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ARTICLE

Stable Isotope Analysis and Chronology Building at the Hokfv-Mocvse Cultural Site, the Earliest Evidence for South Atlantic Shell-Ring Villages

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Abstract

Circular shell rings along the South Atlantic coast of the United States are vestiges of the earliest sedentary villages in North America, dating to 4500–3000 BP. However, little is known about when Indigenous communities began constructing these shell-ring villages. This article presents data from the Hokfv-Mocvse Shell Ring on Ossabaw Island, Georgia. Although shell rings are often associated with the earliest ceramics in North America, no ceramics were encountered in our excavations at Hokfv-Mocvse, and the only materials recovered were projectile points similar to points found over 300 km inland. Bayesian modeling of radiocarbon dates indicates that the ring was occupied between 5090 and 4735 cal BP (95% confidence), making it the earliest dated shell ring in the region. Additionally, shell geochemistry and oyster paleobiology data suggest that inhabitants were living at the ring year-round and had established institutions at that time to manage oyster fisheries sustainably. Hokfv-Mocvse therefore provides evidence for Indigenous people settling in year-round villages and adapting to coastal environments in the region centuries before the adoption of pottery. The establishment of villages marks a visible archaeological shift toward settling down and occupying island ecosystems on a more permanent basis and in larger numbers than ever before in the region.

Resumen

Los anillos de concha con forma circular o arqueada a lo largo de la costa del Atlántico Sur de los Estados Unidos son vestigios de las primeras aldeas sedentarias en América del Norte. La mayoría de los anillos datan entre 4500–3000 BP. Sin embargo, se sabe poco sobre cuándo las comunidades indígenas colonizaron por primera vez la zona costera o comenzaron a construir anillos de conchas como lugares de habitación. Presentamos datos del anillo de conchas Hokfv-Mocvse (en muskogeano, "nueva concha") recientemente redescubierto en la isla Ossabaw, en Georgia. Si bien los anillos de concha a menudo se asocian con la cerámica más antigua de América del Norte, no se encontró ninguna cerámica en nuestras excavaciones y los únicos materiales recuperados fueron puntas de proyectil similares a las encontradas a más de 300 km al interior. Un modelo bayesiano de datación por radiocarbono del sitio indica que el anillo fue ocupado entre 5090–4735 cal. BP (95% de confianza), lo que indica que es el anillo de conchas más antiguo de los Estados Unidos datado con seguridad. Además, los datos paleobiológicos e isótopos de las conchas de ostras del sitio sugieren que los habitantes ocuparon el anillo durante el año entero y ya habían establecido instituciones para gestionar de manera sostenible la extracción de ostras. Por lo tanto, el anillo de conchas de Hokfv-Mocvse proporciona evidencia de que los pueblos indígenas se asentaron en aldeas durante todo el año y se adaptaron a los entornos costeros de la costa de Georgia siglos antes de la adopción de cerámica. El establecimiento de aldeas marca un cambio arqueológico visible de la ocupación en continuación de los ecosistemas insulares y en mayor número de lo antes evidenciado en la costa del Atlántico Sur.

Keywords: shell-ring village; Bayesian radiocarbon modeling; shell geochemistry

Palabras clave: aldea de anillos de concha; modelización bayesiana de radio carbono; geoquímica de conchas

The settlement and subsequent establishment of permanent villages in coastal environments was a significant turning point for human populations across the globe, although these occurred at different times and under different environmental circumstances (Erlandson 2001; Erlandson and Fitzpatrick 2006; Feinman and Neizel 2023; Fitzpatrick et al. 2015). Archaeologists have recently turned from explaining settling down—that is, the shift from a mobile to more sedentary lifeway—as a response to external drivers to considering the role of internal social and political shifts and institutions in this process, which require details about local environments, as well as the precise timing for the onset of various social and political conditions (see Feinman and Neizel 2023). To comprehend the nature of settling down requires a detailed understanding of not only environmental conditions but also a clear history of the timing of when varying institutions, traits, and technologies emerged in a region. Here, we consider evidence for the earliest settled villages in the southeastern United States. These early villages are shell rings—large arcuate to circular piles of shellfish deposited around a central plaza area. Previously, archaeologists held that such settlements coincided with the adoption of pottery and the establishment of oyster fisheries in the region. Our new data show that these rings predate the invention of pottery along the Atlantic coast and demonstrate the onset of viable oyster reef fisheries in the region almost half a millennium earlier than previously thought by both ecologists and archaeologists (see Russo 2006; Sanger 2015; Sassaman 1996; Thompson et al. 2024).

On the South Atlantic coast of North America, the settlement of the coastal barrier islands and the reliance on tidal marsh and marine resources during the Late Archaic (ca. 5000–3000 BP) is associated with the emergence of new socioecological systems, including some of the first sedentary villages in North America (Cajigas et al. 2023; Colaninno and Compton 2019; Sanger and Ogden 2018; Thompson and Andrus 2011). These early villages predate agricultural economies and were instead, as Thompson (2018, 2023) argues, characterized by the establishment of institutions centered on the harvesting and management of oyster and coastal fisheries via cooperation and collective action. This is supported by dozens of circular and arcuate shell-ring midden sites on the Georgia, South Carolina, and northern Florida Atlantic coast, which provide some of the earliest evidence for not only the first settlement of the barrier islands but also year-round occupation and sustainable shellfish-harvesting practices among hunter-gatherer communities in the region (Thompson et al. 2020). These cultural sites provide important insights into the emergence of coastal lifeways of Ancestral Muskogean communities, whose traditional homelands include inland and coastal Georgia. Here, we use "Ancestral Muskogean" to refer collectively to the ancestors of groups of Indigenous peoples in the region who spoke dialects of the Muskogean language; this term is based in cultural and geographical affiliation and was developed in consultation with federally recognized tribes, such as the Muscogee Nation (Martin 2004).

Shell-ring villages and oyster fisheries along the southeastern Atlantic seaboard have generally been thought to emerge around 4,500 years ago when marsh ecosystems in the region formed as sea levels rose and mixed with freshwater inputs (Crusoe and DePratter 1976; Garland et al. 2022; Thompson 2018). In fact, most shell-ring villages along the Georgia coast that have secure radiocarbon dates were in use between 4400 and 3800 years cal BP, and some persisted longer (see Russo 2006; Sanger 2015; Sassaman 1996; Thompson et al. 2024). Although Ancestral Muskogean groups continued to construct large shell middens and midden mounds later in time, shell rings are distinctive to the Late Archaic period. Interpretations of these rings have varied from locations of ceremonial gatherings to places of permanent, year-round residence, with the latter being the current and more widely held view (Sanger and Ogden 2018; Thompson 2018; Thompson and Moore 2015). Year-round occupation has been documented at multiple rings in the region, such as the Sapelo Shell Rings, and is indicated primarily by oxygen isotope data (e.g., Andrus and Thompson 2012; Garland and Thompson 2023; Thompson and Andrus 2011) but also by seasonal signatures in faunal assemblages

(Colaninno 2012). These shell rings also date after, or at least coincide with, the invention of pottery, with the oldest known pottery traditions in the southeastern United States being fiber-tempered ceramics from the site of Rabbit Mount on the Savannah River, 4300–3800 BP (Sassaman and Gilmore 2021:12n5). Recent research indicates that it is unlikely any pottery in the region predates 4500 BP (Sassaman and Gilmore 2021).

