ANNUAL REVIEWS

Annual Review of Anthropology

Cultural-Environmental Systems and the Archaeology of Climate Change and Social Complexity: Midwest and Southeast United States

Sissel Schroeder[1] and A.J. White[2]

[1]Department of Anthropology, University of Wisconsin–Madison, Madison, Wisconsin, USA; email: sissel.schroeder@wisc.edu

[2]Department of Earth Science, California State University, Long Beach, California, USA

Annu. Rev. Anthropol. 2024. 53:147–63

The *Annual Review of Anthropology* is online at anthro.annualreviews.org

https://doi.org/10.1146/annurev-anthro-101819-110206

Keywords

archaeology, climate change, proxy records, Midwest, Southeast, Mississippian culture

Abstract

The investigation of dynamic fully integrated cultural-environmental systems is one grand challenge facing archaeologists in this century. In the Midwest and Southeast United States, archaeologists recently increased their study of Mississippian social systems (ca. AD 1000–1600) in relationship to paleoclimate and paleoenvironmental data. Significant differences in chronological control between archaeological chronologies and paleoenvironmental records pose challenges to the study of cultural-environmental systems in this region and often result in equifinal results. Three major lines of paleoenvironmental records are reviewed: bald cypress tree-ring records, the Living Blended Drought Atlas (LBDA), and lake-bottom sediment cores. The strongest approaches include local and regional multiproxy environmental records from the same location as a well-investigated archaeological site(s) or region(s). In the rare case where the cores also encode a regional population history, it may be possible to develop stronger inferences that consider variation within and between communities and their vulnerability to climate change and environmental catastrophes.

INTRODUCTION

About a decade ago, Kintigh and colleagues published an article in *American Antiquity* in which they identified 25 "grand challenges" facing archaeologists in the twenty-first century, all of which could be subsumed under the general topic of "cultural processes and the operation of coupled human and natural systems" (Kintigh et al. 2014, p. 7). Archaeological interest in understanding humans in relationship to climate change, ecology, and the environment was evident as early as the 1840s in Scandinavia (Trigger 2006) and has steadily grown. A survey of words (stem words climat*, environment*, and ecolog*) used in articles published in English in 117 archaeology journals indexed by JSTOR (accessed in December 2022 through the University of Wisconsin–Madison's Libraries database) shows that archaeologists have grown increasingly interested in the environment over the past 70 years with modest increases in attention to climate and ecology over the same time span (**Figure 1**).

In the years since the publication of Kintigh et al. (2014), scholarly interest has shifted from the investigation of two separate yet coupled systems, one human and one natural, to the study of dynamic and fully integrated cultural-environmental systems—the entangled questions of how humans have shaped ecosystems and how the natural environment and climate change have shaped humans and their societies. To successfully study integrated cultural-environmental systems, it is necessary to identify local as well as regional archives of climate change that are specific to the time period during which a site (or region) was occupied, to have a rich archaeological record from the site (or region) from which social behavior can be inferred, and to have tight chronological control over both the paleoenvironmental and archaeological records, all of which make the challenge even greater. Few places in the world meet these criteria [e.g., the southwestern United States (e.g., Bellorado & Anderson 2013, Benson & Berry 2009, Benson et al. 2007, Cordell et al. 2007, Schwindt et al. 2016) and the islands of the North Atlantic during Medieval times (e.g., Church et al. 2005, Dugmore et al. 2007, McGovern et al. 1988)]; however, people's lives and experiences are embedded in the natural world, and to exclude nature from consideration means

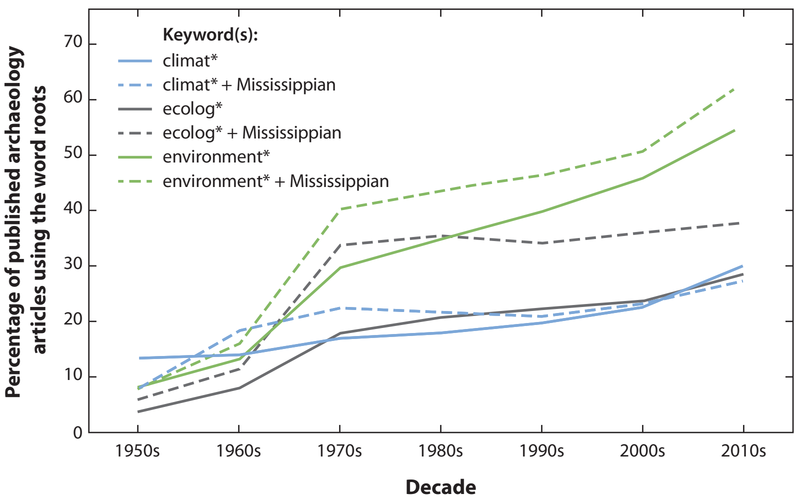

Figure 1

Percentage of published articles by decade that include climat*, environment*, and ecology* for archaeology journals and the topic Mississippian archaeology. Dashed lines: denominator is the number of papers that include the keyword "archaeology." Solid lines: denominator is the number of papers that include keywords "archaeology" and "Mississippian."

developing an incomplete understanding of culture change and persistence in the past, potentially hampering the ability to consider the impact of climate and environmental change in the present and future. For example, archaeologists are only just starting to consider some lessons from the present and applying them to the past: Those past experiences influence people's perceptions of the present (traditional knowledge), ontology (world view) colors how people think about things like the environment, and people's experiences and vulnerabilities may differ based on their social/economic/political identities within and between societies (e.g., Rivera-Collazo 2022, Thomas et al. 2019, Zych & Richards 2022).

The study of dynamic and fully integrated cultural-environmental systems is a developing area of scholarship that entwines two broad approaches that have typically been separate interpretive frameworks in US archaeology: those that emphasize ecology-environment-climate (often associated with processual archaeology) and those that center humans (usually associated with the postprocessual critique, e.g., practice theory, agency, memory). These theoretical perspectives usually sit in different scholarly domains—the natural sciences/quantitative social sciences and the humanities/humanistic social sciences—where intellectual comfort zones can be challenging to transcend, especially for individual scholars. The divide between human- and environment-oriented theoretical frameworks is deepened by fundamental differences in the type of data each framework regularly employs. Archaeological sites, artifacts, ecofacts, and features tell us much about the human past, but they are inadequate paleoenvironmental archives due to preferential and inconsistent collection of faunal and botanical material, deposition defined by cultural over natural processes (Schiffer 1975), and frequent disturbances, such as construction, burials, excavation, and plowing, that may obscure the environmental signal. Conversely, paleoenvironmental archives, including speleothems, glaciers, lake and ocean sediments, and tree rings, record paleoenvironmental conditions on a regular basis and are mostly undisturbed by human processes. While these archives are influenced by human activity through burning (Wahl et al. 2019), agriculture (Taylor et al. 2013), and heavy metal pollution (Pompeani et al. 2013, pp. 5548–49, figure 4), by themselves they tell us very little about changes in culture.

The disconnect between paleoenvironmental and archaeological data can be exacerbated by differing geographical scales to which each archive applies, significant distances between archives, and independent chronologies that compound temporal uncertainty when correlated. Paleoenvironmental data derived from glacial and deep ocean cores reflect processes occurring at a global level; while these data inform our understanding of climate change through Earth's history (Keigwin et al. 1994, Steffensen et al. 2008), how applicable their information is to the local level of individual archaeological sites is unclear. For archives that reflect a more local to regional signal, such as speleothems and lake cores, the cultural area under study must be sufficiently close to the archive for the paleoenvironmental data to be applicable. Further problems can arise from compounded temporal uncertainty when correlating archaeological trends with paleoenvironmental signals due to their independent chronologies. Radiocarbon age models are frequently inconsistent in recording decadal climate change over the past thousand years (Blaauw et al. 2007), and this uncertainty limits a close examination of coupled cultural-environmental systems.

