For the first drive, the depth of the water minus the length of the core barrel determined the length of drive rods required. After the recovery of the first drive, the sediment core was then extruded from the core barrel and packaged in a liner. Prior to the second drive, the starting depth of the sediment core was recorded, and ending drive depth was marked on the drive rod. The coring procedure was then repeated for each successive drive.

Table 6 summarizes the names and depths of the cores/core sections that were recovered and vertically correlated to create a composite sediment section.

Table 6. Recovered cores/core sections

Core Name	Type	Sediment Depth (cm)
GP13BC1	Biological	0–115
GP13 LC2D1	Livingston, Drive 1	0–192 (recovered, but lost in field)
GP13 LC2D2	Livingston, Drive 2	192–278
GP13 LC2D3	Livingston, Drive 3	284–377
GP13 LC2D4	Livingston, Drive 4	382–477
GP13 LC2D5	Livingston, Drive 5	481–577
GP13 LC2D6	Livingston, Drive 6	575–670

2.3.3 Assessment of Field Operations and Achievement of Objectives

Coring operations at Gorton Pond proceeded smoothly, and both the Biological and Livingston coring systems performed as expected. Subsequent analysis of the recovered cores indicated that a nearly complete post-glacial sedimentary record was recovered. Paleoenviromental proxy analyses from the recovered cores provided the basis for the construction of a regional paleoenvironmental reference record the for the entire study area.

Drive 1 of GP13 LC2 displayed poor preservation of stratigraphy in the saturated sediments and was determined to be inappropriate for further use. Because the biological core was only 115 cm in total length, there was a gap in the sediment record to the starting depth (192 cm) of GP13 LC2 Drive 2. Due to time constraints, the gap in the sediment record was addressed with an additional core to be obtained during a subsequent field effort. 2014

2.4 Greenwich Bay – Cedar Tree Beach: Underwater Archaeological Investigations

VSP data recorded in 2013 during the second phase of the geoarchaeological field investigation of the Cedar Tree Beach study area produced visual evidence of archaeologically sensitive and formerly subaerial sediments and possible cultural features and artifacts at several of the probed locations. These locations were hierarchically organized based on their information potential and distribution across the study area. Two areas with the greatest information potential located at opposite ends of the study area were selective VSP probe-point "S2" and systematic VSP probe-point "B17" (Figure 4). VSP probe-point S2 was selected because it was observed in the VSP video data to contain a stratified, oxidized, desiccated and sunbaked (indicative of a formerly subaerial surface), organic, archaeologically sensitive, soil-like deposit buried approximately 1.3 m below the surface of the sub-tidal bay floor. VSP probe-point B17 was selected because it was observed in the VSP video data to contain what appeared to be stratified organic sediments with a single piece of lithic chipping debris, as well as wood and charcoal, embedded in it, at a depth of approximately 1.5 m below the bay floor's sub-tidal surface.

Each of these two areas were chosen to be subjected to the final, and most invasive, of the three phases of marine geoarchaeological investigation that were conducted in the Cedar Tree Beach study area—the excavation of 1x1 m underwater DTUs. Underwater archaeological excavation was conducted in the Cedar Tree Beach study area in three separate field deployments that took place during the months of June, July, and October of 2014.

2.4.1 Excavation of Underwater Dredge Test Unit S2, June 2014

2.4.1.1 Justification and Goals

Excavation of 1x1 m underwater DTUs is, like all archaeological excavation, inherently destructive; however, it provides a larger physical "window" through which to observe, sample, and document the geoarchaeological record. From a scientific research perspective, as long as the excavation is conducted properly and well-documented, the information gained is generally thought to justify the destruction of the excavated portion of the investigated cultural site. This is a perspective that is not widely shared by many Tribal people, for whom the Earth, and their ancestral cultural sites that are a part of it, have inherent spirituality that is best left undisturbed and protected from destruction. In order to respect the importance of this perspective, the originally planned underwater archaeological excavations of six 1x1 m DTUs was reduced to two DTUs, representing a nearly 70 percent decrease in the amount of disturbance to the seafloor caused by this particular phase of the geoarchaeological field investigation at Cedar Tree Beach and a commensurate decrease in the information learned about the site. The justification for excavating these two locations was that they would provide information that would enable the further evaluation of the extent, nature, and content of the preserved, stratified, and formerly subaerial sediments within the full study area, and that it would provide an opportunity for determining the presence/absence of cultural deposits at the two sampled locations (i.e., selective probe-point location S2 and the systematic probe-point location B17) (Figure 4).

2.4.1.2 Field Operations and Data Quality

Between June 9 and June 18, 2014, a combined team of BOEM, NITHPO, and URI-GSO field personnel commenced the underwater archaeological excavation of the first of two 1 x 1 m DTUs. Table 7 provides a summary of personnel involved with the field effort, and Table 8 summarizes the instrumentation used.

Table 7. Project personnel for Greenwich Bay – Cedar Tree Beach underwater dredge text unit 52 (June 2014)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Doug Harris	NITHPO	X	X	-	-
John Brown, IV	URI	-	X	-	-
Chali Machado	URI	-	X	-	-
Norman Machado	URI	-	X	-	-
Brian Jordan	BOEM	X	X	-	-
Brandi Carrier	BOEM	-	X	-	-
Willie Hoffman	BOEM	-	X	-	-

Table 8. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO Pontoon Boat	Dive platform	9-m long motorized custom barge
Induction Dredge System	Underwater archaeological excavation of submerged sediments in 10 cm levels	Honda water-pump attached to 8-cm diameter dredge-head and exhaust hose fitted with 3-mm to 6-mm mesh bags at its end to act as a screen
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 2 m at the study area

On each day of the underwater excavation, the URI-GSO pontoon boat transited with the field team, diving equipment, and underwater excavation equipment from the Ponaug Marina in Apponaug Cove out to the Cedar Tree Beach study area, and the boat was anchored close to the excavation location. All underwater excavation was accomplished by a team of archaeological scuba divers from URI-GSO, NITHPO, and BOEM working together to excavate the DTU underwater by hand, assisted by an 8 cm diameter induction dredge. Excavation was conducted following natural stratum changes, or in 10 cm levels when individual strata exceed 10 cm in thickness. All excavated materials were screened through one of two different sizes (3 and 6 mm) nylon mesh bags. These bags were attached to the end of the dredge's exhaust hose and were replaced with a new bag with each change in stratum or 10 cm level. The larger-sized mesh bag was used during the excavation of marine sediment overburden, and the smaller-sized mesh bag was used when culturally sensitive strata depths noted in the VSP data were approached. Each dredge bag's contents were examined and sifted by topside personnel looking for evidence of artifacts and ecofacts. Recovered artifacts and ecofacts were retained, labeled, bagged (to keep them wet), and then inventoried when brought back to the laboratory at URI-GSO for final processing, analysis, and cataloging of their contents.

2.4.1.2 Assessment of Field Operations and Data Acquisition Procedures

The pontoon boat was a suitable platform for conducting diving and underwater excavation operations with a large field team at the S2 DTU site and the underwater excavation equipment worked as expected; however, unfavorable tides and inclement weather days limited field operations. These unfavorable conditions were exacerbated by a) poor underwater visibility, which ranged from 0 to 1 m and made underwater video- and photo-documentation difficult to accomplish; and b) the non-cohesive nature of the fine silt comprising the uppermost sediment strata in the S2 DTU, which caused the side-walls of the DTU to slump-in overnight and the perimeter of the DTU to expand into circle extending about 0.25 m beyond the limits of the square DTU. The combination of unfavorable environmental conditions and the extra time required to conduct onsite training in underwater excavation procedures, in which some members of the field team had no previous experience, resulted in the excavation of the S2 DTU proceeding much more slowly than anticipated, taking a total of 40 hours over two different field deployments.

The fieldwork conducted during this initial deployment marked two significant milestones in the history of New England archaeology as 1) the first time that Tribal scientific divers/field specialists performed archaeological excavation of DTUs underwater and 2) the first time in URI or BOEM's history that their archaeological staff had worked underwater side-by-side with Tribal field specialists.

2.4.2 Completion of the Excavation of Underwater Dredge Test Unit S2, July 2014

2.4.2.1 Justification and Goals

The justification and goals were the same as described above in Section 2.4.1.

2.4.2.2 Field Operations and Data Quality

Field operations for this deployment were essentially the same as those described in Sections 2.4.1 with several exceptions. Underwater excavation of the S2 DTU was completed in July 2014 by a reduced field team composed of two archaeological divers from URI and NITHPO and a topside field specialist from URI, who staged diving operations from the shore of Cedar Tree Beach and employed a 2.5-m square, portable, modular-construction, "dock-block" raft (termed the "R/V *Lego*"), for transporting and operating the underwater excavation equipment. Table 9 summarizes the project personnel involved in the field effort, and Table 10 details the survey vessel and instrumentation used.

Table 9. Project personnel for underwater dredge text unit 52 (July 2014)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Norman Machado	NITHPO	-	X	-	-
Michael Robinson	URI	-	X	-	-

Table 10. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO R/V *Lego*	Dredging Equipment Platform	2.5-m square "dock-block" portable raft equipped with marine archaeological dredging equipment
Induction Dredge System	Underwater archaeological excavation of submerged sediments in 10-cm levels	Honda water-pump attached to 8-cm diameter dredge-head and exhaust hose fitted with 3-mm to 6-mm mesh bags at its end to act as a screen
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 2 m at the study area

Access to the Cedar Tree Beach study area for this deployment, and for the subsequent October 2014 deployment, was attained through the same public right-of-way to the beach utilized during the gradiometric survey, and by crossing and/or occupying (with the owners' permissions) the Bacarri, Gallonio, Jacques, and Pickering beach-front properties.

The R/V *Lego* components, diving gear, and the excavation equipment were transported from the URI-GSO to the Cedar Tree Beach public right-of-way by truck and assembled on site. The assembled R/V *Lego* was then hand-pulled down to the water by the field personnel, where it was loaded with the diving and underwater excavation equipment. The R/V *Lego* was then pushed out to the location of the S2 DTU and anchored approximately 10 m away from it to allow adequate space for deploying the dredge's various hoses. Excavation was conducted using the same equipment and procedures as used during the initial June 2014 excavation deployment. The one methodological difference was that a 1x1 m by 30 cm tall by 7 mm thick clear plexiglass cofferdam, custom-made for the project by Michael Robinson, was employed to prevent the uppermost sediment stratum from slumping-in during excavation. At the end of each field day, the R/V *Lego* was brought to shore, hauled across the beach and the Jacques property, and stored overnight on the Pickering property. In addition to allowing the temporary storage of the excavation platform on their property for the duration of the July and October deployments, the Pickerings also generously shared off-road parking space in their driveway for project vehicles and opened their home to the field team as a place to change, shower, and use the restroom.

Upon completion of the excavation, the S2 DTU was backfilled with plastic bags of clean builder's sand. The last 20 cm of the DTU were filled by dumping the clean builder's sand into the top of the unit so that the plastic bags were not visible and the bay floor was as close to its natural appearance as possible. The plastic bags were retained on the bags of sand used to fill the lower part of the unit to assist in identifying the excavated unit in the event that additional archaeological excavation work is ever undertaken again in the Cedar Tree Beach study area.

Visual observations and note-taking, as well as video- and photo-documentation, conducted during the excavation of the S2 DTU were limited in their quality and extent by the extremely poor underwater visibility conditions that persisted in the study area and generally only allowed for minimal underwater note-taking and very short-range imaging. Despite this challenge, stratigraphy within the S2 DTU was video-documented successfully using a handheld GoPro Hero 4 (Black) high-definition video camera. A plastic folding-rule extending the full depth of the DTU was included in the video as a graphic scale. This video was reviewed to ascertain the precise thicknesses of each stratum in the overall stratigraphic sequence and correlated with field observations and notes about the contents of the different strata to produce a record of the S2 DTU's stratigraphy and contents. A sample of *in situ* organic material from the formerly subaerial stratum visible in the side-wall of the excavation unit, and several organic macrofossils that were identified and retained

during the topside sifting of the mesh dredge bag were collected for accelerator mass spectrometry (AMS) radiocarbon dating by Beta Analytic.

2.4.2.3 Assessment of Field Operations and Data Acquisition Procedures

The addition of the plexiglass cofferdam was effective in halting the slumping of uppermost sediments in the upper stratum. Below the 30-cm level, sediments progressively became more cohesive, and additional coffer-damming was not necessary; however, maintaining straight and vertical side-walls while working inside the DTU with the dredge-head proved impossible due to the relatively great (1.52 m) excavated depth of the DTU that was required to reach the targeted formerly subaerial sediments that had been observed in the VSP data from that location.

2.4.3 Underwater Excavation of B17 DTU, October 2014

2.4.3.1 Justification and Goals

The overall justification and goals for excavating at the B17 DTU location were essentially the same as those described above for the S2 DTU in Section 3.1.1. More specifically, the B17 VSP probe-point was selected for archaeological testing because it contained what appeared to be stratified organic sediments with a single piece of lithic chipping debris, as well as wood and charcoal, embedded in it, which were observed during the analysis of the VSP video data to be at a depth of approximately 1.5 m below the bay floor's surface. The VSP B17 DTU location was also selected, because of its position on the opposite side of the study area, which provided a window into the paleoenvironmental history on the study area's opposite (eastern) end.