To understand why coastal groups settled down requires an interpretive framework that considers not only the environment but also the nature and timing of emerging institutions. Collective action is a framework used to understand how people manage problems that develop when people come together and complete tasks, such as tasks revolving around the use of common-pool resources that have the potential to be overexploited (Blanton and Fargher 2016; Carballo et al. 2014; DeMarrais and Earle 2017). Collective action as an interpretive framework has been applied to understand how Ancestral Muskogeans of the Georgia coast managed oyster reefs and coastal fisheries, which are common-pool resources (Garland and Thompson 2023; Thompson 2018). A great deal of archaeological research has shown that Indigenous communities across the globe sustainably harvested oysters for millennia (Jenkins and Gallivan 2020; Reeder-Myers et al. 2022; Rick et al. 2016; Thompson et al. 2020). Along the Georgia coast, the management of oyster and other coastal fisheries is associated with settling down in permanent villages. Coresidential aggregation at shell-ring villages provided a way for communities to work together to manage coastal ecosystems that are easily impacted by human activity and environmental change (Garland et al. 2022; Thompson 2018). The circular layout of the villages themselves is also argued to relate to the emergence of early institutions that promoted collective action and minimized self-aggrandizing behaviors (see Thompson 2023). The circular arrangement of villages has been observed around the world and as far back as the terminal Pleistocene some 12,000 years ago, such as at the circular Eastern Woodland site of Bull Brook in Massachusetts (Anderson 2012; Flannery and Marcus 2012:131; Robinson et al. 2009). In general, scholars have argued that the circular arrangement of houses represents early institutions that fostered social equality, because the production and consumption behaviors of each household could be observed by everyone within a settlement (Flannery and Marcus 2012; Thompson 2023). In coastal settings, these early institutions were likely centered on rules and practices, at both the inter- and intravillage level, to foster healthy oyster and coastal fisheries.

Most of these early villages were abandoned around 3800 BP in the context of environmental instability that included lowering sea level and increased rainfall fluctuation (Garland et al. 2022; Sanger 2010, 2015). Little, however, is known about how these villages came into existence and the broader conditions under which they emerged. The beginning of these villages and the discussed institutions likely concurred with a migration event to the Atlantic coast of Georgia, given that there is little archaeological evidence for occupations prior to the Late Archaic; however, some of this evidence is thought to have been obscured by the rising sea level (Garland et al. 2021; Thompson 2023). Sea-level modeling by Turck (2012) suggests that marsh formation was sufficient for populations to have settled on the barrier islands prior to the Late Archaic. Until now, however, there have only been a few archaeological sites in the coastal zone of Georgia that predate 4500 BP, and none show evidence for coastal adaptations for marine resources.

Here, we discuss the recently identified preceramic Hokfv-Mocvse (Muskogean for "new seashell") Shell Ring. Material culture and Bayesian radiocarbon modeling indicated that the site is the earliest known shell ring in the region, predating all other shell rings by at least 400 years and possibly representing a time during which Ancestral Muskogean communities first settled the Georgia barrier islands. In this article, we integrate Bayesian radiocarbon modeling, oxygen isotope ($\delta^{18}O$) analysis, oyster paleobiology data, and sea-level back forecast modeling to examine the timing and nature of the earliest known settlement of Georgia's barrier islands. Hokfv-Mocvse has significant implications for our understanding of the human and natural history of the Georgia coast and provides important insight into the earliest settlement of the Georgia barrier islands by Ancestral Muskogean communities. In addition, it provides critical evidence on the establishment of oyster fisheries in the region and the emergence of preceramic sedentary village life in eastern North America some 5,000 years ago.

Hokfv-Mocvse and Its Place among Shell-Ring Villages of the South Atlantic Coast

Hokfv-Mocvse is located on the northern end of Ossabaw Island's Pleistocene core, directly adjacent to a bluff edge eroding into Cabbage Garden Creek (Figure 1). The shell ring was identified during a probe survey during the summer of 2022 and subsequently confirmed in lidar images (Figure 2). Other shell rings on the Georgia coast have also been recently identified via lidar technology (see

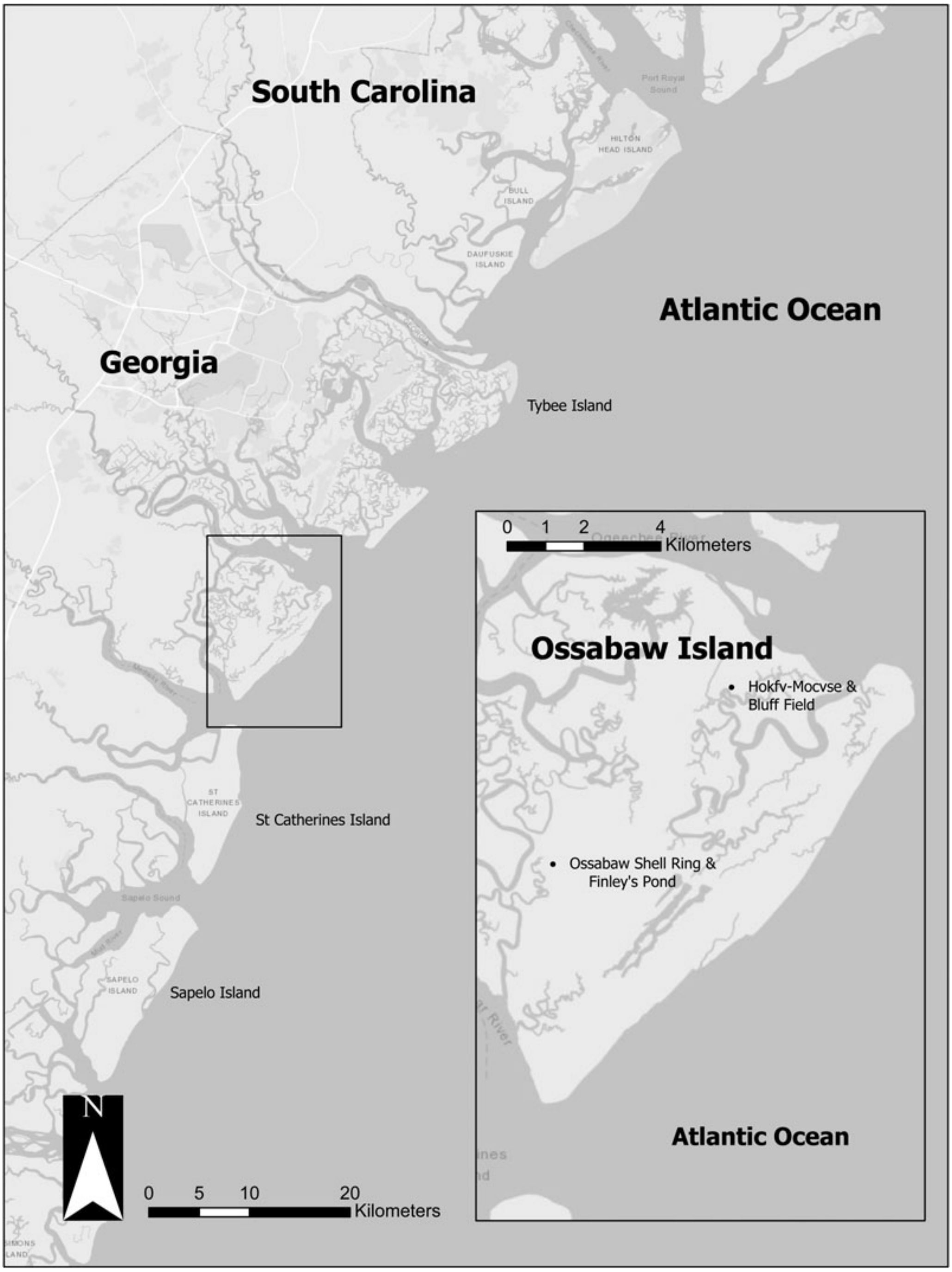

Figure 1. Map showing location of Ossabaw Island and the Hokfv-Mocvse shell ring.