Despite these challenges, the recognition of cultural-environmental systems as dynamic and fully integrated pushes us to think beyond the dualisms that characterize many of the theories that have guided archaeological research from its antiquarian beginnings and that are common in Western worldviews (Harris & Cipolla 2017, Latour 1993, Thomas 2004). At the same time, however, it creates opportunities for productive conversations and collaborations across the traditional intellectual divide between science and the humanities, which archaeology is uniquely positioned to straddle (e.g., Yoffee & Fowles 2011). In the US Midwest and Southeast, several interdisciplinary teams focused on Mississippian societies are beginning to grapple with these challenges.

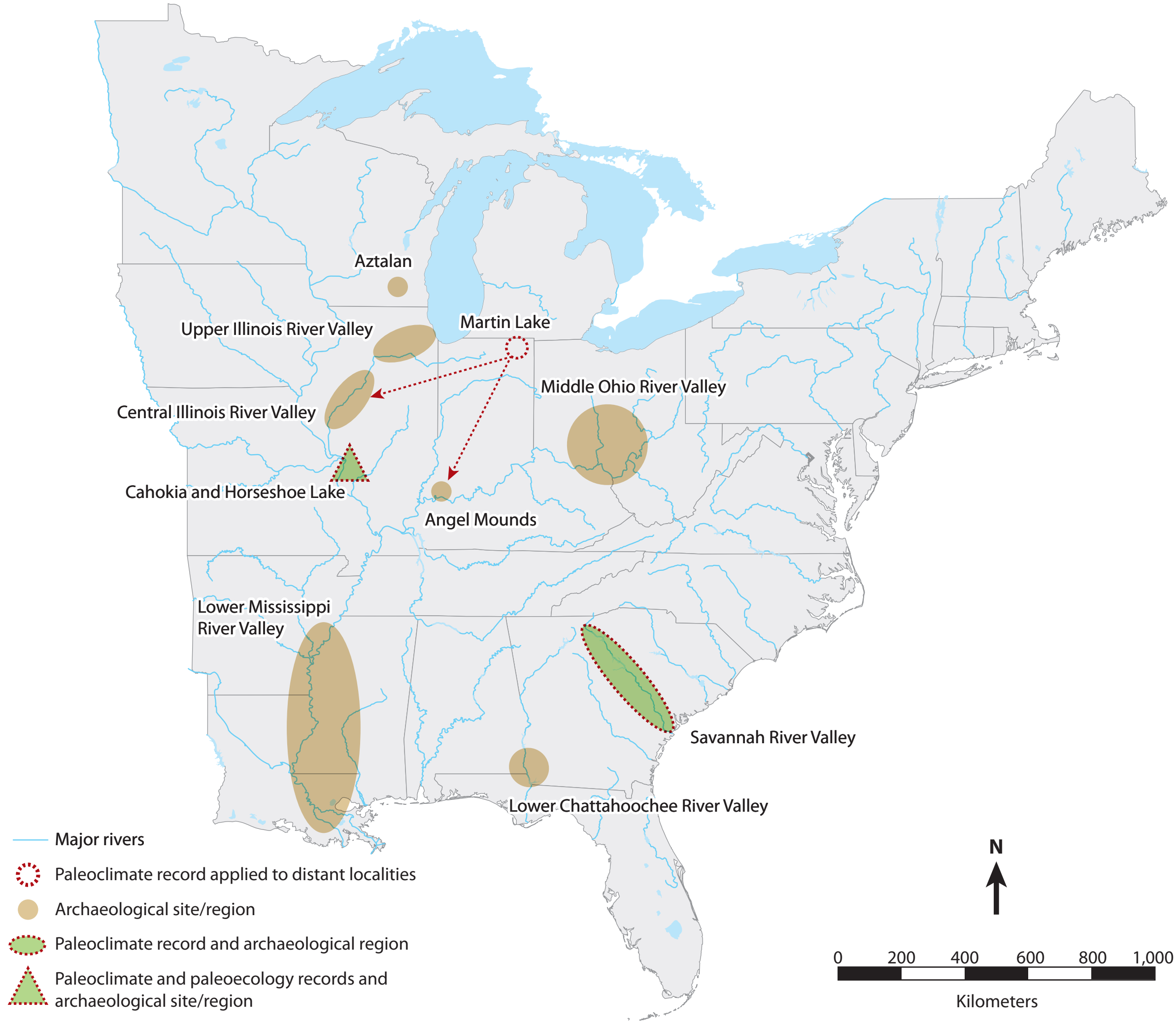

Figure 2

Mississippian archaeological sites and regions (Angel, Aztalan, Cahokia, Central Illinois River Valley, Upper Illinois River Valley, Middle Ohio Valley, Lower Chattahoochee River Valley, and Savannah River Valley) and paleoclimate/paleoenvironmental records (Horseshoe Lake, Martin Lake, and Savannah River Valley) discussed in this article.

MISSISSIPPIAN SOCIETIES IN THE MIDWEST AND SOUTHEAST

Efforts to investigate cultural-environmental systems as dynamic and fully integrated hold a lot of potential with regard to sociopolitically complex agricultural societies such as those that were part of the Mississippian archaeological cultural tradition, which existed across the southern Midwest and the Southeast between approximately AD 1000 and AD 1600 (**Figure 2**). Many Mississippian sites have been well-investigated, which has led to the recognition of considerable variation in cultural practices despite broadly shared patterns of intensive food production (i.e., agriculture) based largely on maize and indigenous domesticates, social inequality, dynamic political hierarchies, settlement hierarchies, and social integration and disintegration (e.g., Blitz 2010, Milner 1998, Muller 1997, Pauketat 2002, Rogers & Smith 2005, Schroeder 2004a, Smith 1978).

Considerable emphasis has been placed on the warm period of the Medieval Climatic Anomaly, which is seen as having facilitated the expansion of maize agriculture across the Midwest (e.g., Griffin 1961), and on climate variation, particularly drought, to which maize agriculture is considered to be vulnerable (Anderson et al. 1995, Benson et al. 2009, Bird et al. 2017, Blanton & Thomas 2008, Meeks & Anderson 2013). Each sociopolitical system had a unique trajectory, some short-lived and others lasting for centuries, but change, transformation, reorganization, resilience, vulnerability, and population movement were included (e.g., Anderson 1994, 2001; Hally & Chamblee 2019). The wealth of archaeological evidence available for these regions is supplemented by a variety of high-resolution paleoenvironmental records such as oxygen stable isotope ratios and pollen archives in sediment cores, tree-ring records, and speleothems, which offer proxies for global and regional climate in the past and, in some places, local records that document environmental disasters and human impacts on vegetation and soils (e.g., Aharon et al. 2012; Batchelor et al. 2022; Bird et al. 2017; Delcourt & Delcourt 1987; Delcourt et al. 1998; Denniston et al. 1999; Dorale et al. 1992; Munoz et al. 2014, 2015; Stahle & Cleaveland 1994; Stahle et al. 1985, 2007; White et al. 2019).

Despite the potential to examine Mississippian societies as dynamic and fully integrated cultural-environmental systems, there remains a tension between archaeologists who emphasize the ways in which human experiences are embedded in physical, natural, climatological, and social environments (e.g., Schroeder 2004b) and those who resist the idea that change in the physical, natural, and climatological environments should be considered alongside intrinsic and extrinsic social factors implicated in culture change (e.g., Baires et al. 2015; Emerson 1997; Pauketat 1994, 1998). And few have successfully drawn together ecological perspectives and agentive perspectives in a manner that explores "the multi-directional, intergenerational and interregional impact of individual, localized actions, consumption practices and engagements with the human:nonhuman:geological world" (Shaw 2016, p. 461), which is a huge challenge in a region where the archaeological chronologies are coarse-grained. Yet there is great potential to make progress on these issues, especially in places where multiproxy paleoenvironmental and archaeological data exist in the same locality.

