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HOW-TO SERIES

Monitoring Shoreline Erosion at Calusa Island: A Community-Accessible Method

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Abstract
At coastal archaeological sites, measuring erosion rates and assessing artifact loss are vital to understanding the timescale(s) and spatial magnitude of past and future site loss. We describe a straightforward low-tech methodology for documenting shoreline erosion developed by professionals and volunteers over seven years at Calusa Island Midden (8LL45), one of the few remaining sites with an Archaic component in the Pine Island Sound region of coastal Southwest Florida. We outline the evolution of the methodology since its launch in 2016 and describe issues encountered and solutions implemented. We also describe the use of the data to guide archaeological research and document the impacts of major storms at the site. The response to Hurricane Ian in 2022 is one example of how simply collected data can inform site management. This methodology can be implemented easily at other coastal sites at low cost and in collaboration with communities, volunteers, and heritage site managers.

Resumen
Cuando nos enfrentamos a un sitio arqueológico que se deteriora, el primer paso es evaluar y documentar las condiciones. En los sitios costeros, es esencial medir las tasas de erosión y evaluar la pérdida de artefactos para comunicar la escala de tiempo y magnitud de la pérdida pasada y futura del sitio. Describimos una metodología sencilla de baja tecnología para documentar la erosión en la costa, desarrollada por profesionales y voluntarias(os) a lo largo de siete años en la isla Calusa, uno de los pocos sitios del período Arcaico que quedan en la región de Pine Island Sound, en el suroeste de Florida. Resumimos la evolución de la metodología desde su instalación en 2016 y describimos los problemas encontrados y las soluciones implementadas. También proporcionamos ejemplos de la utilidad de la metodología para orientar la investigación arqueológica y para documentar los impactos de las grandes tormentas en el sitio de la isla, incluido el huracán Ian en 2022. Esta metodología se puede implementar fácilmente en otros sitios costeros a bajo costo y en colaboración con voluntarias(os) de la comunidad local y gestoras(es) de sitios patrimoniales.

Keywords: coastal site erosion; citizen science; climate change; Florida archaeology; site monitoring

Palabras clave: erosión de sitios costeros; participación de voluntarios; cambio climático; arqueología de Florida; monitoreo de sitios

Archaeological sites around the world are increasingly being affected by rising sea levels and higher storm frequency/intensity caused by climate change (Dawson et al. 2017, 2021; Miller and Murray 2018). Tracking erosion at coastal archaeological sites is a challenge, and organizations across the globe are working to document this loss using a variety of methodologies and technology (Hambrecht and Rockman 2017; Holtz et al. 2014). Many approaches involve technologically advanced methods of data collection and analysis that are beyond the scope of nonprofessionals (Hil 2020; Howland et al. 2018; O'Rourke 2017; Pourkerman et al. 2018): this limits the involvement of dedicated contributors such as local communities and other interested nonprofessionals. Here, we present an example of a community-involved, low-cost, and low-tech method for documenting loss at the eroding Calusa Island Midden site (8LL45). Located on Florida's southwest Gulf Coast, the site provides an exemplary location to develop innovative approaches to monitoring and documenting coastal site loss for use in archaeological research and site management.

The site is named after its location on Calusa Island, a diminutive island within the Pine Island Sound region (Figure 1a). Calusa Island is regionally unique within southwest Florida in preserving evidence of people and environments from the Terminal Archaic period, 1200–500 BC (Marquardt 1999; see Haney et al. 2016). "Calusa" is the name Spanish invaders recorded for the Indigenous communities that inhabited most of southwest Florida (Marquardt and Walker 2012). Today, there are two federally recognized descendant tribes that have land and reside in Florida: the Seminole Tribe of Florida and the Miccosukee Tribe of Indians of Florida. The Calusa Island Midden site spans parcels privately owned by individuals and the Calusa Land Trust (CLT), an organization dedicated to the protection of "the natural diversity and beauty of the Pine Island region" (Calusa Land Trust 2023). Long-term collaborations in heritage preservation between the Florida Public Archaeology Network (FPAN), the Florida Museum of Natural History (FM) Randell Research Center (RRC), and the CLT provide the foundation of the work presented here. Future efforts in site monitoring will continue to include collaborative input from a variety of heritage management and preservation experts, as well as local and descendant communities.

The North Beach area of 8LL45 is composed of a dense shell midden. Vegetation along the midden edge includes trees, brush, and mangrove stands, with gumbo limbo (*Bursera simaruba*) and mangrove dominating the vegetative diversity. Because of its coastal orientation, this portion of the site is extremely vulnerable to erosion due to broad-scale sea-level rise and catastrophic storm events, as well as day-to-day impacts such as kayak landings and tourist visits (Figure 1b). Aerial photography shows the loss of trees along the shoreline since 1944 as reported in Haney and colleagues in 2016 (Figure 1a). In 2016, the island's sole permanent resident reported that more than 12 m (about 40 ft.) of the midden had eroded since the late 1970s, averaging more than 0.3 m (1 ft.) of loss per year (Figure 1a; Haney et al. 2016). During this time, midden materials, including worked and unworked shells and pottery, were observed eroding onto the shoreline and into the water, sometimes being redeposited farther down the beach. These trends continue in the present.

