Modeling Regional Radicarbon Trends: A Case Study from the East Texas Woodland Period

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MODELING REGIONAL RADIOCARBON TRENDS: A CASE STUDY FROM THE EAST TEXAS WOODLAND PERIOD

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ABSTRACT. The East Texas Radiocarbon Database contributes to an analysis of tempo and place for Woodland era (~500 BC–AD 800) archaeological sites within the region. The temporal and spatial distributions of calibrated 14C ages (n = 127) with a standard deviation (ΔT) of 61 from archaeological sites with Woodland components (n = 51) are useful in exploring the development and geographical continuity of the peoples in east Texas, and lead to a refinement of our current chronological understanding of the period. While analysis of summed probability distributions (SPDs) produces less than significant findings due to sample size, they are used here to illustrate the method of date combination prior to the production of site- and period-specific SPDs. Through the incorporation of this method, the number of 14C dates is reduced to 85 with a ΔT of 54. The resultant data set is then subjected to statistical analyses that conclude with the separation of the east Texas Woodland period into the Early Woodland (~500 BC–AD 0), Middle Woodland (~AD 0–400), and Late Woodland (~AD 400–800) periods.

INTRODUCTION

Archaeologists have a lengthy history of tinkering with the manipulation of radiocarbon data, and have made much progress since first advocating for a more flexible method of processing data through the employment of a punch-card data retrieval system (see Taylor et al. 1968). Through the advent and acceptance of novel methodological approaches, we continue to make significant progress in our understanding and manipulation of regional cultural chronologies (Wendorf et al. 1979; Hassan 1984; Bever 2006; Bamforth and Grund 2012).

Rick’s (1987) innovative explanation and subsequent employment of 14C dates as data garnered acceptance and use within studies of occupational patterns and population dynamics (see Kuzmin and Keates 2005), which use the number of occupations—in lieu of the number of 14C dates—as a method to view the spatial and temporal dynamics of human distribution (Straus et al. 2000). To that end, this study includes the assumptions that (1) 14C dates that can be combined via the OxCal X test represent a single occupational episode, (2) the summed probability distribution for archaeological sites with 4 or more 14C assays illustrates the discrete or diffuse nature of occupational episodes, and (3) median dates represent the age of highest probability within each date range.

Through a variety of academic, avocational, and cultural resource management pursuits, archaeologists have obtained 127 14C dates from 51 Woodland period sites across east Texas (Tables 1 and 2). The bulk of these dates were collected with the intention of exploring locally based research questions and are employed here within a discussion of macrolevel trends, using a descriptive analysis of the results from date combination, summed probability distributions, and statistics to apprise the subsequent inferences (see Bernard 2006). While the distribution of recognized Woodland sites (or components) is easily plotted spatially, this paper represents the first attempt to synthesize these combined data and illustrate the temporal relationships that exist between 14C dates collected across the east Texas region over the last 40 yr.

The East Texas Radiocarbon Database (ETRD) represents a sizeable sample of dates produced within a relatively small geographic region on the southwestern border of the Woodland culture area. This research refines our current knowledge regarding the temporal complexities within the Woodland period, providing a snapshot of temporal trends extracted from an understudied sample of 14C dates. The temporal and spatial distributions of calibrated 14C ages are useful in exploring the development and geographic continuity of the Woodland peoples and lead to a better understanding of the current chronological framework. From these data, it is possible to establish temporal associ-
ations that correlate with site abandonment, decreases or increases in local populations, and an intensification of landscape usage throughout the Woodland period. These data are particularly helpful since paleoenvironmental models for east Texas are not able to be constructed due to the highly acidic soils (Bryant and Holloway 1985).

The inductive methodology employed here informs a regional chronology for east Texas Woodland sites (DeWalt and Pelto 1985). The goals of this article are to explore the process of ^14C^ date combination from sites with 4 or more samples \( (n = 11) \) to decrease sampling bias for statistical analysis and determine the modified summed probability distributions (see Michczyńska and Pazdur 2004; Bamforth and Grund 2012; Williams 2012), and secondly to employ the resulting median dates within a statistical analysis of regional trends.

**EAST TEXAS RADIOCARBON DATABASE**

Story (1990) provided the first published compendium of ^14C^ dates from east Texas, and the extensive ^14C^ database from investigations at Cooper Lake (Fields et al. 1997: Appendix B) led to Pertainment’s (1997, 1998) initial efforts to synthesize these data. In its current form, the ETRD is comprised of 1248 ^14C^ dates from a total of 199 archaeological sites that range in age from Paleoindian through Historic. This is a substantial increase from the 520 dates previously published (Pertta and Selden 2011), and the vast majority of the ^14C^ dates in the database are the product of cultural resource management (CRM) projects in east Texas.

**METHODS OF ANALYSIS**

^14C^ dates used within this research were collected from CRM reports and publications, were synthesized, then recalibrated with OxCal v 4.1.7 (Bronk Ramsey 2012) and IntCal09 (Reimer et al. 2009) (Table 1) (Perttula and Selden 2011). The completed database was analyzed using a variety of statistical processes (histograms, barplots, boxplots, kernel density, and hierarchical cluster analysis) within version 2.15.1 of R (http://www.r-project.org/), and summed probability distributions (SPDs) were produced using OxCal. Statistical calculations were made using negative numbers to represent BC and positive numbers to represent AD (Sirkin 2006).

With few exceptions where conventional ^14C^ ages were reported—to include older assays found to lack \( \delta^{13}C \) dates—value estimates were made for fractionation correction as suggested by Stuiver and Reimer (1993: Table 1): –25‰ for nutshell and charcoal (C3 plants), and –10‰ for charred maize (C4 plants).

The Woodland sample was selected from the ETRD on the basis of median age. If the median age fell within the currently accepted temporal construct (~500 BC–AD 800) for the Woodland period (see Story 1990; Perttula and Nelson 2004; Perttula 2008a), it was included. Dates from sites found to lack geographic coordinates, with a standard deviation greater than 200 yr, or from non-archaeological contexts (i.e. geoarchaeological profile, backhoe trench, or cutbank not on a site) were removed from the sample. The remaining dates were combined and comprise the basis of the Woodland period statistical sample. Data fields from the ETRD include site name, trinomial (site number), assay number, raw age, \( \delta^{13}C \), corrected ^14C^ age, 2\( \sigma \) age range, and median age (Table 2).

