Midcontinental Journal of Archaeology

ISSN: 0146-1109 (Print) 2327-4271 (Online) Journal homepage: http://www.tandfonline.com/loi/ymca20

An Interdisciplinary Human-Environmental Examination of Effects Consistent with the Anthropocene in the Lower Illinois River Valley

Carol E. Colaninno, John H. Chick, Terrance J. Martin, Autumn M. Painter, Kelly B. Brown, Curtis T. Dopson, Ariana O. Enzerink, Stephanie R. Goesmann, Tom Higgins, Nigel Q. Knutzen, Erin N. Laute, Paula M. Long, Paige L. Ottenfeld, Abigail T. Uehling & Lillian C. Ward

MIDCONTINENTAL JOURNAL OF ARCHAEOLOGY, 2017
VOL. 42, NO. 3, 266–290
https://doi.org/10.1080/01461109.2017.1375067

An Interdisciplinary Human-Environmental Examination of Effects Consistent with the Anthropocene in the Lower Illinois River Valley

Carol E. Colaninno[a], John H. Chick[b], Terrance J. Martin[c], Autumn M. Painter[d], Kelly B. Brown[e], Curtis T. Dopson[f], Ariana O. Enzerink[g], Stephanie R. Goesmann[h], Tom Higgins[i], Nigel Q. Knutzen[j], Erin N. Laute[k], Paula M. Long[l], Paige L. Ottenfeld[m], Abigail T. Uehling[n] and Lillian C. Ward[o]

[a]Center for STEM Research, Education, & Outreach, Southern Illinois University Edwardsville, IL, USA; [b]Great Rivers Field Station, Illinois Natural History Survey, University of Illinois Urbana–Champaign, Alton, IL, USA; [c]Department of Anthropology, Illinois State Museum, Springfield, IL, USA; [d]Department of Anthropology, Michigan State University, East Lansing, MI, USA; [e]Veterans Curation Program, New South Associates, Augusta, GA, USA; [f]Department of Anthropology, University of West Georgia, Carrollton, GA, USA; [g]Department of Neurobiology and Behavior, Cornell University, Ithaca, NY, USA; [h]Department of Biology, Blackburn College, Carlinville, IL, USA; [i]Westchester County Department of Environmental Facilities, NY, USA; [j]Department of Anthropology, Southern Illinois University Edwardsville, Edwardsville, IL, USA; [k]World Bird Sanctuary, Memphis Zoo, Memphis, TN, USA; [l]Department of Anthropology, University of Central Arkansas, Conway, AR, USA; [m]Tennessee Department of Environment and Conservation, Nashville, TN, USA; [n]Department of Biology, Hamilton College, Clinton, NY, USA; [o]Department of Geology, Aquinas College, Grand Rapids, MI, USA

ABSTRACT

Using archaeological and ecological data of animal communities, and fish communities in particular, we test for evidence consistent with the Anthropocene in the lower Illinois River valley across millennia. Environmental impacts by preindustrialized peoples may be minor compared to current alterations; however, this hypothesis is untested and should be assessed. Using the relative abundance of fish taxa, we tested for differences among archaeological and modern time periods, taking advantage of published zooarchaeological data sets and newly analyzed data. Collections from all archaeological time periods differed significantly from modern collections, but the relative abundance of fishes did not differ significantly among archaeological time periods. Sociopolitical context, material culture, plant-based subsistence patterns, and the use of animal classes shifted temporally, but these differences did not extend to the relative abundance of fish families. Our results suggest that dominating human influences on fish communities did not occur prior to the Late Woodland period in the lower Illinois River.

KEYWORDS
Anthropocene; Interdisciplinary research; Zooarchaeology; lower Illinois River valley

CONTACT Carol E. Colaninno ccolani@siue.edu
Supplemental data for this article can be accessed at https://doi.org/10.1080/01461109.2017.1375067

A growing consensus, emerging from multiple scientific disciplines, suggests that anthropogenic actions have moved Earth's biosphere into a new epoch: the Anthropocene (Balter 2013; Corlett 2015; Crutzen 2006; Crutzen and Stoermer 2000; Steffen et al. 2007; Zalasiewicz et al. 2010). This term characterizes our current time period in which human actions have as much or more impact on Earth's ecosystems as natural drivers and processes do (Corlett 2015; Crutzen and Stoermer 2000). Although many have recognized the magnitude of human influences on ecosystems today, scholars continue to debate the timing, scope, and globally identifiable markers that may define the parameters of the Anthropocene (Oldfield et al. 2014; Smith and Zeder 2013). Within this debate, few have coupled archaeological and ecological data sets that document deep-time trends in human-environmental relations (Reitz and Shackley 2012). When combined, these data sets span millennia of human actions and influences in ecosystems. With the immediate need to articulate the current state of the Anthropocene within the longevity of human dimensions of ecological change, the archaeological record can provide the deep-time data informing a more comprehensive view of the timing, sociocultural context, and regional variation in which humans interact with environments through resiliency or change (Campbell and Butler 2010; Redman et al. 2004; Reitz 2014).

We make an initial attempt to document trends in the relative abundance of fishes in archaeofaunal collections and modern fish monitoring data that may signal evidence consistent with the onset of the Anthropocene within the localized context of the lower Illinois River valley. Further, we apply multivariate techniques, standard among ecological studies (Boaventura et al. 2002; Clarke 1993; Clarke and Warwick 1994; Poff et al. 2007; Solomon et al. 2016) but less often applied in archaeology (but see Rigaud et al. 2015), to compare modern and archaeological data sets, while also examining temporal similarities from the Middle Woodland (ca. 50 BC–AD 250) through current times (AD 2013).

The lower Illinois River valley provides an ideal laboratory in which to archaeologically examine changes among animal communities harvested by humans for millennia. People have lived on the land surrounding the Illinois River and its tributary streams and on its broad floodplain, bluffs, and upland areas for over eight millennia (Wiant et al. 2008). A rich and diverse suite of plants and animals inhabited this river-floodplain ecosystem, providing nutritional and economic sources for the people who currently and once used these environments (Sparks 2010; Sparks et al. 1998; Styles 2011). Archaeologists have noted broad correlations between data collected on cultural institutions, animal use, and, in some cases, environmental parameters in the lower Illinois River valley (Styles 2000, 2011). In particular, Styles (2011) observed trends that extend from the Early Archaic (8000–6000 BC) into the Mississippian (AD 1000–1300) period in the relative abundance of various animal classes, families, and species. Archaeofaunal collections representing the earliest components of this temporal sequence suggest that people made more extensive use of terrestrial mammals than did Woodland and Mississippian populations, who fished to a greater extent (Styles 2011). These trends appear to align with changing cultural institutions and environmental fluctuations and suggest that people shifted subsistence practices to accommodate varying socioenvironmental parameters.

Although these trends are noted within archaeofaunal collections in past applications, these data were viewed broadly, across an expansive temporal sequence. A more detailed documentation of animal use within a spatially confined temporal sequence has not been explored. Such an analysis may refine parameters for the timing of and context in which we can find evidence for shifts in animal communities that may be consistent with trends leading to the Anthropocene. Along those lines, the relative abundance of fishes recovered in archaeological contexts has not been compared to systemically collected abundance data from present-day fish sampling efforts to more thoroughly understand changes to river systems. We present the results of an analysis of similarity (ANOSIM) using the Bray-Curtis similarity matrix to test for differences among temporal groupings, both archaeological and modern.

Evidence consistent with localized parameters that signal the emergence of the Anthropocene may be observed in a progression through time, where more ancient archaeofaunal collections are less similar to modern communities and more recent archaeofaunal collections more closely resemble modern samples exposed to intense human influences (Chick and Pegg 2001; Chick et al. 2013; Moore et al. 2010; National Research Council 2009; Sparks 2010). In contrast, if archaeofaunal collections from all archaeological time periods are equally dissimilar to modern samples, there would be no evidence consistent with the onset of the Anthropocene during those archaeological periods examined.

Environmental Setting and Archaeological Context

The lower Illinois River valley begins roughly near present-day Meredosia, Illinois, and extends to the confluence of the Illinois and Mississippi Rivers near Grafton, Illinois (Figure 1). Prominent features of this river valley are the broad, low gradient Illinois River, the expansive floodplain, and the steep limestone bluffs that line the valley margins extending into uplands. Within the floodplain, there were numerous habitats, such as backwater lakes, marshes, mud flats, mesic forests, and mesic prairies. Historically, uplands along the bluff margins included mixed-hardwood and oak-hickory forests, with stretches of prairie and grasslands. In the upland and floodplain forests reside numerous mammalian taxa that have been particularly important to humans for millennia (Purdue and Styles 1986): most notably white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), squirrel (*Sciurus* spp.), and opossum (*Didelphis virginiana*).

