WHITE-TAILED DEER HERBIVORY ON FOREST REGENERATION FOLLOWING FIRE AND THINNING TREATMENTS IN SOUTHERN OHIO MIXED OAK FORESTS

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ABSTRACT—The effects of white-tailed deer browsing on species richness, density and height of forest regeneration were examined on three oak dominated forests in southern Ohio. Each study site consisted of four - 20 ha silvicultural treatments, resulting in 12 experimental units. Mean estimated post harvest deer densities were 6 deer km^{-2}. Three pairs of plots were established within each treatment at each location, and a 2.4 m tall deer exclosure fence was installed around one plot from each pair in the summer 2001. Species and diameter (cm) of all overstory and midstory vegetation were recorded. All woody stems between 10 and 150 cm tall were identified, and height (cm), basal diameter (mm) and evidence of deer browse were recorded in 2001, 2002 and 2003 on sub-plots within each plot. Overall mean height of regeneration was 16.1 percent lower on un-fenced plots, but species richness and seedling density did not differ between fencing treatments. Blackgum, which had 40 percent lower mean heights on unfenced treatments, was the only species tested that was significantly affected by fencing treatment. Silvicultural treatment had no significant effect on overall mean seedling height; however, treatment effects were significant for chestnut oak, red maple and greenbrier.

Oak (*Quercus* spp. L) dominated forests occupy approximately 46 percent of the forestland in the eastern United States (Mc Williams et al. 2002). In Ohio, oak dominates 59 percent of the forestland, and this percentage is even greater in the southeastern portion of the state (77 percent; Griffith et al. 1993). Most of the mature second-growth forest in southern Ohio established following severe disturbance from past agricultural or industrial usage (Hutchinson et al. 2003). Iron furnaces, fueled by charcoal that was produced from repeated cutting of forests, have had a lasting effect of the forest cover of southeastern Ohio (Stout 1933; Hutchinson et al. 2003). Also, during establishment these forests were exposed to repeated fire, with fire return intervals ranging from 5 to 15 years (Sutherland et al. 2003). These frequent fires continued in southern Ohio until organized fire suppression was established in 1923 (Sutherland 1997). At the time these forests became established (mid 1800's to early 1900's) white-tailed deer (*Odocoileus virginianus* Zimm.) populations in southern Ohio were likely to have been in decline (Iverson and Iverson 1999). In fact, from 1904 to 1923 white-tailed deer were absent from Ohio (ODNR 2003).

Today, advanced regeneration in these oak dominated forests ranges from high percentages of red maple (*Acer rubrum* L.) and other shade tolerant species on sites with minimal canopy disturbance to regeneration dominated by pioneer species like yellow-poplar (*Liriodendron tulipifera* L.) on sites with considerable canopy disturbance (Lorimer 1993). In fact, numerous studies have reported a distinct lack of oak regeneration throughout the oak-hickory region on all but the driest of sites (Clark 1993). Many studies including McCarthy et al. (1987), and Goebel and Hix (1997) have found that advanced oak regeneration is probably inadequate to successfully maintain a significant proportion of oak in these forests following canopy disturbance. Reasons most commonly cited for this lack of oak regeneration include: 1) cutting practices which remove individual trees and often do not supply adequate canopy disturbance to provide sufficient light (Burns and Honkala 1990), and 2) the lack of repeated disturbance from fire since oaks are typically less susceptible to injury and are able to repeatedly produce sprouts (Huddle and Pallardy 1999, Dey 2002, Brose and VanLear 1998).

