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Origin, development, and impact of mountain laurel thickets on the mixed-oak forests of the central Appalachian Mountains, USA

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ABSTRACT

Throughout forests of the northern hemisphere, some species of ericaceous shrubs can form persistent understories that interfere with forest regeneration processes. In the Appalachian Mountains of eastern North America, mountain laurel (*Kalmia latifolia*) may interfere in the regeneration of mixed-oak (*Quercus* spp.) forests. To verify this possibility, I conducted a dendroecology study from 2001 to 2005 in three mixed-oak stands with mountain laurel thickets to elucidate how and when the thickets originated, developed, and were impacting hardwood seedlings. At all three sites, the oldest mountain laurel dated to the 1930s when the stands emerged from a period of recurring disturbance. However, most of the mountain laurel has originated since the 1950s when the stands were generally undisturbed. More recently, insect defoliations have accelerated the development of the thickets by increasing available sunlight. A strong negative relationship exists between the percent cover of mountain laurel and the density of hardwood seedlings with 20–30% cover being sufficient to inhibit seedling establishment and survival. Perpetuating mixed-oak forests that contain mountain laurel thickets will require reducing shrub cover to less than 20–30% at the beginning of the regeneration process to help ensure adequate densities of hardwood seedlings.

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1. Introduction

Of all the forest types found in eastern North America, natural resource professionals, landowners, and the general public especially value the upland mixed-oak (*Quercus* spp.) forest because of its biological diversity, ecological services, and economic worth (Smith, 2006). Depending on local conditions, this widespread forest type often contains several species of oak, an assortment of other hardwood species, and a diverse understory plant community. Despite its extensive range, the upland mixed-oak forest has chronic regeneration difficulties because of competing and interfering vegetation, excessive browsing by whitetail deer (*Odocoileus virginianus*), disease/insect problems, lack of periodic fire, and unsustainable harvesting practices (Abrams and Downs, 1990; Aldrich et al., 2005; Schuler and Gillespie, 2000). Consequently, perpetuation of upland mixed-oak forests is in doubt (Healy et al., 1997; McWilliams et al., 2004; Woodall et al., 2008). Of these factors, the competing/interfering vegetation problem is probably the most deleterious and widespread (Brose, 2011; Crow, 1988; Lorimer, 1993; Lorimer et al., 1994). Generally, that problem correlates with site quality; competing/interfering vegetation is much more problematic on high productivity sites than on low productivity sites (Gould et al., 2005; Johnson et al., 2009; Ross et al., 1986; Weaver and Robertson, 1981). In fact, competing/interfering vegetation is often not considered an obstacle to regenerating mixed-oak forests on low-quality sites (Johnson et al., 2009).

An exception to the generality of low quality site – lack of competing/interfering vegetation may be the occurrence of mountain laurel (*Kalmia latifolia*) on such sites throughout the Appalachian Mountains of the eastern United States. This ericaceous shrub grows up to 4 m tall and broad, and has large, thick evergreen leaves. When multiple mountain laurels grow in close proximity to each other their branches intersect, creating a dense thicket. Such thickets can consist of thousands of stems/hectare and cover several hectares. Hardwood seedlings, especially oak seedlings, are usually scarce in mountain laurel thickets, making forest renewal an arduous, protracted process.

Mountain laurel may be one of a suite of ericaceous shrub species capable of becoming an obstacle to forest renewal (Royo and Carson, 2006). Elsewhere in the eastern United States, rosebay rhododendron (*Rhododendron maximum*) interferes with the establishment, survival, and growth of the seedlings of conifer and hardwood species in riparian zones and other mesic areas while black huckleberry (*Gaylussaccia baccata*) behaves similarly on xeric sites (Beckage et al., 2000; Chastain and Townsend, 2008; Clinton et al.,

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1994; Lei et al., 2002; Monk et al., 1985; Phillips and Murdy, 1985). In eastern Canada, sheep laurel (*Kalmia angustifolia*) has been shown to exert direct negative effects on the survival and growth of black spruce (*Picea mariana*) seedlings (Inderjit and Mallik, 1996; Yamasaki et al., 1998, 2002). Relative to sheep laurel and rosebay rhododendron, mountain laurel has not been studied extensively. Chapman (1950) conducted the earliest research on the shrub, a multi-year study done in Connecticut. He showed that mountain laurel was long-lived, at least 75 years, slow-growing (7–30 cm/year height growth), quite shade tolerant, and its thickets reduced understory insolation to less than 5% of full sunlight. In a follow-up study in Connecticut, Kurmes (1961) found that mountain laurel seed had its highest germination rates on moss and moist mineral soil, the shrub responded to increases in sunlight with increased height growth, and its thickets spread through mixed-oak forests via layering of its lowermost branches. More recently, ecophysiology research of mountain laurel reported that (1) the shrub had increased photosynthetic capacity and water use efficiency with increases in available sunlight, (2) its abundance was positively correlated with soil Ca:Al ratios less than 0.3 and to increasing soil acidity, (3) its evergreen foliage may sequester Mn, P, and Zn, and (4) its release of phenolic compounds may inhibit nitrogen mineralization (Huebner et al., 2014; Lipscomb and Nilsen, 1990a,b; Nilsen et al., 2001). Established and recent natural history research has shown mountain laurel thickets to be strongly associated with dry, exposed topographic positions and with gypsy moth (*Lymantria dispar*) defoliations (Chastain and Townsend, 2008; Clinton et al., 1994; Monk et al., 1985).

