Shifting Deer Hunting Strategies as a Result of Environmental Changes along the Little and Great Miami Rivers of Southwest Ohio and Southeast Indiana

Research Thesis

Presented in partial fulfillment of the requirements for graduation *with research distinction* in Anthropological Sciences in the undergraduate colleges of the Ohio State University

by

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Introduction

This study analyzes white-tailed deer (*Odocoileus virginianus*) remains from five Fort Ancient archaeological sites along the Little and Great Miami Rivers of southwest Ohio and southeast Indiana to compare how the combination of varying ecologies alongside changing climate conditions impacted the hunting strategies of past people in this region. The focus is on the time period between about AD 1000-1650, during which significant climate change occurred. Through a framework of Human Behavioral Ecology (HBE), we find that Fort Ancient groups changed subsistence practices based on two external circumstances, climate and environment. Qualities such as lowland vs. upland environments, depression of resources, changes in corn production, and the transition to the Little Ice Age allow this study to model the decisions of Fort Ancient hunters through a framework of HBE. The results of this study contribute to a broader understanding of human subsistence change and resource depression during cultural and environmental transitions.

Background

The Fort Ancient culture includes the regions of southern Ohio, southeast Indiana, northern Kentucky, and adjacent portions of West Virginia (Cook 2017; Drooker 1997, Griffin 1943) and lasted from circa AD 1000 to AD 1650. Likely, the Fort Ancient Culture arose from a hybrid of local Woodland folks and Mississippians migrants new to the region at a time of sustained droughts in their home regions (Figure 1) (Comstock and Cook 2018; Cook 2017; Griffin 1943). The study area for the present project is along the Little and Great Miami Rivers of southwest Ohio and southeast Indiana (see Figure 1). At the onset of the Fort Ancient culture, their hunter-gatherer-EAC-focused dietary practices shifted to include a sedentary lifestyle and a substantial focus on maize agriculture (Cook 2017; Pollack 2002). These villages were independent and autonomous, and evidence indicates that they were either strictly egalitarian (Griffin 1992; Pollack 2002), or transegalitarian with situational hierarchies (Cook 2017; Henderson 1998).

This study focuses on five sites that were occupied during the Early, Middle and Late Fort Ancient time periods on the Great and Little Miami Rivers of Southwest Ohio and Southeast Indiana. The temporal sequence used here includes four distinct but variously overlapping time periods following Cook (2017) (Figures 2 and 3): First, the Guard and Turpin sites both fall within Time Period 1 (AD 1000-1300). During Time Period 2 (AD 1150-1300), Fort Ancient occupations continued at Guard and Turpin but expanded to include components at SunWatch and Taylor. In Time Period 3, Hahn was initially occupied along with the later and more substantial uses of SunWatch and Taylor (AD 1250-1450). Lastly, in Time Period 4 (AD 1400-1675), only the later and more substantial use of Hahn occurred. These sites can be generally categorized into Early (Guard and Turpin), Middle (Taylor, SunWatch, and Hahn [early/Anderson component]), and Late Fort Ancient periods (Hahn [later/Madisonville component]).

Each of the time periods are characterized with different Fort Ancient cultural developments and subsistence styles. The Early Fort Ancient time period is characterized by a shift from semi-mobile foraging/Eastern Agricultural Complex plant production/maintenance to farming with a focus on maize, although maize was present in small amounts in the preceding Woodland times (Cook 2017). The early period entailed high amounts of maize farming, houses built using wall trenches (a non-local Mississippian technique [Alt and Pauketat 2011]), shell-tempered pottery, and villages both small and large (Cook 2017; Cowan 1987). In the Middle Fort Ancient time period, village life spread upriver (Cook 2017). Finally, the Late Fort Ancient time period demonstrates aggregation in a few key areas in the lower Little Miami Valley with a shift away from intensive maize consumption (at least by some segments of villages) and a concomitant emphasis on bison hunting (Cook 2017; Drooker 1997).

The Study Sites

The two study sites located in the Great Miami River Valley are Guard and SunWatch. The Guard site (12D29) is located on a large floodplain where the Great Miami River meets the Ohio River near present-day Lawrenceburg, Indiana and contains evidence for an Early Fort Ancient occupation (c. AD 1000-1300) (Cook et al. 2017). Recent excavations by The Ohio State University have led to substantial information regarding the prehistory of this site, with summer excavations in 2012, 2014, 2016, 2017, 2018, and 2019. This village was large and circular, filled with many structures around a central plaza area (Cook et al. 2018). The Guard site consists of wall trench houses and a distinct pattern of decorated shell tempered pottery near houses and plain pottery within a central plaza. The center of this plaza includes a large marker post.

The SunWatch site (33My57) is found in Dayton, Ohio and is located on a small floodplain in the upper reaches of the Great Miami River. Intensive archaeological work produced evidence of a village dated to the Middle Fort Ancient time period (ca., AD 1150-1450) (Cook 2017). This large circular village contains an outer ring of house structures. Inside this domestic ring is a smaller ring that contains burials, ritual features, hearths, and storage pits, oriented around a large central ritual post. SunWatch likely represents a movement upriver of a small splinter group from Guard or other early sites mixing with local groups (see Cook 2017).

The three sites located in the Little Miami River Valley are Hahn, Taylor and Turpin. The Turpin site (33Ha19) is located in Anderson Township, Ohio, in the lower valley and has both Late Woodland (ca., AD 400-1000) and Early Fort Ancient (ca., AD 1000-1300) components (Comstock 2017; Cook 2017; Oehler 1973; Riggs 1998). Only materials from Fort Ancient contexts are used in this study. This site contained multiple circular but small villages around a large earthen mound and surrounding burial pattern. These communities are similar in many respects to small, contemporaneous Mississippian and Emergent Mississippian sites (Cook 2017).

The Taylor site (33Wa10) is located in Oregonia, Ohio, in uplands that overlook the Little Miami River. This site produces evidence from the second and third Fort Ancient time period (AD 1150-1450). Excavations date back to the late nineteenth century (Moorehead 1892). Recent assessment of the Taylor site suggests that the site is oriented around a central plaza much like other Fort Ancient villages (Cook 2017). Early excavations focused on a mound and associated burials. Examining deer remains from this locale provides insight into the lifestyle of Fort Ancient agriculturalists in constricted upland settings with a demonstrably lower reliance on maize agriculture (Cook and Price 2015).

The last archaeological site used within this study is Hahn. The Hahn site (33Ha10) is located in Newtown, Ohio and contains evidence for a Middle Fort Ancient component (i.e."Anderson") and a Late Fort Ancient (i.e. "Madisonville) component (Robert Genheimer, personal communication). The features at Hahn were delineated between Anderson and Madisonville components on the basis of diagnostic pottery and radiocarbon dates when possible. Recent excavations by the Cincinnati Museum Center have provided a wealth of information about the lifestyles of people at Hahn (Genheimer 2014). The earlier Anderson phase includes Late Woodland Mississippian influence (Swinney 2015). The later Madisonville component has the possibility to provide insight into human responses to the Little Ice Age, as its onset coincided with significant changes in climate. The Madisonville Horizon, evident after AD 1450, exhibits similar villages in terms of structure although they may at times have been larger and/or more densely occupied (see Drooker 1997 for more on the cultural dynamics of this time period in general). The ability to examine two somewhat-distinct temporal components at the same site allows for a controlled comparison linking either side of a major climatic shift at the onset of the Little Ice Age (see below).

White-tailed Deer and Subsistence Practices

Fort Ancient excavations reveal the trash these maize farmers left behind that can assist archaeologists in uncovering how people lived in the past. Within this refuse are various animal bones, shells, and botanical remains that provide insight into the subsistence practices of these peoples. The study of zooarchaeological remains can allow us better to understand what animal sources were selected for within a society (Reitz 1999). Because white-tailed deer remains are so prevalent within trash pits at Fort Ancient sites, and there is a general lack of deer analyses within the study area (but see Deppen and Cook 2014 for one of the exceptions), further insight into deer hunting strategies can inform us about changes in subsistence practices related to differences in site ecology and climate change over time.

In particular, the age and size profiles of white-tailed deer from archaeological sites can further our understanding of abundance and scarcity within different sites when related to climatic and environmental changes. This can be accomplished through the study of tooth wear patterns (Severinghaus 1949), crown heights (Severinghaus 1949), and astragali robusticity (Purdue 1987 [a,b]). Through these measures, we can learn more about the variety of deer populations found at each site, and hopefully some of the processes behind the patterns.

Optimal Foraging Theory (OFT), within a larger framework of HBE, posits that humans will most often choose the best possible outcome with the most efficient energy possibility (Bettinger 1991; Winterhalder 2001). White-tailed deer, the most abundant ungulate within the Middle Ohio Valley, are a prime choice for hunting, and certain ages and sex/sizes are more optimal than others for consumption purposes. Previous archaeological studies have described the “prime age” of white-tailed deer as 2.5-6 years (Perttula et al. 2012), while others describe the prime age as beyond thirty months, or 2.5 years, for any animals (Gilbert et al 2007). For this study, we will follow the study of Perttula et al. (2012) and classify prime aged deer as in between 2.5 and 6 years, or 30-72 months. Additionally, we will follow the assumptions of Optimal Foraging theory, and assume that the Fort Ancient people classified larger deer as more favorable, because they reflect a higher caloric return.

