Dendrochronological investigation of disturbance history for a native American site in Northwestern Pennsylvania

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Ruffner, Charles M. and Marc D. Abrams (School of Forest Resources, Pennsylvania State University, University Park, PA 16802). Dendrochronological investigation of disturbance history for a native American site in Northwestern Pennsylvania. J. Torrey Bot. Soc. 129: 251–260. 2002.—Dendrochronological methods were used to identify the disturbance history of a Late Woodland Seneca Iroquois settlement in northwestern Pennsylvania. The impacts of aboriginal disturbance on the landscape are widely speculative and few studies have attempted to characterize these disturbances. Increment cores taken from a 426 year old white oak forest remnant yielded information on the disturbance regime on this site during Native American (Late Woodland 1550–1700); Historic 1700–1800 and European (post 1800) settlement periods. Disturbances during the early and late native periods were more synchronous and of lower intensity (increase in growth rate) with a disturbance free interval (DFI) of 26.2 ± 4.0 years and 11.0 ± 0.7 years (mean ± SE), respectively. The shorter return interval during the later native period is attributed to the increased population pressure at this site due to immigration of natives in the face of European expansion from the eastern seaboard. The disturbance regime following European settlement is significantly longer with a DFI of 28.5 ± 2.8 years, representing the selective removal of merchantable timber for the sawmill located at the site. Although investigated, no climatic variables showed significant correlation with tree growth to explain these patterns. This study represents a rare opportunity to document the changes in disturbance regime between two drastically different cultures and land uses.

Key words: dendrochronology, native American, European settlement, anthropogenic disturbance.

The impact of Native Americans on pre-European settlement vegetation in eastern North America has been widely studied. Many researchers have reported the impact of native agricultural clearing and burning on pre-settlement forests (Day 1953; Chapman et al. 1982; Pyne 1983; Patterson and Sassaman 1988; Dorney and Dorney 1989; DeVivo 1991; Hammett 1992; Clark and Royall 1995; Delcourt et al. 1998). Nearly all reference an anthropogenic landscape mosaic of successional forest and old-fields. These studies rely on a number of methodologies to investigate native landscape manipulation. Some rely on historical accounts of native fire uses or infer disturbances from witness tree analysis (Day 1953; Pyne 1983; Ruffner 1999). Still others utilize paleoecology to identify native burning practices and subsequent vegetation change (Grimm 1984; Patterson and Sassaman 1988; Clark and Royall 1995; Delcourt et al. 1998; Fuller et al. 1998). Few, however, have linked dendrochronological methods to the archaeological record to document native impacts on pre-European settlement vegetation (Barrett and Arno 1982; Guyette and Dey 1995; Guyette and Cutter 1997).

We learned of a 426 year old stand of white oaks immediately adjacent to the Seneca Iroquois village site at Buckaloons, along the upper Allegheny River in northwestern Pennsylvania. This small stand (2.5 ha) of old trees presented a rare opportunity to document the disturbance history of a Native American site using dendrochronological methods. We hypothesized that periodic human disturbance, not climate or edaphic factors, was responsible for oak maintenance on this site. The objectives of this study were to 1) establish the disturbance history of this small oak remnant using radial growth analysis, and 2) link this disturbance history to the historical record from the adjacent Native American village site.

Study Area. General Description. The Allegheny River flows through the unglaciated High Allegheny Plateau of northwestern Pennsylvania. This physiographic region is characterized by broad flat-topped ridges that are deeply dissected by dendritic streams (Fenneman 1938). The Ander’s Run oak site is located on an elevated terrace above the Allegheny River in Warren County, Pennsylvania (Fig. 1) (UTM coordinates E 642960, N 4631315). The site comprises Chenango soils (mesic Typic Dystrochrepts), characterized as being well drained, formed in water-sorted gravel and sand derived from acidic sandstone and shale (Cerutti 1985). Climate of the region is typified as cool and humid. Average tem-
Fig. 1. Site location map of Ander's Run old-growth, *Quercus alba* remnant near archaeological sites on Irving Flats in Warren County, Pennsylvania.

Temperatures range from 20°C in the summer to −2°C in the winter months. Total annual precipitation is 109 cm with 61 cm falling during the growing season between April and September (Cerutti 1985).

