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Collective action and shellfish harvesting practices among Late Archaic villagers of the South Atlantic Bight

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ABSTRACT

Indigenous coastal communities across the globe sustainably harvested oysters and other shellfish species for millennia. European colonialism and the emergence of market-based institutions, however, lead to the eventual demise of many oyster reefs and fisheries beginning in the late 1800 s. Circular shell rings situated on Georgia's South Atlantic coast are the preserved remnants of Native American village communities during the Late Archaic (5000–3000 cal. BP). Mollusk shells from these archaeological contexts hold chemical clues into past human-environmental interactions and thus give insight into Indigenous histories and sustainable shellfish harvesting practices. In this paper, we interpret shellfish geochemistry data (oxygen isotopes, $\delta^{18}O$) from the Sapelo Island Shell Ring Complex within a theoretical framework of cooperation and collective action to understand the ways in which Ancestral Muskogean people of Sapelo Island, Georgia, effectively managed and sustained oyster reefs and other coastal fisheries during the Late Archaic. More specifically, $\delta^{18}O$ values from 18 oysters and 57 clams were used to determine season of harvest and to estimate salinity values of the habitats from which the shells were harvested. Results demonstrate considerable variation in estimated salinity values and some statistically significant differences in $\delta^{18}O$ and salinity values between shells harvested in different seasons. This indicates that the sedentary villagers who lived at the Sapelo Shell Ring Complex were moving around seasonally and using an array of habitats. We argue that this suggests the presence of social institutions or rules that governed the use of coastal estuaries so that mollusks were not overexploited.

1. Introduction

Archaeological and ethnohistorical data indicate that many Indigenous communities in coastal environments across the globe sustainably harvested oysters and other mollusks species for thousands of years (e.g., Jenkins and Gallivan, 2020; Reeder-Myers et al., 2020, 2022; Rick et al., 2016; Waselkov, 1987; Thompson et al., 2020). In fact, oyster reefs on the Atlantic and Gulf Coasts of Southeastern North America remained relatively stable for millennia despite large-scale harvesting practices (Reeder-Myers et al., 2022; Thompson et al., 2020). This is evidenced by relatively stable patterns of, or even increases in, oyster sizes across time, as well as the persistence of large shell mounds and middens found in the region, such as Mound Key, a massive shell mound located on Florida's Gulf Coast that is approximately 10 m high and consists of some 700,000 m^3 of marine shell, mainly oyster (Lulewicz et al., 2017; Milanich, 1998; Reed-Myers et al., 2022; Rick et al., 2016; Thompson et al., 2018, 2020). European colonialism and the emergence of market-based institutions and capitalist commercial fisheries, however, lead to the overexploitation and eventual demise of many oyster reefs in the region beginning in the late 1800 s (Reeder-Myers et al., 2022; Drake, 1891). Despite the contrast between Indigenous and Colonial harvesting of these fisheries, we still have much to learn about the mechanisms, structures, and practices behind the sustainability of Indigenous fishing practices. As Reeder-Myers and colleagues (2022:1) argue, the creation of effective strategies to manage contemporary oyster reefs and coastal fisheries must incorporate Indigenous histories and collaborations. This reflects a broader movement to work with and for Indigenous partners and to incorporate Indigenous knowledge into research on climate change, both of which archaeology can play a role.

Circular shell rings are the material remains of Late Archaic (5000–3000 cal. BP) villages communities that developed along the Georgia coast in the traditional homelands of Ancestral Muskogean people. Here, we use the term "Ancestral Muskogean" to refer collectively to groups of Native Americans that spoke dialects of the

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Muskogean language (Thompson et al., 2022; Martin, 2004). The Sapelo Shell Ring Complex on Sapelo Island, Georgia, provides a window into the lifeways, history, and cultures of Indigenous communities that inhabited the region starting over 4500 years ago (Fig. 1). Mollusk shells from these archaeological contexts, specifically, hold chemical clues into human-environmental entanglements that lend insight into sustainable shellfish harvesting practices of the Ancestral Muskogean people and other Indigenous communities (Garland et al., 2022; Lulewicz et al., 2018; Thompson and Andrus, 2011, 2013). Recent research by Garland et al. (2022) suggests that the three Sapelo shell rings were occupied at different times between 4290 and 3845 cal. BP, with some generational overlap. Ring II was the first shell ring village to be constructed and the last of the shell rings, Ring III, was abandoned ca. 3845 cal. BP. The authors also examine multiple proxies (including the oxygen isotope data used here) of environmental instability linked with the rise and abandonment of the Sapelo Shell Rings. They argue that aggregation and collective action at shell ring villages provided a way for Indigenous communities to successfully and sustainably manage fisheries experiencing environmental perturbations observable at decadal and generational time scales. In this publication, Garland and colleagues show that continued environmental instability during the time in which the rings were occupied eventually led to the collapse in fisheries and the cessation of shell ring construction around 3845 cal. BP. However, their focus is primarily on the environmental components of shell ring villages rather than what mollusk geochemistry data can tell us about Indigenous shellfish harvesting practices.

In this paper, we interpret mollusk geochemistry data (oxygen isotope, $\delta^{18}O$) within a theoretical framework of cooperation and collective action to understand the ways in which Ancestral Muskogean people effectively managed and sustained oyster reefs and other coastal fisheries surrounding Sapelo Island, despite shorter periods of local environmental instability that impacted the surrounding coastal estuaries (see Garland et al., 2022; Thompson et al., 2020). Collective action is an interpretive framework used to understand how people manage problems, such as aggrandizing and individualizing behaviors, that emerge when people come together and cooperate to complete tasks and activities (Blanton and Fargher, 2016:3). This is especially the case for activities concerning the production and use of resources, whether

