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THE IMPACT OF **DEER BROWSING** ON ALLEGHENY HARDWOOD REGENERATION

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THE IMPACT OF **DEER BROWSING** ON ALLEGHENY HARDWOOD REGENERATION

by David A. Marquis

ABSTRACT

To evaluate the impact of deer browsing on Allegheny hardwood regeneration, surveys were made of vegetation inside and outside deer exclosures in 13 stands that had been clearcut 5 to 16 years earlier. The surveys showed that browsing by white-tailed deer has resulted in regeneration failures in 25 to 40 percent of the areas studied. Pin cherry and sugar maple were the species most severely reduced by browsing, while beech, birch, and striped maple sometimes increased in proportion to other species in areas subjected to deer.

The surveys also showed that successful regeneration was obtained in spite of deer browsing in over half of the clearcuts studied. Although not demonstrated here, other research has shown that the areas most likely to regenerate satisfactorily are those that contain abundant advance regeneration.

Data from this study, although limited, suggest that regeneration in 4- to 5-year-old clearcuts can be judged satisfactory if at least 60 percent of the 6-foot-radius plots examined are stocked with at least 2 desirable stems over 3 feet tall, or at least 100 desirable stems of any size.

SCIENTIFIC NAMES OF TREES MENTIONED IN THIS REPORT

Common name	*Scientific name*
Sugar maple	*Acer saccharum* Marsh
Red maple	*Acer rubrum* L.
Striped maple	*Acer pensylvanicum* L.
Yellow birch	*Betula alleghaniensis* Britton
Black birch	*Betula lenta* L.
Beech	*Fagus grandifolia* Ehrh.
White ash	*Fraxinus americana* L.
Yellow-poplar	*Liriodendron tulipifera* L.
Cucumber-tree	*Magnolia acuminata* L.
Aspen	*Populus grandidentata* Michx. or *Populus tremuloides* Michx.
Black cherry	*Prunus serotina* Ehrh.
Pin cherry	*Prunus pensylvanica* L.
Red oak	*Quercus rubra* L.
Eastern hemlock	*Tsuga canadensis* (L.) Carr.

DEER BROWSING: A PROBLEM IN REGENERATION

HEAVILY FORESTED areas on the Allegheny Plateau in Pennsylvania and New York have supported an unusually large deer herd since the 1920s, and browsing of woody plants by these deer has affected development of vegetation for a long time *(Frontz 1930; Bramble and English 1948; Bennett 1957; Marquis 1973)*.

Understory vegetation is extremely sparse in most undisturbed Allegheny hardwood stands, and new seedlings that appear after forest cutting are often severely browsed. Many deer-exclosure studies on the Allegheny Plateau have demonstrated how deer delay, and sometimes entirely prevent, tree reproduction *(Grisez 1957; Shafer et al. 1961; Jordan 1967)*. In addition to interfering with the development of new trees, excessive browsing reduces further browse production, degrading deer range conditions, *(Stiteler and Shaw 1966)* which results in deer that are undersized and undernourished *(Jordan 1970)*.

Because there is much variation from place to place in the quantity and vigor of tree reproduction and the amount of deer browsing, it is difficult to judge the true impact of deer on tree regeneration. Most exclosure studies involve only one or two exclosures within a limited area. Such studies leave little basis on which to judge such important questions as how frequently and under what conditions deer actually prevent establishment of a new forest stand. To do this, data from a large number of exclosures over a wide range of sites and conditions are needed.

During the 1950s and 1960s, the Allegheny National Forest installed a series of deer exclosures in various stands. Most of these exclosures were located in recently cutover areas. In 1971, vegetation surveys were made on plots both inside and outside 13 of these exclosures (table 1). The results obtained from these surveys provide a measure of the impact of deer browsing on Allegheny hardwood regeneration in a four-county area in Northwestern Pennsylvania.

