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SCLEROCRONOLOGICAL MEASURES OF SEASONALITY AT A LATE WOODLAND MOUND ON THE MISSISSIPPI GULF COAST

John H. Blitz, C. Fred T. Andrus, and Lauren E. Downs

*Seasonality of site occupation has been an important issue in the archaeology of precolumbian coastal populations in the U.S. Southeast. Sclerochronological oxygen isotope measurements to estimate season of capture were performed on marsh clam (*Rangia cuneata*) and oyster (*Crassostrea virginica*) shells from a Late Woodland platform mound in coastal Mississippi. This study is the first oxygen isotope analysis of archaeological *Rangia cuneata*. The results of the study, supported by vertebrate faunal and plant seasonal indicators and depositional circumstances, indicate that mound trash deposits were generated by short-term activities during the spring and summer months. Factors that could reduce the precision of the seasonal estimates are identified.*

*Las conchas de moluscos marinos recuperadas en sitios arqueológicos son utilizadas para estimar la temporada de captura con regularidad creciente. La precisión de estas estimaciones típicamente se limita a diferenciar entre períodos húmedos y secos o períodos cálidos y fríos. Sin embargo, también es posible utilizar estos registros para identificar eventos de más corta duración. Se realizaron mediciones de isótopos de oxígeno en conchas de almeja de pantano (*Rangia cuneata*) y de ostra americana (*Crassostrea virginica*). Las conchas se encontraron en depósitos de basura sellados en un montículo de 1.200 años de antigüedad (Late Woodland) en la costa de Mississippi, EE.UU. Las mediciones de isótopos de oxígeno indican la temperatura del agua en el momento en que se recogieron los moluscos, lo cual es la base para construir una cronología estacional de la concha (esclero cronología). Se identificaron varios factores que pueden reducir la precisión de las estimaciones estacionales. Los resultados de la cronología estacional de la concha, con apoyo de datos adicionales estratigráficos y de fauna, indican que los depósitos de basura de los montículos fueron generados por eventos a corto plazo, que tal vez duraron menos de un día, durante los meses de primavera y verano.*

The season of capture of animal species identified in the archaeological record is an established method for detecting group mobility and identifying sedentism (e.g., Monks 1981; Reitz et al. 2012). Season of capture measures demarcate temporal intervals such as months of a year or warm and cold periods based on expectations derived from species lifecycles or habitats. Sclerochronology concerns “the study of physical and chemical variations in the accretionary hard tissues of organisms, and the temporal context in which they formed” (Quitmyer and Jones 2012:135). Sclerochronological oxygen isotope measurements of shell can identify the

season of capture for some molluscan species, as revealed by studies of coastal sites in the U.S. Southeast (Andrus 2011, 2012; Andrus and Crowe 2008; Keene 2004; Thompson and Andrus 2011). Oxygen isotope distributions measured from the shells of most molluscan species are a function of water temperature and the oxygen isotope content of ambient water (related to salinity), which under certain conditions permits the distributions to be correlated to a range of water temperatures that span warm and cold months (Shackleton 1973). We illustrate this potential with a case study of sclerochronological analysis of *Crassostrea virginica* (oyster) and *Rangia*

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cuneata (marsh clam) from a Late Woodland period platform mound in coastal Mississippi. This analysis is the first application of sclerochronological oxygen isotope measures to *R. cuneata*, which together with the more thoroughly studied oyster, is the dominant bivalve species in pre-columbian middens on the Gulf Coast of the U.S. Southeast.

Our study had two objectives. First, we wanted to evaluate the accuracy of the novel oxygen isotope analysis of *R. cuneata*, as well as that of oyster, as a season of capture measure. We follow a consensus among researchers that the most reliable assessments of site seasonality require multiple, independent lines of evidence (Waselkov 2012; Wing 2012), which in this case are the shell oxygen isotope readings of *R. cuneata* and oyster, the associated vertebrate faunal remains, and the depositional circumstances of the samples. Second, the broader purpose of the sclerochronological analysis was to determine if mound shell deposits had been generated by activities restricted to specific seasons or if the deposits had accumulated throughout the year. As discussed below, determining whether a monumental ritual facility such as a platform mound was used for temporary seasonal or longer-term, multiple-season activities has important implications for the development of social hierarchy.

Seasonality at Monumental Sites in the Lower Southeast

In the lower U.S. Southeast, in particular on the Atlantic and Gulf coastal plains where domesticates were often absent or a minor aspect of the subsistence economy (Anderson and Sassaman 2012:144–149), research on site seasonality has been especially concerned with the sites of non-agricultural populations. Increasingly, efforts to identify temporary or permanent site occupations have become linked to the processual implications of monument construction, in particular earthen mounds and shell rings, as nodes of social integration and increased social complexity (Thompson and Andrus 2011). In part, this is because previous assumptions about the mobility and social complexity of food-collecting populations, and the social implications of monument construction, have been reevaluated. Monument construction,

although often linked to sedentism, increased social hierarchy, and large populations, may occur without these conditions (Howey 2012:27–32). Furthermore, there is no necessary relationship between the size of the monument and the duration of use (Blitz and Livingood 2004; Kidder 2011). Ancient Southeastern sites with monumental construction span a settlement continuum from ceremonial places with episodic use by groups who were not in long-term residence to civic-ceremonial precincts embedded in the multiple-season habitation sites of sedentary communities (Anderson and Sassaman 2012:76, 132–133, 149–150). Given this new understanding, there can be no a priori assertions about mobility, social complexity, and monument construction at ancient Southeastern sites without adequate site investigations, even though there is strong theoretical and empirical support for a processual relationship between these factors (Cobb and Nassaney 2002; Lindauer and Blitz 1997; Sassaman 2004). A complicating issue is that coastal sites, in particular those with shell middens, may be complex palimpsests of multi-component deposition. Under these circumstances, it is a challenge to locate undisturbed contexts of short duration that are relevant to understanding long-term historical process. Monumental facilities with sequential layering and sealing of deposits are one of the best archaeological contexts for this purpose at coastal sites (Thompson and Andrus 2011:318–320).

