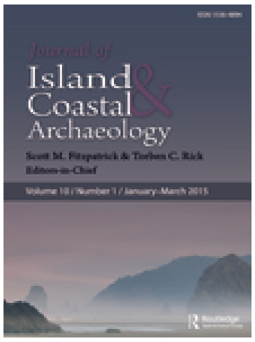

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Keeping Pace With Rising Sea: The First 6 Years of the Lower Suwannee Archaeological Survey, Gulf Coastal Florida

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ABSTRACT

Low-gradient coastlines are susceptible to inundation by rising water, but they also promote marsh aggradation that has the potential to keep pace with sea-level rise. Synergies among hydrodynamics, coastal geomorphology, and marsh ecology preclude a simple linear relationship between higher water and shoreline transgression. As an archive of human use of low-gradient coastlines, archaeological data introduce additional mitigating factors, such as landscape alteration, resource extraction, and the cultural value of place. The Lower Suwannee Archaeological Survey (LSAS) is an ongoing effort to document the history of coastal dwelling since the mid-Holocene, when the rate and magnitude of sea-level rise diminished and the northern Gulf coast of Florida transitioned into an aggradational regime. Results of the first 6 years of the LSAS suggest that multicentury periods of relative stability were punctuated by site abandonment and relocation. Subsistence economies involving the exploitation of oyster and fish, however, were largely unaffected as communities redistributed themselves with changes in shoreline position and estuarine ecology. After AD 200,

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civic-ceremonial centers were established at several locations along the northern Gulf coast, fixing in place not only the infrastructure of daily living (villages), but also that of religious practice, notably cemeteries and ceremonial mounds. Intensified use of coastal resources at this time can be traced to a ritual economy involving large gatherings of people, terraforming, feasting, and the circulation of socially valued goods. To the extent that religious practices buffered the risks of coastal living, large civic-ceremonial centers, like aggrading marshes, afforded opportunities to "outpace" sea-level rise. On the other hand, centers introduced a permanence to coastal land-use that proved unsustainable in the long term.

Keywords mariculture, mortuary practice, ritual economy, sea-level rise, terraforming

The Lower Suwannee Archaeological Survey (LSAS) was launched in 2009 as a partnership between the Laboratory of Southeastern Archaeology, the University of Florida, and U.S. Fish and Wildlife Services (USFWS) to inventory, sample, and interpret the aboriginal archaeological record of the northern Gulf Coast of Florida (Sassaman et al. 2011, 2014). Comprised of two wildlife refuges spanning 42 km of coastline—from the towns of Horseshoe Beach to Cedar Key (Figure 1)—the study area has largely escaped modern development. Despite the limited amount of previous survey, ongoing coastal erosion attending sea-level rise and other forces has exposed archaeological deposits along the shore and on islands, contributing to an inventory of over 100 sites, many of which will disappear in coming decades. Part of the LSAS's purpose is to salvage information from endangered sites.

Beyond rescue efforts, the LSAS involves reconnaissance survey of landforms currently unaffected by coastal erosion—basically "upland" units—as well as excavation at sites containing information relevant to particular research projects. Graduate students of the University of Florida guide much of the research, and their individual projects are integrated in an overall agenda to document human responses to sea-level rise since the fifth millennium BP, when levels rose to within 1–2 m of the modern range. Sites of coastal occupations predating about 4500 cal BP are now inundated by Gulf waters (Faught 2004) or were impacted by shoreline transgression, like those in the current intertidal zone.

Here we summarize the results of the first 6 years of the LSAS through the perspective of sea-level rise. The study area consists of a low-gradient coastline whose configuration and subaerial extent are particularly vulnerable to changes in sea level. The sea has risen about 80 m and the shoreline retreated 250 km since humans first arrived in the region in the late Pleistocene. Most of this took place in the first two millennia of the Holocene, when pulses of rising water repeatedly overstepped coastlines (Donoghue 2011:28–29). Since about 6,000 years ago, the coastline of the study area has been comparably stable within a regime of marsh aggradation and intermittent transgression. Conditions grew increasingly favorable for sustained coastal settlement, but occasionally the equilibrium between rising water and aggrading marshes was disrupted by climate events that impacted estuarine ecology. Oyster bioherms (i.e., oyster reefs of mounded, often ridge-like form) factor into this history as both a measure of economic potential for humans and a structural component for impounding the sediment and freshwater plumes of a healthy estuary.

As we outline below, coastal settlement until about AD 200 was punctuated by episodes of abandonment and relocation—some evidently in response to climate events—but with little change to subsistence economies centered on oysters, fish, and other estuarine resources. After this time, settlement shifted to large civic-ceremonial centers and resource use intensified to meet the growing demands of a regional ritual

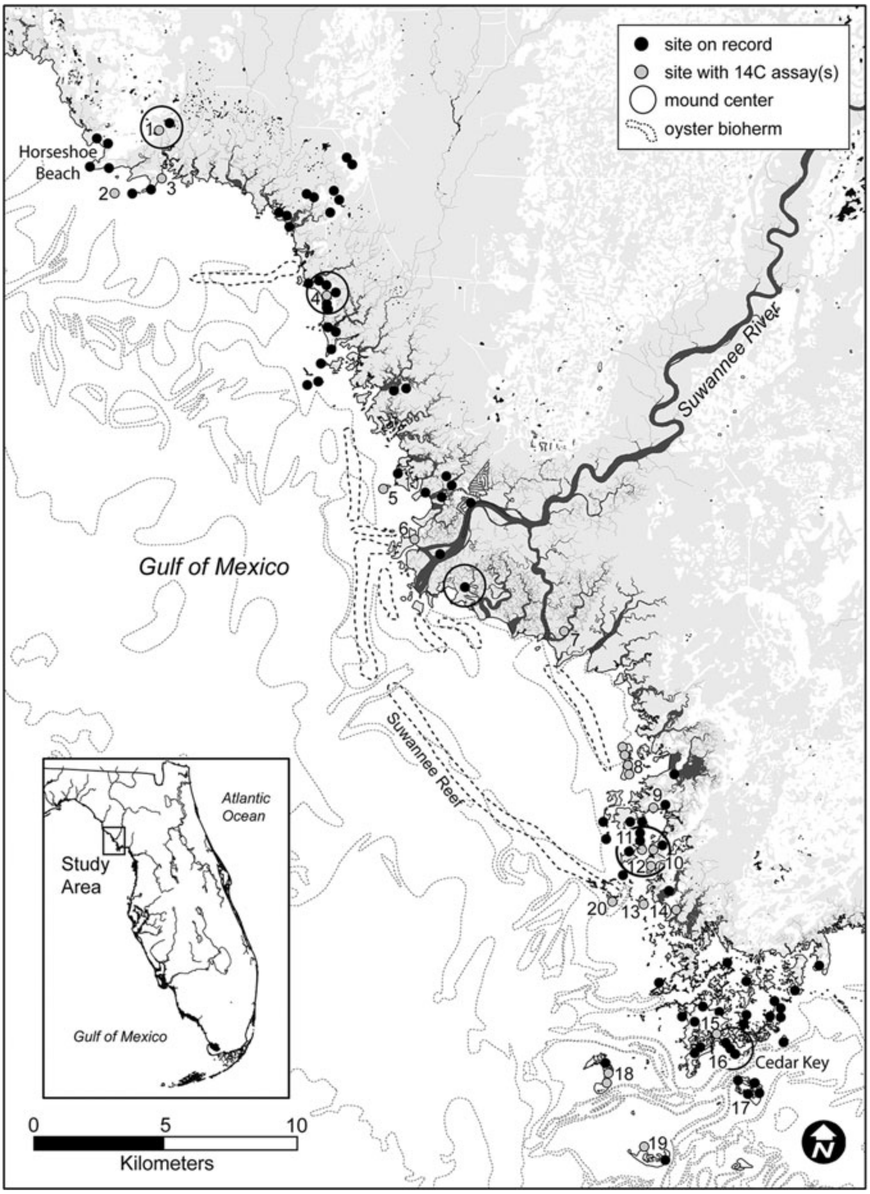

Figure 1. *Map of the study area of the Lower Suwannee Archaeological Survey, showing the modern shoreline and islands, major oyster bioherms (many now extinct or threatened), and modern bathymetry at a contour interval of 0.9 m. Shaded area on land is wetland; white area is "upland," at least 2 m amsl. Also shown are the locations of archaeological sites (small shaded circles) and mound centers (large open circles). Site/island names keyed to numbers as follows: 1. Garden Patch; 2. Bird Island; 3. Butler Island; 4. Hughes Mound; 5. Cat Island; 6. Little Bradford; 7. Dan May; 8. Deer Island; 9. Raleigh Island; 10. Shell Mound; 11. Palmetto Mound; 12. Komar; 13. McClamory Key; 14. Richards Island; 15. Ehrbar; 16. Cedar Key mound complex; 17. Atsena Otie; 18. North Key; 19. Seahorse Key; 20. Derrick Key.*

economy. Although the permanence of land use may have accentuated vulnerabilities to environmental change, sites of habitation aggraded upwards, like marshes, to keep pace with rising water. By AD 700, however, most centers were abandoned and settlements resumed being less centralized. That nonlocal items and persons continued to be emplaced in caches and cemeteries of abandoned centers suggests that they endured as historical resources (i.e., "sedimented" histories) for coastal residents and the interior communities to which they were allied. We begin our review of LSAS results with further detail on the environmental synergies of this eventful history.