A BRIEF HISTORY OF ARCHAEOLOGICAL CONCERN WITH THE PALEOENVIRONMENT

An interest in contextualizing archaeological evidence with paleoenvironmental settings and collaboration with natural scientists can be traced back to Scandinavian archaeologists as early as the 1840s (Trigger 2006) and to Clark's excavations at Star Carr in Great Britain between 1949 and 1951 (Clark 1954). In the United States, Taylor (1948), Steward & Setzler (1938), and others (e.g., Wedel 1941) were early proponents of approaches that integrated a consideration of the paleoenvironment and ecology into archaeological studies. Successful efforts to reconstruct ancient climatic conditions in relation to archaeological phenomena in the United States began in the early twentieth century in the Southwest, where arid conditions created excellent preservation conditions for wooden beams from ancient Puebloan buildings that encoded dating and climate records in the tree rings (e.g., Douglass 1929). But research projects were not intentionally and routinely designed to bring archaeologists together with palynologists, botanists, zoologists, malacologists, geologists, and other natural scientists to investigate the relationship between human cultures, their environmental settings (with a particular focus on subsistence economies and a functionalist interpretive perspective), and paleoclimate until after WWII (e.g., Baerreis & Bryson 1965; Baerreis et al. 1976; Bennett 1944; Braidwood 1974; Caldwell 1958; Griffin 1961; MacNeish 1967, 1974; Schwartz 1957; Wedel 1953).

Archaeologists working in the Midwest and Southeast on the time span of the Mississippian archaeological cultural tradition (roughly AD 1000–1600) initially emphasized temperature and how a warmer climate facilitated the northward expansion of maize-dependent peoples, during what we now call the Medieval Climatic Anomaly, roughly AD 950–1250 (Mann et al. 2009), and how a cooler climate during the Little Ice Age, which began around AD 1400 (Mann et al. 2009) led to cultural changes in the Midwest that included a shift away from maize to hunting (Baerreis & Bryson 1965, Baerreis et al. 1976, Griffin 1961). By the 1980s and 1990s, these approaches were criticized for being environmentally deterministic because of the focus on climate as an external source of change. This situation was particularly evident in studies centered on Cahokia, where many scholars were eschewing the environment, instead emphasizing perspectives that centered the role of human agency in ideology, political dynamics, cultural mediation of change, and historical contingency (e.g., Emerson 1997; Pauketat 1994, 1998).

By the early 2000s, interest in the impact of climate change on Mississippian cultures reemerged with an emphasis on drought and its implications for an increased risk of maize shortfalls and the destabilization of sociopolitically complex societies (e.g., Aharon et al. 2012; Anderson et al. 1995; Benson et al. 2007, 2009; Meeks & Anderson 2013). By the 2010s, scholars were exploring climate change in a more holistic manner, bringing together records of temperature, drought, flooding, environmental catastrophes, and archaeological culture change to more thoroughly investigate the synergistic effects of internal (e.g., social, genealogical, political, and economic) and external (e.g., environmental, anthropogenic, and climatic) variables implicated in marked culture change as well as societal transformation in different settings in the Midwest and Southeast (e.g., Bird et al. 2017; Munoz et al. 2014, 2015; Ritchison & Anderson 2022; Schroeder et al. 2022; White et al. 2019).

DATA CHALLENGES

Despite the availability of annually resolved paleoenvironmental databases such as the Palmer Drought Severity Index (PDSI) (Palmer 1965) and the Living Blended Drought Atlas (LBDA) (Cook et al. 2010, 2014), cultural chronologies available in the Midwest and Southeast, which are usually based on ceramics, are typically resolved to a century, rarely to 50 years, and sometimes to a greater time span. Even when radiocarbon dates are available, the statistical margin of error makes it difficult to develop refined enough control over time to be able to propose a causal relationship when, at best, only a correlation exists between the records.

For research on climate change and culture change around the world, the fact that correlation does not equal causation is a difficult challenge to overcome (Baires et al. 2015; Cobb 2022, p. 390; Kintigh & Ingram 2018; Shennan et al. 2013; Zaro et al. 2013). However, when climate change and environmental catastrophe are implicated in cultural change, it is worth tackling the challenge of exploring this correlation and the concatenation of additional factors that may be involved with the goal of developing "models to explain why changes occurred in the way they did" (Cobb 2022, p. 388). The way forward may be to move beyond dualisms such as cause and effect or the push and pull factors that frequently appear in the literature on climate change and cultural change to recognize that humans (and nonhuman entities) are entwined with each other and the environmental-ecological-climatological setting in which they exist in highly complex ways, including differences in vulnerability and precarity between and within societies (e.g., Rivera-Collazo 2022).

Research that engages with the interplay among and integration of culture, environment, and climate requires multiple lines of interdisciplinary data as well as big data approaches (e.g., Ritchison & Anderson 2022). Research collaborations that crosscut data sources and advances in analytical methods and data science are facilitating more fine-grained analyses of dynamic, integrated socioenvironmental systems and stimulating the investigation of these issues by archaeologists. A number of interdisciplinary teams are involved in efforts to integrate culture-environment-climate in archaeological research on the Mississippian archaeological cultural tradition in the Midwest and Southeast (Anderson et al. 1995; Bird et al. 2017; Krus et al. 2023; Munoz et al. 2014, 2015; Ritchison & Anderson 2022; White et al. 2019), and this work is establishing strong empirical foundations to develop ways of exploring and explaining why sociocultural changes occurred when they did and in the way they did, as called for by Cobb (2022). Yet most of these studies have found it difficult to overcome the incommensurate chronological resolution of paleoenvironmental and archaeological lines of evidence.

The remainder of this review focuses on three sources of paleoclimate proxies to highlight the strengths of and challenges to the investigation of dynamic and integrated cultural-environmental systems in the Midwest and Southeast: (*a*) bald cypress tree-ring records from the Savannah River Valley and the central and north coasts of Georgia; (*b*) the PDSI record and the LBDA, which expanded the PDSI record and recalibrated it; and (*c*) paleoecological proxy records from lake-bottom sediment cores. Lake-bottom sediment cores can be analyzed in various ways, including (*a*) oxygen stable isotope ratios, which encode variation in seasonal rainfall; (*b*) pollen records, which capture temporal changes in plant communities that may be a consequence of climate change, human activity, or catastrophic environmental events; (*c*) reconstruction of flood histories for a watershed; and (*d*) potentially fecal stanol records. Fecal stanol records describe changes in the relative size of the population living around the lake that can be directly connected to the records of oxygen stable isotope ratios, pollen, and flood histories within the same core to more holistically study the dynamic and integrated cultural-environmental system of the people living around the lake and to work toward identifying human responses to environmental catastrophe.

PALEOENVIRONMENTAL PROXIES AND THE INVESTIGATION OF CULTURAL-ENVIRONMENTAL SYSTEMS

Bald Cypress Tree-Ring Chronologies and Hydroclimate in the Southeast

In the temperate Southeast and Midwest, tree-ring records are widely scattered (see Ljungqvist et al. 2020), rarely available for the same locality as the archaeological site(s) of interest, and even more rarely available from archaeological contexts in numbers sufficient to allow for the development of statistical age models based on the tree rings. Bald cypress, however, is a rare exception and has been particularly useful in reconstructing hydroclimate in the Southeast. A bald cypress tree-ring record from Butler Island near the mouth of the Altamaha River in Georgia spans from 3,161 BC to AD 2016 and is the longest tree-ring chronology in eastern North America (Napora 2021). One from the Lower Altamaha River on the Central Georgia Coast spans AD 930–1985 (Blanton & Thomas 2008, Stahle et al. 1985, Stahle & Cleaveland 1994), and two bald cypress tree-ring records for the region around the Savannah River Valley in Georgia and South Carolina cover the years from AD 1005 to 1985 (Anderson et al. 1995, Stahle et al. 1985, Stahle & Cleaveland 1994).

