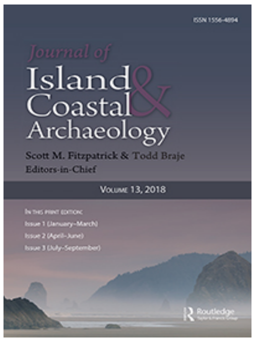

The Journal of Island and Coastal Archaeology

ISSN: 1556-4894 (Print) 1556-1828 (Online) Journal homepage: http://www.tandfonline.com/loi/uica20

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To cite this article: Isabelle H. Lulewicz, Victor D. Thompson, Thomas J. Pluckhahn, C. Fred T. Andrus & Oindrila Das (2018) Exploring Oyster (Crassostrea virginica) Habitat Collection via Oxygen Isotope Geochemistry and its Implications for Ritual and Mound Construction at Crystal River and Roberts Island, Florida, The Journal of Island and Coastal Archaeology, 13:3, 388-404, DOI: 10.1080/15564894.2017.1363096

To link to this article: https://doi.org/10.1080/15564894.2017.1363096

Published online: 28 Sep 2017.

The Journal of Island & Coastal Archaeology, 13:388–404, 2018

ISSN: 1556-4894 print / 1556-1828 online
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Exploring Oyster (*Crassostrea virginica*) Habitat Collection via Oxygen Isotope Geochemistry and its Implications for Ritual and Mound Construction at Crystal River and Roberts Island, Florida

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ABSTRACT

*Research at Crystal River and Roberts Island Shell Mound Complex, on the western coast of Florida, USA, offers a quantitative assessment of the temporality of shell deposit construction, Native subsistence practices, and mobility patterns through stable oxygen isotope data from eastern oyster (*C. virginica*). The $\delta^{18}O_{water}$ values of oysters vary synchronously with salinity, assuming relatively constant $\delta^{18}O_{water}$/salinity gradients since the time of occupation, allowing for an examination of shifts in oyster habitat exploitation over time. Our previous (Thompson et al. 2015) study indicated that midden accumulation occurred throughout the year, while oysters from mound deposits were collected in colder months. New data indicate that in addition to differential season of collection, habitat exploitation also varied. During early occupation at the site, oysters were collected primarily from lower saline habitats, while in later phases oysters were obtained from higher salinity waters; we relate*

Received 15 January 2017; accepted 7 July 2017.
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this to a lower sea level and concomitant settlement shift seaward. Additionally, oyster from later mound contexts was collected from higher saline habitats relative to those in midden contexts; Native people may have targeted specific bioherms at certain times for the year for feasting-related mound construction.

Keywords coastal, economy and subsistence, mobility, paleoenvironment, Southeast

INTRODUCTION

Oxygen isotope data acquired from archaeological mollusk material are most often used to assess season of collection or to reconstruct high resolution paleoclimate conditions, such as sea surface temperature or precipitation patterns on seasonal timescales (Andrus 2011; Twaddle et al. 2015; Walker 2013; Wang et al. 2013). Most recently in the American Southeast this method is used to address depositional rates of large-scale shell deposits from a variety of different time periods (Andrus 2012; Andrus and Thompson 2012; Blitz et al. 2014; Thompson and Andrus 2011; Thompson and Andrus 2013). Methods used to determine season of collection from shellfish seek to evaluate issues centered on mobility and seasonal exploitation of resources (Andrus 2012; Burchell et al. 2013; Hausmann and Meredith Williams 2016; Jew et al. 2013; West 2013). This method is based on the model that the distribution of oxygen isotopes in the majority of bivalve mollusks ($\delta^{18}O_{carbonate}$) is largely a function of water temperature and oxygen isotope concentration of the ambient water ($\delta^{18}O_{water}$). Here, we address these issues, but also seek to evaluate the nature and temporality of large-scale shell deposits from Crystal River (8CI1) and the Roberts Island Shell Mound Complex (8CI36, 37, 39, 40, 41, and 576), which represent early monumental constructions in the region. We aim to offer better quantitative assessments of the temporality of monument construction, Native subsistence practices, and mobility patterns. Our goal was not to ascertain specific habitats from which each oyster was collected, but rather to gather general trends of collection practices over time through determining the salinity ranges of the habitat, or natural environments in which oysters live, from which the mollusks were collected (see Andrus and Thompson 2012; Lesure et al. 2009; Thompson and Andrus 2013). To do so, we couple a previous Bayesian analysis of radiocarbon dates (Pluckhahn et al. 2015) and oxygen isotope analysis of *Crassosstrea virginica* shells, also known as the Eastern oyster, for season of collection (Thompson et al. 2015), with an evaluation of the same oxygen isotopic data to examine habitat collection.

STUDY AREA

Sea-level history for the Florida Gulf Coast is a multicomponent issue, experiencing various fluctuations over the last two millennia (Ballsillie and Donoghue 2004; Walker 1992:275–290; Walker et al. 1994, 1995; Wang et al. 2013). Current sea-level reconstructions for this area provide well-defined curves for long-term change but do not elucidate the variation at an appropriate resolution (Ballsillie and Donoghue 2004). Thus, it is unclear how the central Gulf Coast experienced these sea-level fluctuations. For a more in-depth discussion, see Thompson et al. 2015. At this point, we only partially understand the implications of the larger climatic and geological changes and acknowledge the presence of more minor fluctuations within each climatic age, such as the Roman Warm Period, the Vandal Minimum, and the Little Ice Age. When coupled with larger atmospheric circulation patterns, these minor fluctuations greatly affect sea level. However, the wide, shallow continental shelf of the Gulf provides a buffer system by precluding or dampening large sea swells before reaching shore (Goodbred and Hine 1995), while small tidal range and shallow water may contribute to storm and wind driven tides of greater magnitude compared to astronomically driven tides. Each bay along the Florida Gulf Coast has the potential to differentially respond to changing sea level. All of such events have the potential to affect the availability and location of resources.