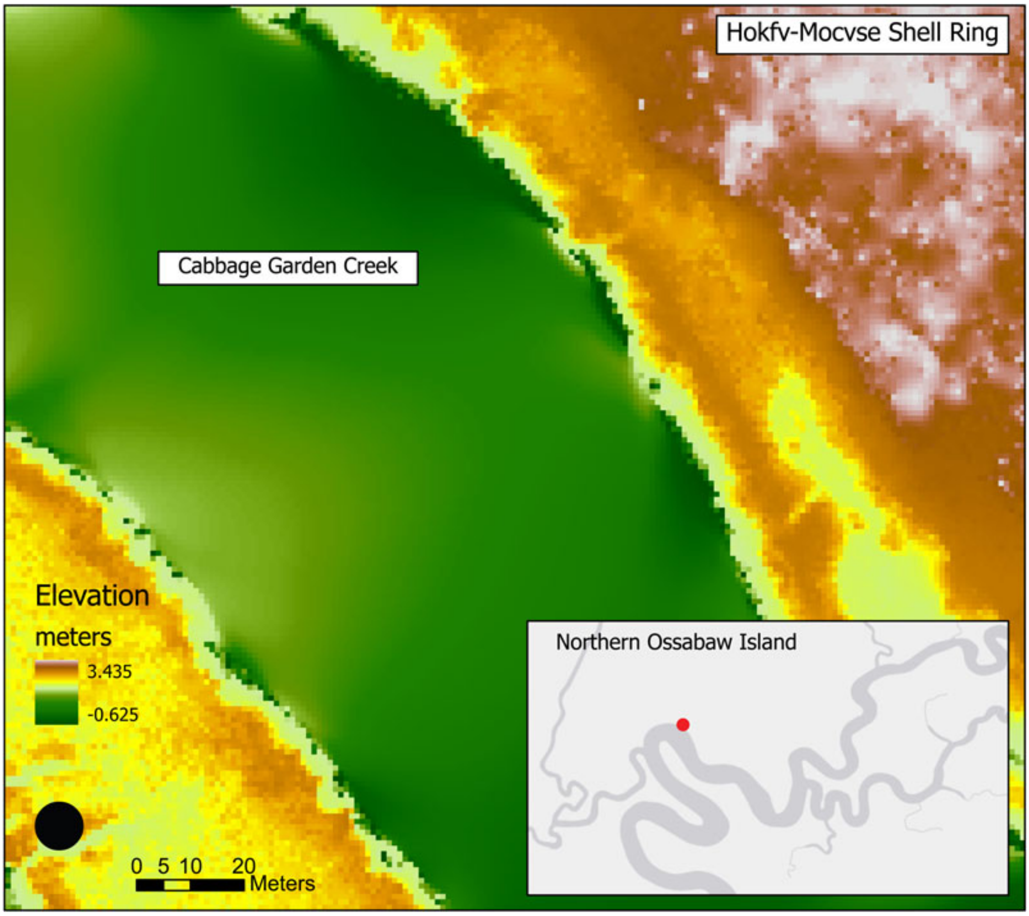

Figure 2. Lidar image of the shell ring and its location on Ossabaw Island. (Color online)

Davis et al. 2019, 2020). During the summer of 2022, a team from the University of Georgia opened up four 1 × 1 m units along the arm of the shell ring. We also conducted a series of shovel tests on the arms and backside of the shell ring based on lidar image and probing. All units were excavated stratigraphically at 10 cm levels until sterile soil was encountered. Shovel tests were excavated as 50 × 50 cm pits in arbitrary 20 cm levels to a closing depth of 60 cm, or when sterile soil was encountered. A 25 × 25 cm column sample was taken in the northwest corner of each level of the shell-ring units, from which we sampled shells for isotope analysis and pulled samples for shell measurements. Radiocarbon samples were taken from multiple levels of each excavation unit. Methods and sample sizes are discussed in more detail in the subsequent sections.

Hokfv-Mocvse is consistent with other shell rings in the region in that it is characterized as a circular, possibly arcuate, shaped ring, measuring some 60 m in diameter, with an internal plaza area of approximately 40 m in diameter. The ring consists of a dense shell layer some 0.30–0.50 m think, with no gaps in the stratigraphy, possibly suggesting continuous occupation (Figure 2). Furthermore, the shell ring consists of some 1,084 m^3, with eastern oyster (*Crassostrea virginica*) being the primary shell taxa represented. There are dozens of Late Archaic shell rings in the region, varying in size and height (see Thompson et al. 2024). Some are quite small, such as the Oemler Ring, which measures 23 m in diameter; others are large, such as Fig Island Ring 1, which measures 157 m in diameter (DePratter 1991; Russo 2002; Thompson et al. 2024). The rings also vary in height—from as little as 0.3 m, as seen with sites such as the Pockoy and Coosaw Shell Rings, to the 4.7 m tall Fig Island Ring 1 (Heide and Russo 2003; Russo 2002). Although on the smaller size in terms of shell volume, Hokfv-Mocvse is still consistent with other shell rings in the regions, such as the Ossabaw Shell Ring, which consists of 787 m^3 of shell.

Chronology and Bayesian Modeling of Hokfv-Mocvse

To date the ring securely, we analyzed a total of 19 AMS radiocarbon samples (see also Thompson et al. [2024] for details and how this site is situated in our larger study of shell-ring chronology and Supplemental Text 1 and 2 for details on our Radiocarbon AMS methods). Four samples come from pre-ring deposits, two samples come from the uppermost levels of one excavation, and the remaining 12 are from levels demonstrably associated with shell deposition as part of the ring itself (see Table 1 for uncalibrated dates, sample contexts, and $\delta^{13}C$). Sample selection included primarily deer (*Odocoileus virginianus*), bone, and charred hickory nut (*Carya* spp). For the pre-ring samples and the two most recent dates, we calibrated these dates in OxCal and report them here for context and discussion of the shell-ring dates. For the 12 associated with the shell deposits that comprise the ring, we constructed a series of Bayesian models in OxCal 4.4.4 (Bronk Ramsey 2009) using the IntCal20 ^{14}C calibration curve (Reimer et al. 2020). These models are based on our knowledge of the types of samples, their overall contexts, and stratigraphic ordering. Briefly, the construction of models based on a priori information allows for further constraints upon the date ranges than simple calibration alone (Hamilton and Krus 2018). Following Manning and Birch (2022), commands and functions in OxCal are presented as capitalized words for clarity (e.g., Date, Phase, etc.; see Manning and Birch 2022). For models to be considered significant in OxCal and indicate good agreement between dates and the stipulated parameters, the A_{model} agreement must exceed 60 (Bronk Ramsey 1995; Marquardt et al. 2020). For the dates associated with shell deposition, we constructed three different models as a sensitivity analysis. We report all three models for clarity and transparency of the Bayesian modeling process. All modeled dates are provided in italics, and the structure of the models can be observed from the bracketed structure of the probability distribution plots in addition to the runfiles and tables provided (see Supplemental Tables 1–4 and Supplemental Runfiles 1–3). Dates are reported in years BP and rounded to the nearest 10.

Model 1 places all the dates from the test units into one Phase that contains several ordered Sequences (Figure 3a). The order of the dates within each Sequence is the stratigraphic order from which the excavators recovered each sample. There was no observed obvious mixing of deposits in the excavations, except in the upper levels (levels 1 and 2) in test unit Op. D-1, which are not included in the model. Because the excavation units along the ring do not present a clear stratigraphic relationship to one another, these were placed in an overarching Phase, as stated above. The results of Model 1 (A_{model} 114) indicate good agreement between dates and the stipulated parameters, exceeding the 60 threshold. The model estimates a start date for the ring of *5060–4920 cal BP* (68.3 hpd) and an end date of *4840–4790 cal BP* (68.3 hpd), and a start date for the ring of *5090–4900 cal. BP* (95.4 hpd) and an end date of *4850–4730 cal. BP* (95.4 hpd).

Model 2 uses the exact same structure as Model 1; however, in this one, a General Outlier model is applied to all the dates (Figure 3b). The results of Model 2 indicate good agreement.

The A_{model} (116.6) for the model indicates good agreement as well—that is, exceeding the 60 threshold. The model estimates a start date for the ring of *5060–4890 cal BP* (68.3 hpd) and an end date of *4840–4790 cal BP* (68.3 hpd), and a start date for the ring of *5080–4880 cal BP* (95.4 hpd) and an end date of *4870–4740 cal BP* (95.4 hpd).

Model 3 is identical to Model 2 in structure, except that we apply a KDE command with a LnN(ln (125), ln (2) to summarize the probability distribution, which places emphasis on the earlier part of the distribution rather than later (i.e., <125 years); see earlier discussion (Figure 3c). The results of Model 3 (A_{model} 95.2) indicate good agreement, exceeding the 60 threshold. The model estimates a start date for the ring of *5040–4910 cal BP* (68.3 hpd) and an end date of *4840–4800 cal. BP* (68.3 hpd), and a start date for the ring of *5060–4880 cal BP* (95.4 hpd) and an end date of *4870–4770 cal BP* (95.4 hpd). Interval of occupation is estimated to be 80–230 years (68.3 hpd) and 20–270 years (95.3 hpd).