In the following sections we describe the monitoring methodology used at the North Beach area of Calusa Island to document coastal erosion, including the changes made over seven years based on experience with and evaluation of the methods; we also present the valuable data collected and briefly comment on how the data have informed academic research, storm response, and management at the site. This methodology can be used by site managers and citizen scientists to assess the condition and stability of other coastal archaeological sites and as the basis for any number of academic and management projects worldwide based on individual site needs, data, and goals. Moreover, this methodology can complement more high-tech site documentation efforts such as aerial lidar and shoreline remote sensing by providing detailed data of shoreline changes best observed in person (e.g., undercuts not visible from aerial perspectives).

Methodology

Initial Installation

The initial monitoring protocol was designed to require few technical tools and to have instructions clear enough to be implemented by a diverse group of volunteers, some with little to no archaeological experience. In April 2016, the RRC partnered with the CLT to establish an ongoing monitoring project to document and define site loss at the North Beach area of 8LL45 (Figure 1a–c). With the permission of the CLT, archaeologists installed half-inch-diameter steel rebar vertically into the midden at fixed reference points for measuring the distance to the midden's edge and to divide the approximately 100 m (328 ft.) stretch of shoreline into eight distinct sections to better document erosional patterns and distribution of artifacts from the midden (Figure 1c). Rebar were placed approximately 10 m apart and 2 m inland of the eroding edge and adjusted to fit seamlessly into the existing landscape. Rebar C, for example, was placed abutting a palm tree, making it less likely to cause a safety risk to