Crystal River and Roberts Island are neighboring, mostly sequential shell mound sites on the central Gulf Coast of Florida (Figure 1). Roberts Island is located less than 1 km downstream of the Crystal River site at the junction of the Crystal and Salt Rivers. The Crystal River flows from its headwaters in Kings Bay to the east for 11 km to the west to the Gulf of Mexico. Kings Bay is not fed by significant inflowing rivers or streams but rather is supplied with freshwater from multiple nearby springs. The water temperatures in Kings Bay and the environments continuing to the Gulf of Mexico vary little compared to other regions. This could partly be due to the temperature of spring water remaining relatively constant year-round at a temperature of approximately 23°C (Scott et al. 2004). Water temperatures, downstream of Kings Bay and associated stream, range between around 16°C in the winter and 28°C in the summer (http://www.swfwmd.state.fl.us/). This area of the coast experiences small semi-diurnal tides (http://co-ops.nos.noaa.gov/). Values for the $\delta^{18}O_{water}$ values taken from the nearby Homosassa Springs are reported to be approximately −3.28‰ (Yobbi 1992) while open ocean values in the Gulf of Mexico are reported to be approximately 0.9‰ (Yobbi 1992). Both sites are located in a region known as the Springs Coast for its crystal clear waters and high biodiversity. During the Native American occupation of Crystal River and Roberts Island sea level fluctuated dramatically based on available data from surrounding regions of Florida and nearby states (Colquhoun and Brooks 1986; Tanner 1991, 2000; Walker 1992, 2013).

Crystal River is a 7-h site composed of extensive midden, one 8 m tall platform mound (Mound A), two flat-topped mounds (Mound H and K), two burial complexes (Mound G and Mounds C–F), a large plaza, and a few other, less well-defined mounds (Pluckhahn et al. 2010) (Figure 2). The neighboring site of Roberts Island is an anthropogenic shell island where extensive midden accumulation allowed for occupation of this otherwise marshy location at all tidal ranges (see Figure 2). Five separate sites comprise the whole complex of related sites and encompass approximately 2 ha; we collectively refer to these as Roberts Island. There are three platform mounds, mounded middens, and a large oval depression ringed with a high shell ridge. This latter feature is similar to the so-called water courts of southwest Florida (see Pluckhahn and Thompson 2017). For the current paper, we are primarily concerned with the midden deposits and the largest of the three platform mounds, which is a 4 m tall, rectangular, stepped mound with a ramp connecting the summit to the plaza-like area to the east (Pluckhahn et al. 2015; Pluckhahn et al. 2016). The Eastern oyster dominates the shell bearing landscapes at both Crystal River and Roberts Island.

The results from a recent Bayesian modeling program of 26 radiocarbon dates from both Crystal River and Roberts Island suggest that the best solution is a four-phase, sequential ordering that allows us to characterize the broader trends of social interactions (see Pluckhahn et al. 2015). Phase 1 has a modeled start date of *cal. AD 65–224* and end date of *cal. AD 143–265* (95% probability ranges). During this phase there is evidence for the onset of midden accumulation and for the start of activities in the area of Mound J at Crystal River. Phase 2 has a modeled start date for *cal. AD 221–321* and end date of *cal. AD 435–544* (95% probability ranges). During this phase, the inhabitants of Crystal River expanded the midden to its later J-shaped form and constructed two small platform