An interesting and unstudied aspect of mountain laurel thickets is their ecological history. Questions remain about when and under what conditions current mountain laurel thickets originated and developed as well as what are their likely future and the future of the surrounding forests. Dendroecological techniques can be used to address these and related questions by analyzing age structure and radial growth in relation to land-use history. In this study, I elucidate how three mountain laurel thickets and the surrounding mixed-oak forests began and developed through time. Specific research questions are: (1) What are the age structures of the thickets and the overstory trees? (2) When did both originate and what were the circumstances of their origins? (3) What has been the disturbance history of the thickets and overstory trees and how have they responded to the disturbances? and (4) What impacts are the thickets having on hardwood seedlings? Understanding the ecological history of mountain laurel thickets and their effects on hardwood seedlings will aid foresters and forest landowners in managing them so they do not become problematic to oak regeneration efforts.

2. Methods

2.1. Study sites

This study was conducted from 2001 to 2005 in three upland oak stands located across Pennsylvania (Fig. 1). The westernmost site (41°19′03″N, 79°02′21″W) was on Clear Creek State Forest (CCSF) while the easternmost site (41°18′27″N, 75°05′50″W) was on Delaware State Forest (DESF). The third site was in central Pennsylvania (40°42′59″N, 77°54′03″W) on the Rothrock State Forest (RRSF). Despite being 150–400 km from each other, the three study stands shared a number of characteristics. Each stand was 15- to 20-ha, situated on the upper slopes or summits of hills, had a stony loam soil, and an oak site index$_{50}$ of 16–20 m (Braker, 1981; Taylor, 1969; Zarichansky, 1964). Chestnut oak (*Quercus montana*) and northern red oak (*Quercus rubra*) were the most abundant oak species, but black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), and white oak (*Quercus alba*) were also present. Associated tree species included blackgum (*Nyssa sylvatica*), pitch pine (*Pinus rigida*), red maple (*Acer rubrum*), serviceberry (*Amelanchier arborea*), and white pine (*Pinus strobus*). Canopy cover was not ubiquitous due to past canopy disturbances, but I visually estimated overstory stocking to be more than 70%. Mountain laurel dominated the understory plant community with its abundance ranging from individual shrubs to thickets covering a few hectares. Also present were other shrub species such as bear oak (*Quercus ilicifolia*), blueberry (*Vaccinium* spp.), huckleberry (*Gaylussacia* spp.), and sweet-fern (*Comptonia peregrina*). Herbaceous plant diversity was quite limited; it consisted of small areas of hay-scented fern (*Dennstaedtia punctilobula*) and scattered specimens of beetleweed (*Galax aphylla*), goat's rue (*Tephrosia virginiana*), trailing arbutus (*Epigaea repens*), and wintergreen (*Gautheria procumbens*). Hardwood seedlings were of the same species as the overstory trees and ranged in abundance from non-existent to ubiquitous.

Because these sites were 150–400 km apart, they differed in a number of characteristics. The CCSF site was in the Allegheny Plateau region while the DESF and RRSF sites were in the Pocono Plateau and Ridge/Valley regions, respectively (Schultz, 1999). Their weather varied with CCSF being the coolest and wettest, RRSF being the warmest and driest, and DESF was intermediate (Braker, 1981; Taylor, 1969; Zarichansky, 1964). The RRSF site was on a north aspect while the other two sites had southeastern aspects. The CCSF site was the highest, approximately 575 m, while DESF and RRSF were between 450 and 500 m. Their histories differed too; RRSF probably had been subjected to short-rotation timber harvesting for several decades due to its proximity to charcoal iron furnaces while the other two sites likely experienced just one or two timber harvests in the early 1900s (DeCoster, 1995; Eggert, 1994).

2.2. Sampling and lab procedures

In 2001 and 2002 at each site, I systematically established four 0.001-ha circular plots per hectare (84–100 plots per site) to uniformly inventory the understory. In these plots, I tallied all hardwood reproduction less than 3 m tall by species and height class using established sampling procedures (Marquis et al., 1992). Additionally, I visually estimated the cover of mountain laurel on the plot to the nearest 5%.

From the center of every-other understory plot, I used a 2.3 m prism to determine which nearby overstory trees more than 3 m tall were in a variable-radius plot. Selected trees were identified to species, measured for diameter to the nearest 2.5 cm at 1.4 m above the ground (dbh), and assigned to a canopy class (dominant, co-dominant, intermediate or suppressed) based on visual observation. For aging and radial growth analysis, I randomly chose four of these trees (two dominant or co-dominant and two intermediate or suppressed) in each overstory plot. If the selected tree was larger than 10 cm dbh, I extracted two increment cores from its bole at a height of approximately 30 cm above the ground. These cores were taken from the opposite sides of the tree and parallel to the contour so as to avoid any reaction wood that may distort the annual rings (Speer, 2010). If the selected tree was less than 10 cm dbh, then it was felled with a chain saw and a cross section cut from its base at ground level. Finally, I cut a cross section from the base of the mountain laurel (larger than 2.5 cm basal diameter) nearest each sampled overstory tree.

The sampling collected 690 cores and 759 cross sections from the three sites. In August 2002, a structure fire at the Forestry Sciences Lab in Irvine, Pennsylvania resulted in the loss of 324 cores and 513 cross sections. This loss was spread fairly evenly among the three sites; each was left with 96–119 cores and 101–