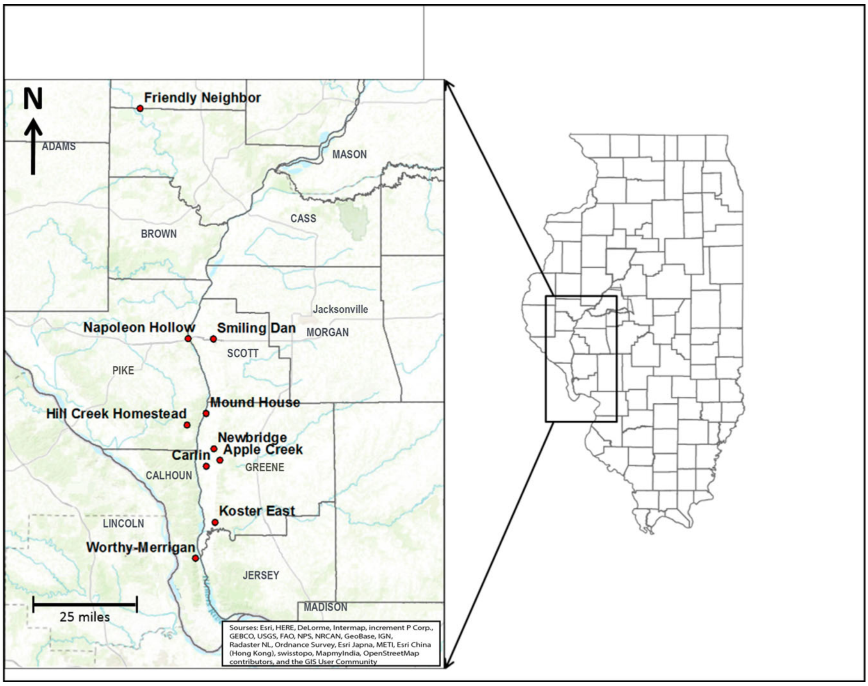

Figure 1. Location of archaeological sites included in this study.

Turkeys (*Meleagris gallopavo*), another taxon exploited by people, also inhabit upland forests (Holt 2005; Shelford 1963; Styles 1981).

The Illinois River, along with its tributary streams and backwater lakes, provides habitat for an array of aquatic to semiaquatic taxa, including mussels, fishes, turtles, waterfowl, and mammals (Smith 1961). Today, fishes most common to the Illinois River, its tributary streams, and its backwater lakes include members of the shad family (Clupeidae), most notably gizzard shad (*Dorosoma cepedianum*), along with suckers (Catostomidae), minnows (Cyprinidae), catfishes (Ictaluridae), and bass, crappie, and sunfish (Centrarchidae). Not all of these families are among those most frequently represented archaeologically. Archaeofaunal collections indicate that people once living in the lower Illinois River valley commonly used gar (*Lepisosteus* spp.), bowfin (*Amia calva*), and freshwater catfish, along with suckers and sunfish, in addition to various other fish taxa (Styles 1981).

People have resided in the lower Illinois River valley for millennia, though cultural practices throughout this temporal trajectory were not uniform. Although zooarchaeological samples have been analyzed from both Archaic (8000–600 BC) and Early Woodland (600–50 BC) components in the lower Illinois River valley (Neusius 1982; Purdue and Styles 1982), these segments of the temporal sequence are not included in this analysis because robust samples from multiple sites are currently limited. Rather, we focused on deposits with well-preserved faunal remains from Middle Woodland (50 BC–AD 250), Late Woodland (AD 250–1000), and Mississippian (AD 1000–1300) sites.

In the Midwest, the Middle Woodland period is well studied and has been characterized as a time of regional stylistic expression integrated into extensive trade networks that potentially reified social and community bonds within this network (Charles et al. 2004). In the lower Illinois Valley, there is a strong archaeological signature for increases in the number of settlements, with a large number of village and mound sites (Buikstra 1976; Charles et al. 1986). Middle Woodland people, although still moving about the landscape, built relatively permanent villages and made use of native cultigens.

The transition from the Middle to the Late Woodland is most notably marked by the discontinuation of Middle Woodland regional trade networks and the more elaborate material culture that characterizes the Middle Woodland period (McElrath et al. 2000). Late Woodland population numbers, that is, the number of people living in the valley, appear to have increased from the Middle to the Late Woodland (Studenmund 2000). There also appears to be a shift in sociopolitical organizations in the transition to the Late Woodland (Studenmund 2000). People continued to rely on locally available resources (Styles 2011), although two important innovations occurred during this period: the acceptance of the bow and arrow and greater emphasis on maize agriculture. Although numerous scholars have analyzed archaeofaunal remains from Late Woodland deposits (Kelly 1984, 1987; Styles 1981), there are no clear trends specifically associated with vertebrate faunal use and the innovations of the bow and arrow and maize agriculture (Styles 2011).

Unlike other physiographic regions abutting the lower Illinois River valley, notably the American Bottom and central Illinois Valley, the Mississippian period here was not marked by the emergence of highly organized hierarchical chiefdoms (Kelly 1990) and the large political centers associated with them (Conner 2016; Milner 2006). Mississippian homestead sites, with demonstrated connections to larger American Bottom and central Illinois Valley Mississippian towns and cities are known (Conner 1985), but lower Illinois River valley Mississippian sites do not contain evidence that these locations were densely occupied villages. Rather they appear to have been smaller, sparsely populated farmsteads (Goldstein 1980:22).

Although people have used the Illinois River, its tributaries, and its backwater lakes for millennia, over the past two centuries people have drastically modified this floodplain river (Butzer 1977; Sparks 2010; Sparks et al. 1998). Since around the 1880s, American economic, cultural, and governmental practices and policies have drastically modified this river through the construction of dams and levees and the conversion of floodplain habitats into agricultural and urban landscapes (Angradi et al. 2011; Moore et al. 2010). Presently, these human-induced alterations obscure much of the lower Illinois River valley's natural physical properties and have resulted in a drastically different system compared to those prior to more recent human interventions (Butzer 1977:13). Similarly, animal populations and communities using this river system and others have been affected by invasive species, climate change, human predation, nutrient loading, and the influx of hormone-disrupting chemicals (Brugam et al. 2017; Chick et al. 2003; Chick and Pegg 2001; Irons et al. 2007; Solomon et al. 2016).

Our goal is to explore patterns in the ways people have used rivers, employing ichthyofaunal data as a proxy that may show initial indications of anthropogenic influences on fish community structure and shifts toward conditions consistent with the characterization of the Anthropocene in the Illinois River system. Furthermore, we explore correlations between variations in societal characteristics and fish use from the Middle Woodland through the modern-day temporal sequence. Although the cultural filter clearly influences archaeological representation of animals (Reed 1963), this line of investigation may reveal early signs of those shifts consistent with the Anthropocene in the physiographic region of the lower Illinois River valley.

Materials and Methods

All archaeofaunal collections included in this analysis are from lower Illinois River valley archaeological sites and surrounding uplands, thereby limiting, although not entirely controlling, spatial variability (see Figure 1). We selected collections from 10 archaeological sites representing 13 temporal components, ranging from the Middle Woodland to the Late Mississippian (Table 1). Out of these 13 collections, eight are derived from previously published reports (Colburn 1985; Parmalee et al. 1972; Styles 1981; Styles and Purdue 1986; Styles et al. 1985), while five collections were analyzed by students of a National Science Foundation Research Experience for Undergraduates program and have not been reported elsewhere (Supplemental Tables 1–5). The archaeofaunal collections were subjected to various recovery methods. Some were excavated in the 1960s, prior to now-established flotation sampling (Parmalee et al. 1972), while

Table 1. Names and Site Numbers for Archaeological Sites in the Lower Illinois River Valley.

Site Name	Site Number	Time Period	Analyst or Publication
Napoleon Hollow	11PK500	Middle Woodland	Styles and Purdue (1986)
Mound House	11GE7	Middle Woodland	Nigel Knutzen 2015*
Apple Creek	11GE2	Middle and Late Woodland	Parmalee et al. (1972)
Friendly Neighbor		Late Woodland	Paula Long 2015*
Carlin		Late Woodland	Styles (1981)
Newbridge	11GE456	Late Woodland	Styles (1981)
Koster East Early	11GE4	Late Woodland	Ariana Enzerink 2015*
Koster East Late	11GE4	Late Woodland	Paige Ottenfeld 2015*
Smiling Dan	11ST123	Middle and Late Woodland	Styles et al. (1985)
Worthy-Merrigan	11C382	Early Mississippian	Curtis Dopson 2015*
Hill Creek Homestead	11PK525	Mississippian	Colburn (1985)

Note: Temporal designations are based on published radiocarbon dates and relative dates (Farnsworth et al. 1991; King et al. 2011; Stafford and Sant 1985; Wettersten 1983).
*Analysis conducted by students of the 2015 NSF REU.

others were excavated as recently as this decade. Furthermore, as some of these collections were analyzed before established and standardized zooarchaeological methods (Grayson 1973, 1979; Reitz and Wing 2008), specifics of secondary measures, such as minimum number of individuals (MNI), derived from primary observations of the collection vary.

Although recovery and methodological biases limit the interpretative power of this analysis, we attempt to minimize these biases by summarizing and comparing collections using the measure of MNI. MNI is simply the minimum number of individuals needed to account for all specimens in a collection (Grayson 1979:203–224; Reitz and Wing 2008:205–210; White 1953). This secondary quantification is complicated by the way analysts define analytical groupings based on excavation techniques and context (Grayson 1973). This was not consistently applied across all collections reported. In some cases, the zooarchaeologist defined analytical groups based on discrete depositions (Styles 1981), whereas in other cases, all excavated materials, regardless of context within the site, were considered one grouping. If collections from each cultural stratum or feature were considered discrete samples, and the calculated MNI within the samples were quantified separately and then summed, the resulting MNI values may count each individual more than once, resulting in an overestimation. Conversely, if the zooarchaeologist treated the collection of animal remains from the entire site as one analytical unit, the resulting number may be an underestimation.