ENVIRONMENTAL SYNERGIES

The Lower Suwannee study area is an open-marine shoreline with expansive salt marshes, seagrass beds, oyster beds and reefs, and tidal creeks along a crenulated shoreline dotted with numerous low-relief islands, tree hammocks, and relict dunes. The Suwannee River debouches into the Gulf of Mexico at the coastal midpoint of the study area, where its delta and distributary channels accentuate the marshy shoreline. As part of the larger Big Bend region of the Florida Gulf Coast, the Lower Suwannee area has surface geology influenced by structural variations in shallow, low-relief limestone substrate (Davis 1997:165–166). The karst topography resulting from dissolution and collapse of limestone includes broad depressions that form embayments, hammocks formed on bedrock nubs, and marsh island archipelagos on flooded, irregular bedrock planes.

In addition to karst-related features, the Lower Suwannee area contains a large number of relict dunes, many of which have been reworked as water levels rose (Wright et al. 2005). Varying in size and elevation, dunes in the area formed during the late Pleistocene under drier and cooler conditions than present (Iverster et al. 2001), and with sea level down about 100 m. Only a few dunes maintain their original morphology, with parallel arms open to the southwest and heads to the northeast. Remnants vary in elevation from only a meter or two above mean sea level (amsl) up to 17 m amsl at Seahorse Key, the highest elevation along the northern Gulf coast. Besides offering topographic relief for human settlement, dunes provided a major source of sediment for marsh aggradation and the development of sandy shoals on which seagrass beds flourished. The Lower Suwannee is an otherwise sediment-poor regime. The river itself is the only appreciable source of sand from the interior of the peninsula; other freshwater inputs come from springs that carry virtually no sediment.

Freshwater input is intrinsic to an estuarine system and the fish, shellfish, and other biota on which humans came to depend. Ubiquitous at aboriginal sites of all ages in the study area are the remains of the Eastern oyster (*Crassostrea virginia*). Oysters can tolerate a wide range of salinity levels (~5–35 ppt), and can thrive in both subtidal and intertidal conditions. However, at the higher range of salinity in subtidal conditions, oysters are subject to parasites (e.g., oyster drills and sponges) that compromise survival and productivity. Recent increases in salinity due to groundwater extraction upstream in the Suwannee River valley are contributing to the collapse of major subtidal reefs in the area (Berquist et al. 2006; Seavey et al. 2011). The largest in the area, the Suwannee Reef (Figure 1), is essentially extinct. The consequences of reef collapse go beyond a diminished source of food for coastal communities to alter the balance between marsh aggradation and sea-level rise. Healthy, expanding subtidal reefs help to "trap" sediment in the intertidal zone and thus create potential for marsh aggradation to keep pace with rising sea.

The Lower Suwannee area has been subject to several programs of geological coring and remote sensing to detect changes in relative sea level over the past few millennia (Goodbred et al. 1998; Hine et al. 1988; Wright et al. 2005), when human occupation of the area thrived. In addition, a recent program of coring in Horseshoe Cove (McFadden 2014, 2016) brings the scale of observation down to the level of a site cluster (at the north end of the study area) whose chronology can be correlated with events and processes attending sea-level rise, including storm surges. None of these studies has detected any evidence for higher-than-present stands during the Holocene (see Donahue 2011), nor evidence for major regressions in recent millennia, such as the ones proposed for the South Atlantic ca. 4,300–3,600 (Gayes et al. 1992) and 3,200–2,500 years ago (Colquhoun and Brooks 1986; DePratter and Howard 1981). However, documented in these studies are several instances of overstepping of the shoreline, when the sea transgressed rapidly after multicentury periods of relative stability.

The history of sea-level rise in the vicinity of the Suwannee delta exemplifies the punctuated nature of shoreline transgression. Wright et al. (2005) established that prior to 8,000 years ago, when sea level was down ~10 m, the delta was at least 15 km from its current relative position and supported only a thin veneer of sediment. As water rose, the flat shelf of the delta was quickly flooded and by about 5,400 years ago the shoreline was within 8 km of its current position. The rate of rise slowed considerably after this time, leading to the formation of oyster bioherms offshore, which trapped marine and other biogenic sediments landward. For a millennium, sediment accretion kept pace with rising sea until about 4,400 years ago, when the shoreline was overstepped and sea transgressed another 2 km. New bioherms became established proximate to the new shoreline by about 3,600 years ago. The modern marsh system began to form after about 2,350 years ago, following a transgression of unspecified magnitude. Another transgression of 2–3 km occurred between about 1,900 and 1,700 years ago in Waccasassa Bay, about 30 km south of the delta (Goodbred et al. 1998). Although this event may not have affected the delta area due to backfilling of distributary channels, the coastline just north of the delta, which lacks substantial oyster bioherms, was overstepped at about this time to reach its near-modern position (Wright et al. 2005:634).

In sum, the study area has long been vulnerable to changes in sea level, primarily because of the low gradient of its bedrock platform. Where the combination of freshwater input and a sediment source led to prolific oyster reefs and development of marsh landward of reefs, aggradation could keep pace with rising water. Transgression of the shoreline was evidently eventful, even as sea levels rose incrementally, because of imbalances among freshwater input, oyster health, and sediment supply. The effects of sea-level rise were highly localized because of these and other factors. Human response to sea-level rise may have been just as localized, although both the time-depth of experience (i.e., memory) and geographic reach of social interactions (i.e., regional networks) mitigated any direct relationships among climate-related events, perception of change, and human intervention. The archaeological details of human experience on the coast have to be assembled independently of sea-level histories to begin to infer how one relates to the other.

ARCHAEOLOGICAL RECORD OF THE LOWER SUWANNEE

Currently, the Florida State Master Site Files contains records on 111 aboriginal archaeological sites in the study area (Figure 1). Details about these sites come from accounts of early exploration (e.g., Moore 1902), compliance reports (e.g., Dorian 1980), and results of our own survey and testing. Many sites are known to us because they are actively eroding in the intertidal zone (Figure 2). These are among the most conspicuous archaeological remains, presenting themselves at low tide as cutbanks of shell and organic midden. Local collectors visit these exposures routinely, especially after storms undercut banks and uproot trees. A few responsible collectors have assisted by recording sites and donating collections with site-level provenience.

Through 2015, staff and affiliates of the LSAS have investigated 25 sites through subsurface testing. Usually this is limited to one or two 1 × 2 m units, which provide first-order observations on stratigraphy and features, as well as opportunities to recover artifacts in context and collect bulk samples for specialized analyses. The exceptions are

Figure 2. *Photographs of eroding beachface middens. Clockwise from upper left: McClamory Key, Deer Island, Little Bradford Island, Big Pine Island.*

Garden Patch (Wallis and McFadden 2014) and Shell Mound (Sassaman et al. 2013, 2015b), two civic-ceremonial centers that have warranted more testing because they are large and complex sites. The strategy for testing throughout—whether project-wide or at large sites—has been to sample extensively in order to broaden our perspective on variation among sites.

Variability Among Sites

At least 20 sites (18%) in the study area contain or contained mounds. The inventory includes several examples of mortuary mounds comprised of both sand and shell, some with caches of nonlocal items; platform mounds of shell and sand that may or may not have supported structures, but if so, most likely communal facilities, not domiciles; and shell mounds that have no definitive purpose or form but in some cases appear to have been erected quickly (Figure 3). These latter examples and all those involving burials and ritual infrastructure can be considered deliberate constructions, what we call *terraforming* in our discussion below. Multiple mounds tend to occur at civic-ceremonial centers dating after AD 200, such as Garden Patch to the north and Shell Mound to the south. A cluster of mounds in the town of Cedar Key likely constitutes a third possible center, one around Shired Island a fourth, and one at the mouth of the Suwannee Delta a possible fifth. Spread roughly evenly across the full expanse of the study area, mound centers average about 10 km apart (Figure 1). Another 50 km to the south of the study area are located Crystal River and Roberts Island, two civic-ceremonial centers with elaborate mounds and related infrastructure