2.4.3.2 Field Operations and Data Quality

Field operations during this third and final field deployment to conduct underwater excavation in the Cedar Tree Beach study area were completed over just a three-day period. Table 11 summarizes the project personnel involved in the field effort, and Table 12 details the survey vessel and instrumentation used. Field activities were performed in essentially the same way as those

Table 11. Project personnel for underwater excavation of B17 DTU (October 2014)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Norman Machado	URI	-	X	X	-
Michael Robinson	URI	-	X	X	-
Sean Davis	URI	-	X	X	-

Table 12. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO R/V *Lego*	Dredging Equipment Platform	2.5-m square "dock-block" portable raft equipped with marine archaeological dredging equipment
Induction Dredge System	Underwater archaeological excavation of submerged sediments in 10-cm levels	Honda water-pump attached to 8-cm diameter dredge-head and exhaust hose fitted with 3-mm to 6-mm mesh bags at its end to act as a screen
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 2 m at the study area

above in Section 3.1.2 for the completion of the S2 DTU (i.e., excavation was completed using the clear plexiglass cofferdam by a reduced field crew using R/V *Lego*, the small, portable, modular excavation equipment platform. Positioning of the B17 DTU location for excavation was accomplished using the handheld GPS unit, with the precise position of the archaeological testing location confirmed by relocating the small depression left in the bottom by the VSP at the B17 VSP probe-point.

2.4.3.3 Assessment of Field Operations and Data Acquisition Procedures

The combination of experience, along with the colder, clearer waters of autumn, led to improved efficiency in field operations. Excavation of the B17 DTU down to a maximum depth of 1.8 m below the surface of the bay floor proceeded efficiently and quickly with all equipment working as expected. Excavation and documentation of the B17 DTU required just 9 hours to complete, thereby representing a significant improvement in the overall amount of time required to excavate a 1x1 m DTU in similar conditions. Upon the completion of the documentation work, the B17 DTU was backfilled with clean builder's sand in the same manner as the S2 DTU was backfilled.

2.5 Greenwich Bay: Vibracoring Offshore of Cedar Tree Beach

2.5.1 Vibracore Equipment Testing

2.5.1.1 Justification and Goals

Vibracoring is a useful coring methodology, particularly in sandy environments where other traditional coring methods become difficult. With several coring operations being planned in both nearshore and offshore environments, a test of our vibracoring equipment was performed to help determine the most suitable setup.

2.5.1.2 Field Operations and Data Quality

Field work at Greenwich Bay began on June 26, 2014. Table 13 summarizes the project personnel involved in the field effort, and Table 14 details the survey vessel and instrumentation used. Personnel were selected based on availability and experience.

Table 13. Project personnel for vibracoring offshore of Cedar Tree Beach (2014)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	-	X	X	-
Danielle Cares	URI-GSO	-	X	X	-
Casey Hearn	URI-GSO	-	X	X	-
Chip Heil	URI-GSO	X	X	X	-
John King	URI-GSO	X	X	X	X

Table 14. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Vibracore system	Sediment coring	Rossfelder P-3 Vibra-Percussive system with 60-m working depth, accommodating 3- or 4-inch core barrels typically 3–6 m in length.
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 9 ft at the study area

The vibracoring system was transported to Greenwich Bay on the R/V Shanna Rose. The pontoon boat was trailered to Ponaug Marina in Warwick, RI, launched, and transited to Greenwich Bay to rendezvous with the R/V Shanna Rose. The generator set ("genset") and vibracore head were transferred to the pontoon boat, and the pontoon boat returned to the marina for pre-coring setup. The boat was successfully rigged for vibracoring, and the vibracoring system was briefly powered on at the dock.

Coring operations began on June 27, 2014. The pontoon boat was transited to the Cedar Tree Beach study area. A handheld GPS was used to record the core's location and a portable depth finder measured the water depth. The boat was anchored using two Danforth anchors from the bow and a zinc weight deployed from the stern. A 3-m long, 4-inch diameter PVC core barrel was fitted with a stainless-steel core cutter and core catcher and attached to the vibracore head. The vibracoring system was lowered by hydraulic winch to the seafloor and powered on. After a full drive was achieved, the vibracoring system was powered off and pulled back to the surface. The core barrel was detached from the vibracore head and the recovered sediment was measured to be 306.5 cm. The core barrel was capped and stored for transit. Table 15 summarizes the core characteristics, and Figure 6 illustrates the location of recovered core (CTB-14).

Table 15. Core characteristics.

Core Name	Type	Sediment Depth (cm)
CTB VC-14	Vibracore	0–306.5

The pontoon boat was returned to the marina and the vibracoring gear and boat were brought back to URI-GSO for storage.

Figure 6. Location of sediment cores obtained near Cedar Tree Beach, Warwick, Rhode Island in June (CTB VC-14) and December (CTB VC-17, Apponaug Cove B1 2014)
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

2.5.1.3 Assessment of Field Operations and Data Acquisition Procedures

Having recovered a full core barrel, the coring team was satisfied with the functionality of the vibracoring system. The test was conducted in marine sediments composed primarily of fine sand and silt. The 4-in diameter PVC core barrel performed well in these sediments; however, it was unclear if this would be the case in coarser (i.e. medium-coarse sand and gravel) sediments. Similarly, if buried terrestrial/lakefloor sediments are encountered, it is uncertain how well the system would perform. Future coring operations would demonstrate the limits of our vibracoring system. (For further discussion, see Section 3.2.2.)

2.5.2 Additional Vibracoring in the Cedar Tree Beach Area

2.5.2.1 Justification and Goals

After preliminary testing of the vibracoring system along Cedar Tree Beach in June 2014 (see Section 3.2.1), additional vibracores were planned to supplement existing archaeological data (i.e., dredge pits, video probe survey). These cores were intended to provide an undisturbed look at

the sub-surface geology, with the goal of identifying buried terrestrial deposits. Identified terrestrial deposits can be depth correlated with sub-bottom profiler data and mapped throughout the study area. This paleolandscape reconstruction paired with existing archaeological data at Cedar Tree Beach enables a site-specific assessment of archaeological sensitivity.

2.5.2.2 Field Operations and Data Quality

Field operations began on December 15, 2014. Table 16 summarizes the project personnel involved in the field effort, and Table 17 details the survey vessel and instrumentation used. Once again, personnel selected for this field operation was based on availability and experience.

Table 16. Project personnel for additional vibracoring in the Cedar Tree Beach area (2014)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	X	X	X	X
Mike Dalton	URI-GSO	-	X	-	-
Casey Hearn	URI-GSO	X	X	-	-
John King	URI-GSO	X	X	X	X

Table 17. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Vibracore system	Sediment coring	Rossfelder P-3 Vibra-Percussive system with 600-m working depth, accommodating 3- or 4-inch core barrels typically 3–6 m in length
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 9 ft at the study area

The vibracoring system and the URI-GSO pontoon boat were transported to Ponaug Marina in Warwick, RI. The boat was launched and moved to a slip where the vibracoring system was loaded and set up. After setup was complete, the boat transited to Apponaug Cove, just to the northwest of the Cedar Tree Beach study area, and a handheld GPS was used to navigate to a preselected coring location. Water depth was measured by a portable depth sounder, and the boat was anchored in position. A vibracore barrel was assembled, attached to the vibracore head and lowered to the seafloor. Once on the seafloor, the system was powered on, and a vibracore was collected. The system was powered off, and the core barrel was pulled back to the deck of the pontoon boat. The recovered sediment length was measured as 200 cm and the core was capped and stored on the deck of the boat.

After a successful recovery from Apponaug Cove (Figure 6, “Apponaug Cove B1 2014”), the boat was transited to the Cedar Tree Beach study area. The first coring site targeted was CTB VCH-17 (Figure 6) on the east side of the study area. The vibracoring procedure was repeated once on station. Recovery of sediment at this station proved to be significantly more difficult due to shallower (~1 m) water depths and coarser sand. With three attempts, two cores were successfully recovered, measuring 60 and 80 cm in length. Vibracoring through this coarser sand led to the core catcher components becoming damaged. Typically, the core catcher prevents sediment from falling back through the core barrel when recovering the core. At this station, the core catchers were

damaged, reducing their effectiveness at preventing sediment loss. On the last attempt, all sediment was lost from the core barrel. Due to the poor recovery, coring operations were ended. The boat and vibracoring equipment were transported back to URI-GSO for storage. Table 18 summarizes the sediment recovered at the coring location.

Table 18. Sediment recovered at coring location

Core Name	Type	Sediment Depth (cm)
Apponaug Cove B1 2014	Vibracore	0–200
CTB VC-17 (CTB1)	Vibracore	0–60
CTB VC-17 (CTB2)	Vibracore	0–80

2.5.2.3 Assessment of Field Operations and Data Acquisition Procedures

The coring operation at Cedar Tree Beach proved to be difficult due to coarse sediment. Recovery of sediment was difficult due to damage to the core catchers, causing much of the sediment to be lost. As a result, more robust core catchers were fabricated for use in future vibracoring operations to improve the recovery of sediment in the core barrels. Also, to promote sediment recovery, we reduced the core barrel diameter to 3 in. The weight of the sediment in the core barrel would be considerably lighter and therefore would be less likely to damage the core catchers. For better chances of success during the next coring operation, it was critical to coincide coring operations with the peak high tide, especially at the more inshore coring locations.

3 2015

3.1 Gorton Pond: Coring

3.1.1 Justification and Goals

A primary goal of this coring operation was to address an existing data gap in a previously collected Livingston core (GP-13 LC2D1, see Section 2.3). The uppermost section of this core was determined to be too low quality in the field due to poor preservation of stratigraphy. Additional Biological and Livingston cores were collected at nearby sites along the pond to contribute to the local paleoenvironmental reconstruction produced by Morissette (2014).

3.1.2 Field Operations and Data Quality

Figure 7 illustrates the location of the cores recovered during the coring effort, and Table 19 summarizes the project personnel involved in the field effort. Due to thick ice cover of Gorton Pond (~ 30 cm), coring operations were conducted without the use of a coring platform. Beginning on the morning of March 11, 2015, the coring gear was loaded into a truck and transported from URI-GSO to Gorton Pond. Upon arrival, all coring gear was hand carried or pulled on toboggans to the coring location, which was located using the handheld GPS. A hole in the ice was opened using an ice auger at each location, and the water depth was subsequently measured. First, biological cores were collected at three separate locations. Coring operations were then switched to Livingstone coring, in which two multi-drive sediment cores were collected very near to the first and third biological core locations. All cores were properly packaged on site and transported back to URI-GSO for storage, processing, and analysis.

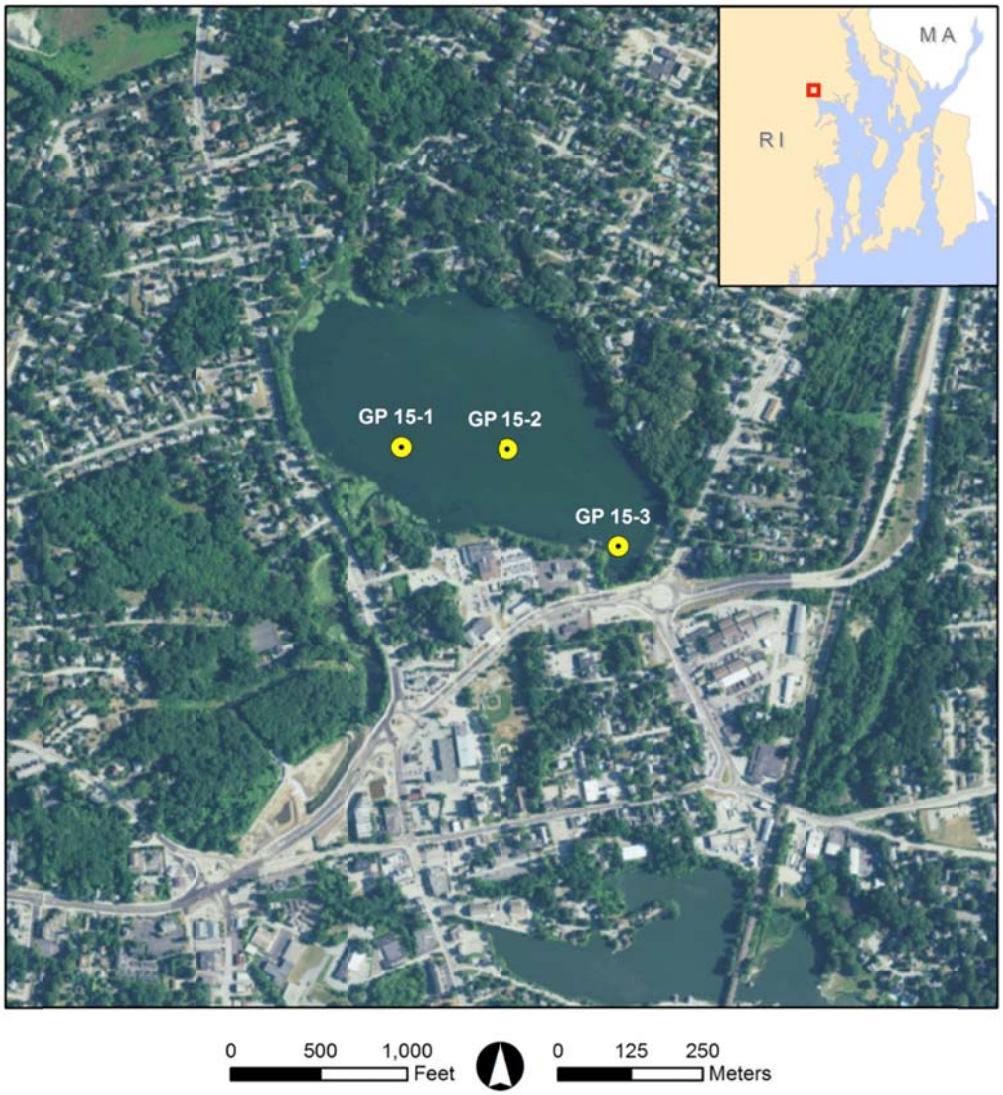

Figure 7. Location of sediment cores (GP 15-1, GP 15-2, and GP 15-3) obtained in Gorton Pond, Warwick, Rhode Island

Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

Table 19. Project personnel for Gorton Pond coring (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	-	X	-	-
Casey Hearn	URI-GSO	-	X	-	-
John King	URI-GSO	X	X	X	X
David Robinson	URI-GSO	X	X	X	X
Michael Robinson	URI-GSO	-	X	-	-
Noah Robinson	URI-GSO	-	X	-	-

Table 20. Survey vessel and instrumentation

Equipment	Function	Description
Livingston-type coring system	Sediment coring	Optimized for use in lakes containing up to 25 m of post-glacial sediment; obtains continuous 1–1.5 m core sections through a cased hole
Biological-type coring system	Sediment coring	<2 m coring capacity; 2.4 m polycarbonate liner; optimized for use in flocculent or loosely compacted sediments
Garmin GPSMap 76 Portable GPS	Navigational position	Positional accuracy approximately + 9 ft at the study area

Note: No coring platform or vessel required due to thick ice cover.