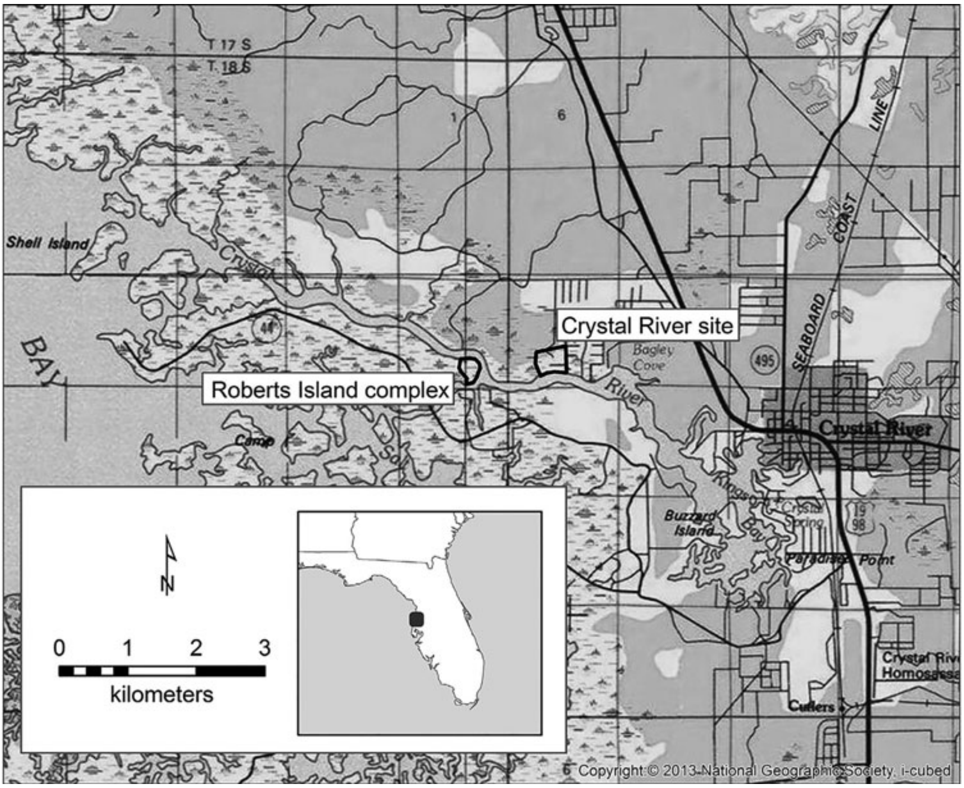

Figure 1. *Location of Crystal River (8CI1) and Roberts Island Shell Mound Complex (8CI36, 37, 39, 40, 41, and 576) on the Central Gulf Coast of Florida, USA (adapted from Pluckhahn et al. 2015:fig. 1).*

mounds, Mound H and K. Phases 1 and 2 roughly correspond with the latter part of the Roman Warm Period of AD 1–500 during which sea levels were rising and the climate was generally warming, interspersed with periods of slower sea-level rise and cooler temperatures; again the nature of these small-scale fluctuations and how they were manifested on the landscape is largely unknown (Ballsillie and Donoghue 2004; Walker 2013:39; Wang et al. 2013). Phase 3 has a modeled start date of *cal. AD 479–634* and end date of *cal. AD 663–809* (95% probability ranges). During this phase there is a contraction of the midden at Crystal River and initial occupation at Roberts Island. The settlement at Crystal River diminished; however, there may have been some final alteration of the largest platform mound, Mound A. Phase 3 is climatically characterized by cooler and drier climate regionally (Wang et al. 2013). It is also contemporaneous with a sea-level regression and higher climatic variability between AD 550 and AD 650 (Tanner 2000:93). Phase 4 has a modeled start date of *cal. AD 722–881* and end date of *cal. AD 890–1068* (95% probability ranges). During this final phase, the occupation at Crystal River continued to diminish, as Roberts Island rose to prominence as the primary ceremonial center of the region and continued the importation on nonlocal material. Phase 4 is also characterized by the construction of two of the three platform mounds and extensive midden accumulation at Roberts Island

Figure 2. *Site layouts of Crystal River (8CI1) and Roberts Island Shell Mound Complex (8CI36, 37, 39, 40, 41, and 576) (Pluckhahn et al. 2015; Thompson et al. 2015).*

(Pluckhahn et al. 2015). In terms of climate, this phase began with lowest sea level experienced by site occupants at around AD 850 (Walker 2013) and continued to warm to temperature at or above modern temperatures and sea level rising to approximately modern levels (Walker 2013:40).

The habitats surrounding Crystal River vary in temperature from around16°C in the winter to around 28°C in the winter (http://www.swfwmd.state.fl.us/). Also, they lack a seasonal periodicity in coastal salinity. These characteristics produce $\delta^{18}O$ seasonal oscillations within shell material consequent of water temperature as opposed to salinity. However, it is salinity that serves as one of the dominant controlling factors behind the distribution of molluscan species within an estuarine ecosystem (Dame 1996; Hudson 1990). Eastern oyster can tolerate low salinities anywhere from 5 to 10 psu and high salinities from 32 to 37 psu, open ocean salinity (Andrus and Thompson 2012; Eastern Oyster Biological Review Team 2007; Shumway 1996). Because they can tolerate such a wide range of salinities, the $\delta^{18}O_{water}$ values strongly influence $\delta^{18}O_{shell}$ values (see Surge et al. 2001, 2003). Because the salinity varies drastically between the habitats available for oyster exploitation around Crystal River we evaluate the $\delta^{18}O_{carbonate}$ for changes in salinity regimes (Evans et al. 2010; see Figures 2–3). Modern oyster beds can be found in close proximity to both sites (Evans et al. 2010:fig. 3.2-1).). The $\delta^{18}O$ profiles from *C. virginica* have been shown to oscillate seasonally in the southeastern US (Andrus and Crowe 2000; Andrus and Thompson 2012; Kirby et al. 1998; Surge et al. 2001, 2003; Thompson et al. 2015).

Laboratory and Analytical Methods

Laboratory methods follow those outlined in previous studies (Andrus and Crowe 2000; Andrus and Thompson 2012; Thompson and Andrus 2011, 2013; Thompson et al. 2015). Briefly, only left

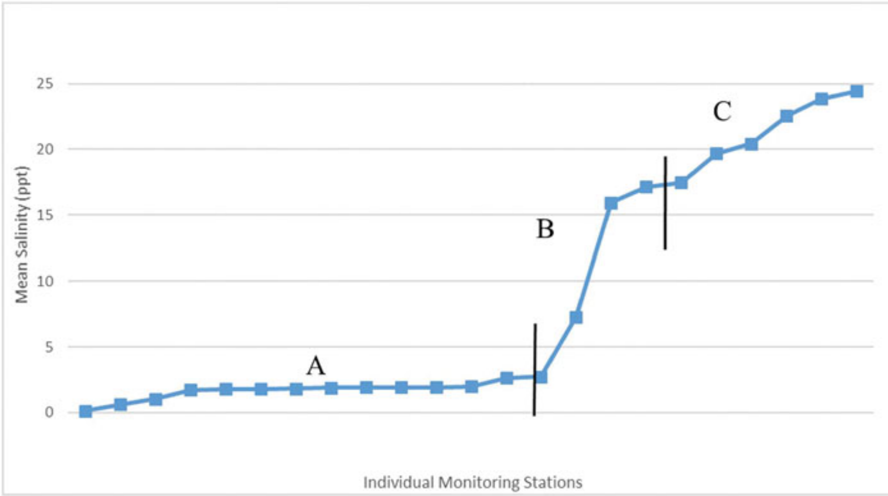

Figure 3. *Plotted local mean salinity. Represent the salinity gradient from data stations located with the Kings Bay (A) representing more freshwater environments, data stations located along the Crystal River (B) representing environments with intermediate salinity, and stations located within marsh/estuarine environments (C) representing those environments with higher salinity. The x-axis represents each individual monitoring station plotted in increasing mean salinity.*