Anderson collaborated on a study that translated the tree-ring records for the Savannah River Valley into relative estimates of maize productivity to explore the impact of variable hydroclimate on the fortunes of the sociopolitically complex Mississippian societies that flourished and foundered in the region between AD 1005 and 1600 (Anderson et al. 1995). The Savannah River Valley study is one of the earliest efforts to model a dynamic and fully integrated Mississippian cultural-environmental system (Anderson et al. 1995). A strength of this study is that the paleoclimate proxy is from the same drainage basin as the archaeological record and provides insights into local and regional environmental conditions. Anderson and colleagues (1995) examined how variation in modeled yields and the possibility of surpluses to buffer the frequency and magnitude of shortfalls (due to drought conditions) may have affected the cultural and political organizations of these societies. At the time, the regional ceramic chronology had a temporal resolution of about 100–150 years, so Anderson and colleagues were limited to suggesting hypotheses about the relationship between hydroclimate and sociopolitical change rather than being able to draw any clear conclusions about the impact of climate change on people and sociopolitical systems in the Savannah River Valley. In particular, they identified a 75-year time span during which drought would have occurred in ~30% of the years. These years of drought led to food shortfalls that would have created significant challenges for leaders whose various efforts to draw followers, such as hosting feasts and developing new symbolic behaviors, ultimately failed to sustain the political centers in the Savannah River Valley, resulting in its abandonment in the waning years of the fifteenth century (Anderson et al. 1995; Ritchison & Anderson 2022; Stephenson et al. 2015). The Valley was not repopulated again, despite the return of more favorable climatic conditions, perhaps because of geopolitical conditions in the broader region and perhaps attesting to the long-term impact of people's perceptions of their experiences with agricultural resource shortfalls and sociopolitical precarity (Anderson 1994, Anderson et al. 1995, Ritchison & Anderson 2022).

Tree Rings, the Palmer Drought Severity Index, and Living Blended Drought Atlas in the Midwest and Southeast

The PDSI (Palmer 1965) and a modified version, the Palmer Modified Drought Index (PMDI), bring together historic instrumentation measures of summer surface air temperature and precipitation with calculations of potential evapotranspiration to create a standardized relative estimate of soil dryness that typically ranges from −4 (dry/extreme drought) to +4 (extremely wet). The recently recalibrated LBDAv2 combines the PMDI with tree-ring data to push the record of drought conditions and severity back as far as 2,000 years in some regions (Cook et al. 2010, 2014), making it an appealing tool for archaeologists interested in exploring the relationship between climate and society. These open access data have been used by archaeologists in the Midwest and Southeast with and without the active collaboration of paleoenvironmental scientists to explore hydroclimate variability in relationship to cultural changes at Cahokia, Illinois (Benson et al. 2007, 2009; Nolan & Cook 2010); Aztalan, Wisconsin (Zych & Richards 2022); the Middle Ohio River Valley (Comstock 2017, Comstock & Cook 2018, Cook & Comstock 2022b); the Upper Illinois River Valley (Emerson et al. 2022); the Lower Chattahoochee River Valley in Tennessee (Brannan 2022); and the Lower Mississippi Valley (Mehta & Rodning 2022).

The LBDA data points are on a 0.5° grid (approximately one point every 55 km along a north–south line and an east–west line) across the lower 48 states, while the 1,845 annual tree-ring chronologies in the LBDA are discontinuously distributed with more records in the west than in the east. The LBDA is well suited for reconstructing drought through wet conditions at regional scales but, as Ljungqvist et al. (2020) argued, the LBDA does not adequately capture local hydroclimate variability, which is as important as regional hydroclimate to archaeologists seeking to understand integrated cultural-environmental relationships. Because of the thinner distribution of tree-ring records across many parts of the Eastern Woodlands, archaeologists are typically limited to only one or two LBDA data points to describe local conditions.

The LBDA offers an annually resolved hydroclimate proxy, but the archaeological chronologies used for the Midwest and Southeast typically have a 50–100-year or greater imprecision to them. Partly in an effort to address the disconnect in temporal resolution between the paleoclimate archive and archaeological chronologies, and partly in recognition that human societies might be adaptable to annual variation but struggle to cope with longer-term abnormal climatic conditions (see Anderson et al. 1995), archaeologists typically look at moving averages (e.g., Brannan 2022, Cook & Comstock 2022b, Mehta & Rodning 2022, Zych & Richards 2022) or decadal averages (e.g., Emerson et al. 2022) to identify multiyear periods where conditions were persistently wet or dry. In most of these studies, the initial florescence and expansion of Mississippian societies are associated with normal hydroclimate conditions or wet conditions, whereas drought conditions, when they persisted for multiple years, correlated with significant culture change, such as settlement abandonment, out-migration, sociopolitical reorganization, adjustments in the appropriation of labor, and material evidence of social unrest or violence (e.g., Benson et al. 2009). Because of the significant differences in dating precision between the hydroclimate and archaeological records, archaeologists are constrained to offering hypotheses about the role of climate change and variability in sociopolitical change.

Scholars who have explored past hydroclimate conditions in the Midwest and Southeast with the LBDA have reached divergent conclusions about the role of climate change in culture change. Some concluded that climate change, while an important variable, had little or no impact on the particular dimension of culture change that interested them (e.g., Brannan 2022, Emerson et al. 2022, Hedman et al. 2022, Zych & Richards 2022), whereas others highlighted the correlation between climate change and culture change and suggested that climate change was one among many factors, including social and economic, that contributed to cultural changes inferred from the archaeological record (e.g., Benson et al. 2009, Cook & Comstock 2022b, Ritchison & Anderson 2022). However, all the researchers struggled to connect regional hydroclimate proxies resolved at an annual or decadal temporal scale with the less precise archaeological chronologies, making it difficult to move past issues of equifinality. Bayesian modeling is helping to refine some of these archaeological chronologies (Bronk Ramsey 2009, Emerson et al. 2022, Krus et al. 2023, Ritchison & Anderson 2022, Thompson & Krus 2018), perhaps to the decade or a generation for a portion of the chronology (e.g., Krus et al. 2015, Stephenson et al. 2015). That said, resolution on the order of a century is more common (e.g., Emerson et al. 2022, Krus 2016), creating challenges for incorporating an agentive perspective or moving beyond dualistic interpretive structures (e.g., climate had an impact, albeit complex, versus climate did not have an impact). For example, Zych & Richards (2022, p. 186) explicitly raise the importance of considering the diverse worldviews of past peoples who experienced persistent drought and engaged with climatic variability as a nonhuman agent in the world but for whom the coarse-grained nature of the cultural chronologies for their region complicate efforts to operationalize these considerations.

Lake-Bottom Sediment Cores and Paleoenvironmental Proxies

Lake-bottom sediment cores are especially valuable because they can be analyzed for oxygen stable isotope ratios of endogenic carbonate material that encodes variation in seasonal precipitation (e.g., Bird et al. 2017, Krus et al. 2023, Pompeani et al. 2021, White et al. 2019), relative abundance of pollen grains that capture temporal changes in terrestrial plant communities (e.g., Delcourt et al. 1998, Munoz et al. 2014), and differences in sediment grain size that can be used to reconstruct flood histories for the watershed (e.g., Munoz et al. 2015). Pollen and sediment grain size capture local paleoenvironmental variation, while oxygen stable isotope ratios index regional paleoclimate variation. Depending on the number of accelerator mass spectrometry (AMS) dates obtained across the entire core, control over sedimentation rates, and sampling resolution, the age model may have a temporal resolution on the order of 5–10 years for some segments of the core, but the temporal resolution is often coarser for other segments (e.g., Bird et al. 2017, Munoz et al. 2014).

While lake-bottom sediment cores hold considerable potential for archaeology, there are some drawbacks. Lakes that are well suited to coring for paleoenvironmental reconstruction are often not in close proximity to the archaeological site(s) or region(s) of interest (see **Figure 1**) and are therefore useful as a proxy for regional paleoclimate only. Such is the case for the high-resolution core from Martin Lake in northeastern Indiana that has been applied to two localities in the Midwest: the Central Illinois River Valley, located more than 400 km to the west-southwest (Bird et al. 2017, Krus et al. 2023, Wilson & Bird 2022), and Angel Mounds, located more than 450 km to the southwest (Krus et al. 2023).