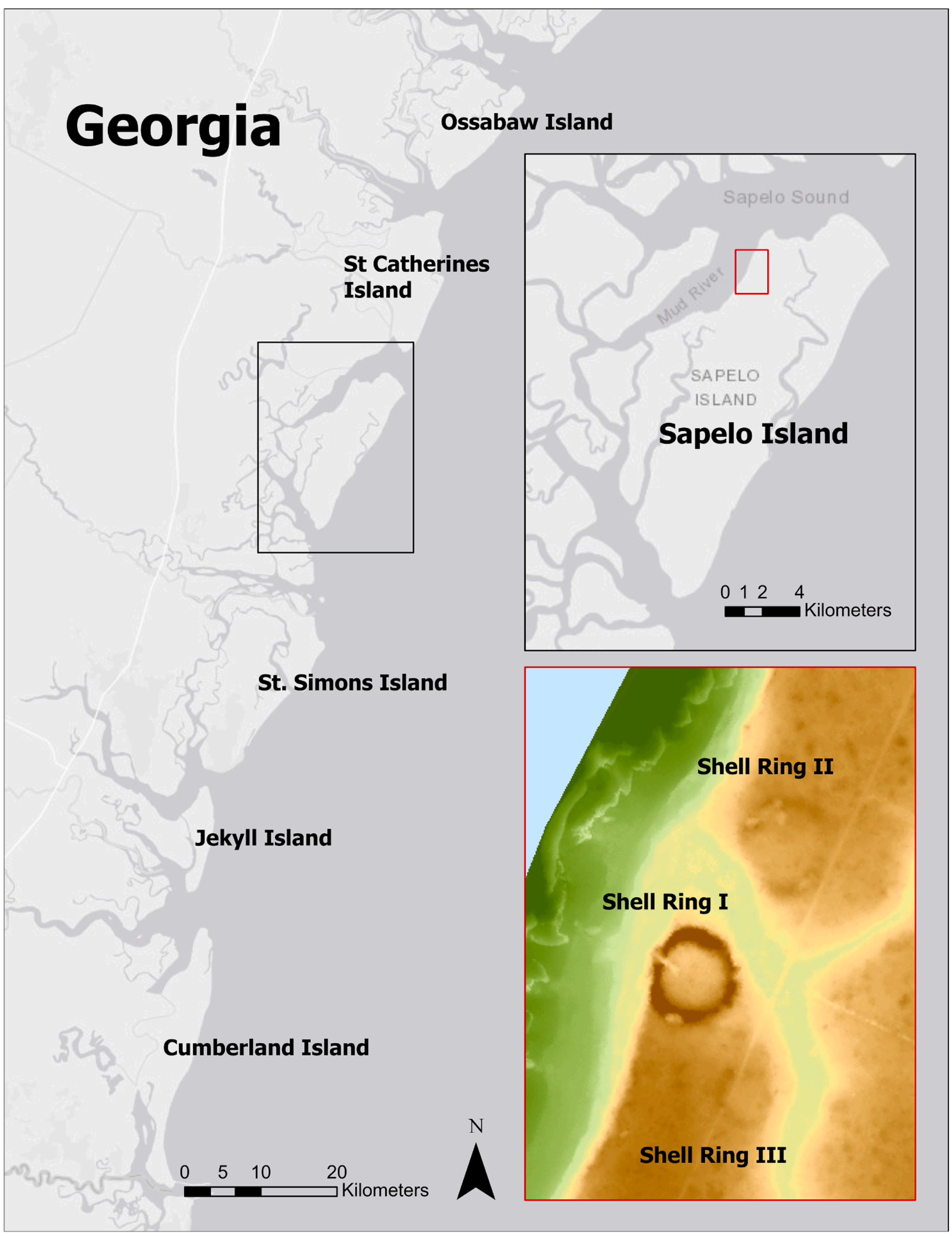

Fig. 1. Map showing the location of Sapelo Island, along with its surrounding estuaries and the Sapelo Shell Ring Complex.

private goods, public goods, or common pool resources (Blanton and Fargher, 2016; Carballo et al., 2014; DeMarrais and Earle, 2017; Thompson et al., 2022). Common pool resources are resources that are subtractable in that they have potential to be overexploited (Ostrom et al., 1994:7). The social institutions and rules that govern the collection and use of such common pool source resources so that they are not overexploited, is an important topic in coastal archaeology, and provides a classical example of a collective action problem.

Shellfish, such as oysters and other marine mollusk species found in coastal estuaries, were primary common pool resources during the Late Archaic period in the American Southeast because they were collectively and intensively harvested yet have the potential to be overexploited (Acheson, 2015; Thompson, 2022). Ethnographic and ecological studies have shown that even small-scaled harvesting can have significant impacts on shellfish populations and associated biological communities (see Mannino and Thomas, 2002). For example, ecological studies in places such as Chile, southern Africa, Canada, and Australia have shown that excluding human foragers in certain areas increased the size and abundance of gastropod and other mollusk species, even in as little as a few decades (Mannino and Thomas, 2002 [Castillo and Duran, 1985; Keough et al., 1993; Wallace, 1999]). Moreover, Anderson (1981:118) demonstrated that 27-m^2 of mollusk shells could be collected in an hour by one person; at this rate, a family of 4–5 people could deplete a population of mollusks in a few seasons. Archaeological research also has shown than human shell fishing practices can impact the health of oyster reefs and coastal fisheries, with some demonstrating examples of sustainable practices and others overharvesting (see Claassen, 1998; Erlandson et al., 2011; Fitzpatrick et al., 2008; Keegan et al., 2003; Poteate et al., 2015; Thompson et al., 2020). Whether shell fishing practices are sustainable or not is primarily evidenced in the archaeological record by temporal changes in shell size, age-profiles, and abundance (Claassen, 1998; Mannino and Thomas, 2002). For example, Keegan et al. (2003) demonstrate that temporal changes in the abundance of specific mollusks species at two pre-European contact sites in Jamaica was in part due to over harvesting, though environmental change also played a role. In contrast, Thompson and colleagues (2020) ague that oysters were sustainably harvested along the Georgia coast for thousands of years in spite of environmental fluctuations and as indicated by an increase in oyster size from the Late Archaic (5000–3000 cal. BP) through Mississippian periods (1000–370 cal. BP). Thompson (2006) also argues that the Sapelo Shell Ring Complex was the home to at least 125 villagers, with even more people living across Sapelo Island and the surrounding area. Moreover, archaeological evidence suggests that inhabitants at the Sapelo Shell Ring complex and other shell ring villages along the South Atlantic and Gulf coasts were partaking in large-scale mollusk harvesting, especially oysters, with some of these sites estimated to consist of hundreds of millions oyster shells used in their construction (Reeder-Myers et al., 2022). Given that research shows that oyster and other mollusk species were sustainably harvested along the Georgia coasts for millennia in spite large-scale harvesting by populations large enough to impact oyster reef health, there must have been social intuitions and rules that governed their harvesting, and these institutions likely developed early and persisted across time.

We know that villagers at the Sapelo Shell Ring Complex, and other Late Archaic shell rings in the region, were sedentary and at least some portion of the population inhabited the shell rings year-round (Andrus and Thompson, 2012; Cannarozzi and Kowalewski, 2019; Colaninno and Compton, 2019; Sanger et al., 2020; Thompson and Andrus, 2011). However, sedentary villagers often travel beyond their immediate settlement, and "maintained access to and knowledge of a broader area" (Cummings, 2020:739). In fact, faunal and survey data indicate that estuarine environments between the islands and the mainland were the most frequently used and heavily target habitats of the Georgia Bight (Colaninno, 2010; Colaninno and Compton, 2019; Pennings et al., 2012; Reitz, 2014). Moreover, the use of canoes, whose existence has been documented in contemporaneous sites in Florida (Wheeler et al., 2003), and twice-a-day tides would have allowed people to easily travel across large areas of coastal estuaries (up to 20 km/day) surrounding Sapelo Island (Andrus and Thompson, 2012; DePratter, 2010). Travel within the estuaries would have put people in contact with different communities (Andrus and Thompson, 2012; Turck and Thompson, 2016; Thompson, 2018). As noted by Thompson (2018:28), this present two collective action problems among sedentary villagers during the Late Archaic: (1) cooperation and conflict resolution among intervillage groups, and (2) cooperation and rules aimed at sustainably managing oyster reefs and fisheries.

