Retention of logging debris to reduce deer browsing and promote forest regeneration

Honors Thesis

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by

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Abstract

One of the most important species in northeastern forest ecosystems is the white-tailed deer (*Odocoileus virginianus*). Browsing by these herbivores can influence patterns of forest regeneration following a timber harvest. Logging debris, or “slash”, has the potential to inhibit deer browsing and enhance forest regeneration in a cutover area. At two heavily logged sites in the Arnot Forest, NY, study plots containing experimental seedlings and natural vegetation were created in May 2004 and monitored thru November 2006. Each plot received one of three treatments: open - cleared of logging debris; tops – tree tops and debris-covered; or fenced - cleared of debris and fenced to exclude deer. Levels of deer browsing in experimental seedlings and natural vegetation, tree seedling growth, and natural vegetation richness, were compared among these treatments. We found significantly higher deer browsing on experimental seedlings (*p* = .0053) and palatable herbaceous vegetation (*p* = .0094) in open plots, than tops-covered or fenced plots. Cumulative deer browsing negatively correlated with mean experimental seedling height at the plot level (*p* = .0296), resulting in higher black cherry (*Prunus serotina*) seedling growth in protected fenced and tops treatments. Additionally, logging debris was found to benefit common management objectives, such as herb richness and relative abundance of desirable timber tree seedlings. We conclude that logging debris left in place after a forest thinning can effectively inhibit deer browsing and promote forest regeneration. The degree of protection afforded by tree tops was intermediate between unprotected and fenced areas. The minimal effort and cost associated with this technique would make it highly preferable to constructing fences to improve regeneration. As white-tailed deer become increasingly overabundant, alternative options for the sustainable regeneration of forests are necessary; the post-harvest retention of logging debris *in situ* provides such an alternative.

Introduction

The white-tailed deer (*Odocoileus virginianus*) is one of the most extensively studied mammal species in the United States. These ungulates are often described as overabundant, especially in eastern North America (Augustine and Calasta 2003; McShea *et al.* 1997; Stromayer and Warren 1997; Jones *et al.* 1993). High abundances of white-
tailed deer result in many ecosystem-level impacts, which have become increasingly apparent (Cote et al. 2004; Rooney and Waller 2003; Rooney 2001; Stout 1998; Schmitz and Sinclair 1997; Hobbs 1996). Indeed, studies have affirmed the role of white-tailed deer as a keystone herbivore in forest ecosystems (Waller and Alverson 1997; McShea and Rappole 1992). Yet the implications of keystone status are complex (Power et al. 1996), and cannot be generalized to all forests. Keystone status notwithstanding, deer have a large impact on forest ecosystems in particular, because these herbivores cause significant alterations in forest vegetation structure and composition (Gill and Beardall 2001; Russell et al. 2001; Augustine and McNaughton 1998; Frelich and Lorimer 1985; Beals et al. 1960; Grahm 1954).

One of the most important influences of white-tailed deer in the landscape is their ability to alter the regeneration patterns of forests. It is clear that browsing can reduce or halt forest regeneration and alter species composition in both harvested and non-harvested northeastern forests (Sage et al. 2003; Stout 1998; Healy 1997; Tilghman 1989; Webb et al. 1956). In recent decades, research has begun to address the relationships between silviculture and deer browsing in northern hardwood systems (Kraft et al. 2004; Horsely et al. 2003; Hughes and Fahey 1991; Behrend et al. 1970; Tierson et al. 1966). However, few have identified natural and practical solutions to what could be described as forest regeneration crisis.

