CANOPY OPENINGS AND WHITE-TAILED DEER INFLUENCE THE UNDERSTORY VEGETATION IN MIXED OAK WOODLOTS[1]

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Abstract: Effects of canopy opening and white-tailed deer on ground level vegetation are being assessed in south-central Pennsylvania. Herbaceous plants and woody seedlings are being monitored in three unevenaged, mixed oak woodlots at Gettysburg National Military Park. Canopy opening levels on 0.20 ha treatment units were closed (~100% canopy), small (50-60% canopy) and large (0% canopy). Number of white-tailed deer during April have averaged about 0.40 deer per ha since 1992. Overstory treatments were conducted in March 1993. Fences to exclude deer were installed on one-half of the understory inventory plots. Before treatment inventories (1992) of the July herbaceous vegetation indicated 30% of the ground was covered by broadleafs, grasses and vines. Total herbaceous coverage increased to 54% of the area in the first growing season after treatment. Woodlot, canopy opening and fencing significantly influenced the coverage of herbaceous vegetation. Overall, total herbaceous coverage increased from 38% in the closed canopy treatment to 50% and 75% in the small and large canopy treatments, respectively. Compared to before treatment values, overall total herbaceous coverage in the first growing season after treatment increased 19% on all unfenced plots and 30% on all fenced plots. Before treatment inventories of the woody vegetation recorded an average of 5.6 shrub and 4.0 tree species seedlings per m^2. In the first growing season after treatment, number of shrub and tree seedlings increased to 6.7 and 8.6 stems per m^2, respectively. Ash dominated the tree species with an average of 2.0 seedlings per m^2 before treatment and 2.5 seedlings per m^2 after treatment. Average number of oak seedling in the first growing season after treatment (0.9 per m^2) was the same as before treatment. Woodlot was the only factor that consistently influenced the number of before and after treatment seedlings. Before treatment average numbers of shrub and tree seedlings were 12.3, 6.9 and 9.5 per m^2 for Bushman Hill, Herr Ridge and Powers Hill woodlots, respectively. In the first growing season after treatment, average number of shrub and tree seedlings for Bushman Hill, Herr Ridge and Powers Hill increased to 15.2, 7.8 and 13.1 per m^2, respectively. Overall, there were 2.1 shrub species and 3.7 tree species germinates in the first growing season after treatment. Most abundant germinates were ash ($0.6/m^2$), grape ($1.7/m^2$), redbud ($0.2/m^2$) and yellow-poplar ($2.9/m^2$). Canopy treatment and litter conditions, but not fencing, significantly influenced the abundance and species composition of the germinates.

INTRODUCTION

Gettysburg National Military Park (GNMP) was established in 1895 to commemorate the July 1863 Civil War battle. Originally established under the US War Department, GNMP was transferred to the National Park Service in 1933. GNMP presently covers about 1560 ha, with 643 ha occupied by woodlots. These woodlots range in size from 2 to 24 ha.

Before the battle, the woodlots were important cultural resources for the residents. Historic photographs and documents, and recent research reports (Fairweather and Cavanaugh 1990, Storm and others 1994) suggest a general pattern to the 1863 condition and subsequent development of these woodlots. Open-grown white oak (*Quercus*

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alba L.) trees were the dominant vegetation in 1863. In 1993, there were about 15 residual white oak trees per ha that were >135 years old. These trees typically had rapidly tapering boles with wide spreading crowns that had large diameter branches originating near the ground. Their diameters at 1.4 m above ground (DBH) generally were >60 cm. A second group of trees became established around 1900 (±25 years) when the understocked woodlots were retired from active agriculture. This group of trees was mainly northern red oak (*Quercus rubra* L.), black oak (*Quercus velutina* Lam.) white oak, bitternut hickory (*Carya cordiformis* (Wangenh.) K. Koch.), mockernut hickory (*Carya tomentosa* Nutt.) and shagbark hickory (*Carya ovata* (Mill.) K. Koch). These trees were generally between 30 and 60 cm in diameter in 1993, with closed stand architecture of slowly tapering boles with narrow crowns. A third group of trees developed in response to occasional openings in the canopy. These trees were mainly black cherry (*Prunus serotina* Ehrh.), flowering dogwood (*Cornus florida* L.), mazzard cherry (*Prunus avium* L.), white ash (*Fraxinus americana* L.) and hickories. In 1993, the third group of trees was generally between 3 and 30 cm in diameter.

