TREE-RING RESEARCH, *Vol. 73(2), 2017, pp. 136–148*
DOI: http://dx.doi.org/10.3959/1536-1098-73.2.136

USING DENDROCHRONOLOGY TO INVESTIGATE THE HISTORICAL AND EDUCATIONAL VALUE OF TWO LOG STRUCTURES AT BEAR PAW STATE NATURAL AREA, NORTH CAROLINA, USA

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ABSTRACT

During May 2013, the Bear Paw State Natural Area near Boone, North Carolina acquired an 11.5 ha tract of land and two log cabins from David Wray of Blowing Rock, North Carolina. Work was soon underway to determine the historical nature of these two buildings and to evaluate them for consideration for the National Register of Historic Places. A historic structure report, completed as a collaboration between Appalachian State University and the North Carolina Division of Parks and Recreation, was unable to discover much about the history of the two log cabins except that they were both likely moved to their current location in the early 20th Century. To determine when the cabins were built, we extracted core samples from logs in both cabins and compared the tree-ring patterns to region-wide, precisely-dated reference chronologies. We dated the tulip poplar tree-ring chronology from the Big Cabin to the period 1675–1859. Cutting dates on several of the logs revealed tree harvest likely occurred between fall 1859 and spring 1860. Some logs had outermost rings that dated to 1857 and 1858. Still, these logs may have been harvested a few years earlier, or some of the outer rings may have been lost during construction or sampling. We were unable to absolutely date an 81-year long American chestnut chronology from the Small Cabin. Our results confirmed that the Big Cabin was an Antebellum Period structure (pre-American Civil War) and therefore has potential historical significance. Because we still cannot tie this cabin to a historical figure or a historical event, the cabin cannot be nominated yet for inclusion in the National Register of Historic Places, but the identification of an original construction date for the cabin may contribute to further assessment for inclusion on a local or national register. In the meantime, we intend to use this cabin in annual summer workshops for undergraduate students taking courses at Appalachian State University so that more students can be exposed to the hands-on nature of scientific inquiry and can learn the value of dendrochronology for understanding human and environmental history.

Keywords: Dendrochronology, tree rings, North Carolina, log cabin, construction history.

INTRODUCTION

The Bear Paw State Natural Area was authorized by the North Carolina General Assembly in 2008 to begin the process of land acquisitions with a specific focus "on conservation of sites of special scientific and ecological value" (North Carolina State Parks 2008). In May 2013, contributions from Fred and Alice Stanback, the North Carolina Natural Heritage Trust Fund, and the North Carolina Parks and Recreation Trust Fund allowed the purchase of an 11.5 ha parcel of land from David Wray of Blowing Rock, North Carolina. The new plot of land expanded the original Bear Paw State Natural Area lands from 144 to 155.5 ha (Bray 2015). The presence of two log cabins on the land sparked a collaborative project between the State of North Carolina Division of Parks and Recreation and Appalachian State University to learn more about the possible historical significance of the two structures. Matthew Bray, a student at Appalachian State University, was hired to complete a historic structure report for the two buildings with

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Figure 1. The south façade of the Big Cabin.

the intention of providing park officials the information needed to determine feasibility of preservation and/or rehabilitation of these structures for use as part of a future day-use area while also evaluating the history of the two structures to determine their historic nature (Bray 2015).

The larger of the two cabins ("Big Cabin" as it is known locally) is a one-and-a-half story, double-pen log house with corner, half-dovetail and square notching (Figure 1). The stacked-pier foundation and the exterior chimney are both constructed of native fieldstone, and a framed, board-and-batten-sided addition is attached to the rear of the cabin (Bray 2015). As on the outside of the structure, the interior logs and chinking are exposed and unfinished, showing evidence of extensive repairs. The smaller cabin ("Small Cabin" as it is known locally) is a one-story, single-pen log house with corner, half-dovetail notching (Figure 2). The foundation is composed of a combination of concrete block tiers and continuous fieldstone, and the exterior chimney is constructed of fieldstone. Like the Big Cabin, the Small Cabin includes a framed, board-and-batten-sided addition at the rear, and the logs and chinking, with evident repairs, are exposed on the interior of the cabin (Bray 2015). Both cabins display evidence of reassembly and repair, including modern chinking (Bray 2015). Differences in the coloration of logs, inconsistency with the number of visible growth rings (Figures 3-4), and circular saw marks used in the Big Cabin also indicate replacement. Neither of the two cabins display high-quality craftsmanship. Both structures feature

Figure 2. The Small Cabin viewed from the southeast corner. Although no replacement logs were obvious when analyzing this structure, the logs were a much smaller diameter compared to the bottom logs on the Big Cabin.

Figure 3. A portion of the west wall of the Big Cabin. The larger-diameter bottom logs on the interior and exterior walls of this cabin were a distinct grayish-yellow color, whereas all other logs were smaller in diameter and a deep reddish brown color. The lower logs also contained many more rings than the upper logs. We determined the lower logs were original to the structure whereas the upper logs were later replacements.