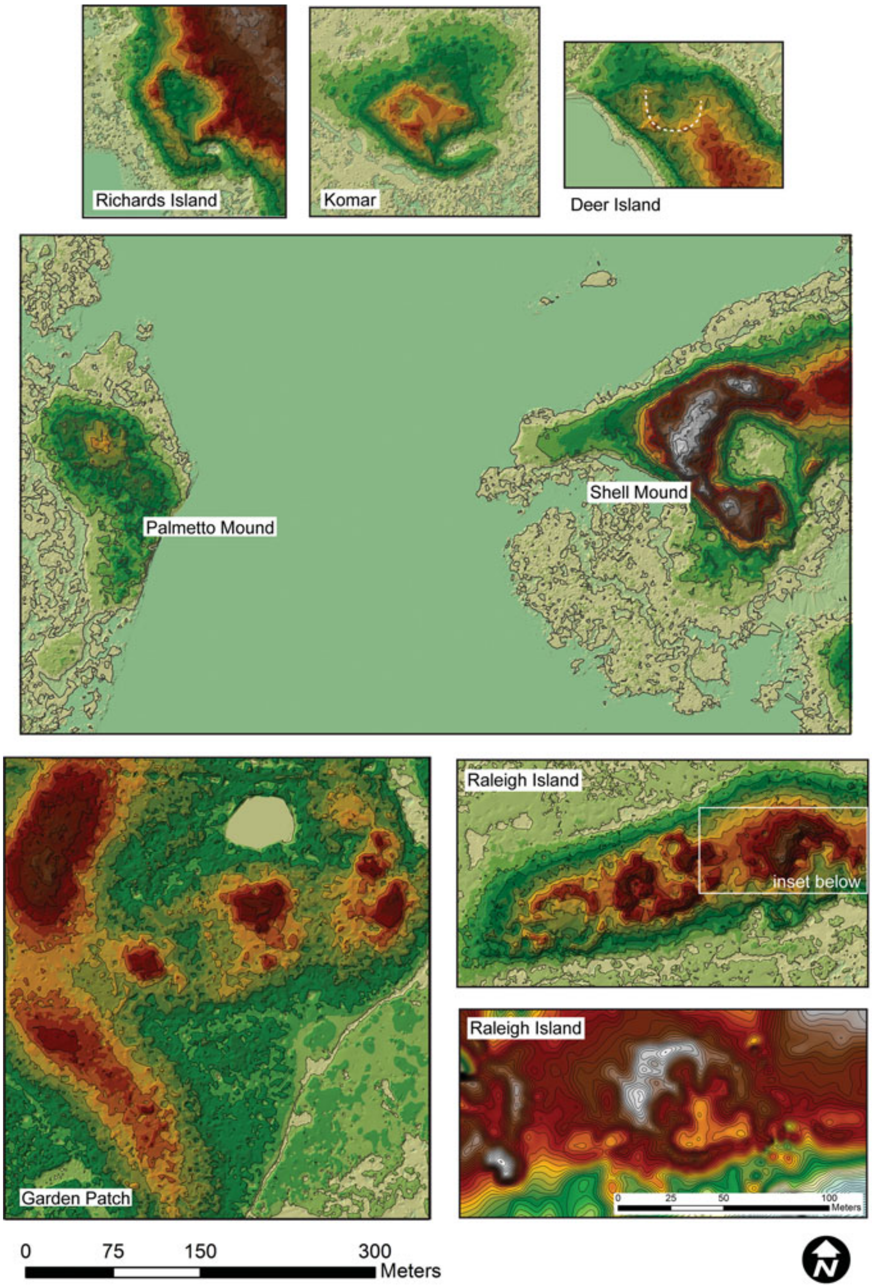

Figure 3. *LiDAR-generated topographic maps of select mound centers and shell rings in the study area. The contour interval of all maps except the inset map for Raleigh Island (bottom right) is 50 cm. The Raleigh Island inset map was generated from topographic data collected with a Nikon DTM 310 Total Station; its contour interval is 20 cm. The linear or slightly arcuate ridges of topographic relief at most of the sites, such as those on the western margin of Garden Patch, are relict dunes on which anthropogenic deposits were emplaced.*

(Pluckhahn et al. 2015; Thompson and Pluckhahn 2010). All such centers are "civic" in the sense they housed resident populations whose everyday material footprints lie adjacent to or within mound complexes, often in semi-circular arrays of middens presumed to be associated with houses.

Human interments occur in contexts other than mounds. Burials emplaced in shell midden have been exposed along eroded shorelines in recent decades. Although these are not well dated, two were observed in middens estimated to date about 2,000 years BP. Other burials are much older. At least two and possibly three consist of clusters of burials (cemeteries) emplaced in low-relief dune sands that have been directly or indirectly dated to the Late Archaic period, roughly 5,000 to 3,500 years BP (Sassaman et al. 2015a; Stojanowski and Doran 1998). Notably, these cemeteries were established when sea level was lower and the coastline farther seaward than present. That some of the burials are secondary suggests that Late Archaic cemeteries may have been relocated landward as water levels in the area rose (Sassaman 2016). All told, 32 (28.8 percent) sites in the project area purportedly contain or contained human burials.

Survey has revealed a large number of above-ground deposits of shell in arcuate (ring-like) or linear ridges, some quite large. They are often located along the ridges of relict dunes (Figure 3), but also at low elevation, and appear to date no earlier than ca. 200 BC. One cluster of rings and ridges in the vicinity of Shell Mound dates to the twelfth and thirteenth centuries AD, nearly half a millennium after that center was abandoned. Irrespective of age, above-ground shell deposits in arcs ranging from ~10 to 70 m in diameter and up to 2 m tall mark locations of intensive habitation.

Subterranean features are common at sites across the study area (Figure 4). Postholes are ubiquitous at many sites. They have been observed beneath mounded sand and shell at civic-ceremonial centers (e.g., Figure 4a) and below the near-surface middens of smaller sites (e.g., Figure 4b). At Shell Mound, a few postholes were apparently chinked with shell (Figure 4c) or, in some cases, filled with shell after posts were removed. Efforts to delineate the full plans of structures involving in-ground posts have been frustrated by the generally small size of excavations to date. Still, the widespread occurrence of postholes at sites of all sizes points to traditions of substantial architecture.

Also common at sites are pits of various size and shape. An assemblage of pits at Shell Mound is especially noteworthy. At one location on the northern interior rim of this 180-m-diameter, U-shaped ridge is a cluster of massive pits, several of which are shown in profile in Figure 4d. Ranging up to 2 m wide and 1.8 m deep, these pits were dug into dune sands for purposes that are not altogether clear. They were backfilled with mostly sand, but also pottery sherds, flaked stone, shell, and, in some cases, assemblages of vertebrate faunal remains suggestive of large-scale consumption. More common at sites across the region are pits that average about 50 cm in diameter and just as deep (Figure 4e), and generally filled with shell midden, but occasionally with caches of shells from taxa (e.g., *Busycon* sp., *Mercenaria* sp., *Melongena corona*) that are known to have been modified for technological or ornamental purposes (Figure 4f). Formal hearths have not been observed although areas of thermal alteration throughout middens are not uncommon (e.g., Bullen and Dolan 1960).

Finally, many of the sites investigated to date are well stratified, multicomponent sites. Those on islands currently distant from shore are especially well stratified, some with basal components dating to the Late Archaic era (e.g., Figure 5a), others with components not well represented in the larger inventory of near-shore sites (e.g., Figure 5b). In all such cases we observe sequences with hiatuses of one or more centuries between strata. At some sites, strata of sand separate shell-bearing deposits, apparently indicative of storm-surge deposition (McFadden 2014, 2016). In these and other cases, scoured surfaces are evident in the unconformities between consecutive strata. A dramatic example is seen in Figure 5c, from Little Bradford (8DI32), which was scoured by a 1993 storm surge that deposited 30–40 cm of sand on

Figure 4. *Examples of features at project area sites: a. postholes below Mound V at Garden Patch; b. postholes and pits at Dan May; c. shell-filled posthole at Shell Mound; d. large pits at Shell Mound (outlined by dashed lines); e. small, hemispherical pit at Shell Mound; f. cache of shell at base of pit at Komar.*

top as it receded. Other examples of truncated profiles are known from sites on Way Key (e.g., Figure 5d), at locations of modern development in the town of Cedar Key.

The discontinuous sequences of many stratified sites in the study area stand in contrast to those that accumulated quickly and continuously at places like Shell Mound (Figure 5e). In certain locations across this site upwards of 4 m of shell, mostly oyster, accumulated over a thick organic midden in about a century. As noted earlier, deposits emplaced this quickly are regarded as terraforming, or purposeful constructions, on which we elaborate after reviewing the radiometric chronology of sites we have tested so far.

Chronology and Relative Elevation of Sites

An ongoing goal of the LSAS is to assemble a chronology of coastal dwelling at

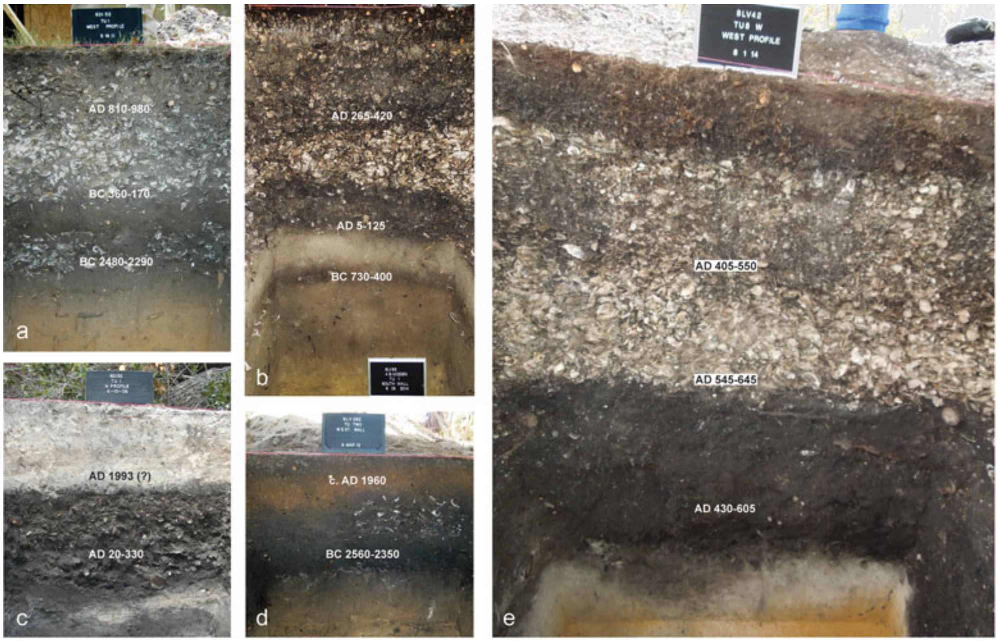

Figure 5. *Examples of stratigraphic profiles from study area sites, with 2-sigma calibrated age estimates of strata assayed by samples of charcoal: a. Bird Island; b. Midden at North Key; c. Little Bradford; d. Ehrbar; e. near apex of north ridge at Shell Mound.*

the resolution of one century or less. Currently, 80 samples of wood charcoal, charred hickory nutshell, or soot from the surface of sherds have provided AMS age estimates for components at 19 sites (Table 1), and another two from Garden Patch were obtained from deer bone (Wallis et al. 2015). Another eight conventional radiocarbon assays were run on marine shell from sites on two of the offshore islands (North Key and Seahorse Key). Reported here for the first time, these assays on shell were obtained in the late 1980s by Borremans (1989) in her survey of the Cedar Keys. We include these in our inventory but acknowledge the lack of a local reservoir correction for marine shell (e.g., Thomas 2008).