The following table summarizes the characteristics of the recovered cores.

Table 21. Characteristics of recovered cores

Core Name	Type	Sediment Depth (cm)
GP15-1	Biological	0–189
GP15-1	Livingston, Drive 1	169–286
GP15-1	Livingston, Drive 2	286–356
GP15-2	Biological	0–203
GP15-3	Biological	0–186
GP15-3	Livingston, Drive 1	170–287
GP15-3	Livingston, Drive 2	287–304

3.1.3 Assessment of Field Operations and Data Acquisition Procedures

All cores were successfully collected, with no notable disturbances or gaps in the sediment record. Biological cores maintained good sediment/water interfaces, and the objectives of the field effort were achieved.

3.2 Greenwich Bay – Cedar Tree Beach: Vibracoring

3.2.1 Justification and Goals

The primary goal of collecting additional vibracores at the Cedar Tree Beach site was to aid in the construction of a site-specific geologic framework. Numerous pre-contact period Native American stone tools have been found along the beach at Cedar Tree Beach. Without having identified a source, terrestrial geologic stratum and the near pristine nature of the tools suggests that tools are preserved in a shallow buried terrestrial setting just offshore of Cedar Tree Beach. Thus, an additional goal was to capture the longest possible vibracore and identify any potential terrestrial deposits contained within the core.

3.2.2 Field Operations and Data Quality

Selected vibracore locations were planned to provide geological context of the Cedar Tree Beach archaeological site. For efficient site characterization, a transect approach was favored. Coring sites were planned in three-core shore-parallel and three-core shore perpendicular transects. Vibracoring field operations took place over three days: May 14, May 20 and May 21, 2015. Table 22 summarizes the project personnel involved in the field effort, and Table 23 summarizes the instrumentation used.

Table 22. Project personnel for Greenwich Bay – Cedar Tree Branch vibracoring (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
John King	URI-GSO	X	X	X	X
Mike Dalton	URI-GSO	-	X	-	-
Casey Hearn	URI-GSO	-	X	-	-
Brian Caccioppoli	URI-GSO	X	X	X	X
Chip Heil	URI-GSO	-	X	-	-

Table 23. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Vibracore system	Sediment coring	Rossfelder P-3 Vibro-Percussive system with 600-m working depth, accommodating 8- or 10-cm core barrels typically 3–6 m in length
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately + 9 ft at the study area

Beginning on May 14, 2015, all vibracoring equipment and the pontoon boat were transported to Ponaug Marina in Warwick, RI. The pontoon boat was launched at the boat ramp and pulled into a transient slip to re-rig the boat for vibracore operations. A tripod coring frame was erected and centered over the boat's moon pool, and the vibracore head was raised into position via the boat's hydraulic winch and secured for transit. Using the handheld GPS for navigation, the boat was driven to the Cedar Tree Beach study area and stationed on the first coring location CTB-VC10-1. A core cutter and core catcher were attached to a previously prepared 4-in diameter PVC core barrel, which was then affixed to the vibracore head. The vibracore was powered on by the generator and lowered for core collection. After refusal, the vibracore was powered off and raised to the surface by the hydraulic winch. The core barrel was then disassembled, recovery length was measured and the core barrel was capped. Water depths were too shallow to continue coring at the Cedar Tree Beach study area. A second core was collected in nearby Apponaug Cove (Apponaug Cove 2015-1). Coring operations were complete for the day, and the boat was transited back to Ponaug Marina.

Coring operations continued on May 20, 2015 and May 21, 2015. During this two-day consecutive span, five additional vibracores were collected following the methodology detailed above. Figure 8 illustrates the location of recovered cores.

Figure 8. Location of cores obtained at Cedar Tree Beach and nearby Apponaug Cove
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

The following table summarizes the characteristics of recovered cores.

Table 24. Characteristics of recovered cores

Core Name	Type	Sediment Depth (cm)
CTB VC-4	Vibracore	0–83
CTB VC-5	Vibracore	0–116.5
CTB VC-9	Vibracore	0–262.5
CTB VC-6	Vibracore	0–210
CTB VC-10/1	Vibracore	0–288
CTB VC-10/2	Vibracore	0–284
Apponaug Cove 2015-1	Vibracore	0–300

3.2.3 Assessment of Field Operations and Data Acquisition Procedures

Several challenges needed to be addressed during field operations. The first day of coring operations (May 14) was effectively cut short due to the remaining coring sites being too shallow to access without being at higher point in the tidal cycle.

On the second day (May 20), coring site CTB VC-4 proved to be challenging. On the first attempt at this site, the core barrel went into the seafloor on a notable angle. When trying to retrieve the core, the bolts securing the core barrel to the vibracore head ripped through the PVC core barrel, detaching the vibracore head from the barrel. Due to shallow depths, the core barrel was still protruding through the boat moon pool and was eventually recovered. A second attempt at this core site achieved better penetration; however, when the core barrel was retrieved and inspected, the core catcher was destroyed, and no sediment recovery was achieved.

On all three days, recovery was significantly less than the length of the 3-m core barrel. Most core catchers had significant damage upon inspection following the coring attempt. Also, the large diameter of the core barrel likely prevented maximum sediment penetration. Ultimately, it was determined that a 7.6-cm steel core barrel would likely yield better coring results.

3.3 Block Island: Reconnaissance Excursions (May, June)

3.3.1 Justification and Goals

Two reconnaissance field excursions were made to Block Island on May 29 and June 14, 2015. Block Island is located 21 km south of mainland Rhode Island and centered in the project's Block Island study area. Accessible only by ferry, boat, or small plane, fieldwork staged from Block Island requires more extensive logistical planning than fieldwork staged from mainland Rhode Island. The goals of the 2015 Spring field reconnaissance excursions to Block Island were to assess onsite logistics for accessing the island's Wash Pond and Fresh Pond for coring operations; conduct low-tide walkover survey of the intertidal zone on Block Island's West Beach to photo-document, record GPS locations, and collect samples of exposed peat deposits and tree stumps in grow positions reported to be visible and accessible; and evaluate the area's potential to warrant further geoarchaeological investigation.

3.3.2 Project Personnel (Table 25)

3.3.3 Field Operations and Data Quality

Lands adjacent to Wash and Fresh Ponds (Figure 9) were examined during the May 29, 2017 field reconnaissance excursion to identify logistically optimal options for accessing both ponds with URI-GSO's small portable, modular coring platform—the R/V *Lego*. Table 25 summarizes the personnel involved with the field effort. No survey vessel was used; all fieldwork was performed from shore. Instrumentation during the field reconnaissance excursions included a digital camera, a handheld Garmin GPS for recording the locations of exposed peat deposits and tree stumps for subsequent plotting in ArcGIS, and a Haglöf increment borer (for acquiring wood samples from the tree stumps).

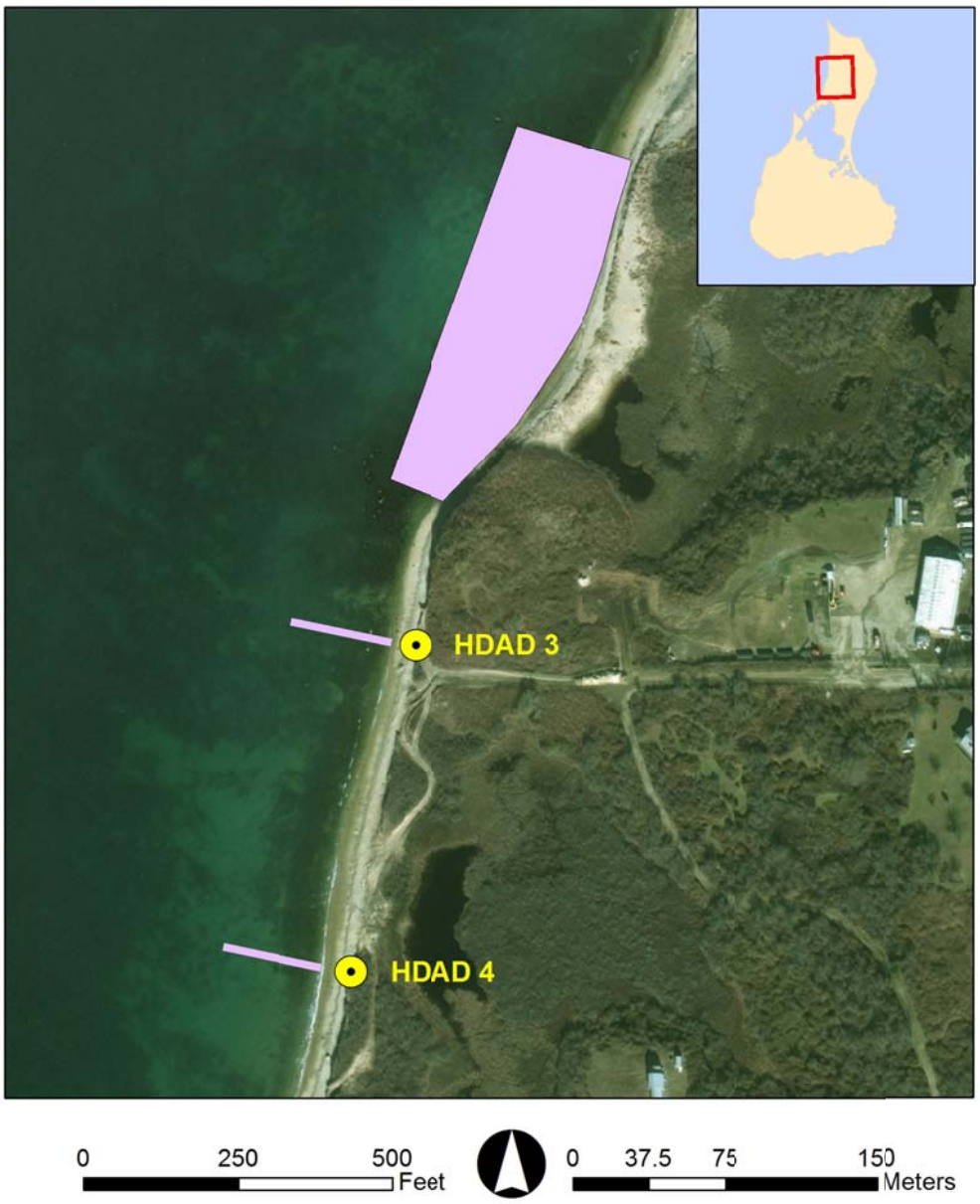

Figure 9. Locations of geoarchaeological investigations at West Beach, Block Island.
Purple shading shows study area locations. Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

Table 25. Project personnel for Block Island reconnaissance excursions (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Tim Dencker	Copenhagen University	-	X	-	-
Brian Cacciopoli	URI-GSO	-	X	-	-

It was determined that access to Wash Pond would require transporting the coring equipment and platform to the island by truck on the ferry and then down West Beach Road to the beach. From the end of the road, which terminates at the beach, coring equipment and partially assembled sections of the R/V *Lego* coring platform would then have to be hand carried down the beach to be assembled for launching into Wash Pond from its western shore. Access to Fresh Pond was determined to be optimal from its southern shore, which would require obtaining permission to park and carry the equipment and disassembled coring platform components across private property to the pond.

Walkover survey of the West Beach field reconnaissance area conducted on May 29, 2017 documented five areas of intertidal peat deposits (designated Peat Areas 1 through 5), the northernmost of which included three tree stumps and multiple small sapling stumps in growth positions. These peat deposits and tree stumps were examined and photo-documented. Samples of the shoreward and seaward tree stumps were recovered separately with the Haglöf increment borer (cleaned between samples) for radiocarbon dating. Several of the peat deposits appeared to extend out into the water beyond the low-tide level—in some cases a significant distance (ca. 50 m)— based on the dark appearance of the seafloor in areas of exposed peat that contrasted with the otherwise lighter-colored sandy seafloor. The exposed peat was observed to have rocks and pieces of wood fragments of roots and branches of varying diameter and size embedded in it. The observed stratigraphy in the areas with peat consisted of: 1) an upper layer of coarse sand, gravel, cobbles and boulders; 2) a middle layer of peat; and 3) a lower layer of gray clay with organic inclusions.