Figure 4. A photograph of one of the original logs of the Big Cabin, which clearly shows the numerous tree rings. In this photo, the growth sequence is from the lower portion of the log to the upper portion.

unevenly hewn and randomly-sized logs, concrete chinking, uneven foundations, mixed and repaired notching, and other visible repairs. However, these are most likely evidence of reassembly and may not be truly representative of the original construction. Based on the current state of both structures, disassembly and a more structurally-sound (including foundation replacement) and historically accurate restoration has been recommended (Bray 2015).

The Big Cabin is located at the end of the paved portion of Dutch Creek Road, which winds along the valley of Dutch Creek from Valle Crucis to the rugged base of Hanging Rock Mountain in North Carolina. Permanent settlement in this valley is believed to have begun in the early to mid-19th Century (Huhes 1995; Bray 2015). One of the earliest land grants in the area was that of Frederick and Myra Pope Shook, who in 1845 purchased 40.5 ha along Dutch Creek (Hughes 1995; Bray 2015). Others who settled in the valley included brothers Aaron, James, and Jacob Townsend, Willian van Dyke, Hugh Fox, George Sifford, and Peter Townsend, all during the mid-19th Century (Hughes 1995; Bray 2015). According to oral history, the Big Cabin was relocated from a farm lower in Dutch Creek Valley and reassembled at its current location in the early 1900s (Bray 2015). If this is the case, the Big Cabin was potentially constructed by one of the above listed owners of property in the valley and may therefore date to the Antebellum Period (*ca*. 1812 to 1860). However, scarce documentation exists for the Big Cabin outside of oral histories, which are largely confined to the 20th Century. According to these histories, a kitchen and bathroom were added in the 1950s, and the Big Cabin was used as a rental property from the 1960s to the 1980s (Bray 2015). The Small Cabin is also located on Dutch Creek Road, approximately 0.20 km northeast of the Big Cabin. Like the Big Cabin, the Small Cabin was probably relocated from a site lower in the Dutch Creek Valley, where it was originally used as an agricultural outbuilding (Bray 2015). A kitchen and bathroom were added to the back of the cabin in the 1950s, and it was occupied from the 1960s to the 1980s (Bray 2015). A dendrochronological analysis of the Big and Small Cabins may help to clarify the histories of each structure, but further contribution to the identification of specific, original owners is unlikely.

Neither cabin was reported to house a person important to the history of the area, and given the relocation and significant repair of the two cabins, the likelihood of either being a candidate for a local or national historic register is low (Bray 2015). However, knowledge of the construction dates for the two cabins will still be helpful to park officials, who wish to utilize the cabins when the newly acquired tract of land is converted to a day-use area as part of the long-term strategic plan for Bear Paw State Natural Area. Construction dates can provide valuable insights on possible builders and later residents, which could potentially lead to a greater understanding of the historical significance of the cabins and could reopen consideration for inclusion in a local or national register. For example, if the cabins indeed date to the Antebellum Period (*ca*. 1812 to 1860), then the cabins potentially could have historical significance for local or national registers because intact structures built before the American Civil War are rare across the rural Appalachian landscape. However, even without eligibility for such registers, the two cabins may be valuable as artifacts of local history. Recycling historic building materials was a common local practice, and the Big and Small Cabins may serve as landmarks of local "recycled" architecture. In addition, if accurately restored to a historical period, the two cabins will be valuable for educational purposes. Our overarching objective was to apply dendrochronological methods to determine the construction dates of the two cabins by extracting cores from the logs used to build both structures. From these cores, we sought to obtain tree-ring measurement data and temporal sequences of tree-ring patterns that could aid in the absolute dating of the felling years for the trees used to build the cabins.

METHODS

Field Methods

We first visually inspected the logs used to build the Big Cabin (Figure 3), and we could immediately see that many of the original logs had been replaced, based on differences in the coloration of the logs, the number of growth rings visible (Figure 4), and the presence of distinctive marks made by a circular saw versus hand hewn logs. We identified original logs near the base on all exterior and interior walls in the structure, forming the first two rows of logs at the base (Figure 3). We were unable to identify such marked differences between logs of the Small Cabin (Figure 2) and therefore assumed all logs in this cabin were original.

We extracted 12-mm diameter cores from both structures using a specially-designed, hollow drill bit powered by a variable-speed 13-mm (0.5 in) drill. We collected cores from the basal end of the log (*i.e.* the end with greater diameter) to ensure that as many rings as possible were collected. We collected cores from the underside of logs so that the holes left were not readily visible and so that sawdust could evacuate during sampling. For all cores, we sampled along the rounded edges of a log, especially where we identified bark, to capture the outermost rings needed to determine accurate cutting dates for harvested logs. Some of the Big Cabin logs had been squared, making it impossible to obtain the outermost rings. All of the Small Cabin logs possessed some curvature. We took cores at an angle according to the location of the pith that was plainly visible on the end of each log. Once extracted, the cores were immediately mounted on core mounts with the cells vertically aligned. All cores were then labeled according to cabin, compass direction of wall, the log number, and core letter (if needed), *e.g.* BCN05A = Big Cabin, North wall, log 5 (sequential from the bottom sill log = log 01), core "A." Cores taken from the interior central wall of the Big Cabin were labeled simply as "BCM" = "Middle." Locations from where all cores on all logs were extracted were sketched to keep a record of sample locations.

