Journal of Archaeological Method and Theory
https://doi.org/10.1007/s10816-023-09613-w

RESEARCH

The Beginning of the End: Abandonment Micro-histories in the Mississippian Vacant Quarter

Charles R. Cobb[1] · Anthony M. Krus[2] · Aaron Deter-Wolf[3] · Kevin E. Smith[4] · Edmond A. Boudreaux III[5] · Brad R. Lieb[6]

Accepted: 5 June 2023

Abstract

In a poorly understood yet recurring phenomenon, communities occupying diverse settings within a region may undertake large-scale migrations that cannot be easily attributed to single variables such as climate change. As a result, the study of these movements has increasingly focused on the distinct histories of localities to address how they may have articulated as large-scale abandonments. We adopt this micro-history perspective on the fourteenth to fifteenth century depopulation of a large portion of the North American Midwest and Southeast, popularly referred to as the Vacant Quarter. Our research on the Middle Cumberland drainage within the Vacant Quarter suggests that a significant exodus began slowly ca. 1300 CE; then, it accelerated extremely rapidly in the first half of the fifteenth century CE. This genesis of this trajectory seems to be related to a pattern of severe droughts, but it was brought to a close by social and demographic challenges such as endemic conflict and adverse health conditions.

Keywords Vacant Quarter · Drought · Abandonment · Mississippian Period · Tennessee

✉ Charles R. Cobb
ccobb@flmnh.ufl.edu

[1] Florida Museum of Natural History, University of Florida, Gainesville, FL, USA

[2] Department of Sociology and Anthropology, University of South Dakota, Vermillion, SD, USA

[3] Tennessee Division of Archaeology, Nashville, TN, USA

[4] Department of Sociology and Anthropology, Middle Tennessee State University, Murfreesboro, TN, USA

[5] Anthropology and Middle Eastern Cultures, Mississippi State University, Starkville, MS, USA

[6] Department of Culture and Humanities, The Chickasaw Nation, Ada, OK, USA

Published online: 29 June 2023

Following the British defeat of General Erwin Rommel's German forces at the battle of El Alamein in north Africa during WWII, Winston Churchill famously remarked: "Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning." In this rich chronological turn of phrase, Churchill underscored questions archaeologists want to answer about dramatic end-times (often characterized as collapse)—not only when they occurred, but why they occurred and what were circumstances like beforehand? Furthermore, how were those conditions experienced by people, and was it apparent to them that an irreversible and steep decline was in store? And how is it evident to archaeologists that the beginning of the end was nigh?

These issues are particularly salient for regional abandonments. There are many examples worldwide of large-scale depopulations, ranging from Copper Age western Iberia (Lillios, 1993) to Bronze Age Mesopotamia (Weiss *et al.,* 1993) to the European Neolithic (Downey *et al.,* 2016). These represent only a fraction of what seems to be a common phenomenon. Their recurrence seems to have a particular hold for archaeology. If regional abandonments were exceedingly rare, it would perhaps be easier to attribute them to somewhat obvious forcing variables—climatic shifts like the Little Ice Age or abrupt geophysical events such as volcanic eruptions. While social upheaval and regional abandonments do sometimes follow such external perturbations, however, they just as often do not (Hegmon *et al.,* 2018; Kintigh & Ingram, 2018; Sandweiss & Maasch, 2022; Scheffer *et al.,* 2021). In short, sizeable depopulation episodes represent a highly intriguing quandary: Their frequency would seem to speak to some kind of underlying general principles, yet their apparent variable and unpredictable multi-causality is suggestive of a historically idiosyncratic character.

Much of the research on regional abandonments over the last three decades, particularly in the North American Southwest—title to the most dedicated and systematic study of these phenomena anywhere—has increasingly focused on the local and the contingent. General correspondences between massive droughts and significant regional depopulations have been well documented in the Southwest (Cordell, 2000; Lekson & Cameron, 1995; Schlanger & Wilshusen, 1993; Schwindt *et al.,* 2016; Van West & Dean, 2000; Varien, 1999). But archaeologists in that region have also refined in detail the ways by which neighboring communities and sub-regions may have differentially experienced and mediated circumstances leading up to their departures—including variation in the actual act of leaving itself (*e.g.,* Fish & Fish, 1993, p. 99; Schlanger and Wilshusen, 1993, p. 85; Schwindt *et al.,* 2016, p. 74).

Our ongoing research on a very large-scale depopulation of the American midcontinent in the fourteenth and fifteenth centuries AD, popularly referred to as the Vacant Quarter (a term coined by Stephen Williams [1990]), emphasizes the trend toward local nuance. This vast area stretched from the Central Mississippi River Valley eastward to the Middle Cumberland drainage of central Tennessee and southward to the Middle Tombigbee drainage in eastern Mississippi (Fig. 1). Like the Southwest, the abandonment was associated with a series of severe, multi-decadal droughts. Yet research on Vacant Quarter micro-histories is still in its infancy and we have a poor grasp of how an apparent large-scale process may have been composed of intertwined paths. Our work in the Middle Cumberland drainage region (MCR) of Tennessee serves as an initial exploration in that direction. We are interested in two issues in particular. First, is it possible to demarcate the beginning of

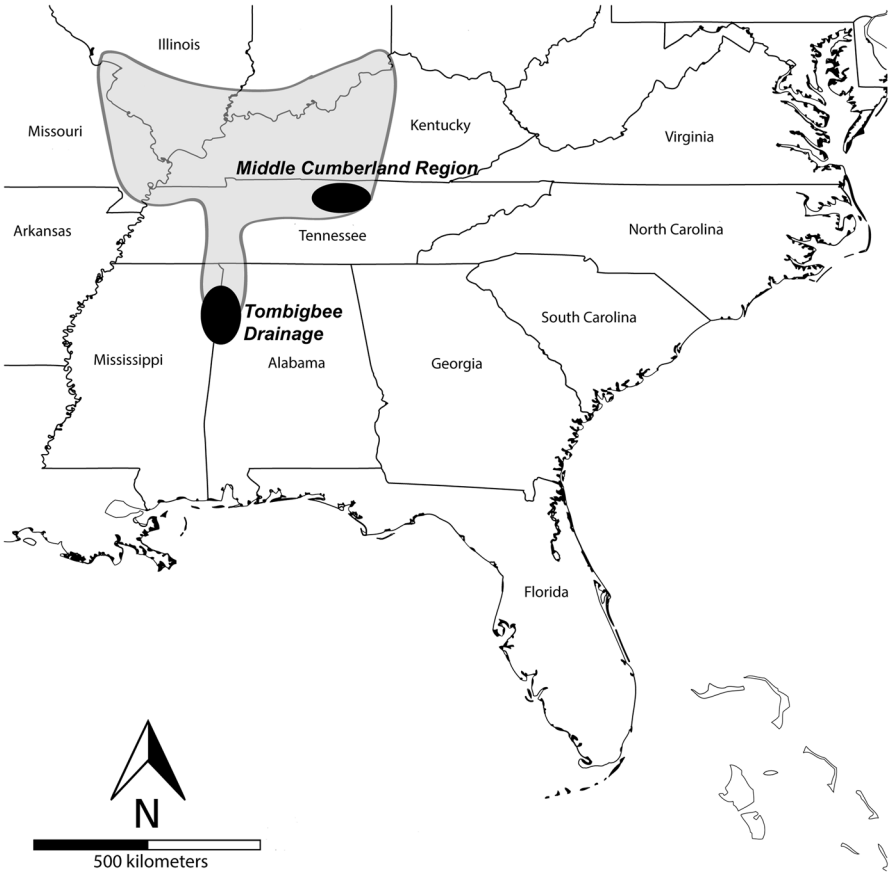

Fig. 1 Vacant Quarter and study areas

the end and the relative tempo of that final abandonment? Second, what were conditions like for communities on the cusp of departure? Our ability to satisfactorily address such questions across multiple areas of the Vacant Quarter eventually will provide the basis for addressing how local histories articulated across a large region could foster a depopulation of unprecedented magnitude in eastern North America.

Micro-histories and Regional Abandonments

Some discussion of definitions is useful prior to entering the core of our study. Because depopulation occurs at various scales, our notion of *regional* for eastern North America refers to—at a minimum—a lengthy stretch of a drainage, on the order of 50 km or so. We rely on a drainage as one kind of a region because of the ubiquity of waterways in eastern North America and the propensity for human populations to map onto these settings. Alternatively, we would apply the same

approximate minimal metric to the diameter of a general polygon encompassing multiple environmental zones (which describes the Vacant Quarter). This is a somewhat arbitrary definition that attempts to impart a sense of geography to the notion of large scale.

The term *abandonment* has come under critical scrutiny for various reasons. It can imply a certain sense of failure or relinquishment of the occupation of a region, when it is more properly viewed as a strategy of resilience (Nelson & Schachner, 2002, pp. 168–169). Groups opt for new locations to maintain their social cohesion even if that comes at the cost of transformation. In fact, abandoned regions may be re-occupied at some point even if not within the lifetimes of the emigrants. Furthermore, *abandoned* may connote a complete evacuation. As is often the case, however, small numbers of people may remain in a region otherwise depopulated of its major settlements. Alternative terms that have been advanced, such as depopulation, do not seem to be immune to the same criticisms, though. So, we retain the use of the term abandonment here, with appropriate caveats concerning human intentionality and complete disappearance from the landscape.