We attempt to overcome some of the biases that might result from grouping methods by standardizing these measures using the relative abundance of estimated individuals rather than count (MNI of each species divided by the summation of MNI among all species). Although the relative abundance of MNI will not overcome all biases associated with quantification differences, this method should be most comparable to modern fish-monitoring data recorded in catch-per-unit-effort as this measure counts individuals rather than bones, weight, or biomass. Furthermore, those archaeologists who previously synthesized regional data sets in the Illinois River valley have used MNI, making our application of this measure more comparable to prior work (Styles 2011).

Throughout the temporal range represented among these 13 collections, we compare similarities in archaeofaunal collections among two different summarizations of Vertebrata taxa. We compare similarities in the relative abundance of animal classes with some further subdivisions, including bony fishes, turtles, snakes, birds, white-tailed deer, other mammals, and commensal taxa. For simplicity's sake, we refer to this summarization as *animal classes*. Comparison of animal classes acts as a proxy to help understand how people in the lower Illinois River valley used animals in a broad sense.

More specifically, to examine human interactions and anthropogenic modifications of the lower Illinois River from the Middle Woodland to modern times, we investigate the relative abundance of fishes from families frequently recovered in both archaeological and modern samples. Fish families studied include gars (Lepisosteidae); bowfins (Amiidae); suckers; freshwater catfishes; basses, crappie, and sunfishes; and drum (Sciaenidae). Fishes from other families are in these collections but are excluded from the current study. Less than 10% of fish individuals in the archaeological collections were from other families.

We incorporate modern, standardized fish-monitoring data from two ecological programs, the Long Term Resource Monitoring (LTRM) element of the U.S. Army Corps of Engineer's Upper Mississippi River Restoration program and the Long-Term Survey and Assessment of Large River Fishes in Illinois (LTEF). These monitoring programs are highly standardized, with the goal of sampling the entire fish community. Because the modern ecological monitoring programs collect roughly an order of magnitude more species of fishes than are represented in archaeological collections, we restricted the data used from the monitoring program to only those fish taxa in the families listed above. Otherwise, the number of additional species represented in the ecological monitoring programs would overwhelm any other differences in the relative abundance of fishes compared to the archaeological data.

LTRM electrofishing data extend from 1994 to 2013 and represent the La Grange Reach of the Illinois River, a 78 river-mile reach between the La Grange Lock and Dam and Peoria Lock and Dam, and Pool 26 of the Mississippi River, a 40 river-mile reach between the Mel Price Locks and Dam near Alton, Illinois, and Lock and Dam 25 near Winfield, Missouri (Figure 2). The LTRM uses a stratified-random design, with random samples collected in several major habitat strata, including the main channel, side channels, contiguous backwater lakes, and impounded areas (Ratcliff et al. 2014). This sampling design allows the calculation of reach-wide means, in which data from each habitat stratum are weighted by the proportion of area each habitat comprises in the reach. Pulsed DC electrofishing boats are used and each sample consists of a 15-minute electrofishing run. Samples are collected in three time periods between June 15 and October 31 each year (Ratcliff et al. 2014). We calculated reach-wide mean catch-per-unit-effort (number of fish per 15-minute sample) for each fish taxon across all years for the La Grange Reach and Pool 26.

The LTEF program also samples fish with electrofishing, but the methods and study design differ. This program uses a three-phase AC electrofishing boat (Koel and Sparks 2002). We used data from LTEF Reach 7, which is the La Grange Reach of the Illinois River, and LTEF Reach 8, which is an 80 river-mile reach between the La Grange Lock and Dam and the confluence of the Illinois and Mississippi Rivers in Grafton, Illinois (see Figure 2). Six fixed sites in main or side channels are sampled with electrofishing for one hour in each of these reaches once per year. We divided the data from each reach into two time periods, early (1958–1979) and late (1980–2014), because notable changes in the fish community occurred in the Illinois River associated with pollution in the early years followed by improved water quality after the establishment of the Clean Water Act (Pegg

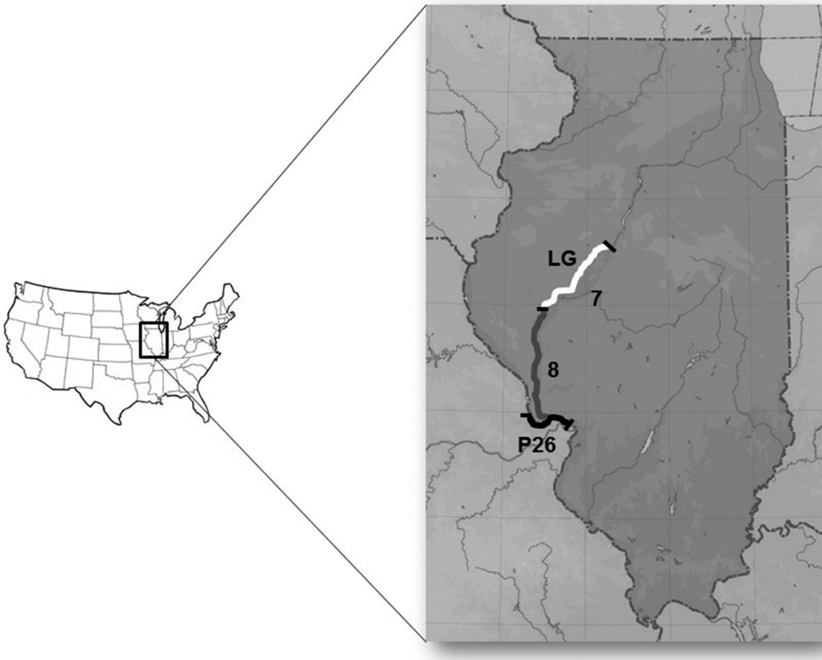

Figure 2. Location of modern ecological sampling sites included in this study. *P26* represents Pool 26 on the Mississippi River, while *7*, *8*, and *LG* represent reaches 7, 8, and La Grange of the Illinois River.

and McClelland 2004). We calculate mean catch-per-unit-effort (number of fish per 1-hour sample) for each fish taxon in each reach and time period (early and late).

Using analysis of similarity (ANOSIM), we tested for differences in (1) the relative abundance of individuals represented in each studied fish family among time periods (archaeological to modern) and (2) the relative abundance of individuals in each studied animal class among archaeological time periods (Middle Woodland to Mississippian). Analysis of similarity is a nonmetric, multivariate analog to analysis of variance (Clarke and Warwick 1994). An advantage of this analytical technique is that all data are converted to a Bray-Curtis similarity matrix prior to quantitative analysis, thus avoiding issues of multivariate normality and homoscedasticity that can invalidate other univariate and multivariate analyses (Clarke et al. 2006). Like the MNI data from the archaeological collections, catch-per-unit-effort data from the monitoring programs were converted to relative proportions. Three of the archaeological collections, Friendly Neighbor, Mound House, and Worthy-Merrigan, did not have enough individual fish (MNI < 30) to calculate meaningful relative proportion estimates and are omitted from the fish family analysis. As a result, we cannot conduct statistical comparisons using the Mississippian time period, though we plot the one remaining Mississippian collection.

Bray-Curtis similarity measures the similarity (S) between sites j and k using the following formula:

$$S_{jk} = 100\left\{1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})}\right\}$$

Because we are using relative abundance for our study, y_{ij} = the relative abundance of species i in site j and y_{ik} = the relative abundance of species i in site k.

We illustrate the groupings of sites using nonmetric multidimensional scaling (NMDS), a multivariate ordination technique used to visualize the similarity among sites (or samples) in two, three, or more dimensions (Clarke 1993; Clarke and Warwick 1994). Sites that are closer together on an NMDS plot are more similar (i.e., greater value of S_{jk}), whereas sites that are farther apart are less similar (i.e., lower value of S_{jk}). An NMDS plot can be thought of as a map of the similarity among sites (or samples) in two or three dimensions. Because NMDS plots are nonmetric (i.e., based on Bray-Curtis similarity values), the ordination dimensions have strictly relative scales that do not correspond to specific metrics and are thus not labeled. Data points on an NMDS plot that are closer together have a greater similarity than data points that are farther apart. All analyses were conducted using Primer-E ecological statistical software.

Results

We found significant differences ($P \leq 0.001$; R = 0.747) in the relative abundance of fish families among time periods extending to the present day. The modern time period differed significantly from the Middle and Late Woodland time periods ($P \leq 0.02$; R $\geq$ 0.893; Figure 3). There were no significant differences between the Middle and Late Woodland periods ($P \geq 0.238$; R = 0.16). Although there are other groupings present within the archaeological data, those groups do not correspond with our studied time periods (see Figure 3).

The fish families contributing to the differences between the modern time period and all archaeological time periods include bowfin (Amiidae), which are represented with greater frequency during archaeological time periods (Figure 4a), whereas sunfishes (Centrarchidae) and drum (Sciaenidae) are more frequently represented in modern times (Figure 4b and 4c). Freshwater catfish (Ictaluridae) are more represented among most archaeological collections compared to modern ones (Figure 5a); however, this difference in the past and present data becomes more pronounced when we consider only the representation of bullhead catfishes (*Ameiurus* spp.; Figure 5b). For all archaeological collections, bullhead catfishes are much more abundant than they are in modern monitoring data, with the exception of the Apple Creek Middle Woodland component (see Figure 5a and 5b).