Based on field observations, it was assumed that the exposed intertidal peat deposits represented a small visible window of a much larger and more extensive peat deposit, possibly associated with a coastal pond or swamp that was partially buried beneath the coarse sand, gravel, cobbles, and boulders that comprise much of this section of West Beach's upper stratigraphic layer. A small surface scoop-sample of the peat in Peat Area 5 was also removed for sieving, microscopic analysis, and dating. Samples and GPS positions for the exposed ends of all five of the peat deposits and for all three of the tree stumps were collected and recorded during the second reconnaissance excursion to the West Beach area that was made on June 14, 2015. Additional logistical planning of future fieldwork was also done while out on the island.

3.3.4 Assessment of Field Operations and Data Acquisition Procedures

Field operations were successful in evaluating the logistical constraints of conducting future sediment coring operations in Wash and Fresh Ponds on Block Island. The walkover reconnaissance of the section of West Beach with its exposed peat deposits, tree stumps, and other intact and exposed elements of glacial and post-glacial strata indicated that the area immediately

offshore had high potential for containing elements of an archaeologically sensitive submerged paleocultural landscape that warranted further geoarchaeological investigation and mapping.

3.4 Block Island – Wash Pond: Coring

3.4.1 Justification and Goals

Wash Pond is a small brackish salt pond located on the northern peninsula of Block Island, RI (Figure 10). The pond is immediately adjacent to the West Beach archaeological site identified during underwater archaeological investigations by the project team. The close proximity of the pond to both the archaeological site and the modern beach create a unique site with the potential for both a storm overwash record at the west edge of the pond and high-quality paleoenvironmental record near the center. Similar to the approach with Gorton Pond, two coring systems were implemented: the Biological coring system to capture the sediment-water interface and preserve the core top, and the Livingston coring system to extract the longest record possible.

The remote site at Wash Pond presented numerous logistical challenges; there is no road access to Wash Pond and no boat ramp, and it is separated from the surf zone by a 45-m wide berm of beach sand and cobbles. In addition, the closest road access point to the beach is more than 350 m to the south.

Figure 10. Location of sediment cores obtained at Wash Pond, Block Island, Rhode Island
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

3.4.2 Field Operations and Data Quality

On June 25, 2015, a rented box truck and a URI pickup truck were loaded with coring gear and the partially assembled sub-sections of the coring platform. The difficult site location necessitated the use of a portable dock-block platform, which consists of modular plastic blocks that can be transported to and assembled in the field. Loaded with coring gear and crew and secured by a safety railing, the de-constructible and portable assemblage provides a stable working platform for coring operations and can be powered by one or more portable electric trolling motors. The vehicles were transported to Block Island on the ferry and then driven to the closest road access point at the west end of West Beach Road. Platform sections were carried along West Beach for

final assembly on the shore of Wash Pond. Table 26 summarizes the personnel involved with the field effort, and Table 27 details the instrumentation used.

Table 26. Project personnel for Block Island – Wash Pond coring (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
John King	URI-GSO	X	X	X	X
Sean Scannell	URI-GSO	-	X	-	-
Casey Hearn	URI-GSO	X	X	-	X
Noah Robinson	URI-GSO	-	X	-	-

Table 27. Survey vessel and instrumentation

Equipment	Function	Description
Livingston-type coring system	Sediment coring	Optimized for use in lakes containing thick post-glacial sediment; obtains continuous 1–1.5 m core sections, used through a cased hole for recovery in deep water
Biological-type coring system	Sediment coring	<2 m coring capacity; 2.4 m polycarbonate liner; optimized for use in flocculent or loosely compacted sediments
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately ± 9 ft at the study area

No bathymetry data was available for the small pond, so a brief depth survey was undertaken prior to coring operations. A small, portable fish finder was monitored for depth soundings along two transects, one east-west and another north-south, to locate the area of the pond likely to contain the thickest sediment record. These uncorrelated depth transects were specifically intended to inform the choice of coring locations for this field program and were not appropriate for use as recorded bathymetry.

Two coring locations were chosen for the pond (Figure 10); a central location near the depositional center of the pond and a site on the western edge just beyond the slope of the overwash sand deposit. These locations were chosen to provide the most complete paleoenvironmental and storm records possible while avoiding sites with sediment conditions that were not conducive to effective coring with our equipment.

Both biological cores recovered adequately long sections and terminated in stiff layer, precluding the need for additional cores of this type in the pond. Although Biological core WP15-2Bio missed the sediment-water interface, WP15-1LC did not. A Livingston core was also taken at the western coring site, managing two drives for a cumulative recovered length of 130 cm. This core started from a depth of 74 cm (the upper section already represented by the biological core from this site) and consisted of two drives (74–176 cm and 176–204 cm). The water depths at the two coring sites were similar at approximately 2.1m, the maximum observed depth of the pond.

The following table summarizes the characteristics of recovered cores.

Table 28. Characteristics of recovered cores

Core Name	Type	Sediment Depth (cm)
WP15-1Bio	Biological	188.4 cm of sediment recovered, sediment-water interface missed
WP15-2Bio	Biological	0–167
WPC15-1LC	Livingston	Drive 1: 74–176 cm; Drive 2: 176–204 cm

After the conclusion of coring activities, the platform was disassembled and returned to the University during demobilization the following day.

3.4.3 Assessment of Field Operations and Data Acquisition Procedures

Coring operations on Wash Pond were largely successful despite the substantial challenge of transporting equipment to and from the site. The process of carrying 3x3 dock-block sections along the beach by hand was extremely labor intensive and time consuming, though few alternatives were available. Attempts were made to float some sections in the surf and drag them from the road access point to the berm adjacent to the pond, but this was also difficult and slow especially given the high wind conditions on both days. A more attractive method of getting the platform close to the coring sites may have been to fully assemble the platform close to the road access point, launch it and tow it through the surf zone, and drag it across the berm to the pond. However, weather conditions at the site would have to permit this approach. The fully assembled dock-block platform is also prohibitively heavy and only reluctantly slides downslope across the sand. With no other boat access to the pond and the absolute need for a stable working platform to perform coring operations, the dock-block platform ultimately proved a successful method in an otherwise inaccessible location.

3.5 Block Island – West Beach: Geoarchaeological Investigation

3.5.1 Justification and Goals

Walkover reconnaissance of the section of West Beach with its exposed peat deposits, tree stumps, and other intact and exposed elements of glacial and post-glacial strata (Figure 9) indicated that the area immediately offshore had high potential for containing elements of an archaeologically sensitive submerged paleocultural landscape that warranted further geoarchaeological investigation and mapping.

3.5.2 Field Operations and Data Quality

A week of non-disturbance geoarchaeological visual examination and mapping by archaeological divers from BOEM, URI, and former staff members of NITHPO who had transitioned to being full-time URI undergraduate students was conducted in the West Beach study area (Figure 9) between June 21 and June 27, 2015. Table 29 summarizes the personnel involved with the field effort. No survey vessel was required; all fieldwork and diving operations were staged from shore. Instrumentation included a handheld Garmin portable GPS unit and a GoPro Hero-4 (Black) digital high-definition underwater video/still camera.

Table 29. Project personnel for the Block Island – West Branch geoarchaeological investigation (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Chali Machado	URI	X	X	X	-
Norman Machado	URI	X	X	X	-
Brian Jordan	BOEM	X	X	-	-
Melanie Damour	BOEM	-	X	-	-
Doug Jones	BOEM	-	X	-	-

Field personnel transited to and from Block Island via ferries out of Point Judith, Rhode Island, on a daily basis for the duration of the deployment. A day of fieldwork was lost to inclement weather (strong southwesterly winds), but conditions for the remainder of the field deployment were good with underwater visibility ranging from approximately 2 to 10 m. This excellent underwater visibility allowed for high-quality underwater observations, note-taking, and video- and photo-documentation. Fieldwork focused on systematic visual exploration, mapping, and characterization of the surface of the submerged seafloor in the areas extending seaward of the exposed intertidal deposits of peat. This systematic mapping was accomplished by installing a 100-m long baseline tape onshore, oriented parallel to the beach's generally north-south axis, from which a series of 10-m spaced, 50-m long tape-measured surveyed transects were extended out into the water. Each of these transects was surveyed visually and video-documented by divers who recorded their observations on an underwater slate as they swam the distance of the measuring-tape transect. The northern end of the baseline corresponded with the location of the northernmost, documented, exposed intertidal peat deposit (containing the three tree stumps). The positions of the ends of the baseline and the survey transects were recorded with the handheld GPS, which reported position accuracies of +/- 2.5 m. In addition to the systematic visual survey of the seafloor, the archaeological divers also performed non-patterned exploration of the seafloor. A concentration of three pieces of quartz chipping debris found embedded in the sub-tidal, exposed portion of the northernmost peat deposit (i.e., the one containing the three tree stumps) were video-documented underwater *in situ*, their location recorded using GPS, and the pieces recovered by URI-GSO, where they are presently stored.

3.5.3 Assessment of Field Operations and Data Acquisition Procedures

Field operations went smoothly, although the daily transits to and from the island somewhat limited the number of actual fieldwork hours that were available each day. Based on this fact, it was determined that for future field deployments it would be logistically better to rent lodging on-island for a majority of the field team and make periodic trips back to the URI-GSO to refill the project divers' air cylinders (there is no American Academy of Sciences-approved air-fill station on Block Island). Data acquisition procedures were effective in obtaining systematically recorded visual descriptions and video-documentation of the diver-surveyed transects and other investigated areas of the seafloor within the northern part of the West Beach study area. It was concluded at the end of the fieldwork that additional field investigation of the submerged portion of the West Beach study area was warranted and should focus on the southern half of the area that extended down to the southernmost area of exposed intertidal peat.

3.6 Greenwich Bay: Geophysical Investigation

3.6.1 Justification and Goals

A previous CHIRP sub-bottom survey effort conducted in 2006 produced 24 parallel sub-bottom lines at 300-m spacing, with broad coverage throughout Greenwich Bay. Interpretation of this dataset was provided in Morissette (2014). Several prominent acoustic reflectors representing geologic erosional unconformities were identified and mapped within the study area. In particular, reflectors representing the ravinement surface (marine unconformity) and acoustic basement (lowest identified reflector) were digitized. Two interpolated surfaces representing these paleolandscapes (depth to ravinement surface and depth to acoustic basement) were generated. It became clear that the 300-m line spacing with no perpendicular crossing lines was insufficient for producing paleolandscape reconstructions with enough detail to inform archaeological sensitivity models. To improve the paleolandscape reconstructions, 100-m lines and 300-m perpendicular tie lines were surveyed across the Greenwich Bay study area.

3.6.2 Field Operations and Data Quality

Sub-bottom profile data were collected over four days: June 29–30, July 2, and July 26, 2015. Beginning on June 29, the pontoon boat, CHIRP sub-bottom profiler and ancillary equipment were transported from URI-GSO to Ponaug Marina in Warwick, RI. Table 30 summarizes the personnel involved with the field effort, and Table 31 details the instrumentation used.

Table 30. Project personnel for Greenwich Bay geophysical investigation (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	X	X	X	X
Casey Hearn	URI-GSO	X	X	-	-
Sean Scannell	URI-GSO	-	X	-	-

Table 31. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO Pontoon Boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Teledyne Benthos CHIRP III, DSP-664 Transceiver	Sub-bottom profiler	Surface towed “catamaran” source producing a CHIRP waveform 2–7 kHz frequency sweep pulse with integrated hydrophones
Applanix POS MV V4	Navigation & motion compensation	Inertial Navigation System with two Trimble GNSS (Global Navigation Satellite System) receivers

The boat was launched at the marina and pulled into a transient slip so that the survey equipment could be loaded and setup. After setup, the pontoon boat and crew transited to Greenwich Bay using Hypack software for navigation. Prior to the survey, survey lines had been created at the established 100-m spacing (300 m for perpendicular tie lines). As the boat approached the first survey line, the CHIRP sub-bottom profiler was deployed and slowly paid out aft of the stern and

secured to a cleat. After the proper settings (e.g., pulse length, repetition rate) were determined, the survey continued as planned.

During the survey, SonarWiz acquisition software allowed for real-time viewing of sub-bottom data, which allowed the survey team to determine that the data were of high quality. Survey operations continued until the dataset was complete. Figure 11 illustrates the tracklines along which data was collected during the 2015 field effort, complementing existing CHIRP data collected in 2006. Together these data achieve 100m trackline spacing with 300m perpendicular tie lines.