Regarding the second collective action problem put forth by Thompson (2018), we argue that there were social institutions and rules in place that governed the use of coastal estuaries to protect them from being overexploited, and to a degree these practices can be inferred from the shell isotope geochemistry data. This question is- how exactly did people cooperate and what rules or practices ensured that oyster reefs and other fisheries were not overexploited? One possible practice would be season mobility and the targeting of a wide range of habitats in order to prevent any single oyster bed or fishery from being overexploited. To that end, we use $\delta^{18}O_{carbonate}$ values obtained from hard clams and oysters to estimate season of collection and the salinity of the habitats where Ancestral Muskogean people collected mollusks. Estimated salinity values are then used to infer seasonal mobility, or lack thereof, among Late Archaic villagers that inhabited the Sapelo Shell Ring Complex. We hypothesize that there will be statistically significant differences in mean $\delta^{18}O_{water}$ and salinity values between shells harvested in different seasons. We also hypothesize wide variations in estimated $\delta^{18}O_{water}$ salinity values and that there will be significant differences in salinity variation between shells harvested during different seasons. In sum, results demonstrate considerable variation in estimated salinity values and some statistically significant differences in $\delta^{18}O$ and salinity values between shells harvested in different seasons. This indicates that the sedentary villagers who lived at the Sapelo Shell Ring Complex were moving around seasonally and targeting a wide variety of habitats. We argue that this suggests some sort of social institutions or rules that governed the use of coastal estuaries so that mollusks were not overexploited.

2. Materials and methods

2.1. Sapelo Island: sample and environmental context

The Georgia Bight encompasses a section of the South Atlantic Coast from Cape Hatteras in southern North Carolina to Cape Canaveral in northern Florida. There are many Late Archaic (5000 – 3000 BP) circular and accurate shaped shell rings on the barrier islands of this region. As previously mentioned, these shell rings not only represent some of the earliest settlements along the Georgia Coast, but also are among the earliest villages in North America. Communities began to occupy these barrier islands by 4500 BP and possibly earlier as some sites may now lie underwater owing to rising sea levels during the beginning of the Holocene (Anderson et al., 2017; Thompson and Worth, 2011). Coastal estuaries formed around 5000 BP as the rising seas met freshwater input. Shortly thereafter, people were living year-round at shell ring villages, such as the Ossabaw Shell Ring, Sapelo Shell Ring Complex, and St. Catherines and McQueen shell rings, all located on barrier islands of the Georgia coast.

Sapelo Island is a barrier island located approximately 80 km south of the present-day city of Savannah, Georgia and situated between St. Catherines Island and St. Simons Island to the north and south, respectively. It is separated from the mainland by an intertidal area consisting of tidal creeks, salt marshes, and smaller islands. Estuaries and salt marshes surrounding Sapelo Island are dominated by *Spartina* spp. Oyster (*Crassostrea virginica*) reefs are found on hard substrates across the island and in close association with *Spartina* spp. In contrast, hard clams (*Mercenaria* spp.) are often found on softer substrates (Andrus and

Thompson, 2012).

The Altamaha River is the closest freshwater river that drains into the estuaries surrounding Sapelo Island. In estuaries that meet the Altamaha River, $\delta^{18}O_{water}$ values average −3.2 ‰ (Copeland and Kendall, 2000; Andrus and Thompson, 2012). These values increase and are on average 1 ‰ in the open ocean (Bigg and Rohling, 2000; Jones et al., 2004: Schmidt et al., 1999). The habitats surrounding Sapelo vary in temperature across seasons ranging from 10 °C in the winter and 30 °C in the summer. However, $\delta^{18}O_{water}$ values more likely reflect seasonal temperatures and salinity differences than temperature differences across habitats. Previous data collected by Andrus and Thompson (2012) indicate that while water temperatures do not vary across different habitats surrounding Sapelo island, salinity values do vary, range from 0 to 10 psu further inland at the mouth of the Altamaha River and up to 30 psu or higher closer to the open ocean.

2.2. Mollusk geochemistry

Oxygen Isotope ($\delta^{18}O$) analysis of mollusk shells obtained from archaeological contexts is a commonly used method for examining seasonal mobility, paleoclimate and environmental change, and human-environmental interactions (e.g., Andrus and Crow, 2000; Thompson and Andrus, 2011; Walker and Surge 2006). Oxygen isotopic values in mollusk shells ($\delta^{18}O_{carbonate}$) covary with the oxygen isotopes composition of ambient water ($\delta^{18}O_{water}$) and water temperature of the water that they grow in. Moreover, $\delta^{18}O_{water}$ covaries with salinity levels in coastal estuaries (Andrus, 2011; Coplen and Kendall, 2000; Jones et al., 1989; Kirby et al., 1998). Oxygen isotopic values and salinity levels in coastal estuaries are driven by the amount of freshwater input into the estuary, and often exists on a gradient, with both $\delta^{18}O_{water}$ and salinity values decreasing with increasing distance from the ocean (Coplen and Kendall 2000; Elliot et al., 2003). Salinity values in coastal estuaries can also be influenced by environmental change; both increased rainfall patterns and lower sea levels can lead to increased freshwater input and reduced salinity in coastal estuaries . Retrodicting salinity values from oxygen isotope analysis of mollusks shells can thus be used to explore Indigenous harvesting practices in the past, such as seasons during which mollusks were collected and the range of oyster beds and estuaries targeted, as well local environmental changes.

Archaeologists and geochemists in the North America southeast primarily examine two species of mollusks in isotope studies: hard clams (*Mercenaria* spp.) and eastern oysters (*Crassostrea virginica)*, both of which have a wide salinity tolerance and are often found in close association with one another in coastal estuaries. Hard clams generally tolerate salinity levels between 17 and 37 psu, with optimal growth between 20 and 30 psu (Kraeuter and Castagna, 2001; Grizzle et al., 2001). Oysters' tolerance is slightly wider, between 5 and 37 psu, with the most ideal growth conditions generally between 14 and 28 psu (Bartol, 1999; Shumway, 1996). Both species grow incrementally, which allows us to determine the season of collection based on the season oscillation of $\delta^{18}O$ values (see below). To provide a recent example of how shell geochemistry can be used to examine shellfish harvesting practices, Lulewicz and colleagues (2018) examined $\delta^{18}O_{carbonate}$ values in mollusks shells collected from Crystal River, a shell mound site located on Florida's Gulf Coast. Though authors found that Native American communities at this site harvested mollusk shells from a wide range of habitats. However, the habitats targeted changed over time with a shift from lower to higher saline habitats, which likely reflected changing settlement patterns as people moved seaward as sea levels lowered across time.