Geographic Focus

A sample of Fort Ancient villages located along the Little and Great Miami Rivers of southwest Ohio and southeast Indiana are the focus of this study (see Figure 1). Groups alongside both rivers generally migrated north over time, establishing similar villages along the way (Cook 2017). While in generally similar environments, there are notable distinctions between these two rivers. The Great Miami River "is characterized by large floodplains and relatively low topographic relief until relatively close to its mouth where it enters the Dearborn Uplands" (Cook 2017: 61). The Little Miami River, on the other hand, "is characterized more by constricted floodplains with relatively high topographic relief throughout much of its extent" (Cook 2017: 61), although the lower valley does have a very large floodplain.

The differences between the lower and upper portions of each river valley are also important to consider for purposes of the present study. First, Guard, Hahn, and Turpin, within the lower valleys of both rivers are in/near large floodplains (Cook 2017). These floodplains are beneficial for vegetative growth and the production of maize (DeLaney 1995). Deer are often attracted not only to this vegetative growth, but also the maize itself within such areas can lead to larger deer (Delger et al. 2001). Additionally, Guard, Hahn, and Turpin can each be characterized as located within edge habitats, which include varying ecologies, such as closed forests, grasslands, and open woodlands. Previous archaeological literature proves that white-tailed deer prefer such environmental edges as they include options for multiple seasons and climatic conditions (Hurley 2012; McCullough 1985).

Figures 4a and 4b show deer abundance and forest cover within America, suggesting a relationship between the two. Figure 4c demonstrates the forest cover in Ohio. Deer generally prefer seeds, nuts, acorns, and fruits, which are found in forested environments (McCullough 1985). The lower valley sites have more forest cover, while the upper valley sites are either outside of forest cover (SunWatch), or within sparse cover (Taylor) compared to the lower valley sites.

SunWatch and Taylor are found in the upper portions of the Great and Little Miami valleys, respectively (Cook 2017). Because they are not positioned in relation to equivalently large floodplains in edge environments, maize production and vegetative diversity at these Middle Fort Ancient sites was lower than the partially contemporaneous lower valley sites (Cook 2017). As mentioned above, forest cover near SunWatch in Taylor is relatively lower than those sites in the lower portions of each valley, which presumably would lead to conditions of smaller deer overall (see Figure 5 for more details on topography and vegetation associated with the study sites).

Climate Change

Two distinct climatic regimes characterize the rise and fall of the Fort Ancient cultural tradition. First, the Medieval Climatic Anomaly (a.k.a., Medieval Warm Period [ca., AD 800 to 1300]) encompasses varying droughts as well as wet conditions throughout the time (Comstock and Cook 2018). Around AD 1300 a relatively rapid transition occurred into the Little Ice Age (Baerris 1976; Cook et al. 2004) (Figure 6). This shift included “conditions cooling, rendering agricultural economies riskier than before” (Cook 2017: 63). Notably, this change in climate roughly coincides with the transition between the third and fourth Fort Ancient time period, and the start of the Madisonville component of Hahn, perhaps signifying a relationship between climate change and the lifestyle differences seen in the Late period (see Drooker 1997). As described by Comstock and Cook (2018: 4), "altering access to resources, and how people and animals behave, influences shifts in subsistence patterns, which have contingent effects on society." The Little Ice Age certainly affected the natural vegetative growth, maize production, and animal species within the Middle Ohio Valley. This study will further investigate how climate change altered resource availability and hunting practices in this portion of the Fort Ancient region.

Research Hypotheses

Optimality theory aims to explain the subsistence strategies of all organisms, describing their focus as towards optimality and evolutionary goals (Foley 1985). Although this theory has been used in broad contexts of various species, it can also be applicable towards hunter-gatherer practices within anthropological fields, such as archaeology. According to Winterhalder, "the theory provides a cluster of simple models, partially derived from neo-Darwinian postulates, which produce operational hypotheses about foraging behaviors expected in different environmental circumstances" (Winterhalder 1981: 13). Hypotheses described below assume that the subsistence strategies of Fort Ancient hunters will align with goals of optimality, seeking the most efficient source of energy for their region. Optimal Foraging Theory in general terms is applicable to agricultural societies as well (Winterhalder 2006).

The initial environments chosen during the first and second time periods of Fort Ancient culture are within ideal environmental circumstances for hunting deer, which are open and wide floodplains where there were extensive maize fields that would have attracted deer as well as being surrounded by upland environments teeming with deer. Additionally, the climate is referred to as the Medieval Climate Anomaly (a.k.a., the Medieval Warm Period), which supports very well the other key dietary staple for Fort Ancient folks: maize. Because the early inhabitation of Lower Valley Fort Ancient sites such as Guard and Taylor had not faced depression of resources and include ideal environments, we hypothesize that deer populations at these sites were more prime aged and larger than other sites within this area.

Another aspect of OFT, the Marginal Value theorem, discusses when certain resources will be abandoned in favor of others (Foley 1985). Foley states that as the search time increases, and a patch is no longer viable for sustainable usage, people may leave the area to find one with better optimization. Once the resources were depleted around Lower Valley sites, Fort Ancient people, under the expectations of optimality, would have moved upriver to find an area with better resources. However, because the Upper Valley sites are a bit less productive in agricultural terms as well as deer viability, we hypothesize that that there will be smaller and fewer prime deer in the SunWatch and Taylor assemblages.

Because the introduction of the last time period reflects a shift from the Medieval Climate Anomaly to the Little Ice Age, there should be differences for deer populations represented in each of these groups. Smaller, less prime deer should be more frequent in sites from the latest Fort Ancient time period due to climate change changes associated with the Little Ice Age. Therefore, the data would reflect the smallest, least-primed aged deer at the Late Fort Ancient/Madisonville context at Hahn.

Figure 1: Mississippian cultural influence on Fort Ancient culture. Study Area in rectangular box (from trails.mdah.ms.gov)

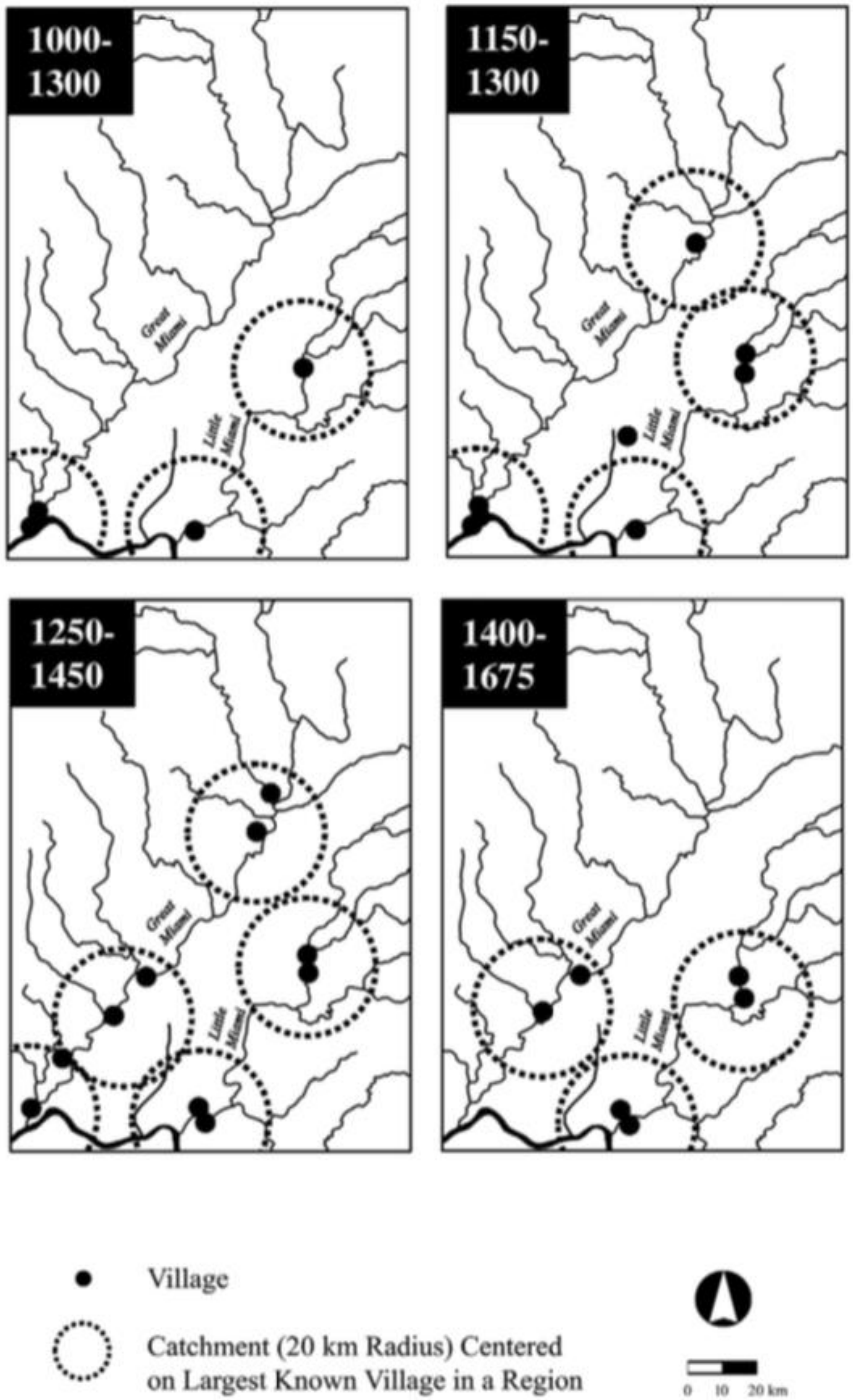


Figure 2: Fort Ancient time periods (from Cook 2017)

