Forest Ecology and Management 257 (2009) 2235–2240

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Identifying dendroecological growth releases in American beech, jack pine, and white oak: Within-tree sampling strategy

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ARTICLE INFO

Article history:
Received 6 January 2009
Received in revised form 23 February 2009
Accepted 25 February 2009

Keywords:
Dendrochronology
Dendroecology
Growth releases
Tree rings

ABSTRACT

The objective of this project was to identify the timing of growth release events detected from tree ring widths and compare whether two cores taken from the same tree reconstructed the same disturbance history. This research question is important because current dendroecological reconstructions of canopy disturbance rely on sampling one core per tree; however, the variation of releases from different cores from the same tree has never been evaluated. We sampled two increment cores from 20 jack pine, 17 white oak, and 19 American beech and identified release events with two commonly employed methods: radial growth averaging technique and boundary line criteria. In jack pine, 85% of the paired cores showed identical releases with the radial growth averaging technique, but 15% of the paired cores varied in reconstructed growth releases. In the jack pine, no releases were identified with the boundary line criteria for any of the paired cores. In the white oak, 65% had identical releases identified with the radial growth averaging technique and 35% of the pairs showed differences. The boundary line criteria for white oak had agreement between releases for 76% of the pairs and different release histories for 24% of the pairs. In the American beech, we were only able to use the radial growth averaging technique and this method showed identical release timing for 79% of the paired cores and differences in 21% of the paired cores. This level of within-tree growth variation is unlikely to influence identification of stand-wide disturbances; however, for reconstructions of small-scale disturbances it is likely to under-represent disturbance events. Therefore, for small-scale disturbance reconstructions, we recommend dendroecologists consider sampling two cores per tree instead of the standard sample of one core per tree.

1. Introduction

Dendroecologists have developed a number of techniques for identifying disturbance-related growth releases in the tree ring record. The goal of each of these techniques is to distinguish disturbance-related releases from climate-induced increases in growth. Early techniques hinged on the assumption that in comparison to climate-induced signals, releases due to disturbance tended to be more vigorous and sustained as the tree occupied newly formed canopy gaps (Lorimer, 1985; Lorimer and Frelich, 1989; Nowacki and Abrams, 1997). Among the most widely applied approaches is radial growth averaging, in which releases are identified as sustained pulses in relative growth rate; this technique has been employed in a number of forest ecosystems to reconstruct historical gap dynamics, canopy recruitment rates, and disturbance frequency (Piovesan et al., 2005; Zhang et al., 2007; Gutiérrez et al., 2008; Pederson et al., 2008). The specifics of these criteria vary widely according to species and study objective with for example, the most stringent thresholds established to detect severe disturbances. The Nowacki and Abrams (1997) criteria for overstory oak have been among the most thoroughly investigated, and validation studies have shown that peak radial growth response corresponds to the disturbance date, and that the magnitude of release response, in terms of percent-growth change, corresponds to the degree of crown release (Rentch et al., 2002, 2003). An extension of the running mean techniques, the boundary line release criteria proposed by Black and Abrams (2003) incorporates the effects of prior growth history, in an attempt to better standardize releases across various age, crown, and size classes and potentially species (Splechtna et al., 2005; Nagel et al., 2007; Bhuta et al., 2009). In the recently developed "absolute increase" method, the release threshold for a species is set in terms of absolute growth rate, which indirectly incorporates the effects of prior growth rate and species on release magnitude (Fraver and White, 2005). Alternatively, the "divergence" technique attempts to separate growth patterns unique to

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0378-1127/$ – see front matter
doi:10.1016/j.foreco.2009.02.031

individual from those of the population in order to identify the formation of fine-scale canopy gaps (Thompson et al., 2007). In another novel methodology, Druckenbrod (2005) employed autoregressive modeling as a mean to identify steps and pulses in growth as evidence of releases as well as suppressions.

The recent focus on methods for identifying disturbance-related release events in the tree ring record led us to question how important is sample collection in disturbance reconstruction? Unlike many tree ring based climate reconstructions, most disturbance reconstructions depend upon a single sample per tree (Abrams et al., 1998; Orwig et al., 2001; Rozas, 2004; Busby et al., 2008a; Kincaid and Parker, 2008; Pederson et al., 2008). This is an important difference because the underlying assumption is that a single core sampled from any aspect on the stem will accurately reflect the tree-level, and ultimately stand-level, disturbance history (Fritts, 1991). However, this assumption seems to be challenged by research which shows that growth occurs at different rates and times around the circumference of a tree stem (Ogata et al., 2002; Gričar and Čufar, 2008) and is considered when determining the number of increment cores to extract to accurately calculate basal area increment (Biging and Wensel, 1988; Gregoire et al., 1990). Thus, our research goal was to determine whether two radii sampled from different sides of a tree will record the same disturbance history. If the answer is no, then all of the fine-tuning of release identification techniques at the analysis stage is for naught until researchers can account for within-tree growth variation. In this study, we address this issue in three diverse species, jack pine (*Pinus banksiana*), white oak (*Quercus alba*), and American beech (*Fagus grandifolia*), which includes conifer and deciduous species as well as a range of understory tolerance levels. All three of these species have been employed in reconstructing disturbance histories and therefore had a proven record for responsiveness to disturbance events in past research (Abrams and Copenheaver, 1999; Copenheaver and Abrams, 2003; Druckenbrod, 2005; Fraver and White, 2005).