In this study, we conducted incremental oxygen ($\delta^{18}O$) isotope analysis on oysters (n = 18) and clams (n = 59) collected from multiple proveniences at each shell ring in the Sapelo Shell Ring Complex. Twenty of these shells were sampled recently as part of a larger isotope and radiocarbon project focusing on the Georgia and South Carolina Coast, and the remaining data have been previously published (Andrus and Thompson, 2012; Thompson and Andrus, 2011). Here, we are attempting to reevaluate these earlier studies, with the addition of more samples and within a framework of collective action, as discussed above. Overall isotopic methods and data have already been reported in Garland et al., (2022) and Andrus and Thompson (2012). In short, only left oyster valves with a complete and preserved chondrophore were selected for analysis, as well as clams with an intact edge. Shells that were dead upon collection, as evidenced by sponge bores and other signs of activity by epibiont species on the interior of the shell, were not selected for analysis (Cobb, 1969; Warburton, 1958). A macro-sectioning saw was used to bisect oyster shells along their chondrophore and clams along their longest axis. This method produced approximately 12.7-mm thick sections, which were then mounted onto slides using Crystalbond™ adhesive. A Grizzly Benchtop milling system was used to sample each shell, starting at the growing edge in sectioned oyster sample and the ventral margin in each clam sample. Our sampling strategy targeted the chalky calcitic areas on the internal surface of each oyster shell hinge, avoiding the foliated calcite and aragonite regions near the hinge surface (Carriker and Palmer, 1979; Surge et al., 2003; Zimmt et al., 2019). Oyster samples were taken incrementally and at an average of 300–400 mm in width and 300–400 mm in depth. For clams, samples were taken from the inner aragonite layers along the transected margin. Using a rounded bur, clam samples were taken sequentially and slightly overlapping, starting at the ventral margin. Each sample was milled to a depth of approximately 0.5-mm. We took approximately 12–20 samples from each oyster and 20 samples from each clam, which captures around one-years' worth of growth prior to the time at which the shells were collected.

The methods described above resulted in powered carbonate samples, approximately 0.100–0.500 mg in weight. The powdered carbonate samples were weighed using tin capsules and then transferred into Exetainer® 12 ml borosilicate vials. The analysis of $\delta^{18}O$ and $\delta^{13}C$ was done using a Thermo Gas Bench coupled to a Delta V IRMS with a GC Pal auto-sampler at the University of Georgia's Center for Applied Isotope Analysis. First, atmospheric gases was removed from the samples with helium and acidified with phosphoric acid to convert solid carbonates to CO_2 gas. The target gas was then concentrated as a frozen solid within a loop submerged in a liquid nitrogen bath. Subsequently, the gas was released back into the helium carrier gas to the IRMS. The oxygen and carbon isotope values are reported in parts per mil (‰) relative to the VPDB standard by correcting to multiple NBS-19 analyses (typically 14) per run.

The $\delta^{18}O_{carbonate}$ values for each individual shell were plotted and divided into equal thirds (see Fig. 2). These graphs were used to determine the season during which each shell was harvested. If the value of the first sample (time at which the shell was harvested) falls in the bottom third of values, then the shell was estimated to have been collected in the summer, and if it falls in the top third, then the shell was estimated to have been harvested in the summer. This reflects a trend of more negative $\delta^{18}O_{water}$ in warmer summer water. If the first value falls in the middle third of values, then the shell was harvested in either the fall or spring, depending on whether the subsequent values were trending more negative or positive. Next, salinity was estimated from shell $\delta^{18}O_{carbonate}$ values following published methods established for the area (following Garland et al., 2022 as outlined by Andrus and Thompson, 2012; Harding, 2010). These equations first estimate $\delta^{18}O_{water}$ values for the most negative $\delta^{18}O_{carbonate}$ value (representing summer) in each clam and oyster, respectively. The estimated $\delta^{18}O_{water}$ values are then used to retrodict salinity for each shell. Mean salinity and variations in salinity values were compared between each shell ring; this was done for both species combined and each species separately.

2.3. Equations

Summer $\delta^{18}O_{water}$ value in clams: Water temperature (°C) = 20–4.42 ($\delta^{18}O_{argonite} - x$)