The micro-history approach toward regional abandonments emphasizes the social and cultural intricacies of proximate causality, while not dispensing with issues of ultimate causality that may be more Malthusian in nature. It is well-documented, for example, that the desertion of large portions of the American Southwest over the last millennium—notably, the northern San Juan, Mimbres, and Hohokam regions—was preceded by excessive dry periods that likely undermined the subsistence economies of the agriculture-dependent towns (Cordell, 2000; Kintigh & Ingram, 2018; Lekson & Cameron, 1995; Schlanger & Wilshusen, 1993; Schwindt *et al.,* 2016; Van West & Dean, 2000; Varien, 1999). Similar observations have been made for abandonments elsewhere worldwide (*e.g.,* Jacobson *et al.,* 2022; Lillios, 1993; Rosen, 2007). Yet the size and diversity of the affected regions present a paradox: How does one reconcile mono-causal, climatic arguments for the desertion of a large area that may be characterized by a wide spectrum of social and ecological environments (Lillios, 1993, p. 180)?

In an attempt to resolve issues of scale and causality, a number of Southwestern archaeologists have made the argument that regional abandonments should be viewed as nested occurrences that are best apprehended through smaller scales of analysis defined by physiographic or social modalities such as river valleys or even individual communities (*e.g.,* Cordell, 1998; Fish & Fish, 1993, p. 99; Schlanger and Wilshusen, 1993, p. 85; Schwindt *et al.,* 2016, p. 74). Rosen (2007) has made a similar suggestion for the Near East. From this perspective, it is possible to address how variables such as demography, subsistence, conflict, disease, ecology, and social organization may have varying degrees of sensitivity to climate change or other major external stressors. In turn, such variables can be conceived of as a mix of proximate prompters that initiate local abandonments in ways phrased as rationalized actions. Advocacy for a spatial condensation in analytical scale has been accompanied by a call for a particular focus on the beginning of the end, where attention is directed toward the period immediately before departure and a search for waxing vulnerabilities and warning signs that conditions were amiss (Glowacki, 2010, 2020; Nelson & Schachner, 2002; Nelson *et al.,* 2014; Spielmann *et al.,* 2016) (although Scheffer *et al.,* 2021 warn that

"internal" social signs may not always be evident). Such signs might include, but are not limited to, conflict (fortifications, bodily trauma), concerns with defense (population aggregation, strategic placement of communities), disease (crowd infections and nutritional distress), and adverse impacts to subsistence (narrowing of diet breadth). As Glowacki (2020, p. 27) argues, "it is the intersectionality of the varied stressors and enablers at multiple scales and how they change over time that create the dynamics of leaving."

While these evolving perspectives on abandonment are still working to close the scalar gap between micro-histories and their expression as regional abandonments, they have added considerable insight into the varying nature of well-known depopulation episodes. Hill *et al.,* (2004) note that the putative disappearance of the Hohokam culture in southern Arizona ca. CE 1450 has all the appearance of a collapse or catastrophe. But their research in the lower San Pedro Valley illustrates a dynamically oscillating history marked by considerable immigration, coalescence, and aggregation into larger (but fewer) settlements in the 1200 s. This was followed by a complex process of gradual depopulation beginning in the mid 1300 s that was complete by the mid 1400 s. Rather than a dramatic en masse emigration, the Hohokam disappearance—at least in this drainage—was manifested as a humble departure of a remnant population. To the northwest, it is possible that the modern Akimel O'odham in the Phoenix Basin represent an unbroken continuum of the Hohokam. Post-Classic settlements in that region, however, have traditionally been difficult to identify because of their more ephemeral nature, although there do seem to be strong continuities in material culture. Thus, the idea of a Hohokam "collapse"—at least in this region—may be overstated (Loendorf & Lewis, 2017; Ravesloot *et al.,* 2009).

Adopting a similar granular approach to abandonment in the Mesa Verde region to the north, Glowacki (2010) believes that the process began with a gradual movement of peoples from the western to eastern Mesa Verde sub-regions in the early 1200 s, with a massive exodus from the latter area occurring in the late 1200s CE. Similar variable patterns have been documented for the well-known "collapse" of the Classic Maya in Mesoamerica. What was once thought to be a broad and encompassing depopulation and social decline occurring within a relatively brief period is now recognized as a variegated phenomenon at least 300 years in the making. Depopulation hit the Lowland Maya area particularly hard, yet varied dramatically over the larger Maya region. In fact, a number of major centers continued to thrive until the European colonial era (Aimers, 2007; Turner & Sabloff, 2012).

All of the preceding studies note that climatic variables seem to play some triggering role in the processes leading to regional abandonment. At the same time, they emphasize that the application of a micro-history lens to episodes of depopulation reveals extremely complex human interventions and interactions that may vary widely between adjoining sub-regions, and even within the same locality. Moreover, the tempo of abandonment within any one area may change over time, also as a result of multi-causal factors. It is with these conclusions in mind that we have initiated our own long-term research on micro-histories of abandonment in the Vacant Quarter.

The Vacant Quarter and the MCR

Stephen Williams (1983, 1990) defined the Vacant Quarter through a remarkable bit of archaeological sleuthing that relied on a combination of artifact horizon markers, ceramic seriations, and very coarse radiocarbon dates. He estimated that a significant portion of the North American Midwest and South was largely vacated by sedentary groups in the interval of ca. CE 1450–1550 (Fig. 1). Although there originally were some skeptics (notably Lewis, 1986, 1990), subsequent studies have supported Williams's hypothesis (Benson *et al.,* 2009; Cobb & Butler, 2002; Krus & Cobb, 2018; Meeks & Anderson, 2013). The notion that climate change was somehow implicated in this exodus has been supported by data from the Palmer Drought Severity Index (PDSI),[1] which suggests that a series of severe multi-decadal droughts struck the Southeast beginning sometime in the thirteenth century CE (E. R. Cook *et al.,* 2007; B. I. Cook *et al.,* 2014, p. 388). The eastward shift of these droughts through the 1200 s and 1400 s (Cook *et al.,* 2007, p. 112) also corresponds to the archaeological record of depopulation. Whereas Cahokia and the American Bottom region in the central Mississippi River valley were largely vacated by around CE 1300 (Benson et al., 2009), the MCR to the east was abandoned over a century later (Krus & Cobb, 2018). In the interests of balance, though, it should be pointed out that the interval of CE 1000–1100, a time when Mississippian cultures seemed to be expanding in the Southeast, also appeared to be characterized by severe droughts in many localities (Cook *et al.,* 2014, p. 388). This simply reinforces the fuzzy correspondence between inclement climate and population relocations (Kintigh & Ingram, 2018).

The sheer size and diversity of the Vacant Quarter abandonment presents a major challenge in explaining its causes, consequences and variability. It contains some of the largest drainages in eastern North America, including portions of the Mississippi, Ohio, Tennessee, and Cumberland Rivers. Prior to the 1400s, these areas contained large Mississippian period (ca. CE 1000-1600) settlement systems, characterized by sizable towns, common traditions of iconography, major investments in mounds and other earthworks, complex political systems equated with chiefdoms, and a strong reliance on maize agriculture (Blitz, 2010; Cobb, 2003). Moreover, Mississippian communities successfully radiated into a variety of interior settings within the Vacant Quarter, ranging from prairie to rugged uplands (*e.g.,* Boudreaux *et al.,* 2020; Butler & Cobb, 2004; Pauketat, 2003). Added to the diversity in settlement settings, there was considerable variation between polities in terms of size, demography, political complexity, dependence on maize, and basic elements of material culture. In itself, these kinds of distinctions would seem to argue for the likelihood of differential responses to external stressors of any kind. As Steponaitis (1991) has observed, Mississippian regions across the Southeast could experience

[1] The PDSI relies on temperature and precipitation values derived from tree-ring reconstructions to estimate variation in soil moisture (https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi). Various aspects of this scale have come under critique (*e.g.,* Alley, 1984; Blain and Xavier, 2019). Nevertheless, it is effectively the best general guide available to archaeologists for paleoclimate assessments o3ver the last millennium in the American Southeast.

dramatically divergent political trajectories even within similar environmental settings. Complex and contingent mixes of chiefly strategies of mobilizing labor, long-distance exchange, and unpredictable relations with neighboring polities played an important part in shaping distinctive Mississippian communities and polities. What could account for such a broad range of societies occupying so many kinds of ecozones to depart such a vast area?

Further complicating the origins of the Vacant Quarter, we now know it was not an isolated instance of abandonment. Since the publication of Williams's original thesis, broadly contemporary abandonments elsewhere in the Southeast have been documented. These include the Yazoo Basin in Mississippi (Williams, 2001), much of the Savannah River drainage between South Carolina and Georgia (Anderson, 1994; Ritchison & Anderson, 2022), and a significant portion of the Carolina coast (Cable, 2020). Hypotheses to account for these depopulations vary. Ritchison and Anderson (2022) believe climate change was a strong impetus for the exodus from the middle Savannah drainage. For the Carolina coastal region, Cable (2020, p. 205–208) has advanced the novel idea that deadly hemorrhagic fever epidemics may have been promoted by dry/wet cycles when rodent populations (the primary vector) boomed during periods of abundant precipitation following severe droughts.

The picture that has now emerged is one where the lower Midwest and Southeast experienced temporally overlapping regional abandonments of varying size; these ecologically heterogeneous regions seem to have been largely, if not completely, depopulated; and the populated areas in-between sustained thriving Mississippian cultures in settings very similar to the ones that were abandoned. Although one cannot discount the likely importance of severe and protracted droughts in triggering these abandonments, it is difficult to account for this mosaic in climatic and environmental terms alone.

The MCR is in the easternmost portion of the Vacant Quarter (Fig. 1). It was home to a large number of Mississippian sites distributed across an area encompassing about 50 km north–south and 70 km east–west. These ranged from one- to two-structure hamlets to large, multi-mound centers. Because so many of these sites were severely damaged or destroyed by the growth of the city of Nashville, it is difficult to ascertain the scale and density of settlement. Perhaps the best proxy of the impressive demography of the Mississippian presence is the huge volume of stone box graves that once populated the region, a burial tradition characterized by the interment of individuals within a crypt composed of stone (usually sandstone) slabs. Nineteenth-century accounts describe thousands of these mortuary features scattered across the landscape, suggesting a high population density for at least a portion of the Mississippian period (Jolley, 1983).

