Impact of Deer Browsing on Regeneration in Mixed Stands in Southern New England

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ABSTRACT. *Browsing preferences by white-tailed deer were evaluated for 6 tree species in northeastern Connecticut. Deer density averaged 23/mile^2. Deer exhibited no species-specific preferences for seedlings greater than 19 in. For seedlings less than 19 in., hemlock and black birch were preferred. Red maple, sugar maple, and white pine seedlings were avoided. Red oak seedlings were neither preferred nor avoided. A much higher proportion of seedlings greater than 19.7 in. in height was browsed, regardless of species. Browsing preferences for species in the smaller seedling class, combined with a lack of preference for species in the larger class may result in future stands with less diverse tree species composition. Deer densities in excess of 23/mile^2 may be incompatible with regeneration of diverse forests in southern New England. North. J. Appl. For. 12(3):115–120.*

Studies have demonstrated that deer can negatively affect the establishment of natural regeneration on forested lands in the northeastern United States [Stoeckeler et al. 1957, Tierson et al. 1966, Marquis 1981, Frelich and Lorimer 1985, Tilghman 1989, Metropolitan District Commission (MDC) 1989]. Deer densities of 60-80/ mile^2 on the Quabbin Reservation in central Massachusetts result in virtually no regeneration (MDC 1989). Behrend et al. (1970) and Tilghman (1989) estimated that densities of approximately 17–18/mile^2 are compatible with adequate hardwood regeneration in the Adirondack region of northern New York State and the Allegheny region of Pennsylvania.

Preferential browsing by deer of some tree species alters the short- and long-term development and future composition of a stand (Marquis 1981, Whitney 1984, Frelich and Lorimer 1985, Tilghman 1989). Furthermore, commercially desirable species, such as red oak and sugar maple, are known to be dependent on an adequate stocking of advanced reproduction in the understory if they are to be successfully regenerated (Marquis et al. 1992, Sander 1977, Hornbeck and Leak 1992, Kelty 1988, Leak et al. 1987). Browsing by deer could therefore significantly impact the establishment of certain species in the understory, and consequent composition and development of future stands.

Most northeastern studies have investigated the relationship between deer browsing and regeneration in northern hardwood, hemlock, or Allegheny hardwood (cherry-maple type) stands in New York or Pennsylvania (Stoeckeler et al. 1957, Tierson et al. 1966, Marquis 1981, Frelich and Lorimer 1985, Tilghman 1989). There have been no such investigations published for stands located in the transition hardwood region of southern New England (Connecticut, Massachusetts, and Rhode Island). With a different mixture of species (stands frequently dominated by oak), deer browse preferences and impact on regeneration may be different.

In southern New England most forests consist of a mosaic of naturally regenerated even-aged mixed-species stands in the 60–80 yr age class, resulting from a variety of large-scale natural and human-induced disturbances, including agricultural abandonment, clearcutting for fuelwood or pine timber, and the hurricane of 1938. The prevalent species composition of this region is referred to as the "transition hardwoods–white pine–hemlock forest vegetation zone" by Westveld et al. (1956), and typically includes such species as red oak, black oak, white oak, red maple, sugar maple, black birch, white birch, white ash, several species of hickory, eastern white pine, and eastern hemlock.

Braun (1950) referred to the forest composition of southern New England as being in either the hemlock–white pine–northern hardwoods region or the glaciated section of the oak-chestnut forest region. The boundary between these two regions runs roughly east-west through northern Connecticut, but is indefinite. Westveld et al. (1956) stated that hardwoods typical of more northern forests and southern forests meet in a complex mosaic of cover types. With the exception of the coastal pitch pine forests of Cape Cod and the higher elevation northern hardwood forests of the Berkshire Hills region, the forests of the tri-state southern New England region can be considered similar in overall composition.

Because so many of the forests of this region are evenaged and in a sawtimber size class (i.e., commercially mature; Brooks et al. 1993), it is appropriate to consider the potential for future establishment of their natural regeneration. Our objectives in this study were to survey regeneration in the transition hardwood type to characterize the overall prevalence of deer browsing, browse preferences, and potential impact of these preferences on regeneration.