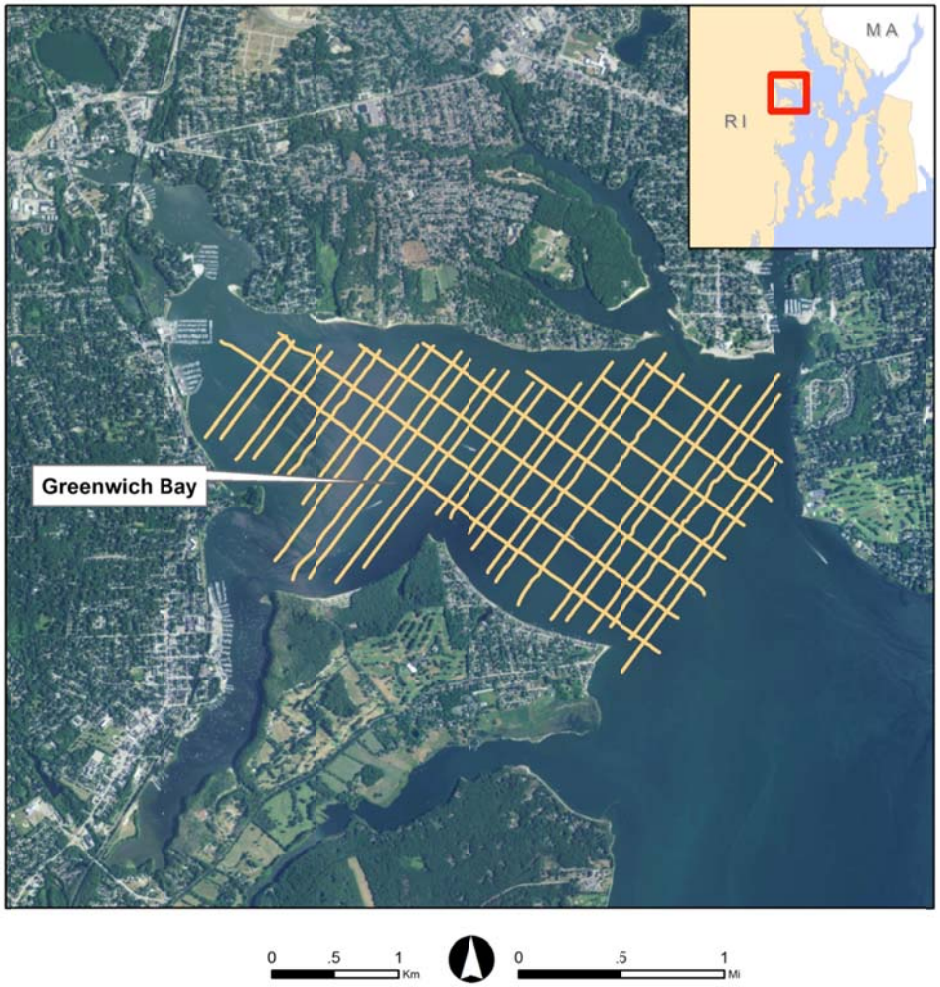

Figure 11. Location of sub-bottom sonar survey tracklines (orange lines) in Greenwich Bay, Rhode Island.
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

3.6.3 Assessment of Field Operations and Data Acquisition Procedures

After the first day of surveying, the data were quickly loaded into SonarWiz for a quality check and preliminary processing. It was determined that although the data were of high quality, the highest repetition rate and shortest pulse length should be favored for data collection going forward. This would ensure the highest achievable resolution.

During data acquisition, the best data came from the middle portion of Greenwich Bay, where penetration was highest. As the bay constricts on the less energetic western end, the sediments appeared to be gaseous, which quickly attenuates the CHIRP signal. The eastern portion is higher energy where Greenwich Bay meets the west passage of Narragansett Bay and is dominated by broad sandy platforms of greater reflectivity, which also reduced penetration.

The only notable mishap during the four-day survey was a failed voltage regulator on the outboard motor. This was discovered on July 1, a day intended for surveying, but instead was spent replacing the part. Survey operations were resumed the following day.

3.7 Mud Hole: EN565 Vibracores (August)

3.7.1 Justification and Goals

In August 2012, a geophysical survey of the Mud Hole study area produced a partial coverage side-scan mosaic and 37 CHIRP sub-bottom profiles. The sub-bottom profiles were processed and interpreted in Caccioppoli (2015). To ground-truth the geological interpretations of the sub-bottom profiles, sediment cores were strategically planned to capture apparent lithological changes.

3.7.2 Survey Procedures and Data Quality

On Friday, August 21, 2015, all cruise equipment, including sub-bottom profilers and vibracoring equipment, were transported to Senesco Marine LLC in North Kingstown, RI, where the R/V *Endeavor* was docked. A quick functionality test of all equipment was performed to ensure that all equipment required for the cruise was accounted for and operational. Table 32 summarizes the personnel involved in the field effort, and Table 33 details the equipment used.

Table 32. Project personnel for EN565 vibracores (2015)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	X	X	X	X
Sierra Davis	URI-GSO	-	X	X	-
Casey Hearn	URI-GSO	X	X	X	X
Mitch Kennedy	URI-GSO	X	X	X	-
Muckquashim Hopkins	NITHPO	-	X	-	-
John King	URI-GSO	X	X	X	X
Chali Machado	Narragansett Indian Tribe/URI	-	X	X	-
Norman Machado	Narragansett Indian Tribe/URI	-	X	X	-
David Robinson	URI-GSO	X	X	X	X
Sean Scannell	URI-GSO	X	X	X	-

Table 33. Survey vessel and instrumentation

Equipment	Function	Description
R/V *Endeavor*	Survey vessel	185' Ocean/Intermediate class research vessel with lab spaces, several winches and cranes and transducer well. Compliments 12 crew, 17 scientists and one marine technician
Vibracore system	Sediment Coring	Rossfelder P-3 Vibra-Percussive system with 600-m working depth, accommodating 8- or 10-cm core barrels typically 3–6 m in length
Applanix POS MV V4	Navigation & motion compensation	Inertial Navigation System with two Trimble GNSS receivers

On Sunday, August 23, 2015, the R/V *Endeavor* departed North Kingstown and began its transit to Block Island Sound to begin the seismic reflection surveying component of the cruise. This portion of the cruise is not relevant to this report. Surveying continued until Tuesday, August 25, and the R/V *Endeavor* transited to the Mud Hole study area (Figure 12). Once on site, ship operations were switched to vibracoring. The first station, "VC-01", was selected due to a very thick, fine-grained marine mud layer identified in an existing CHIRP sub-bottom profile.

Prior to deployment, the vibracoring system was prepared and assembled. Plastic core liners were inserted into the 6-m core barrels. The core barrel, cutter, and catcher were assembled and attached to the vibracore head. To ensure that the entire vibracoring assembly remained upright in deep water during deployment and recovery, a purpose-built assembly with a series of weights and floats was utilized. The entire coring assembly was then deployed aft of the stern, using a cable winch run through the stern A-frame. Two deck-mounted air-tugger winches were used in tandem to prevent the coring assembly from swinging with vessel motion. As the vibracoring system was being deployed, field notes were kept noting latitude/longitude, water depth, time, and measurements of cable tension. Just before the vibracoring system reached the bottom, the system was powered on. The cable out and cable tension were monitored to determine when a full core / refusal was achieved. Before recovery, the vibracore system was powered off. Once on deck, the core barrel assembly was removed from the vibracore head, and the core liner extruded from the core barrel. The recovered sediment length was measured, and the core was packaged and placed in cold storage. These vibracoring methods were repeated at each subsequent station. Coring operations were continued during daylight hours and lasted until Thursday, August 27, with 16 cores attempted and 15 successfully recovered. At the end of coring operations, each vibracore was cut into 1-m segments, labeled, and packaged for transport back to URI-GSO.

3.7.3 Assessment of Field Operations and Data Acquisition Procedures

Vibracoring operations were very successful, with 15 out of 16 attempted vibracores recovered (Figure 12). At station VC-11, the core barrel became separated from the vibracore head and was lost. The longest sediment core recovered was 5.24 m in length from station VC-01. The shortest core was 0.94 m from station VC-13, which penetrated a gravelly sand lithology. Preliminary interpretations of two split vibracores indicated recovery of both marine material and fine-grained lake sediment, representing both marine and terrestrial paleoenvironments. The sediment depth of observed lithology changes was in excellent agreement with a prominent regional reflector in previously acquired CHIRP sub-bottom profiles (Caccioppoli 2015).

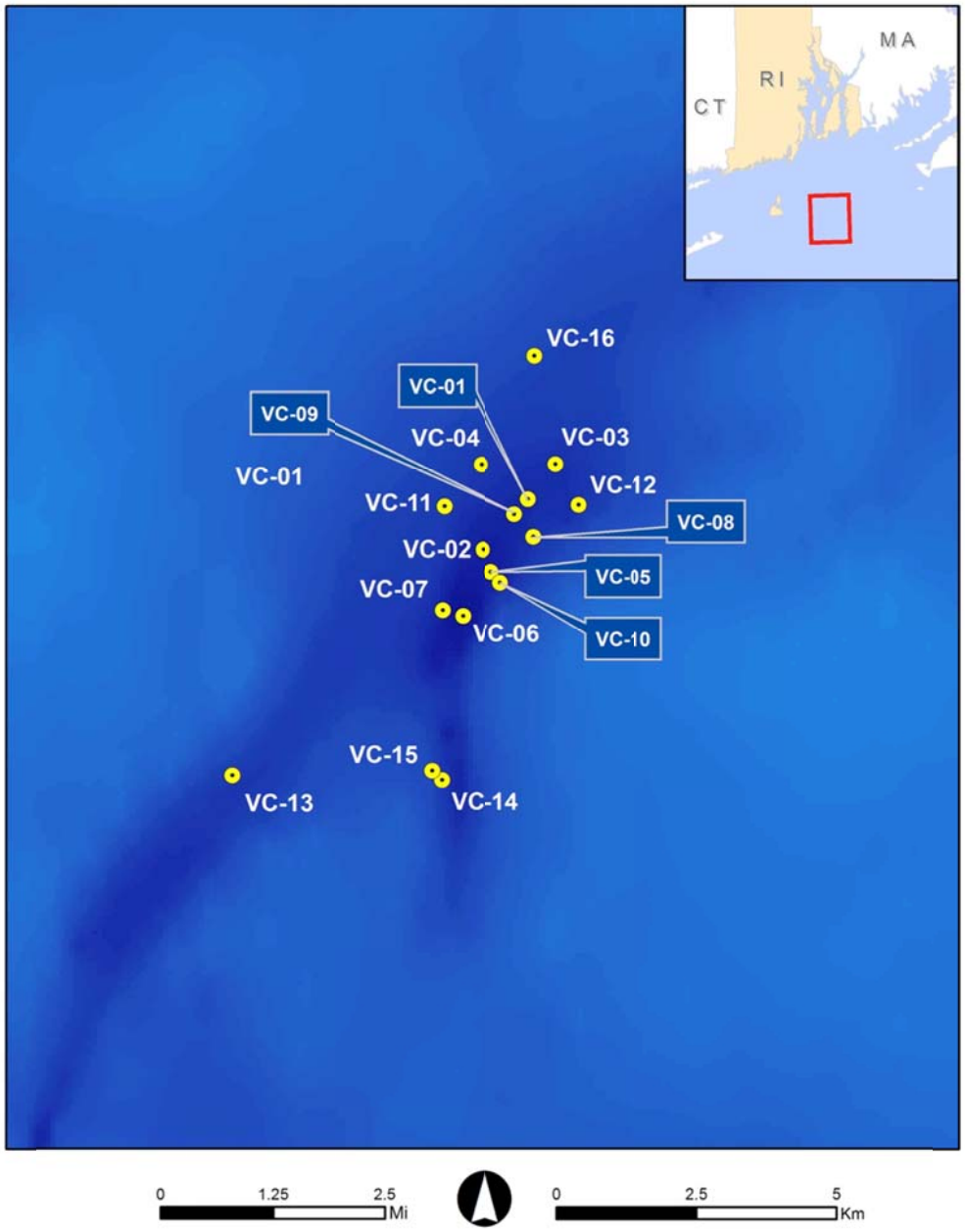

Figure 12. Location of vibracores (yellow dots) obtained at "The Mud Hole" on the Rhode Island continental shelf

Basemap: 3 arc-second bathymetric image, NOAA Northeast Atlantic Coastal Relief Model, https://www.ngdc.noaa.gov/mgg/coastal/grddas01/grddas01.htm

4 2016

4.1 Block Island – West Beach: Archaeological Investigation

4.1.1 Justification and Goals

A non-disturbance underwater visual reconnaissance survey conducted in 2015 by a field team of archaeological divers from BOEM and URI in the waters off of West Beach identified a unique submerged paleocultural landscape. This submerged paleocultural landscape appeared to be extensive and consisted of 1) deposits of exposed peat extending seaward from previously identified intertidal peat deposits onshore and 2) a sub-tidal concentration of quartz chipping debris found *in situ*, embedded in the surface of a large area of peat, which was produced by pre-contact period stone tool manufacture or modifications that occurred when the area was subaerially exposed land. These discoveries led URI and BOEM to conclude that additional underwater geoarchaeological investigation was warranted in 2016. The goals of the 2016 non-disturbance visual reconnaissance survey were to explore and map significant elements of the submerged paleocultural landscape present in the southern half of the West Beach study area, as well as to conduct visual reconnaissance investigations of two 50-m transects extending seaward of low-relief upland areas on shore containing archaeological sites HDAD-3 and HDAD-4 to assess how much, if any, of these archaeologically sensitive upland coastal geological features and their cultural deposits were preserved in the water.

4.1.2 Survey Procedures and Data Quality

Two weeks of non-patterned, non-disturbance/minimal disturbance, underwater exploration, video-documentation, and feature-mapping fieldwork was conducted between May 2 and May 13, 2016 to record the extensive submerged paleocultural landscape extending into the nearshore waters off of West Beach. Table 34 summarizes the personnel involved with the field effort.

Table 34. Project personnel for Block Island – West Beach archaeological investigation (2016)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
David Robinson	URI-GSO	X	X	X	X
Chali Machado	URI	-	X	X	-
Norman Machado	URI	-	X	X	-
Taylor Losure	URI	-	X	-	-
Brian Jordan	BOEM	X	X	-	-

No survey vessel was required; all fieldwork and diving operations were staged from shore. Instrumentation included a handheld Garmin portable GPS unit and a GoPro Hero-4 (Black) digital high-definition underwater video/still camera. A trowel, a wood chisel and hammer, a gouge-auger hand-operated corer (3x100 cm) and labeled plastic zip-lock bags were also used to collect small (5 to 10 cm^3) wood and sediment samples.

