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Original article

Stadium Woods: A dendroecological analysis of an old-growth forest fragment on a university campus

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ABSTRACT

On the Virginia Tech campus, adjacent to the football stadium is a 4.6-ha forest fragment that contains a population of unusually large white oak (*Quercus alba* L.) trees. We used dendroecology and sampled vegetation in fixed area plots to reconstruct the disturbance history of this forest fragment and compared the radial-growth averaging criteria and the boundary-line release criteria for identifying canopy disturbances. Structurally, the Stadium Woods has an inverse-J diameter distribution and trees present in all canopy strata. The oldest white oak had periods of asynchronous suppression and release indicating a closed canopy forest with periodic canopy disturbances. The boundary-line release criteria detect a broader range of growth releases, whereas the radial-growth averaging criteria are more specialized for capturing canopy gaps. Release events identified with the boundary-line release criteria lagged an average of 5.8 years behind those identified with the radial-growth averaging criteria because the boundary line release criteria identifies the year of maximum percent growth change, whereas the radial-growth averaging criteria identifies the first year with a detectable increase in radial growth. The Stadium Woods represents a unique collection of unusually large white oak trees growing in a heavily populated area and reveals the importance of long-term tree-ring chronologies stored within urban forest fragments.

Introduction

Much of our knowledge of forest stand dynamics and historical disturbance regimes originates from dendroecological analysis of tree-ring records from old-growth forests (Fritts and Swetnam, 1989; Lorimer and Frelich, 1989). Frequency and intensity of natural disturbances such as wind throw, ice storms, insect outbreaks, and fires can be reconstructed by dating scars, growth releases, or cohorts of tree establishment that followed disturbance events (Shumway et al., 2001; Jeffries et al., 2006; Lafon, 2006; Greenberg et al., 2011). Tree-ring patterns can also record the history of human activities such as logging, grazing, and the location of historical transportation routes (Ericsson et al., 2003; Motta et al., 2006; Cowell and Hayes, 2007).

The distribution and history of eastern old-growth forests in North America generally follow two patterns: (1) trees that were never cleared during European settlement because they were growing on very steep slopes or on soils unsuitable for agriculture (Therrell and Stahle, 1998) or (2) small old-growth forest fragments surrounded by land that has been heavily impacted by humans (Abrams and Copenheaver, 1999). Most eastern old-growth forests fit the former pattern (Muller, 2003; Pederson, 2010) and the few old-growth forest fragments in populated areas typically contain informal trails, exotic species, and a lower native biodiversity (Matlack, 1997; Jim, 2004). However, these forest fragments contain tree-ring records that often pre-date the fragmentation of the forest and can be used to reconstruct long-historical records of stand and gap dynamics (Lorimer, 1985).

The two most common techniques for reconstructing stand dynamics are the radial growth averaging criteria and the boundary-line release criteria. The radial-growth averaging criteria was developed by Nowacki and Abrams (1997) to identify canopy disturbances in mixed oak (*Quercus*) stands in the central Appalachian Mountains and targets increases in radial growth rate that persist in the tree ring record for a minimum period of time (10 years), corresponding to typical gap closure time for this forest type. The boundary-line release criteria developed by Black and Abrams (2003) to identify growth releases caused by canopy disturbance based on the growth potential for a given species and prior growth exhibited for an individual tree, such that trees with rapid growth

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rates must experience relatively smaller percent growth change as an indication of a release compared to trees with extremely slow growth rates. The inclusion of prior growth rates assumes that trees growing extremely fast are growing close to their biological maximum, and even under improved growing conditions are unable to demonstrate proportionally the same increase in growth as a tree released from suppressed conditions (Phipps, 2005). A recent study indicates that at extremely low productivity sites, the boundary-line release criteria underestimates the frequency of release events in sites (Ziaco et al., 2012).

On the campus of Virginia Tech, a large land-grant university in the southeastern United States, is a remnant old-growth white oak (*Quercus alba* L.) stand. Although this forested stand is heavily impacted by undergraduate forestry laboratories, military training exercises for the Virginia Tech Corps of Cadets, and by students walking between the town and the university, it contains an unusually high density of large white oak trees. This site provides the unique opportunity to explore the dendroecology of heavily disturbed old-growth fragment. Thus, the objectives of this research were to: (1) use structural data and tree-ring releases to reconstruct the disturbance history of Stadium Woods, and (2) contrast the radial-growth averaging criteria (Nowacki and Abrams, 1997) with the boundary-line release criteria (Black and Abrams, 2003).