Forests of the Allegheny Plateau have been classified as hemlock—white pine—northern hardwoods (Nichols 1935; Braun 1950). Although much has been written concerning the ecology and disturbance history of these forests (Lutz 1930; Hough and Forbes 1943; Whitney 1990; Abrams and Orwig 1996), few studies have investigated the distribution and successional dynamics of oak in this region. Both Gordon (1940) and Küchler (1964) mapped northward extensions of oak along river valleys into southern New York. Previous authors have suggested some oak communities represent edaphic climax on poor, droughty soils (Gordon 1940; Braun 1950). Ruffner (1999) suggested that these northward extensions may reflect native American agricultural clearing and manipulation of mast resources based on analysis of catchment resources.
Prehistoric Context. Throughout the Holocene, the Allegheny River watershed served as a major transportation, trade, and communication artery for Archaic (8500–1000 BC) and Woodland (1000 BC–AD 1600) cultures. The Buckaloons site has the longest human occupational record in northwestern Pennsylvania with discontinuous occupation in both prehistoric cultural periods identified above (Lantz 1975).

Prior to European settlement, several cultures occupied the Buckaloons site including the Late Woodland (AD 1000–1600) Allegheny Valley Iroquois and the Historic (1600–1800) Seneca Iroquois (Quinn and Adovasio 1996). Settlement patterns of these groups are generally characterized by base camps on river terraces surrounded by large catchment areas from which raw materials were procured at ancillary sites (Lantz 1989; Ruffner 1999). These native groups were semi-sedentary horticulturists practicing swidden agriculture whereby forests were cleared and burned to create open areas in which sunflower (Helianthus annuus), maize (Zea mays), squash (Cucurbita pepo), and beans (Phaseolus vulgaris) were cultivated (Ketchum 1864; Parker 1968; Sykes 1980; Wymer 1993; Dimmick 1994; Snow 1994). By AD 1500, settlements were large, pallisaded villages with longhouses and garden plots capable of supporting up to 250–300 people (Snow 1994; Quinn and Adovasio 1996).

Based on archaeological reconstructions, the prehistoric landscape resembled a mosaic pattern of (1) active croplands near palisaded settlements, (2) abandoned clearings with early successional taxa, and (3) open forest stands dominated by fire adapted species such as oak and hickory (Chapman et al. 1982; Delcourt 1987; Delcourt et al. 1998). Throughout the eastern deciduous biome, numerous studies have attributed floral and faunal changes to anthropogenic disturbance and resource manipulation (Adovasio et al. 1985; Patterson and Sassaman 1988; Delcourt et al. 1998; Fuller et al. 1998; Johnson and Athens 1998). In the northeast, paleoecological studies have reported higher oak pollen and charcoal abundance near inland riverine sites which suggests that native practices of frequent burning influenced species composition through the maintenance of oak species (Patterson and Sassaman 1988; Clark and Royall 1994; Fuller et al. 1998). Ongoing paleoecological investigations are attempting to elucidate the potential cultural-vegetation interactions across the Allegheny Plateau (Ruffner et al. 1997).

Historic Context. The Historic period witnessed the expansion of the Seneca Iroquois out of their Genesee Valley homeland into the upper Allegheny River drainage (Snow 1994). They established numerous villages along the Allegheny River including Buckaloons of the current study (Kent et al. 1981). In 1749, a French expedition, under the command of Baron de Celeron, laid claim to the Allegheny River drainage and stopped at the sites of Conewango and Buckaloons to treaty with the Seneca (Schenk 1887). By 1753 the French had established an outpost at Buckaloons and although no garrison structure has ever been unearthed at Buckaloons, French and British government documents reference a “fort” at Buckaloons. Between 1700–1780, the site apparently supported a large population of emigrant natives pushed westward by European pressure in eastern Pennsylvania and was continually inhabited through the French and Indian War and the American Revolution (McConnell 1992). During the latter conflict, the Seneca supported the British and in 1779, a punitive expedition under Colonel Brodhead was dispatched to the Seneca villages on the upper Allegheny River. Brodhead recorded in his journal that his army destroyed Seneca villages at Complanter, Conewango, and Buckaloons. He estimated that over 500 acres (202 ha) of cropland were burned along with 150 longhouses and corn stores (Donehoo 1923). The native village at Buckaloons was never rebuilt.