The need for sustainable forestry techniques that reduce deer impacts, while promoting timber productivity and ecosystem recovery, is becoming increasingly urgent. A feasible solution to ameliorate the impacts of white-tailed deer utilizes logging debris, a woody byproduct of logging procedures often referred to as “slash”. Common forestry practices in the Northeast manage post-harvest logging debris in three ways: they may be left to decay in situ, used for firewood or mulch, or entirely removed from the area. Previous studies have documented the benefits of the retention of logging debris for both invertebrates and vertebrates at the community or species level. (Gunnarsson et al. 2004; Moses and Boutin 2001; Bengtsson et al. 1998). Such logging debris also has the potential to mitigate deer browsing and thus promote forest regeneration (Grisez 1960). Nevertheless, unsightly woody materials are traditionally removed for aesthetic reasons or minimal firewood revenue, and the benefits of leaving them in place has yet to receive
widespread attention as a feasible solution. Our study evaluates the potential for logging debris to reduce deer browsing in a northern hardwood ecosystem, and assesses the extent of improved forest regeneration resulting from this process.

Historically, methods of deer control and common forestry techniques have been disconnected. In most efforts to protect forest areas from excessive deer browsing, forest managers have had only two reliable options: 1) using recreational hunting to regulate deer populations or 2) erecting fencing to exclude deer from the protected area. The first method, lethal removal, has been deemed one of the most feasible options for successful control of deer population levels in forests (Jacobson 2001; Behrend et al. 1970). Consequently, hunting is accepted as a necessary forest management technique on both private and public lands in most Northeastern forests (Riley et al. 2003; Kelty and Nyland 1981; Tierson et al. 1966). However, this method alone is not always sufficient to ensure adequate forest regeneration (Cretaz and Kelty 2002), and if hunting is not continuous, forests have much less chance to naturally regenerate (Riley et al. 2003; Brown et al. 2000). The second method, which involves constructing deer exclosures, has enhanced regeneration in many forest types (Harlow and Downing 1970; Ross et al. 1970; Tierson et al. 1966; Webb et al. 1956). Furthermore, fences can be designed to last many years and this can serve as a good long-term solution for improved forest regeneration (Ross et al. 1970; Webb et al. 1956). However, constructing fencing is often undesirable or not possible due to high capital and labor requirements, or subsequent reduced access to the enclosed area (Jacobson 2001).

The integration of a new control technique, functioning within the framework of sustainable forestry management, would provide a third viable alternative. Furthermore, as deer populations increase, practical solutions may be necessary to prevent further stagnation of natural regeneration processes in Northeastern forests. This provided the impetus for our study, the objectives of which were to: 1) to document levels of deer browsing in open versus logging debris-covered areas; 2) to evaluate the impacts of this browsing on seedling growth and survivorship; and 3) to compare natural regeneration in fenced, open, and debris-covered areas. Ultimately, our study provides a simple and effective forest management tool that addresses multiple regeneration objectives in the presence of deer.
Methods

This study was conducted at two interior forest sites in the Arnot Teaching and Research Forest, located at 42.3° N latitude and 76.6° W longitude in Tompkins and Schuyler counties of New York State. The forest covers 1,600 hectares, most of which is mixed hardwood forest in a wide range of successional stages, under multiple management regimes. In the Arnot Forest area, white-tailed deer densities for the nearby townships of Van Etten and Cayuta are calculated annually by the DEC based on reported hunting success. The estimated numbers of deer per square mile for these townships ranges between 4.27 and 8.51 for the years 2003 to 2005. Study activities extended from May 2004 to December 2006.

Prior to silvicultural treatment, the two selected study sites consisted of 80 to 100 year-old even-aged northern hardwoods. A regeneration logging cut in the summer of 2004 left 10 to 20 % of the standing basal area at both sites. To prevent undesirable species from regenerating in the cutover site, American beech (Fagus grandifolia) saplings were cut during the harvest, and a herbicide treatment was performed to limit the spread of the native invasive fern (Dennstaedtia punctilobula). In our study sites, logging debris was intentionally retained following harvest, creating a
matrix of tree tops, log piles and open areas at both study sites. Sites were less than 1 ha in size, situated within logged stands of 20 to 21 ha. At each site, there was a network of evenly distributed skid trails that provided access to each area. In the interior of both sites, a series of 15 plots was established at each site in organized rows between these skid trails. Each row of sample plots consisted of 36 m² areas separated by a minimum of 20 m (Fig. 1).