Earthen mounds and similar ceremonial facilities may encapsulate the physical evidence of sequential episodes of construction, use, refurbishment, hiatus, reuse, termination, and abandonment. Such episodes have often been tied to significant social changes for the affiliated group, such as transitions in leadership, the founding of new communities, claims to territories, the creation of charter myths, and assertions of rank (e.g., Anderson 1994:126–129; Blitz and Lorenz 2006:12–14; Pauketat and Alt 2003). For example, seasonal aggregation at monumental ritual facilities may provide a context for group solidarity and integrate dispersed families, but without a continuous proprietary role in the rites, leadership may remain temporary, fluid, and situational (see DeBoer and Blitz 1991 for a modern ethnographic example). Monumental ritual facilities used for intervals shorter than a gener-

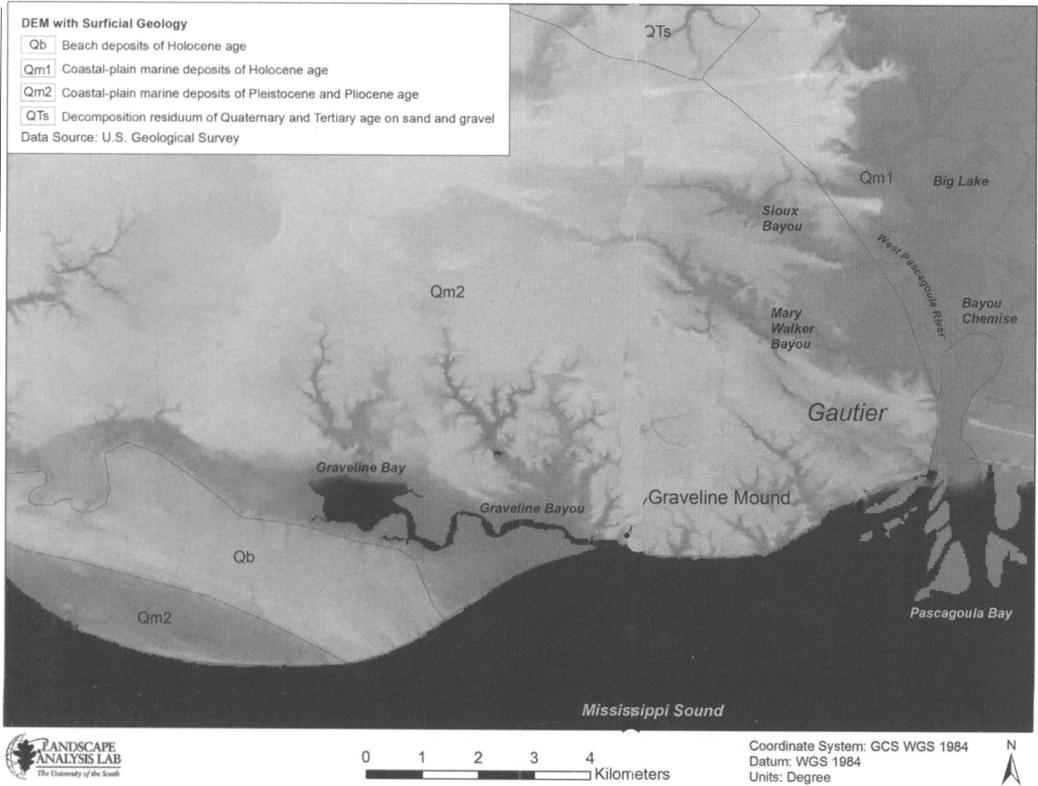


Figure 1. Location of Graveline Mound on the Mississippi Gulf Coast (Reproduced from Sherwood et al. 2013: Figure 1, © 2013 Society for American Archaeology, used by permission).

ation at nonresidential sites are the expected result of societies without formal or institutionalized leadership, i.e. “sequential hierarchy” (Johnson 1982). Monumental ritual facilities at multiple-season residential sites invite ongoing maintenance and provide a long-term context for individuals and groups to expand their roles in ceremonials, increase the frequency and variety of the events, and routinize sponsorship or assert ownership of the facility and the associated rituals. At residential sites, monumental ritual facilities continuously rebuilt over intervals longer than a generation are a more secure basis for permanent positions of authority, institutionalized leadership, or “simultaneous hierarchy” (Johnson 1982).

Empirical support for these claims is found in comparative studies of Southeastern platform mounds (Brown 1994; Jefferies 1994; Knight 1990, 2001; Lindauer and Blitz 1997; Pluckhahn 1996); some mounds have features and assem-

blages that indicate temporary or periodic use for inclusive special-purpose ceremonials such as feasting, while other mounds have evidence of multiple, long-duration construction episodes and more permanent residences with a greater variety of exclusive activities that reinforced social differentiation. A more secure understanding of these conditions and the historical circumstances at specific sites requires compressed time scales. At coastal sites where mollusk shells can be recovered in association with monumental ceremonial facilities, sclerochronological oxygen isotope measurements can identify season of capture (Andrus 2011, 2012) and, potentially, measure the periodicity and duration of mound construction and use at seasonal scales.

The Graveline Mound Site

We had the opportunity to apply oxygen isotope sclerochronology to assess seasonality at the

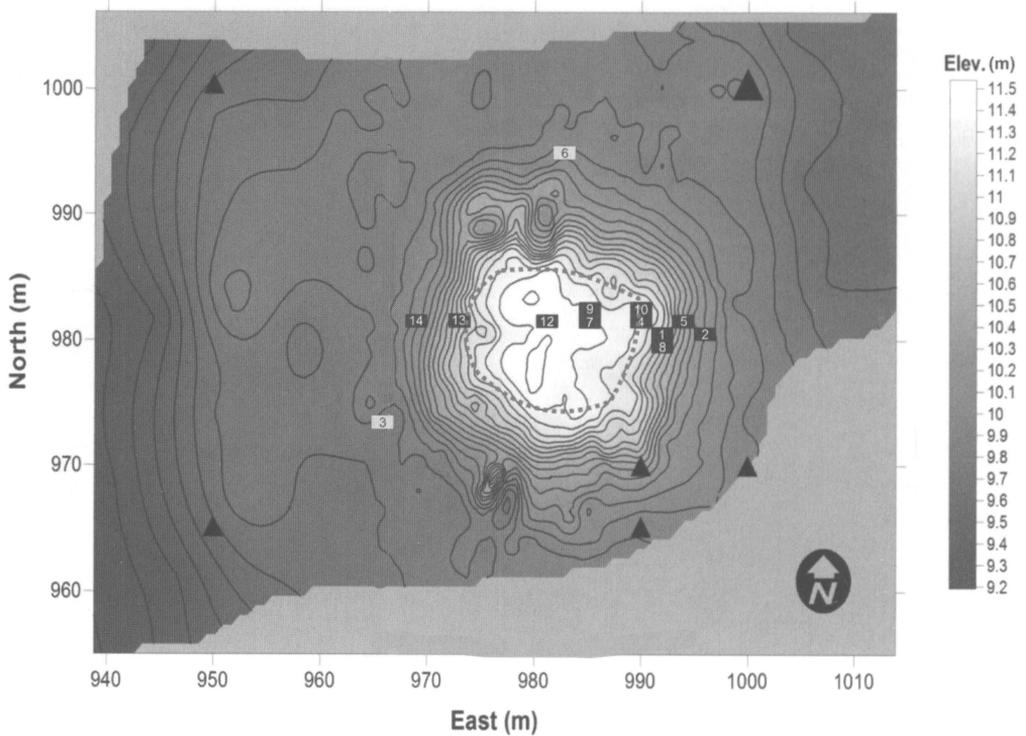


Figure 2. Topographic plan view of Graveline Mound with excavation units (squares) and datums (triangles) located. The dashed line represents the projected extent of Stage I (Reproduced from Sherwood et al. 2013: Figure 2, © 2013 Society for American Archaeology, used by permission).