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In a review of the literature on the effects of white-tailed deer on plants and plant communities, Russell et al. (2001) cite numerous studies which have been conducted to elucidate the effects of high densities of white-tailed deer on forest regeneration in northern hardwood forests. These studies indicate that deer can significantly influence the morphology and growth rates of tree seedlings (Jacobs 1969, Tierson et al. 1966). Effects of deer on survival are less obvious, but on sites with high densities (> 8.5 deer km^{-2}) deer have prevented the recruitment of tree seedlings into the sapling and larger size classes (Russell et al. 2001, Healy 1997, Trumbull et al. 1989), and since deer feed selectively, species diversity can also be significantly affected (Harlow and Downing 1970, Tilghman 1989). Because white-tailed deer browsing has been linked with much of the failure of forest regeneration in Pennsylvania and other northern states (Marquis and Brenneman 1981), it is often assumed to be a contributing factor to oak regeneration problems in the oak-hickory region (Lorimer 1993, Boerner and Brinkman 1996). However, very few studies have been conducted in these oak dominated forests to verify this assumption (Russell et al. 2001), and even less is known about the combined effects of timber harvest, prescribed fire, and white-tailed deer browsing on oak dominated forests with deer densities that more closely resemble pre-European settlement levels (approximately 3 to 8 deer km^{-2}; McCabe and McCabe 1997, Russell et al. 2001, Horsley et al. 2003).

The objective of this study was to examine the effect of white-tailed deer browsing on the height, density, and composition of woody regeneration in oak hickory forests following thinning and prescribed fire treatments. Long-term results from this study should provide much needed information to help forest and wildlife managers in southern Ohio and the Central Hardwood Forest to make sound decisions about the management of these valuable forest and wildlife resources.

Study Area

This study was conducted on the Ohio Hills site of the Fire and Fire Surrogate Study (FFS; Prasad 2003) in mature oak-dominated forests at Tar Hollow (TAR) and Zaleski (ZAL) State Forests, and the Raccoon Ecological Management Area (REMA) in Ross and Vinton Counties of southern Ohio. These forests are located in the Unglaciated Allegheny Plateau of southern Ohio and are characterized by high hills, sharp ridges, and narrow valleys (McNab and Avers 1994). Elevations range from over 300 m to below 210 m MSL. Soils on all three forests are dominated by the Gilpin series and consist of mostly loams and silt loams that are acidic and well drained (Sutherland et. al. 2003, Boerner and Sutherland 2003).

Pre-harvest inventories (2000; data on file at Delaware Forest Service, Delaware, OH) indicate that oaks (*Q. prinus* L, *Q. alba* L., *Q. velutina* Lam., *Q. rubra* L. and *Q. coccinea* Muench.) represented 74.6, 86.0 and 88.5 percent of the basal area of canopy trees at TAR, REMA and ZAL, respectively. The greatest percentage of oaks occurred on the xeric and intermediate sites. Dendroecological analysis of dominant trees harvested from these sites, indicate that these forests established from 1850 to 1870, 1870 to 1905 and 1895 to 1905 at REMA, ZAL and TAR, respectively (data on file at Delaware Forest Service, Delaware, OH). Ohio Department of Natural Resources, Division of Wildlife, estimates of post-harvest deer densities from 2000 to 2002 averaged 6.3 and 5.4 deer km^{-2} for Vinton (REMA and ZAL) and Ross Counties (TAR), respectively (Data on file at the Waterloo Wildlife Research Area, Athens Ohio).

Materials and Methods

The Ohio Hills Site is comprised of four silvicultural treatment units (20 ha) at each location (REMA, TAR and ZAL). Treatments include the following: no treatment control (C), thin (T), thin and prescribed burn (TB), and prescribed burn only (B). Harvests in treatments T and TB consist of selective removal of canopy and mid-story trees in the fall and winter or 2000-2001 resulting in approximately 19.5 $m^2 \cdot ha^{-1}$ of residual basal area (data on file at Delaware Forest Service, Delaware, OH). Oaks and hickories (*Carya* spp. Nutt.) were favored when possible, while red maple and other shade tolerant species were targeted for removal. Prescribed burns were conducted on the B and TB sites in March and April of 2001. Fire behavior varied within and among treatments, but flame heights averaged less than 1 m at all sites.

One pair of 400 m^2 (20 × 20m) plots was established within each of three moisture classes (mesic, intermediate and xeric) based on an integrated moisture index (IMI; Iverson and Prasad 2003) in each of the four treatments at all three locations during the summer of 2001. One plot from each pair was randomly chosen for installation of a deer proof fence in the summer of 2001. Each exclosure consists of 2.4 m black mesh barrier made of UV stable polypropylene installed just beyond the perimeter of the plot. A total of 72 plots (36 fenced and 36 unfenced) were established. Species and DBH of mid-story and overstory vegetation were recorded at the time of establishment.