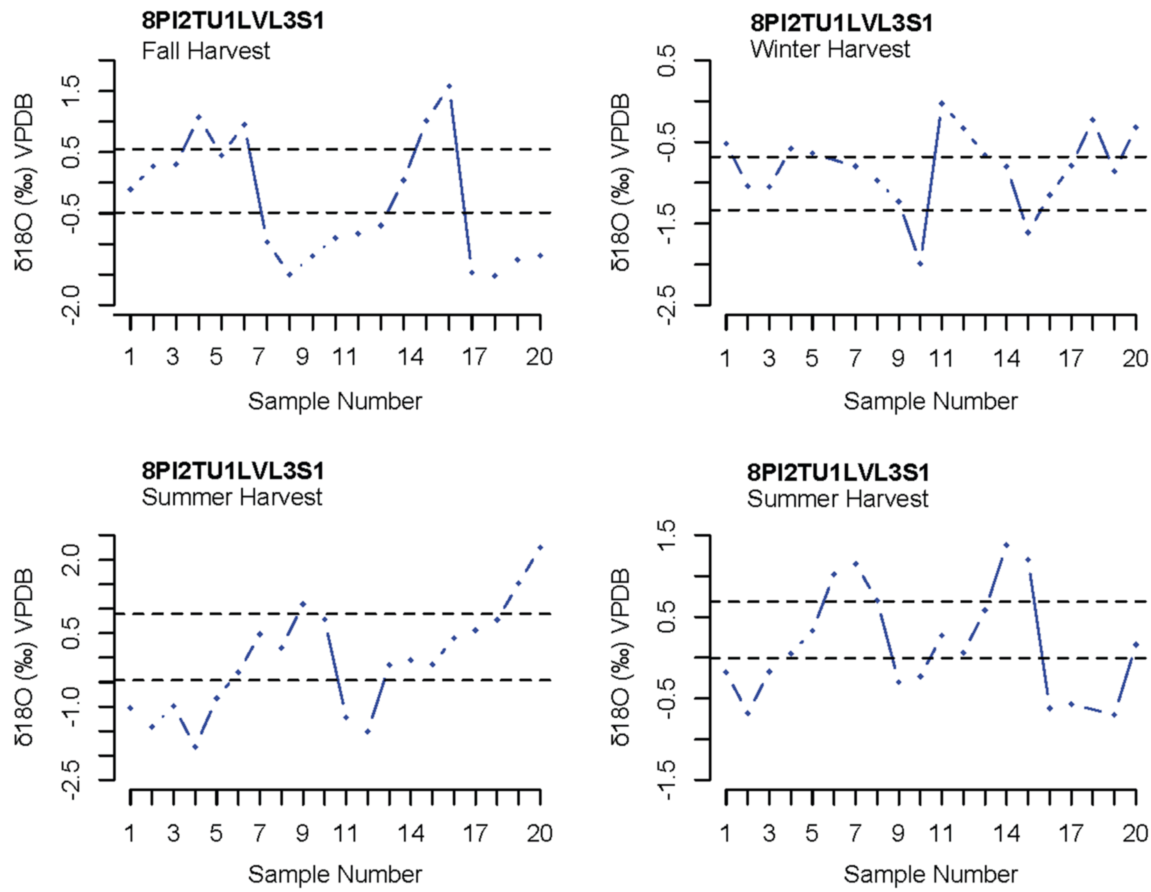

Fig. 2. Oxygen isotope ($\delta^{18}O_{carbonate}$) profiles for a subset of shells showing seasonal fluctuations in oxygen values and season of collection.

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 $x = \delta^{18}O_{water}$

Summer $\delta^{18}O_{water}$ value in clams: 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.

Estimated salinity: $\delta^{18}O_{water} = 0.13(y) - 3.4$

whereas $\delta^{18}O_{water}$ is calculated by equation 1 or 2, and y = estimated salinity (psu).

3. Results

Oxygen ($\delta^{18}O_{carbonate}$) values varied among all oyster and clam shells, mean $\delta^{18}O_{carbonate}$ ranging between −4.0 ‰ to 0.5 ‰, and estimated $\delta^{18}O_{water}$ ranging between −2.9 ‰ and 1.8 ‰ (Table 1). Most shells have sinusoidal $\delta^{18}O_{carbonate}$ profiles, which suggests seasonal fluctuations in water temperature. This allowed us to estimate the season of capture and pinpoint summer $\delta^{18}O$ values (e.g., the most negative value within each shell profile) used to retrodict salinity (Fig. 2). Results show that shells were harvested year-round, with each season represented. However, most shells (77 %) in this sample were harvested during either winter or spring, and a number of shells (n = 12) did not have enough variation in their $\delta^{18}O_{carbonate}$ profiles to determine season of capture (Fig. 3).

Retrodicted salinity values ranged between 4 and 40 psu. All but three shells had estimated salinity values that fell within the expected range for each species. One shell specifically had extremely negative $\delta^{18}O_{carbonate}$ values and was thus excluded from analysis. Since there were only a few shells (n = 4) representative of spring or fall, we only made comparisons between shells harvested in the winter (n = 31) and summer (n = 28). Mean estimated salinity was 27.1 (psu) for shells harvested in summer and 23.7 (psu) for shells harvested in winter (Fig. 4). Mean summer $\delta^{18}O_{water}$ values were 0.07 for shells harvested in the summer and −0.47 ‰ for shells harvested in the winter. At the mean level, summer $\delta^{18}O_{water}$ values are significantly different in regard to season of collection (*t*-test: $p = 0.02$). However, there are no statistically significant differences in estimated salinity values between shells harvested during different seasons, though the p-value is approaching statistical significance (*t*-test: $p = 0.07$). Shells harvested in the winter had greater variance in estimated salinity compared to summer. Similar to salinity, however, these differences were not statistically significant (*t*-test: $p = 0.24$). Since oysters and clams live in different habitats, and have different salinity tolerances, we also made these comparisons for each species separately. Interestingly, the are no statistically significant differences in estimated salinity for oysters harvested in the summer and winter (*t*-test: $p = 0.94$). Lack of statistical difference, however, could be because the majority of oyster shells were harvested in the winter, with fewer shells and a small range of salinity values for oysters harvested in summer. In contrast, estimated salinity is statistically different among clams harvested in summer and winter (*t*-test: $p = 0.05$) (Fig. 4).

4. Discussion

Oysters and other mollusk species were integral components of a larger economic resource base on the Georgia coast. However, mollusks were not only an important food source for coastal people in coastal environments, but also were woven into broader political, social, and ritual landscapes, which can be seen in the sheer abundance of mollusks in shell rings, mounds, and middens in the region. The data presented

Table 1
Raw oxygen ($\delta^{18}O$) and estimated salinity (psu) values for each shell.