All three models exhibit almost identical summary results. Model 3 presents the most constrained date range of the date estimates from each of the three models; however, this estimate is only slightly more restricted than the others, within a decade or two on both its start and end boundaries. To

Table 1. Uncorrected AMS Dates and Context for Each Sample.

UGAMS#	Site No. with Internal Sample ID	Provenience	Material	δ^{13}C (‰)	δ^{15}N (‰)	^{14}C Years BP	±
UGAMS-59905	9CH160_F1_LVL2_S1	Op. F1, Level 2	*Odocoileus virginianus*	−21.91	6.03	4290	25
UGAMS-59906	9CH160_F1_LVL4_S1	Op. F1, Level 4	*Odocoileus virginianus*	−22.79	3.58	4300	25
UGAMS-59907	9CH160_F1_LVL4_S2	Op. F1, Level 4	hickory nut (*Carya* spp.)	−27.65	n/a	4430	25
UGAMS-59908	9CH160_F1_LVL5_S2	Op. F1, Level 5	hickory nut (*Carya* spp.)	−26.11	n/a	4410	25
UGAMS-59909	9CH160_C1_LVL3_S1	Op. C1, Level 3	hickory nut (*Carya* spp.)	−26.73	n/a	4370	25
UGAMS-59910	9CH160_C1_LVL3_S2	Op. C1, Level 3	*Odocoileus virginianus*	−22.51	4.47	4390	25
UGAMS-59911	9CH160_C1_LVL4_S1	Op. C1, Level 4	hickory nut (*Carya* spp.)	−25.24	n/a	4420	25
UGAMS-59912	9CH160_C1_LVL5_S1	Op. C1, Level 5	hickory nut (*Carya* spp.)	−27.30	n/a	4680	25
UGAMS-59913	9CH160_C1_LVL7_S1	Op. C1, Level 7	hickory nut (*Carya* spp.)	−26.43	n/a	5760	25
UGAMS-59914	9CH160_D1_LVL2_S1	Op. D1, Level 2	hickory nut (*Carya* spp.)	−28.06	n/a	1810	20
UGAMS-59915	9CH160_D1_LVL2_S2	Op. D1, Level 2	*Odocoileus virginianus*	−22.36	n/a	3980	25
UGAMS-59916	9CH160_D1_LVL3_S1	Op. D1, Level 3	*Odocoileus virginianus*	−22.32	5.52	4330	25
UGAMS-59917	9CH160_D1_LVL4_S1	Op. D1, Level 4	*Odocoileus virginianus*	−22.35	5.08	4390	25
UGAMS-59918	9CH160_D1_LVL5_S1	Op. D1, Level 5	hickory nut (*Carya* spp.)	−25.71	n/a	5760	30
UGAMS-59919	9CH160_E1_LVL2_S1	Op. E1, Level 2	hickory nut (*Carya* spp.)	−26.56	n/a	4420	25
UGAMS-59920	9CH160_E1_LVL2_S2	Op. E1, Level 2	*Odocoileus virginianus*	−22.13	4.61	4190	25
UGAMS-59921	9CH160_E1_LVL3_S1	Op. E1, Level 3	hickory nut (*Carya* spp.)	−25.40	n/a	4390	25
UGAMS-59922	9CH160_E1_LVL4_S1	Op. E1, Level 4	hickory nut (*Carya* spp.)	−27.39	n/a	4410	20
UGAMS-59923	9CH160_E1_LVL5_S1	Op. E1, Level 5	hickory nut (*Carya* spp.)	−26.38	n/a	5720	25

summarize, the KDE distribution for Model 3 has a median date of 4890 BP with a range of 4940–4830 (68%) and 5020–4810 (95%). Therefore, we feel that we have confidently dated the buildup of ring deposits and the duration of the village occupation. That said, when we compare the estimated occupation of the ring to the pre-ring dates from the excavations, the latter are considerably older. The oldest ones are over 1,500 years older than the ring itself. The implications of this are not exactly clear given that (1) all these dates were run on carbonized hickory nuts and (2) there are other dated shell-ring sites that present similar results, suggesting much earlier occupation of the islands or perhaps forest fires in hickory grove stands. None of these dates have associated artifacts or shell deposits. Therefore, we report them to provide a complete description and accounting of all radiocarbon dates at the site. The two younger dates may be associated with reoccupation of the site, given that we did recover a few ceramic sherds from the Late Archaic period, as well as other sherds from much more recent time frames.

Material Culture at Hokfv-Mocvse

No ceramics were uncovered beyond the first few centimeters of the excavation units. The only cultural materials encountered at the ring that were associated with shell deposits were four quartz projectile points (hereafter referred to as PPKs) similar to Middle to Late Archaic Morrow Mountain and other early Late Archaic stemmed PPKs found farther inland (Figure 4). One of these was found on the surface on top of the ring, and another one from a wall scrape; however, the other two were found in situ in the excavation unit levels dating to *4905–4860* and *4985–4870 cal BP* (68.3 hpd). In Georgia, one of the most interesting technological traditions of the Middle Archaic and early Late Archaic in the northern half of the state is the use of quartz as a raw material for tool stone. Although early peoples had also used quartz to produce projectile points, the sheer number of projectile points produced from it in the Middle Archaic indicates a preference for the use of this material (Caldwell 1954; Sassaman and Anderson 1994; Sassaman et al. 1988). Morrow Mountain Points were primarily in use between 7500 and 6500 BP in parts of northern Georgia, Alabama, and Tennessee; however, for the region and parts of South Carolina, people continued to use Morrow Mountain–like points as late as 4700 BP (see Anderson and Joseph 1988:154–181; Ledbetter 1995:54–58; Wood et al. 1986:286), which is consistent with the findings and modeled dates at the Hokfv-Mocvse shell ring.

Mollusk Shell Geochemistry

Sclerochronological oxygen isotope analysis ($\delta^{18}O_{carbonate}$) of mollusk shells from archaeological contexts is widely used to examine shellfish harvesting practices and the occupational history of cultural

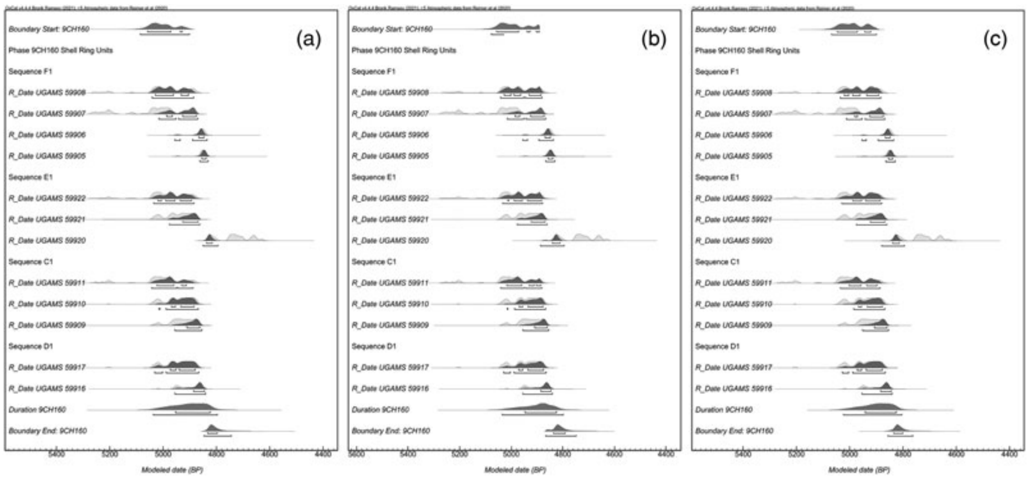

Figure 3. AMS Probability distributions for (a) Model 1, (b) Model 2, and (c) Model 3.