valves with a complete chondrophore and void of epibiont activity in the shell interiors were selected for analysis (indicating live capture). Each shell was bisected along the chondrophore and mounted onto a slide with a Crystalbond™ thermal adhesive. Following this, shells were cut into ca. 1 mm thick sections using a slow speed diamond wafering saw. Those shells appearing fragile and prone to fracture were covered with a thin layer of metal epoxy (JB Kwik Weld) on the section of shell in contact with the saw blade (Schöne et al. 2005). This epoxy is not included in the sections of shell sampled.

On average we extracted 19 samples from each oyster following its ontogeny using a New Wave Merchantek micromilling system. Sampling avoided aragonite areas on the shell and only focused on the calcitic regions (Carriker and Palmer 1979). Each sample captured approximately one year or more worth of growth. Samples were taken immediately adjacent to each other equidistantly, typically between 300 and 350 mm and milled to a depth of between 300–400 mm. The powered carbonate samples were then weighed and loaded into 4.5 ml borosilicate vials.

All samples were analyzed for $\delta^{13}C$ and $\delta^{18}O$ using a Thermo Gas Bench II coupled with either a Thermo Delta V or Thermo Delta Plus isotope ratio mass spectrometer in continuous flow mode at the University of Alabama Stable Isotope Laboratory in the Department of Geological Sciences. The system was flushed with ultra-pure He prior to extraction; then we reacted each carbonate sample with orthophosphoric acid in the sealed vials at 25°C.

The values for each sample are reported in parts per mil (‰) relative to the VPDB standard by correcting to multiple NBS-19 analyses (typically 14) per run (Figure 4). NBS-19 was also used to assess and correct for drift and sample size linearity if needed. Average precision (1σ) of all runs was ±0.07‰ for $\delta^{13}C$ and ±0.1‰ for $\delta^{18}O$ as measured on each sample run (1σ range for $\delta^{13}C$ was ±0.02–0.19‰ and $\delta^{18}O$ was ±0.02–0.2‰).

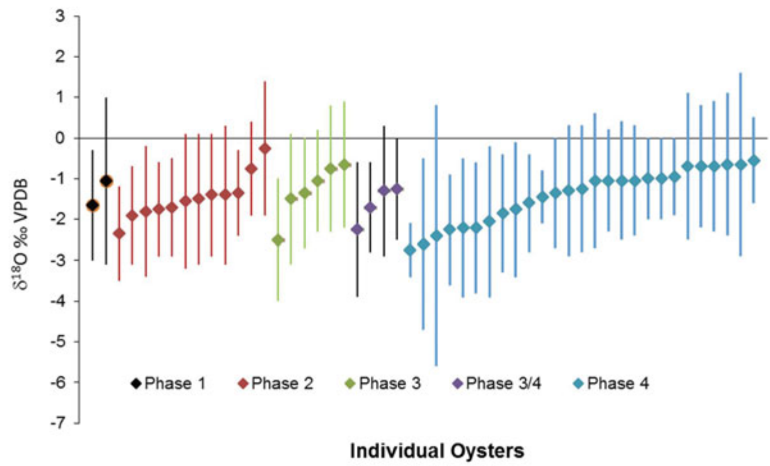

Figure 4. *Median $\delta^{18}O_{carbonate}$ values (nodes) and ranges (vertical bars). Y axis is $\delta^{18}O$ for individual oysters in ‰ relative to VPDB. Phase 1:* cal. AD 65–224–cal. AD 143–265*; Phase 2:* cal. AD 221–321–cal. AD 435–544*; Phase 3:* cal. AD 479–634–cal. AD 663–809*; Phase 4:* cal. AD 722–881–cal. AD 890–1068 *(all modeled dates here at 95% probability range).*

Predicted Salinities

In order to obtain the predicted oyster $\delta^{18}O$, we follow the methods previously outlined in Andrus and Thompson (2012) as informed by Epstein et al. (1953), Harding et al. (2010), and Surge et al. (2001). Equation (1) yields the predicted $\delta^{18}O_{water}$ values found in Table 1. Equation (2) represents a simple end-member model of the salinity/ $\delta^{18}O_{water}$ relationship so as to create a comparative model between the predicted salinities from the shell isotope data and the habitats surrounding Crystal River and Roberts Island. The data for the freshwater and oceanic $\delta^{18}O$ end-members were collected from the nearby Homosassa River, Halls River Springs, and the Gulf of Mexico (Yobbi 1992). Equation (2), using the predicted $\delta^{18}O_{water}$ values calculated from Equation (1), yields the predicted salinity values in Table 2.