**Treatments**

Each of the 30 sample plots received one of three treatments; fence, open, or tops. These treatments were arranged in a regular and alternating pattern with one of each in each of five rows of each site (Fig. 1). The treatments were: 1) Fence - The perimeter of the sample plot was enclosed with 1 in. mesh nylon fencing to a height of 2 m. Any large logging debris were removed from the fenced area to simulate cleared space. The fence was intended to prevent deer from entering and browsing within these plots. 2) Open - The area was cleared of logging debris in the same manner as the fenced plots, but deer were not excluded. 3) Tops – The area was initially cleared of logging debris for consistency, but subsequently covered with tree tops and branches, simulating areas left covered with slash following harvest. These three treatments were constructed on plots in a rotating order at each site to minimize potential bias of landscape position (Fig. 1a).

**Experimental Seedlings**

In the northeast sector of 24 of the 30 plots, one year-old black cherry (*Prunus serotina*) and red oak (*Quercus rubra*) tree seedlings were planted about 300 days after harvest. Ten individuals of each species were planted in an alternating pattern in the corner of each plot (Fig. 1b), resulting in a total sample of 480 planted tree seedlings. In the 24 plots seedling heights were measured biweekly from June to August 2005, and once more in June of 2006. Additionally, the number of seedlings with evidence of deer browsing was recorded at each plot at the time of each sampling. A final survey of deer browsing on planted seedlings was conducted during November 2006. Factors other than deer browsing that may have affected seedling growth were inventoried during height measurements. For example, throughout the survey 74% of seedlings showed damage
by insects, and less than 2% were browsed by rabbits. Insect damage and rabbit browsing appeared indiscriminate among species and treatments, with no significant differences in insect or rabbit damage between treatments. Thus, these measures were omitted from further analyses. Also, four plots (1 fenced, 2 open, and 2 tops treatments) with more than 10% invasive fern coverage were removed from some calculations.

Natural Vegetation Surveys

In addition to measurement on the experimental seedlings, surveys of the herbaceous and woody vegetation naturally occurring within each of the 30 sample plots were performed in September 2005 and June 2006. Vegetation was inventoried in 1 m² sample areas within each plot. Survey subplots were located at the plot center, and at the plot perimeter (Fig. 1b). All stems over 3 cm in height were identified to the level of genus and tallied within each subplot. Woody seedlings were identified to species and recorded in the same manner. All stems showing evidence of deer browse in a given subplot were noted.

Quantifying Debris

To accurately describe and quantify the arrangement of woody debris in the study plots, a unique photographic method was implemented. Using a balloon-supported camera, sub-canopy aerial photographs of some plots were taken (Fig. 2). Color selection and histogram tools in Adobe Photoshop software were then used to isolate and measure logging debris in these digital photographs. Based on pixel counts, the percent cover of logging debris was calculated to be between

Figure 2. The left picture shows the balloon-camera sampling device used to obtain aerial photographs. The upper right photograph is an example of an aerial view of a debris covered plot obtained using this method, with the plot boundary drawn over the image. The processed image on the lower right represents the same plot after utilization of color analysis to isolate those pixels representing woody material.
40 and 60% of the total ground area within tops plots (Fig. 2). The average percent cover of woody material, a measure of tops density, increased consistently from the edge to the center of the plot (Fig. 3). Additionally, grid surveys of logging debris height above the ground was performed on these plots. The maximum height of woody material above the forest floor was lower near the perimeter of the plot, and higher near the plot center, where branches were heaped (Fig. 3).

**Figure 3.** Profiles of a logging debris covered plot. The maximum debris height above the forest floor was measured at 1 m intervals on a 6 x 6 meter grid placed over the plot. These height values were then grouped according to distance from the plot edge, and averaged. The percent of tops cover was derived from pixel counts of woody material captured in aerial photographs. The mean percent cover was calculated at 0.25, 0.75, 1.50, and 2.50 meters from the plot perimeter. Both height and percent cover of debris increased toward the plot center. Experimental seedlings were located under this gradient of logging debris protection.