Graveline Mound site (22JA503) in Jackson County, Mississippi. Graveline is a Late Woodland period mound located on the Gulf of Mexico (Figure 1). The mound is radiocarbon dated cal A.D. 590–780. It is a single-component construction of the Graveline phase, recognized by a grog-tempered ceramic assemblage dominated by the chronological types Marksville Incised and Larto Red (Blitz and Mann 2000). A rectangular platform, the mound measures 30 m north-south, 25 m east-west, and rises 1.65 m above the current ground level. The 2010 excavation results produced a detailed picture of mound form, chronology, and use, and secured the shell samples for the oxygen isotope analysis (Blitz and Downs, eds. 2014).

Graveline Mound in Local and Regional Context

Suburban development confined investigations to the mound and a 70-x-50-m surrounding area (Figure 2). A grid of auger samples, shovel tests, and small excavation units failed to detect midden,

features, or other evidence of habitation in the project area (Downs 2014). All detectable activities were confined to the mound. Graveline Mound is the largest of seven mounds within a 1-km area along the coastal strand (Moore 1905). Eroded shell middens occur within 200 m of Graveline and the other mounds. Access to these mounds and middens has been restricted and there are no published excavations to clarify the chronological relationships. At present, the site settlement pattern of the Graveline mound group appears to consist of mounds devoid of adjacent habitation evidence and spatially separated from nearby shell middens distributed along the shoreline.

At this point in our understanding of regional archaeology, it is not clear if there was seasonal residential mobility for coastal native populations; even though the mounds lack adjacent habitation evidence, they may have been used by populations residing year-round nearby. With the exception of the multiple-mound group, Graveline phase sites recorded by survey are multicompo-

ment shell/earth middens, but subsistence and seasonality data are unavailable for these sites (Blitz and Mann 2000). Given these limitations, our objective here is to assess the utility of shell oxygen isotope analysis as a measure for the seasonality of mound use.

Mound Excavation and Sample Context

Eleven 2-x-1-m units were excavated to expose a cross-section of Graveline Mound; three of these units were expanded into contiguous 2-x-2-m blocks. Mound strata, features, and chronology, presented at length elsewhere (Blitz and Downs 2014; Sherwood et al. 2013), are summarized here. Initial mound Stage I had the configuration of a low embankment that enclosed or demarcated a central space free of artifacts and features. Piles of oyster and clam shells were dumped on the outer edge of Stage I. Stage II, composed of zoned sand fills, covered the central area, Stage I, and the associated shell deposits. Stage III, the final construction stage, was a deposit of clean sand and plinthite-rich soil that encapsulated the previous stages. Stratigraphy provides the first critical observation that Graveline Mound was constructed in a short time span. Geoarchaeological inspection of strata profiles and thin-section particle size analysis failed to find evidence of erosion or A horizon development that would indicate a significant construction hiatus between Stages II and III (Sherwood et al. 2013). No features or midden and few artifacts were associated with Stages II or III. No human remains were found anywhere in the mound, nor was there evidence of substantial shelters. Although it is possible that structure remains or other features went undetected beyond the limits of excavation, the absence of artifacts and midden on or surrounding the final mound configuration suggests that Stages II and III were terminal construction events that sealed Stage I and did not serve as occupied surfaces.

Except for a few isolated finds incorporated into mound fill, artifacts were restricted to Stage I contexts. The artifact assemblage consisted almost entirely of potsherds ($n = 1,689$) derived from plain coarse-ware jars and smaller, elaborately incised or painted bowls and beakers. Small quantities of debitage ($n = 80$) representative of regional lithic sources were present, suggesting

low-level use or maintenance of stone tools. The only other artifacts were five hafted bifaces, one biface fragment, a broken ceramic pendant, a sharpened catfish spine, and a tiny piece of non-local mica. The limited quantity and diversity of artifacts suggests Stage I activities focused on food consumption in a ritual format, and not the broader range of activities expected at habitation sites. All detectable uses of the mound were associated with Stage I, and soon thereafter, Stage I was covered by the relatively rapid addition of Stages II and III.

Stage I shell deposits were composed of clam shells (*R. cuneata*), oyster shells (*C. virginica*), fish bone, potsherds, charcoal, and ash (Blitz and Downs 2014). No cultigens were present, but seeds of yaupon holly (*Ilex vomitoria*) and morning glory (*Convolvulus/Ipomoea* spp.) suggest the consumption of stimulants and hallucinogens (Peles and Scarry 2014). The shell deposits had the appearance of piles created by collecting the debris into a container and then dumping it just to the exterior edge of the central activity area demarcated by Stage I (Figure 3). Evidence indicates that the shell deposits were generated during intervals of short duration. The piles were distinct and separated, although several were superimposed. Potsherds were not weathered; fish bones were found articulated; and some bivalve shells were still attached at the hinge. We attribute this preservation to a formation process in which the trash was not moved very far and not exposed very long before covered by Stage II. The unmixed separation of the individual shell piles, the apparently short interval of their creation, the association of vertebrate fauna and botanical remains with the potential for an independent seasonal assessment, and the rapid sealing of the deposits in an undisturbed context presented the ideal opportunity to determine if oyster and clam oxygen isotope measurements could identify the seasons of mound use.