A cluster of 9 sample plots was located inside and another one outside each exclosure. The sample plots were arranged in 3 rows of 3 plots each, with 40 feet between plots. The cluster outside the exclosure was located in an area judged to have been as similar as possible to that inside the fence, on the basis

Table 1.—Exclosures surveyed

Stand No.	Sale area	Cutting complete	Fence built	Fence height	Area explosed
		Year	*Year*	*Feet*	*Acres*
	RECENT CLEARCUTS				
1	Railroad Run	1966	1966	6	0.5
2	North Branch Sugar Run	1965	1966	6	0.5
3	Hemlock Run	1966	1966	6	0.5
4	Wolf Run	1969	1969	8	8.0
5	Slide Run No. 2	1963	1963	8	0.5
6	Long Hollow	1965	1966	8	0.5
7	Lower Morrison	1965	1966	8	0.5
8	Fork Run	1966	1966	8	0.5
9	Farnsworth	1965	1966	8	0.5
10	Kinzua Trail	1965	1966	8	0.5
	OLDER CLEARCUTS				
13	Chappel Fork	1957	1957	8	1.0
14	Cherry Grove	1957	1957	8	1.2
20	Silver Creek	1956	1957	8	1.0

of topography, drainage, residual stand density, etc. The center plot of the outside cluster was located at least 100 feet from the fence to avoid atypical conditions that sometimes exist in the heavily traveled zone near the fence.

Sample plots were circular, with a radius of 6 feet. Trees were recorded by species and height classes, and the exact height of the tallest individual of each important species was recorded. Percentage of ground area covered by six major groups of herbaceous ground-cover plants was also recorded.

Several species groups are mentioned throughout the data tabulations that follow. *Preferred species* are those preferred for timber production; they include black cherry, sugar maple, red maple, yellow-popular, cucumber tree, and red oak. *Commercial species* are all those commercially valuable for timber; they include the preferred species plus beech, yellow birch, black birch, other oaks, hickory, and hemlock.

The students "t" test for paired observations was used to make statistical comparisons among fenced and unfenced plots.

The sample plot size used in this study (6-foot-radius, 1/385-acre) was selected because it corresponds approximately to the area occupied by a single tree of average diameter in a fully stocked Allegheny hardwood stand when that stand reaches merchantable size. Mean stand diameter of 8 inches is assumed to be the size at which the stand becomes merchantable. Fully stocked (A-level in stocking guides) Allegheny hardwood stands with mean diameter of 8 inches vary from about 330 to 485 trees per acre for stands with 0 to 80 percent intolerant species *(Roach 1974)*.

Such plots provide an especially appropriate size on which to judge reproduction stocking. If each 1/385-acre plot contains at least one stem that survives until the stand reaches merchantable size, the resulting stand will be fully stocked. It follows, therefore, that the proportion of these 1/385-acre plots satisfactorily stocked with reproduction should be related directly to the stocking level of the stand when it reaches merchantable size *(Leak 1969)*.

Since many stems present during the reproduction stage will die before the stand reaches merchantable size, it is apparent that more than one stem must be present to consider a reproduction plot satisfactorily stocked. Unfortunately, the definition of what constitutes a satisfactorily stocked plot at various ages has not yet been developed for Allegheny hardwoods. Therefore, in this report I have assumed a range of criteria—based on experience and observation in this type and data on normal mortality rates for northern hardwoods in New England *(Leak 1969)*—and have applied these assumed criteria to evaluate probable future stocking.

The assumed criteria include 10, 25, 50, 100, and 150 stems per plot. However, such criteria based on the number of stems of all sizes are not likely to be very reliable predictors of future stocking in Allegheny hardwoods, because deer browsing prevents many of these stems from growing beyond seedling size. More reliable criteria would be the numbers of stems that have already grown—or will soon grow—beyond the reach of deer. For this reason, criteria based on a minimum of 1 or 2 stems over 5 feet tall, and 2 or 5 stems over 3 feet tall per plot, have also been included here.

Of course, 100 percent stocking is not necessary. In older stands, the number of trees is frequently reduced by thinning to stimulate more rapid growth of the residuals. No yield is lost so long as the number of trees is not reduced below the level required for full site occupancy. This level, often referred to as the **B** level in stocking guides, is about 60 percent of normal stocking. Thus, any stand that has at least 60 percent stocking when it reaches merchantable size would be considered satisfactory. The 60 percent figure has therefore been used as the breaking point between satisfactory and unsatisfactory stocking of reproduction plots as well.

The nine sample plots used in this study would not provide an adequate sample on which to evaluate regeneration stocking of an entire clearcut, but were considered satisfactory here because the total area evaluated was limited to the ½ acre inside (or similar area outside) the deer exclosure.

RESULTS AND DISCUSSION

Older Clearcuts

There were three older clearcuts (15 to 16 years since cutting) available with satisfactory exclosures, and all of these had been examined once before, when they were 4 to 5 years old. Jordan *(1967)* has published the data from the earlier survey in these three cuttings.