**Statistical Analyses**

To compare browsing of experimental seedlings among treatments, the total number of seedlings at each plot, and the observed number browsed on a given date, were used to calculate the percent of seedlings browsed. The resulting 8 replications per
treatment were then analyzed for significant differences using a fixed-effect ANOVA for individual sample dates. For cumulative results, once an individual seedling had been recorded as browsed it remained in this category from that date forward. Browsing on natural vegetation was analyzed at the plot level in a similar fashion. Percentages were calculated based on the proportion of total palatable stems browsed at a given plot. Browsing was then compared by treatment using fixed ANOVA analysis of selected dates.

Individual seedlings were tagged with identification numbers 1 thru 20 at each plot. This allowed the tracking of survival and the measurements of heights of every seedling throughout the duration of the study. The numbers of dead seedlings per plot on the last sample date were compared among treatments using an ANOVA. The mean height of all seedlings in each treatment was calculated and plotted by sample day. Height measurements were organized by species (black cherry vs. red oak) and treatment (fence, open, or tops) and a fixed-effects ANOVA was used to detect significant differences. To eliminate the slowest growers, the tallest 10, 15, 20, 25, and 30% of each species were isolated. An ANOVA was then used to identify significant differences in seedling height between treatments for these categories.

To determine the effect of deer browsing on seedling height, height growth and browsing were compared at the plot level. Mean black cherry height on the last sample day was calculated for each plot, and these values were normalized. The proportion of black cherry seedlings browsed was also calculated by plot, and the combined values were graphed and analyzed with a GLM linear regression. Plots with 10% or more invasive fern cover (N=4) were omitted from these results. In addition, red oak seedlings were omitted from these calculations due to minimal vertical growth.

For each treatment, the presence or absence of 26 herb and seedling genera were recorded yielding a measure of richness. These binary data were then analyzed for overlap between treatments using Jaccard’s Coefficient \([J = j/(a + b - j)]\) where \(a\) is the number of genera found in a given treatment, and \(b\) is the number found in another treatment, and \(j\) is the number found in both.

Final tallies of seedling species from the second natural vegetation survey were summed for each treatment. These data were categorized as desirable timber or
undesirable seedling species. The absolute abundances of non-timber species at each plot and mean numbers were compared. Counts of seedling species were then normalized by treatment to yield a measure of relative abundance for each species. The proportions of each species contributing to the total abundance of a particular treatment were split into either timber or non-timber categories and the percent relative abundance for each species was calculated.

Results

Effect of Treatment on Deer Browsing

Levels of deer browsing were higher in open areas than in areas with logging debris. Over the course of the seven browse surveys on experimental seedlings, differences between treatments became increasingly significant after the third sample (Fig. 4). Surveys in both June and November of 2006 yielded strongly significant differences in the percent of seedlings browsed among treatments (p = .0078 and p =

![Figure 4](image-url)
The effect of treatment on deer browsing was observed at both sites and for both black cherry and red oak seedlings. By the final survey in November of 2006, more than 56% of the seedlings in open areas had been browsed by deer. In contrast, only 21% of the seedlings under tree tops, and 1% of the fenced seedlings, had been browsed.

A similar pattern of treatment effect on deer browsing was found on naturally occurring vegetation within the sample plots. This did not include all vegetation however, and although all stems in the survey area were checked for deer browsing, the only abundant herbaceous plants consistently browsed by deer were red-berried elder (*Sambucus racemosa*) and raspberries (*Rubus spp*). Nevertheless, these species were a good indicator of deer browsing preferences, because little variation in their abundance was observed between treatments (N[fence] = 60; N[tops] = 56; N[open] = 63). *Rubus* was an especially good indicator, and its stems were far more abundant than *Sambucus* (N[Rubus]=164; N[Sambucus]=15) during the first survey.