GPS was used to map features of that landscape, which was found to contain four sub-tidal tree stumps in their original growth positions (one with a toppled trunk), an extensive area of exposed tree-root mat, an extensive area of exposed paleosols which included a potential hearth feature, and a stepped series of stratigraphically- and paleoenvironmentally-differentiated wetland/pond sediments. Evidence of a glacial outwash-till basement layer, an overlying loess layer, a paleosols

layer, and three distinctly separate peat layers overlying the paleosols were also recorded and provided evidence of the sequencing and timing of how the area transitioned from a wooded low area, to a marsh, to a beach, and then to an inundated marine environment. Details about these different paleolandforms, the conditions that allowed them to be preserved, and the prevailing paleoenvironmental conditions that were represented on site were all noted and considered as part of the fieldwork that was performed. Small samples of the different strata represented in the paleolandforms, including the exposed, fire-impinged surface of the paleosols within the potential hearth feature, the tree stumps and the paleosols from which they had grown were collected for microscopic analysis and AMS radiocarbon dating by Beta Analytic. These samples were collected using the simple hand-held tools described above. A series of overlapping, time-lapse photographic transects of the study area were documenting using the GoPro Hero-4 (Black) underwater camera. Exposed sequences of underwater stratigraphy visible underwater in a predominantly plan view, similar to that exposed on shore and visible in profile in the upland and pond-margin areas, were compared. In addition to the archaeological diver survey of the primary West Beach underwater archaeological study area, two 50-m transects extending seaward of low-relief upland areas on shore containing archaeological sites HDAD-3 and HDAD-4 were visually examined and video-documented to assess how much, if any, of these archaeologically sensitive upland coastal geological features and their cultural deposits were preserved in the water.

Underwater field notes and video- and photographic documentation data quality were good, as underwater visibility on site was between 5 and 15 m. The cold temperature of the water limited dive times to about one hour per dive. In general, two dives were made per day on the site.

4.1.3 Assessment of Field Operations and Data Acquisition Procedures

Field operations went smoothly and all equipment utilized for the fieldwork operated as expected. Staging operations from the island with field personnel lodging on-island for the duration of the deployment allowed for additional time on site working and reduced the overall logistical challenges of the field project. Data acquisition procedures were adequate for reconnaissance-level assessment and mapping of the study area. Difficulties were encountered with creating photomosaics and 3D photogrammetric models of the study area from the series of overlapping, time-lapse photographic transects due to the partially dynamic nature of the imaged seafloor as a consequence of swell-driven seaweed movement over large portions of the photographed area. Use of stationary visual reference points positioned on the bottom may be an effective solution to this problem during future photographic surveys.

4.2 EN580—Capacity-Building Cruise

4.2.1 Justification and Goals

The major objective of cruise was to provide a unique educational, training, and outreach experience in geophysical and geological surveying methods to representatives from the Tribal Historic Preservation Offices of Indian Tribes located in the northeastern US. This type of experience did not exist in the US prior to the initiation of this project. Many Tribal representatives have not had the opportunity to observe and participate in geological and geophysical data acquisition or to provide their perspectives and suggestions about ways in which surveying methods could be more sensitive to Tribal concerns. This short cruise was designed to introduce participants to a variety of surveying techniques onboard an oceanographic research vessel, including acquisition, processing, and interpretation of bathymetry, side-scan sonar, seismic

reflection profiling, and sediment coring. In addition, the time onboard ship provided an excellent opportunity for sharing perspectives and concerns between diverse groups.

4.2.2 Survey Procedures and Data Quality

Equipment mobilization took place primarily on June 3 with final preparations made on June 5 during the first phase of the capacity-building event. Table 35 summarizes the personnel that took part in the field effort, and Table 35 details the equipment used.

Table 35. Project personnel for the EN580 cruise.

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Onboard Science Team Participants					
John King	URI-GSO	X	X	X	X
David Robinson	URI-GSO	X	X	X	X
Doug Harris	NITHPO	-	X	-	-
Brian Jordan	BOEM	X	X	-	X
Casey Hearn	URI-GSO	X	X	X	X
Sierra Davis	URI-GSO	X	X	-	-
Alex DiCiccio	URI-GSO	-	X	-	-
Rick Getchell	Aroostook Band of Micmacs/All Nations Consulting, LLC	-	X	-	-
Tammy Getchell	Aroostook Band of Micmacs/All Nations Consulting, LLC	-	X	-	-
Norman Machado	Narragansett Indian Tribe/URI	-	X	X	-
Sean Scannell	URI-GSO	-	X	X	-
Kiowa Spears	NITHPO	-	X	-	-
Nakai Northup	Mashantucket Pequot Tribe	-	X	-	-
Cheryl Stedtler	Nipmuc Nation	-	X	-	-
Chali Machado	Narragansett Indian Tribe (URI)	-	X	X	-
Jorgen Denker	Viking Ship Museum	-	X	-	-
Onshore Science Team Telepresence Participants					
Carol Gibson	URI-GSO	X	X	X	X
Max Garcia-Brown	NITHPO	-	X	-	-
Eileen Thomas	Mohegan Tribe	-	X	-	-
Robert Pockalny	URI-GSO	X	X	-	-
Dwight Coleman	URI-GSO	X	X	-	-

Table 36. Survey vessel and instrumentation.

Equipment	Function	Description
R/V *Endeavor*	Survey vessel	185' Ocean/Intermediate class research vessel with lab spaces, several winches and cranes and transducer well. Compliments 12 crew, 17 scientists and one marine technician
Vibracore system	Sediment Coring	Rossfelder P-3 Vibra-Percussive system with 600-m working depth, accommodating 8- or 10-cm core barrels typically 3–6 m in length
Applanix POS MV V4	Navigation & motion compensation	Inertial Navigation System with two Trimble GNSS receivers
HMS-620 Bubble Gun	Sub-bottom sound source	Surface towed "catamaran" source producing a 70–1,700 Hz sound pulse. Used in conjunction with a separate towed single-channel hydrophone streamer

The R/V *Endeavor* left the dock on June 6 initially intending to transit to the eastern side of Block Island to begin a series of geophysical survey lines. Poor weather conditions over the previous days had worsened and resulted in a swell of 2.5–3 m in the targeted survey area. In the interest of acquiring the highest quality data possible and allowing the capacity-building activities to continue unabated, the survey was adjusted to a more sheltered area just south of the mouth of Narragansett Bay and Aquidneck Island (Figure 13).

Geophysical surveying and marine mammal observing began at 15:19 GMT (11:19 EST) and continued until 00:22 GMT. Three survey lines were chosen to fill gaps in existing available sonar data from a 1980 survey conducted by the US Geological Survey's Coastal and Marine Geology Program (McMullen et al. 2009). The HMS-620 Bubblegun was chosen for its performance in sediment types with a higher sand fraction. Previous cruises had utilized the CHIRP sub-bottom system but had observed limited penetration depth in nearby offshore regions with more sand.

Vibracoring operations began on June 7th under improved swell conditions. Three coring targets were chosen from pre-existing data (McMullen et al. 2009) (Figure 13) with the goal of recovering the longest possible records in pockets of deeper sediment. Coring procedures were conducted very closely to the successful EN565 cruise from the previous year (see Section 4.7) with a few exceptions. The deckboard air-tugger system for stabilization during launch and recovery was reconfigured by the ship's Boson to be less complicated. Hand lines replaced air-tuggers where possible, simplifying the operation in lighter swell conditions. The same 6-m long, 3-in diameter barrels were used for EN-580 vibracoring, lined with plastic and terminating with a core cutter and internal core catcher. Core catcher fingers were bent inwards by hand to the approximate ideal closed shape in an attempt to improve the length of recovered material.

Three vibracores were recovered of similar lengths between 283 and 299 cm. The final recovered vibracore terminated in a sediment section with stiffer, darker sediment likely containing a higher fraction of organic matter and possibly representing the upper extent of the pre-inundation paleolandscape. A fourth vibracore was attempted, but the entire core barrel was lost during pullout with no sediment recovered from the site.

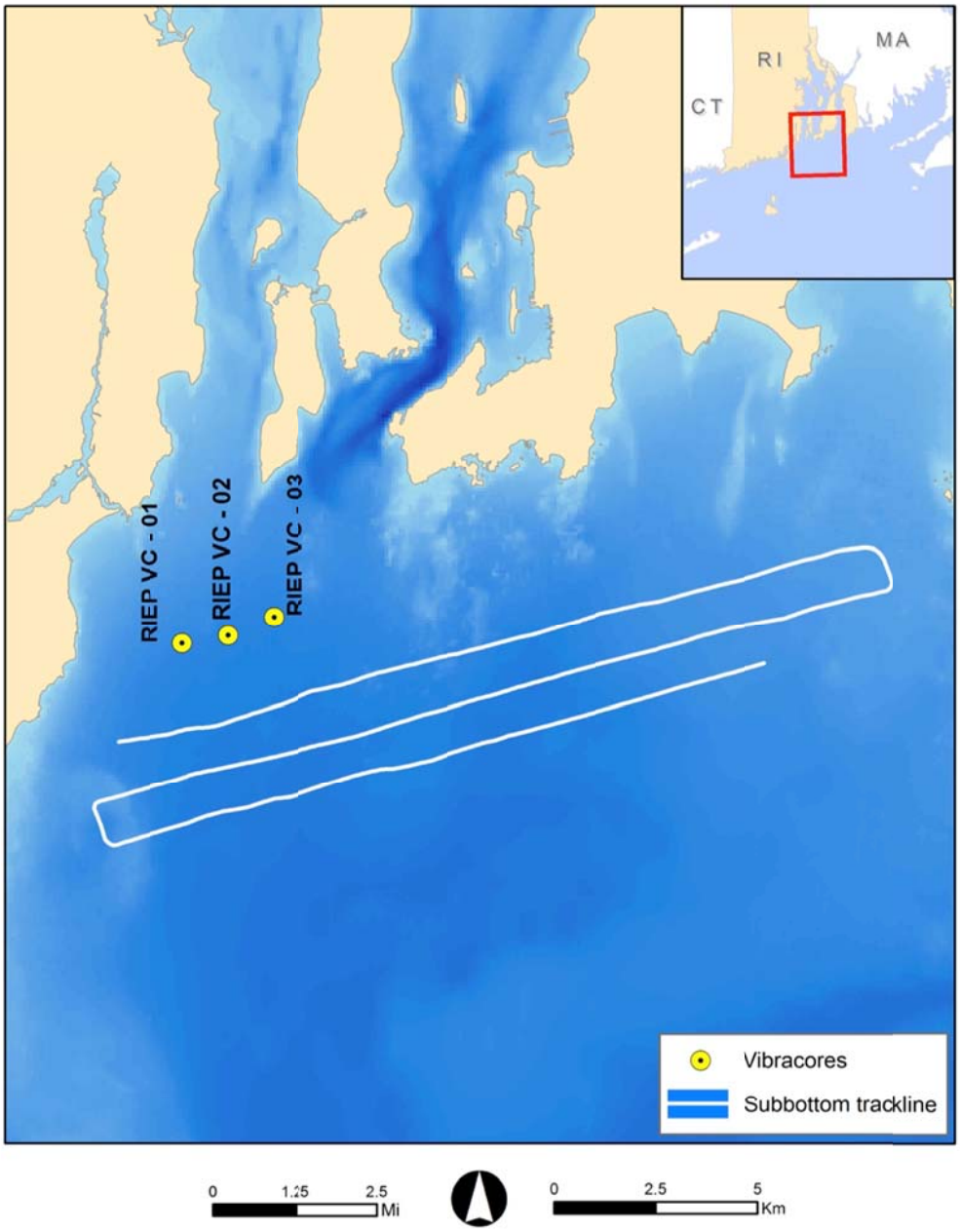

Figure 13. Location of sub-bottom sonar survey trackline (white line) and vibracores (yellow dots) south of Narragansett Bay, Rhode Island

Basemap: 3 arc-second bathymetric image, NOAA Northeast Atlantic Coastal Relief Model, https://www.ngdc.noaa.gov/mgg/coastal/grddas01/grddas01.htm

4.2.3 Use of Telepresence Technology

A particularly unusual aspect of this cruise was the opportunity to test two-way "telepresence" technology, which allowed individuals who did not participate in the cruise to view daytime onboard activities in real time and to participate in onboard discussions. This technology was provided to the project team through collaboration with URI-GSO's "Inner Space Center"

(http://innerspacecenter.org). A videographer from the Inner Space Center was onboard the research vessel for the duration of the cruise and provided continuous live-stream video coverage of shipboard activities, which was transmitted in high definition (via Internet2) to the Inner Space Center base station. Onshore participants could view and participate in shipboard activities by:

- Visiting the Inner Space Center on the URI-GSO campus, which allowed participants to view onboard activities and newly acquired data on a large projection screen and multiple computer monitors. Participants at the Inner Space Center were also able to communicate in real time with onboard personnel through the use of two-way audio and video connections, which facilitated active participation in shipboard discussions; or

- Accessing an online link to real-time video through a web browser, which allowed participants to view shipboard activities from a computer, tablet, or smart phone but did not allow communication between shore-based and onboard personnel.

Telepresence technology was enabled throughout the entire cruise from approximately 7:00 am to 11:00 pm and was customized according the activities occurring onboard the research vessel.

4.2.4 Assessment of Field Operations, Data Acquisition Procedures, and Telepresence Technology

Both the geophysical survey and vibracoring components of the scientific goals of EN-580 were successful and built off the experiences of the previous year's cruise. Data quality for the bubblegun sub-bottom system was high, with penetration depths similar to those of previous studies in the region.