Study Area

The study was conducted on the 7800 ac Yale-Myers Forest, located in the northeastern corner of Connecticut. It is largely composed of a mosaic of even-aged stands originating from natural and human-induced disturbances typical of the region. Because the stands were too young for final commercial harvest, few regeneration harvests have been conducted over the past 50 yr, but thinnings or some level of intermediate silvicultural treatment have been implemented throughout the property. The goal of these thinnings was to improve the quality of residual stands by removing inferior individuals or species of low commercial value (e.g., red maple, black birch), without altering the even-aged structure of the stands (Oliver 1978).

Methods

In 1982, 30 transects were randomly located throughout the Yale-Myers Forest. Ten 13.2 ft radius plots were systematically located along each transect, at intervals of 66 ft. Each transect was aligned in a north-south direction. The plots were revisited occasionally in subsequent years, but due to incomplete data, no analysis can be made. In summer 1986, pellet group counts and regeneration surveys were conducted on these transects. Results and conclusions reported in this paper are based solely on 1986 data.

The mean number of pellet groups/plot was determined for each cover type. Estimates of deer density were derived by the technique described by Bennett et al. (1940) and Eberhardt and Van Etten (1956) using a defecation rate of 13 pellet groups per day, an estimated period of deposition (time since the plots had last been visited and all previous pellet groups removed), and 13.2-ft radius plots.

Fuller (1991) indicated the limitations of the pellet group method to accurately index deer densities or population changes. Our estimates were further complicated by the fact that pellet group counts were made in the summer, after the springtime birth of fawns. As a result, estimates of deer density may be low, since fawns were added to the population in May, and were not depositing pellet groups over the full deposition period. For these reasons, we report the mean and standard error of the number of pellet groups/plot by cover type, in addition to the derived estimate of deer density.

The three predominant overstory cover types in which sampling occurred were hardwood (largely composed of red oak, red maple, sugar maple, and black birch), n = 136 plots, hemlock/ hardwood, n = 110 plots; and eastern white pine/ hemlock/ hardwood, n = 30 plots. The remaining 24 plots occurred in either pure hemlock stands or wetlands and were not included in the study due to the small sample size of each condition. Because of their random assignment, the distribution of transects varied by cover types.

All seedlings were counted by species, and assigned to one of two size classes (i.e., less than 19.7 in., and 19.7 to 36 in., hereafter referred to as the small and large size classes). Each seedling was assessed for signs of browsing that had occurred since the previous growing season. If a seedling had one or more twigs browsed, it was considered browsed. No finer resolution of browse impact (e.g., the number of browsed twigs on an individual seedling) was made. The number of seedlings per acre and the incidence of browsing were calculated for the six principal species present: red oak, black birch, red maple, white pine, sugar maple, and eastern hemlock.

Chi-square analysis was used to detect browse preference by species and size class, by comparing availability of seedlings (i.e., the proportion of seedlings by species available) with the proportion of browsed seedlings by species (White and Garrott 1990, 186–191). If deer exhibited no preference, browsed seedlings of a given species would appear at the same proportion as that species appears in the mix of available seedlings. Highly significant differences indicate either a strong preference for or avoidance of a given species Preference or avoidance was determined by comparing the availability of a particular species with the confidence interval around the estimate of its use. Confidence limits were calculated by the method suggested by White and Garrott (1990, 188), using Bonferroni normal statistics. A significance level of 0.10 was used.

Results

Deer Density

Estimates of deer density ranged from 21.8 to 26.7 deer/ mile^2 within cover types (Table 1). Mean deer density across cover types was 23.3 deer/mile^2.

Seedling Availability and Occurrence of Browsing

Results of the regeneration survey were reported (Kittredge and Ashton, 1990). The overwhelming majority of seedlings

Table 1. Pellet group counts (mean number of pellet groups/plot and standard errors) and deer density estimates (mean number of deer/ mile^2, and standard errors), by cover type.