European settlement of the Allegheny River area began after the purchase of northwestern Pennsylvania in 1789. Beginning in 1795, two Colonial surveyors, General Irvine and Andrew Ellicott, surveyed tracts in the area. Irvine purchased the parcels along the Buckaloons area including the study site which was later developed into a large farm by his son. In 1826 a sawmill was erected at the mouth of Ander’s Run and white pine in the drainage was cut and processed through the 1880s and sent downstream to the Pittsburg building market. The Irvine family maintained the farm into the early 1900s after which the Irvine Flats (Buckaloons site) was purchased by the US Forest Service and the woodlands in Ander’s Run were purchased by the National Forge Company. The woodland property was then purchased in 1963 by the Western Pennsylvania Conservancy and later sold in 1989 to the Commonwealth of Pennsylvania as a conservation easement.
Methods. Because the old-growth remnant is so small (2.5 ha) with just a few trees spanning the last 400 years of the site, only a reconstruction of the stand's disturbance history was attempted via radial growth analysis. Within the remnant, 17 trees were cored at stump height for age determination and radial growth analysis. During increment core collection we noted numerous fire scars in the stand and soil sampling revealed several charcoal lenses in the soil horizons. Unfortunately, we were not able to collect fire scar samples due to landowner constraints. In the laboratory, cores were dried, mounted, sanded and skeleton-plotted to determine signature years for cross-dating cores (Phipps 1985). Cross-dating accuracy was verified using the program COFECHA in the International Tree Ring Data Bank Program Library (ITRDBL) (Cook et al. 1997). Cores from the eight oldest white oak specimens were used to develop a master chronology spanning 426 years. Annual growth increments were measured with a tree-ring measuring-device (Regents Instruments Inc. Quebec, Canada) and recorded using the MACDENDRO microcomputer program. A standardized ring width index for each tree was created by dividing yearly measured growth values by expected values obtained from fitting either a linear or negative exponential regression to measured values or the mean growth increment (Fritts and Swetnam 1989). Standardization removes the age-related growth trend and converts all series to the same relative variance, giving each equal weight when averaged together into the master chronology (Fritts 1976).

All cores were examined for periods of suppression and release based on conservative and moderate criteria established by Lorimer and Freligh (1989). They defined a major sustained release as a ≥100% average growth increase lasting at least 15 years, and a moderate temporary release as a ≥50% average growth increase lasting from 10 to 15 years. Minor growth increases were detected using the more liberal criterion of Nowacki and Abrams (1997). They reported releases in oak trees exhibiting a 25% growth increase lasting at least 10 years. Their more liberal criteria was used in this study to detect possible understory burns in the oak stand adjacent to the Native American site. Our assumption here is that trees respond with short lived, low to moderate levels of increased growth to understory burns which recycle nutrients and reduce understory competition. In contrast, residual trees respond to large canopy level disturbances and the increased amount of resources with prolonged, high growth rates (Lorimer and Freligh 1989; Abrams et al. 1995; Nowacki and Abrams 1997; Ruffner and Abrams 1998). These criteria were used to identify disturbance events in the tree-ring record.

The chronology was divided into three time periods matching the cultural periods identified on the site: Late Woodland-Native (1550–1700), Historic-Native (1700–1800), and European (1800–1996). Stand level disturbance events were identified as distinct growth/injury suppressions followed by an immediate growth increase shared by two or more individual trees. To document the changing disturbance regime from native to European occupation, disturbance events identified through radial growth analysis were analyzed with ANOVA to test for significant differences (using Tukey's LSD procedure) between length of disturbance free intervals.

Annual and mean seasonal (winter, December 1–February 28; spring, March 1–May 31; summer, June 1–August 31; fall, September 1–November 30) climate variables (Palmer drought severity index (PDSI), precipitation, and temperature) from 1895–1996 were correlated (Pearson's) with tree growth (National Oceanic and Atmospheric Administration 1996). No significance was noted for any climate—growth correlation and thus are not presented in the results.

Results and Discussion. The master chronology coupled with release events revealed significant differences (p < 0.01) between native and European disturbance regimes (Fig. 2). The radial growth pattern from 1600–1700 is characterized by distinct periods of high growth decreasing slowly over 15–27 years separated by short periods of below average growth (Figure 2A). From 1700–1800 the growth pattern is characterized by shorter periods of above average growth punctuated by below average growth (Fig. 2A). Radial growth of the last period, 1800–1996, is characterized by slowly aggregating growth periods punctuated by rather low growth suppression periods (Fig. 2B). Growth patterns of individual trees suggest fairly low growth throughout the life of the oldest individuals with high frequency variation across these trees (Fig. 3A, B, C). While growth during these years appears fairly constant, minor disturbances were impacting these trees as detected by Nowacki and Abrams' (1999) more liberal release criterion. Of the three oldest trees, only one ex-
more low frequency variation and larger growth responses following disturbances.