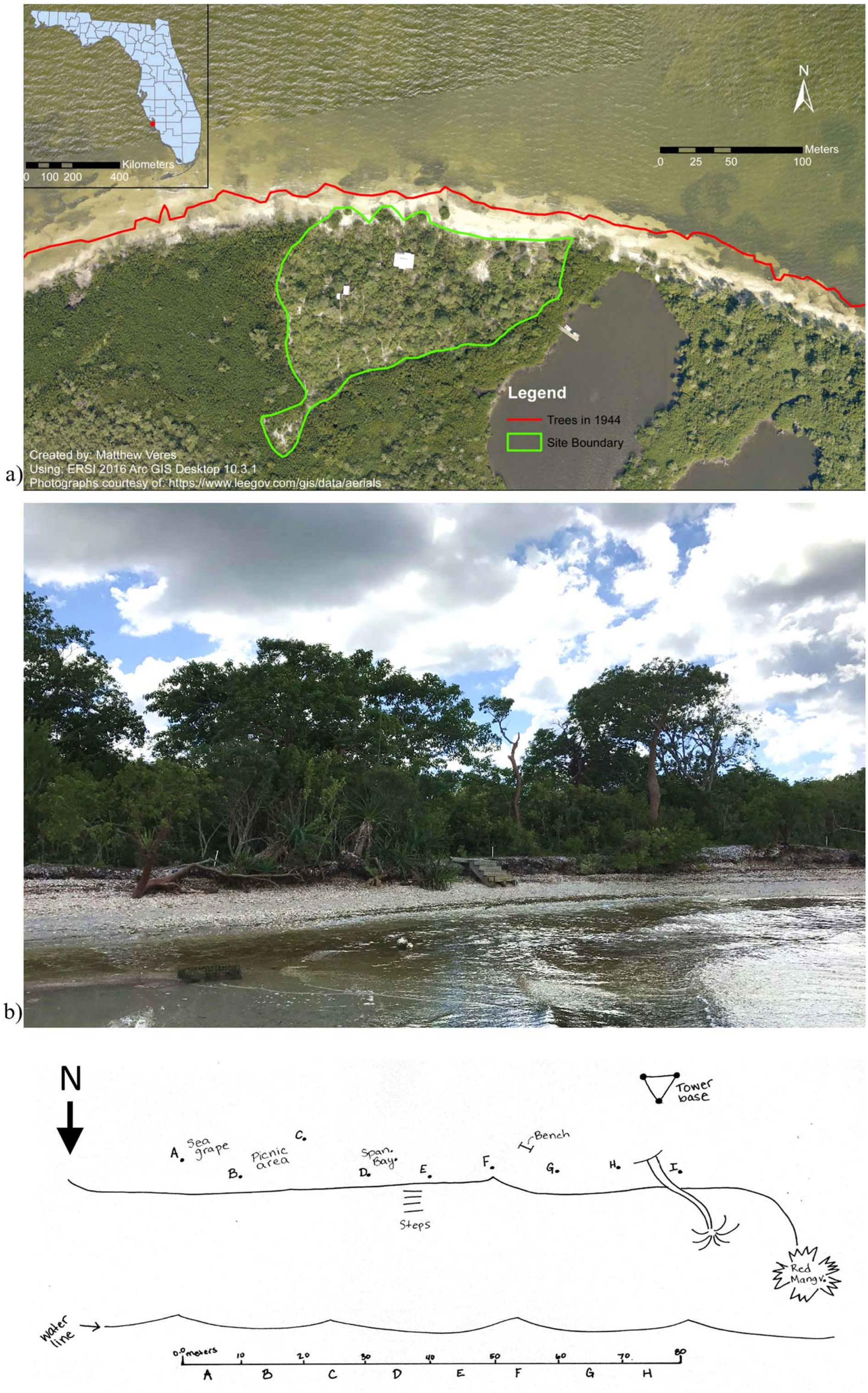

Figure 1. (a) Comparison of tree lines (coastline) between the 1944 USGS aerial photograph and the 2016 Lee County aerial photograph (from Haney et al. 2016); (b) photo of Calusa Island North Beach, October 13, 2017; (c) map of Calusa Island North Beach, including rebar indicated by letters and major landmarks across the beach.

island visitors. The rebar locations were tied into a local grid system established by island residents and then referenced to prominent landscape features along the shoreline, providing the spatial foundations for the monitoring protocol (Figure 1c). Some rebar were since removed by natural forces or visitors; however, because the original locations were documented they were easily replaced. In 2019, the rebar locations were geolocated using a total station as part of a site-wide survey.

As erosion occurs, the distance between the rebar and the edge progressively diminishes, enabling a calculation of the rate of change. Following the establishment of the monitoring protocol, and with support of the CLT and private Calusa Island landowners, the RRC and FPAN partnered to continue site monitoring and documentation of artifacts and material loss. To maximize documentation and engagement, a group of RRC volunteers were trained by FPAN and RRC archaeologists and empowered to visit the site independently.

Subsequent Monitoring

Working with a group of 26 people—13 trained archaeologists and 13 volunteers—since 2016, the site has been recorded 31 times, with visits made based on the availability of personnel. Initial plans included monitoring once a month; however, because of the fluctuation of volunteers who live in the area seasonally, hurricanes, and a global pandemic, monitoring visits were less consistent. Although ideally site visits would be regularly scheduled, the opportunistic timing of monitoring visits does not diminish the value of data collected, especially when evaluated over time.

Since 2016, the methodology has evolved to reduce the potential for measuring error. In the initial protocol, a pair of monitors were instructed to pull a measuring tape from the rebar to the erosional edge and record the measurement. This simple technique had the potential for varied techniques that would introduce error. These variations included how each individual held the tape in relation to the rebar, subjective decisions of where the erosional edge began, the angle of the tape to the erosional edge, and the horizontal level of the measuring tape across the area between the rebar and the edge. Each of these differing interpretations and subsequent decisions can result in centimeters of difference in measurements from one visit to another that may inaccurately reflect changes at the site.

To resolve these challenges, we then created a protocol that is printed and kept in a kit that volunteers and professionals use for monitoring along North Beach. It was detailed enough that monitors could visit the site with no recollection of their training and could still collect consistent and accurate data. FPAN staff met with volunteers at the site to train them in the protocol, the site, and the necessary techniques (using a compass and plumb bob, taking photos, etc). Although straightforward, the protocol does require a degree of skill and coordination that should be understood by anyone seeking to replicate the methodology and the volunteers they enlist. The combination of the complexity of the protocol and the difficulty in accessing the island (requiring a boat or kayak trip) required the careful selection of volunteers for the Calusa Island project. The protocol is abbreviated here to focus solely on the monitoring technique; the full protocol, which includes photos and details for documenting artifacts, is on file with the southwest and southeast regional FPAN offices and the RRC. All data collected during the monitoring are reported to and filed with the FPAN.

Calusa Island North Beach Monitoring Protocol

Measure the midden edge using rebar. There are nine rebar along the midden (Figure 1c). Carefully follow the protocol in Table 1 and see Figure 2a–c to ensure accurate and consistent measurements.

Measure the undercut, if present. In some areas, the midden has eroded more at the base where it meets the beach than at the top where you measured the edge. This is called an undercut (Figure 2d–e). Carefully follow the protocol in Table 1 to ensure accurate and consistent measurements.

Rebar Photos. Take two photos of each rebar; these will help us track how the beach looks over time at each location.