The heartwood of cores taken from the Big Cabin was a noticeable green-to-yellow or almost brown color, and the sapwood when present was a distinct tan or cream color. Large pores in the earlywood were lacking (hence, a diffuse porous tree species), but the wood contained distinct, numerous, and very thin rays. These clues helped identify the specimens as tulip poplar (*Liriodendron tulipifera* L.) (Hoadley 1990), a common species used in construction of log houses (Rehder 2012). Tulip poplar logs were also found in the Small Cabin, but a few logs did indeed have large earlywood pores (hence, a ring porous species). In the laboratory, we identified this species as American chestnut (*Castanea dentata* (Marshall) Borkh.) based on the heartwood coloration, uniseriate rays that were barely visible, oval-shaped pores, tyloses present within the pores, and pore distribution in both the earlywood and latewood (Hoadley 1990).

Sanding and Measuring

We sanded each core with a bench sander using progressively finer sandpaper, beginning with ANSI 80-grit (177–210 μm) and ending with ANSI 400-grit (20.6–23.6 μm) (Orvis and Grissino-Mayer 2002), to create the polished surface necessary for accurate tree-ring identification and ring-width measurements. Once sanded, we marked the tree rings on all cores using standard decadal dot notation (Stokes and Smiley 1996; Speer 2010) and then measured all rings to 0.001-mm accuracy using a Velmex measuring system coupled with MeasureJ2X software. We began measuring with the innermost complete ring assigned to relative year "1" and ended with the outermost complete ring.

Within-Tree Crossmatching

Tulip poplar trees can grow to be extremely large (Beck 1990). The bottom two rows of logs that were assumed to be original to the Big Cabin were indeed quite large (Figure 3), with pith most often located on the corner or edge, or not identified. In these cases, logs could have been sectioned from the same height around pith. In some logs, however, the pith was located near center, which would indicate that these logs were also sectioned one on top of the other from a tree. Both cases are possible given the size of the sampled Big Cabin logs and the positions of pith. Based on these observations, we suspected that some of the logs in the Big Cabin could represent the same tree and used the computer program COFECHA (Holmes 1983) to investigate this hypothesis. We initially attempted to identify such logs by entering the set of measurements into COFECHA as undated series (Holmes 1983; Grissino-Mayer 2001). COFECHA then attempted to crossmatch each measurement series with all other measurement series, creating a table of the top correlations and their respective t-values. Those values allowed us to match rings from one core with contemporaneous rings from all other cores. We designated an arbitrary t-value threshold of 6.0, with a minimum 40-year overlap, to suggest that logs came from the same tree (Grissino-Mayer *et al.* 2010). A standard t-value ≥ 3.5 was required to indicate statistical crossmatching between different trees (Baillie 1982; Holmes 1983; Wigley *et al.* 1987; Laxton and Litton 1989; Grissino-Mayer 2001; Schaub *et al.* 2005).

Internal Crossmatching

We used COFECHA to perform segmented time-series correlation analyses (40-year ring segments lagged by 10 years), which suggested a possible temporal placement for each series in the data set relative to each other (Holmes 1983; Grissino-Mayer 2001). We began by identifying a set of measurement series that crossmatched with statistically significant correlations, and then tested all other series one at a time against this initial data set. We added any new series that crossmatched with a high degree of statistical certainty to the growing data set. The final result was a data set of series matched in time relative to each other. A core was considered crossmatched with the other cores when its interseries correlation coefficient was ≥ 0.40 (although individual correlation values often were much higher, *e.g.* $r = 0.85$ with $t >> 4.0$ and $p < 0.0001$) and when COFECHA suggested a temporal adjustment that was identical for all or most of the segments tested (*e.g.* "+31"). The result of the between-tree crossmatching exercise was a set of tree-ring measurement series that were properly aligned in time relative to each other, but not absolutely dated. Lastly, we created a floating chronology from the series that were matched relative to each other using ARSTAN (Cook 1985) to absolutely crossdate this chronology against a data set of chronologies pulled from the International Tree-Ring Data Bank (ITRDB) (Grissino-Mayer and Fritts 1997).

External Crossdating

To date the floating chronologies from both cabins, we developed regional tulip poplar and American chestnut chronologies. We downloaded eight tulip poplar chronologies and nine American chestnut chronologies from the ITRDB, all of which were sampled within the surrounding region (Table 1). We used COFECHA to statistically crossdate the undated chronologies for both cabins with the reference chronologies, again using 40-year segments lagged by 10 years. Crossdating was achieved when COFECHA suggested a common temporal adjustment for all or most tested segments and these segments also displayed statistically significant (usually $p < 0.001$) correlations against the reference chronology. We then used the program EDRM (Edit Ring Measurement) (Holmes 1992) to manually adjust the rings on each measurement series to their exact calendar years, and then used ARSTAN (Cook 1985) to create the final dated chronologies for both the Big and Small Cabins. We overlaid the two dated cabin chronologies along with the reference chronologies to graphically verify the statistical crossdating (Grissino-Mayer 2001).