Figure 4. Quartz projective points found at Hokfv-Mocvse.

sites in coastal areas, specifically answering questions regarding sedentism and seasonal mobility as indicated by whether the sites were occupied year round or only during specific seasons (see Andrus and Crowe 2000; Jones et al. 1989, 2004; Thompson and Andrus 2011; Walker and Surge 2006). Oxygen isotopes from ambient water ($\delta^{18}O_{water}$) are incorporated into mollusk shells during growth and development. Moreover, $\delta^{18}O_{water}$ covaries with salinity values, with salinity values decreasing the farther away from open ocean and the closer to continental freshwater sources (Andrus 2011; Coplen and Kendall 2000; Elliot et al. 2003; Jones et al. 1989; Kirby et al. 1998). Therefore, $\delta^{18}O_{carbonate}$ values in shells are correlated with both the temperature and salinity values of water in which they live and grow. Sclerochronological $\delta^{18}O_{carbonate}$ sampling of mollusk shells reveals seasonal fluctuations in water temperature, and the $\delta^{18}O_{carbonate}$ at the growing edge of the shell can reveal the season in which the mollusk was harvested (Garland and Thompson 2023). Year-round occupation is evidenced by a sample of shells that represent collection during multiple seasons throughout the year. Previous isotope work at other shell villages, such as the Sapelo Shell Rings, has shown year-round occupation of such sites. Estimated salinity from summer $\delta^{18}O$ values is used to examine habitat use (see Andrus and Thompson 2012; Garland and Thompson 2023).

In this study, we incrementally sampled 13 oysters and two clam shells for oxygen ($\delta^{18}O$) isotope analysis. These values are used to estimate season of collection and range of habitats used based on estimated summer salinity values. The samples were selected from multiple provenances at the Hokfv-Mocvse shell ring. The isotopic methods used in the study are outlined in full detail in Garland et alia (2022) and Andrus and Thompson (2012). Each shell was carefully examined for any evidence of fouling and epibiont activity, such as sponge boring into the interior of the shell. Equations 1 and 2 were first used to estimate summer $\delta^{18}O_{water}$ values for each clam and oyster, respectively. Salinity (psu) was then estimated from shell $\delta^{18}O_{water}$ values using a modern salinity-$\delta^{18}O_{water}$ relationship established for the local environments around Ossabaw Island. More specifically, 12 modern water samples were collected across the estuaries surrounding Ossabaw Island and analyzed for salinity and $\delta^{18}O_{water}$ (Figure 5a and Supplemental Table 4). Equation 3 represents a linear regression for the relationship between salinity and $\delta^{18}O_{water}$ in the modern water samples (Figure 5b). This regression was used to estimate salinity for each shell.

Equations

Equation 1. Summer $\delta^{18}O_{water}$ value in clams: Water temperature (°C) $= 20 - 4.42(\delta^{18}O_{argonite} - x)$; whereas 31°C is assumed to be the threshold of summer growth cessation for clams [31]; $\delta^{18}O_{argonite}$ is the most negative value in each clam's profile; and $x = \delta^{18}O_{water}$.

Equation 2. Summer $\delta^{18}O_{water}$ value in oysters: Water temperature (°C) $= 16.5 - 4.3(\delta^{18}O_{calcite} - x) + 0.14(\delta^{18}O_{calcite} - x)^2$; whereas 28°C is assumed to be the threshold of summer growth cessation for oysters; $\delta^{18}O_{calcite}$ is the most negative value in each oyster's profile, and $x = \delta^{18}O_{water}$. Additionally, a 0.2‰ correction was applied to convert VPDB to VSMOW.

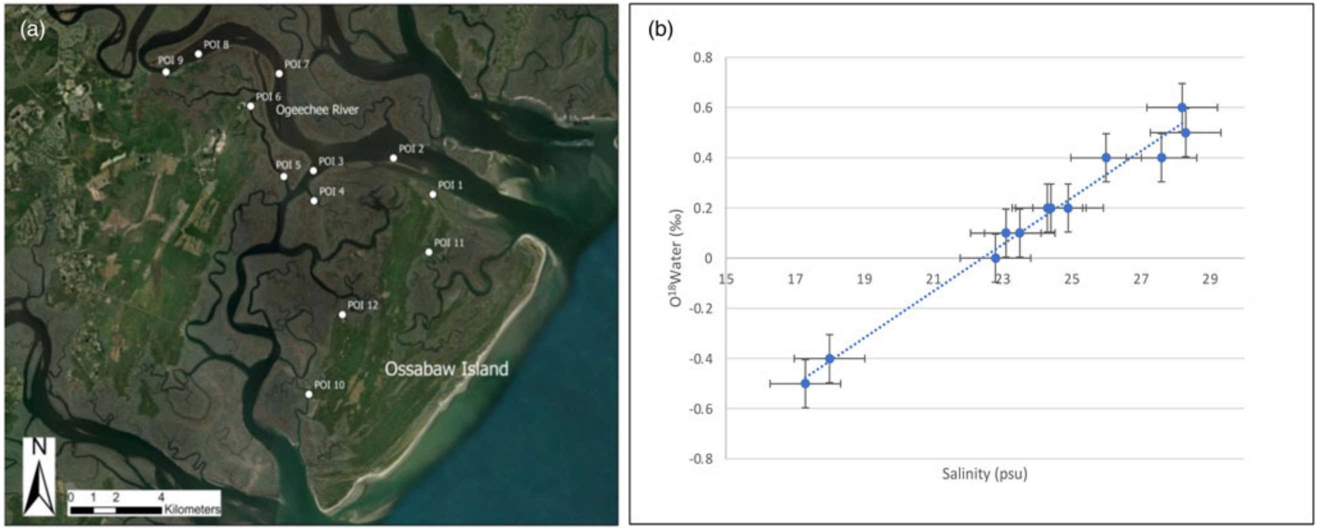

Figure 5. (a) Map showing the location of modern water samples collected to create local oxygen isotope ($\delta^{18}O_{water)}$ and salinity (ppt) gradient for the estuaries behind Ossabaw Island; (b) regression formula for relationship between $\delta^{18}O_{water}$ and salinity. Salinity = 0.093($\delta^{18}O_{water}$) − 2.1.

Equation 3. Estimated salinity: $y = 0.093(\delta^{18}O_{water}) - 2.1$; whereas $\delta^{18}O_{water}$ is calculated by equation 1 or 2, and y = estimated salinity (psu) (Garland and Thompson 2023.)

Shell $\delta^{18}O_{carbonate}$ values ranged from −3.19‰ to 2.36‰, with a mean of −0.99‰. However, these values varied by mollusk species. Oysters had mean $\delta^{18}O_{carbonate}$ of −1.2‰ and clams 0.21‰. Oysters and clams were significantly different regarding mean $\delta^{18}O_{carbonate}$ values ($p < 0.01$). All seasons of collection were represented in the mollusk shells sampled, although the majority were harvested in the winter. More specifically, seven oysters were harvested in the winter, two in the summer, three in the fall, and one in the spring (Figure 6; Table 2). Both clam samples were harvested in the summer. All oyster and clam shells fell within the expected tolerance range for salinity levels (5 and 37 psu for oysters; 17 and 37 psu for clams; see Bartol et al. 1999; Kraeuter and Castagna 2001). Estimated salinity (psu) varied, ranging from 21 to 36 (psu), with an average of 28 (psu). Clams had significantly higher estimated salinity levels compared to oysters ($p < 0.01$). However, our sample only included two clams, so these differences may not be meaningful. These salinity values demonstrate that Ancestral Muskogean communities were exploiting shellfish resources in an array of habitats. More specifically, the modern water samples facilitated the development of a simple spatial model of salinity values for the area around Ossabaw Island, which—though not accounting for the full complexity of the dynamic processes that impact fluctuating salinity on a seasonal basis on the Georgia coast (Di Iorio and Castelao 2013; Kendall and Blanton 1981)—nevertheless explains most of the salinity variation in the area. This spatial modeling of salinity indicates that Ancestral Muskogean communities were likely harvesting mollusks in polyhaline to euhaline zones that were most probably located in the back barrier salt marshes, the barrier islands, and near the open sea, rather than potential sources in mesohaline zones farther inland. Importantly, this zone of optimal exploitation would have likely been located farther to the southeast under lower sea-level conditions (discussed in further detail below).