(1) Facing due north and including the cap of the rebar that denotes the rebar's letter (Figure 3a).
(2) Facing due south from the beach, including the rebar and surroundings (Figure 3b).

Table 1. Instructions for Measuring Midden Edge Using Rebar and for Measuring Undercut.

Measure the Midden Edge Using Rebar	
Step 1	Place the end of the measuring tape aligned with the middle of the top of the rebar. Your tape should not hook on the back of the rebar: it needs to be in the middle of the cap and on top of the rebar (not along the ground; Figure 2a).
Step 2	The person on the other end of the tape should pull it generally to the edge of the midden.
Step 3	The partner at the rebar, using the compass, should align your partner so he or she is due north of the rebar; the measuring tape should also be aligned due north (Figure 2b).
Step 4	Keeping the tape as level as possible, parallel to the ground, the person on the midden edge should use the plumb bob so the point is hanging freely but grazing the edge of the midden. The string of the plumb bob should be grazing the measuring tape, not resting on it. If the string is bent or loose, you need to readjust it so it hangs freely. Use the string of the plumb bob to measure the edge of the midden (wherever the string aligns with the measuring tape is your measurement; Figure 2c).
Step 5	Record your measurements on the Rebar Measurements form.
Measure the Undercut	
Step 1	Take your midden-edge measurement using this protocol. Then, make a mental note of exactly where your plumb bob came to the midden edge.
Step 2	At the spot where the bottom of the plumb bob touched, place the top (the string just below your hand) with the plumb bob hanging to the ground.
Step 3	Keeping the plumb bob hanging from that spot, you need to extend your measuring tape, lock it so it doesn't slide closed. Put the end of the measuring tape at the *deepest point* of the midden overhang, where the cut is deepest. The measuring tape should point straight back at the rebar, keeping your previously established due north line. Use the end of the plumb bob, dangling freely, to graze your measuring tape (Figure 2d,e).
Step 4	Record the measurement on the Rebar Measurements form.

Figure 2. (a–c) Procedures for measuring midden edge using rebar; (d,e) measuring an undercut.

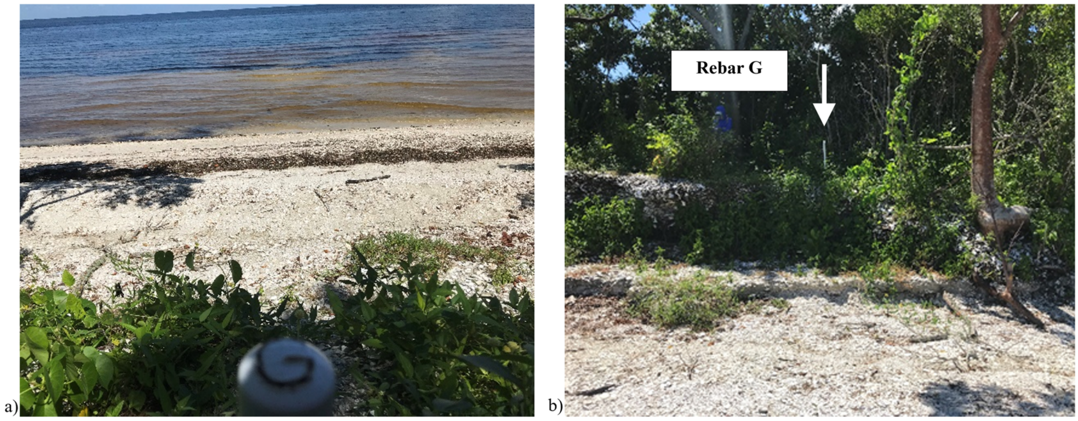

Figure 3. Rebar photos: (a) top of rebar G, facing due north; (b) view of beach and Rebar G facing due south.

Artifact Photos. Take at least two photos of each artifact, both with a scale north arrow.

(1) Close-up with scale north arrow and artifact. This is to help visually identify the artifact with some detail (Figure 4a).
(2) Context with scale north arrow and artifact. This photo is to tie the artifact in with large or fixed landmarks that are easy to find, like large trees, the shed near the picnic area, the stairs, or a rebar (Figure 4b).

Evolution of Methodology over Time and Common Mistakes to Avoid

This methodology produced data that document trends when analyzed over numerous years and anomalies after a large erosional event, such as a hurricane (Figure 5). The varying techniques that introduced error prompted us to update our protocol multiple times (Walker 2016). Many issues we encountered would be easily avoidable for new projects. The following issues caused inconsistencies in the data and were addressed in the following ways:

Issue: Orienting the measuring tape along a consistent line from rebar to erosion edge

Solution: We added the use of a compass to ensure systematic collection of measurements from each rebar due north to the eroding edge (Figure 2a,b)

Issue: Ensuring a consistent angle at which the monitors looked from above the measuring tape down to erosion edge

Solution: We introduced use of a plumb bob to control the vertical line from tape to the erosion edge to ensure it is consistently vertical (Figure 2c).