Following a fairly abrupt appearance of large mound centers in the eleventh and twelfth centuries CE, the population likely peaked in what Moore and Smith (2012, p.208) define as Regional Period III, a proliferation of chiefdoms occurring from about CE 1200 to 1325. They describe the subsequent Regional Period IV (CE 1325–1425) as a period of decentralization and demographic fragmentation, where earthwork construction came to a halt and populations aggregated into autonomous, fortified towns containing sizable cemeteries (Moore & Smith, 2012 , p. 208–210). Based on a limited number of radiocarbon dates, Moore and Smith (2012 , p. 201)

Table 1 Number of radiocarbon dates per site

Site name	Existing dates	Original sample	Dates needed*	New dates obtained
Averbuch	17	17	20	
Brentwood Library	46	8	25	29
East Nashville Mounds	13	13	10	
Gordontown	18	2	10	16
Kellytown	13	N/A		13
Rutherford-Kizer	15	15	15	
Sellars	37	10	40	27

*Additional dates needed to supplement original sample to estimate abandonment within 50-year span at 68.2% probability

presciently hypothesized that abandonment of the region likely occurred in the interval of CE 1425 to 1475 (Regional Period V). This estimate conformed well with our later Bayesian modeling of 74 legacy radiocarbon dates from six late towns, indicating that the final depopulation of the MCR occurred in the late 1400s to early 1500s CE (Krus & Cobb, 2018).

Towns dating to Regional Periods IV and V display considerable evidence of social unrest. They were invariably surrounded by stout wooden palisades punctuated by bastions. Ongoing concern with maintaining these fortifications is demonstrated by episodes of rebuilding original lines or else expanding or contracting new defensive perimeters (Barker & Kline, 2013, pp. 79–90; Moore, 2005, pp. 47–48; Moore *et al.,* 2001, pp. 49–53). Bioarchaeological data parallel the architectural evidence for endemic warfare, expressed regionwide in skeletal signatures of scalping, blunt-force trauma (*e.g.,* depression fractures), and sharp-force trauma (*e.g.,* projectile wounds) (Cobb *et al.,* 2015; Worne *et al.,* 2012). The incidence of trauma increased through time, but that includes evidence for inter-personal as well as intergroup conflict (Worne, 2017). It seems that intra-community friction was one of the major costs of living in nucleated towns. Taken together, these various lines of evidence suggest that the MCR appeared to be undergoing considerable social tumult prior to its depopulation.

Modeling the Decline and Fall

Our more refined analysis of the decades preceding abandonment of the MCR is predicated on two elaborations of standard approaches to Bayesian modeling of chronometric data. First, the simulation experiment in our original study (Krus & Cobb, 2018) indicated that we would need to add scores of additional samples to achieve a satisfactorily tight chronological confidence interval surrounding final abandonment (in the range of 50 years), with posterior probabilities in the 68% (Table 1). Our current study thus incorporates larger sample sizes as a result of the

simulation study.[2] Unfortunately, we were unable to fully achieve our numerical benchmarks due to shortfalls in adequate botanical remains, but our revised Bayesian models did provide significantly more precision to our abandonment estimates. Second, we have conducted a sensitivity analysis based on trapezium boundaries (discussed in detail below) that allows us to estimate when a steep population decline likely occurred.[3]

The calibrated date ranges for modeling were calculated using the terrestrial calibration curve of Reimer *et al.,* (2020) and OxCal v4.4 (Bronk Ramsey, 1998, 2009a). These models follow the structure of the OxCal models presented in Krus and Cobb (2018) and each uses a single set of Boundaries to structure the radiocarbon measurements as being from a discrete period of activity. Sequences were created in these phases to reflect the stratigraphic ordering of the radiocarbon samples (as described in Krus & Cobb, 2018). Additionally, we have further applied chronological hygiene considerations to this dataset through the combination of Charcoal Outlier Modeling (Bronk Ramsey, 2009b; Dee & Bronk Ramsey, 2014; Krus *et al.,* 2019),[4] the exclusion of other samples likely suffering from appreciable offsets, and the modeling of certain contexts as *Termini Post Quos* based on archaeological taphonomic considerations. The underlying uniform prior distribution of the model follows the OxCal defaults and assumes that any event in the model is equally likely to have occurred in any individual year covered by the data (Bronk Ramsey, 1998, p. 470). The A_{model} agreement indices calculated by OxCal are used to evaluate the fit between the OxCal model and data, with values ≥ 60 indicating good agreement (Bronk Ramsey, 2009a). The posterior density estimates from OxCal are presented as probability ranges with end points rounded to the nearest five years. Importantly, the posterior density estimates produced by modeling are not absolute and they will change with the incorporation of future data and/or if modeled from a different perspective.

The A_{model} agreement values are greater than 60 for all of our models, suggesting good overall agreement between the radiocarbon dates and the assumptions of the models. It should be noted, though, that OxCal's Charcoal Outlier algorithm iteratively downweighs the impact of wayward results until the model runs freely and consistently, irrespective of the overlap integral between the posterior results and standardized likelihoods (*i.e.*, the agreement) (Bronk Ramsey, 2009b; Dee & Bronk Ramsey, 2014; Krus

[2] The structures and coding of the Bayesian chronological models created in OxCal, as well as the archaeological contexts of each radiocarbon sample, are fully presented in the supplemental materials (S1 Oxcal Script; S2 RC dates).

[3] OxCal's algorithms for the trapezium prior are detailed in Karlsberg (2006), Lee and Ramsey (2012), and Bronk Ramsey and Lee (2013), with examples of this modeling technique implemented in Lee and Ramsey (2012), Denaire *et al.,* (2017), Fitzpatrick *et al.,* (2017), and Willis *et al.,* (2016).

[4] Charcoal outlier modeling in OxCal was used in all the chronological models to account for unknown inherent age offset in wood charcoal samples (Bronk Ramsey, 2009b). This approach assumes an exponential distribution, with an exponential constant τ of 1 taken over the range -10 to 0, of the charcoal dates (following Bronk Ramsey, 2009b, and OxCal 4.4's default settings for Charcoal Outlier modeling). The shifts are then scaled by a common factor that can lie anywhere between 1 and 1000 years. Non-charcoal radiocarbon measurements were given a prior probability of 5% of being statistical outliers, using the General Outlier Model.

Table 2 Posterior probabilities for the estimated end dates of site occupations

Event dated	*95.4% probability*	*68.2% probability*
Primary model: end of Sellars	*cal CE 1400–1435*	*cal CE 1405–1425*
Primary model: end of Rutherford-Kizer	*cal CE 1330–1465*	*cal CE 1345–1445*
Primary model: end of Brentwood Library	*cal CE 1415–1460*	*cal CE 1420–1445*
Primary model: end of Gordontown	*cal CE 1430–1465*	*cal CE 1435–1455*
Primary model: end of Averbuch	*cal CE 1435–1505*	*cal CE 1445–1475*
Primary model: end of Kellytown	*cal CE 1430–1565*	*cal CE 1440–1510*
Primary model: end of East Nashville Mounds	*cal CE 1430–1615*	*cal CE 1455–1535*
Trapezium model: start of the End for MCR	*cal CE 1390–1445*	*cal CE 1405–1435*
Trapezium model: end of the End for MCR	*cal CE 1450–1480*	*cal CE 1455–1475*

All dates have end points rounded to the nearest five years

et al., 2019). Additionally, convergence values are greater than 95% for all of the models presented in this paper (Bayliss *et al.,* 2011, p. 35; Bronk Ramsey, 1995, p. 429).

Revised Bayesian Models for Individual Site Abandonments

From 2021 to 2022, we retrieved 85 new radiocarbon measurements from four sites occupied during Regional Period IV and V, including one site, Kellytown, not in our original sample. As is typical of the era, all of the sites are palisaded villages. Most of these new radiocarbon measurements derive from short-lived plant samples found in domestic contexts. Added to our earlier suite of legacy dates, there are currently 159 radiocarbon measurements from seven late Mississippian sites.

Our revised models suggest that each of the seven sites experienced abandonments throughout the CE 1400s to early 1500s. Matrices comparing the posterior probabilities were created to best determine the order of site abandonments (Table 2; Fig. 2). The first is represented by the Sellars site, with an abandonment estimate of *cal CE 1405–1425* at 68% probability. At the same level of probability, in statistical chronological order of abandonment are Rutherford-Kizer, *cal CE 1345–1445*; Brentwood Library, *cal CE 1420–1445*; Gordontown, *cal CE 1435–1455*; and Averbuch, *cal CE 1445–1475.* Technically, East Nashville Mounds was the last occupied site in our sample (*cal CE 1455–1535*). There were, however, no additional late Mississippian contexts from which to draw botanical specimens for revising the dates for this site. Hence the probability spread for abandonment is slightly larger than for Kellytown (*cal CE 1440–1510).* Overall, abandonment seems to have been widely occurring in the MCR in the 1400s as a staggered process—yet still within a relatively short time frame.