Storm and others (1994) evaluated the overstory and understory of six GNMP woodlots. They concluded that the species composition, number and size of the trees >12 cm in diameter should be capable of maintaining an acceptable woodlot appearance for at least 25 years. They also concluded that there was a variety of tree species present in the seedling and sapling sizes (stems<12 cm in diameter). Overall there was an adequate number of seedlings (average of 23,584 per ha) but the number of saplings (826 per ha) was about one half the number needed to sustain the woodlots. Furthermore, oak species accounted for 44% of the number of trees in the overstory but only 6% of the sapling-sized stems.

White-tailed deer (*Odocoileus virginianus*) browsing and woodlot management practices may be influencing the height growth and species composition of the understory at GNMP (Bowersox and others 1993, Tzilkowski and others 1993). Average number of white-tailed deer on GNMP during April have increased from 0.25 deer per ha in 1987 to about 0.40 deer per ha since 1992. These deer densities far exceed the Pennsylvania Game Commission management goal of 0.08 deer per ha for the surrounding county. Shrub and tree seedlings recorded in 1987 on demonstration plots located in five GNMP woodlots averaged 7.1 per m^2 in the fenced plots and 7.3 per m^2 in the unfenced plots. By 1991, densities dropped to 6.1 in the fenced areas and 4.2 in the unfenced areas. Loss of seedlings between 1987 and 1991 was substantial for white oak, which dropped from 2.6 to 0.8 per m^2 in the fenced areas and from 3.7 to 0.5 per m^2 in the unfenced areas.

Maintaining these woodlot areas as tree-dominated communities is important to the park's mission to preserve the historic scene. Resource managers want to manage these woodlots to sustain an unevenaged structure. However, the current conditions have raised a concern for the future of these woodlots. They were created under frequent partial cutting practices before 1863 and a change in land use about 1900. There has been no tree cutting activity since 1895. The canopy trees are at or are approaching maturity. The existing woodlots were established at a time when there were no deer. Today's deer density is very high and may be influencing the understory vegetation. A research project has been developed and is being conducted to provide a basis for actively managing these woodlots. This project was designed to evaluate the effects of various size openings in the canopy, with and without white-tailed deer, on understory vegetation. This paper reports on the first growing season responses to these treatments.

PROCEDURES

The gently rolling topography of GNMP is in the Piedmont physiographic region (Lull 1968) of south-central Pennsylvania. Regeneration potential is being evaluated in three mixed oak woodlots. These woodlots are Bushman Hill (22 ha), Herr Ridge (17 ha) and Powers Hill (21 ha). Site quality was about average, and if occupied by evenaged stands the site index for oak would be ≥ 70. A more complete description of the site, soil and vegetation conditions was presented by Bowersox and others (1993).

Locations of the three replications of three canopy treatments in each of the woodlots were selected in April 1992 (Bowersox and others 1993). Felling of the canopy trees was conducted in March 1993. Directional felling was used

to uniformly distribute the residual over the 0.20 ha circular plot. Boles and branches were cut to place all material within 1 meter of the ground. No material was removed from the treatment units. Canopy treatments to the 0.20 ha areas were:

1. Closed. No changes in the overstory. Average stocking levels (based on standards developed for upland central hardwoods by Roach and Gingrich 1968) were 115, 100 and 99% for Bushman Hill, Herr Ridge and Powers Hill, respectively.