Issue: Using the top of the rebar for measurement, as described in Table 1; over time the rebar moved, whether from natural (e.g., wind, erosion) or anthropogenic causes (e.g., boats, kayaks, people lifting/pushing them).

Solution: We began measuring from the bottom of the aboveground rebar, where it was less likely that the angle of the rebar would affect measurement; this is not yet reflected in our protocol because we recently implemented the change and monitoring is now paused. It will be updated before any subsequent visits and is a valuable solution.

Issue: Differentiating between rebar when a rebar is missing. Some have very clear proximity to a notable landmark, but some can be more difficult to differentiate. These difficulties are exacerbated in a project that uses volunteers who train once a year but may not visit the site regularly and who are reliant on the map.

Solution: We covered the length of the aboveground rebar in white PVC pipe; we then capped the PVC and soldered the letter of each rebar into the cap to make each easier to identify in person and in photographs (Figure 3a,b).

Figure 4. Artifact photos: (a) close-up; (b) context.

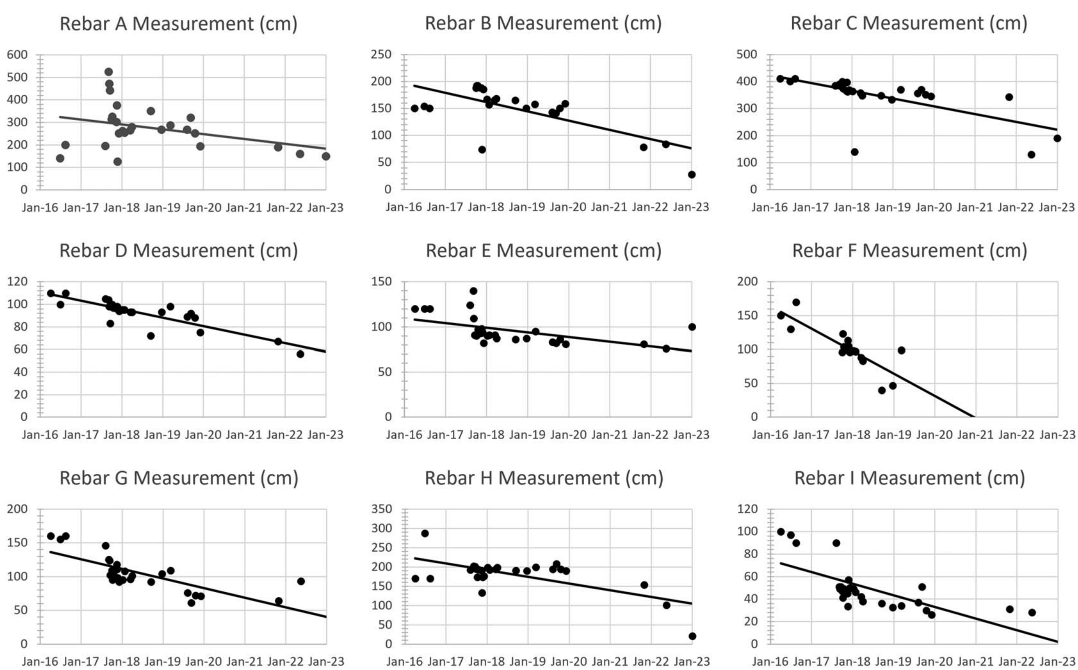

Figure 5. Calusa Island rebar data from April 2016 through January 2023. Each rebar measurement is represented by a single dot, and trend lines show the trends for each rebar. The *y* axis indicates measurements in cm; the *x* axis notes January of each year (for example, Jan 16 represents January 2016). For exact dates and measurements see Table 2. Note anomalous measurements but overall trends of declining measurement indicating erosion.

Issue: Need to replace repar; with multiple rebar running the length of the beach, some were removed by visitors and discarded them in nearby vegetation. Rebar F, which was placed in a fairly open area near a bench and likely attracted more attention than the other ones, was particularly affected.

Solution: Although inconvenient, accurate GPS locations were taken when installed, so they were easy to replace. New projects should consider concealing the rebar.

Alternate solution: An elegant solution for most of these issues was developed by the FPAN West Central office: using a set of two markers flush with the ground to create an easily repeatable straight line when a measuring tape is run from one marker, across the second, and to the erosional line. This methodology was used in 2021 in Pinellas County, Florida, and has proven useful.

