



Stump sprout dynamics in response to reductions in stand density for nine upland hardwood species in the southern Appalachian Mountains



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ABSTRACT

Much about stump sprout dynamics of upland hardwood trees species has been obtained in clearcuts. Information on the response of stump sprouts to alternative silvicultural treatments, including treatments that manipulate stand density and stand structure is lacking. In this study we examined the influence of harvest season and levels of basal area reduction on the probability of sprouting and subsequent sprout growth in the southern Appalachian Mountains. In 2009, 24 – 0.1 ha plots were established in fully-stocked mixed-hardwood forests near Asheville, North Carolina, USA. Basal area was mechanically reduced from below by 10%, 20%, 30%, or 40% between January and February, 2009 (dormant season) and again between July and August, 2010 (growing season), with each harvest season and level of basal area reduction combination randomly applied to three plots. For each stump, we recorded: (1) presence of live sprouts (yes/no); (2) height (m) of the dominant (i.e., tallest) sprout, and (3) area (m²) occupied by individual sprout clumps. All measurements were conducted one, two, and three years post-harvest. We used logistic regression and ANOVA to analyze the probability that a stump sprouts one year post-harvest and annual stump survival (i.e., the presence of at least one live sprout), sprout height, and area.

Probability of sprouting was independent of dbh for red maple, dogwood, sourwood, hickory spp., chestnut oak, yellow-poplar, and sweet birch. For sweet birch the probability of sprouting was affected by harvest season, with 54% and 93% of stumps producing sprouts one year following growing and dormant season harvests, respectively. For blackgum and white oak, dbh was negatively correlated with the probability of sprouting. Stump survival varied by species and year. Third year stump survival was 38% lower for oak and hickory than sourwood and 32% lower than red maple. Dominant sprout height was significantly greater for red maple and sourwood than for oak and hickory, with the greatest height achieved under the 40% reduction in basal area treatment. By year three, dominant sprout height for red maple and sourwood was 40% greater than for oak and hickory and 58% greater than other shade-tolerant midstory species. Our results suggest planning harvests to occur during a particular point in the year with the idea it will limit sprouting and subsequent sprout growth is ineffective and should not be considered a viable means of reducing the production or growth of stump sprouts.

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1. Introduction

The role of stump sprouts in the regeneration of upland hardwood forests in the eastern United States is well documented (Elliott et al., 1997; Beck and Hooper, 1986; Cook et al., 1998). Due to the already developed root systems of parent trees, stump sprouts exhibit rapid growth following disturbance, and can, therefore, greatly influence post-disturbance species composition (Del Tredici, 2001). For example, 11 years after clearcutting

mixed-oak stands in Kentucky, Arthur et al. (1997) report stump sprouts accounted for 50% of all stems, with flowering dogwood (*Cornus florida* L.) and red maple (*Acer rubrum* L.), both prolific sprouters (Buell, 1940; Fei and Steiner, 2009), comprising the greatest percentage of overall basal area. Similarly, Beck and Hooper (1986) found 86% of all dominant/co-dominant stems were comprised of stump sprouts 20 years after clearcutting in a southern Appalachian mixed hardwood stand. Sprouting potential varies by species (Kay et al., 1988a,b; Mann, 1984), and within a species can be influenced by a variety of factors, including tree size or age (e.g., Sands and Abrams, 2009). For many of the species considered desirable due to their ecological and/or economic importance (e.g., oak (*Quercus* spp.) and hickory (*Carya* spp.)), the likelihood of

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sprouting decreases as tree size or age increases, making mature overstory oak and hickory trees an unreliable source of stump sprouts (Mann, 1994; Weigel and Peng, 2002). In contrast, sprouting of less desirable species, which, in the southern Appalachian Mountains, are generally shade-tolerant midstory species (e.g., red maple, sourwood (*Oxydendrum arboreum* L.), blackgum (*Nyssa sylvatica* Marsh.), and flowering dogwood) appears to be less dependent on tree size (Kays et al., 1988a,b; Mann, 1994).

The rapid growth of stump sprouts from some of the less desirable shade-tolerant midstory species can hinder the establishment, growth, and recruitment of the more desirable oak and hickory species (Loftis, 1985; Beck and Hooper, 1986; Arthur et al., 1997; Elliott et al., 1997). Consequently, control of stump sprouts from undesirable tree species following silvicultural treatments is critical when managing for oak and hickory species. If sprouts of undesirable species are left untreated, growing space created by cutting is quickly re-captured making regeneration of desirable species difficult (McGee and Hooper, 1970; Loftis, 1985; Beck and Hooper, 1986). Control of stump sprouts can be accomplished via mechanical or chemical methods as well as through the use of prescribed fire. Although herbicide applications are effective at eliminating stump sprouts (Loftis, 1985), the cost in both material and labor, issues with chemical usage in ecologically sensitive areas, and/or public concern (e.g., Wagner et al., 1998; Shepard et al., 2004; Miller and Miller, 2004; Guynn et al., 2004) may limit where and when herbicide applications can be performed. In regards to mechanical treatment of stump sprouts, a variety of studies suggest cutting when root carbohydrate reserves are low (e.g., during the growing season) (Kays and Canham, 1991; Babeux and Mauffette, 1994; Belz, 2003) may reduce sprouting, stump survival, and/or subsequent sprout growth (Johansson, 1992a, 1992b; Hytönen, 1994). For example, in western North Carolina, Buell (1940) observed a decrease in the growth of flowering dogwood sprouts when trees were cut in July and early August versus late winter or early spring. Similarly, Belz (2003) recommends that to achieve at least 50% mortality of severed red alder (*Alnus rubra* Bong.) stumps, harvesting should be performed between 7 and 19 weeks after budbreak when root starch reserves are at their lowest levels.