Differences in the relative abundance of animal classes among archaeological time periods are not significant ($P = 0.275$; R = 0.087) when all sites are included

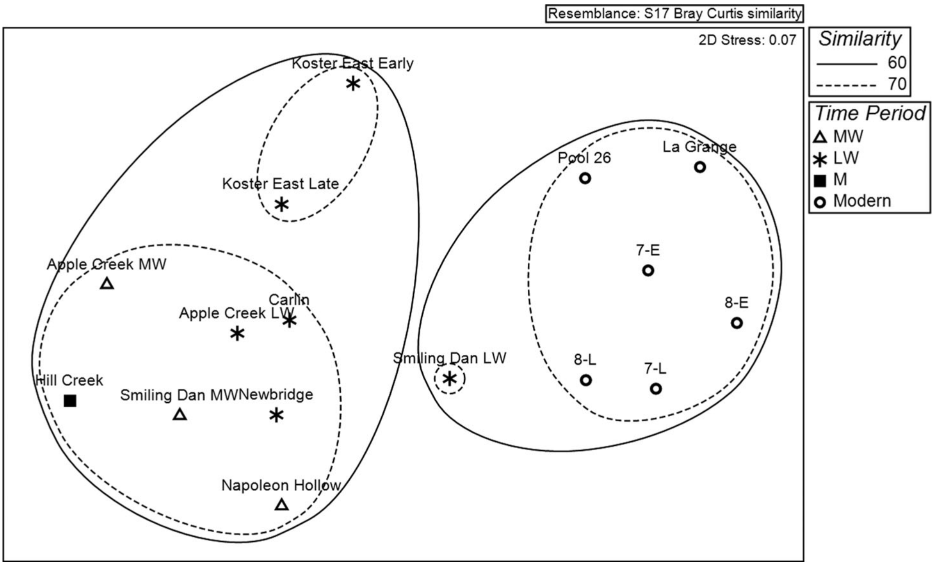

Figure 3. Nonmetric multidimensional scaling plot depicting grouping of sites from archaeological time periods and modern sampling based on Bray-Curtis similarity calculated from the relative abundance of fish families. Two groups are present at 60% similarity, and four groups are present at 70% similarity. Groupings of archaeological sites do not correspond with time period. Modern samples are graphically represented by open circles and include Pool 26 of the Mississippi River and early (7-E, 8-E) and late groupings (7-L, 8-L) for reaches 7, 8, and La Grange of the Illinois River. Archaeological temporal groupings include Middle Woodland (MW), Late Woodland (LW), and Mississippian (M). Temporal groups and abbreviations remain consistent throughout Figures 3–6.

(Figure 6a). When two outliers, the Late Woodland components of Smiling Dan and Friendly Neighbor, are removed from the analysis, differences among time periods are significant (P = 0.002; R = 0.628; Figure 6b). The Middle Woodland period differs significantly from the Late Woodland period (P = 0.008; R = 0.781), whereas the two Mississippian sites did not differ from either Middle or Late Woodland periods. Differences between Middle and Late Woodland time periods are primarily influenced by a greater relative abundance of bony fishes in the Late Woodland (76.5% vs. 60.4%) and a greater relative abundance of birds in the Middle Woodland (10.8% vs. 5.2%) collections.

Discussion

Initial Evidence of Changes with the Anthropocene

We tested for shifts in the relative abundance of individuals within fish families across the time span of several millennia in an attempt to find evidence consistent with the onset of the Anthropocene, when human actions began altering the Illinois River. Although the relative abundance of fish families from modern samples differed from all archaeological time periods, we find no evidence of

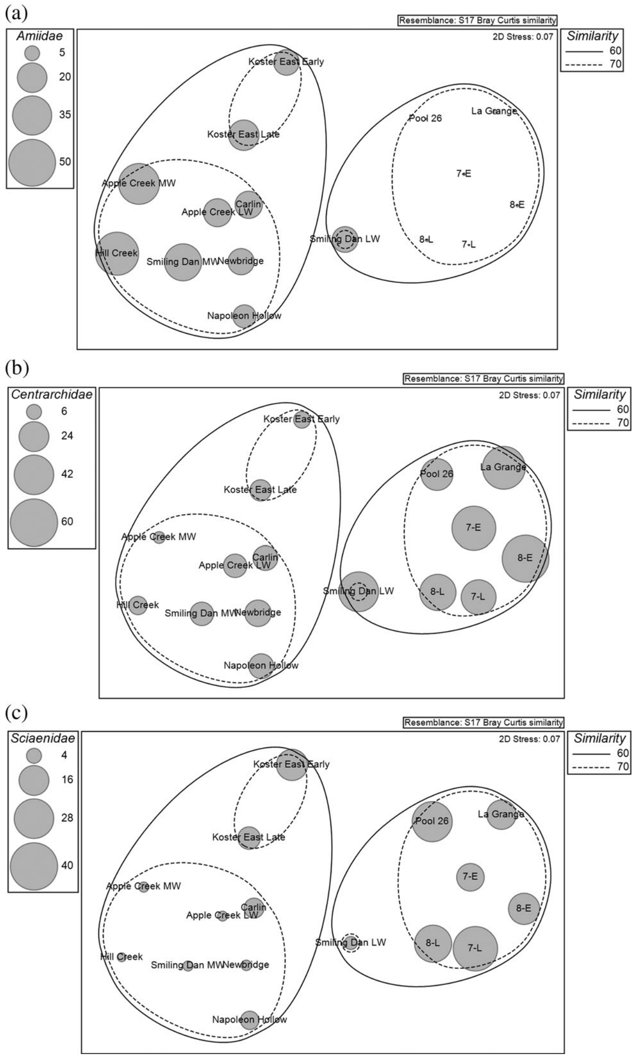

Figure 4. Relative abundance of MNI (archaeological) and catch-per-unit-effort (modern) of (a) Amiidae, (b) Centrarchidae, and (c) Sciaenidae among modern and archaeological data sets overlain on the nonmetric multidimensional scaling plot from Figure 3.

shifts in the relative abundance of fish families among archaeological time periods. The relative abundance of vertebrate animal classes used by humans does differ significantly between the Middle and Late Woodland periods, but within fish families, a similar shift is not noted. There is continued debate regarding those environmental signals that render the Anthropocene distinct from the Holocene, as well as the timing and spatial extent of the onset of the Anthropocene (Waters et al. 2016). Many scholars point to a more recent onset, suggesting this epoch originated within the past 300 years, if not more recently, as researchers detect lasting and persistent chemical, climatic, and biological shifts at a global scale that were nonexistent during the Late Holocene (Crutzen 2006;

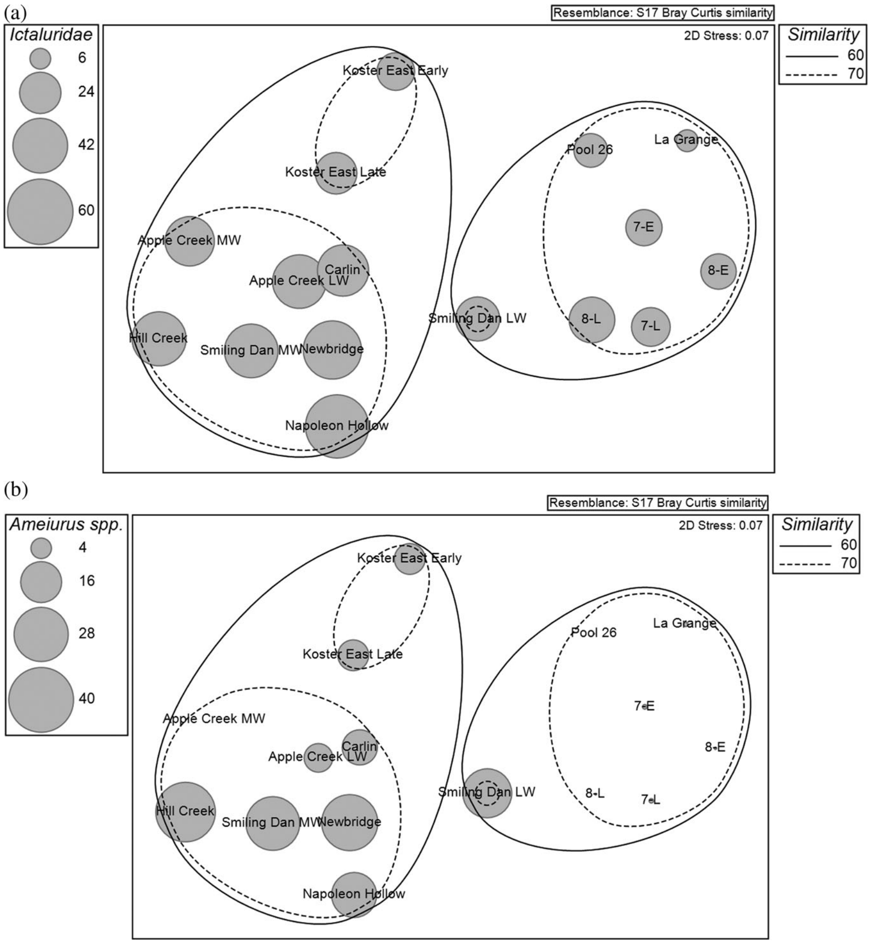

Figure 5. Relative abundance of MNI (archaeological) and catch-per-unit-effort (modern) of (a) Ictaluridae and (b) *Ameiurus* spp. among modern and archaeological data sets overlain on the nonmetric multidimensional scaling plot from Figure 3.