Materials and Methods

All shell samples selected for analysis were derived from the sealed Stage I shell deposits. The shells within each excavation context were sorted and evaluated for preservation. Any shell found to have evidence of epibiont growth in the valve interiors

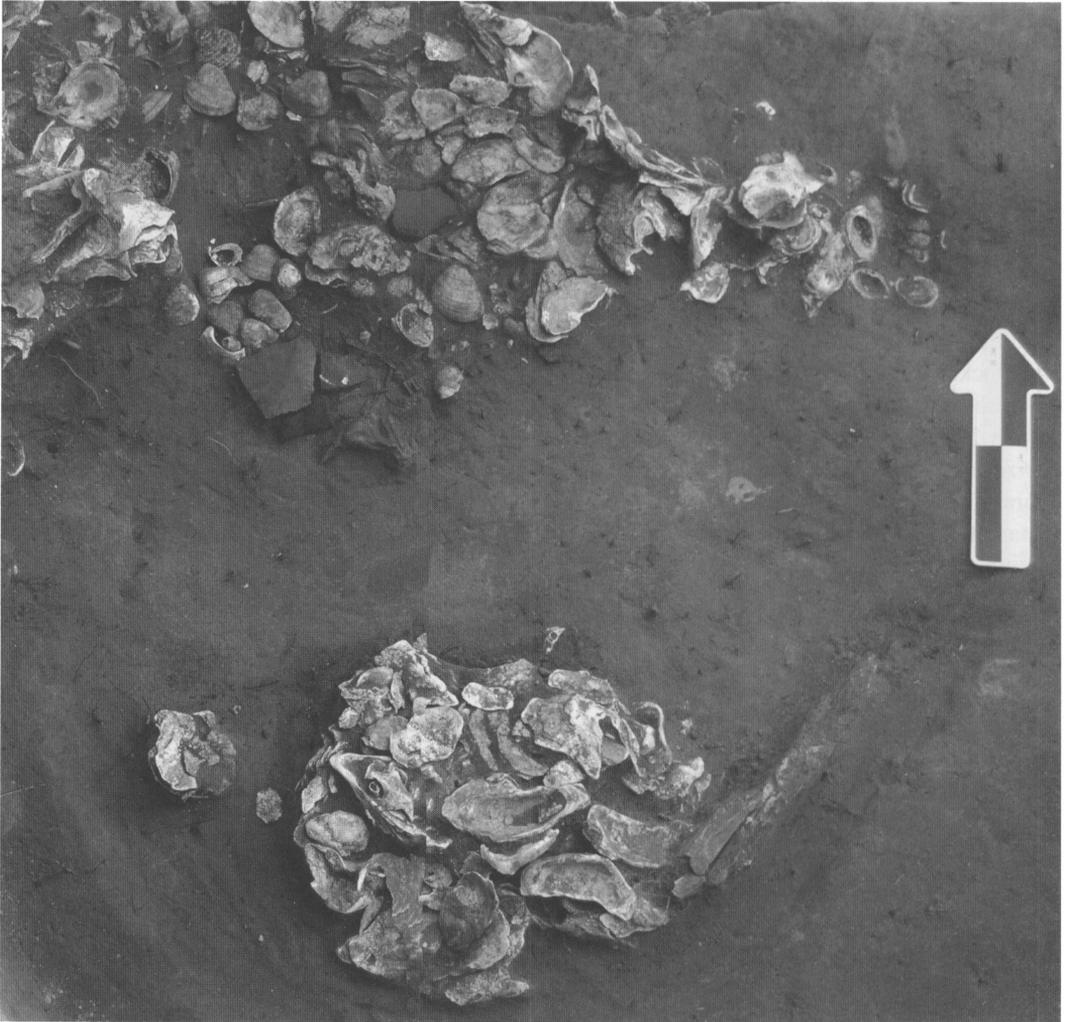


Figure 3. Graveline Mound shell deposit features (Reproduced from Blitz and Downs 2013:Figure 3-10, © 2014 Mississippi Department of Archives and History, used by permission).

was discarded because this may indicate the shell was dead at the time of collection. Only oysters with intact hinge areas of the left valve were analyzed since sampling was to occur across ontogeny as preserved in the area along the chondrophore. Similarly, clams were only analyzed if they contained intact portions of the valve edges. All clam valves were compared to ensure matched pairs were not analyzed. No geriatric samples were analyzed to ensure comparatively rapid growth and permit subseasonal sampling resolution.

Sample Preparation

All shells were bisected across the axis of growth using a water-cooled diamond rock saw (Figure

4). Oysters were cut as close to the center of the chondrophore as permitted by valve curvature. Clams were bisected from the umbo to the ventral margin. Once bisected, the valves were affixed to petrographic slides using Crystalbond thermal adhesive. Sections were then cut using a water-cooled, thin-section, cut-off diamond wafering saw. Each section was approximately 1-mm thick.

Sectioned shells were then mounted onto a New Wave computer-controlled micromilling system. Each shell was sampled multiple times in sequence to create an ontogenetic time-series of data. This was accomplished in the oysters by sampling in sequence along the chondrophore, avoiding all areas in which aragonite may be pre-

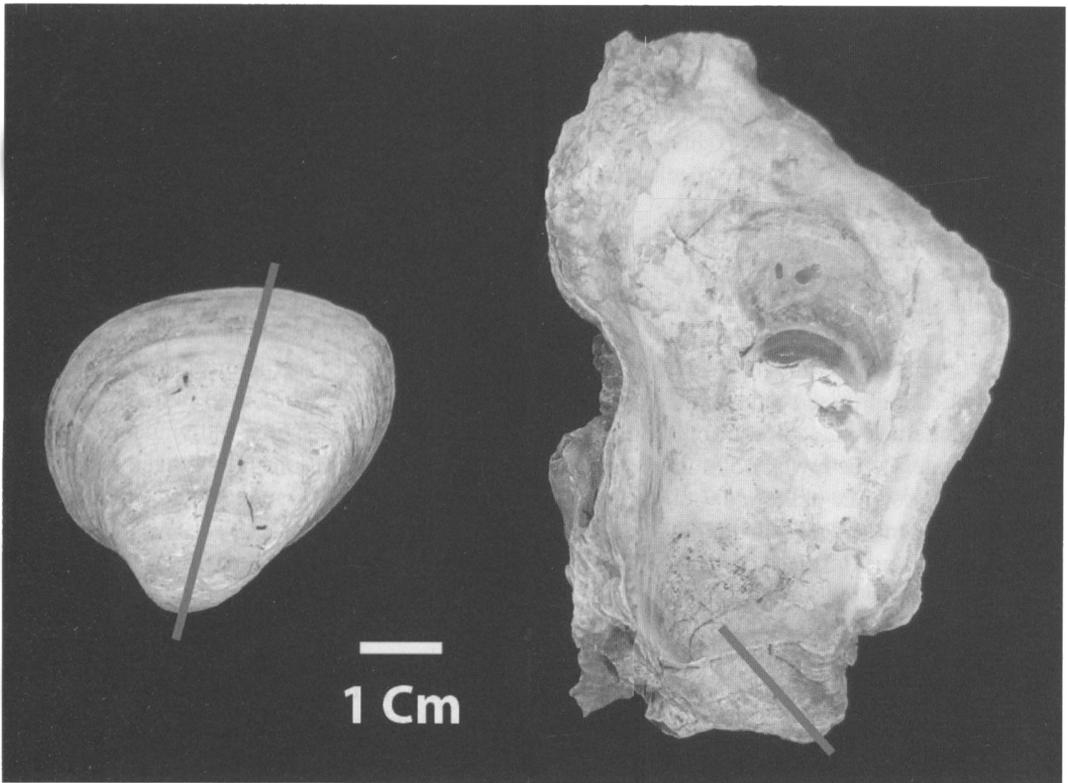


Figure 4. All shells were bisected along axis of growth.