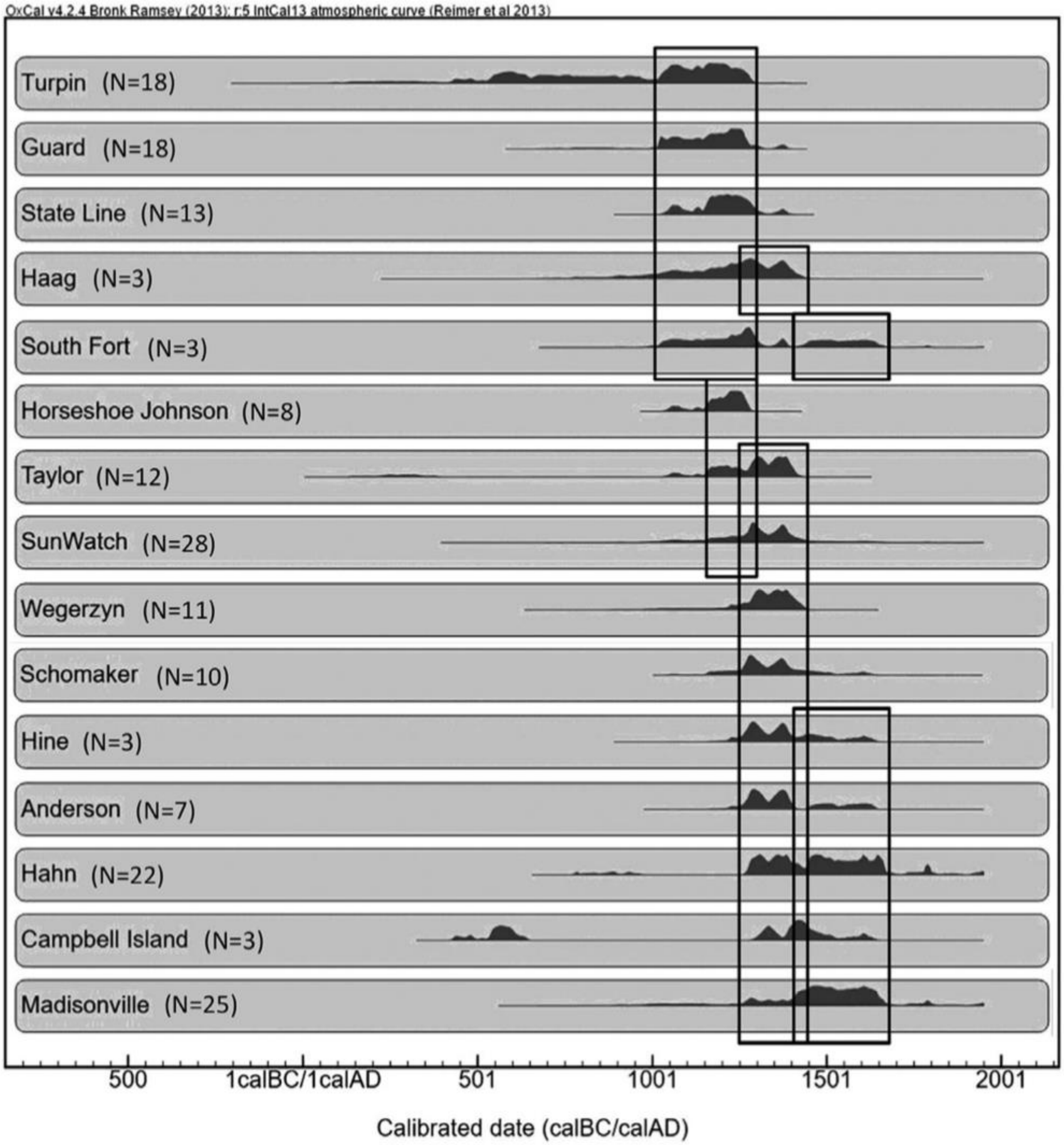


Figure 3: Radiocarbon calibrated dates of Fort Ancient sites (after Cook 2017)

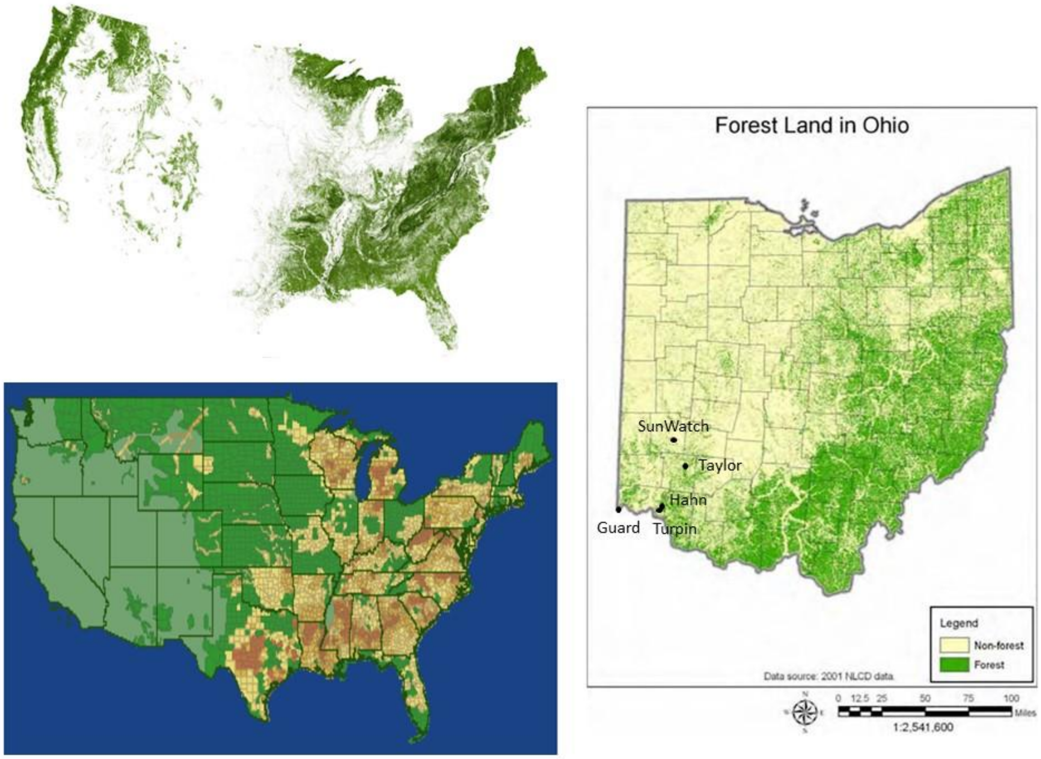


Figure 4: a (top left) United States forest cover (after https://flowingdata.com/2020/03/11/map-of-all-the-trees-and-forests/) , b (lower left) deer populations in the United States (after Deckman 2003), c (right) forest cover in Ohio (after Widmann 2014)