Shell Ring	Species	Sample	Season of Harvest	Oxygen ($\delta^{18}O$)	Salinity (psu)
Shell Ring I	*Crassostrea virginica*	OLTS10	Summer	−0.2	25
Shell Ring I	*Crassostrea virginica*	OLTS9	Winter	−0.3	24
Shell Ring I	*Crassostrea virginica*	OLTS12	Winter	0.4	30
Shell Ring I	*Crassostrea virginica*	OLTS15	Winter	1.2	36
Shell Ring I	*Crassostrea virginica*	OLTS11	Winter	0	27
Shell Ring I	*Crassostrea virginica*	OLTS3	Indeterminant	0.3	24
Shell Ring I	*Crassostrea virginica*	OLTS14	Winter	1.2	36
Shell Ring I	*Mercenaria* spp.	CLTS7	Winter	−0.9	29
Shell Ring I	*Mercenaria* spp.	CLTS6	Indeterminant	0.2	28
Shell Ring I	*Mercenaria* spp.	CLTS4	Winter	−0.3	24
Shell Ring I	*Mercenaria* spp.	CLTS2	Fall	0.7	32
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S1	Spring	1	34
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S2	Summer	0.7	32
Shell Ring II	*Mercenaria* spp.	9MC23A-1-4SQ1S7	Summer	0.8	33
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S6	Summer	1.8	40
Shell Ring II	*Crassostrea virginica*	9MC23A-1-4SQ1S1	Summer	0	26
Shell Ring II	*Mercenaria* spp.	9MC23A-1-5SQ1S1	Summer	0.6	31
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S5	Summer	0.9	34
Shell Ring II	*Mercenaria* spp.	9MC23A-1-2SQ1S1	Summer	1.1	35
Shell Ring II	*Mercenaria* spp.	9MC23A-1-2SQ1S4	Winter	1.5	38
Shell Ring II	*Mercenaria* spp.	9MC23A12SQ1S7	Winter	0.5	30
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S3	Summer	0.6	31
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S4	Winter	−2.2	9
Shell Ring II	*Mercenaria* spp.	9MC23A-1-3SQ1S7	Summer	0.7	32
Shell Ring II	*Mercenaria* spp.	9MC23A-1-2SQ1S5	Summer	0.9	34
Shell Ring II	*Mercenaria* spp.	9MC23A-1-2SQ1S2	Summer	0.9	34
Shell Ring II	*Crassostrea virginica*	9MC23A-1-4SQ1S4	Winter	−0.3	24
Shell Ring II	*Mercenaria* spp.	9MC23A-1-5SQ1S6	Summer	0.5	30
Shell Ring II	*Mercenaria* spp.	9MC23A-1-2SQ1S3	Spring	1.5	38
Shell Ring II	*Mercenaria* spp.	C5A	Indeterminant	−0.3	24
Shell Ring II	*Mercenaria* spp.	C6A	Summer	−1.1	18
Shell Ring II	*Mercenaria* spp.	C6A	Summer	−0.9	19
Shell Ring II	*Mercenaria* spp.	C1A	Indeterminant	−0.3	24
Shell Ring II	*Mercenaria* spp.	C25A	Indeterminant	0	27
Shell Ring II	*Mercenaria* spp.	C2A	Indeterminant	0.3	29
Shell Ring II	*Mercenaria* spp.	C3A	Summer	−0.3	24
Shell Ring II	*Mercenaria* spp.	C12A	Summer	−0.3	24
Shell Ring II	*Mercenaria* spp.	C7A	Winter	−0.2	25
Shell Ring II	*Mercenaria* spp.	C17A	Winter	−0.5	22
Shell Ring II	*Mercenaria* spp.	C9A	Summer	−0.1	26
Shell Ring II	*Mercenaria* spp.	C4A	Summer	−0.4	24
Shell Ring II	*Mercenaria* spp.	C11A	Indeterminant	−0.5	23
Shell Ring II	*Mercenaria* spp.	C20A	Summer	−0.8	20
Shell Ring II	*Mercenaria* spp.	C24A	Summer	0	27
Shell Ring II	*Mercenaria* spp.	C18A	Summer	−0.2	25
Shell Ring II	*Mercenaria* spp.	C22A	Summer	0	26
Shell Ring II	*Mercenaria* spp.	C14A	Summer	0.1	27
Shell Ring II	*Mercenaria* spp.	C26A	Winter	0.2	28
Shell Ring II	*Mercenaria* spp.	C16A	Winter	0.1	27
Shell Ring II	*Mercenaria* spp.	C23A	Indeterminant	0.5	31
Shell Ring II	*Mercenaria* spp.	C21A	Summer	0.2	28
Shell Ring II	*Mercenaria* spp.	C10A	Summer	0.3	29
Shell Ring II	*Mercenaria* spp.	C19A	Summer	0.3	29
Shell Ring II	*Mercenaria* spp.	C8A	Indeterminant	0.5	30
Shell Ring II	*Mercenaria* spp.	C15A	Summer	0.4	29
Shell Ring III	*Crassostrea virginica*	O15	Winter	−1.5	15
Shell Ring III	*Crassostrea virginica*	O13	Winter	−1.9	12
Shell Ring III	*Crassostrea virginica*	O14	Winter	−0.8	20
Shell Ring III	*Crassostrea virginica*	O10	Summer	−0.4	23
Shell Ring III	*Crassostrea virginica*	O4	Winter	−1.1	18
Shell Ring III	*Crassostrea virginica*	O9	Winter	−0.5	23
Shell Ring III	*Crassostrea virginica*	O8	Winter	−0.3	24
Shell Ring III	*Crassostrea virginica*	O5	Winter	−0.9	34
Shell Ring III	*Mercenaria* spp.	O3	Winter	−2.4	8
Shell Ring III	*Mercenaria* spp.	C8	Summer	−1.9	12
Shell Ring III	*Mercenaria* spp.	C1	Winter	−1	19
Shell Ring III	*Mercenaria* spp.	C9	Winter	−1.6	14
Shell Ring III	*Mercenaria* spp.	C4	Winter	−0.8	20
Shell Ring III	*Mercenaria* spp.	C3	Winter	−0.3	24
Shell Ring III	*Mercenaria* spp.	C10	Spring	−0.8	20
Shell Ring III	*Mercenaria* spp.	C13	Indeterminant	−0.1	26
Shell Ring III	*Mercenaria* spp.	C3	Summer	−1.8	13
Shell Ring III	*Mercenaria* spp.	C5	Indeterminant	−1.5	15
Shell Ring III	*Mercenaria* spp.	C7	Indeterminant	−0.9	19

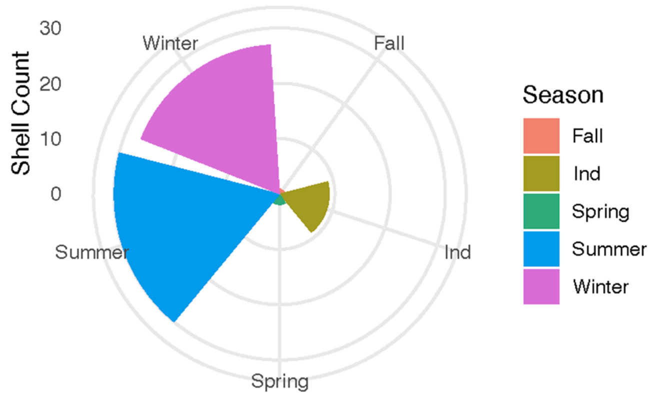

Fig. 3. Graph showing the frequency of shells representative of each season of collection.