sent (e.g., surface of the resilifer). In clams, sequential sampling took place in the middle shell layer. Each sample was taken from a transect plotted using the micromill software parallel to growth increments. Intermediate transects (between growth lines) were interpolated from adjacent growth lines using the New Wave software. Sample transects were equidistantly spaced. The distance between transects varied on different shells according to their size and apparent growth rates, but were commonly spaced between ~ 100 and $\sim 350 \mu\text{m}$, with each transect being ~ 75 – $150 \mu\text{m}$ wide. The goal was to take enough samples from each shell to measure at least one year's worth of shell growth. This typically resulted in 15–20 samples per shell, but in some instance up to 49 samples were made in a single shell (Supplemental Table 1). These methods are similar to what was described in Thompson and Andrus (2011) and Andrus and Thompson (2012) with the same species of oyster and a morphologically similar species of clam.

Sample Analysis

All samples were analyzed for $\delta^{13}\text{C}$ (carbon isotope) and $\delta^{18}\text{O}$ (oxygen isotope) composition at the University of Alabama Stable Isotope Laboratory on a Thermo Delta plus isotope ratio mass spectrometer under continuous He flow mode using a Thermo GasBench II. All data are reported relative to Vienna Pee Dee belemnite (VPDB) in parts per mil (‰). Average precision (1σ) of all runs was $\pm .07\text{‰}$ for $\delta^{13}\text{C}$ and $\pm .1\text{‰}$ for $\delta^{18}\text{O}$ as measured by multiple analyses of NBS-19 on each of the 14 samples runs (range for $\delta^{13}\text{C}$ was $\pm .03$ – $.13\text{‰}$ and $\delta^{18}\text{O}$ was $\pm .09$ – $.2\text{‰}$). These same standard data were used to assess drift and linearity ($\delta^{18}\text{O}$ /peak size) and to correct for each if detected. Aragonite samples (all *R. cuneata* samples) were corrected for oxygen isotope fractionation differences from the calcite NBS-19 standard by subtracting $.29\text{‰}$ for those samples reacted at 25°C and $.34\text{‰}$ for those samples reacted at 50°C . These values were derived from Kim et al. (2007).

Interpretation of the resulting $\delta^{18}\text{O}$ profiles generally followed Andrus and Crowe (2008) and Thompson and Andrus (2011). The basic rationale is that because temperature is the dominant cause of seasonal variation in shell $\delta^{18}\text{O}$ (inversely correlated with temperature) in these species and region, sinusoidal $\delta^{18}\text{O}$ profiles should be expected in shells samples measured sequentially over at least one year of growth (Andrus 2012). The $\delta^{18}\text{O}$ value in the final portion of shell grown prior to capture can be compared to the seasonal oscillation in $\delta^{18}\text{O}$ earlier in ontogeny. This oscillation can be divided into three sections: the upper 1/3 of the range denotes the coldest time of the year (termed “winter”), the lower 1/3 of the range denotes the warmest time of the year (termed “summer”), and the middle 1/3 of the range denotes transitional seasons (termed “spring” if the trend is negative prior to the last samples, or “fall” if the trend is positive). Should the $\delta^{18}\text{O}$ value in carbonate precipitated just prior to death fall within 1σ analytical precision of the lines defining the seasons, then the season of capture is described as either winter/spring, spring/summer, summer/fall, or fall/winter. The seasonal designations do not strictly correspond with astronomical (calendric) seasons because the timing of seasonal water temperature change will vary from year to year and subseasonal variation in $\delta^{18}\text{O}_{\text{water}}$ may complicate the shape of the seasonal cycle in shell $\delta^{18}\text{O}$. Those $\delta^{18}\text{O}$ profiles that did not appear sinusoidal were considered uninterpretable. Likewise, incomplete sinusoids that did not approximate the expected seasonal range ($< \sim 2.5\text{‰}$) were not interpreted.

Results and Interpretation

Stable Isotope Data

One-hundred-sixty-five *C. virginica* and 495 *R. cuneata* samples, derived from 28 shells (7 oysters and 21 clams), were micromilled for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ analysis. The shells were excavated from 10 areas of Stage I. The resulting data are presented in Supplemental Table 1. The mean value of all oyster $\delta^{13}\text{C}$ values is -1.2‰ ($1\sigma = .9$) and the mean of all $\delta^{18}\text{O}$ is -1.3‰ ($1\sigma = 1.3$). The mean value of all clam $\delta^{13}\text{C}$ values is -8‰ ($1\sigma = 2.5$) and the mean $\delta^{18}\text{O}$ is -4.4‰ ($1\sigma = 1.2$). Mean

$\delta^{13}\text{C}$ values of individual oysters range from -1.3‰ to -1.1‰ , and $\delta^{18}\text{O}$ in the same shells range from -1.7‰ to -8‰ . The mean of all clam $\delta^{13}\text{C}$ values is -7.8‰ ($1\sigma = 2.6$) and the mean $\delta^{18}\text{O}$ is -4.4‰ ($1\sigma = 1.2$). Mean isotope values of individual clams was more negative and ranged wider than those for oysters, with $\delta^{13}\text{C}$ values from -9.3‰ to -6.6‰ , and $\delta^{18}\text{O}$ in the same shells range from -5.1‰ to -3.7‰ .

Intrashell $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ variation differed between analyzed shell specimens. Individual oyster shell $\delta^{13}\text{C}$ standard deviations (1σ) ranged from a low of .5 to 1.4, while $\delta^{18}\text{O}$ ranged between 1 and 2 in the same shells. Individual clam shell $\delta^{13}\text{C}$ standard deviations (1σ) ranged from a low of 1.1 to 2.8, and $\delta^{18}\text{O}$ ranged between .6 and 1.4 in the same shells.

Most shells display a generally sinusoidal oxygen isotope profile, or a portion of a sinusoid, that could be interpreted as seasonal (Figure 5). Carbon isotope profiles appear to track with oxygen in some samples, but with lower average amplitude. Linear regressions of $\delta^{13}\text{C} / \delta^{18}\text{O}$ were cross plotted to yield r^2 values .68 and .46 for oyster and clam data respectively.