The sediment cores from Horseshoe Lake, which includes the urban core of Cahokia within its watershed, offer a rare case where the paleoclimate and archaeological records are from the same locality. Multiple cores from this lake have been analyzed (Ollendorf 1993; Munoz et al. 2014a, 2015; Pompeani et al. 2019, 2021; White et al. 2018, 2019). Here, we focus on the Munoz et al. (2014a, 2015) and White et al. (2018, 2019) cores because these have yielded high-resolution data on pollen, allowing the identification of human and climatic impacts on local vegetation, and grain size analysis of the sediments to track the flood history of the watershed. In addition, both cores have been analyzed for fecal stanol concentrations (for more on this method, see Bull et al. 1999, 2002; Leeming et al. 1996; Prost et al. 2017) from which relative changes in local population size can be inferred and directly connected to the paleovegetation record and flood history. Oxygen stable isotopes have been analyzed in one core, offering a proxy for regional hydroclimate (White et al. 2019). A robust age model for one of the cores (Munoz et al. 2015, S3) can be applied to the other core on the basis of distinctive stratigraphic layers, such as the flood deposits. This approach makes it possible to directly compare changes in relative population size with the paleoenvironment and to evaluate the role of flooding, drought, and environmental degradation in Cahokia's sociopolitical reorganization and demographic decline, with implications for external relationships (Schroeder et al. 2022).

The pollen record extends back to about AD 250, when archaeological and palynological evidence indicates limited occupation of the Cahokia area. The pollen evidence indicates extensive land clearing around AD 450 and the initial intensification of food production involving plants associated with the Eastern Agricultural Complex (EAC), showing the impact of people on their environment. The emergence of food production in this area occurs 500 years before the Medieval Climatic Anomaly, the warmer period sometimes credited with making agricultural expansion possible in the Midcontinent (e.g., Baerreis & Bryson 1965, Griffin 1961), and 600 years before Cahokia's emergence as a major regional sociopolitical center. Analysis of sediment particle size indicates that this era was also characterized by periodic high-magnitude floods, which might account for the limited archaeological evidence for occupation of the floodplain. The fecal stanol and oxygen stable isotope records do not extend this far back. Pollen evidence indicates the intensification of agricultural land use practices around AD 600 based on the EAC; maize does not appear to have much presence in the region until AD 900 (Emerson et al. 2020; Simon 2017). Archaeological evidence indicates that population growth accelerated in the region shortly before the AD 1050 "Big Bang" that marks the rise of Cahokia (sensu Pauketat 1994, 1998; see also Milner 1986, 1998; Pauketat & Lopinot 1997). Furthermore, the sediment particle–size analysis indicates that large floods were absent from the Cahokia area between ca. AD 600 and ca. AD 1160. Oxygen stable isotope data and tree-ring records indicate that the climate was conducive to agriculture during these centuries (White et al. 2019; Benson et al. 2009). The fecal stanol record tracks with the archaeological record, indicating that population size within the Horseshoe Lake watershed peaked early in the eleventh century AD and began to decrease shortly after (White et al. 2019).

At a modeled median calibrated age of ca. AD 1160 (Munoz et al. 2019, p. 272), the sediment particle size data indicate that there was a massive high-magnitude flood originating from the Missouri River (Munoz et al. 2015, 2019). This flood was of a magnitude sufficient to inundate most of the floodplain around Cahokia, and it would have forced residents to temporarily relocate to higher elevations available along the margin of the floodplain and retreat into the adjacent uplands. The pollen record indicates a reduction in agricultural land use after the flood, and, by AD 1350, the vegetation had returned to its preagricultural composition (Munoz et al. 2014). The fecal stanol record indicates that the population declined steeply after the massive flood, and the oxygen stable isotope data indicate a roughly synchronous onset of decreased summer rainfall and prolonged drought (Munoz et al. 2015, White et al. 2019) that is also evident in the PDSI/PDMI record for the Cahokia area (Benson et al. 2009). The archaeological record indicates significant sociopolitical transformations at Cahokia by AD 1200, including a decline in mound building, wholesale destruction of communities within Greater Cahokia, the construction of a sequence of palisade walls around Central Cahokia, and the end of certain types of buildings associated with religious practices that likely also ended (e.g., Brennan et al. 2018; Emerson 1997, 2018; Emerson et al. 2008; Iseminger 1990; Kelly 2009; Pauketat 2019; Pauketat et al. 2013; Trubitt 2000). By AD 1350, the region was essentially abandoned (e.g., Milner 1986, 1998; Pauketat & Lopinot 1997).

These records from the Horseshoe Lake sediment cores offer strong evidence of correlations of major flood followed by a drier hydroclimate, reduction in agricultural land use, and steep population decline in the lake's watershed, and these events also correlate with changes in the archaeological record at Cahokia from which significant sociopolitical transformations have been inferred. No other place in the Midwest or Southeast offers such a refined local and regional paleoenvironmental, paleoclimatological, and demographic record in association with a well-investigated archaeological site. It offers a useful case study to consider the entwined nature of culture, people, the environment, and climate. In particular, it provides insights into how people's past experiences and traditional knowledge (e.g., 600 years without high-magnitude floods) might influence their perception of a major flood. It also offers potential insights into how this flood event may have been differentially experienced based on social, economic, ideological, and political identities and connections (i.e., some portion of the population remained or returned to Cahokia after the floodwaters receded, but a significant number did not). Finally, the archaeological hints that religious practices underwent significant changes in the decades after the flood might signal a change in ontology or ontologies.

SUMMARY

Two decades into the twenty-first century, the close entwinement of humans and nature confronts us on an almost daily basis. The extraordinary increase in extreme weather events provides frequent reminders of the effects of climate change that can be attributed at least in part to anthropogenic factors: increased magnitude and spatial extent of drought, wildfires burning large areas of forests and destroying entire communities, catastrophic floods, record-breaking snowfalls, historically frigid and hot temperatures in places unaccustomed to these extremes, and weather whiplash events, among others (e.g., Abatzoglou & Williams 2016; Ault 2020; Ault et al. 2013, 2014; Dai 2013; Faranda et al. 2022; Francis et al. 2022; Handmer et al. 2012; Seneviratne et al. 2012; Zhou et al. 2022). Extreme as well as nonextreme climate events can significantly impact people's lives: They can affect agriculture and food systems, water quality, other natural resources, human health and well-being, and infrastructure and can lead to migration, conflict, disruption of social networks, political instability, and loss of life (Ault et al. 2013, Francis et al. 2022, Handmer et al. 2012).

Coarse-grained chronological control over the archaeological record of the Midwest and Southeast creates an obstacle to investigating the dynamic and integrated cultural-environmental systems of the past, as does the rarity with which paleoenvironmental records are available for the same location as the archaeological site(s) or region(s) of interest. The examples described here show that integrated approaches to social complexity that bring together archaeological evidence with paleoenvironmental and climatological data from the same locality have the best chance of success when they draw on multiple lines of evidence, focus on a single locale, and scale up to the region. With such data, opportunities exist to examine variability in responses to climate change and environmental catastrophe within and between societies. Collaborations between those trained in climate and environmental science and those who adopt humanistic or social science approaches are essential to this endeavor. This kind of work will continue to present considerable challenges until we gain greater refinement over archaeological chronologies.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

LITERATURE CITED

Abatzoglou JT, Williams AP. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *PNAS* 113(42):11770–75

Aharon P, Aldridge D, Hellstrom J. 2012. Rainfall variability and the rise and collapse of the Mississippian chiefdoms: evidence from a DeSoto caverns stalagmite. In *Climates, Landscapes, and Civilizations*, Vol. 198, ed. L Giosan, DQ Fuller, K Nicoll, RK Flad, PD Clift, pp. 35–42. Washington, DC: Am. Geophys. Union

Anderson DG. 1994. *The Savannah River Chiefdoms: Political Change in the Late Prehistoric Southeast*. Tuscaloosa: Univ. Ala. Press

Anderson DG. 2001. Climate and culture change in prehistoric and early historic eastern North America. *Archaeol. East. N. Am.* 29:143–86