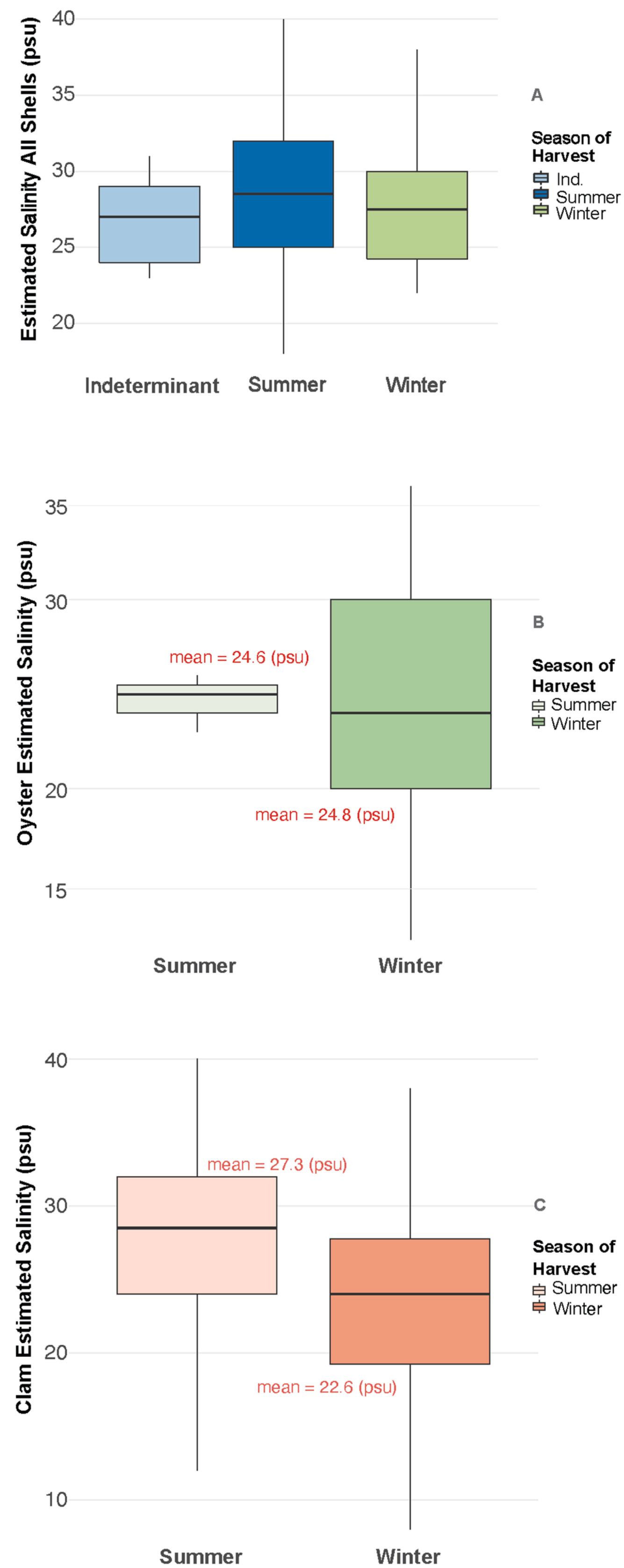

Fig. 4. Estimated salinity comparisons between shells harvested in summer and winter for (A) all shells, (B) just oyster shells, and (C) just clam shells.

here corroborate and contribute to recent research regarding sustainable mollusk harvesting practices among Indigenous peoples of the South Atlantic Coast of North America. Thompson and colleagues (2020) demonstrate a non-random pattern of oyster sizes from shell rings and shell middens along the South Carolina and Georgia coast. They also show that, in most cases, the size of oyster shells increased across time from the Late Archaic (4500–3000 BP) to Mississippian (1150 – 370 BP) period. They argue that these patterns suggest that Indigenous communities along the coast sustainably harvested oysters for thousands of years, and that groups likely had proprietorship over specific estuaries and portions of regional fisheries. Similarly, Reeder-Myers and colleagues (2022) show that oyster fisheries in the Southeastern United States, and elsewhere, were massive and persisted for thousands of years. Importantly, Reeder-Meyers and colleagues argue that we must incorporate Indigenous histories and practices when developing strategies to manage contemporary oyster reefs and coastal fisheries more effectively. Here, we provide some insight into mollusk harvesting practices among Ancestral Muskogee of the Georgia coast - practices that may have been in place to ensure the health of oyster reefs and other fisheries and thus contributed to the persistence of productive fisheries in the region for millennia, from the time of the shell ring up to the point at which market -based institutions developed post-European colonization engendered the collapse of these reef systems.

Andrus and Thompson's (2012) initial analysis on a subset of the shells used in this study found a large variation in $\delta^{18}O$ and estimated salinity values, and that the shells were harvested year-round, with all seasons represented. The additional data presented here corroborates this initial interpretation. Our hypothesis that Indigenous communities on Sapelo island were seasonally targeting resources from an array of habitats was confirmed by the $\delta^{18}O$ and estimated salinity results. The variation in $\delta^{18}O$ and estimated salinity, which ranged from −2.4 ‰–1.8 ‰ and 4–40 (psu), respectively, suggests that inhabitants of the Sapelo Shell Rings were harvesting shells from a wide range of habitats, not just reefs that were close to the village. While these data cannot be used to pinpoint precise geographic locations of the habitats targeted, they do indicate that the Ancestral Muskogean people of Sapelo Island were harvesting shells from salinity habitats near to open ocean values to further inland in estuaries of the upper Sapelo Sound or areas close to the Altamaha River that are characterized by more negative $\delta^{18}O_{water}$ and lower salinity values. Moreover, comparisons between shells harvested during summer and winter point to seasonal mobility among the sedentary villagers, with different habitats harvested during different times of the year. Shells harvested during the winter had more negative summer $\delta^{18}O_{water}$ values and lower estimated salinity values compared to summer; however, only mean $\delta^{18}O_{water}$ was significantly different (though mean difference in salinity was approaching statistical significance). Interesting, when comparing oysters and clams separately, it seems that much of this difference is being driven by clams. There was little difference in mean $\delta^{18}O_{water}$ and estimated salinity between oysters harvested in winter and summer; however, both mean $\delta^{18}O_{water}$ and mean estimated salinity were statistically different among clams harvested in winter and summer. There was, however, much more variation in habitats used during the winter for both clams and oysters. This begs the question, why were inhabitants of the Sapelo Shell Ring Complex harvesting oyster from a wide range of habitats when the village itself was in close proximity to many oyster reefs? Here, we argue that mobility represents a practiced aimed at ensuring that oyster reefs and other coastal fisheries were sustainably managed. Cooperation and collective action, specifically, provide an interpretive lens to examine how these data can speak to subsistence practices among Ancestral Muskogean peoples, and how such practices ensured the sustainable management of shellfisheries surrounding Sapelo Island.

Collective action theories view cooperation as problem-oriented in that it requires institutions or rules to prevent aggrandizing or individualizing behaviors within and even between communities (Blanton and Fargher, 2016; Thompson, 2022). Since oysters and other mollusks are accessible to every-one and have the potential to be depleted, even under small-scaled harvesting (see Anderson, 1981; Castillo and Duran, 1985; Keough et al., 1993; Mannino and Thomas, 2002; Poteate et al., 2015; Wallace, 1999) and since research shows that these reefs persisted for thousands of years despite large-scale harvesting (Thompson et al., 2020), there must have been harvesting rules or other institutions in place to ensure that the reefs were not overexploited by individuals or groups of people. Thomas (2014:174) suggests that inhabitants of the adjacent St. Catherines Island practiced a sort of "pseudo-aquaculture" in which targeting and husbanding specific patches increased post-encounter return rates through selective harvesting, a somewhat similar practice is suggested by Andrus and Thompson (2012). Likewise, Jenkins (2017) argues for a form of mariculture (i.e., marine agriculture) along Florida's Gulf Coast, as evidenced by oyster shell attributes that suggest shelling and culling, although there are still methodological issues to be worked out with this study. These practices would have helped to mediate overharvest; however, given that reefs for the most part are located at varying distances away from villages a problem still persists. That is, how were individual reefs protected from overharvesting both within the villages (e.g., individuals) and from other villages (e.g., other groups)? Put another way, what were the institutions that solved the collective action problem of overharvesting?