Twenty-0.5 m^2 sub-plots were systematically spaced within each plot at the time of fencing (June/July 2001). Woody regeneration between 10 and 150 cm in height was identified to species, and heights (cm) and basal diameters (mm) were recorded at the time of plot establishment. Relative importance values (RIV = [relative density + relative frequency]/2) were calculated for all woody regeneration (10 to 150 cm height). Each woody stem was examined to determine the percentage of branches browsed and a browse class from 0 (0 percent) to 4 (> 75 percent) was assigned. Woody regeneration measurements were repeated in late May to early June of 2002 and 2003.

Correspondence Analysis (CA) was used to evaluate the changes in species composition before, and two years following silvicultural and fencing treatments. An Analysis-of-Variance (ANOVA) was performed on overall mean height of all woody regeneration and on twelve individual woody species by silvicultural treatment (TRT), integrated moisture index class (IMI), and fencing treatment (FENCE). All treatments were treated as fixed effects except location, which was treated as a random effect and dropped from the analysis of higher order interactions. Data were tested for normality and no transformations were warranted.

Results

Basal area of overstory and midstory trees (> 5.0 cm DBH) across all location and silvicultural treatment combinations was dominated by oak, with red maple, yellow-poplar, and hickory comprising a majority of the remaining basal area. Total basal area was 23.1 percent lower on thinned (T and TB; 21.85 ± 1.6 m^2ha^{-1}; mean ± SE) than on unthinned plots (C and B; 28.4 ± 2.0 $m^2ha^{-1)}$. The greatest species difference in basal area between thinned and unthinned plots occurred with red maple which had 70 percent less basal area on the thinned plots (1.0 ± 0.2 m^2ha^{-1}) than on unthinned plots (3.3 ± 0.5 m^2ha^{-1}). In contrast, total oak basal area was only 23.2 percent lower on thinned plots (16.1 ± 1.1 m^2ha^{-1}) than on unthinned plots (20.9 ± 1.8 m^2ha^{-1}).

Relative importance values (RIVs) of three species of woody vines and shrubs accounted for over 44 percent of the total importance of woody regeneration (10 to 150 cm height) at the time of fencing in 2001 (table 1). Mean RIV's (across all treatments) for greenbrier (*Smilax rotundifolia* L.*;* 23.6) were over two times greater than those of any other species. Ericaceous shrub species (*Vaccinium* spp. L. and *Gaylussacia* spp. HBK.) had a combined mean RIV of 10.6, followed closely by viburnums (mostly *V. acerifolium* L., 9.9). Among tree species, sassafras (*Sassafras albidum* Nees.) had the greatest mean RIV (10.2) which was followed closely by red maple (9.3) and oaks (all spp. combined, 8.9). Chestnut oak had the highest mean RIV (3.9) of the oaks followed by white oak, which had a RIV of 1.9.

Correspondence analysis indicated that while the thinning treatments resulted in considerable compositional change, presumably due to increased light to the understory, the deer exclosure treatments yielded little change (fig. 1). Thus, within this period, deer were unable to produce a compositional change in the community (i.e., did not selectively browse certain species to depletion).

ANOVA results reveal significant IMI (*P* = 0.025) class and FENCE (*P* = 0.035) effects on the mean height of woody regeneration (table 2). Seedlings were significantly taller on plots in xeric locations (47.6 ± 2.9 cm; mean ± SE) than on intermediate (37.3 ± 2.9) and mesic (38.1 ± 2.9) locations (fig. 2). Mean height of regeneration was also significantly greater on fenced (44.6 ± 2.3 cm.) than on unfenced plots (fig. 3). There were no significant effects due to TRT (*P* = 0.078), and none of the interactions among TRT, IMI and FENCE were significant.

Table 1.—Relative Importance values (Relative Density + Relative Frequency/2) of woody regeneration at the time of fencing in 2001 by location and treatment.