By the first sample date, the percent of these palatable stems browsed at each plot was significantly different (p = .0094) between treatments (Fig. 5). Browsing of the palatable species was far more common in open plots than debris covered plots. During the first survey, 41% of palatable stems in open plots showed signs of browsing, while only 14% of stems in tops treatments and no stems in fenced areas were browsed. Additionally, few tops plots had browsing rates of 20% or higher, whereas many open

![Figure 5](image-url)
plots exceeded 60%. No browsing on herbaceous vegetation was observed during the second survey in September, 2006. This was likely due to seasonal variations in browse preference, as evidenced by the extensive browsing on experimental seedlings at this time (Fig. 4).

**Experimental Seedling Growth and Survival**

Throughout the study survivorship rates of >94% were observed for the experimental seedlings, resulting in no significant differences in survivorship among treatments. Seedling height growth varied by site, but to a greater extent by species. By the last sample date, red oak seedlings had attained mean height of 32.6 cm (N=240), compared with a mean height of 51.5 cm for black cherry (N=240), despite starting at comparable sizes. Due to such slow height growth, no significant differences in height between treatments were observed for red oak seedlings. In contrast, by the final survey mean black cherry height was much greater in fenced and tops treatments ($\bar{x} = 55.4$ cm

![Effect of Treatment on Seedling Height Gain](image)

**Figure 6.** Line graph displaying mean black cherry seedling height gain for each treatment in relation to sample day. Less variation between treatments was observed for earlier samples, with differences in seedling height growth becoming more visible in the final sample.
and 50.6 cm respectively), than open areas ($\bar{x} = 48.0$ cm). To account for initial differences in mean seedling heights among treatments, the mean height gain was calculated for black cherry seedlings in each treatment for each sample interval. By the last sample day, fenced and tops plots had achieved the greatest height growth relative to their initial condition, and open plots the least (Fig. 6). However, some black cherry seedlings showed minimal vertical growth, which likely accounted for lack of significant differences among treatments. When these slow growers were omitted from calculations, leaving only the tallest 25%, differences in mean black cherry heights among treatments were significant ($p < .05$).

Browsing had a strong impact on black cherry seedling growth at the plot level (Fig. 7). There was a strong negative correlation between the percent of seedlings browsed at a given plot, and normalized mean seedling height ($p[\text{linear regression}] = .0296$). The observed relationship between browsing and mean black cherry height occurred independent of treatment.

**Figure 7.** Scatter plot with linear regression showing the indirect relationship between plot-level black cherry browsing and normalized mean seedling height. Fern covered plots were omitted from this analysis.
Flora Richness

During surveys of natural vegetation a total of 26 herb and seedling genera were recorded (Table 1). At both study sites, herbaceous vegetation in fenced areas was most diverse ($N[\text{genera}] = 14$), followed by tops treatment plots ($N[\text{genera}] = 10$), and then open treatments ($N[\text{genera}] = 8$). Most tree seedling genera occurred in all treatments; however, few herbs were found across all three treatments. Herb richness was most similar between fence and tops treatments ($Jaccard’s = .41$), with less generic overlap occurring between fence and open, or tops and open ($J = .38$ and .39 respectively).

Table 1. List of the herb and seedling genera found in all treatments at both sites and their respective presence or absence in each treatment. Based on data from both survey dates in September 2005 and June 2006.