(1)

$$\delta^{18}O_{water} = -\delta^{18}O_{carbonate} - 0.20 + (4.30 - (18.49 - 0.56^{*} \times (16.5 - T))^{0.5})/(0.28)$$

(2)

$$\text{Predicted Salinity(psu)} = (\delta^{18}O_{water} + 3.28)/0.05$$

RESULTS

In order to relate the shell oxygen isotope values to ancient habitats and in the absence of quantified paleo water quality data such as temperature, and salinity, modern published and quality controlled measurements were obtained from a total of 23 different stations managed by the Southwest Florida Management District and available online at http://www.swfwmd.state.fl.us (Figure 5). These sites were chosen to represent a diverse set of salinities in proximity to both Crystal River and Roberts Island. Eleven stations located in the Kings Bay were chosen to represent the more freshwater end member salinities. The other 12 stations were chosen for their locations along Crystal River and throughout the marsh environments for their representation of higher saline environments. In addition to modern water temperature and salinity data, freshwater and saltwater $\delta^{18}O$ value

Table 1. **Predicted Oyster $\delta^{18}O$ values for each site.**

Site	Dates	Location UTM	Mean T	1 σ	Mean Salinity (ppt)	1 σ	Dates	Predicted Oyster $\delta^{18}O$ Values
Kings Bay KBN2	1/18/2006–7/28/2015	28.8948, −82.5907	23.71	1.09	0.13	0.07	5/1/2007–5/23/2016	− 5.06
Kings Bay KBN1	8/14/2003–7/28/2015	28.8981, −82.5975	24.01	1.88	0.63	0.41	5/1/2007–4/14/2016	− 5.06
Kings Bay KBN3	1/18/2006–7/28/2015	28.8947, −82.5988	23.93	2.27	1.04	0.5	5/1/2007–4/14/2016	− 4.99
Kings Bay KBS8	1/19/2006–7/28/2015	28.8817, −82.5946	23.93	1.34	1.73	0.71	5/3/2007–4/14/2016	− 4.90
Kings Bay KBC7	1/19/2006–7/28/2015	28.8873, −82.5973	24.03	2.77	1.78	0.41	5/2/2007–4/14/2016	− 4.91
Kings Bay KBC6	1/18/2006–7/28/2015	28.8864, −82.6014	23.80	3.29	1.8	0.58	5/1/2007–4/14/2016	− 4.86
Kings Bay KBN5	1/18/2006–7/28/2015	28.8913, −82.6001	23.59	2.98	1.82	0.75	5/1/2007–4/14/2016	− 4.81
Kings Bay KBN4	1/18/2006–7/28/2015	28.8926, −82.6055	23.66	3	1.93	0.93	5/1/2007–4/14/2016	− 4.81
Kings Bay KBS10	1/19/2006–7/28/2015	28.8824, −82.5986	23.88	2.61	1.94	0.56	5/3/2007–4/14/2016	− 4.86
Kings Bay KBS11	1/19/2006–7/28/2015	28.8802, −82.6026	23.49	3.22	1.94	0.45	5/3/2007–4/14/216	− 4.78
Kings Bay KBS12	1/19/2006–7/28/2015	28.8809, −82.6067	23.20	4.14	1.99	0.44	5/3/2007–4/14/2016	− 4.71

(*Continued on next page*)

Table 1. **(Continued)**

Site	Dates	Location UTM	Mean T	1 σ	Mean Salinity (ppt)	1 σ	Dates	Predicted Oyster $\delta^{18}O$ Values
Crystal River NR Crystal River	6/28/1995–9/29/1998	28.9047, −82.6401	23.36	4.69	2.63	1.93	6/28/1995–9/29/1998	− 4.66
Crystal Citrus 4	11/14/1996–7/28/2015	28.9050, −82.6166	24.47	3.84	2.74	3.6	11/14/1996–7/18/2007	− 4.88
Crystal Citrus 3	11/14/1996–7/14/2015	28.9232, −82.6759	24.18	4.76	7.28	4.95	11/14/1996–7/18/2007	− 4.23
Crystal Citrus 7	11/14/1996–4/15/2015	28.8905, −82.6773	23.85	5.73	15.95	3.47	11/14/1996–7/18/2007	− 3.03
Crystal Citrus 10	11/14/1996–12/5/2004	28.8475, −82.6585	24.47	5.6	17.16	4.03	11/14/1996–7/18/2007	− 3.00
Crystal Citrus 2	11/14/1996–7/14/2015	28.9250, −82.7083	23.58	5.5	17.46	5.52	11/14/1996–7/18/2007	− 2.78
Crystal Citrus 6	11/14/1996–7/14/2015	28.8917, −82.7083	23.14	6.06	19.7	4.24	11/14/1996–7/18/2007	− 2.39
Crystal Citrus 9	11/14/1996–12/28/2004	28.8586, −82.7091	23.63	5.63	20.44	3.75	11/14/1996–7/18/2007	− 2.40
Crystal Citrus 8	11/14/1996–7/14/2015	28.8583, −82.7417	22.99	5.99	22.55	4.45	11/14/1996–7/18/2007	− 1.99
Crystal Citrus 1	11/14/1996–12/28/2004	28.9250, −82.7417	23.21	5.88	23.84	4.82	11/14/1996–7/18/2007	− 1.87
Crystal Citrus 5	11/14/1996–12/28/2004	28.8917, −82.7417	23.00	6.05	24.43	4.26	11/14/1996–7/18/2007	− 1.75