	REMA				TAR				ZAL			
Species	Control	Thin	Thin/ Burn	Burn	Control	Thin	Thin/ Burn	Burn	Control	Thin	Thin/ Burn	Burn
Acer rubrum	9.07	15.18	6.96	11.87	13.89	14.92	2.60	9.47	4.09	4.54	4.54	14.76
Ailanthus altissima	0.00	0.00	0.00	0.00	0.00	0.00	13.88	0.00	0.00	0.00	0.00	0.00
Carpinus caroliniana	0.87	1.93	2.32	0.82	0.74	2.25	0.00	0.00	3.31	0.38	0.00	0.00
Carya glabra	1.31	0.88	0.00	2.38	0.74	0.00	0.00	0.00	2.58	1.76	2.56	1.54
other *Carya* spp.[1]	0.87	0.88	0.00	1.15	0.00	0.00	0.43	0.40	0.00	0.00	0.00	0.99
Corylus americana	1.72	0.00	0.00	1.75	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00
Cornus florida	1.88	0.00	3.33	4.13	0.00	0.75	0.00	1.05	1.63	0.38	0.00	6.19
Fraxinus spp.	0.87	0.88	1.00	0.00	0.37	9.59	0.34	1.12	1.12	0.88	0.00	0.99
Liriodendron tulipifera	0.44	0.00	0.00	11.34	2.54	0.75	2.21	1.45	0.00	0.00	0.40	0.00
Nyssa sylvatica	0.87	3.86	2.16	6.49	3.75	0.37	1.87	1.20	1.12	0.00	8.12	2.74
Oxydendrum arboreum	2.02	2.41	0.66	0.00	0.00	0.75	0.00	6.65	3.14	0.00	0.92	0.00
Parthenocissus spp.	3.46	1.01	3.48	0.00	0.37	1.32	1.78	1.99	2.41	0.00	0.52	0.77
Quercus alba	2.18	6.66	4.81	0.97	0.74	1.12	0.34	0.00	1.68	2.25	0.81	1.76
Quercus coccinea	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	2.79	5.71	1.54
Quercus prinus	2.18	1.89	0.00	2.53	8.36	5.27	0.67	0.80	0.56	12.08	3.28	9.65
Quercus rubra	0.57	3.34	1.99	0.48	0.00	1.12	0.00	0.00	4.65	0.38	0.00	0.00
Quercus velutina	2.02	0.00	0.00	0.97	0.37	1.50	0.00	0.80	2.41	1.99	0.00	2.74
Rhus spp.	0.00	0.44	1.32	0.00	0.00	0.00	5.68	0.00	0.00	0.00	0.40	0.00
Rosa spp.	0.57	0.88	3.31	0.00	0.00	0.37	0.00	0.51	0.00	1.26	1.21	5.06
Rubus spp.	0.00	0.88	3.15	0.48	1.95	1.87	6.39	8.37	0.00	0.88	0.40	5.49
Sassafras albidum	6.45	9.97	4.64	15.54	5.87	3.30	17.38	14.63	17.51	15.39	9.80	1.97
Smilax spp.	22.25	21.06	27.04	10.91	45.60	39.61	18.24	32.73	12.62	13.53	27.41	15.26
Tilia americana	0.44	0.96	4.65	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.00	0.00
Ulmus rubra	0.00	0.00	0.00	0.00	0.74	6.42	2.64	2.72	2.36	0.00	0.00	6.23
Vaccinium spp.[2]	19.91	6.05	5.31	21.89	3.18	0.00	2.02	2.57	0.00	30.86	19.87	15.75
Viburnum spp.	11.90	17.77	17.92	3.42	6.05	0.00	3.03	7.49	33.31	7.14	10.25	1.63
Vitis spp.	2.18	3.08	1.32	1.19	1.95	1.52	14.78	2.32	0.56	3.51	1.37	0.77
Others[3]	5.99	0.00	4.64	1.67	2.06	5.07	5.72	3.73	4.94	0.00	2.41	4.16