| Genera     | Common Name        | Treatment |  |  |  
|------------|-------------------|-----------|---|---|---
|            |                   | Fence    | Open | Tops |
| Aster      | Asters            | 1        | 1   | 0  |
| Eupatorium | Bonesets          | 1        | 1   | 1  |
| Fragaria   | Wild Strawberry   | 0        | 0   | 1  |
| Lonicera   | Honeysuckle       | 1        | 0   | 1  |
| Lycopus    | Bugleweeds        | 1        | 0   | 0  |
| Medeola    | Cucumber Root     | 0        | 1   | 0  |
| Parthenocissus | Woodbine     | 1        | 0   | 0  |
| Phytolacca | Pokeweed          | 0        | 1   | 0  |
| Polygonatum| Solomon's Seals   | 1        | 0   | 0  |
| Prenanthes | Rattlesnake Roots | 0        | 0   | 1  |
| Rhus       | Poison Ivy        | 0        | 0   | 1  |
| Rubus      | Raspberry/Blackberry | 1    | 1   | 1  |
| Sambucus   | Elders            | 1        | 1   | 1  |
| Saponaria  | Soapwort          | 1        | 0   | 0  |
| Solidago   | Goldenrods        | 1        | 1   | 1  |
| Trientalis | Starflower        | 1        | 0   | 0  |
| Uvularia   | Bellworts         | 1        | 0   | 1  |
| Verbascum  | Mulleins          | 1        | 0   | 0  |
| Viola      | Violets           | 1        | 1   | 1  |
| **Herb Diversity** |            | 14 | 8  | 10 |
| Acer       | Maples            | 1        | 1   | 1  |
| Betula     | Birches           | 0        | 0   | 1  |
| Fagus      | Beeches           | 1        | 1   | 1  |
| Fraxinus   | Ashes             | 1        | 1   | 1  |
| Populus    | Aspen             | 1        | 1   | 1  |
| Prunus     | Cherry            | 1        | 1   | 1  |
| Quercus    | Oak               | 1        | 1   | 1  |
| **Seedling Diversity** |        | 6  | 6  | 7  |
| **Total Genera Diversity** |        | 20 | 14 | 17 |
Tree Seedling Stocking and Relative Abundances

During the vegetation surveys, an area of 60 m² was surveyed at both sites (20 m² per treatment) and tree seedlings were identified to species. During the second survey in June 2006, the number of seedlings in open treatments was highest (N=105), followed by fenced (N=80), and tops (N=33) treatments. Despite its higher stocking, 66% of seedlings in open areas were categorized as undesirable timber species (American beech, pin cherry, or striped maple). In contrast, only 40% of tree seedlings in fenced, and 33% of seedlings in tops, were classified as undesirable. Therefore, in open plots much of the increased seedling production was composed of non-timber seedling species (Fig. 8). Additionally, the relative abundance of more desirable timber seedlings was highest in fenced areas (56%), followed by tops (45%), and then open (32%). Red maple and sugar maple were the most abundant timber species in all treatments (Fig. 9).

![Abundance of Undesirable Seedlings](image)

**Figure 8.** Box plots of totaled *Fagus grandifolia*, *Prunus nigra*, and *Acer pennsylvanicum* abundances by plot for the last survey in June 2006. Open plots had a greater potential for high abundances of undesirable species.
Discussion

Our findings indicate that logging debris left in place after a timber harvest can protect seedlings from deer browsing, and thus promote forest regeneration. The presence of residual debris reduced the proportion of experimental black cherry and red oak tree seedlings that were browsed by deer. The protective effect against browsing was not limited to tree seedlings as levels of browsing on herbaceous vegetation were greater in open areas than debris-covered or fenced areas. This supports observations made by T.J. Grisez (1960), who found similar patterns of deer browsing ten years after a harvest in a mixed hardwood forest with much higher deer densities. Therefore, logging debris can act as natural fencing, excluding some deer, reducing the impacts of browsing, and encouraging forest regeneration.
Independent of treatment, deer browsing was observed to control mean black cherry seedling height. This finding supports those of previous studies, designating white-tailed deer as a dominant herbivore controlling post-harvest forest regeneration (Horsley et al. 2003; Behrend et al. 1970; Tierson et al. 1966). Therefore, in any microsite where levels of deer browsing are high, mean seedling heights are likely to be limited. As expected, the height growth of experimental black cherry seedlings in unprotected areas was reduced by deer browsing, and thus seedlings grew taller in debris-covered and fenced areas. Similar results were described by Grisez (1960), who found a greater proportion of black cherry saplings of taller height classes growing through logging debris. Consequently, improved seedling and sapling growth rates under debris, resulting from protection from deer browsing, is likely to speed the regeneration of forests in areas where deer are overabundant, and the effect is likely to be long-lasting.