As Thompson et al., (2020:6) notes, "villages were dependent on local resources and likely enacted practices to encourage the health and productivity of nearby reefs." To understand how such substantiality was achieved, we first need to grasp the challenges to maintaining productive reefs. First, given that reefs are mostly located away from villages, they would be difficult to defend and control through simple force. The costs of constantly monitoring reefs were simply too great. Thus, the size of such common pool resources (i.e., the fishery) presents some obstacles (Ostrom et al., 1994:7). Some other way to prevent overharvesting must have been enacted for groups along the coast. We suggest that there may have been two different mechanisms/institutions by which early villages enacted that prevented overharvesting and abuses of common pool resources in the fishery. One relates to intra-village social space and household cooperation and the other is predicated on intervillage dynamics of ceremonial feasts that integrated multiple villages. We argue that these two institutions were "keystones" (see Holland-Lulewicz et al., 2022) to the functioning of early village life in the region in that they form the core of how labor and resources were allocated and thus were central to the functioning of village life.

The Sapelo Shell Ring Complex villages are laid out in a circular fashion, with households facing an interior plaza. Several researchers point out that these circular village structures promoted a certain degree of cooperation among households (e.g., Thompson, 2018; Sanger, 2015). All three of the plazas at Sapelo were less than 100 m in diameter and likely would have promoted close integration among the families that lived around them. Furthermore, activities conducted in the plaza near households along the village periphery would have been easily observable to all inhabitants. Thus, the openness of the village layout as a whole would make it easy to observe anyone hoarding or coming back with an unusually large harvest of oysters, and indeed other fishes. As Colaninno (2010) argues, the size grade of fish remains from the Sapelo shell rings suggests that inhabitants were using mass capture techniques, which would have required both cooperation and organized labor. It is likely that rules and institutions that developed around coastal fishers were likely intertwined with, or extended to, mollusks as well (Thompson, 2018, 2022). If then these were mostly collective harvests, then rules and norms of not only how much to collect would have been needed as well as rules and institutions of distribution. Thus, if we also consider such central spaces as not only places of ritual but also one where village governance and deliberation (including harvest distributions) took place then it is easy to envision that the vast majority of people would have been involved in such discussions and actions. Such institutions then limit the ability of free riders and dissenters in particular courses of action. As Green (2022:10) notes "the more space a society sets aside for deliberation, the more people can participate in its governance, the greater the likelihood that everyday people will be able to agree to a particular course of collective action."

Reitz (2014:716) argues that coastal fisheries along the South Atlantic coast were managed through social institutions to avoid "overfishing and a system wide collapse." The data certainly suggests that these coastal fisheries including oyster reefs were sustainably maintained for thousands of years. So, how was the collective action problem of fishery sustainability solved at the larger regional level? We suggest that along with the local village level institutions there were intervillage level institutions that promoted interdependencies among these early villagers (see Thompson and Moore, 2015). Specifically, we argue that cooperation of different villages to host feasts served as a mechanism to help mediate and deter overexploitation of resources.

Several authors suggest that it was common for shell ring villages to hold ceremonial feasts and gatherings that included people from outlying villages (see Russo, 2014; Sanger and Ogden, 2018, Thompson, 2018). As Thompson and Moore (2015:260) note, the key to daily life and special events (i.e., feasts) was the production of surpluses, so therefore if one is not able to produce such surpluses then the hosting of feasts and their attendant social benefits diminish or become too costly. While distant reefs and parts of the overall fisheries would have been too difficult to monitor or defend, knowledge of their health and productivity would likely be possessed by neighboring groups. We reason this because the data suggest that the inhabitants of the Sapelo Ring villages appear to be collecting mollusks from a wide range of habitats (see also Andrus and Thompson, 2012). If this pattern holds for other neighboring shell rings, then there likely was considerable overlap in harvesting territories. If these communities hosted feasts together and interacted in other ways, then multiple communities would not only be invested in their own management of reefs and fisheries, but also that good harvests were available for all so that intercommunity feasts could be held periodically. Thus, while shell rings were primarily the focus of daily life, the holding of ceremonies and rituals would have helped to mediate conflict and reaffirm the rules of use of specific parts of the fishery (i.e., proprietary reefs and those held in common) (Turck and Thompson, 2016:52).

As a final point, it is likely the interdependencies of these villages were more than just economic, but social and familial. Among Ancestral Muskogean people, clan systems, lineages, and tribal towns were extremely important (Chaudhuri and Chaudhuri, 2001). These institutions formed the basis of life, governance, and other community affairs. Sanger et al., (2020) argues based on the archaeological record that shell ring communities were matrilocal, suggesting that archaeological research matches Ancestral Muskogean kinship practices. Others have made similar arguments for matrilocal practices among Native American communities in the American southeast, specifically regarding riverine communities in the Savannah River Valley that created Stallings Island pottery (see Sassaman and Rudolphi, 2001). The key point here is that for any one shell ring village, the inhabitants likely had strong ties to other settlements, through marriage, clan affiliation, and other social ties. Information between these individuals regarding the health and wellbeing of the community would have flowed freely among these related peoples. Such free-flowing information would allow for the anticipation of harvest shortfalls and emphasizes the broader collective responsibility of communities to manage the fishery using sustainable practices.

In sum, we argue that seasonal mobility and the targeting of a wide range of habitats represents a social practice that worked to overcome collective action problems revolving around the harvesting of estuarine resources. The collective action problem being how to effectively manage oyster reefs and fisheries that are used by multiple communities and have the potential to be overharvested. Cooperation played out at both the village and intervillage levels. Circular shell villages and intervillage ceremonies, specifically, were two mechanisms or institutions that would have promoted these sustainable harvesting practices. Both would have prevented aggrandizing behaviors and would have ensured the collective responsibility of communities to promote the health of oyster reefs and other fisheries in the area. Future research will test if these patterns hold at shell rings on other adjacent barrier islands and during other time periods. This research, and research alike, underscores the importance of documenting and understanding sustainable mollusk harvesting practices of Indigenous communities that persisted along the Georgia coast, and other regions, for thousands of years. We hope that these histories and practices, along with Indigenous collaboration, can inform and play a key role in creating effective management strategies for modern oyster reefs and coastal fisheries that have been under threat from overexploitation for more than a century.

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Data availability

All raw isotope data is available through the Georgia Coastal Ecosystem Long Term Ecological Research Network website: https://doi.org/10.6073/pasta/4a7b654d265cca39fabaac3f4aeb55b2.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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