Shown at the bottom of Figure 6 is the modeled summed probability distribution of all nonshell calibrated age estimates as calculated with OxCal v 4.2.4 (Bronk Ramsey and Lee 2013). In the upper half of this figure, assays from Garden Patch ($n = 20$) and Shell Mound ($n = 18$) are displayed as separate distributions to illustrate the chronology of civic-ceremonial centers. Distributions for the offshore islands are displayed in the middle of the figure, separated by material assayed (charcoal vs. shell). Shell assays were calibrated with the Marine13 curve available through OxCal.

The total inventory consists of age estimates that span 3,900 calendar years, from 2600 BC to AD 1300. Given the usual biases of archaeological data, notably sample bias, the shape of this distribution cannot be interpreted literally as a relative measure of occupational intensity or population size. For instance, we do not know whether gaps in the distribution—such as those expressed in stratified sequences of offshore islands—reflect periods of abandonment, our sampling protocols, or a lack of preservation. We do know, however, that the highest density modes in the distribution reflect the large number of assays from Garden Patch and Shell Mound, a function of the intensity of

Table 1. **Data on age estimates for sites in the study area of the Lower Suwannee Archaeological Survey.**

Site	Beta #	Provenience	Material	Measured ^{14}C age BP	Delta ^{13}C	Conv. ^{14}C age BP	2 sigma calibrated years BP	2 sigma calibrated years BC/AD
Garden Patch (8DI4)	385477	Area I, Swift Creek	Soot	—	—	1140 ± 30	1175–1055	AD 775–895
	299327	Area I midden	Deer bone	—	-20.4	1140 ± 30	1175–1055	AD 775–895
	385474	Area I, F. 14	Charcoal	1240 ± 30	-26.9	1210 ± 30	1235–1205; 1185–1060	AD 715–745; 765–890
	385475	Area I, F. 16	Charcoal	1220 ± 30	-25.8	1210 ± 30	1235–1205; 1185–1060	AD 715–745; 765–890
	385476	Area I, F. 20	Charcoal	1250 ± 30	-24.8	1250 ± 30	1275–1170; 1160–1080	AD 675–780; 790–870
	299329	Area I midden	Deer bone	—	-20.3	1260 ± 30	1220–1095	AD 730–855
	384265	Area X, Str. III	Nutshell	1450 ± 30	-24.7	1450 ± 30	1390–1300	AD 560–650
	386087	Mound II Str. IV	Charcoal	1500 ± 30	-24.6	1510 ± 30	1515–1460; 1415–1340	AD 435–490; 535–610
	384264	Area X, F. 3	Charcoal	1560 ± 30	-26.3	1540 ± 30	1525–1355	AD 425–595
	386088	Mound II, Str. VI	Charcoal	1600 ± 30	-26.0	1580 ± 30	1545–1400	AD 405–550
	384569	Mound IV, F. 5	Charcoal	1650 ± 30	-27.8	1600 ± 30	1555–1410	AD 395–540
	386496	Area X, Str. IV/V	Charcoal	1650 ± 30	-24.7	1650 ± 30	1610–1525	AD 340–425
	386089	Mound II, Str. VI	Charcoal	1660 ± 30	-26.0	1640 ± 30	1605–1520; 1460–1420	AD 345–430; 490–530
	383175	Mound II, Str. III	Charcoal	1670 ± 30	-26.3	1650 ± 30	1610–1525	AD 340–425
	383174	Mound V, F. 8	Charcoal	1670 ± 30	-24.7	1670 ± 30	1685–1675; 1620–1530	AD 265–275; 330–420
	382227	Mound IV, Str. III/IV	Soot	1690 ± 30	-24.1	1690 ± 30	1695–1650; 1635–1545	AD 255–300; 315–405
	383176	Mound II, F. 4	Charcoal	1720 ± 30	-25.1	1720 ± 30	1710–1555	AD 240–395
	384570	Mound IV, Str. IV	Charcoal	1720 ± 30	-25.0	1720 ± 30	1710–1555	AD 240–395
	338163	Mound V, F. 1	Charcoal	1730 ± 30	-25.6	1730 ± 30	1710–1550	AD 240–400
	382228	Mound IV, Str. IV/V	Soot	1920 ± 30	-25.2	1920 ± 30	1925–1820	AD 25–130

(Continued on next page)

Table 1. **Data on age estimates for sites in the study area of the Lower Suwannee Archaeological Survey *(Continued)*.**

Site	Beta #	Provenience	Material	Measured ^{14}C age BP	Delta ^{13}C	Conv. ^{14}C age BP	2 sigma calibrated years BP	2 sigma calibrated years BC/AD
Shell Mound (8LV42)	321186	TU3 Str. II	Charcoal	1350 ± 30	-25.5	1340 ± 30	1300–1260; 1200–1190	AD 650–690; 750–760
	421089	TU11 Str. X	Charcoal	1370 ± 30	-24.6	1380 ± 30	1330–1280	AD 620–670
	321183	TU1 Str. VIa	Charcoal	1410 ± 30	-24.6	1420 ± 30	1360–1290	AD 600–660
	421091	TU10 F. 34	Charcoal	1430 ± 30	-25.0	1430 ± 30	1375–1295	AD 575–655
	421088	TU11 Str. IV	Charcoal	1460 ± 30	-26.3	1440 ± 30	1380–1295	AD 570–655
	421092	TU13 F. 44	Charcoal	1440 ± 30	-25.3	1440 ± 30	1380–1295	AD 570–655
	321185	TU2 Str. III	Charcoal	1450 ± 30	-25.7	1440 ± 30	1380–1300	AD 570–650
	421095	TU12 F. 39SE	Charcoal	1470 ± 30	-25.5	1460 ± 30	1400–1300	AD 550–650
	392623	TU8 base Str, III	Charcoal	1480 ± 30	-25.4	1470 ± 30	1405–1305	AD 545–645
	321184	TU2 Str. II	Charcoal	1510 ± 30	-26.6	1480 ± 30	1410–1310	AD 540–640
	392624	TU8 Str. Vb	Charcoal	1530 ± 30	-25.9	1520 ± 30	1520–1460; 1440–1435; 1420–1345	AD 430–490; 510–515; 530–605
	392622	TU7 F. 25	Charcoal	1530 ± 30	-25.2	1530 ± 30	1525–1350	AD 425–600
	321182	TU1 Str. V	Charcoal	1540 ± 30	-25.8	1530 ± 30	1520–1350	AD 430–600
	421093	TU10 F. 35 Str. III	Charcoal	1590 ± 30	-26.5	1570 ± 30	1535–1390	AD 415–560
	421087	TU8 Str. IIIa	Charcoal	1600 ± 30	-26.1	1580 ± 30	1545–1400	AD 405–550
	421094	TU12 F. 46N	Charcoal	1610 ± 30	-26.4	1590 ± 30	1550–1405	AD 400–545
	421090	TU10 F. 33	Charcoal	1630 ± 30	-26.6	1600 ± 30	1555–1410	AD 395–540
	411466	TU 9 Str. V	Nutshell	1790 ± 30	-26.1	1770 ± 30	1770–1760; 1735–1610	AD 180–190; 215–340
	321181	TU1 F. 2	Charcoal	3940 ± 30	-26.0	3920 ± 30	4420–4280; 4270–4250	BC 2480–2330; 2320–2300

Palmetto Mound (8LV2)	394977	St. Johns Check Stamped	Soot	730 ± 30	−25.2	730 ± 30	695–660	AD 1255–1290
	421081	TU2 Str, V	Charcoal	1640 ± 30	−24.6	1650 ± 30	1610–1525	AD 340–425
	413226	TU1 Str. VIII	Charcoal	1730 ± 30	−26.9	1700 ± 30	1695–1650; 1635–1545	AD 255–300; 315–405
	421082	TU2 F. 4	Charcoal	2140 ± 30	−25.3	2140 ± 30	2300–2255; 2160–2040; 2015–2010	BC 350–305; 210–90; 65–60
	413225	TU1 Str. VIII	Charcoal	2310 ± 30	−25.6	2300 ± 30	2350–2310	BC 400–360
	394978	St. Johns Plain	Soot	2670 ± 30	−24.7	2670 ± 30	2840–2825; 2795–2750	BC 890–875; 845–800
Bird Island (8DI52)	301594	TU1 Str. IIB	Charcoal	1150 ± 30	−25.7	1140 ± 30	1140–970	AD 810–980
	301595	TU1 Str. IIIB	Charcoal	2170 ± 30	−24.5	2180 ± 30	2310–2120	BC 360–170
	301596	TU1 Str. VB	Charcoal	3930 ± 40	−26.3	3910 ± 40	4430–4240	BC 2480–2290
Butler Island (8DI50)	388846	TU1 Str, II	Charcoal	900 ± 30	−25.3	900 ± 30	915–735	AD 1035–1215
	388845	TU3N Str. V	Charcoal	1070 ± 30	−22.9	1100 ± 30	1065–935	AD 885–1015
	388844	TU3N Str, VIIB	Charcoal	2060 ± 30	−25.1	2060 ± 30	2120–1945	BC 170–AD 5
Hughes Island Mound (8DI45)	347622	Carabelle Punctated	Soot	1300 ± 30	−25.1	1300 ± 30	1290–1180	AD 660–770
Cat Island (8DI29)	270205	TU1 Str. VB	Charcoal	1400 ± 40	−26.3	1380 ± 40	1340–1270	AD 610–680
	270206	TU2 Str. VIC	Charcoal	4040 ± 40	−25.4	4030 ± 40	4780–4770; 4580–4420	BC 2830–2820; 2630–2470
Little Bradford Island (8DI32)	270207	TU1 Str. IIE	Charcoal	1820 ± 40	−25.4	1810 ± 40	1830–1680; 1670–1620	AD 120–260; 280–330
	279609	TU2 Str. IVa	Charcoal	1920 ± 40	−26.2	1900 ± 40	1930–1730	AD 20–220
Dan May	421083	TU1 F. 1	Charcoal	1090 ± 30	−25.3	1090 ± 30	1060–935	AD 890–1015