Anderson DG, Stahle DW, Cleveland MR. 1995. Paleoclimate and the potential food reserves of Mississippian societies: a case study from the Savannah River Valley. *Am. Antiq.* 60:258–86

Ault TR. 2020. On the essentials of drought in a changing climate. *Science* 368(6488):256–60

Ault TR, Cole JE, Overpeck JT, Pederson GT, Meko DM. 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *J. Clim.* 27(20):7529–49

Ault TR, Henebry GM, de Beurs KM, Schwartz MD, Betancourt JL, Moore D. 2013. The false spring of 2012, earliest in North American record. *EOS* 94(20):181–88

Baerreis DA, Bryson RA. 1965. Climatic episodes and the dating of Mississippian cultures. *Wis. Archeol.* 46:203–20

Baerreis DA, Bryson RA Kutzbach JE. 1976. Climate and culture in the western Great Lakes region. *Midcont. J. Archaeol.* 1:39–58

Baires SE, Baltus MR, Buchanan ME. 2015. Correlation does not equal causation: questioning the Great Cahokia Flood. *PNAS* 112(29):E3753

Batchelor CJ, Marcott SA, Orland IJ, Kitajima K. 2022. Late Holocene increase of winter precipitation in mid-continental North America from a seasonally resolved speleothem record. *Geology* 50(7):781–85

Bellorado BA, Anderson KC. 2013. Early Pueblo responses to climate variability: farming traditions, land tenure, and social power in the eastern Mesa Verde region. *KIVA* 78:377–416

Bennett JW. 1944. The interaction of culture and environment in the smaller societies. *Am. Anthropol.* 46(4):461–78

Benson LV, Berry MS. 2009. Climate change and cultural response in the prehistoric American Southwest. *KIVA* 75:89–119

Benson LV, Berry MS, Jolie EA, Spangler JD, Stahle DW, Hattori EM. 2007. Possible impacts of early-11th-, middle-12th, and late-13th-century droughts on western Native Americans and the Mississippian Cahokians. *Quat. Sci. Rev.* 26:336–50

Benson LV, Pauketat TR, Cook ER. 2009. Cahokia's boom and bust in the context of climate change. *Am. Antiq.* 74:467–83

Bird BW, Wilson JJ, Gilhooly WP III, Steinman BA, Stamps L. 2017. Midcontinental Native American population dynamics and late Holocene hydroclimate extremes. *Nat. Sci. Rep.* 7:41628

Blaauw M, Christen JA, Mauquoy D, van der Plicht J, Bennett KD. 2007. Testing the timing of radiocarbon-dated events between proxy archives. *Holocene* 17(2):283–88

Blanton DB, Thomas DH. 2008. Paleoclimates and human responses along the central Georgia coast: a tree-ring perspective. In *Native American Landscapes of St. Catherine's Island, Georgia:* I. *The Theoretical Framework*, ed. DH Thomas, pp. 799–806. Am. Mus. Nat. Hist. Anthropol. (AMNH) Pap. 88. New York: AMNH

Blitz JH. 2010. New perspectives in Mississippian archaeology. *J. Archaeol. Res.* 18(1):1–39

Braidwood RJ. 1974. The Iraq Jarmo project. See Willey 1974, pp. 59–83

Brannan S. 2022. Population aggregation and dispersal as a driver for settlement change in the Lower Chattahoochee River Valley between AD 1100 and 1500. See Cook & Comstock 2022a, pp. 301–20

Brennan TK, Betzenhauser AM, Landsell MB, Plocher LA, Potter VE, Blodgett DF. 2018. Community organization of the East St. Louis precinct. See Emerson et al. 2018, pp. 147–202

Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–60

Bull ID, Lockheart MJ, Elhmmali MM, Roberts DJ, Evershed RP. 2002. The origin of faeces by means of biomarker detection. *Environ. Int.* 27:647–54

Bull ID, Simpson IA, van Bergen PF, Evershed RP. 1999. Muck 'n' molecules: organic geochemical methods for detecting ancient manuring. *Antiquity* 73:86–96

Caldwell JR. 1958. *Trend and Tradition in the Prehistory of the Eastern United States*. Am. Anthropol. Assoc. Mem. 88. Menasha, WI: Am. Anthropol. Assoc.

Church MJ, Arge SV, Brewington S, McGovern TH, Woollett JM, et al. 2005. Puffins, pigs, cod and barley: palaeoeconomy at Undir Junkarinsfløtti, Sandoy, Faroe Islands. *Environ. Archaeol.* 10(2):179–97

Clark JGD. 1954. *Excavations at Star Carr: An Early Mesolithic Site at Seamer near Scarborough, Yorkshire.* Cambridge, UK: Cambridge Univ. Press

Cobb CR. 2022. Reassessing migration and climate change during the Mississippian Period. See Cook & Comstock 2022a, pp. 379–97

Comstock AR. 2017. *Climate change, migration, and the emergence of village life on the Mississippian periphery: a Middle Ohio Valley case study*. PhD Diss., Dep. Anthropol., Ohio State Univ., Columbus

Comstock AR, Cook RA. 2018. Climate change and migration along a Mississippian periphery: a Fort Ancient example. *Am. Antiq.* 83(1):91–108

Cook BI, Seager R, Heim RR Jr., Vose RS, Herweijer C, Woodhouse C. 2010. Megadroughts in North America: placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context. *J. Quat. Sci.* 25(1):48–61

Cook BI, Smerdon JE, Seager R, Cook ER. 2014. Pan-continental droughts in North America over the last millennium. *J. Clim.* 27:383–97

Cook RA, Comstock AR, eds. 2022a. *Following the Mississippian Spread: Climate Change and Migration in the Eastern US (ca. AD 1000–1600)*. New York: Springer

Cook RA, Comstock AR. 2022b. Moving in and moving on: climate change and Mississippian migration in the Middle Ohio Valley. See Cook & Comstock 2022a, pp. 197–226

Cordell LS, Van West CR, Dean JS, Muenchrath DA. 2007. Mesa Verde settlement history and relocation: climate change, social networks, and ancestral Pueblo migration. *KIVA* 72:379–405

Dai A. 2013. Increasing drought under global warming in observations and models. *Nat. Clim. Change* 3:52–58

Delcourt PA, Delcourt HR. 1987. *Long-Term Forest Dynamics of the Temperate Zone: A Case Study of Late-Quaternary Forests in Eastern North America*. New York: Springer-Verlag

Delcourt PA, Delcourt HR, Ison CR, Sharp WE, Gremillion KJ. 1998. Prehistoric human use of fire, the eastern agricultural complex, and Appalachian oak-chestnut forests: paleoecology of Cliff Palace Pond, Kentucky. *Am. Antiq.* 63:263–78

Denniston RF, González LA, Asmerom Y, Baker RG, Reagan MK, Bettis EA III. 1999. Evidence for increased cool season moisture during the middle Holocene. *Geology* 27:815–18

Dorale JA, González IA, Reagan MK, Pickett DA, Murrell MT, Baker RG. 1992. A high-resolution record of Holocene climate change in speleothem calcite from Cold Water Cave, northeast Iowa. *Science* 258:1626–30

Douglass AE. 1929. The secret of the Southwest solved by talkative tree rings. *Nat. Geogr. Mag.* 56:736–70

Dugmore AJ, Keller C, McGovern TH. 2007. Norse Greenland settlement: reflections on climate change, trade, and the contrasting fates of human settlements in the North Atlantic islands. *Arctic Anthropol.* 44(1):12–36

Emerson TE. 1997. *Cahokia and the Archaeology of Power*. Tuscaloosa: Univ. Ala. Press

Emerson TE. 2018. Greater Cahokia—chiefdom, state, or city? Urbanism in the North American midcontinent, AD 1050–1250. See Emerson et al. 2018, pp. 487–535

Emerson TE, Alt SM, Pauketat TR. 2008. Locating American Indian religion at Cahokia and beyond. In *Religion, Archaeology, and the Material World*, ed. L Fogelin, pp. 216–36. Cent. Archaeol. Investig. Occas. Pap. 36. Carbondale: Cent. Archaeol. Investig., South. Ill. Univ.