2. Small. Overstory canopies were reduced by single tree removals to achieve a modified structure (Bowersox and others 1993) goal at 50 to 60% of fully stocked level. Average stocking levels after tree felling were 53, 55 and 52% for Bushman Hill, Herr Ridge and Powers Hill, respectively.

3. Large. All stems >2 cm DBH were felled.

Wire fences 1.2 m high to exclude white-tailed deer were installed in August 1992. Estimates of the free-ranging white-tailed deer April densities for the unfenced areas have been based on actual counts since 1987 (Storm and others 1989, Storm and Tzilkowski 1992). These annual April counts are scheduled to be continued through 1997.

Abundance, composition and structure of understory vegetation were measured before and after the canopy treatments were executed. All understory inventory plots were randomly located in the central 314 m^2 of each 0.20 ha treatment unit to minimize the effect of adjacent community and site conditions. Three pairs of fenced and unfenced 2.0 m^2 circular plots were established in each 0.20 ha treatment unit to inventory the naturally established herbaceous and woody plant community. There were 27 pairs of fenced and unfenced natural regeneration plots per canopy treatment for all study woodlots. July coverage of broadleaf plants, grasses and vines on each plot was ocularly estimated to the nearest 5%. Similarly, coverage by individual herbaceous species was inventoried on a subset (n=9) of the plots. Total herbaceous was the summation of inventory categories, which due to layering, overlap and inclusions, may exceed 100%. Size and number of stems per woody species that were $\leq$ 1.50 cm in height were inventoried in August. Species were placed in Oak, Other Tree, Shrub or Total groups for some analyses. A list of species within each group is presented in Table 2.

A second set of plots was established to measure the abundance and species composition of new woody species germinates. To preserve known and unknown archeological resources in each woodlot, no disturbance to the soil was permitted when the canopy trees were felled. Seedbed conditions of no litter removed and litter removed were established to evaluate the effect of an undisturbed litter layer on the abundance and species composition of the new germinates. New woody species germinates were recorded in a set of two paired fenced and unfenced 4.0 m^2 circular plots per treatment unit. Each set of plots were randomly located within the central 314 m^2 of each treatment unit. One half of each plot was randomly assigned to each litter condition. Litter-removed treatments were conducted in May 1993 with all identifiable leaf and twig material manually removed to expose the humus or mineral soil surface. There were 18 pairs of fenced and unfenced germination plots (each with a 2.0 m^2 sub-plot for no litter removed and a 2.0 m^2 sub-plot for litter removed) per canopy treatment and a total of 54 paired plots for the study. Number of new germinates by species were recorded in August.

Analysis of variance was used to test for significant main and appropriate interaction factors on herbaceous coverage, number of seedlings and number of germinates. Mean separations were performed on those parameters which showed significant treatment effects with Tukey's method of Multiple Comparisons. Significance at the 0.05 level was used in all cases.

RESULTS

Before treatment inventories indicated 43 species of broadleaf plants, 6 species of grasses and 6 species of vines present in the three woodlots. In the first growing season after treatment, there were no overall changes in the presence of specific species on specific plots. Individual plots had an average of 8 species of broadleaf plants (1 to 14

species per plot), 1 species of grass (1 to 3 species per plot) and 3 species of vines (1 to 5 species per plot). Overall, herbaceous vegetation coverage averaged 2% for grasses, 6% for vines, 23% for broadleaf plants and 31% for total herbaceous. There was a significant difference in coverage of broadleaf plants and total herbaceous among the woodlots, and total herbaceous for canopy treatment. Bushman Hill and Powers Hill had significantly greater total herbaceous coverage (41%) than was measured at Herr Ridge (11%). Treatment units designated to receive small canopy and large canopy treatment had total herbaceous coverage of 33 and 37%, respectively. These values were significantly different from the total herbaceous coverage of 21% for those units designated for closed canopy treatment. There was no significant difference between the units designated for small and large canopy treatment. Otherwise, coverage values for all herbaceous vegetation groups were similar among the inventory plots. When averaged over woodlots, before treatment coverage values for non-fenced and fenced plots by canopy treatment ranged from 0 to 6% for grasses, 16 to 26% for broadleaf plants, 2 to 8% for vines and 18 to 37% for total herbaceous (Table 1).