Cover type	Pellet groups/ plot	S.E.	Deer/ mile^2	S.E.
Hardwood	0.985	0.153	21.8	3.4
Hemlock/hardwood	1.109	0.215	24.6	4.7
Pine/hem/hardwood	1.200	0.281	26.7	6.2
Overall forest	1.058	0.118	23.3	2.6

Table 2. Mean number of seedlings per acre in the small size class (less than 19.7 in. in height) and mean percentage browsed, by species and cover type (standard errors in brackets).

	Hardwood		Hemlock–hardwood		Pine–hemlock–hardwood	
Species	No.	%	No.	%	No.	%
Red Oak	185 [32]	35.0 [4.9]	87 [29]	25.0 [6.5]	222 [48]	46.0 [9.4]
Black birch	714 [187]	53.0 [4.3]	942 [200]	36.0 [5.5]	2359 [801]	44.0 [9.8]
Red maple	931 [100]	14.0 [2.4]	656 [116]	8.5 [2.9]	1183 [356]	23.2 [6.2]
White pine	40 [11]	36.0 [7.8]	74 [29]	12.0 [6.8]	1407 [550]	26.6 [7.7]
Sugar maple	272 [88]	16.0 [4.2]	49 [19]	0 0	323 [156]	23.0 [11.6]
Hemlock	212 [39]	58.2 [5.2]	590 [98]	52.9 [4.9]	570 [188]	52.7 [9.6]

observed was in the small size class (Tables 2 and 3), for all species, in all cover types. Incidence of browsing on seedlings in the large size class was generally higher than on seedlings in the small size class.

Browse Preferences by Species

There were significant differences between the proportion of 5 of 6 species of small seedlings available and the proportion browsed (Table 4). Deer preferentially browsed eastern hemlock and black birch seedlings in all cover types. They avoided red maple, white pine, and sugar maple. Red oak was browsed at rates similar to its availability.

Little difference existed between the proportion of larger seedlings available and the proportion browsed (Table 5) suggesting little species preference for seedlings > 19.7 in. There were no species preferences expressed in the hardwood and hemlock-hardwood cover types. Red oak and red maple were modestly preferred in the pine-hemlock-hardwood cover type. In general, the lack of a consistent preference (as compared to the small size class, across cover types), and the higher rates of browse for large size class seedlings (Table 3) suggest a much higher probability of a large seedling being browsed, regardless of its species or cover type. However, because we measured only frequency of browsing, rather than percent of stems browsed, we cannot state unequivocally that the impact of browsing is greater on the taller class of seedlings.

Discussion

Browse of Seedlings in the Large and Small Size Classes

Regeneration guidelines for upland oaks (Sander et al. 1984) require a minimum of one seed origin stem greater than 4.5 ft in height on 59% of the survey plots (1/735-ac) in a stand (i.e., 434/ac). Fewer stems may be compensated for by stump sprouts. For northern hardwoods, Leak et al. (1987) recommend a minimum of one stem at least 3 ft in height on 65% of surveyed milacre plots in an uneven-aged stand (i.e.,

Table 3. Mean number of seedlings per acre in the large size class (greater than 19.7 inches in height) and mean percentage of seedlings browsed, by species and cover type (standard errors in brackets).

	Hardwood		Hemlock–hardwood		Pine–hemlock–hardwood	
Species	No.	%	No.	%	No.	%
Red Oak	20 [8]	62.0 [12.9]	7 [4]	20.0 [19.9]	40 [26]	100.0
Black birch	142 [61]	55.0 [7.9]	83 [30]	39.0 [1.1]	81 [32]	33.0 [16.6]
Red maple	21 [7]	50.0 [13.5]	3 [2]	0.0	54 [40]	94.0 [13.9]
White pine	5 [2]	79.0 [39.3]	1 [1]	100.0	3 [2]	100.0
Sugar maple	74 [26]	57.0 [10.4]	1 [1]	0.0	96 [78]	45.1 [47.6]
Hemlock	3 [2]	100.0	3 [2]	50.0 [25.0]	0	

Table 4. Proportion of seedlings in the small size class available, and confidence interval around the proportion of seedlings browsed ($P = 0.10$ level of significance), Chi-square value indicating the degree of difference, and preference (P), avoidance (A), or indifference (I)