(Continued on next page)

Table 1. **Data on age estimates for sites in the study area of the Lower Suwannee Archaeological Survey *(Continued)*.**

Site	Beta #	Provenience	Material	Measured ^{14}C age BP	Delta ^{13}C	Conv. ^{14}C age BP	2 sigma calibrated years BP	2 sigma calibrated years BC/AD
Deer Island	289503	8LV75 70–95 cmbs	Charcoal	1990 ± 40	-24.4	2000 ± 40	2040–1870	BC 90–AD 80
	289504	8LV75 TU2 Str. II	Charcoal	2040 ± 40	-23.9	2060 ± 40	2130–1930	BC 180–AD 20
	301597	8LV75 TU5 F. 1	Charcoal	2470 ± 30	-26.4	2450 ± 30	2710–2630; 2620–2360	BC 760–680; 670–410
	289505	8LV76 30–40 cmbs	Charcoal	3510 ± 40	-25.2	3510 ± 40	3890–3690	BC 1940–1740
	301591	S Midden TU1–IV	Charcoal	1280 ± 30	-25.3	1280 ± 30	1280–1170	AD 660–780s
	301592	S Midden TU1–VI	Charcoal	3300 ± 30	-24.1	3310 ± 30	3620–3460	BC 1670–1510
	301593	SE Midden TU1–VII	Charcoal	3460 ± 40	-25.8	3450 ± 40	3830–3620	BC 1880–1670
Raleigh Island (8LV293)	381202	TU2 Str. III	Charcoal	930 ± 30	-27.6	890 ± 30	910–730	AD 1040–1220
	381201	TU1 Str. II	Charcoal	1000 ± 30	-27.5	960 ± 30	930–795	AD 1020–1155
Komar Island (8LV290)	381204	TU2 Str. III	Charcoal	1510 ± 30	-26.3	1490 ± 30	1410–1310	AD 540–640
Derrick Key (8LV122)	421080	Wakulla Checked Stamped	Soot	1190 ± 30	-23.5	1210 ± 30	1235–1205; 1185–1060	AD 715–745; 765–890
McClamory Key (8LV288)	331116	TU1 Str. I	Charcoal	850 ± 30	-25.3	850 ± 30	800–690	AD 1160–1260
	329225	STP1	Charcoal	1330 ± 30	-24.9	1330 ± 30	1300–1240; 1200–1180	AD 650–710; 750–770
Richards Island (8LV137)	381199	TU1 Str. IIIA	Charcoal	850 ± 30	-25.8	840 ± 30	795–690	AD 1155–1260
	381203	TU2 Str. III	Charcoal	1170 ± 30	-25.4	1160 ± 30	1175–980	AD 775–970
	381200	TU1 Str. IIIB	Charcoal	1200 ± 30	-25.3	1200 ± 30	1230–1210; 1185–1055	AD 720–740; 765–895

Ehrbar (8LV282)	329223	TU1 Str. IID	Charcoal	3940 ± 30	-24.9	3940 ± 30	4510–4500; 4500–4490; 4440–4350; 4330–4300	BC 2560–2560; 2550–2540; 2490–2400; 2380–2340
	329224	TU2 Str. IIID	Charcoal	3980 ± 30	-26.9	3950 ± 30	4510–4480; 4440–4380; 4370–4350; 4330–4300	BC 2560–2530; 2490–2430; 2420–2400; 2380–2350
Gardiner's Point (8LV68)	36939	16–515	Clam shell	820 ± 60	-0.9	1220 ± 60	910–670	AD 1040–1280
	36937	37–109	Clam shell	950 ± 70	-1.1	1340 ± 70	1040–730	AD 910–1220
	36940	2–1X	Clam shell	1300 ± 80	-2.3	1670 ± 70	1390–1040	AD 560–910
	36938	16–504	Clam shell	1360 ± 70	-0.7	1760 ± 70	1480–1170	AD 470–780
	408514	TU1 Str, II	Charcoal	1800 ± 30	-23.8	1820 ± 30	1825–1695; 1650–1635	AD 125–255; 300–315
A. B. Midden (8LV65)	392619	TU1 Str, III	Charcoal	1690 ± 30	-26.0	1670 ± 30	1685–1675; 1620–1530	AD 265–275; 330–420
	392618	TU1 Str, V	Charcoal	1930 ± 30	-24.6	1940 ± 30	1945–1825	AD 5–125
	392620	TU1 Str, VII	Charcoal	2440 ± 30	-27.5	2400 ± 30	2680–2640; 2610–2600; 2490–2350	BC 730–690; 660–650; 540–400
	40457	141–277	Clam shell	2060 ± 70	—	2450 ± 70	2300–1920	BC 350–30
	40456	67–84x	Clam shell	2120 ± 70	—	2510 ± 70	2330–1990	BC 380–40
	40455	9–8	Clam shell	2190 ± 60	—	2580 ± 60	2410–2090	BC 460–140
	40458	223–278	Clam shell	2560 ± 80	—	2950 ± 80	2870–2400	BC 920–450
Clam Beach (8LV66A)	421084	TU1 Str. II	Charcoal	1690 ± 30	-25.1	1690 ± 30	1695–1655; 1630–1535	AD 255–295; 320–415
	421085	TU1 Str. III	Charcoal	2030 ± 30	-26.4	2010 ± 30	2035–2025; 2005–1890	BC 85–75; BC 55–AD 60
	421086	TU1 F. 1	Charcoal	3630 ± 50	-23.3	3660 ± 50	4145–4115; 4100–3850	BC 2195–2165; 2150–1900

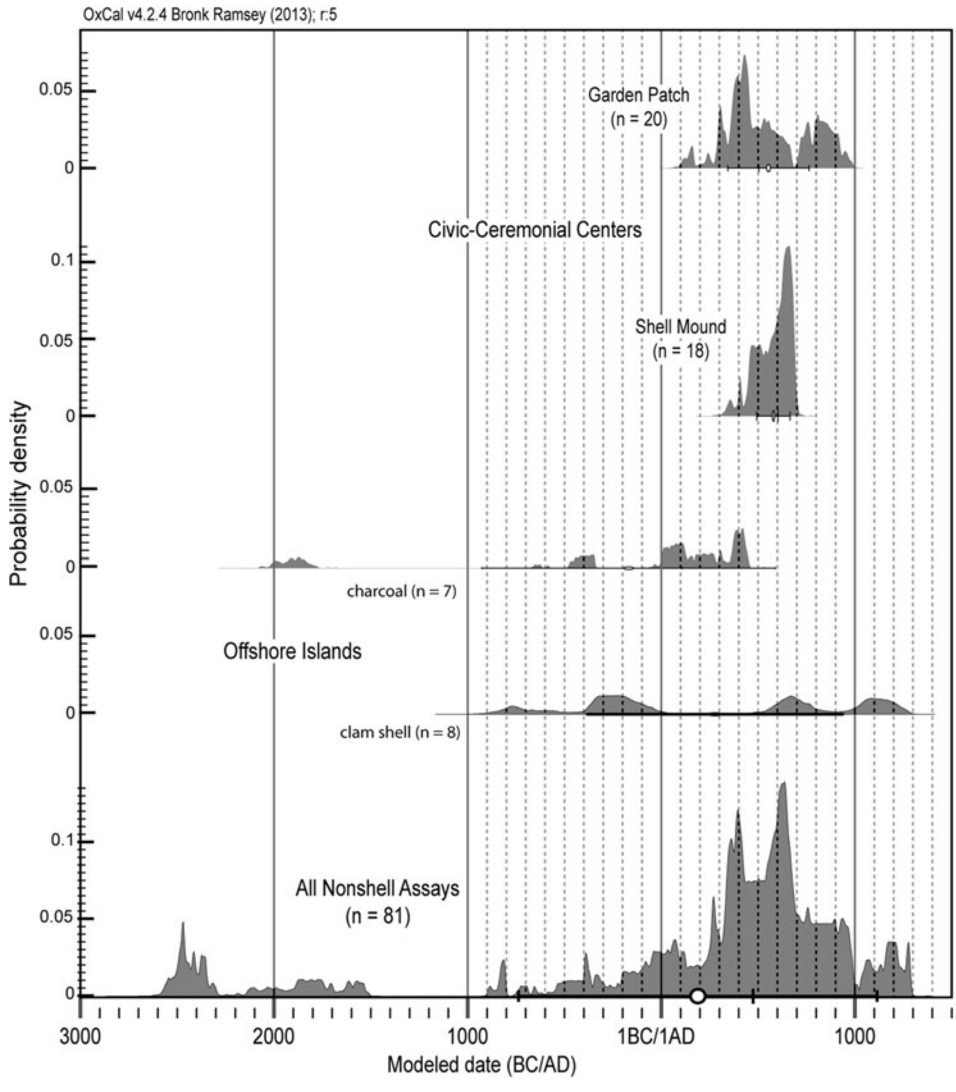

Figure 6. *Probability distribution of 89 age estimates from study area sites (bottom), with those from offshore island (middle) and civic-ceremonial centers (top) disaggregated from the total sample.*

recent field efforts. Bearing in mind these sorts of biases, we suggest that the summed probability distribution provides a reasonable basis for formulating hypotheses about changes in land-use relative to independent sources of data, such as geological evidence for transgressions of sea. The results of such comparisons in turn help to guide future investigations and sampling. Eventually, with more samples, Bayesian phase modeling, as has been applied to Garden Patch (Wallis et al. 2015) and Crystal River (Pluckhahn et al. 2015), can be applied project wide to establish contemporaneity and sequence at a resolution finer than century-scale.