Table 1. Regional tulip poplar and American chestnut chronologies used to date the tree rings extracted from logs of the Big and Small Cabins at the Bear Paw State Natural Area, sorted by beginning year.

Site Name	State and Chronology ID[1]	Latitude (N)	Longitude (W)	Begin Year	End Year
Tulip poplar:					
Forge Creek	TN030	36.533	83.83	1500	2006
Frick Creek	GA011	34.76	84.30	1537	2009
Amicalola	GA010	34.57	84.23	1552	2009
Joyce Kilmer Memorial Forest	NC012	35.35	83.92	1672	1997
Scotts Gap	TN	35.60	83.92	1684	1981
Porters Creek	TN027	35.67	82.38	1698	1997
Boogerman Trail Tennessee	TN016	35.60	83.08	1736	1995
Rainbow Falls Trail	TN023	35.67	83.50	1825	1995
American chestnut:					
Greenbriar	TN013	35.70	83.35	1641	1930
Henwallow Falls	TN014	35.75	83.25	1687	1918
Rainbow Falls Trail	TN015	35.67	83.50	1695	1922
Porters Creek	TN012	35.67	82.38	1700	1924
Ramsey Cascades Trail	TN025	35.70	83.35	1713	1923
Boogerman Trail	NC010	35.60	83.10	1720	1931
Joyce Kilmer Memorial Forest	NC011	35.35	83.92	1737	1928
Laurel Falls Trail	TN011	35.68	83.62	1761	1929
Thomas Divide Trail	NC015	35.58	83.38	1780	1939

[1] ITRDB site codes where GA = Georgia, NC = North Carolina, TN = Tennessee.

Determining Cutting Dates

To determine the cutting date for each log, we examined the terminal rings on all dated cores under high magnification. When samples had bark attached to the outermost ring, the most recent ring formed was easily determined, but most cores were missing bark and others may have lost the outermost rings to decay. A standardized notation system was established to account for these variations and determine the cutting dates of each log, providing the likely year(s) of cabin construction (Bannister *et al.* 1966; Nash 1999; Grissino-Mayer *et al.* 2009):

B: Bark was present, indicating the outermost ring was intact (cutting date);

r: The outermost ring was intact, around a smooth curvature (considered a cutting date);

v: The date was within a few years of the cutting date, based on the presence of sapwood (a near cutting date);

vv: A cutting date was not possible because no sapwood is present and we could not determine how far we were from the outermost ring (a non-cutting date);

++: A ring count was necessary on the outermost rings because these were located in a detached sapwood portion of the core and could not be crossdated.

Once cutting dates for each sample were determined, we noted any clustering of terminal dates around certain calendar years that could indicate the likely year(s) of tree harvesting and, therefore, cabin construction.

RESULTS

We were able to extract 27 cores from the Big Cabin and 15 from the Small Cabin. Of these 42, some cores had too few rings to confidently crossdate (five from the Big Cabin) while others were too broken up to be useful (two from the Big Cabin and four from the Small Cabin). Some cores, including six intact tulip poplar cores from the Small Cabin and one intact tulip poplar core (BCE03A) from the Big Cabin, had an adequate number of rings for crossdating to be achieved, but no convincing match could be found, graphically or statistically. The Big Cabin log from which sample BCE03A was collected did appear similar in size and color to the other sampled logs but could not be

Table 2. Correlation coefficients and their respective t-values (>6.0) between two measurement series from different logs, which suggested the logs were possibly cut from the same tree.

Series 1	Series 2	Years of Overlap	Correlation Coefficient	t-value
MIDDLE 1	MIDDLE 3	118	0.58	7.6
MIDDLE 1	NORTH 3	118	0.59	7.8
MIDDLE 1	SOUTH 3	93	0.58	6.7
MIDDLE 1	NORTHEAST 3	117	0.52	6.5
MIDDLE 1	WEST 2	53	0.67	6.5
MIDDLE 3	MIDDLE 4	150	0.54	7.8
MIDDLE 3	SOUTH 3	130	0.74	12.6
MIDDLE 3	NORTHEAST 2	88	0.57	6.5
MIDDLE 3	NORTHEAST 3	154	0.57	8.5
MIDDLE 3	NORTH 3	114	0.80	14.4
MIDDLE 3	WEST 2	66	0.71	8.0
MIDDLE 4	NORTH 3	141	0.63	9.5
MIDDLE 4	SOUTH 3	153	0.63	9.9
MIDDLE 4	NORTHEAST 2	93	0.62	7.6
MIDDLE 4	NORTHEAST 3	155	0.67	11.1
MIDDLE 4	WEST 2	71	0.71	8.4
NORTH 3	WEST 3	93	0.61	7.3
NORTH 3	SOUTH 3	121	0.79	14.1
NORTH 3	NORTHEAST 3	145	0.67	10.9
NORTH 3	WEST 2	69	0.75	9.4
NORTH 3	NORTHEAST 2	88	0.69	8.8
SOUTH 3	WEST 1	56	0.64	6.1
SOUTH 3	WEST 2	71	0.72	8.6
SOUTH 3	WEST 3	93	0.59	6.9
SOUTH 3	NORTHEAST 2	91	0.57	6.5
SOUTH 3	NORTHEAST 3	157	0.65	10.7
NORTHEAST 2	NORTHEAST 3	95	0.85	15.4
NORTHEAST 3	WEST 1	55	0.63	6.0
NORTHEAST 3	WEST 1	53	0.65	6.1
NORTHEAST 3	WEST 2	71	0.66	7.3