The small changes to the vibracoring operations also appeared to improve performance or had no impact. The improved swell conditions on the day of coring made the complicated air-tugger stabilization unnecessary, thus improving overall efficiency and allowing more cores to be recovered in given period of time. The efforts to improve the function of the core catchers also resulted in fewer lost core catcher teeth and fewer inverted catchers (a sign of sediment loss from the bottom of the section during recovery). The loss of the final vibracore may have been due to bolts loosening at the attachment point near the top of the core barrel. The winch tension sensor did not report a spike at pullout, which usually means that either the core barrel did not penetrate, or, in our case, that the barrel had come loose during penetration and thus gave little resistance during extraction. During on-deck attachment of the core to the vibracore head, each of the securing bolts are tightened firmly and secured with electrical tape to prevent backing out and loss. Despite the efforts to secure the bolts, the powerful motion of the vibracore head still frequently loosens the bolts and may be an area for future improvements.

In general, telepresence technology worked very well. At the beginning of the cruise, bandwidth limitations associated with URI's internet service provider resulted in temporary "blackouts" of audio-visual ship-to-shore links. This problem was addressed by the internet service provider, and although occasional short (several seconds) blackouts continued to occur throughout the duration of the cruise, the inconvenience for shore-based participants was minor.

4.2.5 Assessment of Participant Experience

Participants who were on board the R/V *Endeavor* during the cruise all acknowledged that the experience was worthwhile and educational, and that the lectures, opportunities to observe and participate in marine research fieldwork, and the ensuing discussions that followed were

informative and impactful. Removed from all that is familiar of life on shore, a ship at sea provides a unique and distinctly different physical and cognitive environment for those who are on board. The isolation of a vessel and the comparatively contained space causes and requires that the people who are at sea together relate to one another in a more careful and focused way than they might otherwise relate to each other on land. As a consequence, shipboard experiences tend to be more intimate, more vivid, more intense, and more memorable. The R/V *Endeavor* capacity-building cruise provided the space necessary for all these elements of the experience to be felt by its participants and for progress to be made in understanding how Tribal and non-Tribal researchers can work together at sea on submerged paleocultural landscapes research projects in meaningful and mutually beneficial ways.

Telepresence technology allowed onshore observers to view operations onboard the survey vessel in real time, providing a unique window into the methodologies and challenges associated with geological and geophysical data acquisition. Participants who observed onboard operations from the Inner Space Center were enthusiastic about their experience and stated that the opportunity to view geophysical and geological data acquisition on a survey vessel in real time from shore was very helpful to supplementing their knowledge about the methods and challenges associated with oceanographic research. The ability to participate in onboard discussions remotely was identified as particularly meaningful. Although the logistics and expense associated with using telepresence may be prohibitive in some situations, the extremely positive outcomes from this short cruise suggest that it may be a very effective capacity-building tool.

4.3 Block Island – West Beach: Coring and Geophysical Surveys

4.3.1 Justification and Goals

The identification of exposed terrestrial peat deposits and tree stumps along West Beach, Block Island, as described in Section 5.1, necessitated a site-specific geologic characterization extending offshore. To achieve this, a tightly spaced survey grid was designed with 30-m shore-parallel survey lines and 100-m perpendicular crossing lines along which swath bathymetry, side-scan, and CHIRP sub-bottom profiles were collected. To ground-truth geophysical data, targeted biological and vibracores were planned.

4.3.2 Survey Procedures and Data Quality

On May 3, 2016, the URI-GSO pontoon boat and survey and coring gear were all mobilized from URI-GSO to Block Island, RI by trailer and a rented box truck aboard the Block Island Ferry. Table 37 summarizes the personnel involved in the field operation, and Table 38 summarizes the equipment used.

Table 37. Project personnel for Block Island – West Beach coring and geophysical surveys (2016)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	X	X	X	X
Casey Hearn	URI-GSO	X	X	X	X
John King	URI-GSO	X	X	X	X
Monique LaFrance-Bartley	URI-GSO	X	X	X	-
Taylor Losure	URI Geosciences	-	X	-	-

Table 38. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Biological-type coring system	Sediment coring	<2m coring capacity; 2.4 m polycarbonate liner; optimized for use in flocculent or loosely compacted sediments
Vibracore system	Sediment Coring	Rossfelder P-3 Vibro-Percussive system with 600-m working depth, accommodating 8- or 10-cm core barrels typically 3–6 m in length
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately ± 9 ft at the study area
Edgetech 6205 Multi-Phase Echosounder	Combined side-scan and bathymetric sonar	Pole-mounted, swath bathymetry and dual frequency 550kHz/1,600kHz side-scan system
Teledyne Benthos CHIRP III, DSP-664 Transceiver	Sub-bottom profiler	Surface towed "catamaran" source producing a CHIRP waveform 2–7 kHz frequency sweep pulse with integrated hydrophones
Applanix POS MV V4	Navigation & motion compensation	Inertial Navigation System with two Trimble GNSS receivers

Upon arrival at the study area, the pontoon boat and equipment were transported to Great Salt Pond. The pontoon boat was then launched and tied up at Payne's Dock, and the equipment stored on site in the box truck.

Survey operations began on May 4, 2016. The Edgetech 6205, Benthos CHIRP III, and Applanix POS MV were setup on the pontoon boat before transiting to the West Beach survey area. The Edgetech 6025 was run with a 25-m range, producing a total swath width of 50 m, dependent on water depth. The CHIRP was run at a 63-ms repetition rate and towed 10–15m aft of stern. It was noted that CHIRP penetration was limited, most likely due to a coarse-grained bottom type. The survey lines were completed by the end of day. Figure 14 illustrates the location of the survey transects.

On May 9, 2016, a shoreline trace was conducted using only the Edgetech 6205 to get the most inshore data possible. This was aided by coordinating the survey to occur simultaneously with high tide. The CHIRP was omitted from this additional surveying due to previously observed poor penetration and an abundance of boulders, which made navigation especially difficult.

Beginning on May 11, 2016, field operations were switched to sediment coring. Prior to survey, the pontoon boat was rigged for coring and all coring equipment was loaded onto the boat. The boat was transited to the West Beach site with intentions of collecting biological cores and vibracores in a shore perpendicular transect. Coring locations were selected after reviewing the processed side-scan data to identify fine-grained areas. When arriving at the coring sites, it was determined that the seafloor geology was too coarse for both biological cores and vibracores. After physically probing the seafloor in numerous locations to find sites adequate for coring, coring operations were abandoned. The pontoon boat was then transited back to Great Salt Pond to continue coring operations.

Figure 14. Location of sub-bottom sonar survey tracklines (white lines) in the West Beach area of Block Island, Rhode Island.
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

4.3.3 Assessment of Field Operations and Data Acquisition Procedures

The limited penetration of the CHIRP sub-bottom sonar and the inability to collect sediment cores at West Beach are both due to the coarse seafloor geology. The seafloor is predominantly composed of sand, gravel, cobbles, and boulders as were observed in the side-scan data. Terrestrial deposits observed in the intertidal zone (e.g., tree stumps, peat) were not clearly observed further offshore at the time of planned sediment coring. Because these terrestrial deposits were identified so close to the shoreline, it was determined that an additional shoreline trace should be performed at peak high tide to capture the intertidal zone as completely as possible. This second pass was completed on May 9, 2016 and achieved this intended goal.

The Falmouth Scientific, Inc. (FSI) Bubble Gun, a lower frequency sub-bottom profiler, is more appropriate for use in sand and gravel environments. The trade off, however, is reduced resolution, particularly in the first several meters below the seafloor. Because the peat layer is likely to be shallowly buried by marine deposits, it was determined that the Bubble Gun would likely be inappropriate. On the first day of survey, the Bubble Gun was deployed to determine if it would perform better than the CHIRP. However, as the hydrophone streamer was prepared, we noticed that the oil-filled tubing had a small leak and could not be deployed without contaminating the seawater and risking further damage. With this restriction, only the CHIRP sub-bottom profiler could be used for survey.

Despite the difficulties associated with characterizing the sub-seafloor geology, the side-scan and bathymetric data were of excellent quality. Bedforms such as scour marks and sand waves were easily observed in both datasets.

The only other difficulties encountered during this field effort were related to the weather. During this week, several rain events with high winds prevented data collection.

4.4 Block Island – Great Salt Pond: Coring and Geophysical Survey

4.4.1 Justification and Goals

Great Salt Pond is a nearly fully enclosed salt pond, connected to Block Island Sound by a man-made channel that was dredged in 1895, located on the western side of the salt pond. This area is a low energy environment close to West Beach with a long history of Native American settlement, and sediment cores taken from here could aid in generating the local paleoenvironmental record. To characterize the changes in seafloor and sub-seafloor geology, swath bathymetry, side-scan, and CHIRP sub-bottom profiler data were collected. To ground-truth the geophysical data, targeted sediment cores were planned. For the most complete sedimentary record, biological cores capturing the sediment-water interface and vibracores 3 m and 6 m in length were to be collected at each station.

4.4.2 Survey Procedures and Data Quality

Following the geophysical survey at West Beach, survey work at Great Salt Pond began on May 4, 2016. Table 39 summarizes the personnel involved in the field effort, and Table 40 lists the survey vessel and instrumentation used.

Table 39. Project personnel for the Block Island – Great Salt Pond coring and geophysical survey (2016)

Name	Affiliation	Survey Planning	Field Work	Data Processing	Report Preparation
Brian Caccioppoli	URI-GSO	X	X	X	X
Casey Hearn	URI-GSO	X	X	X	X
John King	URI-GSO	X	X	X	X
Monique LaFrance-Bartley	URI-GSO	X	X	X	-
Taylor Losure	URI Geosciences	-	X	-	-

Table 40. Survey vessel and instrumentation

Equipment	Function	Description
URI-GSO pontoon boat	Survey vessel	28' custom surveying/coring barge with modified A-frame, moon pool, and 5,000 lb capacity winch
Biological-type coring system	Sediment coring	<2 m coring capacity; 2.4 m polycarbonate liner; optimized for use in flocculent or loosely compacted sediments
Vibracore system	Sediment Coring	Rossfelder P-3 Vibra-Percussive system with 600-m working depth, accommodating 8- or 10-cm core barrels typically 3–6 m in length
Garmin GPS Map 76 Portable GPS	Navigational position	Positional accuracy approximately ± 9 ft at the study area
Edgetech 6205 Multi-Phase Echosounder	Combined side-scan and bathymetric sonar	Pole-mounted, swath bathymetry and dual frequency 550kHz/1,600kHz side-scan system
Teledyne Benthos CHIRP III, DSP-664 Transceiver	Sub-bottom profiler	Surface towed "catamaran" source producing a CHIRP waveform 2–7 kHz frequency sweep pulse with integrated hydrophones
Applanix POS MV V4	Navigation & motion compensation	Inertial Navigation System with two Trimble GNSS receivers

To achieve full side-scan coverage at Great Salt Pond, data were recorded at a 50 m range (100-m total swath width). Bathymetry was recorded at a 40-m range (80-m total swath width), providing near full coverage. The CHIRP was operated with a 63-ms repetition rate, the highest resolution setting, with cable layback 15 m aft of stern. Weather conditions began to deteriorate quickly when the survey in Great Salt Pond was underway. After data along two survey lines were collected, it was determined that data quality was not sufficient, and survey operations were terminated.

On May 9, 2016, survey operations were resumed at Great Salt Pond. Due to poor data quality, the two lines that had been previously run were resurveyed. The same settings for swath bathymetry/side-scan and sub-bottom data were used as previously described. Data acquisition continued until all survey lines were completed, after which the pontoon boat returned back to Payne's Dock and the survey equipment was removed and stored. The location of survey transects is illustrated in Figure 15.

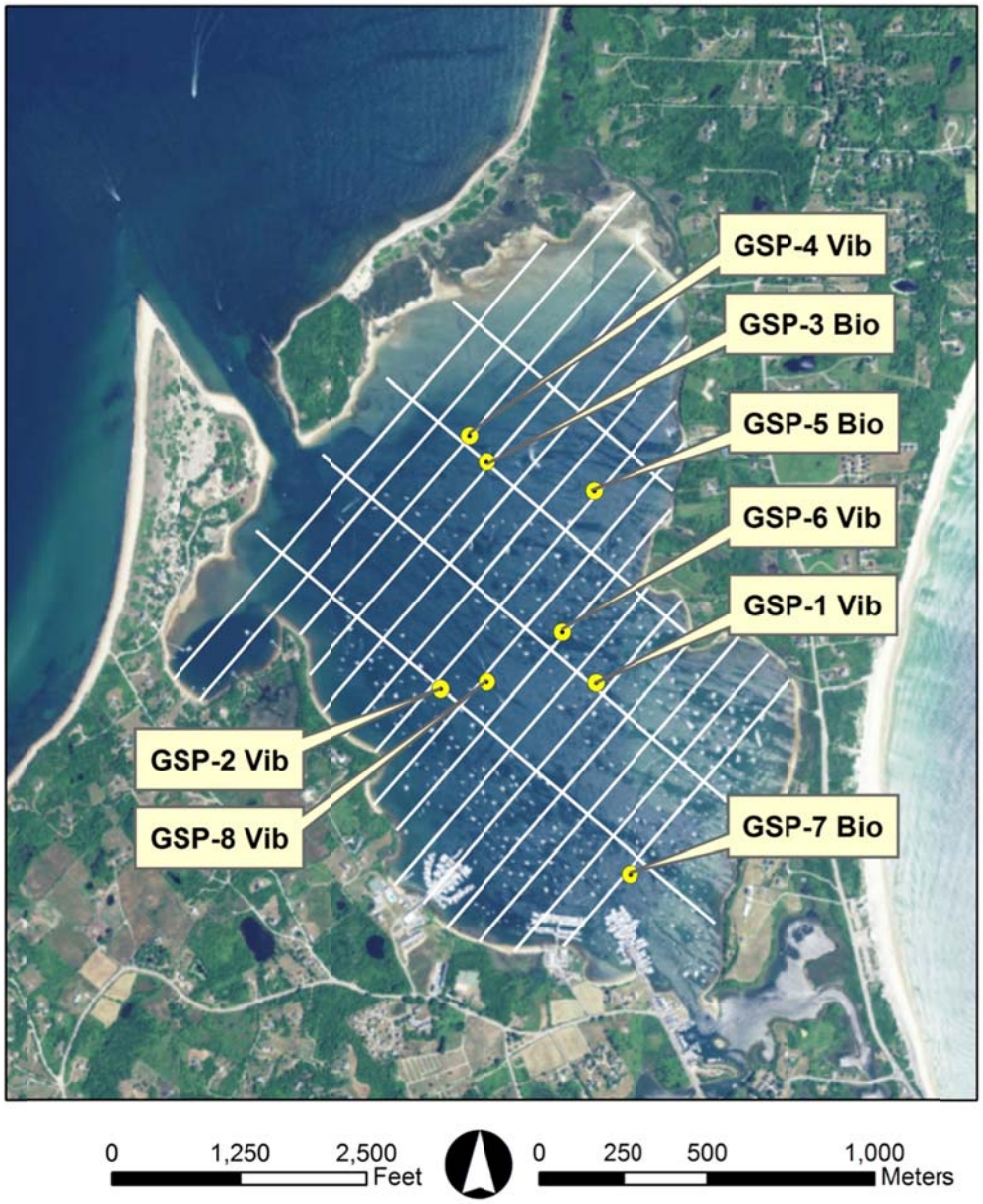

Figure 15. Location of sub-bottom sonar survey tracklines (white lines) and sediment cores in Great Salt Pond, Block Island, Rhode Island
Basemap orthophotograph source: ESRI ArcGIS online—"World Imagery"