Data

Based on the data collected at Calusa Island to date, we can make two important assertions. First, there is a clear negative correlation between the distance from the rebar to the edge of the midden and time (Table 2; Figure 5), which suggests severe erosion at the site. Data gathered from April 2016 to January 2023 show that the rebar-to-edge measurement is declining at an average rate of 77 cm (2.5 ft.) per year (see trendlines in Figure 5). This illustrates the threat to the site posed by major storms and day-to-day erosion. Second, although the midden covers the entire North Beach area, there is significant variability in terms of in situ artifact exposure and distribution documented using the section letters assigned to each rebar, suggesting differing archaeological site components (Figure 1c data available on request from the FM).

Although this methodology has demonstrated the ability of trained volunteers to collect useful data, we acknowledge that more consistent data collection would allow for additional, more refined analyses and conclusions. For example, monthly monitoring would allow for tracking temporal—monthly or seasonal—trends in North Beach shoreline change. Regular monitoring would also show how different causes of erosion may variably affect different midden areas / rebar locations, such as storm events, weather patterns, and visitor traffic.

Using Monitoring Data to Inform Research and Understand Storm Impacts

Archaeological Research

The data from our monitoring program have been foundational for archaeological research on Calusa Island. In 2016, a bulk sample of the eroding midden edge along North Beach was collected, and the first professional archaeological profile was documented (Haney et al. 2016). Three years later, in 2019, an assessment of monitoring data indicated high concentrations of in situ and displaced artifacts (e.g., pottery, worked shells, animal bones) along the east side of North Beach between Rebars B and D. In early 2020, in collaboration with the CLT, the RRC and FPAN conducted the first systematic archaeological shovel test transect across the interior of Calusa Island. In addition, a bulk sample was collected, and a midden profile drawn from the same location as Haney and colleagues' (2016) work to enable comparison of data through time. One of the goals of this work was to understand what cultural resources stand to be lost by erosion over the next five to 10 years.

Although the 2020 field season was cut short by the COVID-19 pandemic, nine shovel tests were completed, the bulk sample was collected, and the midden was profiled. Current results suggest that the shell midden extends across Calusa Island and is up to 1.3 m (4 ft.) deep across portions of the island, and the North Beach area includes cultural components representing Late Archaic to Caloosahatchee I and II (about 1000 BC–AD 1200) occupations, representing some of the earliest and least documented time periods of Indigenous history in the Pine Island Sound region.

Documenting Storm Damage

The North Beach monitoring data and protocol are especially useful for assessing the dynamic and devastating impacts of storms on the site. Most recently, on September 28, 2022, Hurricane Ian struck Pine Island Sound directly, profoundly affecting Calusa Island. Powerful winds, rain, and waves, as well as storm surge reaching 2.7 m (9 ft.), accelerated erosion at parts of the site (as documented in monitoring data) and uprooted trees left newly exposed portions of the midden vulnerable to future erosion

Table 2. Calusa Island Measurements for Eroding Edge and Undercut.

Date	A	A	B	B	C	C	D	D	E	E	F	F	G	G	H	H	I	I
4/14/2016	200	0	150	0	410	0	110	0	120	0	150	0	160	0	170	0	100	0
7/10/2016	140	0	154	0	400	0	100	0	120	0	130	0	155	0	287	0	97	0
8/26/2016	200	0	150	0	410	0	110	0	120	0	170	0	160	0	170	0	90	0
8/18/2017	195	0	—	0	384	0	105	0	124	0	—	0	146	0	192	0	90	0
9/16/2017	525	0	—	0	386	0	104	0	140	0	—	0	125	0	202	0	51	0
9/21/2017	471	0	—	0	390	0	98	0	109	45	—	0	124	45	198	22	49	62
9/29/2017	443	0	—	0	385	0	83	0	91	0	—	0	102	34	201	21	51	65
10/13/2017	314	0	188	0	382	0	99	0	90	40	96	0	109	41	194	29	47	43
10/19/2017	325	0	192	0	399	0	100	0	91	0	123	0	95	11	173	26	41	36
10/27/2017	309	0	192	0	373	0	97	0	97	0	104	0	105	39	193	28	49	65
11/27/2017	301	0	188	0	365	0	96	0	93	0	99	0	118	43	191	29	45	59
11/30/2017	375	0	188	4	397	0	98	32	98	25	113	0	111	35	133	20	34	50
12/6/2017	125	0	74	0	362	0	97	0	94	0	105	0	98	35	173	17	57	68
12/18/2017	251	0	186	0	368	0	94	0	82	0	96	0	92	15	176	11	50	63
1/19/2018	262	0	167	0	364	0	95	50	90	30	98	0	95	33	198	27	49	60
2/6/2018	254	0	157	0	140	0	95	0	91	25	97	0	108	37	192	32	46	60
3/29/2018	265	0	166	0	357	0	93	47	91	24	88	0	96	33	194	34	42	58
4/13/2018	280	0	168	0	348	0	93	0	87	0	83	0	101	10	198	18	38	51
9/28/2018	350	0	165	0	348	0	72	39	86	20	40	0	92	37	191	22	36	50
1/3/2019	267	0	150	0	333	0	93	9	87	26	47	37	104	38	190	17	33	53
3/22/2019	287	0	158	0	370	0	98	0	95	0	99	0	109	36	199	29	34	44
8/20/2019	268	0	143	0	356	0	89	42	83	13	—	0	76	30	194	32	37	51
9/22/2019	321	0	141	0	370	0	92	31	82	14	—	0	61	14	208	0	51	48
10/29/2019	251	0	150	0	351	0	88	44	86	17	—	0	72	28	194	24	30	43