Within the distribution of Woodland ^14C^ assays \( (n = 127) \) from the ETRD, 28 sites were found to have 1 ^14C^ sample, 8 sites have 2 samples, 4 sites have 3 samples, 3 sites have 4 samples, 1 site has 5 samples, 3 sites have 6 samples, two have 7 samples, one has 9 samples, and one has 13 samples. The assays from the 11 sites with 4 or more ^14C^ dates were combined via OxCal for 2 reasons: (1)
to reduce the standard deviation and increase the accuracy of each site’s temporal assignments and (2) to reduce sampling bias created by the number of samples during statistical analyses.

Once combined, a summed probability distribution (SPD) was produced for each of the 11 sites to illustrate the position of each within the period. The dates were plotted in a manner where the SPDs, the combined groups, and the individual assays that inform them can be viewed together. These efforts permit the SPD for the entirety of the Woodland period sample to be contrast with those produced for the 11 sites. This comparison demonstrates the impact that each site has upon the whole of the Woodland period $^{14}$C sample, and allows for a discussion of regional trends within the temporal sample.

This method expands the scholarly impact of existing $^{14}$C dates through their integration within a regional chronology. By combining and recalibrating $^{14}$C dates, and producing site-specific SPDs, the most accurate temporal representation available for the Woodland period in east Texas has been developed. The investigation contrasts site-specific summed probability distributions for 11 sites against the summed probability distribution for the entirety of the Woodland period sample.

<table>
<thead>
<tr>
<th>Trinomial</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>41AN38</td>
<td>Lohse et al. 2004; Perttula et al. 2007, 2011</td>
</tr>
<tr>
<td>41AN120</td>
<td>Perttula 1997</td>
</tr>
<tr>
<td>41BW692</td>
<td>Lohse et al. 2004</td>
</tr>
<tr>
<td>41CE19</td>
<td>Story 1990; Davis et al. 1992; Perttula 2010a,b</td>
</tr>
<tr>
<td>41CP245</td>
<td>Nelson and Perttula 2006</td>
</tr>
<tr>
<td>41CP408</td>
<td>Sherman 2004; Perttula and Ellis 2012</td>
</tr>
<tr>
<td>41DT6</td>
<td>Fields et al. 1993</td>
</tr>
<tr>
<td>41DT16</td>
<td>Fields et al. 1993</td>
</tr>
<tr>
<td>41DT62</td>
<td>Fields et al. 1993</td>
</tr>
<tr>
<td>41DT141</td>
<td>Fields et al. 1997</td>
</tr>
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<td>41HO216</td>
<td>Cooper and Cooper 2005; Perttula and Nelson 2006, 2007</td>
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<tr>
<td>41HP78</td>
<td>Doehner and Larson 1978</td>
</tr>
<tr>
<td>41HP106</td>
<td>Perttula 1999</td>
</tr>
<tr>
<td>41HP137</td>
<td>Fields et al. 1997</td>
</tr>
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<td>41HS15</td>
<td>Fields and Gadus 2012</td>
</tr>
<tr>
<td>41HS16</td>
<td>Webb et al. 1969</td>
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<td>41HS231</td>
<td>Dockall et al. 2008</td>
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<td>41HS843</td>
<td>Gadus et al. 2006</td>
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<td>41HS844</td>
<td>Gadus et al. 2006</td>
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<td>41LR152</td>
<td>Mahoney et al. 2001, 2002</td>
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<td>41LR164</td>
<td>Mahoney et al. 2001, 2002</td>
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<td>41LR297</td>
<td>Bruseth et al. 2009</td>
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<td>41MX5</td>
<td>Brewington et al. 1995</td>
</tr>
<tr>
<td>41NA49</td>
<td>Corbin 1984; Corbin et al. 1984; Corbin and Hart 1998</td>
</tr>
<tr>
<td>41NA231</td>
<td>Perttula 2002, 2008b</td>
</tr>
<tr>
<td>41NA236</td>
<td>Perttula 2000, 2002, 2008b</td>
</tr>
<tr>
<td>41NA243</td>
<td>Perttula 2000, 2002</td>
</tr>
<tr>
<td>41NA244</td>
<td>Perttula 2000, 2002</td>
</tr>
<tr>
<td>41NA248</td>
<td>Perttula 2000, 2002</td>
</tr>
<tr>
<td>41NA264</td>
<td>Perttula 2000, 2002</td>
</tr>
<tr>
<td>41NA280</td>
<td>Perttula 2000, 2002</td>
</tr>
<tr>
<td>41NA290</td>
<td>Perttula 2000, 2002</td>
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Table 1 Data sources for the 51 archaeological sites examined in this study. (Continued)

<table>
<thead>
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<th>Trinomial</th>
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<td>41RK170</td>
<td>Perttula and Nelson 2003</td>
</tr>
<tr>
<td>41RK214</td>
<td>Rogers and Perttula 2004; Perttula and Rogers 2007</td>
</tr>
<tr>
<td>41RK222</td>
<td>Rogers et al. 2001</td>
</tr>
<tr>
<td>41RK328</td>
<td>Cliff et al. 2004</td>
</tr>
<tr>
<td>41RK468</td>
<td>Dixon et al. 2009</td>
</tr>
<tr>
<td>41RK558</td>
<td>Dockall and Fields 2011</td>
</tr>
<tr>
<td>41SM273</td>
<td>Perttula and Nelson 2001, 2004</td>
</tr>
<tr>
<td>41SY41</td>
<td>Perttula 1997</td>
</tr>
<tr>
<td>41TT370</td>
<td>Kotter et al. 1993</td>
</tr>
<tr>
<td>41TT372</td>
<td>Barnhart et al. 1997</td>
</tr>
<tr>
<td>41TT409</td>
<td>Kotter et al. 1993</td>
</tr>
<tr>
<td>41TT550</td>
<td>Dixon et al. 1997; Perttula 1998</td>
</tr>
<tr>
<td>41TT653</td>
<td>Galan 1998; Perttula and Sherman 2009</td>
</tr>
<tr>
<td>41TT847</td>
<td>Hatfield et al. 2008</td>
</tr>
<tr>
<td>41TT865</td>
<td>Perttula et al. 2003; Hatfield et al. 2008</td>
</tr>
<tr>
<td>41UR77</td>
<td>Perttula and Ricklis 2005</td>
</tr>
<tr>
<td>41UR133</td>
<td>Parsons 1998</td>
</tr>
<tr>
<td>41WD495</td>
<td>Bruseth and Perttula 1981</td>
</tr>
</tbody>
</table>