Species	Hardwood cover type Confidence interval, proportion browsed	Proportion available	χ^2	
Red oak	0.06156< P <0.11044	0.079	0.45369	I
Black birch	0.45741< P <0.54459	0.303	97.98902	P
Red maple	0.14003< P <0.20597	0.395	94.45434	A
White pine	0.00710< P <0.03090	0.017	0.17442	I
Sugar maple	0.03762< P <0.07838	0.116	22.20103	A
Hemlock	0.13080< P <0.19520	0.090	45.36451	P
	Hemlock-hardwood			
Red oak	0.01496< P <0.04504	0.036	2.00983	I
Black birch	0.41605< P <0.50395	0.393	9.18304	P
Red maple	0.05263< P <0.09937	0.274	103.23072	A
White pine	0.00240< P <0.02160	0.031	7.88416	A
Sugar maple		0.020	14.80000	
Hemlock	0.37845< P <0.46555	0.246	88.43433	P
	Hemlock-hardwood-pine			
Red oak	0.03610< P <0.05790	0.037	2.85289	I
Black birch	0.45426< P <0.50574	0.389	45.15839	P
Red maple	0.10985< P <0.14415	0.195	59.30590	A
White pine	0.15351< P <0.19249	0.232	30.33563	A
Sugar maple	0.02466< P <0.04334	0.053	10.56836	A
Hemlock	0.12118< P <0.15682	0.094	57.65969	P

650 stems/ac). Prior to a shelterwood removal cut in an even-aged stand, they recommend roughly 5000 stems/ac of established 3-4 ft trees.

Based on these recommendations and the documented scarcity of regeneration greater than 19.7 in., there may not be a sufficient number of seedlings present in the understory to adequately stock a future stand, If continually suppressed below 19.7 in. by browsing, at least some species will not develop beyond the seedling phase. Based on the browsing pressure applied by estimated deer densities of approximately 23/mile^2, when seedlings are less than 19.7 in. deer prefer to browse certain species. However, there is a greater likelihood that seedlings over 19.7 in. in height will be browsed, irrespective of species. Given the small number of seedlings per acre higher than 19.7 in., it is plausible that a relatively small deer population could maintain suppressed

Table 5. Proportion of seedlings in the large size class available, confidence interval around the proportion of seedlings that were browsed ($P = 0.10$ level of significance), Chi-square value indicating the degree of difference, and preference (P), avoidance (A), or indifference (I).

Species	Hardwood cover type Confidence interval, proportion browsed	Proportion available	χ^2	
Red oak	0.02909< P <0.13691	0.075	0.01333	I
Black birch	0.42237< P <0.61763	0.536	0.02827	I
Red maple	0.02014< P <0.11986	0.079	0.18750	I
White pine	0.00000< P <0.05867	0.019	0.33333	I
Sugar maple	0.19226< P <0.36774	0.279	0.00024	I
Hemlock	0.00000< P <0.04736	0.012	0.75000	I
	Hemlock-hardwood			
Red oak	0.00000< P <0.11596	0.071	0.48400	I
Black birch	0.77012< P <1.01588	0.847	0.08312	I
Red maple[a]		0.031	1.10000	
White pine	0.00000< P <0.09358	0.010	0.90000	A
Sugar maple[a]		0.010	0.40000	
Hemlock	0.00000< P <0.11790	0.031	0.14545	I
	Hemlock-hardwood-pine			
Red oak	0.16363< P <0.32437	0.146	9.64065	P
Black birch	0.09471< P <0.23329	0.296	10.21914	A
Red maple	0.22345< P <0.39655	0.197	9.87805	P
White pine	0.00000< P <0.04288	0.011	1.22500	I
Sugar maple	0.18151< P <0.34649	0.350	2.76050	A
Hemlock[b]		0.000		

[a] Browsing not observed.
[b] No hemlock seedlings > 19.7 in. observed.

regeneration by continued browsing. Even if deer density declined, regeneration release could be stifled unless reduced density was maintained. Stoeckeler et al. (1957) concluded that deer populations needed to be kept low for 6–8 yr in northern Wisconsin in order to permit successful regeneration to become established.