Oyster Paleobiology

Much like oxygen isotope values, changes in oyster shell size across time can also be used to examine environmental change and shellfish harvesting practices in the region (see Jenkins 2017; Jenkins and Gallivan 2020; Lulewicz et al. 2017, 2018; Rick et al. 2016; Thompson et al. 2020). Oyster shape and size are influenced by age, human pressures, sub- versus intertidal habitats, and environmental variability, with healthier reefs, climatic stability, and sustainable harvesting practices leading to larger oyster shell size (see Bartol et al. 1999; Kennedy et al. 1996; Lawrence 1988). We measured oyster shells from Hokfv-Mocvse ($n = 145$) and the Late Woodland / Early Mississippian component of Bluff Field ($n = 498$) and compared them to published oyster measurement data from the Late Archaic Ossabaw Shell Ring ($n = 1{,}829$) and Mississippian period site of Finley's Pond ($n = 1{,}430$), both located on Ossabaw Island (Lulewicz et al. 2017). Comparing oyster shell size between these sites provided a

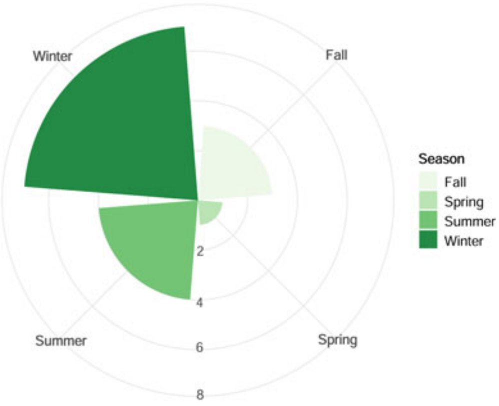

Figure 6. Graph showing the frequency of shells representative of each season of collection. (Color online)

Table 2. Estimated Water Oxygen Values ($\delta^{18}O_{water}$), Salinity (ppt), and Season of Collection for Each Shell Sampled from Hokfv-Mocvse.

Species	Sample ID	$\delta^{18}O_{carbonate}$	$\delta^{18}O_{water}$	Salinity (ppt)	Season
C. virginica	9CH160-D1-LVL4-S1	−2.5	−0.1	26	Winter
C. virginica	9CH160-D1-LVL4-S2	−2.8	−0.3	24	Summer
C. virginica	9CH160-D1-LVL4-S4	−2.2	0.3	28	Winter
C. virginica	9CH160-F1-LVL4-S1	−3.2	−0.7	21	Winter
C. virginica	9CH160-D1-LVL5-S1	−1.8	0.6	31	Fall
C. virginica	9CH160-E1-LVL2-S1	−2.5	−0.1	26	Fall
C. virginica	9CH160-E1-LVL2-S2	−2.7	−0.2	25	Winter
C. virginica	9CH160-D1-LVL2-S1	−1.9	0.6	31	Winter
C. virginica	9CH160-D1-LVL3-S1	−2.4	0.1	27	Summer
C. virginica	9CH160-D1-LVL3-S2	−3.0	−0.5	22	Winter
C. virginica	9CH160-D1-LVL3-S3	−2.3	0.2	28	Spring
C. virginica	9CH160-C1-LVL2-S1	−1.2	1.3	36	Winter
C. virginica	9CH160-C4-LVL2-S1	−2.1	0.4	29	Fall
Mercenaria	9CH160-E1-CLAMS1	−1.6	0.9	33	Summer
Mercenaria	9CH160-E1-CLAMS2	−1.4	1.1	34	Summer

temporal pattern of oyster shell size on Ossabaw Island from the Late Archaic through Mississippian periods. Following previously published methods (Lulewicz et al. 2017), we measured left valve length (LVL) and left valve height (LVH) measurements (mm) using digital, handheld calipers. Shells were randomly sampled from multiple proveniences at Hokfv-Mocvse and Bluff Field, and these comprised only completely intact shells with both LVL and LVH dimensions present. This sample selection strategy was consistent with the previously published data from Finley's Pond and the Ossabaw Shell Ring (Lulewicz et al. 2017).

Variations in shell length and height for each site are shown in Figures 7a and 7b, and all raw oyster measurements are in Table 3. Mean oyster length and height are comparable across sites, aside from oysters collected from Ossabaw Shell Ring. A nonparametric Kruskal-Wallis test suggests that shells from the four sites are significantly different for both mean oyster height and mean oyster length (height: $p < 0.01$; length: $p < 0.01$). However, a post hoc pairwise Mann-Whitney U test shows that only oysters from the Ossabaw Shell Ring are statistically larger than the other sites regarding both height and length (at $p < 0.01$). Shells from Hokfv-Mocvse, Bluff Field, and Finley's Pond are statistically indistinguishable for both oyster height and length ($p < 0.01$).

Previous research by Lulewicz and colleagues (2017) suggests a temporal decline in oyster shell height on Ossabaw Island from the Late Archaic (4500–3000 BP) through Mississippian periods (1000–370 BP). More specifically, their data shows that oyster shells from the Late Archaic Ossabaw Shell Ring were significantly larger than shells from the Mississippian period Finley's Pond site, which the authors argue may suggest harvesting pressures that impacted the health and productivity of local oyster reefs. This, however, may be a more localized effect given that other multisited studies demonstrate an overall increase in oyster shell size across time along the Georgia coast, indicating that the Indigenous communities in the region were sustainably harvesting mollusk shells for millennia (Thompson et al. 2020). The new oyster paleobiology data from Hokfv-Mocvse supports an interpretation that Ancestral Muskogean communities on Ossabaw Island were sustainably harvesting oyster shells, and that the larger shells from the Ossabaw Shell Ring were outliers, possibly reflecting short-term environmental change or other factors. In fact, they were the largest

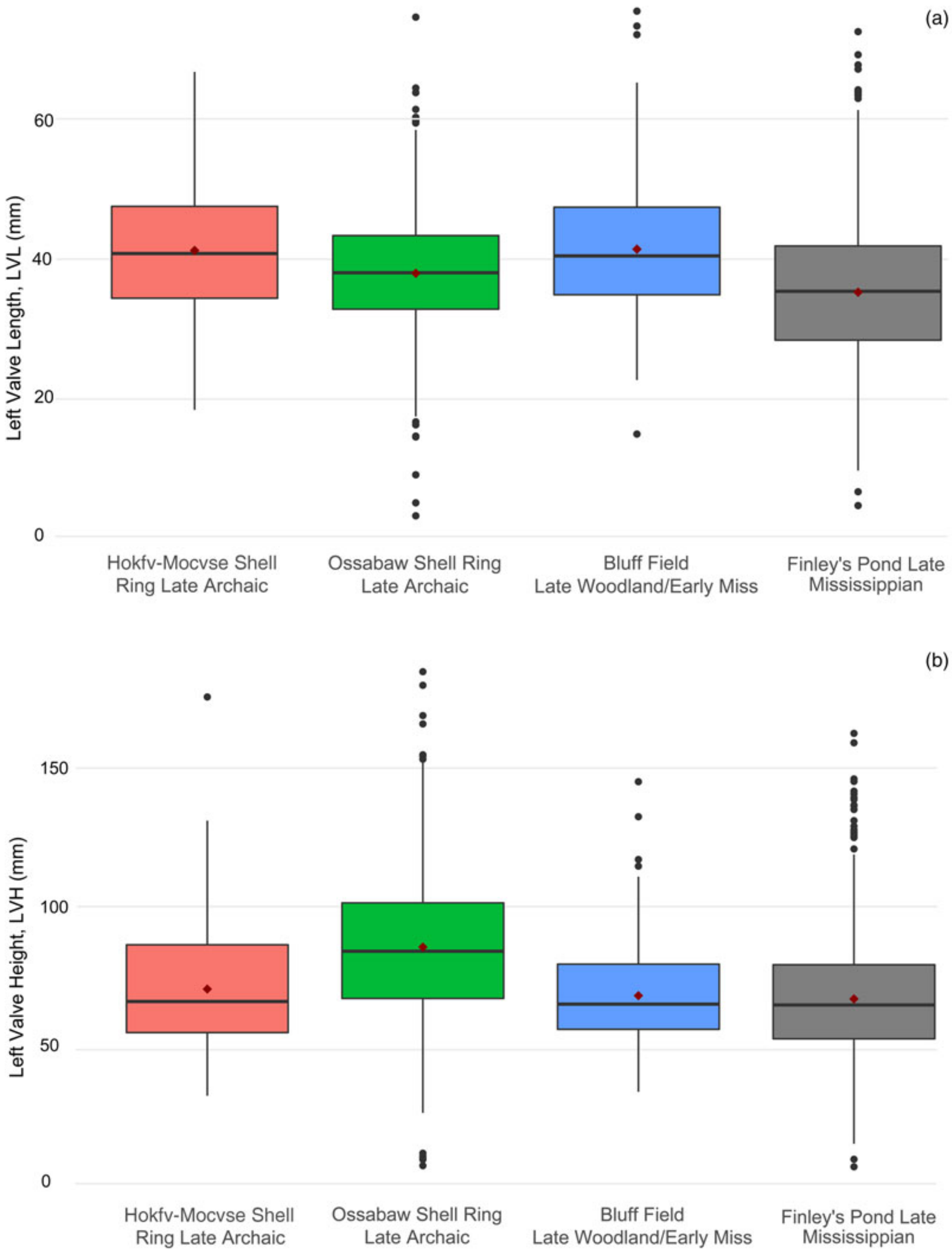

Figure 7. Graph comparing the range and mean of (a) shell height (LVH) and (b) shell length (LVL) between Hokfv-Mocvse, Ossabaw Shell Ring, Bluff Field, and Finley’s Pond.