Crutzen and Stoermer 2000; Edgeworth et al. 2015; Waters et al. 2016). Archaeologists tend to argue that the intensity of human-induced environmental modifications fits within the Anthropocene paradigm since the inception of labor divisions and food production, dating back thousands of years (Malm and Hornborg 2014; Smith and Zeder 2013).

Based on our findings and the substantial modifications to the Illinois River system documented over the last 150 years, we conclude that evidence within the confines of the lower Illinois River valley suggests that we are not yet able to detect evidence signaling the Anthropocene before the Late Woodland period. Given our focus on the relative abundance of fishes and our current data sets, we infer that shifts consistent with the onset of the Anthropocene occurred sometime after the Late Woodland period and before the middle of the last century. Additional data sets, particularly those predating and postdating

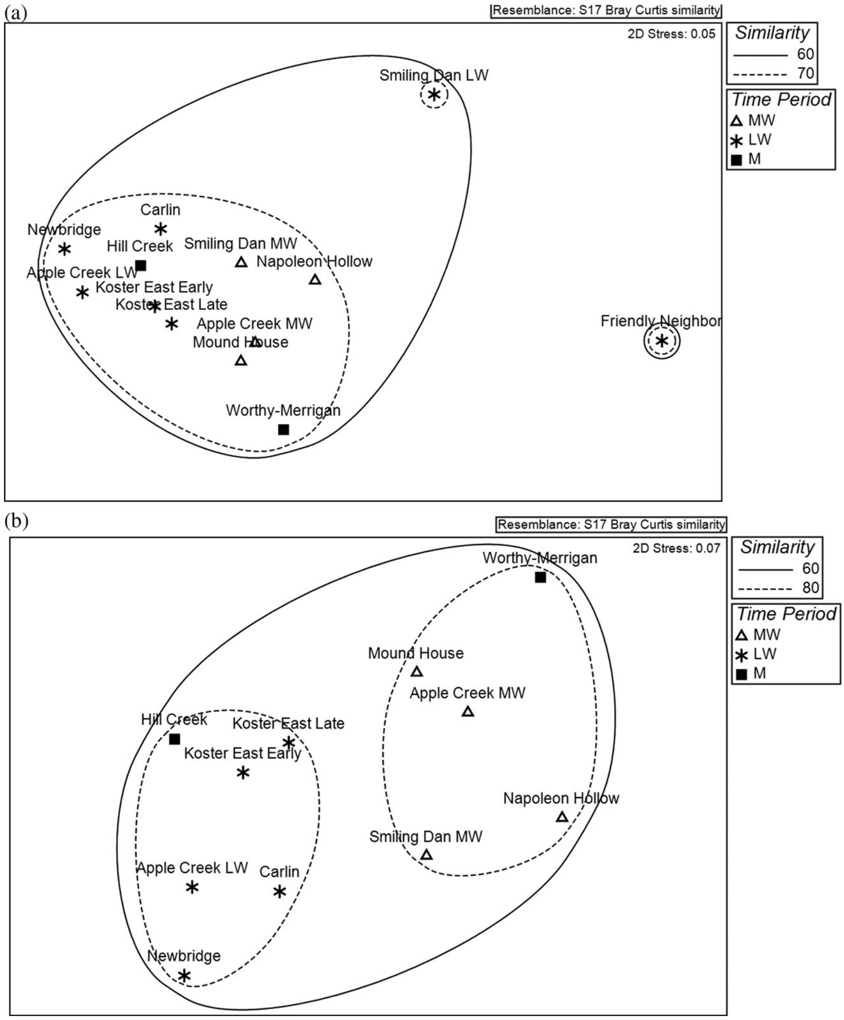

Figure 6. Nonmetric multidimensional scaling plots depicting patterns among archaeological sites and time periods based on Bray-Curtis similarity calculated from the relative abundance of animal classes among (a) all archaeofaunal collections and time periods and (b) excluding the two outliers, the Late Woodland components of Smiling Dan and Friendly Neighbor.

the Middle and Late Woodland periods, are needed to articulate these two time periods. In all analyses, we found signification differences between modern and archaeological ichthyofaunal data sets (see Figure 3). All modern samples share at least 80% similarity, whereas archaeological sites are less tightly clustered. Styles (2011) noted that humans inhabiting the Illinois and Mississippi river valleys made use of fishes and other aquatic animals associated with the productive backwater lakes in the floodplains. Our findings are largely in agreement with this interpretation. The high relative abundance of bowfin, gar, and bullhead catfish in archaeological samples relative to modern sites suggests that pre-contact valley occupants fished and harvested in backwater lakes. These fishes all have adaptations allowing them to thrive in habitats with low oxygen levels (Lagler et al. 1977; McKenzie et al. 1991; Wilson et al. 2000). Backwater lakes with abundant submersed aquatic macrophytes can experience hypoxic conditions either at night, when these plants switch from photosynthesis to respiration, or when they form dense surface canopies, which drastically reduce light penetration (Caraco et al. 2006).

There have been a number of recent abiotic alterations to the Illinois River, changing the location and distribution of hypoxic habitats (Sparks 2010). Beginning in the late nineteenth century, people converted vast areas of the watershed to row-crop agriculture and other land uses that greatly increased sediment loading to the river. This was accompanied by other hydrologic alterations associated with the construction of locks and dams and floodplain levees in the twentieth century. These modifications have drastically reduced or eliminated submersed aquatic vegetation from backwater lakes in the Illinois River valley (Bellrose et al. 1979; Sparks et al. 1990). This dramatic environmental change may have contributed to the shifts in the relative abundance of fish families observed in our study, but other factors must be considered.

We examined samples collected through very different means: archaeological samples are from fishes harvested, prepared, and disposed of by people and subsequently recovered, through various techniques, by archaeologists. Although zooarchaeological remains evidence past human actions, which fishes people captured would have been influenced by their availability and abundance in the environment. Ecological data sets represent a fuller range of the fish community and one less subject to human selection and taphonomic biases. Although the modern samples may be less subject to bias from human use and selection, differences in the relative abundance of fishes in either data set, particularly the archaeological data set, do not perfectly reflect the relative abundance of these animals in the environment. Despite these limitations, archaeologists, geologists, ecologists, and biologists have recognized the value of examining trends in the relative abundance of animal communities from ancient to modern times in an effort to understand the timing and scope of environmental shifts (Peacock 2012; Peacock et al. 2005; Stahl 1996; Wolverton and Lyman 2012).

Although there are inherent differences in the archaeological and modern data sets, we do observe interesting trends beyond the scope of the collection and methodological biases. Importantly, there is a reduction in the representation of fishes dependent on backwater lakes and submersed aquatic macrophytes in modern samples compared to archaeological samples, which may serve as a foundation to more fully understand the initial evidence of environmental shifts that may signal the onset of the Anthropocene in the midcontinent.

In the comparison of fish collections, we see the grouping of two unique samples, modern and archaeological, that may suggest a more modern timing for the onset of the Anthropocene as others have proposed (Crutzen 2006; Crutzen and Stoermer 2000; Edgeworth et al. 2015). However, it is unlikely that any one investigation of archaeological and ecological data from a single geographic area could definitively elucidate the timing of the Anthropocene given the global scope of a geological epoch. Our initial findings do highlight the ways archaeological and modern fish collections can be combined to inform more comprehensive interpretations of today's river systems, while also generating more extensive interpretations of preindustrial fishing practices in the lower Illinois River valley. Additional insights from this approach could be gained by studies that include a larger number of archaeological samples, samples from additional archaeological time periods, and samples with fish MNI great enough to allow analyses at lower taxonomic levels, such as genus or species.

Archaeological Observations

Through the temporal sequence, we expect to see significant differences among human use of all vertebrate animal classes and selected fish families corresponding with designated cultural periods. Given the current data sets, we do find significant differences among animal classes within archaeological time periods when the two outliers are removed (see Figure 6b); however, there are no significant groupings among fish families (see Figure 3). We currently can support the assertion that people shifted their vertebrate-based subsistence practices, based on the animal classes they were hunting, fishing, and capturing, from the Middle to Late Woodland periods. Plant-based subsistence practices, as well as material culture and sociopolitical organization, shifted from the Middle Woodland through the Mississippian period. A similar documented shift in vertebrate-based subsistence is observed through the range of our examined temporal sequence. This trend has been documented among other analyses that have included archaeofaunal collections from the lower Illinois River valley, as well as regions bordering this valley (Styles 2000, 2011). Styles noted in the archaeological collections that over time, and in both the Illinois and Mississippi river valleys, there was an increase in the relative abundance of fishes with a corresponding decline in the number of white-tailed deer. It is interesting to note that we find a similar trend with the addition of more archaeological sites and that this shift occurs both at a localized and at a regional level.

Styles (2011) interpreted this increase in the relative abundance of fishes as a reflection of resource use intensification possibly associated with increasing population or scheduling conflicts that reflect increased time demands related to horticultural practices. We cannot disprove this explanation given our current analysis.

Although we note this trend in temporal units and animal classes, a similar trend specific to fish families among the archaeofaunal collections is not apparent (see Figure 3). We do observe some groupings among archaeological collections, but these groupings do not correspond to temporal destinations. Local changes in the configuration of the Illinois River channel, tributary inputs, and backwater locations can drastically affect animal, particularly fish, distribution and abundance. We may be observing signatures of local proximity to particular habitats that are no longer present in the modern-day floodplain and river system. Analyzing spatial patterning and faunal distribution, both archaeological and modern, is an avenue for future research.