Sensitivity Analysis

As a sensitivity analysis, we also created a regional model for late Mississippian activity in the MCR that incorporates trapezium boundaries. The priors used in this model assume "a gradual increase (introductory period); then, a period of

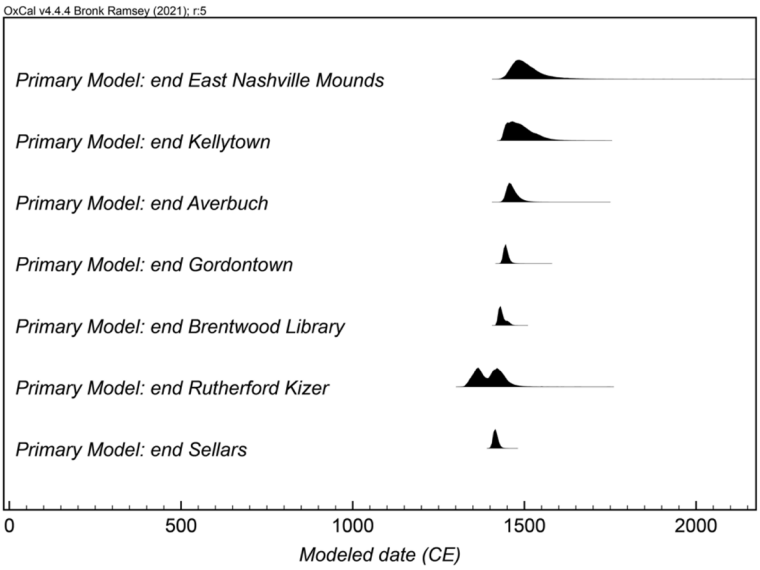

Fig. 2 Posterior probabilities

constant rate of activity (blooming period); and finally, a gradual decrease (period of decline)" (Lee and Ramsey, 2012, p. 107). Interpreting trapezium boundaries in this manner is appropriate if there was an extended abandonment to a region as opposed to an event-like episode, as is suggested by the aggregation of our individual site models (Table 3).

Importantly, the trapezium boundaries provide estimates for both a beginning and ending to the decline of activity in a model. Like the most widely used form of prior for Bayesian chronological modeling (the Uniform prior), the trapezium model still assumes that any event in the model is equally likely to have occurred in any individual year covered by the data. The difference is that the trapezium boundaries estimate four key parameters to characterize the start and end of this activity: (1) the start of the start, (2) the end of the start, (3) the start of the end, and (4) the end of the end. The posterior probabilities for the regional model of abandonment with trapezium boundaries suggest that an upsurge in abandonment of the MCR occurred during CE 1405 to 1435 at 68% probability and that the region was ultimately abandoned in the interval of CE 1455–1475 at 68% probability (Fig. 3; Table 2). This regional model estimates that the escalated final phase of Mississippian abandonment occurred over 25–65 years at 68% probability. The increased sample size of measurements is a significant improvement over the trapezium boundaries derived from our earlier corpus of legacy dates (which estimated the start of the end at *cal CE 1390–1495* and end of the end at *cal 1470–1515*, at 68% probability), and supports the hypothesis that the final abandonment by multiple towns occurred within a fairly compressed period within the fifteenth century CE.

Our proposed chronology for abandonment is further corroborated by the lack of any pre-colonial-era Indigenous sites in the MCR that post-date the early 1500s CE. It

Table 3 Probability matrix that event τ_1 occurred before event τ_2 in the primary models

$\tau_1 < \tau_2$ τ_2 / τ_1	*End of Sellars (40WI1)*	*End of Rutherford-Kizer (40SU15)*	*End of Brentwood Library (40WM210)*	*End of Gordontown (40DV6)*	*End of Averbuch (40DV60)*	*End of Kellytown (40WM10)*	*End of East Nashville Mounds (40DV4)*
End of Sellars (40WI1)		36%	94%	100%	100%	100%	100%
End of Rutherford-Kizer (40SU15)	64%		81%	90%	95%	97%	98%
End of Brentwood Library (40WM210)	5%	19%		83%	95%	97%	99%
End of Gordontown (40DV6)	0%	10%	17%		86%	91%	97%
End of Averbuch (40DV60)	0%	5%	5%	14%		71%	84%
End of Kellytown (40WM10)	0%	3%	3%	9%	29%		63%
End of East Nashville Mounds (40DV4)	0%	2%	1%	3%	16%	37%	

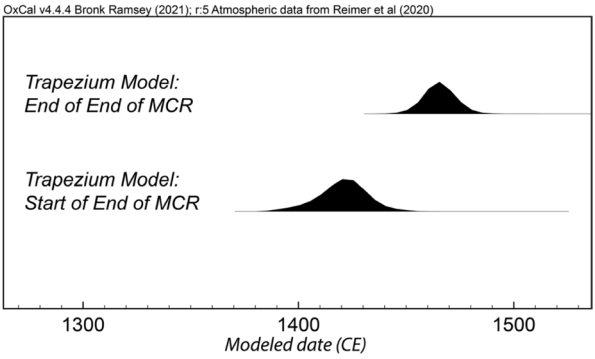

Fig. 3 Trapezium model

is important to acknowledge, however, that our models are based on a sample of seven towns that was dictated by available radiometric samples; it is not known how many contemporary terminal Mississippian towns existed in the MCR. Thus, the scale of the final abandonment is unclear. Still, each of the towns in our sample was large enough to accommodate hundreds of individuals. Keeping in mind the likelihood that there may have been other settlements, it seems that thousands of persons were still inhabiting the region in the fifteenth century—even if that estimate is on the order of lower thousands. Apparently, a substantial number of people departed within relatively short order.

Discussion

In their multi-variate approach toward unraveling dramatic episodes of social re-organization (including abandonment), Hegmon et al. (2018) found that the strongest cluster of interacting causal variables included institutional breakdown, depopulation, and declines in community security (especially as expressed in conflict)—although they are careful to point out that this is an empirical generalization and not a universal. Broadly speaking, these variables seem to have been in play in the MCR. As we have discussed, conflict and depopulation (*i.e.*, abandonment) are well documented, and institutional breakdown potentially is reflected in the shift from mound-center based polities to autonomous towns in the thirteenth to fourteenth centuries CE. Nevertheless, it is important to emphasize that, while such factors may have been linked to the emigration from regions, they may not necessarily have been responsible for initiating the arc of abandonments. In other words, the process or processes—such as climate change—that may have prompted a trajectory of depopulation may not be the same ones that brought it to a close (Dugmore *et al.,* 2007, p. 13; Glowacki, 2010, p. 220). In this light, based on the archaeological data now available from other Mississippian localities and our trapezium model, we propose that there was a two-phase abandonment of the MCR: first, a gradual exodus spurred by adverse climatic conditions that began in the late 1200s and lasted about 150 years; second, a depopulation tipping point in the early 1400s that was complete in 50 years or less. The final abandonment seemingly was precipitated by a convergence of particularly harsh climatic, social, and demographic conditions.

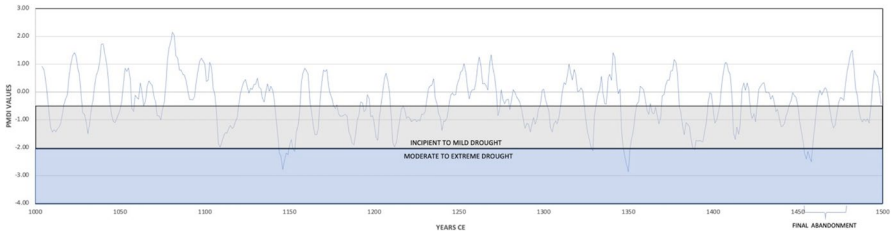

Fig. 4 PMDI averages, where each year represents an average of the PMDI values for the previous five years

The Beginnings of the Exodus

There is now compelling circumstantial evidence that the MCR abandonment began in the late 1200s CE. Strontium isotope data from individuals interred at early (ca. 1020–1280 CE) Fort Ancient sites in the middle Ohio Valley are suggestive of a MCR origin in the latter part of that sub-period (Cook & Price, 2015). It is noteworthy that there is also evidence for the migration of populations from other Vacant Quarter sub-regions (the American Bottom and the lower Ohio Valley) to Fort Ancient sites; the moister environment of the central Ohio Valley in the thirteenth to fifteenth centuries CE seemingly was a draw for widespread Mississippian communities facing environmental and social stressors (Comstock & Cook, 2018). Furthermore, there is archaeological evidence (in the form of artifact types) of populations arriving in southeastern Tennessee from the MCR in the fourteenth century, if not earlier (Sullivan *et al.,* 2022).

Based on precipitation data derived from the Palmer Drought Severity Index (PDSI), these migrations correspond to two challenging centuries for maize agriculture. In their evaluation of the Vacant Quarter hypothesis, Meeks and Anderson (2013) identified four megadrought periods based on PDSI values that occurred between CE 1250 and 1500 in the Southeast (along with multiple shorter duration events). For the MCR specifically, Palmer Modified Drought Index (PMDI) data from the Living Blended Drought Atlas (LBDA) indicate that the entire Mississippian period was characterized by considerable oscillations in precipitation (Fig. 4).[5]

The PMDI, an update of the PDSI, is based on recalibration of 1845 annual tree-ring chronologies used to reconstruct summer environmental moisture values on a 0.5-degree national grid (Cook *et al.,* 2010). Both of these drought indices measure annual environmental moisture on a relative scale from 4 to − 4, with negative values indicating progressively warmer, dryer conditions. Annual PMDI/PDSI values from − 0.50 to − 1.99 indicate incipient to mild drought, while values below − 2.00 reflect moderate to extreme drought conditions. The LBDA and supporting Palmer indices are based on continental-scale data, but nevertheless present one of the best

[5] The annual PMDI values used to classify harvest years are found in the supplemental materials (S3 PDMI values). They were modeled using a polygon of the Middle Cumberland Region (Eckhardt & Deter-Wolf, 2020) and the SKOPE application (Bocinsky *et al.,* 2022) to query the Living Blended Drought Atlas version 2 (Gille *et al.,* 2017).

available options for connecting projected paleoenvironmental data to regional and site-specific culture change in the Midcontinent and Eastern Woodlands during the past 2000 years (*e.g.*, Burnette *et al.,* 2022; Benson *et al.,* 2009; Bird *et al.,* 2017; Brannan, 2020; A. Comstock & R. Cook, 2018; R. A. Cook & A. R. Comstock, 2020, Emerson *et al.,* 2020; Mehta and Rodning, 2020). The development of tools such as the SKOPE (Synthesizing Knowledge of Past Environments) web application (Bocinsky *et al.,* 2022) further provides the ability to query the LBDA for modeled paleoenvironmental reconstructions within specific, geospatially defined regions.