confidently crossdated. In total, 18 problem cores were excluded from further analyses. Our final data set consisted of 19 measured series representing 11 logs for the Big Cabin and 5 series representing 5 logs, all American chestnut, for the Small Cabin.

Within-Tree Crossdating for the Big Cabin

We found several logs that appeared to be crafted from the same tree as shown by their high correlations and associated t-values (Table 2). For example, log 3 North crossdated with logs 3 West ($t = 7.3$, $n = 93$ years); 3 South ($t = 14.1$, $n = 121$); 3 Northeast ($t = 10.9$, $n = 145$); 2 West ($t = 9.4$, $n = 69$); and 2 Northeast ($t = 8.8$, $n = 88$). In turn, the measurement series for log 3 Middle had statistically significant t-values with logs 4 Middle ($t = 7.8$, $n = 150$ years); 3 South ($t = 12.6$, $n = 130$); 2 Northeast ($t = 6.5$, $n = 88$); 3 Northeast ($t = 8.5$, $n = 154$); 3 North ($t = 14.4$, $n = 114$); and 2 West ($t = 8.0$, $n = 66$). After iterating through this process, we found 30 unique combinations of logs (Table 2) with measurement series that displayed statistically significant t-values > 6.0, which included 7 logs: 1 Middle, 3 Middle, 4 Middle, 3 North, 3 South, 2 Northeast, and 3 Northeast. Therefore, seven of the 11 logs sampled likely were cut from the same tree.

Internal Crossdating for the Big Cabin

We were able to internally crossdate the tree rings from 19 cores representing 11 logs (Table 3). The average interseries correlation was 0.73, which is exceptionally high for southeastern tree species. This value was >0.40, the minimum value established to indicate successful crossdating (ITRDB

Table 3. Correlations of 40-year segments (with 10-year overlap) for each of the 19 series from the Big Cabin when tested against a master reference chronology created from all other series for that segment.

Series	First Year	Last Year	−10–29	0–39	10–49	20–59	30–69	40–79	50–89	60–99	70–109	80–119	90–129	100–139	110–149	120–159
BCM01A	38	156					0.74	0.71	0.72	0.87	0.82	0.44	0.46	0.20*	0.27*	0.45
BCM03B	1	155		0.88	0.92	0.89	0.90	0.92	0.91	0.89	0.85	0.57	0.56	0.50	0.60	0.66
BCM03C	25	155				0.95	0.94	0.94	0.91	0.89	0.82	0.56	0.60	0.57	0.63	0.73
BCM04A	−4	150	0.79	0.81	0.87	0.84	0.90	0.90	0.89	0.87	0.82	0.73	0.66	0.49	0.32*	0.33*
BCM04B	60	155								0.47	0.60	0.68	0.69	0.59	0.67	0.60
BCN02A	24	91				0.88	0.87	0.34*	0.28*	0.21*						
BCN03A	35	155					0.93	0.92	0.89	0.89	0.84	0.76	0.72	0.62	0.68	0.65
BCN03B	10	155			0.95	0.92	0.95	0.91	0.88	0.89	0.83	0.82	0.85	0.74	0.70	0.61
BCN03C	22	136				0.90	0.87	0.89	0.88	0.88	0.76	0.60	0.60	0.55		
BCN03D	10	138			0.87	0.84	0.89	0.90	0.88	0.88	0.85	0.69	0.72	0.63		
BCN03E	1	155		0.91	0.93	0.93	0.93	0.92	0.90	0.89	0.77	0.66	0.69	0.64	0.74	0.71
BCS03A	−8	130	0.73	0.83	0.91	0.93	0.91	0.87	0.85	0.86	0.87	0.80	0.73	0.74		
BCS03B	−2	155	0.79	0.82	0.84	0.79	0.83	0.89	0.90	0.87	0.83	0.66	0.62	0.50	0.56	0.51
BCNE02	−6	88	0.86	0.91	0.91	0.88	0.92	0.55	0.51							
BCNE03A	−7	154	0.87	0.91	0.91	0.89	0.92	0.52	0.44	0.36*	0.03*	0.32*	0.35*	0.50	0.45	0.37
BCNE03B	−5	154	0.89	0.91	0.92	0.89	0.91	0.85	0.78	0.79	0.70	0.51	0.54	0.30*	0.35*	0.37
BCW01A	−27	47	0.44	0.66	0.73											
BCW02A	20	90				0.56	0.70	0.73	0.73	0.75						
BCW03A	37	129					0.84	0.84	0.77	0.71	0.64	0.34*	0.23*			
Average			0.77	0.85	0.89	0.86	0.88	0.80	0.77	0.76	0.73	0.61	0.60	0.54	0.54	0.54

*indicates a segment that fell above the statistical threshold for significance at the 0.01 level. The rings in these segments were re-inspected and found to be correctly placed in time.