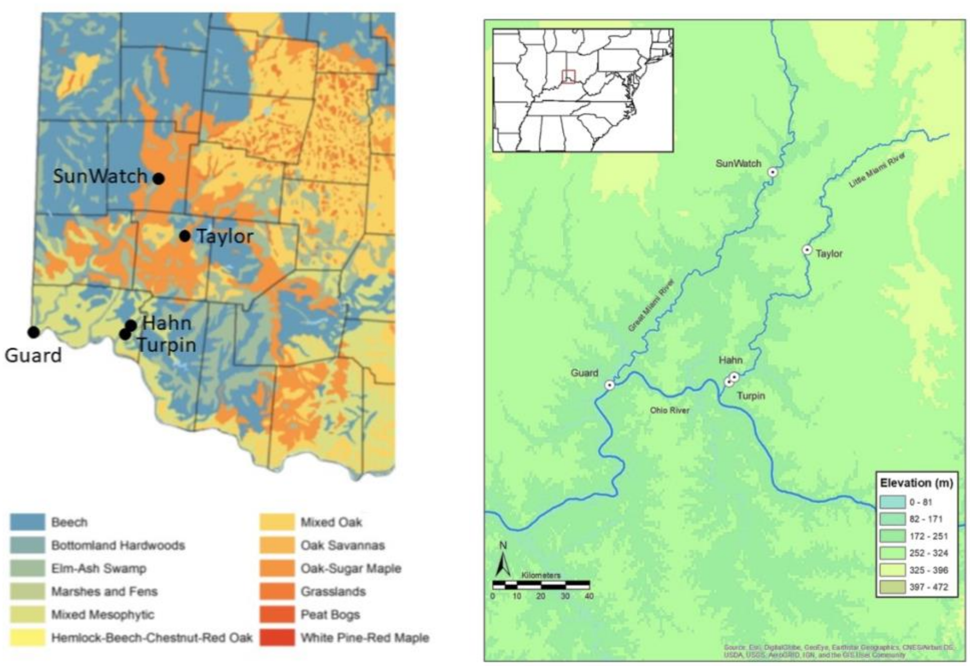


Figure 4: a (left) Vegetation in southwest Ohio (base after https://www.fractracker.org/2013/05/utica-land-use/), b (right) elevations in southwest Ohio and adjacent regions (made by Aaron R. Comstock)

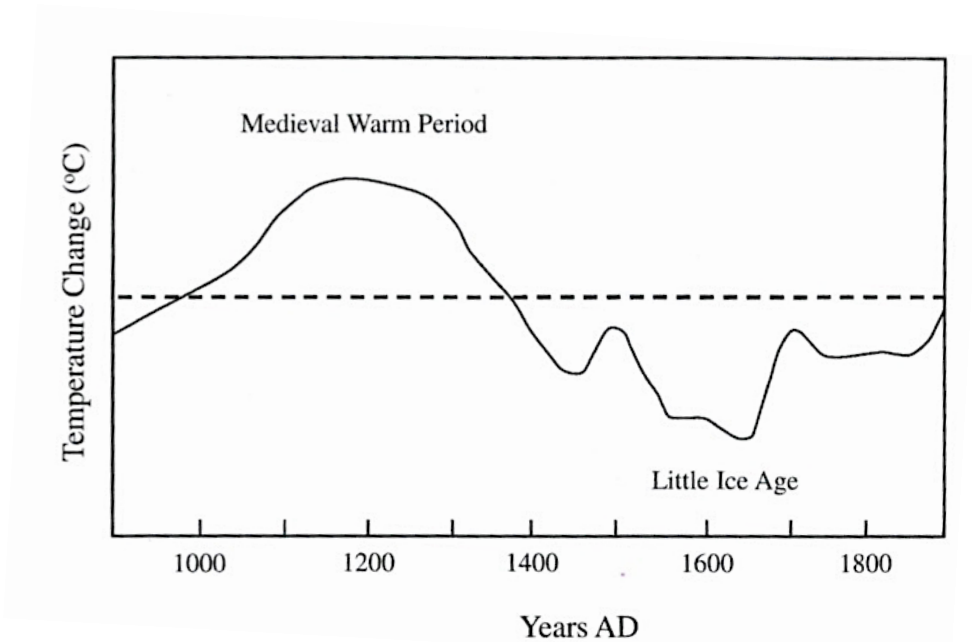


Figure 5: Climate change in Ohio (redrawn by Cook 2017 from www.atmos.washington.edu/1998Q4/project2/group4.htm)

Methods

To address research hypotheses described above, white-tailed deer astragali and mandibles from each site are analyzed. These bones were recovered from trash deposits. For this study, we collected 6 astragali from the Guard site, 95 from SunWatch, 34 from Turpin, 32 from Taylor, 17 from the Anderson component of Hahn, and 17 from the Madisonville component (see above for temporal designation criteria). Astragali have been used in past archaeological analyses because they scale with a white-tailed deer's actual size, allowing for reconstructions of individual deer sizes (Purdue 1987[a]). Determining the average of deer size within each site allows for analysis of changing subsistence practices and strategies as the climate and environment changed. As discussed above, prime deer are assumed to range in age from 2.5 to 6 years (Perttula 2012). Knowing the quality of deer targeted by these past societies allows us to further reconstruct the lives of the Fort Ancient people. Once deer size is established at the assemblage-level, it may also be possible to determine sex (Purdue 1987[a]).

Astragalus measurement methods are tested in *Changes during the Holocene in the Size of White-Tailed Deer (Odocoileus virginianus) from Central Illinois.* In this article, Purdue (1987[a]) tests for variation in measurements of white-tailed deer astragali. These six measurements include: ASMD, medial depth; ASMLEN, medial length; ASLEN, length; ASDW, distal width; ASLLEN, lateral length; and ASLD, lateral depth (Purdue 1987[a]). The use of six measurements allows us to be conservative when comparing the subtle differences between each astragalus. A display of these measurements, as provided in Purdue's article, can be seen in Figure 7. Once these measurements were determined, Purdue (1987[a]) compared them to modern deer reference data-bases to determine the size of each astragalus (Purdue 1987[a]). In reference to this study, once all measurements are collected, comparisons can be made between sites. This study will use Purdue's method of measurement alongside a similar study, next to be mentioned, in order to determine the general size of deer found within each site.

To avoid comparison of six different measurements, a second study, *Estimation of Body Weight of White-Tailed Deer (Odocoileus virginianus) from Bone Size*, was used (Purdue 1987[b]). In this article, Purdue examines the relationship between bone and body size through converting the measurements into volumes. To find the volume of the astragalus, Purdue uses the following formula: (ASMD/2) * (ASMLEN/2) *ASDW * pi. We will use the measurements conducted in Purdue's first mentioned study, in comparison to the next, to compare deer size across sites. Through this method, we no longer compare 6 different measurements across 6 different sites or site components, but instead rely on this composite measure for clarity.

As the data are distributed normally, the astragali within this study will be tested parametrically for significance using SPSS Statistics (Version 25). The data will be compared through the general means of each site through a One-way ANOVA test with a Tukey post-hoc test for multiple variances. Following standard convention, a p-value threshold of 0.05 is used to determine statistical significance. The primary comparisons of astragali measurements are (i) between all sites, (ii) between the Anderson and Madisonville components of the Hahn sites, and (iii) between the lower and upper Miami Valleys.

Deer tooth eruption and wear have been long recognized as indicators of age, as usage across most species of deer will be similar (Severinghaus 1949). This study will focus on the age of deer killed in conjunction with their sizes, found from astragali. Deer mandibles, able to withstand taphonomic processes more readily than most other bones, are found alongside other artifacts left behind within middens. We have sampled white-tailed deer mandibles from the same archaeological sites from which astragali were sampled. In total, there are 9 mandibles from the Guard site, 0 from SunWatch, 14 from Turpin, 16 from Taylor, 11 from the Anderson component of Hahn, and 20 from the Madisonville component of Hahn. A lack of mandibular data from SunWatch is due to inability to obtain the mandibles for the study. Likely, this study will be recalculated in the future once they are analyzed. Despite this problem the combined data will still provide insight into changing subsistence patterns due to climate and environmental changes among the native inhabitants of the Middle Ohio Valley.

Deer aging based on mandibular tooth eruption and wear is conducted in *Dama Dentition: A New Tooth Eruption Wear Method for Assessing the Age of Fallow Deer (Dama Dama)* (Bowen et al. 2016). Although the methods focus on Fallow Deer, we assume that deer tooth sizes and wear rates remain relatively constant between the two temperate forest-dwelling species. To follow methods used in this study, crown height measurements and eruption periods of teeth are taken on all mandible fragments found at each site. The Dp2, P4, M1, M2, and M3 are used when distinguishing eruption, as they can provide distinctive ages (Bowen et al. 2016). This study uses the methods of Bowen and colleagues (2016) when examining crown height and wear. Figure 8 provides pictures of average wear in Fallow teeth relative to age, which we will assume are similar enough to translate to white-tailed deer (Bowen 2016). As these findings are compared between sites, overall data are combined with astragali results. These combined data provide insights into changing subsistence patterns as a result of environmental change.

The method employed by Bowen and colleagues (2016) concludes two different ages, presented within a range of months. The first age is the “Best Fit Age”. This age encompasses how many of the measurements align with those of the specific age group, as seen in Table 1. Some tooth measurements, however, are likely more conclusive than others, such as the Dp4 in deciduous individuals, and the second and third mandibles in adults (Bowen et al. 2016). For this study, we will primarily focus on the “Diagnostic Ages”, as Bowen and colleagues designate them as priority. Because the “Best Fit Age” is given as a range (i.e. 5-12 months), we use the median of each range for simplicity.

The mandibular data are not distributed normally, and will therefore be examined using non-parametric tests. To test significance across sites, we will again use the software program SPSS statistics. Instead of a Parametric One-way ANOVA test, we will use a Nonparametric Kruskal Wallace One-way ANOVA test. Once again, the p-value of significance will be 0.05 to remain conservative.