**Trinomial** refers to the Smithsonian trinomial numbering system where the state is indicated by a number ranging from 1 to 50, the county by 2–3 capital letters, and the site within the county is represented by a number ranging from 1 to infinity.

Table 2 \(^{14}C\) dates for the east Texas Woodland period.^

<table>
<thead>
<tr>
<th>Trinomial</th>
<th>Sample nr</th>
<th>Raw age</th>
<th>(\delta^{13}C) (%)</th>
<th>Corrected (^{14}C) age</th>
<th>1σ age range</th>
<th>2σ age range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>41AN038</td>
<td>Beta-236778</td>
<td>—</td>
<td>–26.2</td>
<td>1290 ± 40</td>
<td>AD 670–722 (0.43), AD 741–770 (0.25)</td>
<td>AD 653–783 (0.91), AD 789–812 (0.03), AD 845–856 (0.01)</td>
<td>722</td>
</tr>
<tr>
<td>41AN038</td>
<td>Beta-236790</td>
<td>—</td>
<td>–25.8</td>
<td>1420 ± 40</td>
<td>AD 604–655 (0.68)</td>
<td>AD 565–666 (0.95)</td>
<td>625</td>
</tr>
<tr>
<td>41AN038</td>
<td>Beta-236794</td>
<td>—</td>
<td>–24.3</td>
<td>1830 ± 50</td>
<td>AD 126–244 (0.68)</td>
<td>AD 70–263 (0.87), AD 278–329 (0.08)</td>
<td>184</td>
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<tr>
<td>41AN120</td>
<td>SMU-669</td>
<td>1744 ± 64</td>
<td>1744 ± 76</td>
<td>AD 215–401 (0.68)</td>
<td>AD 83–434 (0.95), AD 495–505 (0.01)</td>
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<tr>
<td>41BW692</td>
<td>UGA-13420</td>
<td>1270 ± 40</td>
<td>–24.7</td>
<td>1280 ± 40</td>
<td>AD 676–729 (0.40), AD 736–772 (0.28)</td>
<td>AD 657–825 (0.93), AD 841–862 (0.03)</td>
<td>730</td>
</tr>
<tr>
<td>41CE019</td>
<td>Tx-1223</td>
<td>1290 ± 80</td>
<td>–1266 ± 90</td>
<td>AD 665–826 (0.61), AD 840–863 (0.07)</td>
<td>AD 622–972 (0.95)</td>
<td>AD 602–901 (0.91), AD 917–966 (0.04)</td>
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<td>Tx-919</td>
<td>1310 ± 80</td>
<td>–1286 ± 90</td>
<td>AD 665–820 (0.63), AD 842–860 (0.05)</td>
<td>AD 436–490 (0.03), AD 510–517 (0.00), AD 530–891 (0.02)</td>
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<td>41CE019</td>
<td>Tx-105</td>
<td>1120 ± 90</td>
<td>–1361 ± 99</td>
<td>AD 582–775 (0.68)</td>
<td>AD 425–877 (0.95)</td>
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<td>41CE019</td>
<td>Tx-674</td>
<td>1420 ± 100</td>
<td>–1396 ± 108</td>
<td>AD 542–723 (0.61), AD 740–770 (0.07)</td>
<td>AD 422–773 (0.95)</td>
<td>AD 422–773 (0.95)</td>
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<td>41CE019</td>
<td>Tx-3312</td>
<td>1190 ± 80</td>
<td>–1431 ± 90</td>
<td>AD 471–477 (0.01), AD 535–683 (0.67)</td>
<td>AD 418–466 (0.31), AD 482–533 (0.37)</td>
<td>AD 382–560 (0.95)</td>
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<td>41CE019</td>
<td>—</td>
<td>1630 ± 40</td>
<td>–26.7</td>
<td>1600 ± 40</td>
<td>AD 437–468 (0.49), AD 479–534 (0.18)</td>
<td>AD 240–570 (0.95)</td>
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<td>Tx-3695</td>
<td>1400 ± 60</td>
<td>–1641 ± 72</td>
<td>AD 337–468 (0.49), AD 479–534 (0.18)</td>
<td>AD 240–570 (0.95)</td>
<td>AD 657–825 (0.93), AD 841–862 (0.03)</td>
<td>730</td>
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<td>41CP245</td>
<td>Beta-208773</td>
<td>1320 ± 40</td>
<td>–27.5</td>
<td>1280 ± 40</td>
<td>AD 676–729 (0.40), AD 736–772 (0.28)</td>
<td>AD 657–825 (0.93), AD 841–862 (0.03)</td>
<td>730</td>
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<td>41CP245</td>
<td>Beta-208775</td>
<td>1730 ± 40</td>
<td>–27.3</td>
<td>1690 ± 40</td>
<td>AD 261–280 (0.11), AD 326–410 (0.58)</td>
<td>AD 249–426 (0.95)</td>
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Table 2 □C dates for the east Texas Woodland period.a  (Continued)