Table 4. Summary statistics for the 19 measured tree-ring series from 11 logs of the Big Cabin.

Series	First Year	Last Year	Number of Years	Number Segments Tested	Number Segments Flagged	Correlation with Master	t-value	Mean Sensitivity
BCM01A	38	156	119	10	2	0.62	8.51	0.22
BCM03B	1	155	155	13	0	0.81	17.08	0.32
BCM03C	25	155	131	11	0	0.83	16.90	0.33
BCM04A	−4	150	155	14	2	0.70	12.12	0.30
BCM04B	60	155	96	7	0	0.50	5.60	0.28
BCN02A	24	91	68	5	3	0.41	3.65	0.40
BCN03A	35	155	121	10	0	0.82	15.63	0.30
BCN03B	10	155	146	12	0	0.85	19.36	0.34
BCN03C	22	136	115	9	0	0.79	13.70	0.40
BCN03D	10	138	129	10	0	0.81	15.57	0.36
BCN03E	1	155	155	13	0	0.84	19.15	0.39
BCS03A	−8	130	139	12	0	0.82	16.77	0.30
BCS03B	−2	155	158	14	0	0.77	15.07	0.26
BCNE02	−6	88	95	7	0	0.69	9.19	0.34
BCNE03A	−7	154	162	14	4	0.60	9.49	0.32
BCNE03B	−5	154	160	14	2	0.75	14.25	0.30
BCW01A	−27	47	75	3	0	0.65	7.31	0.25
BCW02A	20	90	71	5	0	0.73	8.88	0.34
BCW03A	37	129	93	7	2	0.60	7.15	0.30
Total or average			2343	190	15	0.73	12.39	0.32

2016a), and above the average for tulip poplar (0.62) (ITRDB 2016b). The average mean sensitivity was 0.32, also higher than the average for tulip poplar (ITRDB 2016b). In the southeastern U.S., a minimum mean sensitivity value in the range of 0.18–0.20 is often used to indicate the level of climate sensitivity needed for crossdating. COFECHA flagged 15 of the 190, 40-year segments tested as being problematic (8%) (Table 4), which is below the cut-off of 10% that we require when crossdating tree rings in the southeastern U.S. All flagged segments were carefully re-inspected and assessed as correctly dated. The final data set resulted in a 184-year floating chronology.

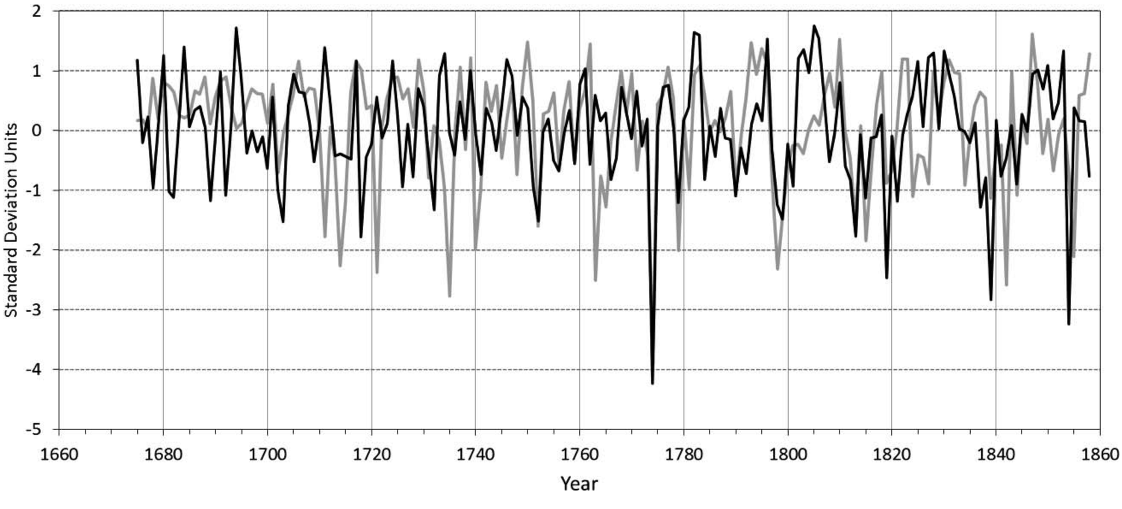

Figure 5. The tulip-poplar tree-ring chronology for the Big Cabin (gray line) displays a statistically significant correlation (r = 0.30, n = 184 years, t = 4.24, p < 0.00001) and similar growth patterns with the tulip poplar reference chronology for the region (black line) over the period 1675–1858. Annual indices for both chronologies were converted to standard deviation units to facilitate the comparison. Note the match in the year 1774, a known drought year in the southeastern U.S.