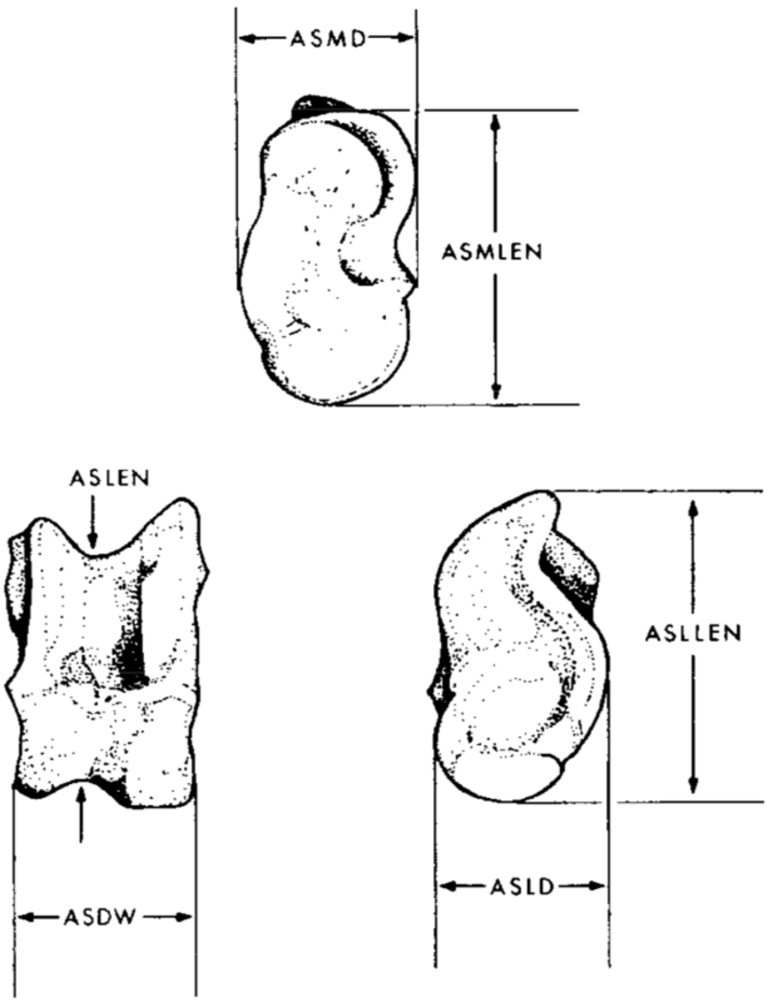


Figure 6: Astragali measurements used to find sex and size (from Purdue 1987[a])

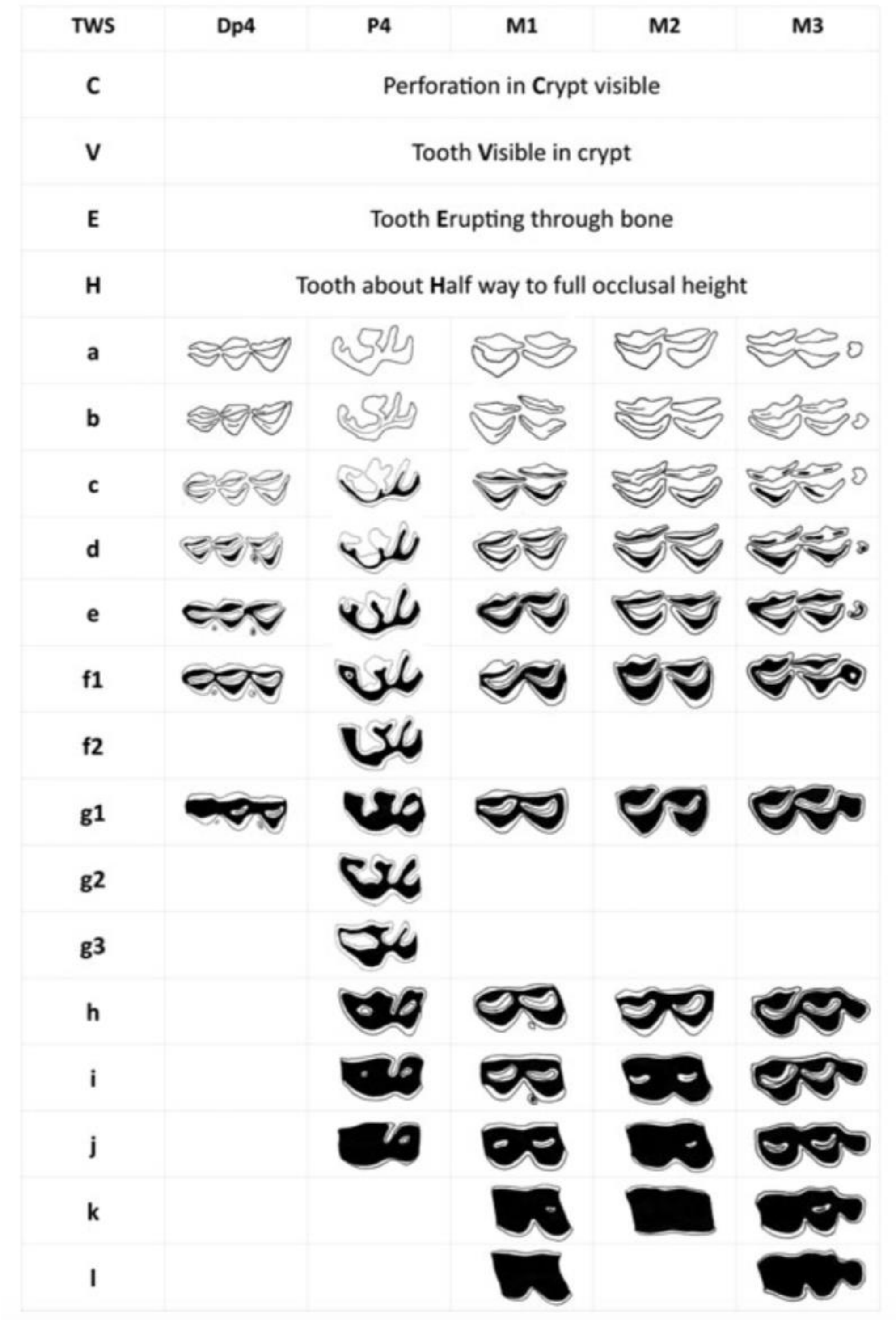


Figure 8: Mandible wear stages (from Bowen 2016)

Mandible wear stage	Descriptor (tooth wear stage)	Estimated age	*n*
A	**Dp4 H**; M1 V	Birth to 7 days	5
B	**Dp4 a–b**; M1 V	Up to 2 months	2
C	**Dp4 c–d**; M1 V–H	4–5 months	2
D	Dp4 d–e; M1 a–b; **M2 C–V**	5–12 months	16
E	Dp4 e–g; M1 c–d; M2 a–c; **M3 C–H**	13–20 months	26
F	P4 a–d; M1 c–d; M2 c–d; **M3 a–b**	20–33 months	6
G	P4 d–e; M1 c–e; M2 d–e; **M3 c–d**	33–54 months	9
H	P4 e–g; M1 f–h; M2 f–g; **M3 e**	44–147 months	19
I	P4 g; M1 g; M2 g; **M3 f**	61–183 months	15
J	P4 g–l; M1 g–j; M2 g–l; **M3 g+**	118–189 months	13

Table 1: Mandible wear stages attributed as Best Fit Ages (from Bowen 2016)

Results

Results are first presented for inter-site comparisons of astragali and then mandibles. Data descriptions such as ranges and standard deviations are found in Table 2. Comparing astragali volume between all sites, Turpin has significantly larger deer than Taylor and SunWatch ($p = 0.003$ and $p < 0.001$, respectively). A difference between Turpin and Guard, with larger deer from Turpin, is approaching significance ($p = 0.075$). There is no statistical significance in deer size when comparing the Anderson component of Hahn to the Madisonville component of Hahn ($p = 0.919$). The results of these comparisons can be seen within Figures 9 and Table 3.