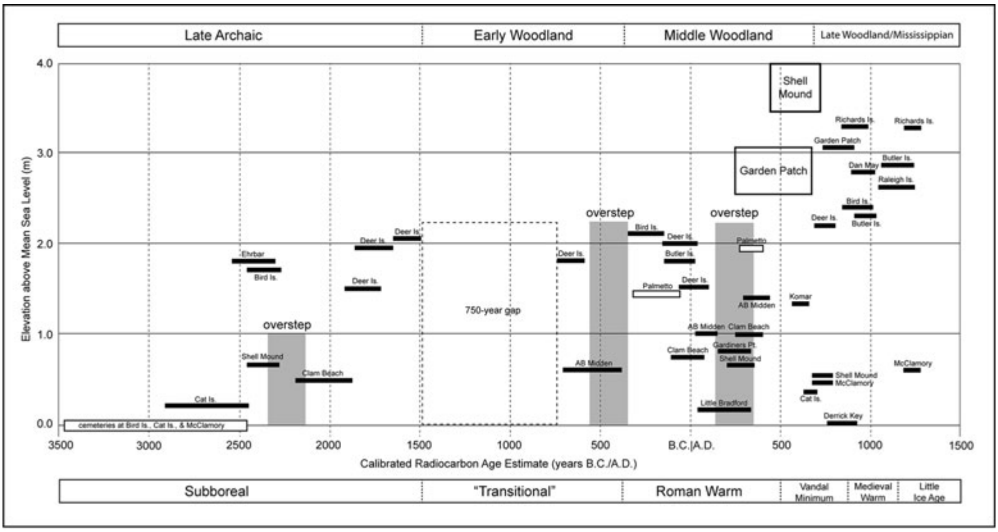

Figure 7. *Calibrated age estimates (two-sigma range) of basal strata of components sites in study area plotted against elevation (m) at mean sea level today. Listed across the top of this figure are culture-historical periods following Milanich (1994) and listed across the bottom are climatic periods following Marquardt (2010) and Walker (2013).*

To interpret the current radiometric chronology in the context of sea-level rise, we provide in Figure 7 a plot of calibrated age estimates (at two-sigma range, across all intercepts) by elevation (m) above mean sea level (amsl) today. With one exception (an assay on soot from a sherd from Derrick Key, a now-submerged island), each of the age estimates is from the basal portion of a subsurface stratum (typically a midden deposit), or a feature. The subsets of assays from Garden Patch and Shell Mound are combined, respectively, in this graph and the height of each of the open boxes signifies mounding of earth and/or shell. The other open boxes of Figure 7 are cemeteries: Palmetto Mound in proximity to Shell Mound, and the trio of Late Archaic cemeteries at Bird Island, Cat Island, and McClamory Key. Three overstep events inferred from geological coring and archaeostratigraphy are included as vertical bars that mark the estimated timing (accounting for uncertainty), but not the relative elevations, of these events.

We refer to Figure 7 repeatedly in the discussion that follows below, but a few observations bear mentioning at the outset. First, the apparent trend for increasingly higher site elevations through time is misleading. Sites predating about 1500 BC that are currently less than 1.0 m amsl were, at the time of occupation, at least 2.0 and as much as 3.0 m amsl. By extension, sites of this age currently at about 2.0 m amsl were at least 4.0–5.0 m amsl at the time they were occupied. Thus, the early land-use pattern may not have differed all that much from the last millennium of aboriginal settlement, when sites at low and high elevations were occupied during times of more-or-less modern sea level. Again, low-elevation, shoreline sites of more ancient times are currently fully subtidal or have been obliterated by erosion.

Second, the 750-year gap in settlement chronology ranging from ca. 1500 to 750 BC may be represented by sites on offshore islands, but currently we have no reliable assays dating to this interval (Figure 6). We suspect that offshore islands offer the greatest potential for near-shore sites of this interval if indeed the sea regressed during the Early Woodland or "Transitional" period

(Figure 7). In this respect it is worth mentioning that the offshore islands consist of dune remnants whose sands have been redistributed in expansive shoals around the islands. Like the delta of the Suwannee River, the sand shoals of these offshore islands appear to have aggraded at a rate equal to or greater than the rate of sea-level rise since ca. 750 BC.

Finally, the "overstep" events in Figure 7 are the only climate-related events for which we have at least nominal data on timing and magnitude, although others of appreciable magnitude likely occurred over the history of coastal settlement. Storms that flooded sites and left subaerial sediments in their wake actually contributed to landform accretion. In such cases, after water receded, relative sea level may have dropped locally. However, the overstep events plotted in Figure 7 mobilized subaqueous sediment to the extent that water encroached quickly and at high enough magnitude to result in 2–3 km of shoreline transgression. Given the general bathymetric contours of the study area, transgressions of this magnitude involved relative increases of about 0.5–1 m in sea level, enough to cause abandonment of open-water, low-elevation sites. Exceptions to this outcome may be expected at locations where sediment sources were abundant and landforms accreted at a high rate, such as offshore islands and landforms of the Suwannee Delta.

IMPACTS OF SEA-LEVEL RISE ON COASTAL SETTLEMENT

Acknowledging that changes in relative sea level over the long term have impacts on the inhabitability of coastlines and the distribution and productivity of marine resources important to humans, we focus our discussion in the section that follows on rapid and impactful transgressive events. The measure of impact in these cases lies at the intersection of climate-related events and situated human practices. Purposeful interventions—abandoning a site, relocating a cemetery, building a mound—can themselves be considered eventful. Ultimately, neither climate-related events nor human interventions are meaningful outside of the longer-term processes and experiences that constitute the "structure" against which events are compared (Gilmore and O'Donoughue 2015). That is, just as overstep events are contingent on the aggradation of nearshore marsh and landforms over the long term, human actions are contingent on perceptions of past experience and the embodied cultural practices that constrain alternatives to "tradition." Our discussion of this eventful history is structured by three related dimensions of human intervention: terraforming, subsistence intensification, and regional integration.

Terraforming

Terraforming in the science-fiction sense of the term is to modify an extraterrestrial planet so as to resemble the earth, specifically for supporting human life as we know it. More generally, terraforming can be viewed as the construction of living space, as in leveling land for habitation (Grier 2014). Beyond landscape engineering, terraforming can also be construed as cosmological practice, materializing core principles of the way the world is believed to be structured, or ought to be structured. This dual meaning is particularly appropriate in the context of civic-ceremonial centers in the study area because they were constructed following spatial and formal principles that were shared across communities of the interior Southeast and historically derived from Hopewell worldviews of the American Midwest. As we elaborate on later, coastal communities at times participated in networks of exchange and movement of persons that connected them with places far and wide. To the extent that participation in extralocal networks of shared belief alleviated the risks of coastal living (see Braun and Plog 1982), the cosmology and practicality of terraforming converged.

If we include formal cemeteries as acts of terraforming, then the oldest instances of terraforming in the study area are the Late Archaic cemeteries that have been exposed in recent decades by rising water. As noted earlier, these cemeteries were established when sea level was down some 1–2 m from its current elevation, that is, before 2500 BC. They thus predate the first overstep event marked in Figure 7 (ca. 2300 BC), but date generally to the end of the transgressive regime of the mid-Holocene, when overstepping of the coastline is presumed to have been more frequent and perhaps of greater magnitude than over the past 4,000 years. In this respect two observations about Late Archaic cemeteries bear relevance to our understanding of human perception and response to sea-level rise in more recent millennia: (1) a prevalence of secondary burials suggests cemeteries include individuals who were first interred elsewhere, arguably seaward at times of lower water levels; and (2) cemeteries precede habitation at two of the three sites, and at one (Bird Island), was followed by the emplacement of nonlocal soapstone vessels after the site was abandoned as a locus of habitation. The siting of these cemeteries and the sequence of site-use thereafter would seem to suggest that Late Archaic communities anticipated the need to relocate sites landward under conditions of transgressive sea. It would thus follow that emplacement of the dead anticipated places of habitation for the living and then places of commemoration in post-abandonment times. Arguably, these interventions were embedded in a cosmology of time and space that referred movement of the sea to movements of the sun, making futures more predictable (Sassaman 2016).

Terraforming after AD 200 involved larger, more permanent infrastructure. At least two major civic-ceremonial centers were constructed in the greater Big Bend area between about AD 200 and 400: Garden Patch at the north end of the study area (Wallis et al. 2015) and Crystal River (Pluckhahn et al. 2015), 50 km south of Cedar Key. Both were sited back from the modern coastline (~3 km for Garden Patch; ~9 km for Crystal River), in the century or two following the overstepping documented at Waccasassa Bay, which is located equidistant between these centers. The installation of mounds and other infrastructure at these locations signal an unprecedented scale of terraforming. These constructions were accompanied by the accumulation of middens indicative of large and presumably permanent resident populations, spatially arrayed in semicircular fashion. Platform mounds, burial mounds, midden ridges, and plazas formed integrated terraformed landscapes with similarities to civic-ceremonial centers of the interior Southeast and ultimately the Midwest. One mortuary complex at Crystal River contained a large assemblage of material culture of Hopewell affinity (Moore 1902).