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<tr>
<th>Trinomialb</th>
<th>Sample nr</th>
<th>Raw age</th>
<th>□13C (‰)</th>
<th>Corrected □14C age 1</th>
<th>1σ age range</th>
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<td>41CP408</td>
<td>Beta-184988</td>
<td>1930 ± 40</td>
<td>-25.9</td>
<td>1920 ± 40</td>
<td>AD 29–38 (0.05), AD 51–128 (0.63)</td>
<td>20–13 BC (0.01), 1 BC–AD 215 (0.95)</td>
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<td>41DT006</td>
<td>Beta-51364</td>
<td>1270 ± 60</td>
<td>-26.2</td>
<td>1250 ± 60</td>
<td>AD 680–818 (0.62), AD 843–860 (0.06)</td>
<td>AD 657–895 (0.95), AD 927–935 (0.01)</td>
<td>768</td>
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<tr>
<td>41DT006</td>
<td>Beta-51366</td>
<td>1300 ± 80</td>
<td>-25.0</td>
<td>1300 ± 80</td>
<td>AD 649–782 (0.63), AD 790–809 (0.05)</td>
<td>AD 599–895 (0.95), AD 925–937 (0.01)</td>
<td>736</td>
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<tr>
<td>41DT006</td>
<td>Beta-51367</td>
<td>1370 ± 80</td>
<td>-25.5</td>
<td>1370 ± 80</td>
<td>AD 595–718 (0.59), AD 743–769 (0.10)</td>
<td>AD 536–876 (0.95)</td>
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<td>Beta-51368</td>
<td>1470 ± 80</td>
<td>-25.8</td>
<td>1460 ± 80</td>
<td>AD 470–478 (0.02), AD 535–660 (0.66)</td>
<td>AD 414–689 (0.95), AD 753–760 (0.00)</td>
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<td>Beta-51365</td>
<td>1790 ± 100</td>
<td>-26.1</td>
<td>1770 ± 100</td>
<td>AD 134–354 (0.65), AD 366–381 (0.04)</td>
<td>AD 27–41 (0.01), AD 48–442 (0.92), AD 455–460 (0.00), AD 484–532 (0.03)</td>
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<tr>
<td>41DT016</td>
<td>Beta-52241</td>
<td>1300 ± 60</td>
<td>-25.5</td>
<td>1290 ± 60</td>
<td>AD 663–775 (0.68)</td>
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<td>Beta-51372</td>
<td>1300 ± 80</td>
<td>-26.0</td>
<td>1290 ± 80</td>
<td>AD 654–782 (0.60), AD 789–810 (0.06), AD 848–855 (0.02)</td>
<td>AD 612–883 (0.95), AD 416–641 (0.95)</td>
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<td>Beta-52242</td>
<td>1330 ± 70</td>
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<td>1310 ± 70</td>
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<td>AD 606–897 (0.94), AD 923–941 (0.01)</td>
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<td>1520 ± 80</td>
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<td>1500 ± 80</td>
<td>AD 436–491 (0.28), AD 509–518 (0.04), AD 529–596 (0.37)</td>
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<td>Beta-52244</td>
<td>1550 ± 90</td>
<td>-24.8</td>
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<td>AD 415–592 (0.68)</td>
<td>AD 620–283 (0.02), AD 324–652 (0.94)</td>
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<td>365 BC–77 AD (0.95)</td>
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<td>Beta-52605</td>
<td>2370 ± 110</td>
<td>-26.5</td>
<td>2360 ± 110</td>
<td>AD 551–773 (0.68)</td>
<td>AD 430–886 (0.95), 363 BC–AD 53 (0.95)</td>
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<td>41DT014</td>
<td>Beta-17400</td>
<td>2100 ± 70</td>
<td>-26.4</td>
<td>2100 ± 70</td>
<td>AD 317–321 BC (0.06), 206–37 BC (0.58), 30–21 BC (0.02), 11–2 BC (0.02)</td>
<td>AD 761–682 BC (0.12), AD 671–347 BC (0.069), 320–206 BC (0.14)</td>
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Table 2 ¹⁴C dates for the east Texas Woodland period. (Continued)

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Table 2 $^{14}$C dates for the east Texas Woodland period. (Continued)