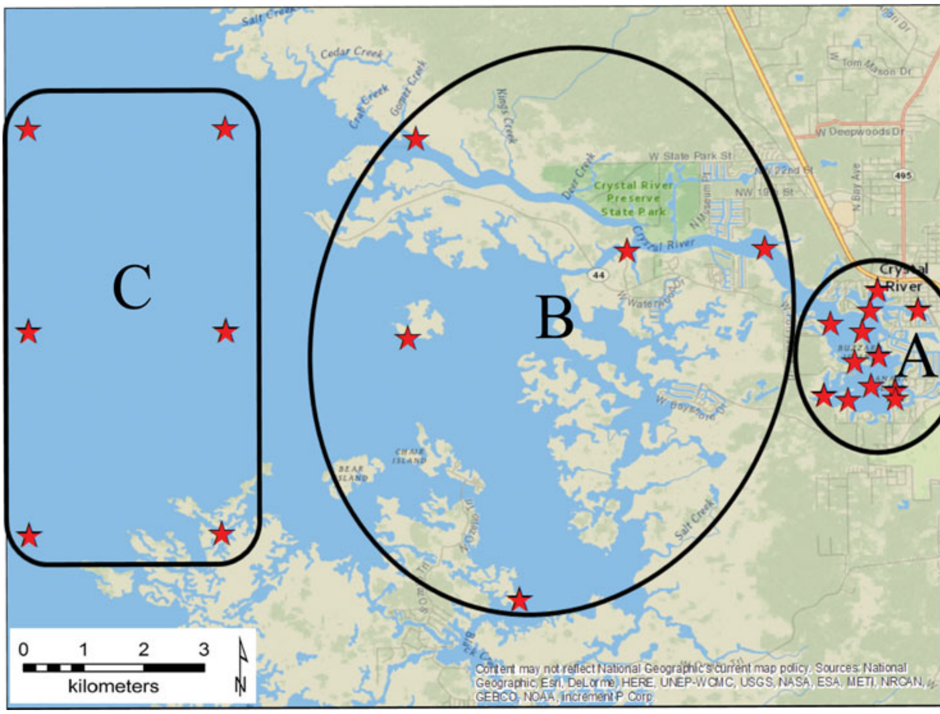

Figure 5. *Location of data stations monitored by Southwest Florida Water Management District used here. Data stations located with the Kings Bay (A), data stations located along the Crystal River (B), and stations located within marsh/estuarine environments (C).*

endmembers were used from the nearby Homosassa River, Halls River Springs, and the Gulf of Mexico. This allows us to create a model of the regional salinity/ $\delta^{18}O_{water}$ gradient in order to compare the habitats surrounding these sites with the shell recovered from both sites.

We interpreted the general trends in habitat of exploitation following the methods previously outlined in Lesure et al. (2009) and Andrus and Thompson (2012), specifically the use of the most negative $\delta^{18}O$ value in each oyster profile to estimate salinity, assuming summer growth cessation. This methodology operates under several assumptions in the absence of quantified paleo water temperature and $\delta^{18}O_{water}$ measurements. The use of modern data assumes a relatively constant $\delta^{18}O_{water}$/salinity gradient since the time of site occupation but provides the means with which to understand the overall differences in $\delta^{18}O_{carbonate}$ values of the samples. Using the expressed relationship between $\delta^{18}O_{carbonate}$, $\delta^{18}O_{water}$, and temperature as demonstrated in multiple isotope thermometry equations (e.g., Böhm et al. 2000; Epstein et al. 1951; Grossman and Ku 1986; Harding et al. 2010; Kirby et al. 1998), we are able to calculate predicted $\delta^{18}O_{water}$ measurements and predicted salinity measurements for the habitats from which the shells were collected. Because we consider the temperature to be almost consistent between the habitats, the differences between absolute values in $\delta^{18}O_{water}$ values calculated from the shells can be attributed to the different habitats from which the shells were collected. Based on the assumption that the $\delta^{18}O_{carbonate}$ values in the

Table 2. **Predicted summer $\delta^{18}O_{water}$ values (VPDB) following Equation (1) and predicted summer salinity values following Equation (2).**

Sample ID	Predicted δ^{18}O Water Values	Predicted Salinity
1206	− 3.25	1
5	− 3.15	3
302	− 3.15	3
696	− 2.95	7
1212	− 2.95	7
4	− 2.95	7
222	− 2.95	7
304	− 2.95	7
684	− 2.75	11
775	− 2.65	13
687	− 2.65	13
689	− 2.65	13
1209	− 2.65	13
13.00	− 2.65	13
121	− 2.45	17
11.04	− 2.45	17
1211	− 2.45	17
276	− 2.45	17
283	− 2.45	17
298	− 2.35	19
226	− 2.35	19
282	− 2.35	19
692	− 2.25	21
697	− 2.25	21
1207	− 2.25	21
219	− 2.25	21
279	− 2.25	21
2	− 2.05	25
221	− 2.05	25
284	− 2.05	25
11.03	− 1.95	27
225	− 1.95	27
272	− 1.95	27
12.02	− 1.85	29
13.03	− 1.85	29
6	− 1.85	29
220	− 1.85	29
287	− 1.75	31
8	− 1.65	33
11.05	− 1.45	37
690	− 1.45	37
13.02	− 1.45	37
7	− 1.45	37
288	− 1.45	37
280**	− 1.35	39
223**	− 1.15	43

(*Continued on next column*)

Table 2. **Continued**

**denotes predicted salinity outside of modern measurements and predicted salinity outside the range for modern *Crassostrea virginica*.

shells represent habitat-specific $\delta^{18}O_{water}$, the results indicate oyster exploitation from habitats widely ranging in salinity. All predicted salinities except for those marked in Table 2 fall within the measured salinities of the modern habitats that surround both sites. Additionally, the predicted salinities fall with the salinity tolerance ranges of modern specimens, with those falling outside the range demarked with Table 2 as well. The general trend in Phases 1 and 2 suggests the oysters were collected primarily from habitats located in areas of lower salinity, or rather more inland (Figure 6). The predicted salinities of the oysters from Phase 3 and Phase 4 suggest the oysters were primarily collected from a wider range of habitats located in areas of comparatively higher salinity and lower salinity (Figure 6).