From the Middle Woodland to the Mississippian, forms of sociopolitical structure and organization changed, and these changes may have altered the way people viewed animals, not just the ways they hunted, fished, and captured them. Within the lower Illinois River valley, over the generations there were shifts in the ways people lived that likely altered the meanings of, perspectives on, stories about, and significance of the animals, plants, and worlds around them (Ingold 2000). Those individuals who and societies that have been interpreted as distinct, although associated communities within archaeologically defined time periods, may have viewed animals differently, resulting in unique cuisine choices. By combining discrete deposits from a number of collections, we may be obscuring more nuanced interpretations of individual, group, and community decisions and perceptions and of local environments.

Although fish remains can be used as environmental indicators and species composition in archaeological deposits may reflect the abundance of these organisms in the environment, the abundance of all archaeofaunal remains are influenced by multiple human filters. Woodland and Mississippian populations made decisions regarding where, when, with whom, and how to fish the Illinois River, tributary streams, and backwater lakes. Archaeofaunal collections are not a direct, unfiltered, ancient sample of what was in the rivers, streams, and backwater lakes millennia and centuries ago: Myriad decisions are embedded within these ancient collections. To more fully enhance our understanding of how people modified and influenced rivers in the deep past and at the onset of the Anthropocene, we must take an interdisciplinary approach that considers multiple lines of both human and environmental data.

Both archaeological and modern data sets are confounded by biases associated with sampling and analytical techniques. This is particularly an issue among the archaeological collections. This analysis examines multiple components from numerous sites that were sampled over the generations by researchers who used various methodological approaches. While data collection from the two ecological-monitoring programs was standardized, biases associated with these modern samples vastly differ from archaeological ones. Although field and laboratory standardization would be difficult given the various situations encountered in both settings, zooarchaeologists have long recognized the greater interpretative power that such standardization would afford our discipline (Lyman 2012; Nagaoka 1994, 2005; Quitmyer 2004; Reitz et al. 2009; Thomas 1969).

Conclusion

We found substantial differences in the representation of fish community structure in zooarchaeological collections throughout the temporal sequence compared to modern ecological data sets, suggesting that any major changes in the ecology of the lower Illinois River consistent with anthropogenic modifications and the emergence of the Anthropocene likely occurred after the Late Woodland period. Although humans have been active agents, modifying and responding to environments of the lower Illinois River valley for millennia, we do not observe significant groupings in the representation of fish remains between archaeological collections from the Middle and Late Woodland periods, though archaeological and modern fish data sets are significantly different. This may be a proxy indicator of recent modifications to our rivers and their ecological communities after the Late Woodland period. Further analyses that expand beyond the borders of the lower Illinois River valley and incorporate more archaeofaunal collections documenting the vast range in human cultural practices are needed to deepen our understanding of the regional extent and timing of human impacts that may be consistent with the characterization of the Anthropocene.

Although our analysis does point to recent river and floodplain modifications in the lower Illinois River valley, we are spatially limited and thus precludes the global synthesis needed to define a true geological epoch, such as the Anthropocene. However, localized archaeological and ecological data sets can be used to test hypotheses related to initial environmental shifts that signal greater affects by people than by natural processes and indicate local and incipient conditions that precede anthropogenic environments. Though local in scale, these types of analyses add to a growing body of research documenting those environmental and social conditions that led to the highly modified environments we see today. Furthermore, coupling zooarchaeological and ecological data sets has the potential to be a valuable tool in our efforts to understand the timing and scope of the emergence of the Anthropocene.

Based on data spanning the temporal range from Middle Woodland to Late Woodland, our analysis suggests that people responded to some aspect of shifting sociopolitical or environmental regimes through measured, significant changes in vertebrate-based subsistence. These changes are not seen in the proportion of fish families people used. Biases associated with the differences in archaeological and modern data, sampling techniques, and analyses limit the interpretative power of the observed temporal trends, but such analyses provide new archaeological interpretations and a better understanding of past people and past and present-day environments.

Acknowledgements

The National Science Foundation Research Experience for Undergraduates (Award No. 1460787) supported this program and research. This project was made possible by the Center for American Archeology, Illinois State Museum, and National Great Rivers Research and Education Center. We would also like to thank the Illinois Natural History Survey, University of Illinois and Arkansas Archeological Survey, University of Arkansas. Thanks go to the senior personnel on the project—Drs. Jane Buikstra, Jason King, and Lyle Guyon and Ms. Natalie Marioni—for support on various aspects of this research and program. Kenneth Farnsworth also provided insight on archaeological excavations for various collections analyzed here. This project would not have been possible without the 10 exceptionally wonderful students who participated in this program: Curtis Dopson, Ariana Enzerink, Stephanie Goesmann, Tom Higgins, Nigel Knutzen, Erin Laute, Paula Long, Paige Ottenfeld, Abby Uehling, and Lillian Ward. Thank you to Dr. Chris Wigda and an anonymous reviewer for their insightful comments.

Notes on Contributors

Carol E. Colaninno (Ph.D.) is an assistant research professor at the Southern Illinois University Edwardsville Center for STEM Education, Research, & Outreach. She is a zooarchaeologist with a focus on educational and public archaeology, as well as understanding deep-time human-environmental interactions in coastal and riverine ecosystems.

John H. Chick (Ph.D.) is principal scientist and director of the Great Rivers Field Station at the Illinois Natural History Survey, University of Illinois Urbana-Champaign. His research focuses on the ecology of large rivers, particularly the Mississippi and Illinois rivers and he is primarily interested in questions related to those factors that have affected fish population and community level processes.

Terrance J. Martin (Ph.D.) is emeritus curator and chair of anthropology at the Illinois State Museum. His primary research interest is zooarchaeology, especially focusing on late prehistoric and early historic sites in the Midwest and Upper Great Lakes regions.

Autumn M. Painter (M.S.) is a doctoral student in anthropology at Michigan State University where she is currently studying foodways through zooarchaeological remains from the Morton Village site in the Illinois River valley.

Kelly B. Brown (B.A.) currently serves as the Archives Laboratory Manager for the Veterans Curation Program in Augusta, Georgia. Her professional interests include zooarchaeological research of prehistoric faunal assemblages, as well as public archaeology, and the rehabilitation of at-risk archaeological collections.

Curtis T. Dopson (B.A.) is a recent graduate of the University of West Georgia where he majored in anthropology.

Ariana O. Enzerink (B.S.) is a recent graduate of Oberlin College where she earned degrees in anthropology and biology and a minor in chemistry. She is currently a laboratory technician in neuroscience at Cornell University.

Stephanie R. Goesmann is an undergraduate student studying biology at Blackburn College.

Tom Higgins (B.A.) is a recent graduate of Siena College and is now working for the Westchester County Department of Environmental Facilities in New York.

Nigel Q. Knutzen is an undergraduate student at Southern Illinois University Edwardsville where he is double majoring in anthropology and theater. He is currently researching human skeletal cremains from the Georgia coast.

Erin N. Laute (B.S.) is a recent graduate of Southeastern Missouri State University with a degree in biology focusing on wildlife conservation and animal science. She currently works at the World Bird Sanctuary with the Memphis Zoo.

Paula M. Long is an undergraduate student at University of Central Arkansas majoring in anthropology.

Paige L. Ottenfeld (B.S.) is a recent graduate of Tennessee Tech University where she double majored in history and geology. She now works at the Tennessee Department of Environment and Conservation.

Abigail T. Uehling is an undergraduate student at Hamilton College where she is majoring in biology with a focus on ecology and conservation biology.

Lillian C. Ward is an undergraduate student at Aquinas College studying geography with an additional focus on biology.

ORCID

Curtis T. Dopson http://orcid.org/0000-0001-9792-2404

References

Angradi, Ted R., David W. Bolgrien, Terri M. Jicha, Mark S. Pearson, Debra L. Taylor, Mary F. Moffett, Karen A. Blocksom, David M. Walters, Colleen M. Elonen, and Leroy E. Anderson (2011) An Assessment of Stressor Extent and Biological Condition in the North American Mid-Continent Great Rivers (USA). *River Systems* 19(2):143–163.

Balter, Michael (2013) Archaeologists Say the "Anthropocene" Is Here—but It Began Long Ago. *Science* 340:261–262.

Bellrose, F. C., F. L., Paveglio, and D. W. Steffeck (1979) Waterfowl Populations and the Changing Environment of the Illinois River Valley. *Bulletin of the Illinois Natural History Survey* 32:1–54.

Boaventura, Diana Pedro Ré, Luís Cancela da Fonseca, and Stephen J. Hawkins (2002) Intertidal Rocky Shore Communities of the Continental Portuguese Coast: Analysis of Distribution Patterns. *Marine Ecology* 23(1):69–90.

Brugam, R. B., K. Little, L. Kohn, P. Brunkow, G. Vogel, and T. Martin (2017) Tracking Change in the Illinois River Using Stable Isotopes in Modern and Ancient Fishes. *River Research and Applications* 33:341–352.

Buikstra, Jane E. (1976) *Hopewell in the Lower Illinois Valley: A Regional Approach to the Study of Human Biological Variability and Prehistoric Behavior*. Northwestern University Archeological Program, Evanston, Illinois.

Butzer, Karl Wilhelm (1977) *Geomorphology of the Lower Illinois Valley as a Spatial-Temporal Context for the Koster Archaic Site*. Illinois State Museum Reports of Investigation No. 34. Illinois State Museum, Springfield.