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<td>1860 ± 45</td>
<td>-22.0</td>
<td>1905 ± 50</td>
<td>AD 26–139 (0.62),</td>
<td>AD 1–14 BC (0.01),</td>
<td>102</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>AD 158–166 (0.02),</td>
<td>AD 1–235 (0.95)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AD 196–209 (0.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41RK222</td>
<td>Beta-72771</td>
<td>1980 ± 100</td>
<td>-24.6</td>
<td>1990 ± 100</td>
<td></td>
<td>351–298 BC (0.03),</td>
<td>-4</td>
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<td></td>
<td></td>
<td></td>
<td>228–222 BC (0.09),</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>211 BC–AD 242 (0.92)</td>
<td></td>
</tr>
<tr>
<td>41RK328</td>
<td>—</td>
<td>1610 ± 40</td>
<td></td>
<td>AD 408–465 (0.35),</td>
<td>AD 348–369 (0.03),</td>
<td>463</td>
<td></td>
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<tr>
<td>41RK468</td>
<td>Beta-239710</td>
<td>2150 ± 40</td>
<td>-26.5</td>
<td>2130 ± 40</td>
<td>AD 482–533 (0.33),</td>
<td>AD 379–474 (0.93),</td>
<td>571</td>
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<tr>
<td>41RK558</td>
<td>Beta-278035</td>
<td>1280 ± 40</td>
<td>-25.9</td>
<td>1270 ± 40</td>
<td>AD 342–326 BC (0.06),</td>
<td>355–290 BC (0.16),</td>
<td>-163</td>
</tr>
<tr>
<td>41SM273</td>
<td>Beta-157990</td>
<td>1270 ± 40</td>
<td>-25.7</td>
<td>1260 ± 40</td>
<td>AD 324–326 BC (0.04),</td>
<td>232–46 BC (0.79)</td>
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<tr>
<td>41SM273</td>
<td>Beta-173089</td>
<td>1310 ± 40</td>
<td>-26.0</td>
<td>1290 ± 40</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>737</td>
</tr>
<tr>
<td>41SM273</td>
<td>Beta-154857</td>
<td>1550 ± 80</td>
<td>-26.0</td>
<td>1530 ± 80</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>722</td>
</tr>
<tr>
<td>41SM273</td>
<td>Beta-154860</td>
<td>1400 ± 60</td>
<td>-25.0</td>
<td>1400 ± 60</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>722</td>
</tr>
<tr>
<td>41SM273</td>
<td>Beta-173097</td>
<td>1720 ± 40</td>
<td>-25.1</td>
<td>1720 ± 40</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>722</td>
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<tr>
<td>41SM273</td>
<td>Beta-182402</td>
<td>1810 ± 40</td>
<td>-25.0</td>
<td>1810 ± 40</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>722</td>
</tr>
<tr>
<td>41SY041</td>
<td>Beta-97897</td>
<td>960 ± 70</td>
<td>-6.0</td>
<td>1270 ± 70</td>
<td>AD 342–326 BC (0.07),</td>
<td>AD 682–774 (0.68),</td>
<td>722</td>
</tr>
<tr>
<td>41TT370</td>
<td>Beta-48882</td>
<td>2140 ± 100</td>
<td>—</td>
<td>2140 ± 100</td>
<td>356–286 BC (0.18),</td>
<td>394 BC–AD 29 (0.95),</td>
<td>-183</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>234–50 BC (0.50)</td>
<td>AD 39–50 (0.01)</td>
<td></td>
</tr>
<tr>
<td>41TT372</td>
<td>Beta-70994</td>
<td>1290 ± 50</td>
<td>-26.4</td>
<td>1270 ± 50</td>
<td>AD 670–778 (0.68),</td>
<td>AD 660–875 (0.95),</td>
<td>744</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AD 735–876 (0.95)</td>
<td>AD 653–876 (0.95)</td>
<td></td>
</tr>
<tr>
<td>41TT372</td>
<td>Beta-71006</td>
<td>1330 ± 60</td>
<td>-26.1</td>
<td>1310 ± 60</td>
<td>AD 657–728 (0.46),</td>
<td>AD 545–724 (0.89),</td>
<td>643</td>
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<tr>
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<td></td>
<td></td>
<td>AD 739–771 (0.06)</td>
<td>AD 739–771 (0.06)</td>
<td></td>
</tr>
</tbody>
</table>
To facilitate the statistical analysis, median ages were used to calculate the frequency of samples within each of the 5 major river basins in east Texas, and that information was used to inform a discussion of the average median age of Woodland sites in each river basin. To conclude the statistical analysis, a kernel density plot was created to explore potential populations within the sample of median ages.

Subsequent modifications include the addition of the North American Datum, UTM zone, UTM northing, UTM easting, and river basin. The river basins used in the analysis are the Red River basin (RRB), Sulphur River basin (SRB), Cypress Creek basin (CCB), Sabine River basin (SaRB), and the Neches River basin (NRB), as currently defined by the Texas Natural Resources Information System (TNRIS 2012) (Figure 1).

### 14C Date Combination

The date combination process assumes that if all assays collected at a particular site draw carbon from the same reservoir, then they should have the same underlying F14C value and can be combined prior to calibration (Bronk Ramsey 2008). The measurements have Gaussian uncertainty distribu-
tions, and $\chi^2$ was used to test the assumption that all ratios are the same to reveal whether compelling evidence exists—at the 95% confidence level—that dates cannot be related to the same event (Bronk Ramsey 2008). Each site-specific figure provides the SPDs, calibrated age range for combined assays, and all dates utilized to inform these results.

Although $^{14}$C determinations are most often represented in the form $A \pm E$ where $A$ is the $^{14}$C estimate (BP) and $E$ represents the standard deviation, the method of date combination can be used to create a new $^{14}$C determination from multiple assays often with the ancillary benefit of a decrease in the standard deviation (Ward and Wilson 1978). To test whether a series of $^{14}$C determinations are consistent, the pooled mean is calculated by way of $A_p$ where

$$A_p = \left(\frac{\sum_{i=1}^{n} A_i / E_i^2}{\sum_{i=1}^{n} 1 / E_i^2}\right)$$  \hspace{1cm} (1)
followed by the test statistic, $T$, where

$$T = \sum_{i=1}^{n} \frac{(A_i - A_p)^2}{E_i^2}$$

(2)

the latter of which illustrates a $\chi^2$ distribution on $n-1$ degrees of freedom under the null hypothesis (see Clark 1975:252; Ward and Wilson 1978:21).

Provided that the $^{14}$C determinations are found not to be significantly different, they can then be combined with the pooled age as $A_p$ given by $i$, and the variance given by

$$V(A_p) = \left(\sum_{i=1}^{n} 1/E_i^2\right)^{-1}$$

(3)

(Ward and Wilson 1978:21), which is a process accessible in OxCal by way of the R_Combine function. Once combined with R_Combine, a new date range, standard deviation, and median age is provided for the combined samples (Figure 2). Within the framework of this study, the new date range replaces the combined dates and was employed within the revised SPD, while the new median date was used for statistical analyses.

**Calibration Curve**

Conventional $^{14}$C dates used within the framework of this study were recalibrated using IntCal09 (Figure 3). The curve serves as the basis for date calibration and can aid the process of archaeological interpretation by highlighting temporal zones with reversals and plateaus. Within the span of time assigned to the east Texas Woodland period (500 BC–AD 800), the curve can be seen to have 3 notable reversals of varying degrees (370–220 BC, AD 240–340, and AD 680–780). There are also 3 plateaus within the curve (500–420 BC, AD 140–210, and AD 430–540). While this does not produce clues regarding human behaviors, it does help to clarify why—even after combination—some date ranges have longer spans of probability for the calibrated date range.
The Woodland sites with 4 or more \(^{14}\)C assays include George C Davis (41CE19), Tick (41DT6), Spike (41DT16), Hurricane Hill (41HP106), Stallings Ranch (41LR297), Naconiche Creek (41NA236), Boyette (41NA285), Herman Ballew (41RK222), Broadway (41SM273), 41TT372, and 41UR77. The number of \(^{14}\)C samples from each site is heavily biased by the variable mitigation strategies and research designs used in archaeological practice. The \(^{14}\)C samples from these sites are refined through date combination, where the results of date combination replaced the original assays, and then incorporated with the remaining 42 samples used in this analysis.