In splitting up the predicted salinities into the different phases, there arises an overall trend for an exploitation of habitats representing higher salinity environments, while exploiting diverse saline habitats. This trend is best represented in the data from Phases 3 and 4 and mirrors the downriver and seaward shift in occupation from Crystal River to Roberts Island. This observation finds further support in

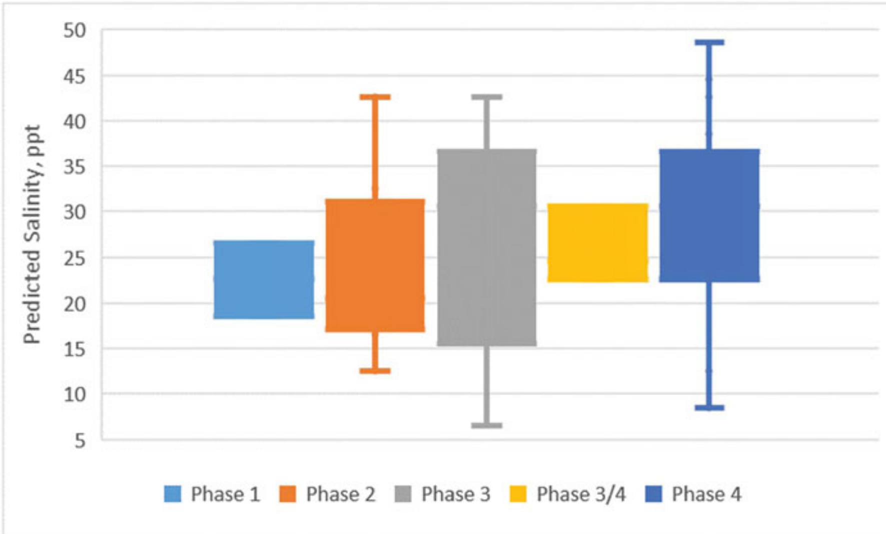

Figure 6. *Predicted shell salinities through time depicting higher predicted salinity of habitat later in site occupation during Phases 3 and 4.*

Sampson's (2015) analysis of oyster taphonomy which notes an increased presence of boring sponge perforations on shell samples from Roberts Island.

As Phase 4 is well represented, we further subdivided the isotopic data from oysters and examined trends from different areas of these sites and separated them generally into midden and mound contexts (Figure 7). The results from midden samples indicate that a wider range of $\delta^{18}O$ values are represented in these data, and thus a wider range in predicted salinity values. Mound samples represent a smaller portion of the predicted salinities and thus came from a more restricted range of habitats. Thus, the general trend is that oysters used in mound construction come from a more restricted habitat range than oysters collected for general, and by extension, more everyday consumption.

DISCUSSION

The predicted values in Table 2 should be carefully considered as trends as opposed to using these calculations to establish direct relationships to specific environments. The reason for this is that many factors play a role in the compounding calculations performed here. This uncertainty in the changes in the local relationship between the $\delta^{18}O_{water}$ and salinity can include the sampling resolution, analytical precision, and the degree of homogeneity between river systems. For example, climate change likely has affected the overall relationship between salinity and $\delta^{18}O$. A change to the net input of freshwater, in combination with local climatic variation also has the potential to affect these values. Even small fluctuations could have an effect on the numerical values of the predicted salinities. Nevertheless, these results do provide a means by which to examine broad-scale trends in habitat collection practices.

Our evaluation of the stable oxygen isotopes from both Crystal River and Roberts Island has led us to new insights regarding the nature of the subsistence practices in the region. In our previous research we note that there was a distinct difference in the season of collection of mollusks

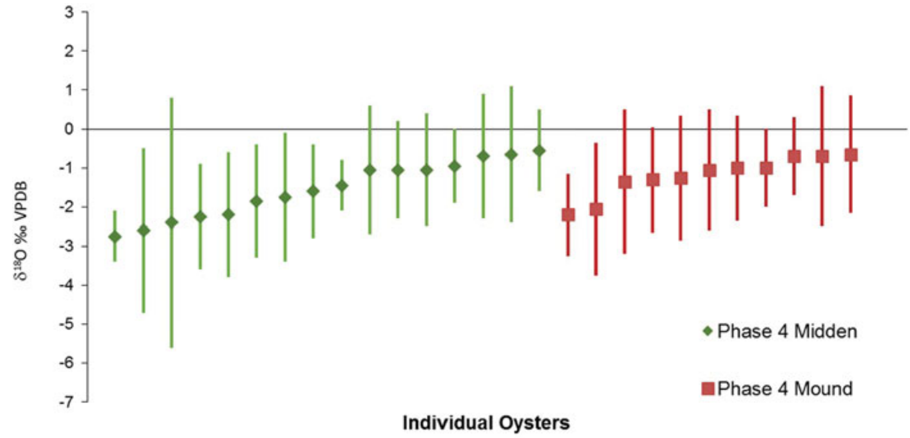

Figure 7. *Median $\delta^{18}O_{carbonate}$ values (nodes) and ranges (vertical bars) for Phases 3 and 4. Y axis is $\delta^{18}O$ for individual oysters in ‰ relative to VPDB.*

between mound and midden context; this was especially pronounced at Roberts Island (Thompson et al. 2015). In addition, our research indicates major shifts in primary site function over time at Crystal River, shifts in architecture and site layout, to the abandonment of Crystal River and the emergence of Roberts Island (Pluckhahn and Thompson 2017; Pluckhahn et al. 2015). The results presented in this paper add yet another dimension to these patterns and allow us to speak broadly to shifts in how the patterns of daily life might have been affected by climate change, as well as how periodic rituals and monument construction may have been financed and supported by surplus collection of oysters. Here, we define surplus as the abundance in a resource, after subsistence needs are met, used in the construction of monuments directly or indirectly, likely partially as a result of feasting events. In what follows, we weave these new insights into a summary of observations based on our previous research at Crystal River and Roberts Island.