[1]Includes: *Carya ovata, Carya tomentosa and Carya cordiformis*
[2]Also includes: *Gaylussacia baccata*
[3]Includes: *Acer saccharum, Aesculus glabra, Amelanchier arborea, Castanea dentata, Cercis canadensis, Gleditsia triacanthos, Hamamelis virginiana, Lindera benzoin, Ostrya virginiana, Prunus serotina, Toxicodendron radicans, Ulmus americana*

Percentage of woody regeneration with evidence of browse in the unfenced plots increased from 13.8 in 2003 to 16.7 in 2003. In both years the percentage of stems browsed varied greatly among species. In 2003 these percentages ranged from 0.0 for few species which include sugar maple (*Acer saccharum* Marsh) and tree-of-heaven (*Ailanthus altissima* Desf.) to 46.8 for flowering dogwood (*Cornus florida* L.). Of the twelve woody species tested in the ANOVA, mean percentages of stems browsed (unfenced plots), across all locations and silvicultural treatments varied from 1.7 ± 1.7 for white oak to 27.1 ± 3.5 for greenbrier. Sassafras had the greatest percentage of stems browsed among tree species (20.4 ± 4.2). Blackgum was the only species tested that revealed significant fence effects ($P = 0.003$; fig. 4A; stems were 57.1 ± 5.4 and 34.9 ± 4.6 cm in height (mean ± SE) in the fenced and unfenced treatments, respectively. FENCE also had an influential effect on sassafras and chestnut oak mean heights (P = 0.082 and 0.068, respectively; table 3.).

Red maple, chestnut oak and green brier were the only species that exhibited significant TRT effects. Red maple seedlings were on average 14.9 ± 6.4 cm (mean ± SE) in the control (C) as compared to 38.7 ± 6.4 cm and 38.3 ± 6.6 cm in height the thin only (T) and the burn only (B) treatments,

Table 2.—Analysis of Variance table for mean height of 2003 woody regeneration (10 to 150cm) all species combined.

Source Term	DF	Sum of Squares	Mean Square	*F*	*P*	Power
Location	2	5369.905	2684.952	13.60	0.000023*	
Treatment (Silvicultural)	3	1422.606	474.2019	2.40	0.079762	0.563277
IMI (Moisture Class)	2	1575.386	787.693	3.99	0.025243*	0.685947
LI	6	2245.833	374.3056	1.90	0.101811	0.641655
Fence Treatment	1	932.2346	932.2346	4.72	0.034966*	0.566550
TF	3	532.35	177.45	0.90	0.449053	0.231320
IF	2	354.1499	177.075	0.90	0.414834	0.195310
TCF	6	232.579	38.76317	0.20	0.976238	0.095232
S	46	9081.547	197.4249			
Total (Adjusted)	71	21746.59				
Total	72					

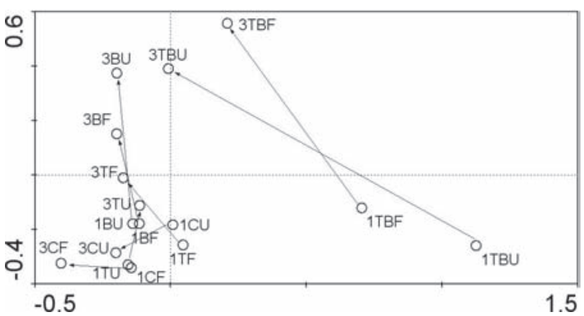

Figure 1.—Correspondence analysis of combined silvicultural (C, T, TB and B) and fence (F and U) treatment effects on species composition from 2001 (1) to 2003 (3).

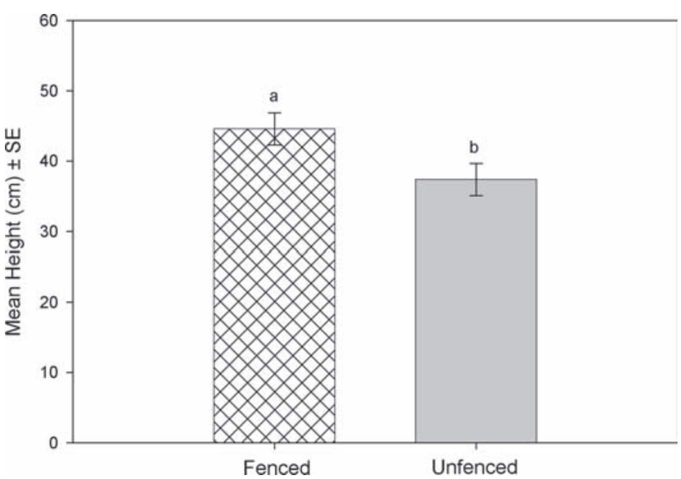

Figure 2.—Mean height of stems 10 to 150 cm by fencing treatment. Error bars represent 1 standard error.