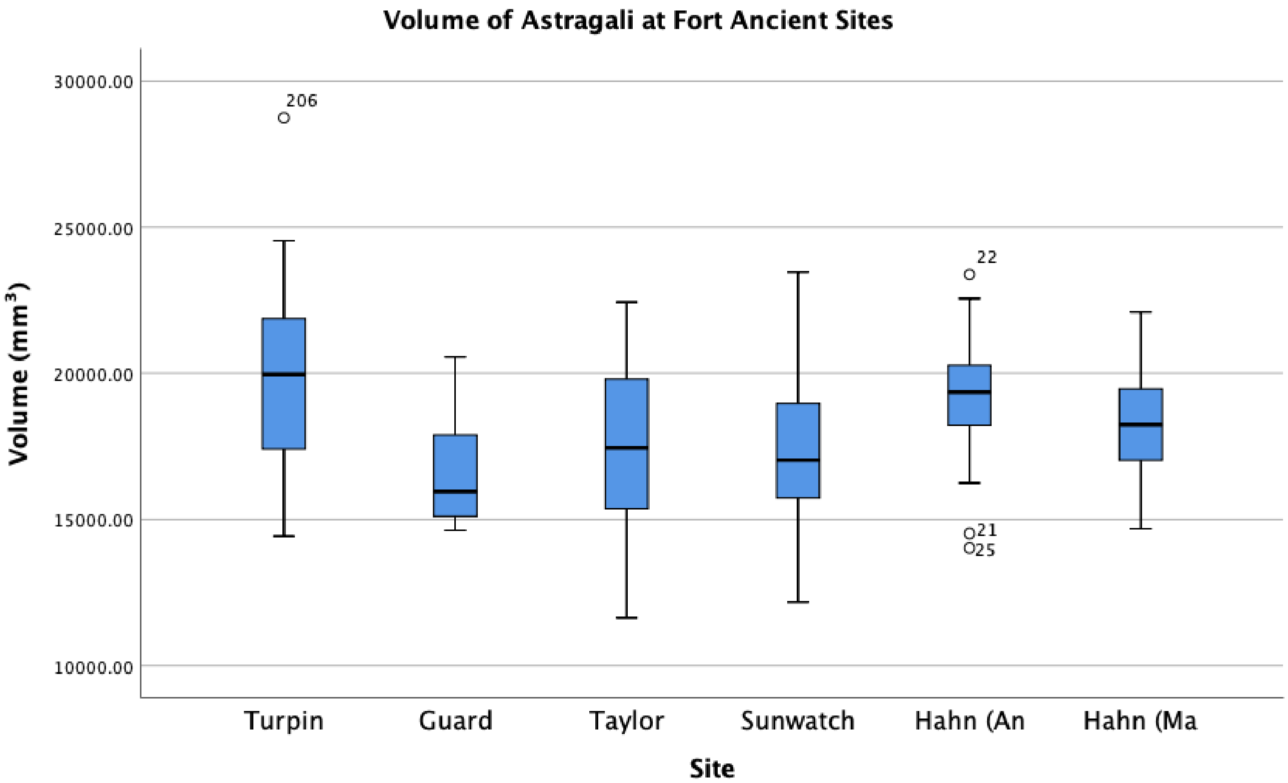


Figure 9: Boxplot of astragali volumes found at varying Fort Ancient sites

Descriptives

Volume

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Guard	6	16679.2317	2215.39787	904.43239	14354.3142	19004.1492	14623.47	20555.49
Hahn_A	17	19019.5478	2544.72061	617.18540	17711.1732	20327.9224	14022.65	23382.09
Hahn_M	17	18140.0546	2255.03235	546.92568	16980.6240	19299.4853	14678.95	22091.04
Taylor	32	17415.8705	2884.34994	509.88585	16375.9515	18455.7896	11637.09	22437.27
SunWatch	95	17346.0748	2272.93246	233.19795	16883.0548	17809.0948	12171.42	23466.40
Turpin	34	19787.8439	3228.32507	553.65318	18661.4280	20914.2598	14430.27	28739.88
Total	201	17959.0064	2725.18117	192.21946	17579.9696	18338.0432	11637.09	28739.88

Table 2: Astragali volume descriptives from SPSS Statistics analysis

Multiple Comparisons

Dependent Variable: Volume
Tukey HSD

(I) Site_Num	(J) Site_Num	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Guard	Hahn_A	-2340.31607	1224.64843	.399	-5865.1880	1184.5558
	Hahn_M	-1460.82288	1224.64843	.840	-4985.6948	2064.0490
	Taylor	-736.63880	1147.33114	.988	-4038.9705	2565.6929
	SunWatch	-666.84309	1085.60255	.990	-3791.5031	2457.8169
	Turpin	-3108.61217	1141.99055	.075	-6395.5722	178.3478
Hahn_A	Guard	2340.31607	1224.64843	.399	-1184.5558	5865.1880
	Hahn_M	879.49319	884.58207	.919	-1666.5751	3425.5615
	Taylor	1603.67727	774.00932	.306	-624.1325	3831.4870
	SunWatch	1673.47298	679.15726	.140	-281.3267	3628.2726
	Turpin	-768.29610	766.07055	.917	-2973.2559	1436.6637
Hahn_M	Guard	1460.82288	1224.64843	.840	-2064.0490	4985.6948
	Hahn_A	-879.49319	884.58207	.919	-3425.5615	1666.5751
	Taylor	724.18408	774.00932	.937	-1503.6257	2951.9938
	SunWatch	793.97979	679.15726	.851	-1160.8199	2748.7794
	Turpin	-1647.78929	766.07055	.266	-3852.7491	557.1705
Taylor	Guard	736.63880	1147.33114	.988	-2565.6929	4038.9705
	Hahn_A	-1603.67727	774.00932	.306	-3831.4870	624.1325
	Hahn_M	-724.18408	774.00932	.937	-2951.9938	1503.6257
	SunWatch	69.79571	527.12385	1.000	-1447.4104	1587.0018
	Turpin	-2371.97337*	635.19214	.003	-4200.2295	-543.7173
SunWatch	Guard	666.84309	1085.60255	.990	-2457.8169	3791.5031
	Hahn_A	-1673.47298	679.15726	.140	-3628.2726	281.3267
	Hahn_M	-793.97979	679.15726	.851	-2748.7794	1160.8199
	Taylor	-69.79571	527.12385	1.000	-1587.0018	1447.4104
	Turpin	-2441.76908*	515.39618	.000	-3925.2197	-958.3184
Turpin	Guard	3108.61217	1141.99055	.075	-178.3478	6395.5722
	Hahn_A	768.29610	766.07055	.917	-1436.6637	2973.2559
	Hahn_M	1647.78929	766.07055	.266	-557.1705	3852.7491
	Taylor	2371.97337*	635.19214	.003	543.7173	4200.2295
	SunWatch	2441.76908*	515.39618	.000	958.3184	3925.2197

*. The mean difference is significant at the 0.05 level.

Table 3: Sitewide description of significance between Fort Ancient sites

When comparing mandibles, there are differences evident when comparing the ages of deer found at Turpin to Taylor (p=0.05) and both components of Hahn (Turpin-Hahn(A): p=0.01; Turpin-Hahn(M): p<0.001). The deer are younger at Turpin in each case. The Madisonville component of Hahn has significantly older deer when compared to Guard (p<0.001), Taylor (p=0.001), Turpin (p<0.001), and its Anderson component of Hahn (p<0.027). Overall, we find older deer at the Madisonville component of Hahn, and younger deer at Turpin and Guard. Deer from Taylor and the Anderson component of the Hahn site have much longer ranges of deer age compared to the other sites. A boxplot depicting a distribution can be seen in Figure 10. The descriptive statistics are in Table 4 and a chart displaying the statistical outputs can be seen in Table 5.