Table 5. Outermost ring dates and types for the 11 logs sampled from the Big Cabin.

Log	Oldest Ring[1]	Youngest Ring[1]	Ring Type[2]	Terminal Ring Information
1 Middle	1740	1859	r	Outer ring appears complete, tree cut any time from fall 1859 to spring 1860
3 Middle	1703	1858	r	Outer ring appears complete, tree cut any time from fall 1858 to spring 1859
4 Middle	1762	1858	v	Outer ring is only partial, no obvious latewood, tree cut summer 1858 or after
2 North	1726	1794	vv	Little sapwood, insect galleries present, a non-cutting date
3 North	1703	1858	r	Outer ring appears complete, tree cut any time from fall 1858 to spring 1859
3 South	1694	1858	r	Outer ring appears complete, tree cut any time from fall 1858 to spring 1859
2 Northeast	1696	1791	vv	Little to no sapwood, no galleries, a non-cutting date
3 Northeast	1695	1857	r	Outer ring appears complete, tree cut any time from fall 1857 to spring 1858
1 West	1675	1750	vv	Little to no sapwood, no galleries, a non-cutting date
2 West	1722	1793	vv	Little to no sapwood, no galleries, a non-cutting date
3 West	1739	1832	vv	Some sapwood present, insect galleries present, a non-cutting date

[1] If two cores were extracted from one log, the oldest or youngest rings on either core are noted here.
[2] See text for explanation.

Internal Crossdating for the Small Cabin

We were able to crossdate the tree rings on only five chestnut cores representing five logs from the Small Cabin. The average interseries correlation was 0.57 and the average mean sensitivity was 0.18, both slightly above the averages for American chestnut (0.56 and 0.15, respectively) (ITRDB 2016b). Of the 23, 40-year segments tested by COFECHA, three (13%) were flagged as being problematic. All flagged segments occurred at the beginning or at the end of each series. These are common locations where such flagged segments occur because these rings may display tree growth patterns that do not reflect the overarching climate patterns that allow crossmatching between trees (Grissino-Mayer 2001). The final data set resulted in an 81-year chronology. We were unable to build a floating chronology from the tulip poplar cores from the small cabin because they would not crossdate.

External Crossdating and Cutting Dates for the Big Cabin

COFECHA found a common and systematic dating adjustment of " + 1702" when testing the undated tree-ring chronology created from the cores extracted from the Big Cabin. Absolute crossdating in COFECHA statistically verified that the tree-ring chronology for the Big Cabin began in the year 1675 and ended in the year 1858 ($r = 0.30$, $n = 184$ years, $t = 4.24$, $p < 0.00001$). A graphical comparison also showed a convincing match (Figure 5). Important pointer years (Schweingruber *et al.* 1990) that were common to both the now-dated tulip poplar chronology and the reference chronology included the narrow rings formed in 1752, 1779, 1798, 1813, 1815, 1819, 1839, and 1854. Particularly important was the correspondence of the extremely narrow ring formed in 1774, a known drought year in the southeastern United States (Pederson *et al.* 2014) and a key year that has assisted in the dating of many oak tree-ring series extracted from historical structures in the southeastern U.S. (Mann 2002; Grissino-Mayer and van de Gevel 2007; Mann *et al.* 2009).

The innermost absolutely dated ring was 1675, and the outermost ring on four of the logs with curvature was dated to 1858 (logs 3 Middle, 4 Middle, 3 North, and 3 South) (Table 5). Close examination of the terminal ring on these four samples, and comparison of their widths with previous rings, showed rings that appeared to be complete on three logs (3 Middle, 3 North, and 3 South). This indicated that these logs were cut during the period between fall 1858 and spring 1859, or during the dormant (winter) season of 1858–1859. Log 4 Middle had an incomplete terminal ring, which indicated that it was cut during or after summer 1858. It also appeared that part of the outermost ring may have been lost during sampling.

Log 3 Northeast had a terminal ring of 1857, and log 1 Middle had a terminal ring of 1859. The 1857 terminal ring on log 3 Northeast appeared complete, which indicated that this log was cut in the dormant season 1857–1858, and the 1859 terminal ring on log 1 Middle appeared complete, which indicated that this log was cut in the dormant season 1859–1860. The remaining samples had terminal rings that dated far from the true harvest date for the logs of the Big Cabin, either because they had been squared during construction or outer rings were lost during construction or sampling. Samples without curvature had little or no sapwood present, and could not provide any information about how close the outermost rings on the sample were to the terminal growth rings prior to cutting. We concluded that logs for the Big Cabin were harvested during the period between fall 1857 and spring 1860.