(*Continued*)

Table 2. Calusa Island Measurements for Eroding Edge and Undercut. (*Continued.*)

Date	A	A	B	B	C	C	D	D	E	E	F	F	G	G	H	H	I	I
12/16/2019	193	0	159	0	345	0	75	49	81	24	—	0	71	26	190	27	26	47
11/10/2021	189	0	79	0	343	0	67	0	81	0	—	0	64	20	154	18	31	44
5/27/2022	160	0	84	0	130	0	56	0	76	0	—	0	93	76	101	0	28	44
1/12/2023	150	0	28	0	190	0	—	0	−100	0	—	0	—	0	21	0	—	0

Note: Dates are mm/dd/yyyy. All measurements are in cm. The first column of each letter indicates measurement from the lettered rebar to the eroding edge; the second column of each letter documents undercut measurements. Em-dashes indicate no measurement taken due to missing rebar. 0 indicates no undercut noted. See Figure 5 for graphs and trend lines.

Figure 6. Rebar E and staircase images from 2017 to 2023. Notable hurricanes during that time were Irma on August 18, 2017, and Ian on September 28, 2022. The staircase was no longer present after Ian, and the midden had eroded 100 cm *past* the rebar.

(Figure 6a,b). Additionally, a significant amount of shell material from the sound was deposited on parts of the beach. These deposits impeded our ability to define the full extent of erosion prior to their deposition; however, they now provide a temporary measure of protection by partially covering erosional edges of the midden.

Most Calusa Island volunteers were displaced from their homes, lost property during the storm, or both, and Calusa Island was inaccessible for weeks. FPAN archaeologists were not able to monitor the site until December 6, 2022, followed by another site visit with RRC archaeologists and CLT members in January 2023. The first visit focused on locating and assessing the contextual integrity of the rebar and documenting overall damage to the North Beach midden area. Many of the rebar survived the storm without alteration, but all experienced corrosion and showed signs of deterioration. Rebar F had been displaced before the storm (likely by visitors to the island), Rebar D and G were missing or displaced after the storm, and the midden surrounding Rebar E and I had eroded past the rebar.

During our second visit, we toured the site with local CLT members and individual property owners. Using Hurricane Ian as an example, our goal was to consider how future hurricanes may affect the site and thus management decision-making. We discussed how the pattern of shoreline erosion followed by storm surge deposition along North Beach created deposits of mixed archaeological and more recent materials (e.g., oysters and sand) along the midden profile. It was clear that the exposed North Beach midden profile is vulnerable to a variety of taphonomic and site formation processes related to large storm events. Based on this observation, and within the context of previous monitoring data indicating rapid loss along Calusa Island's north coastline overall, we recommended against additional destructive (e.g., subsurface) archaeological investigations of the North Beach midden profile for the foreseeable future and the continuation of nondestructive monitoring efforts.

For Calusa Island, the monitoring data demonstrate that a single storm can be the catalyst for immense change and destabilization of a coastal site. Dozens of tropical systems have affected Pine Island Sound, and since 2016 two major hurricanes—Irma in 2017 and Ian in 2022—made landfall within 60 miles (95.5 km) of 8LL45. Our data provide CLT property managers and Calusa Island property owners with information on erosion rates they can apply to site management and preservation decisions. Moving forward, we are exploring the installation of more durable location markers to replace the corroding rebar and moving markers farther inland along their established compass bearings as needed. We, however, intend to continue using the established monitoring protocol for data consistency because of its adaptability for use by volunteer monitors.

Summary and Conclusions

Worldwide, tracking erosion at coastal archaeological sites is a cultural heritage preservation challenge exacerbated by accelerated sea-level rise and increasingly frequent and powerful storms. Documenting the rate of site loss is beyond the capabilities of many managers or entities, including federal, state, municipal, and nonprofit organizations charged with preserving archaeological heritage. However, it is essential that site change be documented to help understand the dynamic impacts of climate change, even if on a small scale. Here we described a low-tech, inexpensive, replicable, and community-accessible monitoring methodology developed at the Calusa Island Midden site to systematically measure shoreline erosion and cultural resource disturbance.