Season of Capture Assessment

The oxygen isotope profiles were interpreted to estimate season of capture as defined above in Methods (see Figure 5 for example data from each season). Three shell oxygen-isotope profiles (all *R. cuneata*) could not be interpreted since they lacked a recognizable portion of a sinusoid and/or displayed a “sawtooth” pattern where alternating samples in sequence oscillated between what are typically the highest and lowest $\delta^{18}\text{O}$ values (two shells from Unit 4, Level N1, Feature 5B and one from Unit 8, Zone 6, Level D, Feature 17G/18F/20D). Such a pattern suggests that time resolution of sampling was poor or that the shell had stopped (or greatly slowed) growth for part of the year. This may be indicative of older, slower growing, individuals where such a pattern is expected (see Henry and Cerrato 2007 and Cannon and Burchell 2009 for discussions of this growth pattern in other taxa).

The remaining 25 shells yielded the season of capture estimates listed in Supplemental Table 1. Three shells yielded estimates that fell at the transition of seasonal values (one spring/summer,

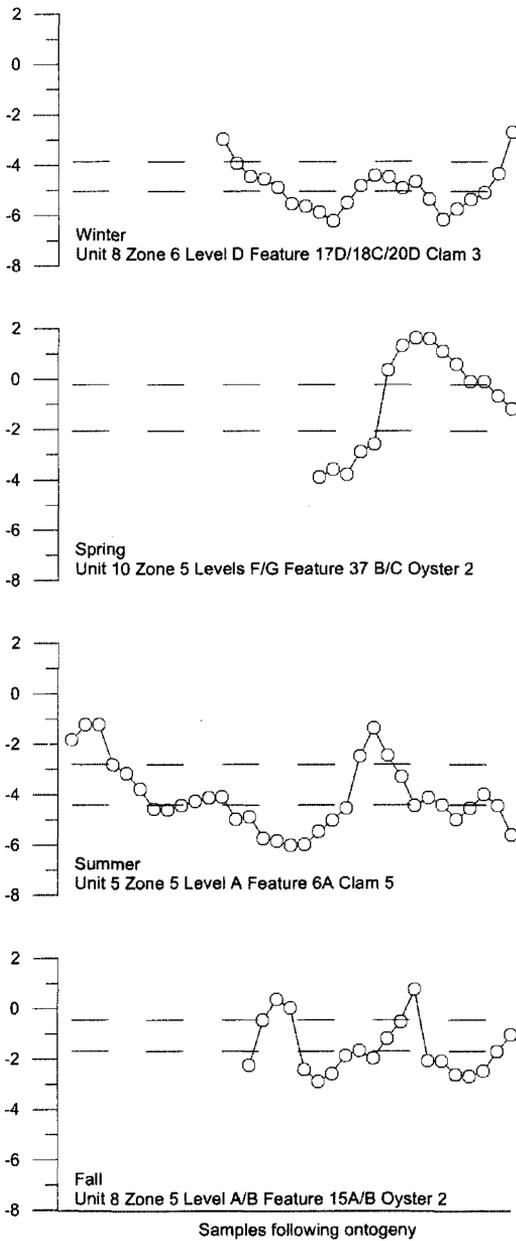


Figure 5. Graveline shell sinusoidal oxygen isotope profiles interpreted as seasonal, with an example for each season.

two winter/spring). This should not be considered as proof that the shells were collected precisely during the transition of seasons, but rather the data are not adequate to resolve the season conclusively and the collection time of the shell could fall within either season. Histograms of the season of capture distributions are presented in Figure

6. Most shells appear to have been captured during warmer seasons, with 40 percent of the shells estimated to have been captured in spring, 32 percent in summer, and four percent in spring/summer. Twelve percent indicated capture in fall, four percent in winter, and eight percent in winter/spring.

Factors Affecting the Precision of Seasonal Estimates

Season of capture determinations are estimates and are not perfectly precise or accurate (Andrus 2011, 2012). This imprecision is due to a number of potentially interrelated factors such as environmental variation, growth patterns, natural history of the organisms, laboratory sampling strategy, and human behavior. The combined effect of temperature and $\delta^{18}\text{O}_{\text{water}}$ on $\delta^{18}\text{O}_{\text{shell}}$ is of particular concern in species collected from estuaries. Both *R. cuneata* and *C. virginica* are estuarine species, with the former being most common in the upper, more brackish reaches, and the latter becoming more common in the lower, more saline waters (Eastern Oyster Biological Review Team 2007; LaSalle and de la Cruz 1985). Temperature and $\delta^{18}\text{O}_{\text{water}}$ are the primary variables that control $\delta^{18}\text{O}_{\text{shell}}$ and this is the fundamental basis of determining season of capture with stable oxygen isotopes in mollusks (Andrus 2011; Shackleton 1973). Salinity and $\delta^{18}\text{O}_{\text{water}}$ typically covary in coastal waters, with both being a product of evaporation, precipitation, continental runoff, and the mixing of waters from different sources (see Schmidt et al. 1999 for example marine data and the International Atomic Energy Agency 2013 for precipitation data). It is ideal if only one of these two factors varies in the habitats of mollusks used for season of capture analyses, but this is not the case in the Gulf of Mexico. Water temperature oscillates seasonally in this area on the order of about 20°C (e.g., Mobile Bay National Estuary Program 2004) while salinity varies at multiple timescales and to different degrees according to specific habitats. At seasonal timescales, temperature is the dominant variable in these mollusks in Gulf of Mexico estuaries (Andrus and Rich 2008; Surge et al. 2001), but excursions in salinity can occur that would alter or obscure the seasonal patterns of temperature-driven $\delta^{18}\text{O}_{\text{shell}}$. Andrus and Rich (2005) illustrate