shells in the entire study by Thompson et alia (2020), which examined shell size across 15 different archaeological sites on the Georgia and South Carolina coasts. The larger shells from the Ossabaw Shell Ring are outliers, and more research needs to be done to determine possible reasons, such as short-term environmental change or differences in habitats used by communities that inhabited the shell rings.

Table 3. Descriptive Statistics for Shell Measurements.

Sites	Time Period	LVL Min.	LVL Max.	LVL Mean	LVH Min.	LVH Max.	LVH Mean
Bluff Field SR	Early Late Archaic	18.0	67.0	41.2	32.0	175.5	70.4
Ossabaw SR	Late Late Archaic	2.7	74.9	37.8	6.7	184.6	85.5
Bluff Field	Late Woodland / Early Mississippian	14.5	75.8	41.3	33.4	145.0	70.0
Finley's Pond	Early Mississippian	4.2	72.8	35.1	6.37	162.4	66.8

Sea-Level Back-Forecast Model

As previously mentioned, tidal marsh systems along the Georgia coast have traditionally been thought to have formed in the context of rising sea level some 4,500 years ago. However, recent research suggests that marshes in the region formed under stable, slow rates of sea-level rise between 4,000 and 6,000 years ago (see Braswell et al. 2020:1). Data from our research suggest that the conditions were in place for the presence of marsh habitats and oyster reefs in the region by at least 5,000 years ago. Although reconstructing ancient coastal conditions is a challenging task that requires consideration of the complex interface between changing geomorphology and the physics of the interaction between continents and the ocean (Borreggine 2023), even simple models that account for local sea level conditions and tidal variation can shed light on the range of potential subsistence exploitation of the ancient environment.

At approximately 5,000 years BP, global sea level would have been between 1.5 m and 4.5 m below present mean sea level, based on various multiproxy reconstructions (see Braswell et al. 2020; Colquhoun and Brooks 1986; Gayes et al. 1992; for the South Atlantic Coast, see Hawkes et al. 2016). To reflect this variation, we developed a simple model, based on bathtub-style modeling but nuanced by accounting for local tidal variation along the Georgia coast based on tidal averages as measured by the National Oceanic and Atmospheric Administration (NOAA) water-level stations. We applied this model to three different sea-level scenarios—1.5 m, 3 m, and 4 m below present—in order to visualize the range of potential ancient sea-level conditions at Ossabaw Island and the surrounding estuaries and to compare these models to historically known oyster beds in the region (Figure 8). These models show that tidal channels behind Ossabaw Island were likely present even at a sea level as low as 4 m below present. Moreover, as shown in Figure 7, most historic oyster beds are situated in areas that were suitable for the establishment of oyster beds as early as 5,000 years ago, even at a modeled sea level of 4 mbp, though optimal salinity zones would have likely extended even farther to the southeast with lower sea level. This modeling helps corroborate the archaeological evidence presented here for the use of certain tidal channels and illustrates the viability of exploitation of known oyster resources as early as 5000 BP.

Discussion and Conclusion

Insight into the timing and nature of the initial settlement of Georgia's coastal barrier islands by Ancestral Muskogean communities has significant implications for our understanding of both Native American history and environmental change in the region. We know that the development of oyster fisheries and the shift to a reliance on marine resources led to the emergence of new socio-ecological systems along the Georgia coast that persisted for centuries, including circular shell-ring villages and institutions that fostered cooperation within and between villages, especially regarding the use of coastal fisheries (see Garland and Thompson 2023; Thompson and Turck 2009; Turck and Thompson 2016). Moreover, it has been shown that these fisheries, and others like them across the globe, have been sustainably managed for thousands of years by Indigenous communities (see Garland et al. 2022; Jenkins 2017; Jenkins and Gallivan 2020; Lepofsky et al. 2015; Reeder-Myers et al. 2022; Rick 2023; Rick et al. 2016; Thompson et al. 2020). The abandonment of shell-ring villages in the region has been well documented to occur circa 3800 BP (see Garland et al. 2022; Sanger 2010;

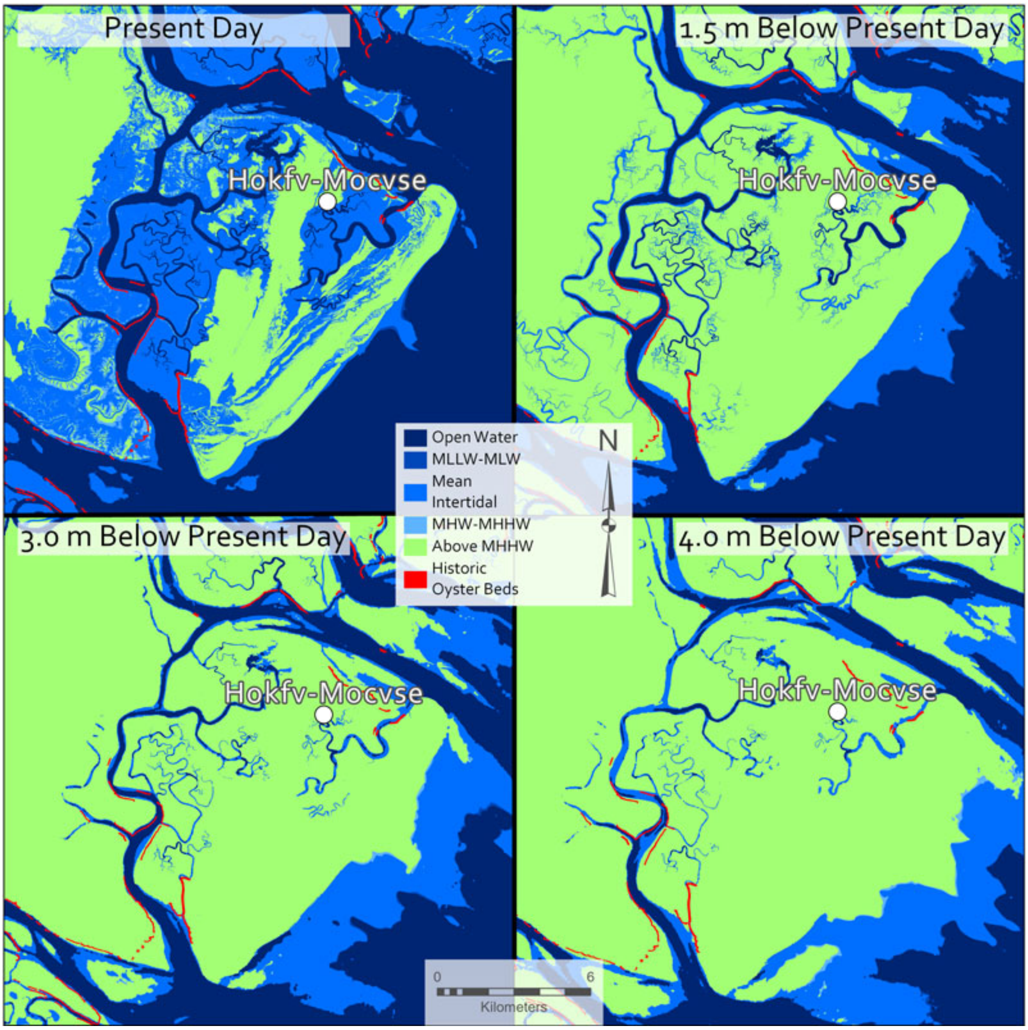

Figure 8. Map showing sea-level models and location of historic oyster beds at current sea levels, 1.5 mbp, 3 mbp, and 4 mbp. (Color online)