Table 1. Average[1] coverage of herbaceous plant groupings by non-fenced and fenced plots, for before and after canopy treatments.

Canopy Treatment		Grasses Fenced		Broadleaf Plants Fenced		Vines Fenced		Total Fenced	
		No	Yes	No	Yes	No	Yes	No	Yes
		(----------%----------)							
Closed	Before	0	1	16	22	2	4	18	27
	After	1	2	21	27	12	14	34	42
Small	Before	1	2	24	26	5	8	30	36
	After	3	2	26	44	10	14	39	60
Large	Before	4	6	25	22	7	8	36	37
	After	11	7	31	55	23	22	65	84

[1] Based on 27 plots per canopy - fence condition.

As compared to before treatment values, canopy treatment resulted in significant increases in the first growing season coverage values for broadleaf plants, vines and total herbaceous. Overall, large canopy treatment had coverage increases of 19% for broadleaf plants, 15% for vines and 38% for total herbaceous. These increases were significantly greater than the 5 to 10% increases for broadleaf plants and vines in the closed and small canopy treatments. Overall, coverage of broadleaf plants and total herbaceous increases were significantly greater on the fenced plots than on the non-fenced plots. Broadleaf plant coverage increased by 5% on the non-fenced plots and 18% for the fenced plots. The increase in total herbaceous coverage was 18% for non-fenced plots and 29% for fenced plots.

Total herbaceous coverage in the first growing season after treatment was significantly different among the woodlots. Overall, total herbaceous coverage at Bushman Hill (58%) and Powers Hill (64%) were significantly different from the coverage at Herr Ridge (41%). Total herbaceous coverage at Bushman Hill and Powers Hill were not significantly different from each other. Coverage values for all groups of herbaceous vegetation were significantly different among canopy treatments. In all cases and when averaged over woodlots and fencing treatments, closed and small canopy treatment coverage values were not significantly different from each other but they were significantly different from the values for the large canopy treatment. Total herbaceous coverage averaged 38, 49 and 75% for closed, small and large canopy treatments, respectively. Fencing resulted in significantly different coverage values for broadleaf

plants and total herbaceous. Unfenced plot coverage averaged 26% for broadleaf plants and 42% for total herbaceous whereas fenced plot coverage averaged 42 and 62%, respectively. Averaged over woodlots, first growing season after treatment coverage values for non-fenced and fenced plots by canopy treatment ranged from 1 to 11% for grasses, 21 to 55% for broadleaf plants, 10 to 23% for vines and 34 to 84% for total herbaceous (Table 1).

Total number of before treatment shrubs and tree species of stems >2 cm DBH was 24 for all woodlots. Individual woodlots ranged from 17 to 24 species. On the individual treatment plots, there was an average of 4.8 species in the before treatment inventories. There was an average of 5.6 shrub seedlings per m^2 and 4.0 tree seedlings per m^2 for the three woodlots (Table 2). *Rubus* spp. with 2.3 stems per m^2 and spicebush (*Lindera benzoin* L.) with 1.6 seedlings per m^2 accounted for a majority of the shrub seedlings. Ash dominated the tree species with an average of 2.0 seedlings per m^2. There was an average of 0.9 Oak seedlings per m^2. The seedlings were dominated by stems in the ≤ 25 cm height class. Oak, Other Tree and Shrub species groups had 2, 9 and 20%, respectively, of the Total in the >25 cm height classes. There were no significant differences in the number of Oak, Other Tree, Shrub and Total seedlings between the plots assigned to be fenced and those to be unfenced. Overall, average Total seedlings per m^2 were significantly different for Bushman Hill (12.3), Herr Ridge (6.9) and Powers Hill (9.5) (Table 2). The average number of Oak seedlings per m^2 at Bushman Hill of 2.1 was significantly different from the 0.2 and 0.3 per m^2 seedlings at Herr Ridge and Powers Hill, respectively.