Projected annual moisture data for the MCR during the period from CE 1350 to about CE 1475 witnessed several moderate to extreme summer droughts, which may account in part for the conditions leading to final abandonment. Notably, the span from about CE 1210 to 1325 is marked by comparatively moist conditions, and this represents the era of the growth of chiefdoms (Moore & Smith, 2012, p. 208). To muddy matters, however, this is the same period when MCR groups began appearing in other Mississippian regions. Those migrations may have begun closer to CE 1300 based on current evidence, however, which coincides with a protracted phase of incipient to mild droughts beginning in the late 1200 s (see Fig. 4). Complicating the picture even more, the century preceding CE 1210 was marked by a number of severe droughts, yet there is no clear evidence of ensuing abandonments. We are thus faced with the well-known conundrum in paleoclimate and abandonment studies, where severe droughts seem to correspond just as frequently with stability as they do with collapse or relocation.

Meeks and Anderson (2013, p. 66) have developed a scale that correlates PDSI/PMDI values with the likelihood of failed maize harvests, providing a somewhat more tangible (if hypothetical) portrayal of the impacts of climate on agricultural productivity. In their scheme, an incipient to mild drought (− 0.50 to − 1.99) is equated with a minimal harvest and a moderate to extreme drought (− 2.00 and lower) represents failed harvests. Applying these criteria to the projected regional drought data shows that both the early (1000–1249 CE) and late (1250–1499 CE) Mississippian subperiods in the MCR were characterized by frequent series of minimal and failed harvest years (Fig. 5). This similarity is reflected by the average cumulative minimal and failed harvest years for the early (24.4 years per 50-year interval) and late (24.2 years per 50-year interval) Mississippian sub-periods (Table 4). Yet the late Mississippian period also has a markedly higher average of likely failed harvests per 50-year span (7.2 years) compared to the first half (4.8 years). The key unanswered question is whether the uptick in failed harvests was sufficient to spur the final exodus?

Social responses to resource scarcity would have contributed to a matrix of adverse health consequences. After 1000 CE in the North American midcontinent, the nucleation of populations into compact, defendable towns due to conflict potentially had far-reaching unintended outcomes due to increased pressure on local resources (Milner & Boldsen, 2023). For example, in their work on the late Mississippian period in the Illinois Valley, VanDerwarker and Wilson (2016) found a correspondence between endemic conflict and reduced dietary breadth that they attributed to the reluctance of populations to wander far from the safety of their fortified settlements. Bioarchaeological data from the MCR confirms that populations

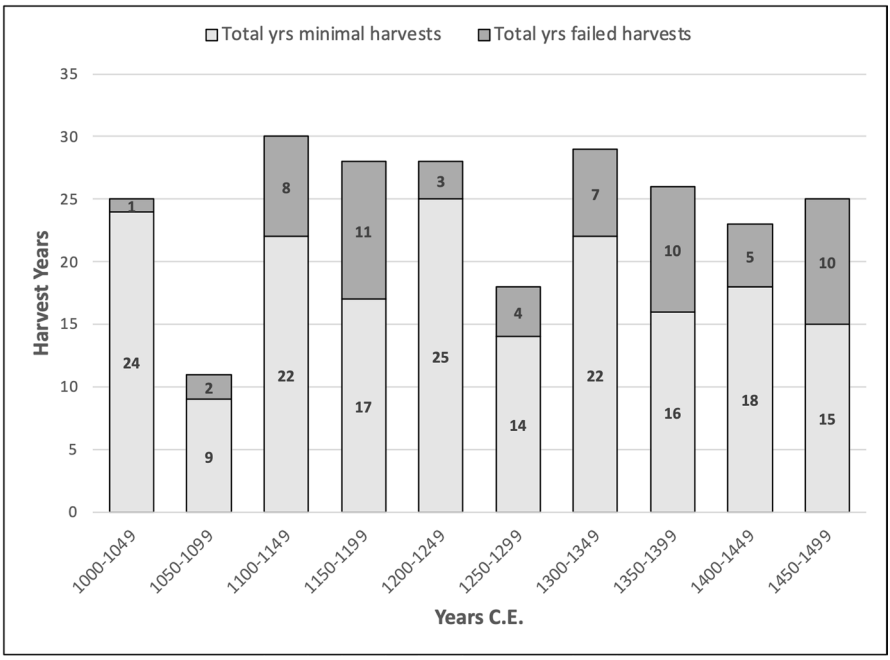

Fig. 5 Failed harvests

Table 4 Minimal and total failed harvest years

Span yrs CE	Total yrs minimal harvests	Total yrs failed harvests	Total minimal and failed harvests
1000–1049	24	1	25
1050–1099	9	2	11
1100–1149	22	8	30
1150–1199	17	11	28
1200–1249	25	3	28
1250–1299	14	4	18
1300–1349	22	7	29
1350–1399	16	10	26
1400–1449	18	5	23
1450–1499	15	10	25

Average minimal and failed harvests, 1000–1249: 24.4; average minimal and failed harvests, 1250–1499: 24.2; average failed harvests, 1000–1249: 4.8; average failed harvests, 1250–1499: 7.2

suffered from nutritional stress (*e.g.,* porotic lesions and linear enamel hypoplasia) and infectious "crowd" diseases (*e.g.,* tuberculosis and treponemal infections) in the latter part of the Mississippian sequence, suggesting health compromises that may

have dampened reproductive fitness and lowered life expectancies (Berryman, 1981; Cobb *et al.,* 2021; Eisenberg, 1991). It is hard to escape the conclusion that MCR populations in the fifteenth century CE suffered the consequences of a sheltered existence with reduced access to resources.

Because the unpredictable rainfall spanned as much as two centuries in the MCR, the recurrent droughts and their potential impacts should not be perceived as a simple cycle of crisis and recovery—their demographic effects can be multigenerational and cumulative. Even an apparently minor drought may generate a demographic crisis if it follows on the heels of multiple preceding events. These effects may be expressed through reduced life expectancies. For example, pregnant women experiencing drought-induced stress represent three generations: themselves, a fetus, and the reproductive cells forming within the fetus. As a result, megadroughts can have extensive ripple effects lasting at least to the third generation following the event itself. Studies of European populations using two centuries of church records suggest that the life expectancies of drought children and grandchildren are significantly impacted, along with many of the non-specific indicators of stress noted in MCR populations (Kaati *et al.,* 2007; ole-MoiYoi, 2013). Furthermore, a growing number of population biologists have proposed that severe droughts may have an epigenetic effect on the human genome beyond three generations, a result of significant environmental changes and related human behaviors (De Rooij *et al.,* 2022; Francis, 2012; Jablonka & Lamb, 2014).

Finally, push factors other than resource scarcity and conflict may have come into play, although they remain speculative at this point. For instance, even if there were still sufficient maize for basic nutrition, declining surpluses may have undercut the largesse to subordinates crucial for maintaining chiefly power (Meeks & Anderson, 2013). Moreover, uncertain harvests may have cast doubt on the abilities of leaders to maintain harmony with the cosmos, thereby threatening their ideological authority (Burnette *et al.,* 2022, pp. 332–333; Comstock *et al.,* 2022, p. 14). Community fractures emanating from widespread dissatisfaction in turn may have prompted fissioning and population outflows at multiple scales. Similar to arguments made by Hill *et al.,* (2004) for the Hohokam abandonment of the San Pedro Valley in Arizona, social factors combined with gradual changes in fertility and mortality may have prompted a steady decline in the MCR populations that has a relatively low archaeological signature.

The Tipping Point

Our notion that the final abandonment was relatively sudden and widespread is supported in part by the fact that the last MCR towns were apparently bustling communities not making obvious preparations for departure in the fifteenth century. They may have been in demographic decline, but they outwardly continued long-established patterns of behavior. This includes the attentiveness to fortifications. Our earlier Bayesian modeling of carbonized post fragments from palisades at four of our sites shows that they were maintained for several generations and well into the 1400s (Krus & Cobb, 2018, p. 314). At the least, the towns were populous enough

to undertake significant communal projects even under the threat of attack. Moreover, these communities typically contain sizable cemeteries with hundreds of interments, further evidence of substantial populations. The mortuary assemblages contain zoomorphic and anthropomorphic pottery, shell gorgets, and other well-made objects that embody the robust continuity of crafting traditions (Barker & Kline, 2013; Klippel *et al.,* 1984; Moore, 2005; Moore *et al.,* 2001). Some of these artifacts are made from non-local raw materials, such as marine shell and copper, indicating that some long-distance trade persisted. The picture that emerges from the fifteenth-century MCR is one of communities sustaining, to all intents and purposes, a "typical" Mississippian lifestyle under trying conditions.

Yet the archaeological record also contains warning signs of an acceleration of problems during the late fourteenth to fifteenth centuries. At two of the towns (Averbuch and Gordontown), wooden palisades were built through community cemeteries, suggestive of hurried constructions under the threat of pending violence (Cobb *et al.,* 2015, p. 54). As noted, there is evidence of growing inter-group and intra-group conflict through time (Worne, 2017). A recent paleodemographic study also indicates a reduction in survivorship from the early to late Mississippian period in the MCR, marked by an upsurge in mortality among males (Fojas, 2022).