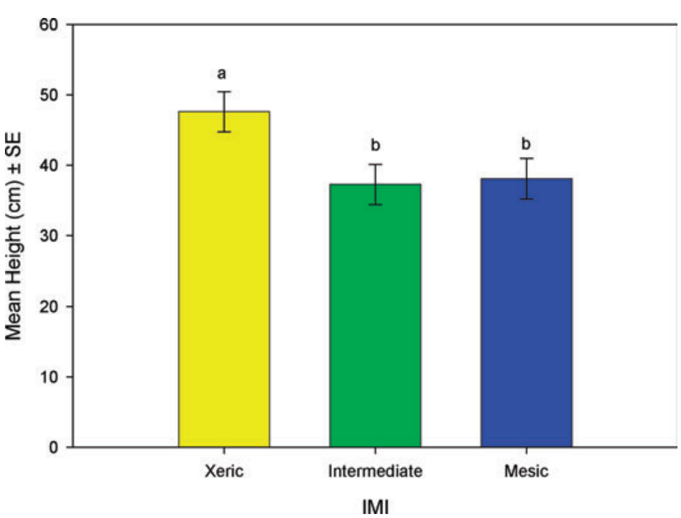

Figure 3.—Mean height of stems 10 to 150 cm by Integrated Moisture Index (IMI) Class. Error bars represent 1 standard error.