The paucity of seedlings in the large size class compared to the small size class is similar to patterns documented elsewhere in the Northeast. In a study using fenced exclosures within clearcuts in the Allegheny region of Pennsylvania, Marquis (1981) reported that after 22 yr in an area with approximately 25 deer/mile^2, the total number of stems inside and outside exclosures was not significantly different. There were, however, differences in species composition and height growth. There were significantly fewer black cherry, sugar maple, red maple, yellow poplar, and red oak seedlings outside the exclosures, especially for stems greater than 59 in. Tierson et al. (1966) reported a similar pattern in the Adirondacks, with a density of approximately 21 deer/mile^2. Inside exclosures, there were over 5261 stems/ac of sugar maple, white ash, and yellow birch over 35 in. in height, but outside exclosures there were no yellow birch over 35 in. present, and only 162 sugar maple stems/ac over 35 in. Tilghman (1989) similarly reported a difference in rates of seedling height growth. In her study, regeneration became established under virtually all deer densities (ranging from 10–80 deer/mile^2), yet the number that developed into taller height classes was limited under higher densities (i.e., greater than 40 deer/mile^2). Trumbull et al. (1989) reported a similar pattern of fewer taller seedlings outside exclosures than within exclosures, in a study on the Allegheny plateau where deer density approximated 22 deer/mile^2.

Browse Preference by Species

The analysis indicates a browse preference in the smaller seedling class for hemlock and black birch (Table 4). If relative deer densities remain approximately the same as those at the time of the study, the possibility of change in the future forest composition exists.

In our study this browse preference was not expressed in seedlings in the large size class. The incidence of browse was considerably higher for this height class, for all species. Seedlings that attained this height were browsed, regardless of species.

We postulate that historic deer densities in this region were low, accounting for the current dominance of hemlock in the canopy. This may also be attributable to preferential timber harvesting practices. Our findings also suggest that if current trends in deer population densities persist, the future forest composition could be one dominated by red maple (because a lack of browse preference in the small size class and its vigorous sprouting ability) and black birch (because of relatively high numbers of seedlings present). Future manipulation of the overstory and its influence on light levels in the understory will play an important role in how these stands develop. Red maple is considered to be tolerant of shade, especially in the seedling stage, while black birch is considered more intolerant [Burns and Honkala 1990].

Severe browsing of regeneration could mute stand development patterns that promote species stratification. In extreme cases, forests could resemble open, monostoried woodlands, dominated by relatively fewer tree species, but with an extensive herbaceous or woody but unpalatable understory (Tilghman 1989). This pattern has also been observed in central Massachusetts on the Quabbin Reservation (MDC 1989).

Application

Managers interested in regenerating stands should consider the browsing pressure that deer populations can impose on seedlings. Given the differential browse preference expressed for small seedlings and the almost universal browse pressure placed on large seedlings when deer population densities are approximately 23/mile^2, it is clear that absolute numbers of seedlings present alone would be inadequate for assessing the regeneration potential of a given stand. Marquis et al. (1992) account for the influence of deer when considering regeneration in the Allegheny hardwood region. Their deer impact index acknowledges the effect of deer browse on regeneration, based on the amount of "deer food" available and the deer density. They estimate that in an area with 24 deer/mile^2 and low-to-medium amounts of deer food available, regeneration could undergo a shift in composition, or even trend towards a monoculture. Conditions of low deer food availability are subjectively estimated by circumstances such as the presence of a distinct browse line, high numbers of browsed stems, and understories dominated by species that are not preferred by deer such as fern.

The results of this study enable foresters to appreciate deer browse impact in forests of southern New England. At an approximate density of 23 deer/mile^2, a shift in species composition of the future stand could occur unless steps are taken, such as those suggested by Marquis et al. (1992) (e.g., fencing, accelerated deer harvest, fertilization to accelerate regeneration development, thinnings throughout the area to provide a greater quantity of deer food and reduce the deer impact index or pressure).

Finally, these results provide an initial benchmark for assessing deer impact on regeneration in southern New England, analogous to similar studies conducted elsewhere in the northeast (Lake States, Adirondacks, Allegheny region). Such information will be useful in the future development of a deer impact index, similar to the one reported by Marquis et al (1992).

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