Campbell, Sarah K., and Virginia L. Butler (2010) Archaeological Evidence for Resilience of Pacific Northwest Salmon Populations and the Socioecological System over the Last ~7,500 Years. *Ecology and Society* 15(1):17.

Caraco, Nina, Jonathan Cole, Stuart Findlay, and Cathleen Wigand (2006) Vascular Plants as Engineers of Oxygen in Aquatic Systems. *BioScience* 56:219–225.

Charles, Douglas K., Jane E. Buikstra, and Lyle W. Konigsberg (1986) Behavioral Implications of Terminal Archaic and Early Woodland Mortuary Practices in the Lower Illinois River Valley. In *Early Woodland Archaeology*, edited by Kenneth B. Farnsworth and Thomas E. Emerson, pp.

458–474. Kampsville Seminars in Archeology, Vol. 2. Center for American Archeology, Kampsville, Illinois.

Charles, Douglas K., Julieann Van Nest, and Jane E. Buikstra (2004) From the Earth: Minerals and Meaning in the Hopewellian World. In *Soils, Stones and Symbols: Cultural Perceptions of the Mineral World*, edited by Nicole Boivin and Mary Ann Owoc, pp. 43–70. UCL Press, London.

Chick, John H., Robert J. Maher, Brooks M. Burr, and Matthew R. Thomas (2003) First Black Carp Captured in US. *Science* 300:1876–1877.

Chick, John H., and Mark A. Pegg (2001) Invasive Carp in the Mississippi River Basin. *Science* 292:2250–2251.

Chick, John H., Lori A. Soeken-Gittinger, Eric N. Ratcliff, Eric J. Gittinger, and Robert Maher (2013) A Decade of Monitoring on Pool 26 of the Upper Mississippi River System: Water Quality and Fish Data from the Upper Mississippi River Restoration Environmental Management Program. *Illinois Natural History Bulletin* 39:323–420.

Clarke, K. Robert (1993) Non-Parametric Multivariate Analysis of Changes in Community Structure. *Australian Journal of Ecology* 18:117–143.

Clarke, K. Robert, Paul J. Somerfield, and M. Gee Chapman (2006) On Resemblance Measures for Ecological Studies, Including Taxonomic Dissimilarities and a Zero-Adjusted Bray-Curtis Coefficient for Denuded Assemblages. *Journal of Experimental Marine Biology and Ecology* 330(1):55–80.

Clarke, K. Robert, and Richard M. Warwick (1994) Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd ed. Natural Environment Research Council, Plymouth Marine Laboratory, Plymouth, UK.

Colburn, Mona L. (1985) Faunal Remains from the Hill Creek Site. In *The Hill Creek Homestead and the Late Mississippian Settlement in the Lower Illinois River Valley*, edited by Michael D. Conner, pp. 171–192. Kampsville Archeological Center Research Series 1. Center for American Archeology, Kampsville, Illinois.

Conner, Michael D. (1985) The Site and Its Context. In *The Hill Creek Homestead and the Late Mississippian Settlement in the Lower Illinois River Valley*, edited by Michael D. Conner, pp. 1–15. Kampsville Archeological Center Research Series 1. Center for American Archeology, Kampsville, Illinois.

Conner, Michael D. (2016) Mississippian Habitation Components at Dickson Mounds in the Central Illinois River Valley. *Midcontinental Journal of Archaeology* 41:67–92.

Corlett, Richard T. (2015) The Anthropocene Concept in Ecology and Conservation. *Trends in Ecology and Evolution* 30(1):36–41.

Crutzen, Paul J. (2006) The "Anthropocene." In *Earth System Science in the Anthropocene*, edited by Eckkart Ehlers and Thomas Krafft, pp. 13–18. Springer, Berlin.

Crutzen, Paul J., and Eugene F. Stoermer (2000) Global Change Newsletter. *The Anthropocene* 41:17–18.

Edgeworth, Matt, Dan deB Richter, Colin Waters, Peter Haff, Cath Neal, and Simon James Price (2015) Diachronous Beginnings of the Anthropocene: The Lower Bounding Surface of Anthropogenic Deposits. *Anthropocene Review* 2:33–58.

Farnsworth, Kenneth B., Thomas E. Emerson, and Rebecca Miller Glenn (1991) Patterns of Late Woodland Mississippian Interaction in the Lower Illinois Valley Drainage. In *Cahokia and the Hinterlands Middle Mississippian Cultures of the Midwest*, edited by Thomas E. Emerson and R. Barry Lewis, pp. 83–118. University of Illinois Press, Urbana.

Goldstein, Lynne G. (1980) *Mississippian Mortuary Practices: A Case Study of Two Cemeteries in the Lower Illinois River Valley*. Northwestern University Archeoloigcal Program, Evanston, Illinois.

Grayson, Donald K. (1973) On the Methodology of Faunal Analysis. *American Antiquity* 38:432–439.

Grayson, Donald K. (1979) On the Quantification of Vertebrate Archaeofauna. In *Advances in Archaeological Method and Theory*, Vol. 2, edited by Michael B. Schiffer, pp. 199–237. Academic Press, New York.

Holt, Julie Zimmermann (2005) Animal Remains from the Carter Creek Site: Late Woodland Adaptive Strategies in the Upland Frontier of West-Central Illinois. *Midcontinental Journal of Archaeology* 30:37–65.

Ingold, Tim (2000) *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*. Routledge, London.

Irons, Kevin S., G. G. Sass, M. A. McClelland, and J. D. Stafford (2007) Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carps in the Illinois River, USA: Is This Evidence for Competition and Reduced Fitness? *Journal of Fish Biology* 71 (Supplemental sd):258–273.

Kelly, John E. (1990) The Emergence of Mississippian Culture in the American Bottom Region. In *The Mississippian Emergence*, edited by Bruce D. Smith, pp. 113–152. University of Alabama Press, Tuscaloosa.

Kelly, Lucretia S. (1984) Faunal Remains. In *The Fish Lake Site*, edited by Andrew C. Fortier, Steven J. Ozuk, and Joyce A. Williams, pp. 199–213. American Bottom Archaeology FAI-270 Site Reports 8. University of Illinois Press, Urbana.

Kelly, Lucretia S. (1987) Patrick Phase Faunal Materials. In *The Range Site: Archaic through Late Woodland Occupations*, edited by John E. Kelly, Andrew C. Fortier, Steven J. Ozuk, and Joyce A. Williams, pp. 350–400. American Bottom Archaeology FAI-270 Site Reports 16. University of Illinois Press, Urbana.

King, Jason L., Jane E. Buikstra, and Douglas K. Charles (2011) Time and Archaeological Traditions in the Lower Illinois Valley. *American Antiquity* 76:500–528.

Koel, Todd M., and Richard E. Sparks (2002) Historical Patterns of River Stage and Fish Communities as Criteria for Operations of Dams on the Illinois River. *River Research and Applications* 18:3–19.

Lagler, Karl F., John E. Bardach, Robert R. Miller, and Dora R. May Passino (1977) *Ichthyology*. 2nd ed. John Wiley and Sons, New York.

Lyman, R. Lee (2012) The Influence of Screen Mesh Size and Size and Shape of Rodent Teeth on Recovery. *Journal of Archaeological Science* 39:1854–1861.

McElrath, Dale L., Thomas E. Emerson, and Andrew C. Fortier (2000) Social Evolution or Social Response? A Fresh Look at the "Goody Gray Cultures" after Four Decades of Midwest Research. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent*, edited by Thomas E. Emerson, Dale L. McElrath, and Andrew C. Fortier, pp. 3–36. University of Nebraska Press, Lincoln.

McKenzie, David J., Sumihisa Aota, and David J. Randall (1991) Ventilatory and Cardiovascular Responses to Blood pH, Plasma Pco_2, Blood O_2 Content, and Catecholamines in an Air-Breathing Fish, the Bowfin (*Amia calva*). *Physiological Zoology* 64(2):432–450.

Malm, Andreas, and Alf Hornborg (2014) The Geology of Mankind? A Critique of the Anthropocene Narrative. *Anthropocene Review* 1:62–69.

Milner, George R. (2006) *The Cahokia Chiefdom: The Archaeology of a Mississippian Society*. University Press of Florida, Gainesville.

Moore, Megan, Susan P. Romano, and Thad Cook (2010) Synthesis of Upper Mississippi River System Submersed and Emergent Aquatic Vegetation: Past, Present, and Future. *Hydrobiologia* 640(1):103–114.

Nagaoka, Lisa (1994) Differential Recovery of Pacific Island Fish Remains: Evidence from the Moturakau Rockshelter, Aitutaki, Cook Islands. *Asian Perspectives* 33:1–17.