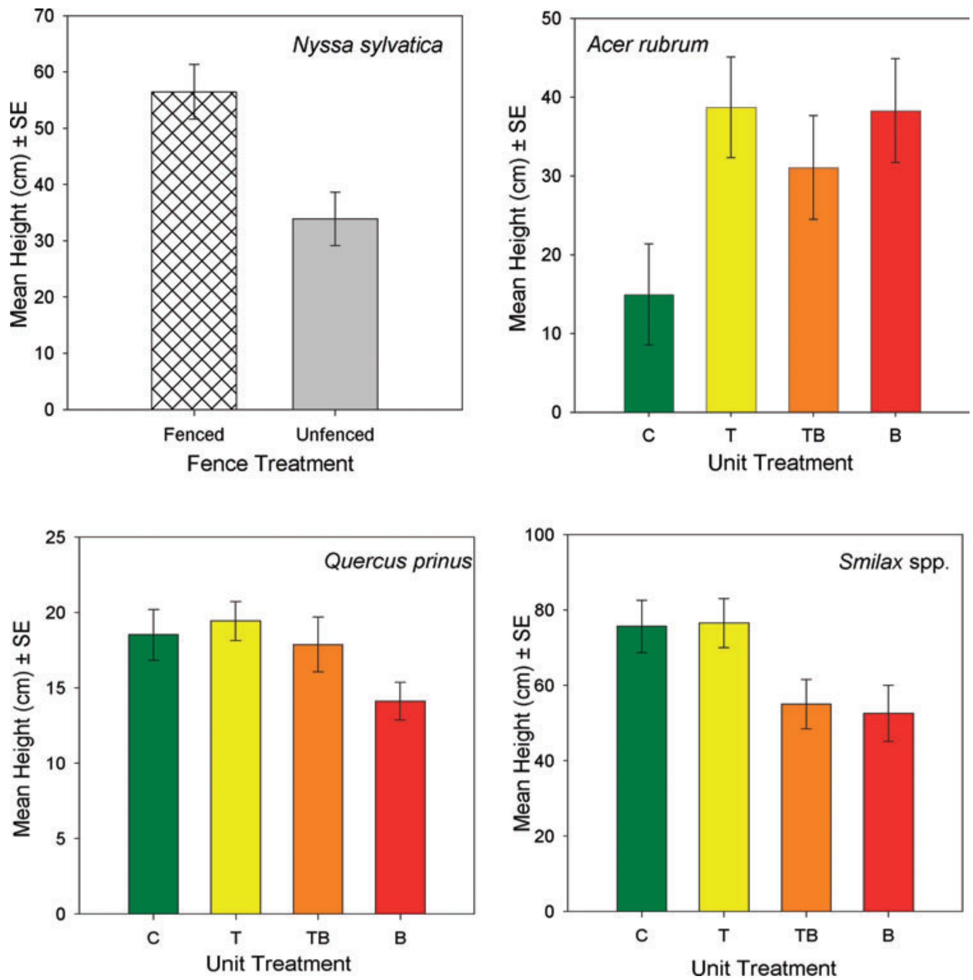

Figure 4.—Mean height of stems 10 to 150 cm by Silvicultural Treatment. C=control, T= thin; TB=thin and burn; and B=burn only. Error bars represent 1 standard error. A) blackgum (*Nyssa sylvatica*); B) red maple (*Acer rubrum*); C) chestnut oak (*Quercus prinus*); D) green brier species (*Smilax* spp.).

respectively (fig. 4B). Chestnut oak seedlings were taller in T (19.4 ± 1.3 cm) than in the B treatments (14.1 ± 1.2 cm; fig. 4C). Greenbrier stems were taller in C (75.7 ± 6.9 cm) and T (76.5 ± 6.5 cm) treatments than in TB (55.1 ± 6.5 cm) and the B treatments (52.6 ± 7.4; fig. 4D).

Discussion

There was a significant over-all increase in height of woody stems (all species combined) with the exclusion of deer, albeit this may be largely driven by the response of one species (blackgum). However, we found no evidence to show that browsing affected species richness, community composition, or density of hardwood regeneration within two years following harvest. This is not surprising since negative effects of deer on plant survival are more difficult to document than effects on growth rates especially on sites with less abundant deer populations (Russell et al. 2001, Inouye et al. 1993, Stang and Shea 1998). Russell et al. (2001) suggest that the under representation of saplings in some tree populations may reflect reductions in seedling survival; however, in a review of white-tailed deer browse studies he indicates that all of the studies that documented failures of recruitment of seedlings into larger classes were conducted on sites with deer densities above 8.5 deer km^{-1}. Our estimated deer densities (approximately 6.0 deer km^{-1}) are considerably lower than this potential threshold.

Table 3.—Mean percentage of stems browsed (unfenced plots) and mean height (cm) of selected species (10 to 150 cm) in 2003 by fencing treatment for all locations and silvicultural treatments.

Species	Percentage of stems browsed	Height (mean ± SE)	
		Fenced	Unfenced
Acer rubrum	13.1 ± 4.1	35.8 ± 5.7	25.7 ± 3.5
Liriodendron tulipifera	3.4 ± 1.6	24.5 ± 4.6	18.3 ± 1.4
Nyssa sylvatica	17.7 ± 7.1	57.1 ± 5.4	34.9 ± 4.6
Oxydendrum arboreum	3.1 ± 3.1	64.3 ± 11.9	54.8 ± 17.5
Quercus alba	1.7 ± 1.7	16.8 ± 2.1	20.0 ± 1.5
Quercus coccinea	15.5 ± 6.6	23.8 ± 4.0	21.9 ± 2.0
Quercus prinus	3.1 ± 1.8	23.7 ± 3.6	19.5 ± 3.4
Quercus rubra	23.8 ± 11.3	32.0 ± 8.2	23.4 ± 3.2
Quercus velutina	7.9 ± 4.3	17.8 ± .4	16.4 ± 1.7
Sassafras albidum	20.4 ± 4.2	32.0 ± 3.2	26.4 ± 2.7
Smilax spp.	27.1 ± 3.5	61.6 ± 6.2	60.1 ± 5.3
Vaccinium spp.	15.0 ± 5.4	22.2 ± 1.28	22.5 ± 1.4

Even if white-tailed deer densities are large enough to have a significant effect on growth and survival of woody regeneration on our sites, it is likely that it is too early in this study to detect them. In Wisconsin, Jacobs (1969) documented a 10 percent reduction in sugar maple survival over a 5 year period, but no saplings died until the fourth year. Other studies only demonstrate infrequent effects of deer. For instance Inouye et al. (1994) were only able to detect reduced rates in height growth of red oak and white pine (*Pinus strobus*) in years two and four of a nine year study. According to Russell et al. (2001) studies of short duration (1 to 3 years) may not be long enough to detect changes in rates of overstory regeneration.