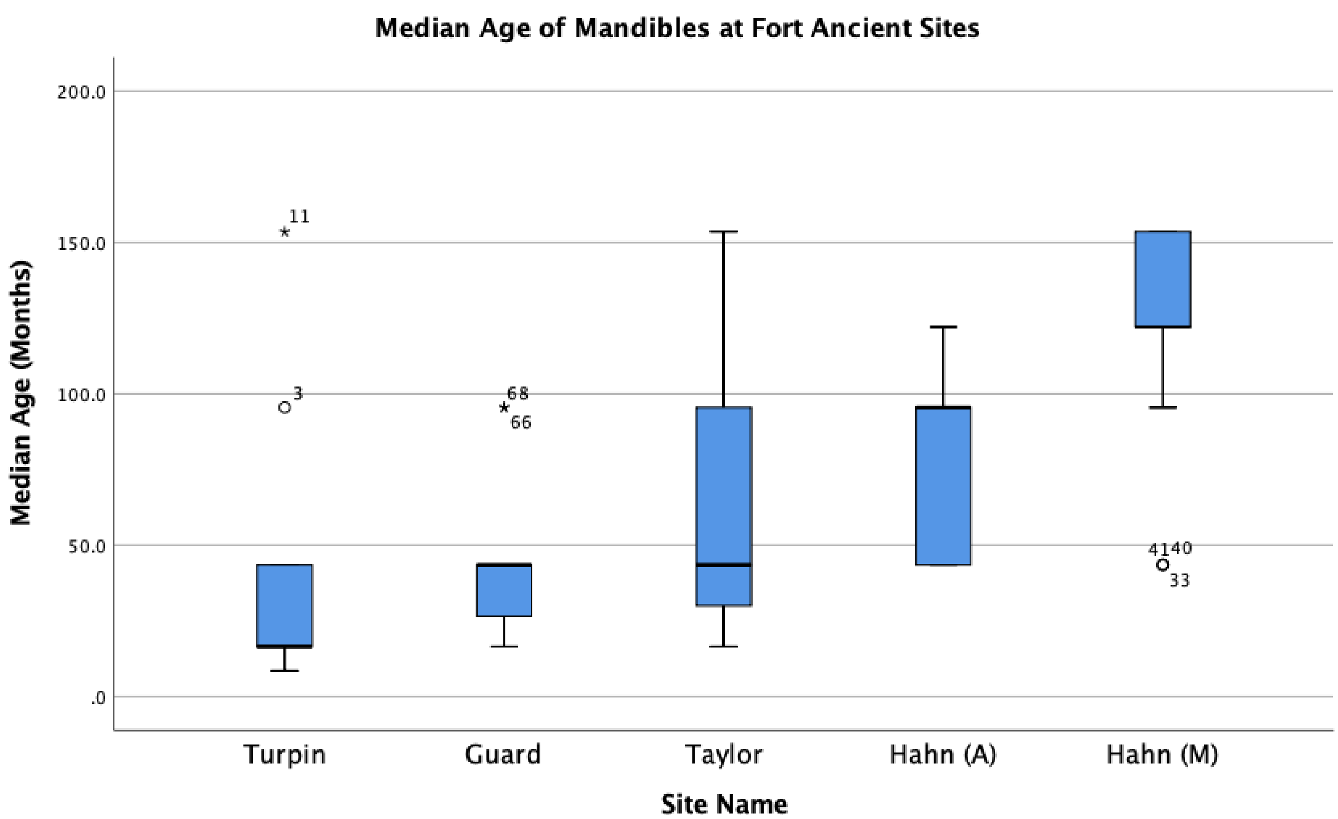


Figure 10: Median age of deer mandibles found at each Fort Ancient site

Descriptives

Median Age

Site Name	Mean	N	Std. Deviation	Std. Error of Mean	Minimum	Maximum
Guard	46.389	9	29.4298	9.8099	16.5	95.5
Hahn (A)	76.682	11	33.2101	10.0132	43.5	122.0
Hahn (M)	123.075	20	38.4544	8.5987	43.5	153.5
Taylor	64.781	16	42.7800	10.6950	16.5	153.5
Turpin	35.357	14	40.8729	10.9237	8.5	153.5
Total	75.057	70	50.0027	5.9765	8.5	153.5

Table 4: Descriptives of mandible ages across Fort Ancient sites

Pairwise Comparisons of Site Name

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Turpin-Guard	7.881	8.540	.923	.356	1.000
Turpin-Taylor	14.339	7.315	1.960	.050	.500
Turpin-Hahn (A)	20.760	8.054	2.578	.010	.099
Turpin-Hahn (M)	37.314	6.966	5.357	.000	.000
Guard-Taylor	-6.458	8.329	-.775	.438	1.000
Guard-Hahn (A)	-12.879	8.984	-1.433	.152	1.000
Guard-Hahn (M)	-29.433	8.023	-3.668	.000	.002
Taylor-Hahn (A)	6.420	7.829	.820	.412	1.000
Taylor-Hahn (M)	22.975	6.705	3.427	.001	.006
Hahn (A)-Hahn (M)	-16.555	7.503	-2.206	.027	.274

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 5: Significance of deer ages across Fort Ancient sites

Discussion

The results of this study align with the assumptions of Optimal Foraging Theory (OFT). At the Early Fort Ancient sites in this study (Guard and Turpin), we see prime aged deer (between 30 and 72 months) being preferentially selected. The range within both of these sites is small, suggesting that inhabitants of both sites had environmental and climactic conditions that allowed for prime selection of deer. The Turpin deer were significantly larger than those recovered from both Taylor and SunWatch, which insinuates conditions allowing for larger deer within the lower valleys. Overall, we see the choice of prime deer within these lower valley, Early Fort Ancient sites.

An important consideration is the notion of patches, or areas that each group decided to live within. More specifically, hunter-gatherers will often choose areas to live based upon optimal benefits that can be accrued (Winterhalder 1981). In this case, as was hypothesized, the lower valley sites appear to be more conducive to hunting larger game than the upper valley sites, such as SunWatch and Taylor due to the large open floodplains beneficial for corn and the growth of vegetation as well as the edge environments in which they were situated.

Another aspect of OFT suggests that certain areas will be left in favor of others when resources dwindle in productivity (Foley 1985). The Marginal Value Theorem (a particular aspect of OFT), discusses that when an area is no longer optimal for usage, people would leave the area to find a better one. This is likely why people moved upriver during the Middle Fort Ancient time period such as from Guard to SunWatch, or from Turpin to Taylor.

As we can see in Figure 10, which displays deer ages within each archaeological site, both Taylor and Hahn (Anderson) demonstrate deer with high variance in age. These deer are not as prime as those from the Early Fort Ancient contexts of Turpin and Hahn. Additionally, these hunters seem to be less particular with their choice in deer, as deer may be more difficult to find, especially in the upland sites such as Taylor and SunWatch, leading to a take what you can get strategy, as described in Deppen and Cook (2014). As discussed earlier, SunWatch mandibles were not able to be obtained. If this were possible, we insinuate that mandibles from this site would indicate similar ages to those in other Middle Fort Ancient contexts.

The results are also consistent with the expectations regarding the effects of the Little Ice age. Taylor is located in a comparatively marginal environment, so the inhabitants of this community moved back to a place where they previously had success in finding prime resources: the lower Little Miami Valley. This movement also aligns with expectations derived from OFT. The Little Ice Age led to a depletion of resources, both in terms of agricultural potential as well as overall deer options. Resource depression would also have been evident as the region had witnessed several hundreds of years of intensive hunting of prime deer. This depletion is reflected in the ages of deer found within the Madisonville component of Hahn, with the oldest deer being over 12.5 years old. Due to the relatively harsh climatic conditions of the Little Ice Age, optimization was not possible to the same degree for these Fort Ancient hunters. They had to settle now more often for older deer than would have been their target in earlier times.

Theoretical Considerations

There are many issues to consider when using the Optimal Foraging Theory as a model for understanding the nature of deer populations available to Fort Ancient hunters. First, we must see whether these sites can adhere all characteristics of an optimality model: including a goal, currency, a phenotypic set, a time frame, and competition (Foley 1985). As suggested by Winterhalder (1981), a general goal for optimality within archaeology is utility, as it is a non-heritable measure of success. Energy can act as currency. Other characteristics deemed necessary from Winterhalder to apply the Optimal Foraging Theory to anthropology may not be applicable or clear-cut. Controversy in academic archaeology challenges the applicability of optimality to hunter-gatherers, deeming it not relevant due to human choice (Mithen 1989). Furthermore, cultural elements impact subsistence practices. Overall, while we must fully consider human agency, using optimality models to learn how subsistence practices change allow researchers to better understand the lifestyles of the past.

Sampling Issues

Although SunWatch mandibles were not able to be obtained for this study, a previous study by Deppen and Cook 2014 titled *Deer Use in Good Times and in Bad: A Fort Ancient Case Study from Southwest Ohio* addresses deer utilization as a response to environmental conditions within various sites of southwest Ohio, one being SunWatch (Deppen and Cook 2014). It must be noted that the methods used by Deppen and Cook are different than the methods used in this study to calculate changes in white-tailed deer populations. However, conclusions made regarding deer hunting patterns at SunWatch in the 2014 study may help fill in the unanswered question of what deer populations looked like at the SunWatch site in comparison to the other sites used in this study. Deppen and Cook (2014) concluded that drought episodes over time led to a reduction in the occurrence of prime-aged and large deer.

As they describe, the hunters seem to have resorted to a “take what you can get strategy” (Deppen and Cook 2014: 81). This strategy also aligns with that we saw at the Taylor site, where there was an increased variance in prime-aged deer, as purposeful selection was not plausible for survival. Based on this and findings at Taylor in the present study, it will be important to add SunWatch age estimates using the same methodology.

A second sample bias concerns the very few astragali at Guard in comparison to the other sites. Due to this, one should be wary of how well they represent the site overall. We suspect that the population of deer at Guard is larger than our sample size suggests, but the only way to examine this will be to obtain additional samples.

A third sampling issue involves excavation extents at study sites. In short, not all sites for which we have reasonable frequencies of samples have been excavated to the same extent. This is a more difficult problem to remedy but should be kept in mind as future excavations occur at those sites. Analyzing astragali and mandibles from only one or two contexts within a site can potentially lead to skewed representation of the actual deer populations during Fort Ancient times. Obtaining bones from only certain contexts of each site could lead to a lack of representation, as there may be population differences in deer consumption. The inclusion of a variety of contexts at Hahn (late/Madisonville), SunWatch, and Taylor allows us to properly assume that the populations are generally representative. This is because archaeological excavations have been extensive, hence the astragali used are likely more representative. Turpin, Hahn (early/Anderson) and Guard excavations have been less extensive, which provide more reasons to wonder if sampling error could be affecting the patterns observed in the data.