41CE19 (George C Davis Site)

The Woodland period \(^{14}\)C dates for the George C Davis site \((n = 7)\) have been combined into 2 groups (Figure 4). Group 1 consists of Tx-1223, -919, -105, -674, and -3312. Group 2 comprises Tx-3695 and a reported conventional \(^{14}\)C age with an assay number that was not reported. The 2σ age ranges for the groups, AD 358–544 for Group 2 and AD 616–773 for Group 1, indicate a possible occupational hiatus of 72 \(^{14}\)C yr. Occupation periods for the 2 \(^{14}\)C groups span 186 and 157 cal \(^{14}\)C yr, respectively.

41DT6 (Tick Site)

All \(^{14}\)C dates from the Tick site \((n = 5)\) were unable to be combined via the OxCal X test (Figure 5). Only 3 assays (Beta-51364, -51366, and -51367) were combined into Group 1, leaving the remaining assays (Beta-51368 and -51365) to populate the balance of the summed probability distribution. This site represents the singular example of overlapping occupations between AD 660–667, and the \(^{14}\)C assays indicate a continuous, but probably episodic, occupation of 831 cal \(^{14}\)C yr.
There are 6 \(^{14}C\) assays from the Spike site, 3 of which were combined, resulting in a final sample of 3 \(^{14}C\) ages. Group 1 consists of Beta-52245 and -52244, and Group 2 includes Beta-52242, -52241, and -51372 (Figure 6). Beta-51371 was not able to be combined with the 2 other groups. Beta-51371 ranges from 336 BC–AD 21, the Group 2 range is AD 434–574, and Group 1 ranges from AD 667–770, indicating a temporal hiatus of 413 cal \(^{14}C\) yr between Beta-51371 and Group 2, and 93 cal \(^{14}C\) yr between Group 2 and Group 1. Occupational periods span 357, 140, and 103 cal \(^{14}C\) yr, respectively.
There are 7 $^{14}$C dates from the Woodland period occupation at the Hurricane Hill site. Six of these (Beta-82913, -82914, -82915, -85866, -82917, and -85868) comprise Group 1, while a single and much earlier assay (Beta-85867) was unable to be combined with the other dates (Figure 7). The Beta-85867 date ranges from 398–202 BC and Group 1 dates indicate an occupation ranging from AD 85–235; there is a temporal hiatus of 287 cal $^{14}$C yr between the 2 occupations. Occupational periods span 150 and 196 cal $^{14}$C yr, respectively.

41LR297 (Stallings Ranch Site)

Only 2 of the $^{14}$C dates from the Stallings Ranch site ($n = 4$) were combined. The assays with the latest (Beta-239524) and the earliest (Beta-237678) calibrated age ranges are plotted individually, and Group 1 consists of Beta-237680 and -237677 (Figure 8). There are 3 possible occupations at Stallings Ranch, the first (Beta-237678) ranging from 736–211 BC, with a peak distribution at 400 BC, Group 1 from AD 432–619, and AD 656–870 for Beta-239524. This indicates a 643 cal $^{14}$C yr hiatus.
between the first and second occupations, and a 37 cal ¹⁴C yr hiatus between the second and third. Occupational periods span 525, 187, and 214 cal ¹⁴C yr, respectively.

41NA236 (Naconiche Creek Site)

The ¹⁴C dates from the Naconiche Creek site \( (n = 9) \) were combined into 2 groups, excluding only a single and older assay (Beta-151098) (Figure 9). Group 1 encompasses the Beta-183857, -203667, -204783, and -203666 samples. Group 2 consists of the samples Beta-204782, -203669, -151097, and -203668. Beta-151098 spans the period from 735–382 BC, Group 2 ranges from AD 56–214, and Group 1 extends from AD 541–636, indicating an occupational hiatus of 438 cal ¹⁴C yr between the first and second occupations, and 327 cal ¹⁴C yr between the second and third occupations. Occupational periods span 353, 158, and 95 cal ¹⁴C yr, respectively.
**41NA285 (Boyette Site)**

$^{14}$C dates from the Boyette site ($n = 6$) were combined into 2 groups with a single uncombined exception (Beta-221420) (Figure 10). Group 1 comprises 3 assays (Beta-221421, -201990, and -204786), while Group 2 consists of 2 assays (Beta-151112 and -201989). Group 2 dates from 197–107 BC, Beta-221420 dates from AD 425–534, and Group 1 ranges from AD 685–770, indicating a temporal hiatus of 532 cal $^{14}$C yr between Group 2 and Beta-221420, and 151 cal $^{14}$C yr between Beta-221420 and Group 1. Occupational periods span 90, 109, and 85 cal $^{14}$C yr, respectively.

![Figure 10 Combined 1σ and 2σ date ranges with median age illustrated, normal and combined summed probability distribution for $^{14}$C dates from the Boyette site (41NA285).](image)

**41RK222 (Herman Ballew Site)**

The $^{14}$C dates from the Herman Ballew site ($n = 6$) were combined into 1 group ($n = 5$), excluding only a single and younger assay (Beta-60093) (Figure 11). Group 1 consists of Beta-60094, -72776, -72770, -72778, and -72771. The 2σ age range for Group 1 is AD 54–221, and AD 439–772 is the calibrated age range for the Beta-60093 assay. This indicates a possible hiatus of 218 cal $^{14}$C yr between occupations. Occupational periods span 167 and 333 cal $^{14}$C yr, respectively.

![Figure 11 Combined 1σ and 2σ date ranges with median age illustrated, normal and combined summed probability distribution for $^{14}$C dates from the Herman Ballew site (41RK222).](image)
41SM273 (Broadway Site)

The 13 \(^{14}\)C dates from the Woodland period occupation at the Broadway site were combined into 3 groups (Figure 12). Group 1 consists of 2 assays (Beta-157990 and -173089), Group 2 has 6 assays (Beta-154860, -157989, -173091, -154857, -173092, and -173095), and Group 3 has 5 assays (Beta-173090, -157991, -182401, -173097, and -182402). Group 3 dates from AD 257–344, Group 2 has an age range from AD 442–574, and Group 1 dates from AD 685–771, indicating a temporal hiatus of 98 cal \(^{14}\)C yr between Group 3 and Group 2, and 111 cal \(^{14}\)C yr between Group 2 and Group 1. Occupational periods span 87, 132, and 86 cal \(^{14}\)C yr, respectively.