Despite frequent suggestions that browsing contributes to poor oak survival and recruitment (Clark 1993, Inouye et al. 1994, Boerner and Brinkman 1996, Stange and Shea 1998, Healy 1997), oak seedlings do not appear to be directly affected by deer browsing after two years of exclusion. Only about 2.5 percent of oak stems were browsed in 2002 (Apsley 2002) and seedling heights were not significantly affected. The percentage of oak stems browsed increased to 10.6 in 2003 with red oak having the greatest percent browsed (23.1). Even with this increase in browsing, which is likely attributed to a greater than average number of days with snow cover in the winter of 2002-2003, there is still no significant effect of deer browsing on oak seedling height. However, there is evidence that oak stump sprouts have been affected. Since oak stump sprout density is relatively low and stump sprouts only occurs on the cut treatments, they are not well represented in the sampling using 0.5 m^2 sub-plots. In the summer of 2003 oak stump sprouts within the 400 m^2 plots on the thin treatments at ZAL were observed and 83 percent of stump sprouts in unfenced areas had evidence of browse damage. The dominant oak stump sprout was 212.7 ± 11.2 and 159.8 ± 17.9 cm in height (mean SE) in fenced and unfenced plots, respectively. It is unclear whether this will have a significant effect on the ability of these sprouts to become established within the stand. Sander et al. (1984) indicate that stump sprouts can be a significant source of oak regeneration and that stems greater that 1.5 m in height are capable of becoming established if the canopy is reduced enough to allow them to compete with more shade tolerant species.

At lower densities white-tailed deer may have an indirect effect on oak regeneration, and it is not yet clear whether this effect will be positive or negative. Red maple, which is often cited as the major impediment to oak regeneration in upland oak forests (Heiligmann et al. 1985, Lorimer 1993) does not appear to be significantly influenced by deer browse. Only 10.8 percent of red maple stems have been browsed and average heights of fenced and unfenced red maple are not significantly different. However, several other non-commercial vine, shrub, and tree species are being more heavily browsed, and the over all height of stems has been reduced. This may eventually have an indirect positive effect on the establishment of oak stems. This effect is most apparent on intermediate and xeric sites, but it has not yet resulted in increased height of oak seedlings. This is not surprising since the silvicultural and fencing treatments were only established for two growing seasons at the time of the last sampling.

Finally, several studies indicate that it can take several years with multiple stage canopy removal for oak seedlings to become established (Sander and Graney 1993). The harvest treatments were prescribed to reduce the basal area to 14 $m^2 \cdot ha^{-1}$; however, the goal was not reached and an average residual basal average of 19.5 $m^2 \cdot ha^{-1}$ remains on harvested treatments (data on file at Delaware Forest Service, Delaware, OH). These treatments may not have provided adequate light for oak regeneration to become established (Hodges and Gardiner 1993). Since fire has been effectively excluded from these sites since 1923 (Sutherland 2003), red maple and other shade tolerant species have had the opportunity to become well established. It may take repeated burns or other silvicultural treatments to reduce the mid-story canopy enough to stimulate oak regeneration (Brose and VanLear 1998).

The second year results from this study indicate minimal direct and indirect effects of deer browse on oak seedlings and their competitors. However, oak seedlings are relatively sparse and deer populations are relatively low (Horsley et al. 2003). Since it will likely take several years for these sites to fully regenerate (Sander and Graney 1979) and since deer densities fluctuate annually, the effect of deer herbivory may not be fully realized for some time on these southern Ohio sites. We plan to continue monitoring these plots through at least 2005.

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