Turck and Thompson 2016); however, less well known is the timing and nature of human settlement, especially in large year-round villages on the South Atlantic coast and the associated socioecological transformations that accompanied this shift. Here, we show evidence for the earliest known oyster fisheries and year-round village life in the region. More specifically, based on material culture and Bayesian radiocarbon models, the preceramic Hokfv-Mocvse shell ring is the earliest known shell ring on the South Atlantic coast, predating all other known shell rings in Georgia by at least 400 years, and it is likely the earliest securely dated known ring in the US Southeast in general. Our current dates make it older than Horr's Island, whose earliest dates come from the mound and not the ring, and Oxeye Ring in northeast Florida (Russo 2006:Table 1). Arguably, both Oxeye and Horr's Island are imprecisely dated given that the primary materials used in the dating were marine species that present large ranges that even when calibrated using the most up-to-date curve (i.e., Marine20; Heaton et al. 2020; local Delta R values −93±).

Like prior studies of later shell rings, our new stable oxygen isotope data suggests that Ancestral Muskogean communities lived at Hokfv-Mocvse year-round, as indicated by shells that were harvested from all seasons. One argument against this is that inhabitats aggregated at the site during different seasons throughout the year rather than living there year-round. However, the latter is unlikely given that most studies on mobile hunter-gatherer societies show that they aggregated during times when resources are the most productive (Ingold 1999). Finally, there are few if any identified nonring habitation sites that are contemporaneous with the rings (see Turck and Thompson 2016). Similar to other studies, the isotope data show a preferential harvesting of oyster in the winter and clam in the summer (see Andrus and Thompson 2012; Garland and Thompson 2023). We are still unclear on the meaning of this trend; however, it may relate to coastal inhabitants switching to oysters during the winter months when other terrestrial resources are not as productive or available. Regardless, these data may point to the emergence of early sedentary villages centuries earlier than previously thought and predating the invention of ceramics in the region. Other scholars have made arguments for preceramic shell rings. Specifically, Russo (2006) makes the case that Oxeye represents a prepottery shell ring, although evidence for this definitively being a prepottery ring is lacking. Excavators recovered small sherds: however, Russo interprets these as being from disturbed contexts or from the surface of the ring that was inundated by the marsh during sea-level rise (Russo 2006:97). What is clear is that there are baked clay objects (i.e., cooking balls) in abundance and therefore ceramic technologies are present at Oxeye (Russo 2006:97).

Also important regarding our work at Hokfv-Mocvse is that estimated salinity values from the oyster shells suggest one possible interpretation that Ancestral Muskogean communities were targeting a wide range of habitats, possibly as a mechanism to sustain healthy oyster reefs and prevent overharvesting (see Andrus and Thompson 2012). Oysters were common-pool resources during the Late Archaic period in southeastern North America given that they were intensively harvested and have the potential to be overharvested, even under small-scaled harvesting pressures (Acheson 2015; Thompson 2023). It is difficult to know how many people inhabited Hokfv-Mocvse. Though the Sapelo Shell Ring Complex much larger, Thompson (2006) argues that as many as 125 people inhabited it. Ethnographic studies, however, have shown that as few as four to five people harvesting some 27 m^2 of mollusks shells per hour has the potential of devastating a mollusk population in only a few seasons (Anderson 1981:118). We argue that the circular layout of villages and the targeting of a wide range of oyster reefs points to the emergence of institutions to limit overharvesting and promote oyster reef health. Others have made similar arguments. For example, Lulewicz and colleagues (2018) and Garland and Thompson (2023) demonstrate a wide range in estimated salinity values in shells from shell midden sites on the Gulf coast of Florida and the Georgia coast, respectively, which they attribute to practices aimed at protecting the health of oyster reefs. Sustainable shellfish harvesting practices are corroborated by data on shell size as well. Shell-size data from Hokfv-Mocvse and later-period sites further support an interpretation that Indigenous communities on Ossabaw Island were sustainably harvesting oysters for thousands of years (Thompson et al. 2020). Given the date of Hokfv-Mocvse, the cultural site may represent the emergence of institutions that persisted across time along the South Atlantic coast.

Sea-level back-forecasting models indicate that estuaries and marshes surrounding Ossabaw Island were formed by 5,000 years ago, and that most historic oyster reefs are situated in areas that could have had productive oyster reefs at the time the shell ring was inhabited, even if the sea level was 4 mbp. Clearly, oyster reefs were present, given that communities living at Hokfv-Mocvse were harvesting oysters in addition to terrestrial resources—such as deer—which were the most common taxa encountered in the excavations. Interestingly, however, we recovered very few fish species in the excavations. Exactly what this means is uncertain because fish remains, if deposited off ring, would not preserve well in the acidic soils of the barrier islands. It may also be that early adaptation to the estuarine and marsh ecosystems forming around 5,000 years ago did not yet include a heavy emphasis on finfishes as we see at later shell-ring villages. Although the formation of tidal marshes and estuarine resources may have been a draw for early populations to settle on the islands, it is possible that these locations had vast hickory groves for thousands of years prior to the establishment of the earliest ringed villages, given the early dates on charred hickory nuts dated at Hokfv-Mocvse. However, more work and further study is needed to resolve if these dates at the site really indicate human presence at that time or some other process (e.g., forest fires).

In conclusion, we argue that the shell oxygen isotope and paleobiology data, and radiocarbon chronology, along with the circular shell arrangement at Hokfv-Mocvse, indicate that the establishment of shell-ring villages occurred sometime around 5,000 years ago. This new work confirms that for the Atlantic Coast, groups inhabited shell rings first in the absence of both pottery and intensive use of finfish. The assemblage from Hokfv-Mocvse looks like other inland late Middle and early Late Archaic sites of interior Georgia, which may have been the source populations for these early villages. More work into the earliest periods of settlement on these islands is needed to explore this pattern further. Additionally, our work at Hokfv-Mocvse provides a high-resolution start date for the creation of shell rings, some 500 to 400 years prior to the creation of pottery. Therefore, the shift to settled villages was not predicated on the invention of new technologies, nor does it seem that the development of estuarine resources was a pull toward the coast. What is clear is that some 500 years or so after the settlement of Hokfv-Mocvse, shell rings became ubiquitous along the Georgia, South Carolina, and northeast Florida coasts, suggesting the widespread adoption of village life during this time.

The establishment of villages marks a visible archaeological shift toward settling down in the landscape and occupying island ecosystems on a more permanent basis and in larger numbers than ever before along the South Atlantic Coast. As Feinman and Neizel (2023:11) point out, the shift to sedentary communities is one that took variable paths, with “zig-zags” and “fits and starts.” Is this what is happening here? Obviously, the gap between Hokfv-Mocvse and the later shell rings of the region may represent one of these fits and starts, or it may be that other shell rings exist and are yet to be found. Regardless, this shift in lifeways ushered in a host of changes both in technology (e.g., the invention of pottery) and in broader complex social relationships surrounding the use rights of shellfish, as observed in our previous studies. Exactly how shell-ring villages came to be so prevalent across the Late Archaic landscape deserves further investigation and represents, like other areas of first villages of the world (e.g., the Levant, Mesoamerica, etc.), a place that can help us understand one of the most important transitions in human history.

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Supplemental Text 1. Radiocarbon AMS Methods.
Supplemental Text 2. References.
Supplemental Table 1. Results of AMS Model 1.
Supplemental Table 2. Results of AMS Model 2.
Supplemental Table 3. Results of AMS Model 3.
Supplemental Table 4. Raw Oxygen Isotope ($\delta^{18}O_{water}$) and Salinity (ppt) Data from Modern Water Sample Collected across the Estuaries Surrounding Ossabaw Island.
Supplemental Runfile 1. 9CH160R1M1.
Supplemental Runfile 2. 9CH160R1M2.
Supplemental Runfile 3. 9CH160R1M3.

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