Materials and methods

Study area

Stadium Woods is an isolated patch of old-growth forest covering approximately 4.6 ha located east of Lane Stadium on the campus of Virginia Tech in Blacksburg, Virginia. The university leased Stadium Woods and 66 ha of surrounding agricultural land in 1915, and later purchased the property in 1920 (Virginia Agricultural and Mechanical College and Polytechnic Institute, 1925). In the 1915 lease agreement, Stadium Woods is described as "that other portion of the land. . .known as the woodland, which contains twelve acres (4.8 ha) by recent survey" (Eggleston's Presidential Files, Special Collections, Virginia Tech). An aerial photograph from 1937 and a 1947 campus map confirm that Stadium Woods was slightly larger prior to the construction of Lane Stadium in 1965 (Wallenstein, 1997). The current overstory is dominated by large-diameter white oaks and the mid-canopy and understory are a mixture of native and invasive trees and shrubs. The total annual precipitation of 1010 mm is evenly distributed throughout the year. The average winter temperature is 0 °C and the average summer temperature is 19 °C. Although there is some topographic relief within the woods, slopes do not exceed 10% and the average elevation of the area is 640 m asl. Stadium Woods soils are a Groseclose-Urban land complex with a rooting zone that exceeds 1220 mm and a moderate available water capacity (Creggar and Hudson, 1985). The Stadium Woods has a site index of 26, meaning even-aged white oak trees will reach 26 m in height within 50 years after germination (Olson, 1959). The high number of unusually large and old white oak are a rare characteristic for this region and classify Stadium Woods as eastern old-growth forest (Hunter and White, 1997).

Field and laboratory work

To quantify structural characteristics within Stadium Woods, thirty 100 m^2 fixed-area plots were randomly located and within each plot, height to top of live crown, diameter at breast height (dbh, 1.4 m), and tree species were recorded on all stems > 10 cm dbh. An increment core was extracted from each tree at 0.5 m above the root collar. While sampling the vegetation plots, we extracted cores from a total of 16 white oak trees. To capture the disturbance history of Stadium Woods, we supplemented the initial collection of white oak increment cores with cores from an additional 17 white oaks. We targeted trees with characteristics associated with older trees, e.g., blocky bark, sinuous trunk, and broken top branches (Pederson, 2010). Some larger white oaks had substantial root buttressing and basal rotting. To avoid boring into rotten sections and to avoid ring width variations caused by buttressing, we cored these stems at 1.4 m. All increment cores were air-dried and glued to wooden holders. Each core was sanded with progressively finer grit sandpaper until it was possible to see the cellular structure of the wood under a microscope.

Within species groups, tree cores were visually crossdated using patterns of narrow and wide ring widths to accurately date the annual rings (Schweingruber et al., 1990). Due to small sample size, the northern red oak (*Quercus rubra* L.), scarlet oak (*Quercus coccinea* Münchh.), and black oak (*Quercus velutina* Lam.) cores were combined into a single red oak group for visual crossdating because a prior study from this region had shown that these three species crossdated well (White et al., 2011). To reduce crossdating problems caused by small sample size, we also combined box elder (*Acer negundo* L.), Norway maple (*Acer platanoides* L.), and red maple (*Acer rubrum* L.) and we created a third group from sweet cherry (*Prunus avium* L.) and black cherry (*Prunus serotina* Ehrh.). After visual crossdating, ring widths from all cores were measured with a TA Tree-Ring Measurement System (Velmex, Inc., Bloomfield, NY). We used the crossdating verification program, COFECHA, available through the Dendrochronology Program Library (Grissino-Mayer, 2001). We had difficulty crossdating understory trees because the common climatic signals used for crossdating were weak relative to tree-specific competition signals and because the tree-ring series were very short (15–20 years). Therefore, we were unable to crossdate 16 of the 46 understory tree cores and these cores were eliminated from further radial-growth analysis. For six species, we had five or fewer cores and this was not a large enough sample size to crossdate properly. Therefore, we did not date or measure ring widths for American beech (*Fagus grandifolia* Ehrh., 1 tree), black locust (*Robinia pseudoacacia* L., 3 trees), black walnut (*Juglans nigra* L., 1 tree), flowering dogwood (*Cornus florida* L., 5 trees), little leaf linden (*Tilia cordata* Mill., 3 trees), and white ash (*Fraxinus americana* L., 1 tree). The remaining increment cores (79 trees) had sufficiently strong common signals and large enough sample size that we were confident in our dating (Table 1).

Data analysis

To quantify the ecological importance of each tree species in Stadium Woods, we calculated an importance value (Barbour et al., 1999). The importance value for each species was an average of the relative frequency (# plots that a species occurs in and therefore a measure of how widely distributed a species was within the stand), relative density (# of stems/ha), and relative dominance (basal area as calculated from the dbh measurements).

We contrasted the radial-growth averaging criteria (Nowacki and Abrams, 1997) and the boundary-line release criteria (Black and Abrams, 2004) for differences in how these methods identified growth releases. The raw tree-ring width measurements from the white oak cores were analyzed to identify percent growth change following Nowacki and Abrams (1997):

$$\%GC = \left[\frac{M_2 - M_1}{M_1}\right] \times 100$$

where %GC is the percent growth change of the average ring width from the previous 10 years (M_2) and the average ring width of the subsequent 10 years (M_1). This process excludes the first and last