Emerson TE, Hedman KM, Fort MA, Emerson KE. 2022. Late pre-contact ethnogenesis, resilience, and movement in the face of climate variation in the Upper Illinois River Valley. See Cook & Comstock 2022a, pp. 139–67

Emerson TE, Hedman KM, Simon ML, Fort MA, Witt KE. 2020. Isotopic confirmation of the timing and intensity of maize consumption in Greater Cahokia. *Am. Antiq.* 85:241–62

Emerson TE, Koldehoff BH, Brennan TK, eds. 2018. *Revealing Greater Cahokia, North America's First Native City: Rediscovery and Large-Scale Excavations of the East St. Louis Precinct*. Urbana: Ill. State Archaeol. Survey, Univ. Ill.

Faranda D, Bourdin S, Ginesta M, Krouma M, Noyelle R, et al. 2022. A climate-change attribution retrospective of some impactful weather extremes of 2021. *Weather Clim. Dyn.* 3(4):1311–40

Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, et al. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge, UK: Cambridge Univ. Press

Francis JA, Skific N, Vavrus SJ, Cohen J. 2022. Measuring "weather whiplash" events in North America: a new large-scale regime approach. *J. Geophys. Res. Atmospheres* 127(17):e2022JD036717

Griffin JB. 1961. Some correlations of climatic and cultural change in eastern North American prehistory. *Ann. New York Acad. Sci.* 95:710–17

Hally DJ, Chamblee JF. 2019. The temporal distribution and duration of Mississippian polities in Alabama, Georgia, Mississippi, and Tennessee. *Am. Antiq.* 84(3):420–37

Handmer J, Honda Y, Kundzewicz Z, Arnell N, Benito G, et al. 2012. Changes in impacts of climate extremes: human systems and ecosystems. See Field et al. 2012, pp. 231–90

Harris OJT, Cipolla CN. 2017. *Archaeological Theory in the New Millennium: Introducing Current Perspectives*. London: Routledge

Hedman KM, Emerson TE, Fort MA, Lambert JM, Betzenhauser AM, Pauketat TR. 2022. Corn, climate, and the human population of Greater Cahokia. See Cook & Comstock 2022a, pp. 37–64

Iseminger WR. 1990. *The Archaeology of the Cahokia Palisade.* Springfield: Ill. Hist. Preserv. Agency

Keigwin LD, Curry WB, Lehman SJ, Johnsen S. 1994. The role of the deep ocean in North Atlantic climate change between 70 and 130 kyr ago. *Nature* 371(6495):323–26

Kelly JE. 2009. Contemplating Cahokia's collapse. In *Global Perspectives on the Collapse of Complex Systems*, ed. JA Railey, RM Reycraft, pp. 147–68. Albuquerque, NM: Maxwell Mus. Anthropol.

Kintigh KW, Altschul JH, Beaudry MC, Drennan RD, Kinzig AP, et al. 2014. Grand challenges for archaeology. *Am. Antiq.* 79:5–24

Kintigh KW, Ingram SE. 2018. Was the drought really responsible? Assessing statistical relationships between climate extremes and cultural transitions. *J. Archaeol. Sci.* 89:25–31

Krus AM. 2016. The timing of Precolumbian militarization in the U.S. Midwest and Southeast. *Am. Antiq.* 81:375–88

Krus AM, Cook RA, Hamilton D. 2015. Bayesian chronological modeling of SunWatch, a Fort Ancient village in Dayton, Ohio. *Radiocarbon* 57:965–77

Krus AM, Hermann EW, Friberg CM, Bird BW, Wilson JJ. 2023. Social change and late Holocene hydroclimate variability in southwest Indiana. *J. Anthropol. Archaeol.* 69:101486

Latour B. 1993. *We Have Never Been Modern*, transl. C Porter. Cambridge, MA: Harvard Univ. Press

Leeming R, Ball A, Ashbolt N, Nichols P. 1996. Using faecal sterols from humans and animals to distinguish faecal pollution in receiving waters. *Water Res.* 30:2893–900

Ljungqvist FC, Piermattei A, Seim A, Krusic PJ, Büntgen U, et al. 2020. Ranking of tree-ring based hydroclimate reconstructions of the past millennium. *Quat. Sci. Rev.* 230:106074

MacNeish RS. 1967. An interdisciplinary approach to an archaeological problem. In *Prehistory of the Tehuacán Valley*, Vol. 1: *Environment and Subsistence*, ed. DS Byers, pp. 14–24. Austin: Univ. Tex. Press

MacNeish RS. 1974. Reflections on my search for the beginnings of agriculture in Mexico. See Willey 1974, pp. 207–34

Mann ME, Zhang Z, Rutherford S, Bradley RS, Hughes MK, et al. 2009. Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. *Science* 326:1256–60

McGovern TH, Bigelow G, Amorosi T, Russell D. 1988. Northern islands, human error, and environmental degradation: a view of social and ecological change in the Medieval North Atlantic. *Hum. Ecol.* 16:225–70

Meeks SC, Anderson DG. 2013. Drought, subsistence stress, and population dynamics: assessing Mississippian abandonment of the vacant quarter. In *Soils, Climate, and Society: Archaeological Investigations in Ancient America*, ed. JD Wingard, SE Hayes, pp. 61–83. Boulder: Univ. Colo. Press

Mehta JM, Rodning CB. 2022. Environment, climate, and Mississippian origins in the Lower Mississippi Valley and the Mississippi River Delta. See Cook & Comstock 2022a, pp. 357–78

Milner GR. 1986. Mississippian period population density in a segment of the Central Mississippi River Valley. *Am. Antiq.* 51:227–38

Milner GR. 1998. *The Cahokia Chiefdom: The Archaeology of a Mississippian Society*. Washington, DC: Smithson. Inst. Press

Muller J. 1997. *Mississippian Political Economy*. New York: Plenum

Munoz SE, Giosan L, Blusztajn J, Rankin C, Stinchcomb GE. 2019. Radiogenic fingerprinting reveals anthropogenic and buffering controls on sediment dynamics of the Mississippi River system. *Geology* 47(3):271–74

Munoz SE, Gruley KE, Massie A, Fike DA, Schroeder S, Williams JW. 2015. Cahokia's emergence and decline coincided with shifts of flood frequency on the Mississippi River. *PNAS* 112(20):6319–24

Munoz SE, Schroeder S, Fike DA, Williams JW. 2014. A record of sustained prehistoric and historic land use from the Cahokia region, Illinois, USA. *Geology* 42:499–502

Napora KG. 2021. *Refining cultural and environmental temporalities at the Late Archaic-Early Woodland Transition on the Georgia coast, USA*. PhD Diss., Dep. Anthropol., Univ. Ga., Athens

Nolan KC, Cook RA. 2010. Volatile climate conditions Cahokia: comment on Benson, Pauketat & Cook 2009. *Am. Antiq.* 75(4):978–83

Ollendorf AL. 1993. *Changing landscapes in the American bottom (USA): an interdisciplinary investigation with an emphasis on the Late-Prehistoric and Early-Prehistoric periods*. PhD Diss., Univ. Minn., Minneapolis

Palmer WC. 1965. *Meteorological drought*. Weather Bur. Res. Pap. 45, US Dep. Commer., Washington, DC

Pauketat TR. 1994. *The Ascent of Chiefs: Cahokia and Mississippian Politics in Native North America*. Tuscaloosa: Univ. Ala. Press

Pauketat TR. 1998. Refiguring the archaeology of Greater Cahokia. *J. Archaeol. Res.* 6(1):45–89

Pauketat TR. 2002. A fourth-generation synthesis of Cahokia and Mississippianization. *Midcont. J. Archaeol.* 27:149–70

Pauketat TR. 2019. Fragile Cahokian and Chacoan orders and infrastructures. In *The Evolution of Fragility: Setting the Terms*, ed. N Yoffee, pp. 89–108. Cambridge, UK: McDonald Inst. Archaeol. Res., Univ. Cambridge