Nearly all disturbances recorded in the tree ring record were either minor or moderate in intensity with only four major releases recorded across the site (Fig. 4). Release events are clearly grouped into the three representative periods for the site: 1) 1600–1700 during which the disturbance free interval averaged 26.2 ± 4.0 years (mean ± SE), 2) 1700–1800 during which the disturbance free interval is significantly shorter at 11.0 ± 0.7 years (mean ± SE), and 3) 1800–1996, the European period, which is significantly longer than either of the Native periods at 28.5 ± 2.8 years (mean ± SE).

The disturbance regime of the Ander's Run oak site has changed through the history of the stand. The Seneca Iroquois period (1600–1800) is characterized by frequent, low intensity disturbances, while the Colonial European period (1800–1996) experienced infrequent, high intensity disturbances (Fig. 2C). The earliest native period (1555–1700) appears to be dominated by disturbance pulses every 20–30 years, which increased residual radial growth. This pattern is not explained by short climatic fluctuations, which are generally not reflected in statistical releases (Lorimer and Freligh 1989) coupled with the lack of correlation between climatic variables and tree growth (tested and found insignificant). While speculative, this growth pattern may be explained by native burning cycles in the oak-hickory forests along the Allegheny River and its tributaries (Ruffner 1999). The Seneca were clearly sedentary agriculturists by this period with substantial villages at Buckaloons, Conewango (Warren), and Complanter (Sugar Flats). Archaeological studies in other regions of western New York have documented their agricultural economy based on corn, squash, and beans (Parker 1968). These studies, however, have also revealed the Seneca's continued utilization of natural forest resources including acorns, walnuts, hickory nuts, and gathered seeds into the Historic period (Parker 1968; Snow 1994). Thus, while Historic natives were clearly agriculturists they augmented their crop harvests with gathered natural foodstuffs (Ritchie and Funk 1973). The longer disturbance return interval for this period suggests that the population was manipulating nearby forest stands to impact browse quality and quantity and alter species composition (cf. Mellars 1976; Ruffner 1999). The 26 year disturbance interval recorded in the tree rings matches previous es-

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**Fig. 2.** Ring-width index for old-growth *Quercus alba* at Ander's Run, Warren County, PA. Upper panel (A) shows first 225 years of chronology during Seneca Iroquois period; middle panel (B) shows last 201 years of Colonial European period. Each includes disturbance dates from which disturbance-free intervals were calculated. Lower panel (C) comprises complete chronology (both A & B) for the Ander’s Run stand.
Fig. 3. Radial growth chronologies of selected *Quercus alba* trees. ← = major release dates, *→ = moderate release dates (as defined by Lorimer and Frelich 1989) + = minor releases (as defined by Nowacki and Abrams 1999).

Estimates for native burning cycles which allowed low intensity fires to burn the understory, killing unwanted species while recycling nutrients for residual oak-chestnut-hickory stands (Munson 1986, 1988; Wykoff 1991; Guyette and Cutter 1997).

From the chronology of socio-political events during the Late Historical period (1700–1800) we know that native groups from eastern Pennsylvania, such as the Lenape (Delaware) and Shawnee, were being pushed westward by European expansion into lands of the Seneca Iroquois, particularly along the Ohio and Allegheny Rivers (McConnell 1992). The years between 1720–1780 witnessed the greatest displacement of native groups into the Ohio Valley (McConnell 1992). On the upper Allegheny River, several Moravian missions were established to help immigrating natives cope with the loss of their lands and lifeways further east (Zeisberger 1912; Donehoo 1923). This abrupt population increase may have exerted a severe strain on the
carrying capacity of the natural resources in the upper Allegheny valley. We speculate that the disturbance regime at the Buckaloons site was intensified by the influx of eastern native groups clearing more areas for agricultural fields and burning existing fields more regularly to maintain adequate harvests. The regular pattern of minor disturbances in the Ander's Run oak chronology during this time period (1713–1765) closely matches this intensified disturbance regime hypothesis (Fig. 2A). Many ecologists report pre-European settlement oak forests burned every 8–17 years with fire frequency highest during periods of native occupation and population expansion (Buell et al. 1954; Guyette and Cutter 1991, 1997; Shumway et al. 2001). Ongoing paleoclimatological studies in northwestern Pennsylvania are investigating this relationship (Ruffner et al. 1997). While it may never be known if these native groups burned the forests regularly, the tree rings record a regular pattern of minor, low-level disturbances contemporaneous with native occupation and population expansion.