Most of the information on stump sprout dynamics of upland hardwood tree species has been obtained following clearcutting (e.g., McGee and Hooper, 1970; Kays et al., 1988a,b; Weigel and Peng, 2002; Sands and Abrams, 2009). As such, information on how stump sprouts respond to alternative silvicultural treatments, including thinning, partial harvesting methods, and site-preparation activities similar in design to thinning treatments and implemented to promote the development of a robust oak and hickory advance reproduction pool (e.g., Loftis, 1990; Ward, 1992) is limited (Atwood et al., 2009) or altogether lacking. In one of the few studies to examine the effects of overstory density on stump sprout potential and growth in bottomland hardwood forests Gardner and Helmig (1997) found no effect of residual overstory on the percent of water oak (*Quercus nigra* L.) stumps that sprouted, but did document greater stump survival after heavy (60% reduction in basal area) versus light (40% reduction in basal area) thinning. In contrast, Lockhart and Chambers (2007) found no difference in either the proportion of cherrybark oak (*Quercus pagoda* Raf.) stumps that sprouted or stump survival following light and heavy thinnings.

Despite the role of stump sprouts in controlling species composition following stand-replacing disturbance in upland hardwood forests across the Central Hardwood Region (e.g., Beck and Hooper, 1986; Cook et al., 1998; Elliott et al., 1997; Arthur et al., 1997) little quantitative information exists regarding sprout dynamics following less than stand-replacing disturbances. Although not intended to regenerate stands, intermediate silvicultural treatments that reduce stand density have the potential to alter understory species composition and recruitment and, thereby, influence the future

regeneration potential of the stand (e.g., Ward, 1992; Bailey and Tappeiner, 1998; Albrecht and McCarthy, 2006; Yeo and Lee, 2006). In this study, we manipulated stand density during two distinct time periods, the growing season and dormant season, to better understand stump sprout dynamics for some of the most common commercial and noncommercial tree species in the southern Appalachians. Specifically, this study was designed to test the hypotheses that species, reductions in stand density, the season of harvest or cutting along with their interactions have no significant effect on (a) the probability that any given cut tree sprouts; (b) the survival of cut stumps; (c) sprout height; and (d) the area occupied by individual sprouts over a three year time period in mixed-upland oak forests of the southern Appalachian Mountains.

2. Methods

2.1. Study area

This study was conducted on Bent Creek Experimental Forest in Asheville, North Carolina, USA (35.5°N, 82.6°W) located in the Blue Ridge Physiographic Province of the southern Appalachian Mountains. Altitudes range from approximately 600 to 1200 m. Winters are generally cool, with January temperatures averaging 2.3 °C, and summers are warm, with July temperatures averaging 22.3 °C (McNab et al., 2004). Total annual precipitation in the Bent Creek Watershed averages approximately 1200 mm, and is evenly distributed throughout the year.

2.2. Experimental design and data collection

In 2009, 24 – 0.1 ha plots were randomly established in mature fully-stocked upland, mixed-hardwood forest types on Bent Creek Experimental Forest (Table 1). Based on documents describing the disturbance history of Bent Creek along with early study files, ages of stands used in this study were estimated to be between 80 and 100 years. Plots were primarily of mixed-oak species composition, with oaks comprising approximately 52% (range 29–74%) of the overall basal area. At the time of plot establishment, diameter at 1.37 m above ground line (dbh; cm) and species of all live trees ≥ 2.5 cm dbh were recorded. Basal area was mechanically reduced from below by 10%, 20%, 30%, or 40% between January and February, 2009 (dormant season) and again between July and August, 2010 (growing season), with each harvest season and basal area reduction combination randomly applied to three plots. Stumps were cut to an approximate height of 30 cm. Following thinning, basal area ($\text{m}^2 \text{ha}^{-1}$) averaged (standard deviation) 32.7 (7.2), 23.9 (3.7), 23.8 (3.4), and 21.5 (3.2) in the 10, 20, 30, and 40% thinning levels, respectively.

On each cut stump, we recorded: (1) the presence of live sprouts (yes/no); (2) height (m) of the dominant sprout in each clump, and (3) the maximum horizontal diameter (m) of the widest axis of the sprout clump (measured across the center of the stump) and the diameter (m) perpendicular to this axis. All sprout measurements were conducted one, two, and three growing seasons post-harvest. Diameter data were then used to calculate the average area of sprouts clumps, with area modeled as an ellipse.

2.3. Statistical analyses

For nine species in which sample size (Table 2) was adequate (red maple, sweet birch, hickory, flowering dogwood, yellow-poplar, blackgum, sourwood, white oak (*Quercus alba* L.), and chestnut oak (*Quercus prinus* L.)), hierarchical logistic regression implemented with PROC GLIMMIX (SAS Institute Inc., 2011) was utilized to individually model the probability of sprouting one year post-

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