External Crossdating and Cutting Dates for the Small Cabin

We were unable to absolutely date the logs from the Small Cabin because the floating chronology (1) lacked sufficient length to perform accurate external crossdating with the regional chronology, and/or (2) lacked sufficient variability to identify the narrow rings necessary when crossdating. Even though we collected 15 samples from the Small Cabin, we were unable to internally crossdate the tulip poplar cores, which left only five American chestnut cores available to date the structure. Although internal crossdating was successful, the resulting chronology was only 81 years long and the outer ring dates of the cores did not align. In addition, COFECHA found two common and systematic dating adjustments that appeared convincing (confirmed with skeleton plots), which resulted in two possible cutting dates for the small cabin. Such ambiguous dating, however, cannot be used to date the year of construction for a historic structure. Reporting ambiguous dates can lead to false assumptions and has long been considered bad practice in dendrochronology (Nash 1999; Henderson *et al.* 2009; Grissino-Mayer *et al.* 2010). The lack of statistically and graphically convincing dating for the Small Cabin meant it must remain, for now, undated.

CONCLUSIONS

We propose that the Big Cabin was built between fall 1857 and spring 1860. However, many of the logs that dated to 1857 and 1858 were found to be most likely cut from the same tree as log 1 Middle, which clearly showed a cutting date during late 1859 or early 1860. We therefore propose that the Big Cabin was constructed between fall 1859 and spring 1860 and that the outer rings of logs 3 Middle, 4 Middle, 3 North, 3 South, and 3 Northeast were lost to decay or when concrete chinking was added to the cabin at an unknown later date. We were unable to absolutely date the Small Cabin based on a lack of sufficient samples (only five), the short length of the floating chronology (81 years), and the lack of variability (*e.g.* narrow rings) required to ensure successful crossdating. More samples are needed to absolutely date the Small Cabin. Our results for the Big Cabin, however, can be used in further efforts to preserve and/or restore the Big Cabin as part of a day-use area in Bear Paw State Natural Area that interprets the lifestyle that existed in southern Appalachia during the mid-19th Century.

Historians and geographers in the region are currently attempting to learn more about the history of these two structures. The buildings currently do not qualify for inclusion in the National Park Service's National Register of Historic Places because they cannot be tied to a prominent individual or historical event (Bray 2005). The construction date for the Big Cabin confirms that this is an Antebellum Period log cabin, and cabins that date to this period are becoming increasingly less common in southern Appalachia. Log cabins and other log structures once numbered in the tens-of-thousands across the southeastern U.S. (Morgan 1980; Rehder 2012), but many have been lost by abandonment, neglect, or fire, often resulting in dilapidated structures visible as merely mounds of decaying logs. Furthermore, such decrepit structures are increasingly becoming (legally) targeted and sometimes (illegally) pilfered by companies that specialize in the repurposing of historic logs. Such logs are commonly incorporated into modern structures as entire walls, fireplace mantels, window and door lintels, or even as borders around garden plots in an attempt to provide a more rustic appearance. Logs cabins are also impermanent by nature and require periodic renovation and restoration to persist, sometimes at the expense of historical integrity. Fortunately, some museums recognize the value of preserving original, intact log structures, including the Museum of Appalachia in Norris, Tennessee, and the Great Smoky Mountains Heritage Center in Townsend, Tennessee. The primary purpose of preserving such structures is to educate the public about Appalachian folkways and to document rural life in 19th Century Appalachia (Rehder 2004).

The significance of such log buildings need not be restricted solely to certain periods, however, and preserved log structures can have value with or without inclusion in local or national registries. We propose to use such historical structures as educational aids to support their preservation, regardless of age and/or registry, and further advocate their value within the modern landscape. During July 2015, faculty associated with Appalachian State University organized a Summer Workshop for ten undergraduate students to participate in the coring of the log cabins as part of the course "Global Change of the Biosphere" offered through the University's Department of Geography and Planning. Over the two-day workshop, students learned (1) the cultural, historical, and environmental significance and usefulness of such log structures, (2) how to extract samples for scientific study, and (3) the importance of dendrochronology for learning about the past environmental history. Implementation of this inquiry-based learning project expanded the potential use of such log structures as key educational components that enrich the student experience beyond the traditional classroom. This relationship is mutually beneficial as researchers gain valuable field assistance while informing students about the methodologies for conducting science correctly. When pursuing future projects that involve the dating of logs from historic structures, we recommend that scientists partner with local schools and universities to invite K-16 instructors and students to participate in the application of the scientific method through dendroarchaeological studies.

ACKNOWLEDGMENTS

This research was supported by Appalachian State University through a Humanities Scholars Grant from the College of Arts and Sciences. The North Carolina Division of Parks & Recreation provided permission to conduct fieldwork at the Bear Paw cabins. We also thank Neva Specht, Tracy Minton, Brandy Belville, Michael Kovalchuk, Grace Schaffner, Steven Ratcliffe, Phillip Richards, Travis Peters, Dawn Davis, Jon Settle, Jae Amoah, Avery Knox, and Matthew Hayes for their valuable field assistance.

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Received 18 June 2016; accepted 20 January 2017.