Table 2. Average[1] before and after treatment number of seedlings per m^2 for the three woodlots, by species group[2].

Species-Time		Bushman Hill	Herr Ridge	Power Hill	Overall
		(----------Number of Stems per Square Meter----------)			
Oak	Before	2.1a	0.2b	0.3b	0.9
	After	2.1a	.2b	.3b	.9
Other Tree	Before	4.4a	1.0b	3.9a	3.1
	After	6.4a	1.2b	6.0a	4.6
Shrub	Before	5.8a	5.6a	5.3a	5.6
	After	6.6a	6.3a	6.9a	6.6
Total	Before	12.3a	6.9c	9.5b	9.6
	After	15.2a	7.8b	13.1a	12.1

[1] Based on 54 plots per woodlot - time of inventory. Woodlot means within species group, by time, with the same letter were not significantly different at the 5% level.

[2] Oak included black, chestnut, northern red, scarlet and white.

Other Tree included American elm, bitternut hickory, black cherry, black gum, black walnut, eastern red cedar, hackberry, mazzard cherry, mockernut hickory, Norway maple, pignut hickory, red maple, shagbark hickory, sugar maple, white ash and yellow-poplar.

Shrub included blackhaw, euonymous, flowering dogwood, grape spp., Japanese barberry, redbud, rose spp., rubus spp., sassafras, serviceberry, spicebush and witch-hazel.

Over all woodlots, there was an increase in the average number of species and seedlings per plot in the first growing season after overstory treatment. There was an after treatment average of 5.4 species per plot, and 6.6 shrub species seedlings and 8.6 tree species seedlings per m^2. For the Shrub group, spicebush and *Rubus* spp. continued to have the most abundant seedlings with 1.8 and 2.6 stems per m^2, respectively. The Other Tree group continued to be dominated by ash which increased to 2.5 stems per m^2 but there was a notable gain with yellow-poplar (*Liriodendron tulipifera* L.). Yellow-poplar increased from 0 seedlings before treatment to 0.9 seedlings per m^2 after treatment. There was no change in the average number of Oak seedlings. There was an increase in the relative number of seedlings in the >25 cm height classes but none of the increases were significantly related to any of the treatments. Oak, Other Tree and Shrub groups had 3, 14 and 34% of the Total seedlings in the >25 cm height classes.

As with before overstory treatment values, woodlot continued to be a significant factor in the number of seedlings present after treatment in the Oak, Other Tree and Total groups. Average woody species seedlings per m^2 of 7.8, 13.1 and 15.2 for Herr Ridge, Powers Hill and Bushman Hill, respectively, were significantly different from each other (Table 2). Average Oak seedlings per m^2 at Bushman Hill (2.1) were significantly different from those at Herr Ridge (0.2) and Powers Hill (0.3). Average Other Tree seedlings per m^2 at Bushman Hill (6.4) and Powers Hill (6.0) were significantly different from those at Herr Ridge (1.2). There were no significant differences in the number of Oak seedlings at Herr Ridge and Powers Hill and the number of Other Tree group seedlings at Bushman Hill and Powers Hill. The only other significant treatment effect was with canopy opening for Other Tree. Average number of Other Tree seedlings per m^2 in the closed canopy (1.8), small canopy (2.7) and large canopy (2.3) treatments were significantly different from each other. This response was mainly due to the number of ash seedlings.