Mortuary activity predated the boom in construction at Crystal River, and perhaps also at Garden Patch. An earlier mortuary mound at the former dates to a time (ca. 300 BC) that Pluckhahn et al. (2015) surmise involved only transient, perhaps seasonal occupations. The initial occupation of Garden Patch (ca. AD 25–130) was likewise ephemeral, but after AD 200, locations of future mounds were anticipated by public or ritual buildings, large pit features, and at least one case of human interment (Wallis and McFadden 2016). Given the emplacement of both sites back from the coast at this time, parallels with land-use practices during the Late Archaic period are apparent, particularly in the landward emplacement of cemeteries.

A third civic-ceremonial center, Shell Mound, was established a bit later than the others, but it too was apparently preceded by a mortuary facility, Palmetto Mound, 500 m to the west (Figure 3). The badly looted Palmetto Mound was recently mapped and tested by Donop (2015), who is also analyzing pottery vessels that were taken from the mortuary in the late nineteenth century and are now curated at the Florida Museum of Natural History. A recent age estimate on a basal feature at the mound places its founding in the third century BC, shortly after the overstep event of ca. 400 BC. Low-elevation landforms were unoccupied during the following two centuries, while the first shell ring was established at Deer Island, a dune remnant about 2.0 m amsl today.

Terraforming at Shell Mound took a much different path than it did at Garden Patch or Crystal River. The first sustained inhabitation of Shell Mound consisted of encampments at relatively low elevation, dating to about AD 200. Over the ensuing century settlement shifted to the dune ridge, about 3.0 m amsl today. Like shell rings of habitation on dune ridges elsewhere, those at Shell Mound were modest in size. However, by about AD 550, an amalgam of rings and small shell mounds formed a U-shaped ridge 180 × 170 in plan (Figure 3). Thus, what appears to have started as a "traditional" land-use practice of relocating to dune ridges as water levels rose became transmuted into a formal site plan on the scale of Garden Patch.

It is worth noting that the rise of Shell Mound as a civic-ceremonial center coincides with waning mound activity at Garden Patch, as well as Crystal River. All three sites were abandoned at about the same time, ca. AD 650–700, although Garden Patch was reoccupied a century later by a community that positioned itself on a ridge to the west of the mound complex (Wallis et al. 2015), while a new civic-ceremonial center with platform mounds was established at Roberts Island (Pluckhahn et al. 2015), 1 km downstream from Crystal River. Palmetto Mound continued to receive pottery and presumably burials well after Shell Mound was abandoned as a place of habitation. Located on Shired Island, about 10 km southeast of Garden Patch, Hughes Mound likewise received mortuary vessels during this time, many with nonlocal provenance. Climate was evidently cooler (Walker 2013), and although it may not have resulted in shoreline regression, cooler climate apparently reduced the vulnerabilities of low-elevation landforms, enabling locations like Roberts Island to sustain large settlement. Islands in the study area that today are completely inundated and/or eroded away (e.g., Derrick Key) were likewise occupied during the final centuries of the first millennium AD.

A final period of terraforming in the study area spans the Medieval Warm period (AD 900–1200), when polities of Mississippian influence arose in the Tampa Bay area to the south and in the Florida panhandle to the north. We have little data yet on either climate events or the influence of regional polities that inflected local developments at this time, except to note that terraforming took a new twist: the construction of amalgamated habitation rings into larger circular compounds, like the ones on Raleigh Island (Figure 3), nearly 3.0 m amsl today. Raleigh Island and another dune remnant (Richards Island) of even greater elevation have produced large assemblages of debris from the manufacture of disk beads from *Busycon* shell, items used widely in Mississippian-era mortuary practice. As with all terraforming in the study area that involved nonportable, permanent infrastructure, the demands of daily living—such as feeding one's families—were likely to have been impacted by demands arising from participation in extralocal affairs.

Subsistence Intensification

Sites in the study area are rife with the remains of vertebrate and invertebrate species of subsistence value to people. Vertebrate faunal remains greater than $\frac{1}{4}$ inch in size are collected in all subsurface test excavations and bulk samples are taken from features, discrete strata, and continuous columns of stratified midden. All invertebrate remains are likewise recovered in bulk samples, but not routinely in general excavation. The identification of archaeofauna is an ongoing task of the LSAS. Archaeofauna analyzed to date come from 45 flotation samples distributed across eight sites spanning 3,600 years of occupation (Palmiotto 2015). Added to this inventory are vertebrate fauna from the 1/4-inch fractions of level fill at select sites (Palmiotto 2015), plus the remains of specific taxa from a large pit at Shell Mound (Sassaman et al. 2015b:96–98). Oyster shells from several sites, most notably Shell Mound, have been analyzed for evidence of mariculture (Jenkins 2016), which we feature in the discussion below.

From the perspective of fine fractions from bulk samples, subsistence economies of the study area did not vary wildly over time or across space. Vertebrate remains from the 1 mm fractions of bulk samples are dominated by the bones of small fish (Palmiotto 2015). Prevalent among them are killifish and pinfish, followed by lesser numbers of toadfish and juvenile silver perch. Larger fish are represented by the remains of sea catfish, sheepshead, mullet, jack, drum, porgy, sea trout, and adult silver perch. The remains of shark, rays, and crab occur less frequently, as do the bones of birds, snakes, rodents, white-tailed deer, and opossum. Oyster shell is present in all midden samples analyzed to date, and the shells of other invertebrate taxa vary across locations, with Carolina marsh clam, hard clam, scallop, crown conch, lightning whelk, tulip shell, pear whelk, and periwinkle among them. A basic and somewhat redundant inventory of fish and shellfish crosscuts time and place in the study area, reflecting an enduring strategy of logistical mobility from habitation sites that were repositioned as needed according to seasonal changes or other short-term perturbations (Palmiotto 2015). The landward emplacement of habitation sites up navigable tidal creeks, which afforded direct access to open gulf waters, was among the settlement options during the Late Archaic period (McFadden 2014), possibly later too.

Deviating markedly from the overall pattern of vertebrate and invertebrate fauna project-wide are the scale and diversity of assemblages from civic-ceremonial centers. The scale of oyster accumulation alone at Shell Mound evinces extraordinary practices. It is impossible at this point to determine the actual volume of shell in this terraformed landscape, but it is unparalleled among extant sites. Knowing that much of the relief of Shell Mound can be owed to an underlying dune ridge, a conservative estimate of the volume of matrix dominated by oyster shell is about 35,000 m^3. At the high end of oyster density values from our bulk samples (35 MNI/liter), that amounts to about 1.2 billion oysters total, and at the low end (12 MNI/liter), 420 million. All of this shell accumulated over a 300-year period (AD 400–700), but large deposits were sometimes emplaced rather quickly, particularly from ca. AD 500–600, when the mound assumed its final shape.

One example of rapid accumulation of oyster shell at Shell Mound is seen in the profile of a test unit at the apex of ridge's northern arm (Figure 5e). Consisting of bedded shell with little soil matrix, the upper 1.4 m of this profile accounts for the vast majority of oyster, but valves continue at low density into the underlying, basal midden to a depth of 2.1 m below surface. As part of a larger project to monitor variation in oyster deposits across the study area, Jenkins (2016) analyzed 3,252 left valves of oysters from a 30 × 30 cm column of this profile for a variety of metric and nonmetric attributes. She found that oyster valves from the bedded shell average about 10 mm higher and 6 mm longer than those from the basal midden. They likewise differ with respect to parasitism (mostly sponge predation), which varies positively with salinity levels (Hopkins 1957). Valves from the bedded shell express evidence for parasitism (i.e., small holes bored into the shell) at a rate of 47.7 percent compared to only 29.9 percent for valves from the basal midden. Adding these observations together Jenkins was able to infer that the upper macrounit contains a higher proportion of subtidal oysters than the lower macrounit, which has more intertidal oysters.

This shift from intertidal to subtidal oysters could very well signal an ecological consequence of the overstepping event dating between AD 100 and 300, essentially bringing subtidal conditions in closer proximity to Shell Mound. However, inasmuch as this shift coincides with terraforming involving shell, how might the shift be indicative of intensified demand? Jenkins's (2016) data on parasitism suggests that shellfishers enacted culling practices that would have enhanced the growth and development of subtidal oysters. A common means of culling is separating clusters by detaching individual oysters by percussion and returning them to the water so that they grow unimpeded. The scars of cluster attachments are evident on the outside of valves, and the presence of parasite holes on scars is presumed to indicate that a detached oyster was returned to the water (as opposed to being harvested immediately). Of the 1,479 valves with parasitism from the bedded shell analyzed by Jenkins, 564 (38.1 percent) show parasitism on attachment scars. Significantly, the rate of scar parasitism increased incrementally from the bottom of the macrounit (34.2 percent) to a high of 54.6 percent about one third up the column and then leveled off to between

43.8 and 48.4 percent before dropping incrementally over the upper 50 cm. Jenkins (2016) has also documented a trend at the base of this macrounit for a disproportionate ratio of left-to-right valves. This implicates another possible maricultural practice that is common today, cultching, which involves the emplacement of shell for seeding oyster beds (Cattagna et al. 1996). The relatively flat right valves of oyster are most conducive to this form of cultching, so perhaps many of those "missing" from the base of the macrounit went into subtidal waters to cultivate oysters. It remains for us to determine if any of these presumptive indicators of mariculture can be replicated with independent samples from other locations at Shell Mound, and beyond. Thus far, sites that feature much less oyster shell and lack ritual infrastructure have not matched the evidence from Shell Mound (Jenkins 2016).