After West Beach was deemed unsuitable for coring, on May 11, 2016, the coring operations began at Great Salt Pond. Prior to coring, features of interest were identified and targeted based on analysis of processed side-scan and CHIRP sub-bottom profiler data. Of particular interest was a deep basin approximately 15.2 m deep, and several channel-like features identified in the sub-bottom profiler data. Vibracoring was first attempted with 3-m core barrels. Four vibracores were collected, with recovered sediment length ranging from 0.70 m to 2.06 m. Coring was switched to biological coring in the afternoon. Only one biological core was collected with a recovered sediment

length of 0.86 m. At this point, increasing winds were creating unstable coring conditions, so operations were discontinued for the day.

The following day (May 12, 2016), coring operations resumed. Two additional biological cores were collected with recovered sediment lengths of 0.86 and 0.92 cm. After capping the biological cores and securing them upright on the pontoon boat, coring operations were switched to vibracoring. A 6-m vibracore was rigged, and the pontoon boat transited to the deepest area of Great Salt Pond (50 ft). The -6m vibracore was successful and a test of our capability of collecting a long vibracore from the pontoon boat. Figure 15 illustrates the locations of recovered vibracores.

After the collection of the last vibracore, the boat was returned to Payne's Dock, and the cores were packaged for transport back to URI-GSO. The coring operations at Great Salt Pond were the last component of the May 2016 field operation in Block Island. The pontoon boat was recovered onto the trailer, and all of the survey and coring equipment were packed for mobilization back to URI-GSO.

4.4.3 Assessment of Field Operations and Data Acquisition Procedures

The acquisition of swath bathymetry/side-scan data and CHIRP sub-bottom data were successful and deemed high quality during acquisition in the field. Preliminary analysis of post-processed datasets confirmed good coverage throughout the pond. The CHIRP sub-bottom profiler achieved significantly better penetration in Great Salt Pond compared to West Beach. This is due to the finer grained sediments throughout the pond. Sub-bottom records were obscured along the flanks of the pond due to sandy sediments and in the deepest portions of the pond where gas charged sediment appeared to be present.

Coring operations were also successful at Great Salt Pond, with four 3-m vibracores, one 6-m vibracore, and three biological cores recovered. Biological cores exhibited excellent preservation of the sediment/water interface, and when paired with the vibracores, provide continuous sediment records of Great Salt Pond.

5 Field Methodology Summary and Recommendations

Field work and data acquisition for the Submerged Paleolandscapes Project required a wide variety of equipment, methods, and technical expertise. The diversity of geological, oceanographic, and archaeological conditions and sites in each of the study areas provided an excellent opportunity to test and refine methods for data acquisition. This report describes all of the field methodology associated with the project and provides an assessment of the effectiveness of the techniques used for geological, archaeological, and geophysical data collection. The following summary provides the "lessons learned" from five years of field data acquisition and recommendations for refining existing field survey protocols.

5.1 Geological and Geophysical Data Acquisition

5.1.1 Sediment Coring

The project team had extensive experience using a variety of sediment coring systems in lake, estuarine, and offshore environments. Coring operations generally proceeded smoothly at all of the study areas or, in situations where difficulties were encountered, relatively minor modifications to existing equipment or procedures resulted in successful recovery. The following recommendations reflect the project team's prior expertise, as well as additional knowledge gained by coring in the project's multiple and geologically diverse study areas.

- Clearly define the purpose of sediment coring before choosing coring equipment. Piston-type cores, or other systems that preserve the sediment-water interface and the uppermost stratigraphy of the core intact, are often required to obtain a continuous, undisturbed sediment record.

- Avoid assuming that vibracoring is always the most preferable coring method. In addition, be aware that vibracoring usually disturbs or fails to recover the unconsolidated upper part (~0–30 cm) of the sediment column.

- When possible, understand the expected surficial and sub-surface geology of the study area before choosing coring equipment. Fine-grained sediments require the use of a piston-coring device to recover undisturbed sediments. If radiometric dating using 210Pb and 137Cs is required, then a piston corer that can recover an undisturbed sediment-water interface should be used. Sandy sediments will require the use of a vibracorer. Vibracorers usually disturb or fail to recover the upper part of the sediment column. Because sandy sediments can't be reliably radiometrically dated, the disturbance effects of vibracorer usually manifest themselves when comparisons are made between depth to lithology changes and depth to reflectors in high-resolution CHIRP sub-bottom sonar records. The depth of the reflectors in the sonar records are often offset 20–50 cm deeper than the associated lithology changes in the core due to the failure to recover or disturbance of the surface sediments.

Be prepared to use a variety of coring methods to obtain a complete and intact sediment record. It is often necessary to develop a "composite core" to thoroughly understand the sediment record at a study area. For example, using a piston-coring system may be necessary to obtain an intact sediment-water interface and preserve the upper (often flocculent) sediments of the stratigraphic record, while Livingston-type piston corers or vibracoring systems are required at the same location to adequately penetrate deeper sediments.

- Vibracoring systems may require modification of the core barrel size or core catcher construction to recover cores in dense, coarse sediments. Usually smaller diameter core barrels and stiffer core catchers are necessary to recover these sediments.

5.1.2 Seismic Reflection (Sub-bottom) Profiling

Sub-bottom profiling was conducted with CHIRP III and BubblePulser systems. The CHIRP system was used in areas where resolution of the uppermost sediment stratigraphy was desired (Greenwich Bay, Great Salt Pond, and West Beach), and the BubblePulser system was used when deeper penetration was required to characterize the ancient geologic history of a study area (south of Narragansett Bay). The equipment performed as expected at each of the study areas, and no technical issues were encountered during data acquisition, except at West Beach, where the seafloor geology (coarse sand, cobbles, and boulders) interfered with acoustic penetration of the sediments by the CHIRP system. Additional recommendations for sub-bottom surveying protocols are provided in the project Final Report.

- Be prepared to use both CHIRP and Bubblepulser-type systems to adequately characterize the sub-surface geology in a study area. This approach is particularly important in situations where deeper penetration is necessary to understand the regional geologic framework of a study area. Avoid assuming that CHIRP systems alone will always provide adequate data.

- Understand the regional geologic history of the study area before developing a survey plan, and ensure that data acquisition is monitored in the field by individuals familiar with this history. In Rhode Island waters, a prominent acoustic reflector is produced by a major unconformity between Cretaceous coastal plain sediments and/or crystalline bedrock and Pleistocene/Holocene sediments. In many cases, fluvial structures and other paleolandscape features are visible in the Cretaceous sediments and could easily be misinterpreted as features of interest to an archaeological sensitivity study. Because the project team had conducted a thorough Desktop Study prior to acquiring new data and understood the regional geologic history of the area, field specialists were able to adjust sub-bottom acquisition parameters "on the fly" in the field in order to focus on acoustic reflectors of interest.

- Plan to perform a preliminary examination of sub-bottom data, including "first pass" data processing, at the end of each field day and before the next day's surveying begins. Data should be reviewed by an individual familiar with the geologic history of the area, so that modifications to equipment settings or procedures can be made to optimize data resolution for upcoming surveys.

5.1.3 Side-Scan Sonar and Swath Bathymetry

A variety of geophysical survey systems are currently available to map surficial sediment types and swath bathymetry. Multibeam systems are often preferred if the survey goal is to obtain high-quality (hydrographic quality) bathymetry and acoustic backscatter characterization of the surficial sediments. However, the swath width obtained by these systems is usually limited to ~ 4X the water depth in the survey area. This limit is not cost effective when mapping in shallow waters, and multibeam systems are not generally used in depths of > 5 m. On the other hand, if the survey goal is to obtain full or high percentage bathymetry coverage and full or overlapping side-scan coverage, then interferometric sonar systems can obtain both types of data simultaneously. The swath width obtained by interferometric sonar systems is reliably 8X the water depth for bathymetry. The range

of the side-scan sonar is determined by the frequency of the system and is usually 15–25X the water depth for systems operating in the 400–600 kHz frequency band. This type of system is much more cost effective for survey work in water depths of 0–50 m.

- Clearly define the goal of surficial sediment mapping for each project, and choose equipment that is appropriate for the oceanographic conditions at the study area. Avoid assuming that one type of equipment will achieve project objectives for all study areas.

5.2 Archaeological Data Acquisition

In the context of marine geoarchaeological research done for the purpose of identifying pre-contact period Native American archaeological deposits and cultural sites within submerged paleocultural landscapes, the traditional role of excavation as the primary method of archaeological data acquisition needs to be examined critically. All forms of archaeological data acquisition, especially non-destructive and minimally invasive remote sensing and limited sub-surface sampling techniques, need to be considered fully, and, when necessary, new approaches developed in collaboration with Tribal research partners and applied in the design and performance of that research.

This mindset was applied to the extent possible in the archaeological data acquisition conducted for this project. In all cases, geologic data acquired through geophysical remote sensing or minimally invasive sediment sampling techniques were utilized for multiple purposes in understanding the geological, paleoenvironmental, and archaeological records and informing data acquisition approaches. The mapping and characterization of the geological and paleoevironmental records, combined with Tribal research partner input about traditional landscape interactions, practices, and preferences, provided a synergistic framework within which archaeological data acquisition efforts were planned and focused.

Identifying elements of the paleocultural landscape that survived the predominantly destructive processes associated with the marine transgression of the land by post-glacial sea level rise, as well as hundreds or thousands of years of impacts from modern marine processes and submergence underwater, is of paramount importance to determining viable locations for conducting marine geoarchaeological research and acquiring data. It is only in the portions of the seafloor where elements of the formerly subaerial landscape once available for habitation and utilization have survived and are identified that there is any possibility of encountering contextually intact archaeological deposits associated with formerly terrestrial (inland or coastal) pre-contact period Native American cultural sites. For this simple reason, virtually all of the archaeological data acquisition efforts that were conducted for this project (off of Cedar Tree Beach in Greenwich Bay and West Beach on Block Island) were done in areas that non-disturbance marine geophysical surveying or visual reconnaissance had indicated or demonstrated the preservation of archaeologically sensitive paleolandscape elements. The only exception was the underwater visual reconnaissance investigation of two transects extending out into the ocean from two different locations along West Beach with low-relief bluffs containing previously identified pre-contact period Native American archaeological deposits, which were examined to determine whether or not anything of either the low-relief upland geological features or the archaeological deposits had survived inundation.

Data acquisition techniques performed specifically for archaeological purposes during this project included: random and systematic non-disturbance visual, photo-/video-graphic, and gradiometric reconnaissance survey; minimally invasive VSP survey; hand-coring of sediments; collection of small-sized, representative samples of sediments and floral materials; and limited, invasive

excavation of just two 1 x 1 m archaeological DTUs. All of these techniques proved informative and provided different types of data that were complimentary to each other and to the geological data that was acquired for the project, while also taking into account the concerns of Tribal research partners about disturbances to the seafloor and to their ancestral cultural sites. Performance of these data acquisition techniques proceeded safely and smoothly with minimal difficulties that required only minor or relatively simple modifications to equipment, procedures, or schedule.

5.3 Real-Time Geospatial Mapping Support

Access to geospatial mapping services during data acquisition allows real-time refinement and/or modification of survey plans and assists with addressing logistical challenges encountered in the field. In addition, providing supplemental geospatial information to a field team may facilitate preliminary data interpretation on site and allow additional surveys to be refined to best achieve project goals. The logistical challenges and diversity of field work required for this project benefited from real-time input from both shore-based and onsite personnel with expertise in geospatial mapping technologies. The following recommendations do not require significant project resources and may streamline field operations:

- Arrange for a shore-based GIS specialist who is familiar with the survey goals and design to be on-call during field operations.
- Investigate the suite of ArcGIS mobile software, which allows real-time interactions and mapping between field- and shore-based personnel by using a tablet device or smart phone in the field. This software allows field personnel to access and visualize the geospatial data used to plan the survey, obtain additional data layers as necessary, and add new data on site.

6 References

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