Various forest management objectives can be achieved through the retention of logging debris. In addition to the benefits of woody debris retention for small mammal and invertebrate communities (Gunnarsson et al. 2004; Moses and Boutin 2001; Bengtsson et al. 1998), debris can improve herb richness and support herb communities that are much different from those in open areas. The selective browsing of deer on specific understory species in a post-harvest area may be the cause of these differences in herb species richness (Kraft et al. 2004; Cretaz and Kelty 2002). Selective browsing may also be a factor in controlling observed differences in the abundance of undesirable tree seedlings among treatments, with a far greater potential for large numbers of undesirable species in open, unprotected, areas. Our results indicate that greater relative abundance of desirable timber species seems to be achieved through complete deer exclusion (fencing), and that tops can achieve intermediate results. In this study, desirable seedling abundances varied a great deal by species, but debris treatments harbored a greater total relative abundance of these species than did open areas.

There are some logical potential mechanisms of protection provided by residual tops. Logging debris that is left in place can have impacts on the microclimate that indirectly affect seedling growth. Reduced light and competition, moderated temperature extremes, and increased nutrient availability are all possible secondary effects of residual logging debris that may alter seedling establishment and growth. However, deer
browsing was the primary mechanism controlling forest regeneration at our study sites. This was demonstrated by significant reductions in seedling growth and herb richness in open versus fenced treatments, the only differences between these treatments being that deer were excluded from the latter. Similarly, areas cleared of debris were browsed more often and to a greater extent than tops-covered areas. Therefore, an open plot may have a greater stocking of established seedlings, but due to higher rates of browsing in these areas, few seedlings attain a height in which they are able to escape deer herbivory. This was observed in our experimental black cherry seedlings, where the superior growers were significantly taller in tops treatments than open treatments. While residual logging debris may impact many environmental processes, one of the promising outcomes was the protection of superior growers from deer browsing, possibly allowing these seedlings to establish future forest generations.

The amount of protection afforded by tree tops would depend on multiple interrelated factors, such as deer population density, debris height and density, the rate of settling of the tops, and the tree seedling species of concern. A favorable debris height and density would be expected to maximize seedling height growth and afford a high degree of protection. It is likely that seedlings under dense and tall debris were limited by light availability, whereas seedlings under little cover were not sheltered from browsing. An optimal height-density ratio of tops protection likely depends on localized site conditions, the specific light requirements of a tree species, and deer density. Thus, further research is needed before prescriptions can be made as to the height, density and total amount of debris needed to ensure adequate stocking. Furthermore, logging debris retention may not be the optimal strategy for regenerating all tree seedling species, such as American beech, which often is not browsed by deer. Red oak, however, is likely to benefit from logging debris as it reaches greater height classes. Mean vertical growth for red oak had just exceeded 32 cm by our last sample date. A similar study found inconsistent results for seedlings of many species under 30 cm (Grisez 1960). Therefore, red oak seedlings in our plots may have simply not yet achieved a height in which deer browsing would limit maximum height growth.

Variability and difficulties notwithstanding, the retention of logging debris could be an excellent tool for sustainable management of northeastern hardwood forests. The
results of this study indicate that retention of logging debris may be essential for improved rates of forest regeneration, exemplified by black cherry seedling growth. In addition, the protection from deer herbivory afforded by residual tree tops also functioned to provide a refuge for herb species that may be preferentially browsed by white-tailed deer. This led directly to higher herbaceous diversity in debris-covered areas, and likely improved overall site diversity. Furthermore, logging debris may act to reduce the abundance of undesirable seedling regeneration, thus reducing the future time, effort, and cost spent on timber stand improvement measures directed at favoring desirable tree species.

As an added value to potential timber regeneration, numerous further benefits to ecosystem recovery could accrue when woody debris is left on site following a timber harvest. Plant diversity is likely to increase, as different species thrive in contrasting and more textured microclimatic conditions, and as some are protected directly from deer browsing. Similarly, the habitat complexity and buffering abilities of downed woody debris can positively impact many forest floor biota. Most importantly, the forest ecosystem is likely to recover faster with logging debris retention, and much is due directly to deer browsing control. Consequently, logging debris retention is an affordable and successful strategy, and could prove to be an essential forest management technique in the northeastern U.S., especially where deer are overabundant.

References


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