Nagaoka, Lisa (2005) Differential Recovery of Pacific Island Fish Remains. *Journal of Archaeological Science* 32:941–955.
National Research Council (2009) *Nutrient Control Actions for Improving Water Quality in the Mississippi River Bain and the Northern Gulf of Mexico*. National Research Council Press, Washington, DC.
Neusius, Sarah Ward (1982) Early–Middle Archaic Subsistence Strategies: Changes in Faunal Exploitation at the Koster Site. Unpublished Ph.D. dissertation, Department of Anthropology, Northwestern University, Evanston, Illinois.
Oldfield, Frank, Anthony D. Barnosky, John Dearing, Marina Fischer-Kowalski, John McNeill, Will Steffen, and Jan Zalasiewicz (2014) The *Anthropocene Review*: Its Significance, Implications and the Rationale for a New Transdisciplinary Journal. *Anthropocene Review* 1:3–7.
Parmalee, Paul W., Andreas A. Paloumpis, and Nancy Wilson (1972) *Animals Utilized by Woodland Peoples Occupying the Apple Creek Site*. Reports of Investigations 23, Illinois Valley Archaeological Program Research Papers 5. Illinois State Museum, Springfield.
Peacock, Evan (2012) Archaeological Freshwater Mussel Remains and Their Use in the Conservation of an Imperiled Fauna. In *Conservation Biology and Applied Zooarchaeology*, edited by Steve Wolverton and R. Lee Lyman, pp. 42–67. University of Arizona Press, Tucson.
Peacock, Evan, Wendell R. Haag, and Melvin L. Warren Jr. (2005) Prehistoric Decline in Freshwater Mussels Coincident with the Advent of Maize Agriculture. *Conservation Biology* 19:547–551.
Pegg, M. A., and M. A. McClelland (2004) Spatial and Temporal Patterns in Fish Communities along the Illinois River. *Ecology of Freshwater Fish* 13:125–135.
Poff, N. LeRoy, Julian D. Olden, David M. Merritt, and David M. Pepin (2007) Homogenization of Regional River Dynamics by Dams and Global Biodiversity Implications. *Proceedings of the National Academy of Sciences of the United States of America* 104:5732–5737.
Purdue, James R., and Bonnie W. Styles (1982) Preliminary Analysis of the Fauna from the Cypress Land Site (11-Ge-119), Greene County, IL. In *Cypress Land: A Late Archaic/Early Woodland Site in the Lower Illinois River Floodplain*, edited by Michael D. Conner, pp. 55–59. Kampsville Archeological Center, Technical Report 2. Center for American Archeology, Kampsville, Illinois.
Purdue, James R., and Bonnie W. Styles (1986) *Dynamics of Mammalian Distribution in the Holocene of Illinois*. Illinois State Museum Reports of Investigation No. 41. Illinois State Museum, Springfield.
Quitmyer, Irvy R. (2004) What Kind of Data Are in the Back Dirt? An Experiment on the Influence of Screen Size on Optimal Data Recovery. *Archaeofauna* 13:109–129.
Ratcliff, Eric N., Erice J. Gittinger, T. Matt O'Hare, and Brian S. Ickes (2014) *Long Term Resource Monitoring Program Procedures: Fish Monitoring*. 2nd ed. Program Report LTRMP 2014-P001, p. 88.
Redman, Charles L., J. Morgan Grove, and Lauren H. Kuby (2004) Integrating Science into the Long-Term Ecological Research (LTER) Network: Social Dimensions of Ecological Change and Ecological Dimensions of Social Change. *Ecosystems* 7(2):161–171.
Reed, Charles A. (1963) Osteoarchaeology. In *Science in Archaeology*, edited by Don Brothwell and E. S. Higgs, pp. 204–216. Basic Books, New York.
Reitz, Elizabeth J. (2014) Continuity and Resilience in the Central Georgia Bight (USA) Fishery between 2760 BC and AD 1580. *Journal of Archaeological Science* 41:716–731.
Reitz. Elizabeth J., Irvy R. Quitmyer, and Rochelle A. Marrinan (2009) What Are We Measuring in the Zooarchaeological Record of Prehispanic Fishing Strategies in the Georgia Bight, USA? *Journal of Island and Coastal Archaeology* 4:2–36.

Reitz, Elizabeth J., and Myra Shackley (2012) *Environmental Archaeology*. Springer Science and Business Media, New York.

Reitz, Elizabeth J., and Elizabeth S. Wing (2008) *Zooarchaeology*, 2nd ed. Cambridge University Press, Cambridge.

Rigaud, Solange, Francesco d'Errico, and Marian Vanhaeren (2015) Ornaments Reveal Resistance of North European Cultures to the Spread of Farming. *PloS One* 10(4):e0121166.

Shelford, Victor Ernest (1963) *The Ecology of North America*. University of Illinois Press, Urbana.

Smith, Bruce D., and Melinda A. Zeder (2013) The Onset of the Anthropocene. *Anthropocene* 4:8–13.

Smith, Philip Wayne (1961) The Amphibians and Reptiles of Illinois. *Illinois Natural History Survey Bulletin*, Vol. 28, No. 1.

Solomon, Levi E., Richard M. Pendleton, John H. Chick, and Andrew F. Casper (2016) Long-Term Changes in Fish Community Structure in Relation to the Establishment of Asian Carps in a Large Floodplain River. *Biological Invasions* 18(10):2883–2895.

Sparks, Richard E. (2010) Forty Years of Science and Management on the Upper Mississippi River: An Analysis of the Past and a View of the Future. *Hydrobiologia* 640(1):3–15.

Sparks, Richard E., Peter B. Bayley, and Lewis L. Kohler (1990) Disturbance and Recovery of Large Floodplain Rivers. *Environmental Management* 14:699–709.

Sparks, Richard E., John C. Nelson, and Yao Yin (1998) Naturalization of the Flood Regime in Regulated Rivers. *BioScience* 48(9):706–720.

Stafford, Barbara D., and Mark B. Sant, Eds. (1985) *Smiling Dan: Structure and Function at a Middle Woodland Settlement in the Illinois Valley*. Kampsville Archeological Center Research Series, Vol. 2. Center for American Archeology, Kampsville, Illinois.

Stahl, Peter W. (1996) Holocene Biodiversity: An Archaeological Perspective from the Americas. *Annual Review of Anthropology* 25:105–126.

Steffen, Will, Paul J. Crutzen, and John R. McNeill (2007) The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature? *AMBIO: A Journal of the Human Environment* 36 (8):614–621.

Studenmund, Sarah (2000) Late Woodland Occupation in the Lower Illinois Valley: Research Questions and Data Sets. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent*, edited by Thomas E. Emerson, Dale L. McElrath, and Andrew C. Fortier, pp. 301–343. University of Nebraska Press, Lincoln.

Styles, Bonnie W. (1981) *Faunal Exploitation and Resource Selection: Early Late Woodland Subsistence in the Lower Illinois Valley*. Northwestern University Archeoloigcal Program, Evanston, Illinois.

Styles, Bonnie W. (2000) Late Woodland Faunal Exploitation in the Midwestern United States. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent*, edited by Thomas E. Emerson, Dale L. McElrath, and Andrew C. Fortier, pp. 77–94. University of Nebraska Press, Lincoln.

Styles, Bonnie W. (2011) Animal Use by Holocene Aboriginal Societies of the Northeast. In *Subsistence Economies of Indigenous North American Societies*, edited by Bruce D. Smith, pp. 483–501. Smithsonian Institution Scholarly Press, Washington, DC.

Styles, Bonnie W., and James R. Purdue (1986) Middle Woodland Faunal Exploitation. In *Woodland Period Occupation of the Napoleon Hollow Site in the Lower Illinois Valley*, edited by Michael D. Wiant and Charles R. McGimsey, pp. 513–526. Kampsville Archeological Center Research Series 6. Center for American Archeology, Kampsville, Illinois.

Styles, Bonnie W., James R. Purdue, and Mona Colburn (1985) Faunal Exploitation at the Smiling Dan Site. In *Smiling Dan: Structure and Function at a Middle Woodland Settlement in the Illinois Valley*, edited by Barbara D. Stafford and Mark B. Sant, pp. 402–446.

Kampsville Archeological Center Research Series 2. Center for American Archeology, Kampsville, Illinois.

Thomas, David Hurst (1969) Great Basin Hunting Patterns: A Quantitative Method for Treating Faunal Remains. *American Antiquity* 34:392–401.

Waters, Colin N., Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, Matt Edgeworth, Erle C. Ellis, and Michael Ellis (2016) The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene. *Science* 351:2622.

Wettersten, Vernon Herbert (1983) A Study of Late Woodland Cultural Change in the Lower Illinois River Valley. Unpublished Ph.D. dissertation, Department of Anthropology, Northwestern University, Evanston, Illinois.

White, Theodore E. (1953) Method of Calculating the Dietary Percentages of Various Food Animals Utilized by Aboriginal Peoples. *American Antiquity* 19:396–398.

Wiant, Michael D., Kenneth B. Farnsworth, and Edwin R. Hajic (2008) The Archaic Period in the Lower Illinois River Basin. In *Archaic Societies: Diversity and Complexity across the Midcontinent*, edited by Thomas E. Emerson, Dale L. McElrath, and Andrew C. Fortier, pp. 229–285. State University of New York Press, Albany.

Wilson, R. J., M. B. Harris, J. E. Remmers, and S. F. Perry (2000) Evolution of Air-Breathing and Central CO(2)/H(+) Respiratory Chemosensitivity: New Insights from an Old Fish? *Journal of Experimental Biology* 203(22):3505–3512.

Wolverton, Steve, and R. Lee Lyman (2012) Introduction to Applied Zooarchaeology. In *Conservation Biology and Applied Zooarchaeology*, edited by Steve Wolverton and R. Lee Lyman, pp. 1–22. University of Arizona Press, Tucson.

Zalasiewicz, Jan, Mark Williams, Will Steffen, and Paul Crutzen (2010) The New World of the Anthropocene 1. *Environmental Science and Technology* 44(7):2228–2231.