Figure 12 Combined 1σ and 2σ date ranges with median age illustrated, normal and combined summed probability distribution for \(^{14}\)C dates from the Broadway site (41SM273).

41TT372

\(^{14}\)C dates for 41TT372 \((n = 4)\) were combined into a single group \((n = 3)\), excluding 1 earlier assay (Beta-70995) (Figure 13). Group 1 consists of Beta-70994, -71006, and -71000. The early assay (Beta-70995) ranges from AD 131–322, and Group 1 dates from AD 659–765, indicating a temporal hiatus of 337 cal \(^{14}\)C yr between occupations. Occupational periods span 191 and 106 cal \(^{14}\)C yr, respectively.

41UR77

\(^{14}\)C dates from 41UR77 \((n = 4)\) were combined into a single group with 2 dates, and there are 2 younger and older exclusions (Beta-166910 and UGA-12971, respectively) that could not be grouped (Figure 14). Group 1 consists of UGA-12983 and UGA-12984. The 2σ age range for UGA-12971 is 358–197 BC, for Group 1 it is AD 133–215, and for Beta-166910 the age range is AD 558–640. This indicates a temporal hiatus of 330 cal \(^{14}\)C yr between the first and second occupations, and 343 cal \(^{14}\)C yr between the second and third occupations. Occupational periods span 161, 82, and 82 cal \(^{14}\)C yr, respectively.
RESULTS

Through the date combination (R_Combine) process, the number of assays decreased from 127 to 85, which lowered the standard deviation for the combined group while reducing the number of median ages to be used in the statistical analysis. Summed probability distributions were then produced for each site with 4 or more dates to better illustrate when diffuse and discrete periods of occupation can be identified.

The SPD for the whole of the Woodland period was created using the revised (i.e. combined from sites with 4 14C assays) sample of 85 14C dates from 51 archaeological sites in east Texas (Figure 15). This representation of these data is not biased by sites with larger numbers of samples due to the date combination process. While not discussed here, those sites with <4 14C assays that conformed to methodological constraints were included in the Woodland SPD.

Temporal Considerations

Incorporating these results into a revised Woodland sample reduces the number of 14C assays from 127 to 85. The final sample represents Woodland components from 51 archaeological sites in the Red River (n = 7 dates), Sulphur River (n = 20), Cypress Creek (n = 10), Sabine River (n = 20), and Neches River (n = 26) basins (Figure 16). The sample was sorted by median age, illustrating that the dates for Woodland period sites—when ordered by appearance—are oldest in the Red River basin (AD 134), followed by Cypress Creek (AD 202), Sulphur (AD 251), Sabine River (AD 296), and Neches River basins (AD 312) (Figure 16).
A summed probability distribution was calculated for the entirety of the Woodland period, and illustrates the temporal placement of Woodland components from key sites in east Texas (Figure 17). Although the number of sites is small, they highlight a possible temporal hiatus of nearly 400 yr in the Red River basin, and another of nearly 200 yr in the Cypress Creek basin, both of which appear here on the basis of data from 1 site in each river basin. The remaining peaks correlate with populations from the kernel density plot, and they illustrate a small peak in the Red River basin around 400 BC followed by slight increases in the dates from the Sulphur, Cypress, and Sabine basins around 200 BC. This is prior to a 200-yr peak in dates from the Sulphur and Sabine River basins for AD 50–220, after which a marked increase occurs in the number of dated Woodland sites for the Sulphur, Cypress, Sabine, and Neches River basins from AD 600–800.

The temporal character of Woodland occupations from the 11 sites has been dissected and then reassembled to illustrate the temporal range of occupations and hiatuses for each (Table 3). The diversity of occupational length within the sample ranges from an average of 95–831 cal 14C yr, with breaks of 0–382 cal 14C yr. Of the 11 sites, 1 may have been continually—if episodically—occupied (41DT6), 4 have 2 discretely dated occupational events (41HP106, 41TT372, 41RK222, and 41CE19), and 6 have 3 discretely dated occupational events (41LR297, 41DT16, 41UR77, 41NA236, 41NA285, and 41SM273).
Figure 17 Summed probability distributions illustrating the impact of the 11 sites on the whole of the period, and upon the associated river basin.

Table 3 Occupations and hiatuses by river basin for sites with 4 $^{14}$C dates.$^{a}$

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Site</th>
<th>O(1)</th>
<th>H(1)</th>
<th>O(2)</th>
<th>H(2)</th>
<th>O(3)</th>
<th>AOL</th>
<th>AHL</th>
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<tbody>
<tr>
<td>Red</td>
<td>41LR297</td>
<td>525</td>
<td>643</td>
<td>187</td>
<td>37</td>
<td>214</td>
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<td>340</td>
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<td>—</td>
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<td>253</td>
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<td>196</td>
<td>—</td>
<td>—</td>
<td>173</td>
<td>287</td>
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<td>337</td>
<td>106</td>
<td>—</td>
<td>—</td>
<td>149</td>
<td>337</td>
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<td>—</td>
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<td>132</td>
<td>111</td>
<td>86</td>
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<td>105</td>
</tr>
</tbody>
</table>

$^{a}$O = occupation; H = hiatus; AOL = average occupation length; AHL = average hiatus length.
Spatial Considerations

It has become increasingly apparent that there was no preference for river basin or natural region by this prehistoric population as they began to intensify upon the landscape within the Post Oak Savanna, Blackland Prairie, and Pineywoods of east Texas. In fact, Woodland period populations settled in all 3 natural regions within the Red, Sulphur, Cypress Creek, Sabine, and Neches River basins. While the great majority of Woodland sites fall within the Austroriparian biotic province (Blair 1950:98), some sites—those in the western Red River and Sulphur River basins—occur within the Texan biotic province. The western boundary of the Austroriparian is limited by moisture (Blair 1950:99), and rainfall amounts range from 44 inches on the western margin of the province to 56 inches on the eastern border of Texas (Window on State Government 2012). While this region boasts the highest annual rainfall for the state, it lies within the Region of Summer Drought as characteristically defined by Carr (1967:17), where he notes that,

“[o]ne abnormal climatologic occurrence which would have deleterious effects on East Texas would be the loss in April and May of the generous rainfalls which occur there during these months and again in November and December. These are the two peak rainfall periods before and after the summer-drought months. The loss of peak rainfalls during these months could result in a year-long drought—not merely a summer drought.”