Shorter-term climate trends may have contributed to the unrest. The decade of 1449 to 1458 was particularly challenging, when every year is defined as experiencing abnormally dry conditions to severe drought (see Fig. 4). The four consecutive years from 1454 to 1457 all represent a high likelihood of failed harvests. Over the course of ten successive dry growing seasons, the stage would have been set for communities to make decisive plans to depart the region. Overall, it is possible that shorter runs of challenging years comprising acute periods of stress may be more likely to trigger dramatic community-wide decisions to relocate rather than punctuated chronic conditions of multidecadal drought over the span of decades or longer. It is noteworthy that the severe 1449–1458 interval coincides with the onset of our final abandonment estimate of *cal CE 1455–1475* (68% probability). These data suggest that the final exodus in the second phase was precipitous and represented a threshold effect. Even though severe droughts occurred earlier in the Mississippian period, particularly critical transitions may be more likely to be associated with major climate events if they are preceded by stretches of societal discontent (Scheffer et al., 2021)—as seems to have been the case in the fifteenth-century MCR.

Conclusion

From a methodological perspective, the simulation experiment from our earlier study (Krus & Cobb, 2018) was critical for guiding the radiocarbon sampling process, although our number of samples was still limited by the availability of organic remains. As a result, several of our new results contain posterior probabilities with 50-year (and smaller) confidence intervals at the 68% and 95% probability ranges (Table 2). This improvement has allowed us to estimate that the end of activity based on our regional model is *cal CE 1450–1480* at 95% probability. Furthermore, the introduction of trapezium boundaries into our model has allowed us to elucidate

what seems to be a crescendo of depopulation beginning in the early 1400s that had come to a close within the 1450–1480 interval.

The genesis of the MCR abandonment seemingly can be attributed in large part to repeated and severe droughts beginning in the late 1200s CE. But the subsequent two centuries of continued emigration likely involved a welter of factors, not the least of which was region-wide conflict. The abandonment began with a protracted exodus to regions like the middle Ohio Valley and eastern Tennessee before accelerating greatly in the fifteenth century. It is possible that earlier populations of emigres in those areas may have made the communities more receptive to accepting a final pulse of immigrants from the Middle Cumberland Region.

Our long-term research objective involves a comparative study of sub-regions within the Vacant Quarter to address variation in the proximate factors that prompted and shaped abandonments, and how they may have been linked as a broad-scale phenomenon. A preliminary analysis of sites in the upper Tombigbee drainage in eastern Mississippi (see Fig. 1), which seems to be the southernmost extension of the Vacant Quarter (Johnson, 1996, p. 247), is suggestive of a distinctively different pattern than seen in the MCR (Krus *et al.,* 2022). There, the final departure seems to have been decades later and the evidence for inter-group conflict is slight. Moreover, the Tombigbee peoples apparently migrated a much shorter distance (on the order of 20–30 km), and this involved a settlement transition from a floodplain environ to a very different ecological setting represented by an upland prairie (Johnson, 1996; Rafferty, 1994).

Abandonment studies now emphasize that history matters. Addressing the micro-histories of specific locales is critical for bridging from local to regional to pan-regional abandonments. This point of departure provides a finer-grained perspective on so-called path dependencies defined by social and environmental opportunities and constraints leading to abandonment which may diverge widely even in adjoining localities (Dugmore et al., 2007, p. 27–28; Glowacki, 2020, p. 27; Nelson et al., 2014, p. 177). As Turner and Sabloff (2012, p.13,912) observe, to explain this variation a "[b]alance between the extremes of generalization and context is required." The complexity inherent in these processes suggests that our explanations may need to rely on a sophisticated melding of social theory with computational modeling to move beyond "coincidences of social and climatic change" (Guedes et al., 2016, p. 14,489).

Ongoing and widespread interest in the putative collapse of societies and related warning signs was highlighted in a relatively recent *New York Times Magazine* article "How Do You Know When Society is About to Fall Apart?" (Ehrenreich, 2020). In his interviews with some of the key archaeologists pursuing this line of research, such as Joseph Tainter (1988) and Patricia McAnany (McAnany *et al.,* 2010), Ehrenreich expressed the anxiety many feel about global environmental, climatic, and social interactions today and explores what lessons archaeology can provide for the present about the likelihood and nature of collapse. As they and other scholars emphasize, not all outcomes of severe challenges are dismal and archaeology can potentially contribute to sustainability science that leads to choices that ameliorate adverse impacts (*e.g.,* Butzer, 2012; Hegmon *et al.,* 2018). Large-scale abandonments and migration are clearly part of this conversation, and it is evident that the public believes archaeology potentially provides important insights into the causes and consequences of these processes. The ball is in our court to provide the longitudinal and comparative research to meet this expectation.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10816-023-09613-w.

Acknowledgements We owe a major debt of gratitude to numerous institutions, organizations, and people that have made this work possible. Our collaborative effort was initiated by the Chickasaw Nation, and they continue to support our work through the Chickasaw Explorers Program. The National Science Foundation (BCS-1916596) provided funding for both field and analytical components of our project. Our respective institutions have also lent backing in various ways: the Florida Museum of Natural History, the University of South Dakota, the Tennessee Division of Archaeology, Middle Tennessee State University, and Mississippi State University. In addition, the McClung Museum at the University of Tennessee-Knoxville and the City of Brentwood, TN, graciously made collections available for our research. Finally, our thanks to the three anonymous reviewers for the journal, who provided extremely useful observations and constructive criticisms.

Author Contribution Charles Cobb, Anthony Krus, and Kevin Smith wrote the main manuscript text. Charles Cobb, Anthony Krus, and Aaron-Deter Wolf prepared the figures and tables. Anthony Krus and Aaron-Deter Wolf developed the primary Bayesian and PMDI studies, respectively. All authors reviewed the manuscript.

Funding This work was supported by the Chickasaw Nation and the National Science Foundation (BCS-1916596).

Data Availability Data are available in the supplemental files and are freely available to researchers.

Declarations

Competing Interests The authors declare no competing interests.

References

Aimers, J. J. (2007). What Maya collapse? Terminal classic variation in the Maya lowlands. *Journal of Archaeological Research, 15*(4), 329–377.

Alley, W. M. (1984). The Palmer Drought Severity Index: Limitations and assumptions. *Journal of Climate and Applied Meteorology, 23*(7), 1100–1109.

Anderson, D. G. (1994). *The Savannah River chiefdoms: Political change in the late prehistoric Southeast*. University of Alabama Press.

Barker, G., & Kline, G. (2013). *Archaeological investigations at Kellytown (40Wm10): A fortified late Mississippian village in middle Tennessee's Harpeth River drainage, Davidson and Williamson Counties, Tennessee*. Tennessee Department of Transportation.

Bayliss, A., van der Plicht, J., Bronk Ramsey, C., McCormac, G., Healy, F., & Whittle, A. (2011). Towards generational time-scales: The quantitative interpretation of archaeological chronologies. In A. Whittle, F. Healy, & A. Bayliss (Eds.), *Gathering time: Dating the early Neolithic enclosures of southern Britain and Ireland* (pp. 17–59). Oxbow.

Benson, L. V., Pauketat, T. R., & Cook, E. R. (2009). Cahokia's boom and bust in the context of climate change. *American Antiquity, 74*(3), 467–483.

Berryman, H. E. (1981). *The Averbuch skeletal series: A study of biological and social stress at a late Mississippian period site from middle Tennessee.* Unpublished PhD dissertation, University of Tennessee.

Bird, B. W., Wilson, J. J., Gilhooly, W. P., III., Steinman, B. A., & Stamps, L. (2017). Midcontinental Native American population dynamics and late Holocene hydroclimate extremes. *Scientific Reports, 7*, 41628.

Blain, G. C., & Xavier, A. C. F. (2019). Transforming the Palmer Drought Severity Index into a standardized multi-scalar index: Assessing the normality assumption under South America tropical-subtropical conditions. *Experimental Agriculture, 55*(5), 752–764.

Blitz, J. H. (2010). New perspectives in Mississippian archaeology. *Journal of Archaeological Research, 18*(1), 1–39.

Bocinsky, K., Gillreath-Brown, A., Kintigh, K., Kinzig, A., Kohler, T., Lee, A., … Pritchard, C. (2022). *Synthesizing knowledge of past environments (SKOPE) web application (version v2022.06)*. from https://doi.org/10.5281/zenodo.6522974 URL: https://app.openskope.org.

Boudreaux, E. A., III, Cobb, C. R., Clark, E., DePratter, C. B., Legg, J., Lieb, B. R., … Smith, S. D. (2020). The early contact period in the Black Prairie of northeast Mississippi. In E. A. Boudreaux III, M. Meyers, & J. K. Johnson (Eds.), *Contact, colonialism, and native communities in the Southeastern United States* (pp. 35–56). University of Florida Press.

Brannan, S. (2020) Population aggregation and dispersal as a driver for settlement change in the lower Chattahoochee River Valley between AD 1100 and 1500. In R. A. Cook & A. R. Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp. 301–322). Springer.

Bronk Ramsey, C. (1995). Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon, 37*(2), 425–430.

Bronk Ramsey, C. (1998). Probability and dating. *Radiocarbon, 40*(1), 461–474.

Bronk Ramsey, C. (2009a). Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*(1), 337–360.

Bronk Ramsey, C. (2009b). Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon, 51*(3), 1023–1045.

Bronk Ramsey, C., & Lee, S. (2013). Recent and planned developments of the program Oxcal. *Radiocarbon, 55*(2–3), 720–730.

Burnette, D. J., Dye, D. H., & Hill, A. A. (2022). Climate change, population migration, and ritual practice in the Lower Mississippi valley. In R. A. Cook & A. R. Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp. 323–356). Springer.

Butler, B. M., & Cobb, C. R. (2004). The Millstone Bluff site: A first approximation. In C. D. Hockensmith & K. C. Carstens (Eds.), *Current archaeological research in Kentucky, volume seven* (pp. 85–109). Kentucky Heritage Council.

Butzer, K. W. (2012). Collapse, environment, and society. *PNAS, 109*(10), 3632–3639.

Cable, J. S. (2020). *Megadrought in the Carolinas: The archaeology of Mississippian collapse, abandonment, and coalescence*. University of Alabama Press.