The final sampling concern has to do with a regional scale, as it is possible that the sites sampled do not fully represent the culture's deer hunting practices. Because only five sites were used within this study, future research would not only include integrating more bones from the five archaeological sites used within this study, but would also entail the integration of additional Fort Ancient sites.

Maize

Additionally, maize as a form of subsistence practice can be related to this study in terms of both human and deer consumption. Cook and Price (2015: 112) note that "maize consumption significantly decreased over time", which contradicts the initial hypothesis of maize intensification (Cook and Price 2015). As this study notes that prime aged deer decrease over time, the same happens to corn production. In relation to this study, we see vegetation (including corn production) prosper in the lower valley, Early Fort Ancient contexts due to the environmental conditions outlined above. People who lived at the Middle Valley sites, SunWatch and Taylor, did not consume as much corn, possibly due to the soil conditions in comparison to large, open floodplains (Cook and Price 2015). Decreased corn productivity not only impacted the inhabitants of these upland sites, but also the deer, as deer are attracted to corn. This is possibly another reason why deer populations are less prime in the Middle Fort Ancient time period. Lastly, both corn production and prime aged deer decreased in the Late Fort Ancient time period. Here, we see a large resource depletion, leading to desperation and a lack of food choice in subsistence practices.

Geography of Deer Sex

This study finds significantly larger deer at Turpin in comparison to Taylor and SunWatch, the upper valley sites. Since size does correlate with sex (sexual dimorphism), it is quite possible that this is a contributing factor to the observed pattern. Specifically, the upland sites of Taylor and SunWatch have more female deer compared to Guard, Hahn, and Turpin: the distinguishing factor between the sites being environment. *Factors influencing white-tailed deer activity patterns and habitat use* by Paul Beier and Dale R. McCullough looks at differences between female and male preferential habitats on the George Reserve in Michigan (Beier and McCullough 1990). Deer activity patterns, analyzed by Beier and McCullough through the use of GPS, are displayed in Figure 11. This study concludes that female white-tailed deer prefer open woodlands, while males do not. Although this study may not be applicable, because the area is a small percentage of our study area, it may still be representative of differences between sex. Taylor and SunWatch fit within this category, and smaller sized populations compared to those of the lower valley.

Figures 12 and 13 compare the sizes of deer populations from Taylor and Turpin. Sexual dimorphism among white-tailed deer allows for further estimation of female and male populations found at each of the sites (Leberg et al. 1992). This is done through comparing the width (ASDW) to the length (ASLLEN) of each astragalus. These depictions insinuate a larger female deer population Taylor in comparison to Turpin. Habitat preference between males and female could be one reason for inter-site variation. Further insight is needed to fully understand differences in females and male white-tailed deer found within Fort Ancient sites.

General Conclusion

Despite some important things to consider for future efforts, the overall pattern is clear. There were changes in Fort Ancient hunting strategies in relation to environmental and climatic changes. Lower valley, earlier Fort Ancient hunters hunted larger, more prime/more male deer due largely to its excellent location in or near very large floodplains and edge habitats. Upper valley Fort Ancient hunters in the second and third time periods of Fort Ancient were utilizing different environments, ones more conducive to smaller, and maybe less prime/more female deer. Lastly, the later (Madisonville) component of Hahn was occupied during the Little Ice Age which appears to have led to a shift toward less-prime/older deer. In sum, a pronounced climate shift and geographic variation in topography and vegetation can be predictably tracked using ecological models as illustrated in this study.

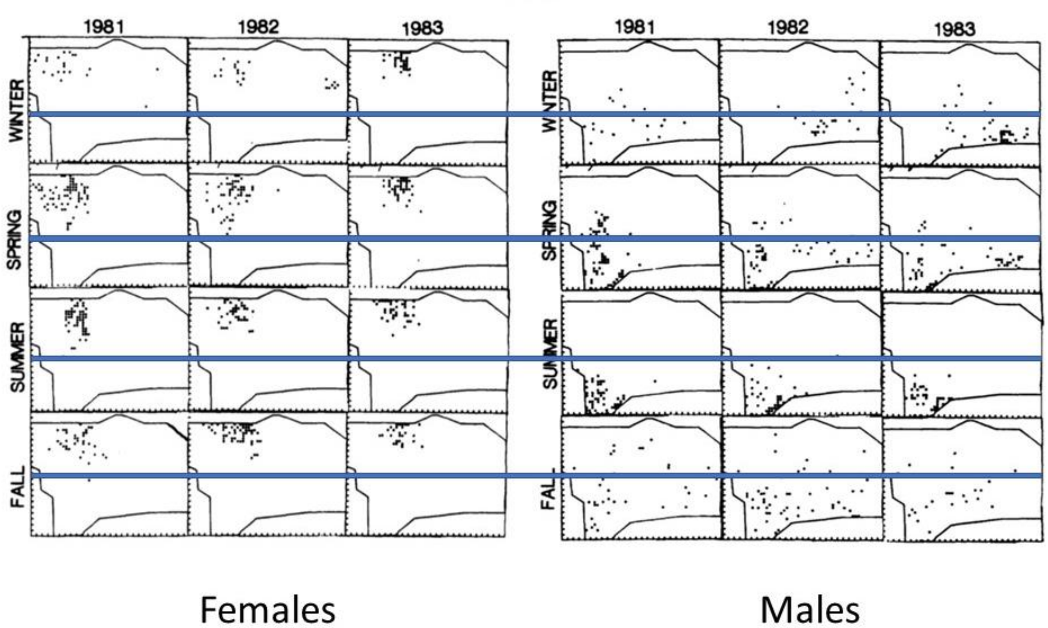
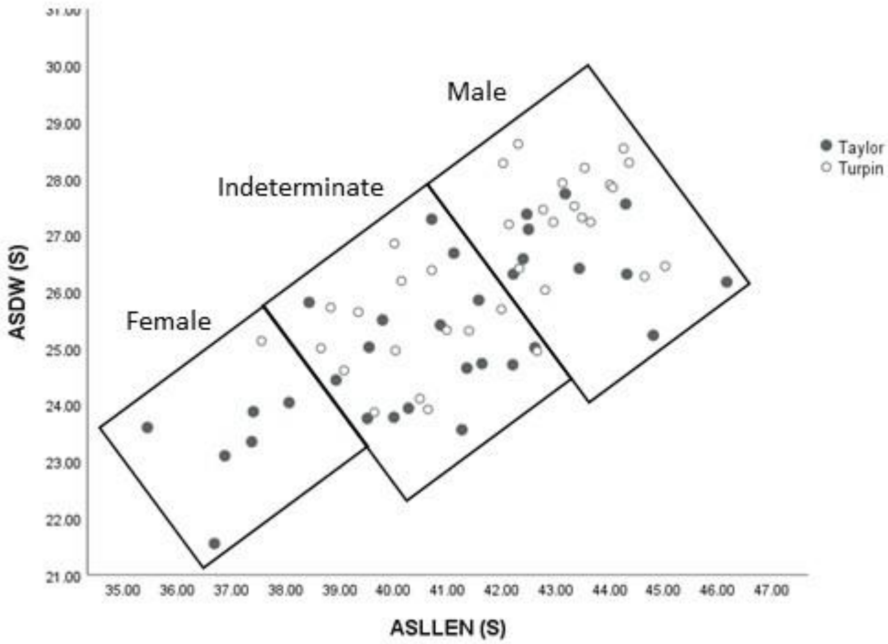
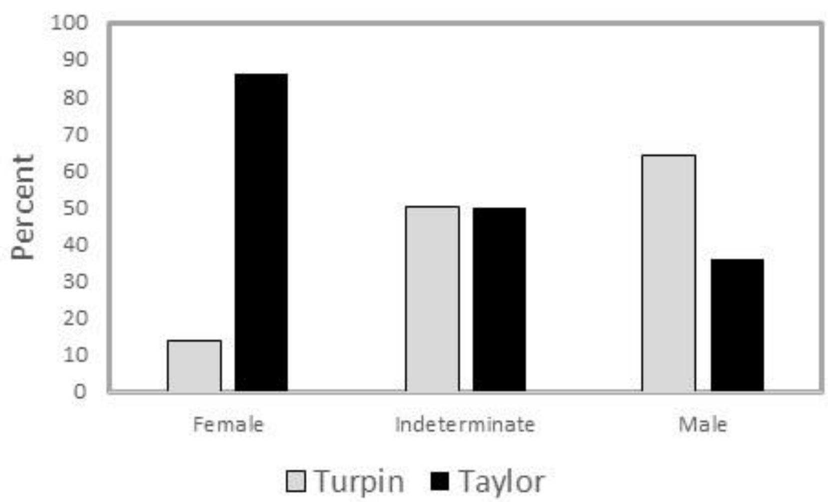


Figure 11: Female vs. Male activity on the George Reserve, Michigan (after Beier and McCullough 2014, lines added in approximate center of the reserve to show the clear distinctions in deer sex primarily in the north vs. the south)





Figures 12 and 13: Deer sex comparison for between Turpin and Taylor (made by Robert A. Cook)

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