This cyclical pattern produces a winter surplus and summer deficiency of water for the region (see Carr 1967: Figure 7), and may be a factor in the geographic location of Woodland-period settlements. While impossible to determine from the record of $^{14}$C dates alone, shifts in residential strategies of these semi-nomadic to semi-sedentary populations may have much to do with the variability in rainfall, since seasonal shortcomings could have caused a dramatic shift in the availability of regionally important ecological resources.

Another consideration of residential strategies is trade. This is defined by Perttula and Bruseth (1990:95) as “the movement of objects or materials to be used in the production of objects back and forth between different groups.” Archaeologically, participation in extra-local trade follows—virtually entirely—500 BC and continues to mature through the entirety of the Woodland period before fluorescing during the Caddo period in east Texas (~800–1680) (Perttula and Bruseth 1990).

Through the analysis of median dates by way of kernel density and hierarchical cluster analysis, Woodland period median dates were found to encompass 3 potential divisions (Figure 18). Although the small sample size prevents these results from achieving the appropriate level of significance—750 by Michczyńska and Pazdur (2004) and 500 by Williams (2012)—they do warrant mention here.

These temporal trends were manifest within the geographic boundaries for east Texas Woodland populations of the Fourche Maline (Schambach 1998, 2002), Mill Creek (Perttula and Nelson 2004), and Mossy Grove (Story 1990) culture areas, and appear to support Schambach’s (1998:128) hypothesis that the Caddo culture developed “in situ in the Trans-Mississippi South.” However, this observation appears true for all 3 currently defined culture areas in east Texas and is not limited to the Fourche Maline.

The demonstrated occupational episodes represent the cultural antecedents of the later prehistoric and protohistoric Caddo populations (~AD 800–1680) and the shift from a hunter-gatherer and horticultural economy to one dominated by agriculture within greater east Texas. While lacking in detailed temporal correlations with the material culture of the different Woodland culture areas, the 11 sites surveyed within this study illustrate a significant increase in site use during the period of AD 400–800.
Figure 18  From left to right, Early Woodland (500 BC–AD 0), Middle Woodland (AD 0–400), and Late Woodland (AD 400–800) archaeological sites
The temporal distribution of occupational episodes for Woodland sites in east Texas (see Figure 17) increased exponentially after AD 400 and the associated hiatuses decreased in both frequency and duration. Prior to AD 400, only 13 occupational episodes occurred throughout an 800 cal $^{14}$C yr period, while the number of occupational episodes increased to 16 during the last 400 cal $^{14}$C yr of the Woodland period. This trend is indicative not only of a larger population, but possibly a more sedentary lifestyle, which may temporally demonstrate the cultural shift from hunter-gatherer to agriculturalist.

**DISCUSSION**

Due to depositional and contextual issues and the wide variety of mitigation strategies and research designs employed throughout the region, the western boundary of the Eastern Woodlands remains one of the least well-known and explored periods in the greater Southeast. This can be seen plainly when the number of components from Woodland period sites is contrast against the much more robust representation of $^{14}$C dates from the Caddo period. The fact that only 127 of the 1248 $^{14}$C samples in the East Texas Radiocarbon Database are representative of this period speaks to the need for further research.

These results present a significant advancement in the manner by which $^{14}$C assays may be manipulated for use within summed probability distributions. At the regional and sometimes local scale, most archaeologists have encountered at least 1 very well-dated site. These sites, while often incredibly informative at the microscale, are fairly detrimental to macrolevel analyses due to the amount of bias they introduce. Through incorporation of date combination to studies of summed probability distribution, the amount of site-specific sample bias can be reduced.

Although not essential to this analysis due to sample size, consideration should be given to taphonomic loss (see Surovell and Brantingham 2007; Surovell et al. 2009; Peros et al. 2010) and land-use patterns (see Grove 2008, 2009, 2011) once the sample size threshold is surpassed. When coupled with the method of date combination, these tools can further clarify much of the ambiguity encountered as we continue to move forward with our analyses of these data at the regional scale.

**SUMMARY AND CONCLUSION**

Regionally, statistical nuances within the data appear to illustrate the likelihood of 3 temporal divisions and an increase in occupational episodes post ~AD 400. While more research needs to be completed to reveal the nature of the cultural shift from hunter-gatherer/part-time horticulturist to a more agriculturalist lifestyle, this investigation illustrates those sites with temporal components that would likely be more fruitful than others within the framework of that endeavor.

Subsequent efforts to refine the chronology of the material culture from these different components should take the form of case studies from specific Woodland period sites where artifacts were recovered in association with $^{14}$C samples. As that effort expands, our knowledge of the temporal and spatial distributions of specific artifact classes, types, and assemblages can be enhanced. We are quickly approaching an era where typological assignments can be associated with $^{14}$C samples in this same manner, but significant advances in correlating these data with specific aspects of archaeological assemblages still need to be made as we progress in our analyses of the Woodland period of east Texas.

This analysis represents only a small sample of $^{14}$C dates from the ETRD, which remains a large and understudied amalgam of $^{14}$C dates that is available for use within current cultural resource manage-
ment endeavors. Through the systematic employment of this methodological approach, it is plausible that similar analyses would strengthen the arguments presented here (i.e. shorter hiatuses during the later and better-understood Caddo period, and longer hiatuses ranging from the Archaic through Paleoindian periods), providing a productive medium through which dialogues regarding the material culture of east Texas can continue to be developed.

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