Cobb, C. R. (2003). Mississippian chiefdoms: How complex? *Annual Review of Anthropology, 32*, 63–84.

Cobb, C. R., & Butler, B. M. (2002). The Vacant Quarter revisited: Late Mississippian abandonment of the lower Ohio valley. *American Antiquity, 67*(4), 625–641.

Cobb, C. R., Krus, A. M., & Steadman, D. W. (2015). Bayesian modeling of the occupation span of the Averbuch site in the Middle Cumberland drainage Tennessee. *Southeastern Archaeology, 34*(1), 46–56.

Cobb, C. R., & Steadman, D. W., et al. (2021). Warfare and structural violence in Mississippian-period southeastern North America. In A. Abar (Ed.), *Pearls, politics, and pistachios* (pp. 375–388). Ex Orient.

Comstock, A., & Cook, R. (2018). Climate change and migration along a Mississippian periphery: A Fort Ancient example. *American Antiquity, 83*(1), 91–108.

Comstock, A. R., Cook, R. A., Blitz, J. H., & Simon, M. L. (2022). Climate change and migration among early agriculturalists: From global to Mississippian perspectives. In R. A. Cook & A. R. Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp. 1–34). Springer.

Cook, B. I., Smerdon, J. E., Seager, R., & Cook, E. R. (2014). Pan-continental droughts in North America over the last millennium. *Journal of Climate, 27*, 383–397.

Cook, E. R., Seager, R., Cane, M. A., & Stahle, D. W. (2007). North American drought: Reconstructions, causes, and consequences. *Earth Science Reviews, 81*, 93–134.

Cook, E. R., Seager, R., Heim, R. R., Vose, R. S., Herweijer, C., & Woodhouse, C. (2010). Megadroughts in North America: Placing IPCC projections of hydroclimatic change in a long-term paleoclimate context. *Journal of Quaternary Science, 25*(1), 48–61.

Cook, R A. & Comstock, A. R. (2020). Moving in and moving on: Climate change and Mississippian migration in the middle Ohio Valley. In R. A. Cook & A. R. Comstock (Eds.), *Following*

the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600) (pp.197–226). Springer.

Cook, R. A., & Price, T. D. (2015). Maize, mounds, and the movement of people: Isotope analysis of a Mississippian/Fort Ancient region. *Journal of Archaeological Science, 61*, 112–128.

Cordell, L. (1998). *Before Pecos: Settlement aggregation at Rowe*. Maxwell Museum of Anthropology, University of New Mexico.

Cordell, L. (2000). Aftermath of chaos in the Pueblo Southwest. In G. Bawden & R. M. Reycraft (Eds.), *Environmental disaster and the archaeology of human response* (pp. 179–193). Maxwell Museum of Anthropology.

De Rooij, S. R., Bleker, L. S., Painter, R. C., Ravelli, A. C., & Roseboom, T. J. (2022). Lessons learned from 25 years of research into long term consequences of prenatal exposure to the Dutch famine 1944–45: The Dutch famine birth cohort. *International Journal of Environmental Health Research, 32*(7), 1432–1446.

Dee, M., & Bronk Ramsey, C. (2014). High-precision Bayesian modeling of samples susceptible to inbuilt age. *Radiocarbon, 56*(1), 83–94.

Denaire, A., Lefranc, P., Wahl, J., Ramsey, C. B., Dunbar, E., Goslar, T., … Whittle, A. (2017). The cultural project: Formal chronological modelling of the Early and Middle Neolithic sequence in lower Alsace. *Journal of Archaeological Method and Theory, 24*(4), 1072–1149.

Downey, S. S., Randall Hass, J., & Shennan, S. J. (2016). European Neolithic societies showed early warning signals of population collapse. *PNAS, 113*(35), 9751–9756. https://doi.org/10.1073/pnas.1602504113

Dugmore, A. J., Keller, C., & McGovern, T. H. (2007). Norse Greenland settlement: Reflections on climate change, trade, and the contrasting fates of human settlements in the North Atlantic islands. *Arctic Anthropology, 44*(1), 12–36.

Eckhardt, S. L., & Deter-Wolf, A. (2020). The Middle Cumberland region. Accessed May 16, 2023, from Figshare.org, https://doi.org/10.6084/m9.figshare.13379816.v2 URL: https://figshare.com/articles/dataset/The_Middle_Cumberland_Region/13379816.

Ehrenreich, B. (2020). How do you known when society is about to fall apart? Retrieved January 15, 2023, from *The New York Times*. https://www.nytimes.com/2020/11/04/magazine/societal-collapse.html.

Eisenberg, L. E. (1991). Mississippian cultural terminations in middle Tennessee: What the bioarchaeological evidence can tell us. In M. L. Powell, P. S. Bridges, & A. M. W. Mires (Eds.), *What mean these bones?: Studies in southeastern bioarchaeology* (pp. 70–88). University of Alabama Press.

Emerson, T. E., Hedman, K. M., Fort, M. A. & Emerson, K. E. (2020). Late pre-contact ethnogenesis, resilience, and movement in the face of climate variation in the upper Illinois River Valley. In R. A. Cook & A. R. Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp.139–168). Springer.

Fish, S. K., & Fish, P. R. (1993). An assessment of abandonment processes in the Hohokam classic period of the Tucson basin. In C. M. Cameron & S. A. Tomka (Eds.), *Abandonment of settlements and regions: Ethnoarchaeological and archaeological approaches* (pp. 99–109). Cambridge University Press.

Fitzpatrick, A. P., Hamilton, D., & Haselgrove, C. (2017). Radiocarbon dating and Bayesian modelling of the late Iron Age cremation burial cemetery at Westhampnett, West Wussex GB. *Archaeologisches Korrespondenzblatt, 47*(3), 359–381.

Fojas, C. L. (2022). Abandonment of the Middle Cumberland region of Tennessee during the Mississippian period: Temporal and sex differences in survivorship. *American Journal of Biological Anthropology, 177*(3), 425–438.

Francis, R. C. (2012). *Epigenetics: How environment shapes our genes*. W. W. Norton & Company.

Gille, E. P., Wahl, E. R., Vose, R. S., & Cook, E. R. (2017). NOAA/WDS paleoclimatology - living blended drought atlas (LBDA) version 2 - recalibrated reconstruction of United States summer PMDI over the last 2000 years. Accessed May 16, 2023, from *NOAA National Centers for Environmental Information DOI:* https://doi.org/10.25921/7xm8-jn36. https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/noaa-recon-22454/html.

Glowacki, D. M. (2010). The social and cultural contexts of the central Mesa Verde region during the thirteenth-century migrations. In T. A. Kohler, M. D. Varien, & A. M. Wright (Eds.), *Leaving Mesa Verde: Peril and change in the thirteenth-century Southwest* (pp. 200–221). University of Arizona Press.

Glowacki, D. M. (2020). The leaving's the thing: The context of Mesa Verde emigration. In M. Lamoureux-St-Hilaire & S. Macrae (Eds.), *Detachment from place: Beyond an archaeology of settlement abandonment* (pp. 23–44). University Press of Colorado.

Guedes, J. A. d., Crabtree, S. A., Bocinsky, R. K., & Kohler, T. A. (2016). Twenty-first century approaches to ancient problems: Climate and society. *PNAS, 113*(51), 11483–14491.

Hegmon, M., Peeples, M. A., on behalf of the LTVTP-NABO collaboration. (2018). The human experience of social transformation: Insights from comparative archaeology. *PLOS ONE, 13*(11), e0208060. https://doi.org/10.1371/journal.pone.0208060.

Hill, J. B., Clark, J. J., Doelle, W. H., & Lyons, P. D. (2004). Prehistoric demography in the Southwest: Migration, coalescence, and Hohokam population decline. *American Antiquity, 69*(4), 689–716.

Jablonka, E., & Lamb, M. J. (2014). *Evolution in four dimensions: Genetic, epigenetic, behavioral and symbolic variation in the history of life*. The MIT Press.

Jacobson, M. J., Pickett, J., Gascoigne, A. L., Fleitmann, D., & Elton, H. (2022). Settlement, environment, and climate change in SW Anatolia: Dynamics of regional variation and the end of antiquity. *PLOS ONE, 16*(6), e0270295. https://doi.org/10.1371/journal.pone.0270295.

Johnson, J. K. (1996). The nature and timing of the late prehistoric settlement of the Black Prairie in northeast Mississippi: A reply to Hogue, Peacock, and Rafferty. *Southeastern Archaeology, 15*(2), 244–247.

Jolley, R. L. (1983). Mississippian adaptations to the Middle Cumberland drainage of central Tennessee. *Midcontinental Journal of Archaeology, 8*(1), 73–90.

Kaati, G., Bygren, L. O., Pembrey, M., & Sjostrom, M. (2007). Transgenerational response to nutrition, early life circumstances, and longevity. *European Journal of Human Genetics, 15*, 784–790.

Karlsberg, A. J. (2006). *Flexible Bayesian methods for archaeological dating*. University of Sheffield.

Kintigh, K. W., & Ingram, S. E. (2018). Was the drought really responsible? Assessing statistical relationships between climate extremes and cultural transitions. *Journal of Archaeological Science, 89*, 25–31.

Klippel, W. E., & Bass, W. M. (Eds.). (1984). *Averbuch: A late Mississippian manifestation in the Nashville Basin (2 vols)*. Department of Anthropology University of Tennessee. Report submitted to the National Park Service.

Krus, A. M., & Cobb, C. R. (2018). The Mississippian fin de siècle in the Middle Cumberland region of Tennessee. *American Antiquity, 83*(2), 302–319.

Krus, A. M., Cobb, C. R., Lieb, B. R., Edmond A. Boudreaux, I., & Hollenbach, K. (2022). *A Mississippian fin de siècle revisited: Chronology for the Mississippian abandonment in the Middle Cumberland region*. Paper presented at the Paper presented at the 87th Annual Meeting of the Society for American Archaeology, Chicago.