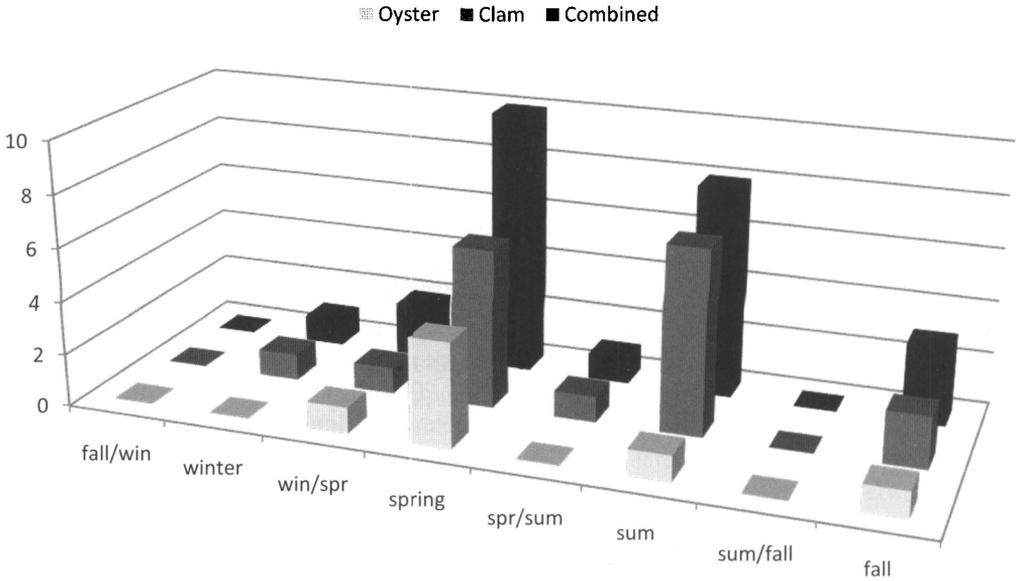


Figure 6. Histograms of the shell season of capture distributions.

one such excursion's effect on *R. cuneata* in nearby Mobile Bay. In such cases, an incorrect season of capture estimate would be made.

Incorrect interpretation could also result from periods of growth cessation. For example, *R. cuneata* has been noted to stop producing shell for variable periods of time. Using macroscopic visual inspection techniques, Aten (1981) measured regular growth cessations in winter and less regular cessations in summer in Texas populations, though the durations of these cessations was not specified. Winter growth breaks are also evident in Louisiana *R. cuneata*, but growth breaks also occurred irregularly in spring and fall (Fairbanks 1963). There is also evidence that brief but frequent cessations may also exist in Mobile Bay, Alabama populations (Cobb et al. 2009). However, it is unlikely that short growth breaks (hours to days) would impact season of capture estimates at the level of precision used in oxygen isotope measures, but breaks from weeks to months would. The contradictions between these studies may suggest habitat-specific shell growth responses to a range of environmental stressors. This apparent irregularity to the periodicity of growth cessation precludes confident assessment of season of capture based solely on visual interpretation of shell morphology. More

extensive modern control studies may be required before such an approach could be validated.

The mean range of the $\delta^{18}\text{O}$ oscillations in the *R. cuneata* shells reported here is 3.6‰. When the Grossman and Ku (1986) oxygen isotope-temperature equations are applied, interpreted for the sake of illustration as solely a product of seasonal temperature variation, this yields a seasonal range of $\sim 16^\circ\text{C}$. This suggests that growth cessations are likely subseasonal, considering time averaging of the shell samples and typical seasonal SST temperatures in the region. For example, mean annual variation in sea surface temperature taken at monthly resolution is $\sim 17^\circ\text{C}$ at nearby Dauphin Island, Alabama (Mobile Bay National Estuary Program 2004; National Oceanographic and Atmospheric Administration 2011). Thus seasonal $\delta^{18}\text{O}$ oscillations are still evident. However, this could still impact the season of capture estimate reliability. For example, if a particular shell ceased growing in the coldest month of the year, the overall amplitude of the resulting $\delta^{18}\text{O}$ curve would be attenuated. This would result in the thresholds dividing the seasonal $\delta^{18}\text{O}$ oscillation into three divisions (described above) being compressed and increase the likelihood of shells being assigned to winter season of capture. Oyster valves are also known to cease growing at summer temperature

extremes that may be present along the northern Gulf of Mexico coast (Surge et al. 2001). However, the average $\delta^{18}\text{O}$ range in the shells reported here is 4.6‰, suggesting growth cessation would be minimal. Considered collectively, the growth cessations will not preclude season of capture analysis in these species, but the accuracy and precision may be negatively impacted in some individual shells due to distortion to the expected seasonal $\delta^{18}\text{O}$ oscillations. Despite these factors, oxygen isotope analysis of *R. cuneata* promises to be more accurate than previous efforts to identify *R. cuneata* seasonality based on shell growth morphology (i.e. Aten 1981).

Another source of incorrect season of capture estimates would be due to inadvertent collection of dead mollusks by the site inhabitants. All analyzed shells were carefully inspected for evidence of death prior to capture, such as epibiont growth in shell interior surfaces, but such inspection is not foolproof. Valves of dead clams and oysters may remain articulated and sometimes fill with sediment, thus protecting the interior surfaces from obvious overgrowth or boring. Collection of dead clams and oysters is almost unavoidable when using rakes and similar tools for mass capture, and even hand collection results in some dead shells mixed with living shells (based on firsthand observation during collection of modern control samples by Andrus). This is especially true of oysters which often grow attached to one another, and dead oysters are commonly found attached to living ones. Some percentage of these shells may end up in the archaeological record and be analyzed, resulting in an incorrect season of capture estimate.

This list of possible sources of error could also include other factors ranging from how the milling strategy impacts the resulting curve to larger issues of the definition of season. Our central point here is that although validation studies support the utility of oxygen isotope analysis as a means of determining season of capture, this method will likely include some shells that yield erroneous estimates. Therefore, overall analysis of site occupation extrapolated from season of capture estimates is most robust when based on multiple samples and independent lines of corroborating evidence, as is the case for Graveline Mound.

Discussion

Season of capture analysis can be extended to infer season of site occupation; such interpretation provides only a minimum period of occupation and may not account for the full complexity of periodic or episodic human behaviors evidenced at a site (see discussions in Monks 1981; Waselkov 1987). As is the case with other seasonality indicators (Waselkov 2012:202; Wing 2012:207), sclerochronological season of capture data are best interpreted within a larger archaeological context, ideally with parallel lines of evidence with independent sources of error, precision, and accuracy. In the Graveline Mound sample, the majority of the clams and oysters appear to have been collected in spring and summer, 14 percent were captured in fall, and only four percent in winter. This suggests while the site may have been occupied at times throughout the year, spring and summer activities resulted in the largest deposits of mollusk remains.