Other deviations from project-wide subsistence patterns are found in the fill of large pit features at Shell Mound (Figure 4d). Contained in the fill of one these features (Feature 25) were abundant remains of vertebrate taxa that are represented in much smaller frequencies elsewhere, some only in scant traces. Fish bone was abundant, as usual, but an inordinate proportion of mullet bone stood out as unusual. From her analysis of the $\frac{1}{4}$-inch fraction of an estimated 447 liters of pit fill, Oliveira identified 1,603 mullet elements and calculated an MNI of 92 (Sassaman et al. 2015b:96). This amounts to a density of mullet bone per unit volume that is an order of magnitude greater than any volumetric sample from other sites, and at least three times the density of mullet from any other sample from Shell Mound. With an average standard length of 279.9 ± 48.4 mm, and limited variation ($cv = 0.17$), the pit assemblage represents a same-age population of mature mullet.

This assemblage of mullet is an example of mass deposition (in a discrete pit feature), but is it also an example of mass capture? And if it is an example of mass capture, was the event unusual in its scale or purpose? The context of this assemblage at Shell Mound helps to address the question of purpose: as with large volumes of oyster, large quantities of fish may signal extradomestic levels of consumption, as in communal feasting. And yet, the scale of consumption says nothing in particular about the scale of capture. How were large numbers of fish acquired? Ongoing research by Mahar (2015) addresses this and other questions about alternative fishing technologies. Experiments in fish weir technology are providing baseline data on return rates by season and location, while also revealing the limits of fixed infrastructure in intertidal settings. We may never observe direct evidence for weirs, fish traps, and other tools of mass capture, but Mahar's results provide a basis for inferring the use of alternative technologies from comparisons between experimental results and archaeological assemblages.

Finally, bird bone in the Shell Mound pit with 92 mullet further underscores the distinctiveness of certain contexts at civic-ceremonial centers. In his analysis of avian fauna, Goodwin identified 140 bony elements from a minimum of 18 birds from nine taxa (Sassaman et al. 2015b:98). All were water birds, half identified as white ibis (*Eudocimus albus*)—four adult, four subadult—followed by two ducks, and single examples of pie-billed grebe, horned grebe, great blue heron, great egret, yellow-crowned night heron, roseate spoonbill, and herring gull. If these taxa were daily fare among residents of Shell Mound and the greater study area, they were not deposited in ways that covaried with more common taxa, like fish and shellfish.

Goodwin is researching the uses of birds in other Woodland contexts across the region (e.g., Milanich et al. 1984), including bird imagery in pottery and other media, such as the platform pipes of Hopewell. Arguably, the inclusion of birds in Feature 25 goes well beyond daily subsistence to signal ritual and social uses of animals and substances, perhaps in conjunction with mortuary practices centered on Palmetto Island. A ground puma tooth, a quartz crystal, and shell-filled postholes in the vicinity of large pits at Shell Mound give us further reason to look beyond daily activities to explain the unusual density, scale, and composition of the pits.

In sum, zooarchaeological data from sites in the study area reveal limited variation in what can be glossed as the *subsistence* or *domestic* economy. Changes in sea level are registered in the availability of certain taxa (e.g., marsh clam, periwinkle, scallop, offshore gastropods), but overriding availability locally was the human capacity for adjusting land-use to changing conditions. In contrast, subsistence budgets were impacted by the establishment of more-or-less fixed infrastructure and larger, more permanent settlement. Evidence for mariculture and mass capture suggest that economies were intensified to produce more, or at least sustain the productivity of a diminishing resource base. What seems to be driving this change is not sea-level rise per se (earlier populations simply adjusted through movement), but instead the demands of a *political* or *ritual* economy. Spielmann (2002) makes this argument more broadly for small-scale societies that invest in ritual infrastructure and socially valued goods. What she calls the "ritual mode of production" is one in which networks of social obligation are ritualized in communal feasts, the construction of ritual infrastructure, and the production of extraordinary material culture. We have already seen glimpses of the first two dimensions and now turn, in a brief final section, to the production and circulation of socially valued goods, which takes us far from the coast.

Regional Integration

Long before civic-ceremonial centers were established on the coast, socially valued goods were imported to sites from sources hundreds of kilometers distant, in the interior Southeast. Emplaced in or near the Late Archaic cemetery at Bird Island, for instance, was an assemblage of at least 15 soapstone vessels with geological provenance over 500 km to the north (Yates 2000). This was not likely a practical concern because pottery was already being made and used on the northern Gulf coast by the time soapstone vessels appeared, after about 1800 BC (Sassaman 2006). By about 1600 BC soapstone vessels were moving from source areas in the southern Appalachians across the Gulf coast and up the Mississippi River, and by 1400 BC delivered to the Poverty Point site in northeast Louisiana by the hundreds.

We do not know how soapstone vessels arrived at places like Bird Island, let alone Poverty Point, but their importation must have been predicated on relationships among people distributed widely across the greater Southeast. Notably, at Bird Island, soapstone vessels were emplaced in or near the cemetery, so their social value may have had a biographical or genealogical dimension to it.

By the time of civic-ceremonial centers on the northern Gulf coast, the volume of socially valued goods deposited in cemeteries and mounds was staggering. The inventory of Hopewellian objects at Crystal River has already been mentioned. We can add to that large inventories of pottery vessels and other nonlocal materials at Palmetto Mound and other mortuary facilities in the study area. Not all such vessels are of foreign provenance, but more than a few are. And not all vessels in or around graves are extraordinary, but among them are effigies of animals, including birds, as well as human heads. A tradition of gifting pottery vessels for mortuary ritual began in the greater Southeast during the Swift Creek era, after about AD 100, arguably a local manifestation of Hopewell rituality. Wallis (2011) analyzed Swift Creek pottery from northeast Florida and southeast Georgia by neutron activation analysis (NAA), petrography, and design similarities to reconstruct networks on social interaction spanning thousands of square kilometers. Similar studies are underway with assemblages from Lower Suwannee area sites (Wallis and Pluckhahn 2015)

Data are thus accumulating that will enable detailed reconstructions of regional social networks at the time of civic-ceremonial centers. Enough data are currently available to suggest a shift from mostly locally made vessels to nonlocal vessels at Palmetto Mound while civic-ceremonial centers were on the wane across the region. Indeed, the mortuary at Palmetto Mound continued to receive vessels and perhaps persons well after Shell Mound was vacated as a place of residence. Evidently, people returned to the coast from places in the interior to either commemorate those already interred, or to emplace others in what they regarded as "traditional" land.

Thus, the fate of coastal people appears to have been shared widely across the greater Southeast. Civic-ceremonial centers of north-central Florida, for instance, are coeval with those of the northern Gulf coast (e.g., Wallis et al. 2014) and may have been recipients of communities who abandoned the coast but returned regularly for ritual activities. Indeed, the genesis of Cades Pond culture of north-central Florida may trace to the displacement and resettlement of Deptford communities of the northern Gulf, a consequence Milanich (1994:228) attributed to demographic growth in the context of sea-level rise. This raises the possibility that social networks predicated on gifting of mortuary vessels served as a safety net for alleviating the vulnerabilities of coastal dwelling by providing options for relocating at times of crisis. We hasten to add that participation in such networks had its costs in the public works projects and provisioning of large gatherings of civic-ceremonial centers, pushing communities into land-use and resource extraction practices that exacerbated the long-term risks of staying on the coast even as the magnitude of sea-level change was only marginal.

CONCLUSION

The geological history of sea-level rise on the northern Gulf coast is complicated by a low-relief coastline that in recent millennia has aggraded well before it retreated, and by freshwater input and oyster bioherms that affect the rate and magnitude of aggradation. The coastal record of human land-use and subsistence is equally complicated by factors that preclude its use as a proxy for sea level. Environmental and cultural change were never in lockstep, and not only because coastal communities could intervene in environmental change with mobility and technology, but because they participated in regional networks whose ritual economies were among the chief sources of subsistence intensification. Before civic-ceremonial centers were established on the coast, communities relocated settlements and cemeteries landward occasionally and maintained more-or-less "traditional" subsistence regimes. Terraformed mound centers after AD 200 may have also been a defense against sea-level rise, but they fixed persons, deceased and alive, in locations subject to change. Participating in networks of shared belief and in the mobilization of socially valued goods, communities at civic-ceremonial centers of the coast mitigated vulnerabilities through social alliances that afforded, if needed, opportunities to relocate to the interior at times of crisis. These networks had their material costs, however, in the rituality of social life, which arguably was a driving force behind innovations in mariculture and mass capture. We can only speculate on whether innovations such as these were an asset or a liability under changing sea level and estuarine conditions, but we suspect that the stationary nature of terraformed places and other infrastructure was ultimately a liability in the long term.

After 6 years, the Lower Suwannee Archaeological Survey has only begun to amass the data needed to comprehend human responses to sea level over the past 4,500 years. There are many parts of the study area that have yet to be investigated. The remnants of another massive civic-ceremonial center lie beneath the town of Cedar Key; mound centers at the mouth of the Suwannee River and around Shired Island are virtually unknown; long stretches of coastline between Shell Mound and Garden Patch remain to be surveyed; and more sites on offshore islands await testing. Add to this the potential for submerged and partly submerged landforms and we expand not only the spatial but temporal depth of the area. More close-interval geological coring is warranted to refine our sense of the pace and magnitude of sea-level change. Landforms just back from the coast require attention too in order to determine if late-period communities did what their Late Archaic predecessors did: establish settlements up tidal creeks, in protected areas. Provenance studies should intensify to more fully understand the geographic and social reach of coastal communities into the far interior.

The LSAS will continue to salvage an archaeological record of human experience with sea-level change as that record continues to be compromised by the very same forces that lend it historical significance. Aside from the ethic of preserving information about threatened resources, the LSAS is motivated to construct a history of human response to sea-level change that has potential for informing modern public policy. How an archaeology of sea-level change informs public policy remains to be seen.

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