Following the destruction of the Seneca villages by the Colonial American Army in 1779 and further migration of those natives to the Midwest, the upper Allegheny valley was uninhabited for nearly 25 years before European settlement. Again, the disturbance-free interval (35 years; 1765–1800) from the tree ring record closely matches this settlement-free period. By the time of initial European land surveying, the village sites along the Allegheny River were undergoing secondary succession after native depopulation. Historical sources support the conclusion of native impacts on these sites. Early European accounts of the Allegheny River clearly reference open "glades along river" and "burnt hills" near Conoquenessing, an Indian village downriver from the study area (Burges 1965). Similarly, during a 1794–1795 surveying expedition, Andrew Ellicott noted the site of Conewango village (present site of Warren) as covered with a luxuriant growth of white oak, black oak, and red oaks, of large size (Schenck 1887). Joshua Sharpless ([1798], cited in Schenck 1887), a minister who visited the Complanter towns on the upper Allegheny River spoke of the fine grasses along Brokenstraw Creek near Buckaloons.

Beginning in the late 1790s, European settlers moved into the Allegheny River valley establishing farms and cottage industries such as blacksmithies, sawmills, and gristmills (Schenk 1887). Locally at Ander's Run, the Irvine family managed a large farm complete with a sawmill by 1826. From the tree ring record, it appears that the Ander's Run stand experienced a severe disturbance sometime between 1835–1845.
which caused considerable damage in the stand followed by a series of releases into the 1870s (Fig. 2b). This growth suppression-release sequence typifies a residual stand’s response following logging disturbances (Nowacki and Abrams 1994; Abrams et al. 1995; Abrams and Orwig 1996; Nowacki and Abrams 1997; Ruffner and Abrams 1998; Orwig and Abrams 1999). Nearly all of the white pine encountered in the remnant date from this period and due to their high density, suggest a fairly large-scale logging operation. Following the disturbance of the 1830s, the stand experienced multiple releases through the 1880s resulting in slowly upgrading growth until another disturbance in the early 1900s. This disturbance does not appear to be as severe with radial growth only being reduced to average rates. Through the 20th century the stand experienced only a few large disturbances in the 1930s and 1960s. Although no logging records exist for the earlier period, the property experienced large-scale logging in the 1960s by the National Forge Company (D. Wary, pers. comm.).

The fact that no climate variables were found to have significant influence on the growth of oak on this site is noteworthy. Many previous authors have speculated that oak found along the Allegheny River was due to poor site conditions such as duffey soil and or xeric ridgetops. If this were the case we would expect oak growth to be highly correlated with sunlight and precipitation indices. In contrast, the alluvial terrace soil conditions at the Ander’s Run site are mesic and nutrient rich, yet oak forests have dominated them for the past 400 years. Most regional ecologists would predict these mesic sites to be dominated by hemlock, sugar maple, or basswood (Marquis 1975; Whitney 1990). While this may represent the regional “climax” forest with little or no natural disturbance, the Ander’s Run site experienced the recurring affects of human disturbances through time which maintained oak dominance on the site. The disturbance chronology developed for this site suggests that the oak fire hypothesis may apply to certain oak populations in northern forests (Lorimer 1985; Abrams 1992; Clark and Royall 1996).

Conclusion. The disparate disturbance history in the stand reflects the changing land-use practices of two very different cultures. The frequent, low intensity disturbance regime of the Native American period suggests regular understory burning while the infrequent, high intensity disturbance regime of Colonial Europeans suggests rotational harvesting of the forest resources. We believe the integration of dendroecological methods with the historical record has improved our understanding of the disturbance history on this site, particularly during two different cultural periods. We also recognize that few archaeological sites of this importance will have old-growth remnants nearby in which this type of investigation could be utilized. Nonetheless, these stands and the dendrochronological record they represent should be identified and further studied so that the transitions from native American to Colonial European landscapes can be better understood. Future research at significant archaeological sites should focus on identifying and mapping adjacent old-growth stands followed by stand level radial-growth analysis, fire history, and stand-structure analysis to relate the development of the stand with the historical record. Following similar studies at these sites, ecologists will be better able to quantify the impact of native groups on vegetation structure, which is currently speculative and equivocal, at best.

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