Krus, A. M., Herrmann, E. W., Pike, M. D., Monaghan, G. W., & Wilson, J. J. (2019). Chronology of a fortified Mississippian village in the central Illinois River Valley. *Radiocarbon, 61*(3), 713–731.

Lee, S., & Ramsey, C. B. (2012). Development and application of the trapezoidal models for archaeological chronologies. *Radiocarbon, 54*(1), 107–122.

Lekson, S. H., & Cameron, C. M. (1995). The abandonment of Chaco Canyon, the Mesa Verde migrations, and the reorganization of the Pueblo world. *Journal of Anthropological Archaeology, 14*(2), 184–202.

Lewis, R. B. (Ed.). (1986). *Mississippian towns of the western Kentucky border: The Adams, Wickliffe, and Sassafras Ridge sites*. Kentucky Heritage Council.

Lewis, R. B. (1990). The late prehistory of the Ohio-Mississippi Rivers confluence region, Kentucky and Missouri. In D. H. Dye & C. A. Cox (Eds.), *Towns and temples along the Mississippi* (pp. 38–58). University of Alabama Press.

Lillios, K. (1993). Regional settlement abandonment at the end of the Copper Age in the lowlands of west-central Portugal. In C. M. Cameron & S. A. Tomka (Eds.), *Abandonment of settlements and regions: Ethnoarchaeological and archaeological approaches* (pp. 110–120). Cambridge University Press.

Loendorf, C., & Lewis, B. V. (2017). Ancestral O'odham: Akimel O'odham cultural traditions and the archaeological record. *American Antiquity, 82*(1), 123–139.

McAnany, P. A., & Yoffee, N. (Eds.). (2010). *Questioning collapse: Human resilience, ecological vulnerability, and the aftermath of empire*. Cambridge University Press.

Meeks, S. C., & Anderson, D. G. (2013). Drought, subsistence stress, and population dynamics: Assessing Mississippian abandonment of the Vacant Quarter. In J. D. Wingard & S. E. Hayes (Eds.), *Soils, climate, and society: Archaeological investigations in ancient America* (pp. 61–83). University Press of Colorado.

Mehta, J. M., & Rodning, C. B. (2020). Environment, climate, and Mississippian origins in the Lower Mississippi Valley and the Mississippi River Delta. In R. A. Cook & A. R. Comstock (Eds.),

Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600) (pp. 357–379). Springer.

Milner, G. R., & Boldsen, J. L. (2023). Population trends and the transition to agriculture: Global processes as seen from North America. *PNAS, 120*(4), e2209478119.

Moore, M. C. (2005). *The Brentwood Library site: A Mississippian town on the Little Harpeth River, Williamson County, Tennessee*. Division of Archaeology Research Series No. 15. Tennessee Department of Environment and Conservation.

Moore, M. C., & Smith, K. E. (Eds.). (2001). *Archaeological excavations at the Rutherford-Kizer site: A Mississippian mound center in Sumner County, Tennessee*. Division of Archaeology Research Series No. 13. Tennessee Department of Environment and Conservation.

Moore, M. C., & Smith, K. E. (2012). *Archaeological expeditions of the Peabody Museum in middle Tennessee, 1877–1884* (Second ed.). Division of Archaeology Research Series No. 16. Tennessee Division of Environment and Conservation.

Nelson, B. A., Chase, A. S. Z., & Hegmon, M. (2014). Transformative relocation in the U.S. Southwest and Mesoamerica. In A. F. Chase & V. L. Scarborough (Eds.), *The resilience and vulnerability of ancient landscapes: Transforming Maya archaeology through IHOPE* (pp. 171–182). Archaeological Papers 24(1). American Anthropological Association.

Nelson, M. C., & Schachner, G. (2002). Understanding abandonments in the North American Southwest. *Journal of Archaeological Research, 10*(2), 167–206.

ole-MoiYoi, O. K. (2013). *Short- and long-term effects of drought on human health*. Case Study prepared for the Global Assessment Report on Disaster Risk Reduction 2013. The United Nations Office for Disaster Risk Reduction.

Pauketat, T. R. (2003). Resettled farmers and the making of a Mississippian polity. *American Antiquity, 68*(1), 39–66.

Rafferty, J. (1994). Gradual or step-wise change: The development of sedentary settlement patterns in northeast Mississippi. *American Antiquity, 59*(3), 405–425.

Ravesloot, J. C., Darling, J. A., & Waters, M. R. (2009). Hohokam and Pima–Maricopa irrigation agriculturalists: Maladaptive or resilient societies? In C. T. Fisher, J. B. Hill, & G. M. Feinman (Eds.), *The archaeology of environmental change* (pp. 232–245). University of Arizona Press.

Reimer, P. J., Austin, W. E. N., Bard, E., Bayliss, A., Blackwell, P. G., Ramsey, … Talamo, S. (2020). The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon, 62*(4), 725-757.

Ritchison, B. T., & Anderson, D. G. (2022). "Vacant Quarters" and population movements: Legacy data and the investigation of a large-scale emigration event from the Savannah River valley to the Georgia coast. In R. A. Cook & A. R. Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp. 257–299). Springer.

Rosen, A. M. (2007). *Civilizing climate: Social responses to climate change in the ancient Near East*. Altamira Press.

Sandweiss, D. H., & Maasch, K. A. (2022). Climatic and cultural transitions in Lambayeque, Peru, 600 to 1540 AD: Medieval warm period to the Spanish conquest. *Geosciences, 12*(6), 238; https://doi.org/10.3390/geosciences12060238.

Scheffer, M., van Nesa, E. H., Bird, D., Bocinsky, R. K., & Kohler, T. A. (2021). Loss of resilience preceded transformations of pre-Hispanic Pueblo societies. *PNAS, 118*(18), e2024397118.

Schlanger, S. H., & Wilshusen, R. H. (1993). Local abandonments and regional conditions in the North American Southwest. In C. M. Cameron & S. A. Tomka (Eds.), *Abandonment of settlements and regions: Ethnoarchaeological and archaeological approaches* (pp. 85–98). Cambridge University Press.

Schwindt, D. M., Bocinsky, R. K., Ordman, S. G., Glowacki, D. M., Varien, M. D., & Kohler, T. A. (2016). The social consequences of climate change in the central Mesa Verde valley. *American Antiquity, 81*(1), 74–96.

Spielmann, K. A., Peeples, M. A., Glowacki, D. M., & Dugmore, A. (2016). Early warning signals of social transformation: A case study from the US Southwest. *PLOS ONE, 11*(10), e0163685. https://doi.org/10.1371/journal.pone.0163685.

Steponaitis, V. P. (1991). Contrasting patterns of Mississippian development. In T. K. Earle (Ed.), *Chiefdoms: Power, economy, and ideology* (pp. 193–228). Cambridge University Press.

Sullivan, L. P., Smith, K. E., Patch, S., Lowry, S., Holland-Lulewicz, J. J., & Meeks, S. (2022). Heading for the hills: New evidence for migrations to the Upper Tennessee valley. In R. A. Cook & A. R.

Comstock (Eds.), *Following the Mississippian spread: Climate change and migration in the eastern US (ca. AD 1000–1600)* (pp. 227–256). Springer.
Tainter, J. A. (1988). *The collapse of complex societies*. Cambridge University Press.
Turner, B. L., II, & Sabloff, J. A. (2012). Classic period collapse of the central Maya lowlands: Insights about human–environment relationships for sustainability. *PNAS, 109*(35), 13908–13914 https://doi.org/10.11073/pnas.1210106109.
Van West, C. R., & Dean, J. S. (2000). Environmental characteristics of the A.D. 900–1300 period in the central Mesa Verde region. *Kiva, 66*(1), 19–44.
VanDerwarker, A. M., & Wilson, G. D. (2016). War, food, and structural violence in the Mississippian Central Illinois valley. In A. M. VanDerwarker & G. D. Wilson (Eds.), *The archaeology of food and warfare* (pp. 75–105). Springer.
Varien, M. D. (1999). *Sedentism and mobility in a social landscape: Mesa Verde and beyond*. University of Arizona Press.
Weiss, H., Courty, M. A., Wetterstrom, W., Guichard, F., Senior, L., Meadow, R., & Curnow, A. (1993). The genesis and collapse of third millennium north Mesopotamian civilization. *Science, 261*(5124), 995–1004.
Williams, S. (1983). Some ruminations on the current strategy of archaeology in the Southeast. *Southeastern Archaeological Conference Bulletin, 21*, 72–81.
Williams, S. (1990). The Vacant Quarter and other late events in the Lower Valley. In D. H. Dye & C. A. Cox (Eds.), *Towns and temples along the Mississippi* (pp. 170–180). University of Alabama Press.
Williams, S. (2001). The Vacant Quarter hypothesis and the Yazoo Delta. In D. S. Brose, C. W. Cowan, & R. C. Mainfort Jr. (Eds.), *Societies in eclipse: Archaeology of the Eastern Woodlands Indians, A.D. 1400–1700* (pp. 191–203). Smithsonian Institution Press.
Willis, C., Marshall, P., McKinley, J., Pitts, M., Pollard, J., Richards, C., … Pearson, M. P. (2016). The dead of Stonehenge. *Antiquity, 90*(350), 337–356.
Worne, H. (2017). Temporal trends in violence during the Mississippian period in the middle Cumberland region of Tennessee. *Southeastern Archaeology, 36*(3), 171–182.
Worne, H., Cobb, C. R., Vidoli, G., & Steadman, D. (2012). The space of war: Connecting geophysical landscapes with skeletal evidence of warfare-related trauma. In D. Martin, R. P. Harrod, & V. Perez (Eds.), *The bioarchaeology of violence* (pp. 141–159). University of Florida Press.