Pauketat TR, Fortier AC, Alt SM, Emerson TE. 2013. A Mississippian conflagration at East St. Louis and its political-historical implications. *J. Field Archaeol.* 38:210–26

Pauketat TR, Lopinot NH. 1997. Cahokian population dynamics. In *Cahokia: Domination and Ideology in the Mississippian World*, ed. TR Pauketat, TE Emerson, pp. 103–23. Lincoln: Univ. Neb. Press

Pompeani DP, Abbott MB, Steinman BA, Bain DJ. 2013. Lake sediments record prehistoric lead pollution related to early copper production in North America. *Environ. Sci. Technol.* 47:5545–52

Pompeani DP, Bird BW, Wilson JJ, Gilhooly WP III, Hillman AL, et al. 2021. Severe Little Ice Age drought in the midcontinental United States during the Mississippian abandonment of Cahokia. *Sci. Rep.* 11:13829

Pompeani DP, Hillman AL, Finkenbinder MS, Bain DJ, Correa-Metrio A, et al. 2019. The environmental impact of a pre-Columbian city based on geochemical insights from lake sediment cores recovered near Cahokia. *Quat. Res.* 91(2):714–28

Prost K, Birk JJ, Lehndorff E, Gerlach R, Amelung W. 2017. Steroid biomarkers revisited—improved source identification of faecal remains in archaeological soil material. *PLOS ONE* 12(1):e0164882

Ritchison BT, Anderson DG. 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. See Cook & Comstock 2022a, pp. 257–98

Rivera-Collazo I. 2022. Environment, climate and people: exploring human responses to climate change. *J. Anthropol. Archaeol.* 68:101460

Rogers JD, Smith BD, eds. 2005. *Mississippian Communities and Households*. Tuscaloosa: Univ. Ala. Press

Schiffer MB. 1975. Archaeology as behavioral science. *Am. Anthropol.* 77(4):836–48

Schroeder S. 2004a. Current research on Late Precontact societies of the midcontinental United States. *J. Archaeol. Res.* 12(4):311–72

Schroeder S. 2004b. Power and place: agency, ecology, and history in the American Bottom, Illinois. *Antiquity* 78:812–27

Schroeder S, White AJ, Stevens LR, Munoz SE. 2022. Regional migration and Cahokian population change in the context of climate change and hydrological events. See Cook & Comstock 2022a, pp. 65–109

Schwartz DW. 1957. Climate change and culture history in the Grand Canyon Region. *Am. Antiq.* 22:372–77

Schwindt DM, Bocinsky RK, Ortman SG, Glowacki DM, Varien MD, Kohler TA. 2016. The social consequences of climate change in the central Mesa Verde region. *Am. Antiq.* 81:74–96

Seneviratne S, Nicholls N, Easterling D, Goodess CM, Kanae S, et al. 2012. Changes in climate extremes and their impacts on the natural physical environment. See Field et al. 2012, pp. 109–230

Shaw J. 2016. Archaeology, climate change and environmental ethics: diachronic perspectives on human:non-human:environment worldviews, activism and care. *World Archaeol.* 48:449–65

Shennan S, Downey SS, Timpson A, Edinborough K, Colledge S, et al. 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nat. Comm.* 4:2486

Simon ML. 2017. Reevaluating the evidence for Middle Woodland maize from the Holding site. *Am. Antiq.* 82(1):140–50

Smith BD. 1978. Variation in Mississippian settlement patterns. In *Mississippian Settlement Patterns*, pp. 479–503. New York: Acad. Press

Stahle DW, Cleaveland MK. 1994. Tree-ring reconstructed rainfall over the southeastern U.S.A. during the Medieval Warm Period and Little Ice Age. *Clim. Change* 26:199–212

Stahle DW, Cook ER, White JWC. 1985. Tree-ring dating of baldcypress and the potential for millennia-long chronologies in the Southeast. *Am. Antiq.* 50(4):796–802

Stahle DW, Fye FK, Cook ER, Griffin RD. 2007. Tree-ring reconstructed megadroughts over North America since AD 1300. *Clim. Change* 83:133–49

Steffensen JP, Andersen KK, Bigler M, Clausen HB, Dahl-Jensen D, et al. 2008. High-resolution Greenland ice core data show abrupt climate change happens in few years. *Science* 321(5889):680–84

Stephenson K, King A, Smith KY. 2015. Space and time: the culture historical setting for the Hollywood phase of the middle Savannah River Valley. In *Archaeological Perspectives on the Southern Appalachians: A Multiscalar Approach*, ed. RA Gougeon, MS Meyers, pp. 171–98. Knoxville: Univ. Tenn. Press

Steward JH, Setzler FM. 1938. Function and configuration in archaeology. *Am. Antiq.* 4(1):4–10

Taylor WW. 1948. *A Study of Archaeology*. Am. Anthropol. Assoc. Mem. 69. Carbondale: South. Ill. Univ., Cent. Archaeol. Investig.

Taylor ZP, Horn SP, Finkelstein DB. 2013. Maize pollen concentrations in Neotropical lake sediments as an indicator of the scale of prehistoric agriculture. *Holocene* 23(1):78–84

Thomas J. 2004. *Archaeology and Modernity*. London: Routledge

Thomas K, Hardy RD, Lazrus H, Mendez M, Orlove B, Rivera-Collazo I, et al. 2019. Explaining differential vulnerability to climate change: a social science review. *WIREs Clim. Change* 10(2):e565

Thompson VD, Krus AM. 2018. Contemplating the history and future of radiocarbon dating in the American Southeast. *Southeast. Archaeol.* 37:1–11

Trigger BG. 2006. *A History of Archaeological Thought*. Cambridge, UK: Cambridge Univ. Press. 2nd ed.

Trubitt MBD. 2000. Mound building and prestige goods exchange: changing strategies in the Cahokia chiefdom. *Am. Antiq.* 65:669–90

Wahl D, Anderson L, Estrada-Belli F, Tokovinine A. 2019. Palaeoenvironmental, epigraphic and archaeological evidence of total warfare among the Classic Maya. *Nat. Hum. Behav.* 3(10):1049–54

Wedel WR. 1941. *Environment and Native Subsistence Economies in the Central Great Plains*. Smithson. Misc. Collect. Vol. 101. Washington, DC: Smithson. Inst.

Wedel WR. 1953. Some aspects of human ecology in the Central Plains. *Am. Anthropol.* 55(4):499–514

White AJ, Stevens LR, Lorenzi V, Munoz SE, Lipo CP, Schroeder S. 2018. An evaluation of fecal stanols as indicators of population change at Cahokia, Illinois. *J. Archaeol. Sci.* 93:129–34

White AJ, Stevens LR, Lorenzi V, Munoz SE, Schroeder S, et al. 2019. Fecal stanols show simultaneous flooding and seasonal precipitation change correlate with Cahokia's population decline. *PNAS* 116(12):5641–66

Willey GR, ed. 1974. *Archaeological Researches in Retrospect*. Cambridge, MA: Winthrop

Wilson JJ, Bird BW. 2022. Drought, diet, demography, and diaspora during the Mississippian Period: a view from the Central Illinois River Valley. See Cook & Comstock 2022a, pp. 113–37

Yoffee N, Fowles SM. 2011. Archaeology in the humanities. *Diogenes* 58(1–2):35–52

Zaro G, Nystrom KC, Keefer DK. 2013. Environmental catastrophe and the archaeological record: complexities of volcanism, floods, and farming in South Coastal Peru, A.D. 1200–1700. *Andean Past* 11:17

Zhou T, Zhang W, Zhang L, Clark R, Qian C, et al. 2022. 2021: a year of unprecedented climate extremes in eastern Asia, North America, and Europe. *Adv. Atmos. Sci*. 39(10):1598–607

Zych TJ, Richards JD. 2022. Pushing and pulling the Mississippian Moment into the western Great Lakes. See Cook & Comstock 2022a, pp. 169–94