There was an average of 2.1 shrub germinates and 3.7 tree germinates per m^2 in the first growing season after treatment. There were seven shrub species that produced a least one germinate. Redbud (*Cercis canadensis* L.) and grape (*Vitis* spp.) had the most abundant shrub species germinates with 0.2 and 1.7 per m^2, respectively. Overall, 11 tree species produced at least one germinate. Ash and yellow-poplar had the most abundant tree species germinates with an average of 0.6 and 2.9 per m^2, respectively. Number of ash, grape, redbud, yellow-poplar, Total Tree, Total Shrub and Total germinates were significantly affected by woodlot, canopy treatment and litter treatment but not by fencing. Except for ash and yellow-poplar, all of these species groups also had significant canopy x litter interaction effects.

Ash was the most abundant before-treatment tree species in the understory of the woodlots. The number of germinates was greatest for the intact litter condition and for the small canopy opening condition (Table 3). In contrast, yellow-poplar seedlings were not present in the before treatment woodlot conditions. However, as the size of canopy opening increased and particularly when the litter was removed, the number of yellow-poplar germinates increased substantially (Table 3). Number of germinates for redbud and grape were differentially influenced by canopy and litter treatment. Litter retained or removed had little effect on germination when the canopy was closed (Table 3). However when openings were made in the canopy, the number of germinates was greater when the litter was removed.

SUMMARY AND CONCLUSIONS

Canopy opening and fencing to exclude deer treatments have been applied in previously unmanaged, unevenaged mixed oak woodlots at GNMP. Abundance, composition and structure of understory herbaceous and woody vegetation was inventoried before treatment and in the first growing season after treatment. Herbaceous vegetation in the first growing season after treatment was responsive to size of opening in the canopy and fencing. Broadleaf plants and vines were more responsive to treatments than were the grasses. Broadleaf plants and vines also had substantial after treatment increases in coverage with increased canopy removal. In addition, broadleaf plants had greater coverage where white-tailed deer were excluded.

Richness of shrub and tree species in the before and after treatment inventories indicated that the conditions were favorable for establishing natural regeneration. In addition, canopy opening and litter conditions could be adjusted to

Table 3. Average[1] number of germinates in the first growing season after treatment for ash, yellow-poplar, grape, redbud, all tree, all shrub and total, by canopy opening and litter treatment.

Species	Closed Canopy Litter Removed		Small Canopy Litter Removed		Large Canopy Litter Removed	
	No	Yes	No	Yes	No	Yes
	(----------Number of Germinates per Square Meter----------)					
Ash	0.4	0.3	1.3	0.8	0.7	0.3
Yellow-poplar	.3	.3	1.5	5.0	3.2	7.2
Grape	.1	.4	.4	4.4	.8	3.8
Redbud	.1	.0	.2	.4	.1	.6
Total Tree	.8	.6	3.1	5.8	4.1	7.6
Total Shrub	.6	.4	.9	5.0	1.1	4.6
Total	1.4	1.0	3.9	10.8	5.3	12.2

[1] Based on 18 plots per canopy - litter condition.

influence the abundance and species mixture of new germinates from natural seed sources. However, the initial size and apparent height growth of the seedlings were of major concern. There was some increase in the relative number of seedlings >25 cm tall in the first growing season after treatment but the increase was small even where the seedlings were protected from white-tailed deer. Before treatment overstory interference on the seedlings' opportunity to grow, and frequent foraging by white-tailed deer may have resulted in seedlings with low energy reserves and poor vigor. The slow height growth of the tree seedlings combined with the rapid response in coverage by the herbaceous vegetation raises a concern about the potential application of large canopy openings to regenerate these woodlots.

Abundance, composition and structure of herbaceous vegetation, shrub and tree seedlings in the second growing season after treatment have been inventoried in 1994. Additional germinates in the second growing season have been recorded. These data and additional data to be collected in the fourth growing season after treatment (1996) will be used to develop management recommendations for the unevenaged mixed oak woodlots at GNMP.

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