Over the past seven years, our results demonstrate not only the effectiveness of the approach in documenting the rates and impacts of erosion but also the relevance of monitoring data to archaeological research and to understanding the scope of site loss due to significant storm events. Our data show the normal rate of erosion at the site, the distribution of displaced artifacts across the site, and the increased impact of storm events. The photographic data are invaluable in communicating the erosional impacts to the site and the incredible changes in appearance after a storm, which reflect the change in site stability (Figure 6). This approach is adaptable to a variety of coastal locations, is affordable to implement and sustain independently, and can also complement any number of high-tech and more costly methods (such as lidar documentation). We hope our approach inspires more collaborative efforts to document and preserve vulnerable coastal cultural sites.

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Data Availability Statement. Data that support the findings of the excavations are still being analyzed. The monitoring data that support the findings of this study are available from the Florida Public Archaeology Network, Florida Atlantic University.

Competing Interests. The authors declare none.

References Cited

Calusa Land Trust. 2023. About CLT. Electronic document, https://www.calusalandtrust.org/about-clt. accessed September 2, 2023.

Dawson, Tom, Joanna Hambly, William Lees, and Sarah Miller. 2021. Proposed Policy Guidelines for Managing Heritage at Risk Based on Public Engagement and Communicating Climate Change. In *The Historic Environment: Policy and Practice*, edited by Hannah Fluck, pp. 1–20. Taylor & Francis, London.

Dawson, Tom, Courtney Nimura, Elías López-Romero, and Marie-Yvane Daire (editors). 2017. *Public Archaeology and Climate Change*. Oxbow Books, Oxford.

Hambrecht, George, and Marcy Rockman. 2017. International Approaches to Climate Change and Cultural Heritage. *American Antiquity* 82(4):627–641.

Haney, Jennifer, Matthew Veres, Karen Walker, William Marquardt, and Lee Newsom. 2016. *Calusa Island, Florida: Monitoring and Preliminary Archaeological Testing at a Late Archaic Shell Midden*. Poster presented at the Southeastern Archaeological Conference, Athens, Georgia.

Hil, Greg. 2020. Better Management through Measurement: Integrating Archaeological Site Features into a GIS-Based Erosion and Sea Level Rise Impact Assessment—Blueskin Bay, New Zealand. *Journal of Island and Coastal Archaeology* 15(1):104–126. https://doi.org/10.1080/15564894.2018.1531331.

Holtz, Debra, Adam Markham, Kate Cell, and Brenda Ekworzel. 2014. *National Landmarks at Risk: How Rising Seas, Floods, and Wildfires Are Threatening the United States' Most Cherished Historic Sites*. Union of Concerned Scientists, Cambridge, Massachusetts.

Howland, Matthew D., Ian W. N. Jones, Mohammad Najjar, and Thomas E. Levy. 2018. Quantifying the Effects of Erosion on Archaeological Sites with Low Altitude Aerial Photography, Structure from Motion, and GIS: A Case Study from Southern Jordan. *Journal of Archaeological Science* 90:62–70.

Marquardt, William H. 1999. Useppa Island in the Archaic and Caloosahatchee Periods. In *The Archaeology of Useppa Island*, Monograph 3, edited by William H. Marquardt, pp. 77–98. Institute of Archaeology and Paleoenvironmental Studies, Gainesville, Florida.

Marquardt, William H., and Karen J. Walker (editors). 2012. *The Archaeology of Pineland: A Coastal Southwest Florida Site Complex, A.D. 50–1710*. Monograph 4. Institute of Archaeology and Paleoenvironmental Studies, University of Florida, Gainesville.

Miller, Sarah E., and Emily Jane Murray. 2018. Heritage Monitoring Scouts: Engaging the Public to Monitor Sites at Risk across Florida. *Conservation and Management of Archaeological Sites* 20(4):234–260.

O'Rourke, Michael J. E. 2017. Archaeological Site Vulnerability Modelling: The Influence of High Impact Storm Events on Models of Shoreline Erosion in the Western Canadian Arctic. *Open Archaeology* 3(1):1–16. https://doi.org/10.1515/opar-2017-0001.

Pourkerman, Majid, Nick Marriner, Christophe Morhange, Morteza Djamali, Sedighe Amjadi, Hamid Lahijani, Abdolmajid Naderi Beni, Matteo Vacchi, Hossein Tofighian, and Majid Shah-Hoesseini. 2018. Tracking Shoreline Erosion of "At Risk" Coastal Archaeology: The Example of Ancient Siraf (Iran, Persian Gulf). *Applied Geography* 101:45–55.

Walker, Karen. 2016. Calusa Island Protocol Background and Introdcution. Manuscript on file with Florida Public Archaeology Network, Southwest Region.

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