2. Materials and methods

2.1. Study sites

American beech was sampled from the Zoar State Forest in King William County, Virginia (Table 1). This 153 ha forest is managed by the Virginia Department of Forestry and has been in their ownership since 1987. The total annual precipitation is 1100 mm and the average temperature in winter is 3 °C and the average temperature in summer is 25 °C. The stand that was sampled was on the river terrace overlooking the Mattaponi River and was dominated by *Carya*, *Fagus*, and *Quercus* and was known to have been selectively harvested in the early 1900s (Copenheaver et al., 2007).

Jack pine was sampled from land managed by the Michigan Department of Natural Resources in Roscommon County, Michigan (Table 1). The total annual precipitation is 810 mm and the average winter temperature is 6 °C and the average summer temperature is 18 °C. The stand was east of Robinson Lake and consisted of naturally regenerated jackpine with an understory of bearberry (*Arctostaphylos uvaursi*) and blueberry (*Vaccinium angustifolim*). There was a small windthrown area in the northeastern section of the stand and trees were not sampled from this section.

White oak was sampled from Buffalo Mountain Natural Area Preserve in Floyd County, Virginia (Table 1). This 200 ha forest is managed by the Virginia Natural Heritage Program. The total annual precipitation is 1046 mm and the average winter temperature is 1.4 °C and the average summer temperature is 20.2 °C. The stand was on the top of Buffalo Mountain (1190 masl) and a mixture of closed-canopy *Quercus*–*Carya* forest interspersed with open grass-dominated glade communities (Copenheaver et al., 2004).

2.2. Field and laboratory work

At each study site, a total of 20 trees were cored twice at stump height (0.5 m). For the beech and the white pine, samples were collected at 180° from each other and for the jack pine, samples were collected at 90° from each other. Trees were selected because of their dominant or co-dominant canopy positions. After collection, all cores were air dried, glued onto wooden core holders, and sanded to allow examination of cellular structure under a dissecting microscope. Cores were excluded from further analysis if they had reaction wood, rot, or branch scars that obscured their annual growth rings. The cores from each site, were cross-dated using narrow years as signature years (Yamaguchi, 1991) and special care was given to the jack pine because of their propensity for false and light ring formation (Volney and Mallett, 1992; Copenheaver et al., 2006). Following visual cross-dating, ring widths of all cores were measured using a TA Tree Ring Measurement System (Velmex Inc., Bloomfield, NY). The cross-dating of the tree ring measurements was then verified with the dating verification program, COFECHA, available through the Dendrochronology Program Library. Any flagged cores were re-examined and dating was corrected. In the white oak, there were three trees for which at least one of the cores was not able to be used because of large sections of rot which prevented accurate dating and measuring; therefore, all subsequent analysis was conducted on 17 pairs of white oaks. In the American beech there was one core with a large branch scar and therefore all subsequent analysis for that species was conducted on 19 pairs of cores. The analysis for the jack pine had 20 pairs of cores.

2.3. Data analysis

To compare the within-tree variation in release events, we opted to use the two most commonly applied release criteria: the radial growth averaging technique (Lorimer and Frelich, 1989; Nowacki and Abrams, 1997) and the boundary line technique (Black and Abrams, 2003, 2004) and compare timing of releases identified within a tree for both techniques. The objective in comparing the two cores from a single tree was to assess whether the number and timing of releases was the same between the two cores; however, because the timing of releases can vary slightly due to individual growth patterns we allowed the timing of a release to count as “the same” if the two release dates were within 5 years of each other. Early work on release criteria focused on establishing the transition date for when a tree moved from an understory to an overstory position, however, subsequent research has used a modification of this approach to identify growth releases in overstory trees. Therefore, we employed a modified

Table 1
Environmental characteristics of the three sites where tree cores were sampled.

Species cored	Soil	Topographic position	Elevation (masl)	Lat./long.
American beech	Loamy sand	River terrace	8	34°47′N, 77°6′W
Jack pine	Sand	Glacial outwash plain	350	44°13′N, 84°46′W
White oak	Loam	Mountain top	1190	36°45′N, 80°28′W