Seasonal Indicators in Associated Vertebrate Faunal and Botanical Remains

Graveline Mound is the only site in the region with oxygen isotope data for archaeological shells. However, an independent measure of seasonality is derived from the vertebrate faunal and botanical remains in the shell deposits (Peles and Scarry 2014; Scott 2014). Of 7,321 bone fragments analyzed, Scott found that estuarine species dominated the vertebrate fauna, 96 to 98 percent of which were fish. Whitetail deer at Graveline Mound was represented by a single skeletal element, in contrast to its ubiquity at interior Woodland sites. Adult fish size and lifecycle habitats are indicative of spring and early summer procurement, possibly using mass-capture techniques such as seines in shallow, nearshore waters (Scott 2014:73). Another seasonal indicator, sea turtle (*Cheloniidae/Dermochelyidae*), inhabits the region only in warm weather. Only the low frequency presence of sea trout (*Cynoscion* spp.) and a single Gulf sturgeon (*Acipenser oxyrinchus desotoi*), is strongly suggestive of cold weather or winter/early spring procurement. Botanical remains, consisting of wild nuts, fruits, starchy and oily seeds, were not abundant. Peles and Scarry (2014:84) observe that the Graveline plant species were locally avail-

able in summer and fall, but caution that botanical remains may not be sensitive seasonal indicators due to possible storage beyond the season of procurement. In sum, the vertebrate faunal and plant remains indicate primarily spring and summer procurement and provide independent evidence in support of the shell oxygen isotope season of capture results. Shell, animal bone, and plant analyses all identify spring and summer as the dominant seasonal signature, even though minor use or brief visits to Graveline Mound in the cold months may have also occurred.

The restricted seasonal range of the Graveline Mound vertebrate faunal remains is particularly informative when compared to the Jackson Landing Mound (22HA515), the only other Late Woodland platform mound in the region with seasonality data (Boudreaux 2011). Located 78 km west of Graveline Mound, Jackson Landing Mound is in a similar coastal estuary environment. In contrast to the almost exclusive reliance on fish (and shellfish) at Graveline Mound with a spring-summer seasonality signature, whitetail deer were abundant in the samples from the Jackson Landing Mound in addition to fish, and it is likely that most of the mound deposits formed during early fall (Scott 2011:277). The mound activities that generated the faunal remains at these two sites appear to be temporally restricted events that generated a markedly seasonal profile. Evidence that food-consumption ceremonies at the two mounds may have occurred in different seasons underscores the potential variability in the scheduling of mound-related activities at coastal sites.

Unfortunately, we lack adequate faunal samples from a Late Woodland non-mound coastal site in the region for comparison to the two mound sites. Adequate faunal samples are available from two regional Middle Woodland nonmound coastal sites with habitation evidence, Godsey (22HR521) in Mississippi and Plash Island (1BA134) in Alabama. Godsey has no definite cold season indicator species (Jewell 2000:167), while Plash Island has both cold season and warm season indicator species (Baker and Klippel 2008:284). The variability in seasonality at the sites discussed here suggests that the diversity and abundance of local resources was sufficient to support multiple-season, perhaps year-round settlement for nonfood

producing populations, as has been argued for more extensively studied regions such as coastal Georgia (Reitz et al. 2012). If this is the case with additional research, then it may be that Woodland mound construction and use was not tied to calendric or regularized rituals “scheduled” to coincide with seasonal residential mobility. Instead, construction and use of mounds such as Graveline and Jackson Landing may represent a local residential population’s transitory response to infrequent events generated by specific crises or the temporary intensification efforts of influential individuals.

Duration of Graveline Mound Use

To reiterate, the physical characteristics of the shell deposits and mound stratigraphy implied rapid formation and deposition (Sherwood et al. 2013). The shell deposits and all other detectable activities at the mound locale were confined to Stage I, which was subsequently capped by the rapid additions of Stages II and III. Considering the potential factors affecting season of capture estimates, discussed above, it is possible that the Stage I mound was only used for intervals during spring and/or summer, and that at least some of the few shells with isotope profiles indicative of fall and winter capture are erroneously interpreted. Collectively, these data suggest there was no permanent occupation of the Stage I mound or immediate surroundings. Instead, it was used for a short period or over several repeated visits in succession. Assuming each use episode resulted in the deposition of mollusks (all Stage I deposits contained mollusks), then it appears as if the site was most intensively visited in spring and summer, and rarely used at other times of the year.

Further insight into the duration and nature of these apparent use episodes can be derived from a feature-by-feature analysis of the season of capture estimate data. Most Stage I shell deposit features contain mollusks interpreted to have been caught over more than one season, but some features contain shells with oxygen isotope profiles indicative of single time periods or events. For example, Feature 17A/18 contained a mixture of clams and oysters, as can be seen in Figure 3. All of the clams ($n = 3$) appear collected in summer. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ isotope profiles of two of the shells (clams 1 and 2, Supplemental Table 1) are

very similar with nearly identical ranges and patterns, suggesting they were harvested together from the same bed and perhaps the same generational cohort. One of the two analyzed oysters from this feature also appears to have been captured in summer, but the remaining shell $\delta^{18}\text{O}$ profile suggested a winter/spring collection. Collectively, it could be argued that this feature resulted from a single, short-term occurrence with little or no mixing of remains from nearby contexts before burial. Features 37 B/C and 17G/18F/20D both could also represent single-occurrence origins based on $\delta^{18}\text{O}$ profiles data (Supplemental Table 1).

The features that contain multiple seasons of capture may be explained by several potential scenarios. It could be that the site was occasionally visited in other times of the year and shells were added to existing deposits. However, the discrete nature of the deposits does not offer strong support for this possibility. Similarly, the well-defined shell features do not contain much evidence of postdepositional mixing of earlier shells, though the possibility cannot be entirely discounted. It may be that oxygen isotope sclerochronology alone does not offer adequate precision and accuracy to conclusively detect all such short and discrete events. Blind tests of this method on modern shells of known collection times may improve our understanding of the limits of this analysis and perhaps quantify precision and accuracy estimates, but in the 40 years since the technique was established, no such assessments have been published.

Conclusions

Results of the oxygen isotope sclerochronology support the conclusion that the Graveline Mound was a nonresidential place used for special-purpose ritualized activities that occurred primarily, or entirely, in spring and summer. Vertebrate faunal remains provide an independent measure and similar conclusion. Geoarchaeological examination of mound soil profiles also indicate that mound construction and use were of brief duration. In sum, Graveline Mound was an unlikely context for the expansion of social hierarchy beyond temporary or situational leadership.

These results offer insight into the limitations

and possibilities of oxygen isotope sclerochronology for the identification of seasonal site activities. We are encouraged by the results of the first oxygen isotope analysis of archaeological *R. cuneata*. Further research is required to determine the limits of precision and accuracy of season of capture estimates using this and other mollusk species on the northern Gulf Coast.

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Supplemental Materials. Supplemental materials are linked to the online version of the paper, which is accessible via the SAA member login at www.saa.org/members-login.

Data Availability Statement. All records, shells, artifacts, and other materials are stored at the Mississippi Department of Archives and History, Jackson, Mississippi.

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