Broadly we argue in two other papers that the large-scale collection of oyster resources at Crystal River was first predicated on the anticipated surplus of oysters for rituals associated with mortuary rites. Over time these patterns shifted to year-round occupation of the Crystal River site (Pluckhahn et al. 2015; Thompson et al. 2015) and can be expanded upon with the data presented here. Mortuary rituals and ceremonies continued to occur; however, the inhabitants began to construct new forms of architecture—platform mounds. The forms of these platform mounds are quite variable: Mounds H and K at Crystal River are relatively small, while Mound A is quite large (Pluckhahn et al. 2010); Mounds H and A had ramps providing access to their summits while Mound K apparently did not. Their constructions also vary considerably: Mound H exhibits alternating shell and sand layers, while Mounds A and K are comprised principally of shell (Norman 2014; Pluckhahn et al. 2010; Thompson and Pluckhahn 2010). As Roberts Island supplants Crystal River as the ceremonial center, builders do not construct mounds at the same scale as they did at Crystal River, opting for smaller yet still elaborate constructions at this new location. Specifically, two mounds at Roberts Island exhibit a stepped pyramid form, a shape unrecognized anywhere else in the Eastern Woodlands, and are comprised almost entirely of shell (Pluckhahn et al. 2016). The way in which the populations at both sites relate the anticipated surplus of oysters with the ritual and mortuary feasts and site construction is only further explained through the trends seen in oyster collection practices elucidated here.

While we do not have the data to speak to trends in the early phases of Crystal River (Phases 1 and 2), we can offer some observations for the final phase of occupation at Crystal River and the subsequent shift in activities to Roberts Island. Specifically, in the later phases (Phases 3 and 4) of occupation at Crystal River and Roberts Island the data presented here suggest to us that there was a trend in gathering oysters from specific habitats for mound construction activities, and likely feasting, during specific times of the year. Our previous research indicates that at both sites the vast majority of the oysters sampled from the mounds exhibit a cool or cold weather season of collection, while oysters from the midden areas exhibit multiple seasons of collection (Thompson et al. 2015). Interestingly, the results here indicate that habitat of exploitation for the oysters recovered from mound contexts is more restricted, as opposed to a wider range of saline environments in general. We attribute this, in part, to large-scale changes in the availability of oysters to beds closer to the Gulf of Mexico due to a sea level lowering during the time Crystal River was abandoned and Roberts Island rises to prominence (see Thompson et al. 2015).

The trends that we describe above have import for how we interpret mound construction in the context of large-scale change in the environment. Certainly, Crystal River itself started off as a special place on the landscape, likely due to the fact that certain resources could be anticipated from year to year that was required for attendant ceremonies that accompanied mortuary rituals (i.e., certain types of food, mainly oysters). The shifts in the seasons of occupations to the emergence of year-round village and mound center played a large part in shifting the practices of villagers and those who may have participated in the ceremonies at the site. Due to large quantities of anticipated surplus, villagers were able to establish oyster collection practices at distinct locations based on the occasion of consumption. We suggest that the single seasonal collection in cool weather months and their concomitant mounding into elaborate architecture may have served as community-building events commemorating and ritually disposing of remains from the harvest (see Thompson and Moore 2015:257).

It may be that the accessibility of new oyster beds played a role in the season-specific practices of elaborate mound construction or perhaps oysters from higher saline environments had some ritual significance for such practices. Alternatively, it could simply be the case that such beds were more productive/larger than their counterparts, and thus afforded easier collection of surpluses. Whatever the case, the focus on specific habitats during certain times of the year would have structured and reinforced a standard ritual calendar, so to speak, as such communities in the surrounding region and host populations occupying Crystal River and subsequently Roberts Island would have been able to anticipate large gathering events. Such gathering at specific times of the year and the resulting large-scale architecture that resulted from these practices may also have served to remind the community of harvest's past and also provide a goal for ceremonies to come. McNiven (2013) suggests that Torres Islanders make a connection between the production of food supply and the contents of mounded middens. In fact, he states that such middens were visual reminders of the historical continuities with the "social lives of their ancestors" (McNiven 2013:576; McNiven and Wright 2008:145). We believe that something similar to the processes and beliefs he outlines may be operating in our study area as well.

CONCLUSIONS

In this paper, we use several lines of evidence to evaluate the occupational periodicity of Crystal River and Roberts Island to address questions regarding the nature of long-term trends of oyster collection. Our revaluation of the oxygen isotope data from these sites provides new insight into the nature of habitat exploitation in the context of both larger scale environmental changes and its importance to specific cultural practices; in this case, mound construction. Our previous studies of reevaluating isotopic data to reconstruct past patterns of habitat exploitation on Sapelo Island, Georgia, focused mostly on the nature of mobility to aid in sustainable collection practices (Andrus and Thompson 2012; Thompson and Andrus 2013). Our work here illustrates yet another aspect of how such data can lend insight into cultural transitions that may not directly link into everyday subsistence economies. While certainly the mounds of the Crystal River region present a somewhat unique opportunity to evaluate these specific questions, we nevertheless argue that evaluating habitat exploitation in this way provides a powerful tool when combined with other datasets to explore and provide more detailed evaluations of how shellfish, to use Meehan's (1982) terms, get from the shellbeds to the shellmiddens, or in this case mounds.

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