Summaries of the average number of stems of various sizes are presented in table 2 for both the current and previous inventories. Total number of stems did not differ significantly between fenced and unfenced areas in 1960 and still did not in 1971 if all commercial species are considered. However, by 1971, the total number of preferred species had been significantly reduced by deer browsing. Preferential feeding has apparently affected the preferred species, producing a change in species composition of the unfenced areas—toward larger proportions of species such as beech and black birch and noncommercial striped maple.

The influence of deer on species composition is most obvious in the effect on noncommercial pin cherry (table 3). This species has been virtually eliminated from the unfenced areas by browsing.

Differences between fenced and unfenced areas in the numbers of stems over 3 feet tall, or over 5 feet tall, were quite large in 1960. Although differences still exist, they were much less dramatic by 1971 (table 2).

Regeneration stocking was much reduced by browsing in the unfenced areas (table 4). Although fenced portions of all three clearcuts are satisfactorily stocked, the unfenced portion of only one of the three clearcuts can be considered satisfactory. One of the other unfenced areas might be considered marginal, as it does have at least 1 commercial (but not preferred) stem per plot over 5 feet tall on 60 percent of the plots.

Experience and observation suggest that 5 stems per plot over 5 feet tall is adequate stocking at 15 to 16 years of age to insure the survival of 1 stem per plot when the stand reaches merchantable size. Assuming

Table 2.—Average number of stems in 15- to 16-year-old clearcuts

(Thousand per acre)

Size of stems	Fenced	Unfenced
PREFERRED SPECIES		
1960:		
Over 5 feet	0.5	0.1
Over 3 feet	2.4	0.4
All sizes	24.9	27.1
1971:		
Over 5 feet:	2.7	1.8
Over 3 feet	3.7	2.2
All sizes	12.0	8.8
COMMERCIAL SPECIES		
1960:		
Over 5 feet	0.6	0.1
Over 3 feet	2.7	0.5
All sizes	25.4	27.6
1971:		
Over 5 feet	3.7	2.2
Over 3 feet	4.5	3.0
All Sizes	11.6	11.8

Table 3.—Number of pin cherry stems in 15- to 16-year-old clearcuts

(Thousand per acre)

Item	Fenced	Unfenced
Number present 1960	4.1	0.2
Number present 1971	1.8	0.2
Number over 5 feet in 1960	2.2	0.0
Number over 5 feet in 1971	1.8	0.0

Table 4.—Proportion of 15- to 16-year old clearcuts satisfactorily stocked

Stands in which at least 60 percent of plots are stocked with--	Fenced	Unfenced
	Percent	*Percent*
Preferred species:		
5 stems over 5 feet tall	100	0
2 stems over 5 feet tall	100	33
1 stem over 5 feet tall	100	33
Commercial species:		
5 stems over 5 feet tall	100	33
2 stems over 5 feet tall	100	33
1 stem over 5 feet tall	100	67

that this is an appropriate measure of stocking in 15- to 16-year-old stands, I examined the 1960 data on these three clearcuts to see what measure of stocking at 4 to 5 years of age provides the most reliable means of predicting which clearcuts will be satisfactorily stocked when they reach 15 to 16 years of age. Data from a few of the many stocking criteria examined are shown in table 5.

Regressions run on the various stocking criteria provide a crude measure of the effectiveness of each criterion (table 5). Several of the criteria shown seem to have some value as predictors. However, the one that seems to have most potential value is the proportion of plots that contained at least 2 stems over 3 feet tall or 100 seedlings of any size. This criterion is the only one that showed complete agreement with the stocking evaluations at 15 to 16 years of age. That is, all areas at least 60 percent stocked at age 4 to 5 years on the basis of this criterion were still at least 60 percent stocked at age 15 to 16 years; and all areas less than 60 percent stocked were still less than 60 percent stocked at age 15 to 16 years.

No other criterion performed as well, although one other one actually had a higher R^2 value. A considerable amount of additional data from other areas will be needed to provide rigorous tests and permit selection of the best criterion. But in the interim, stocking of Allegheny hardwood reproduction in 4- to 5-year-old clearcuts can probably be evaluated with reasonable accuracy on the basis of the proportion of 6-foot-radius plots stocked with at least 2 commercial stems over 3 feet tall or 100 stems of any size.

Recent Clearcuts

There were 10 exclosures in recent clearcuts (5 to 6 years old), and there was much variation among them in the impact that deer had on regeneration. Two of the 10 areas were almost completely bare of trees except where they had been protected by the deer exclosure (fig. 1). The other eight areas showed the influence of deer in varying degrees.

The total number of stems found in the unfenced areas averaged slightly less (not significant) than in the fenced areas (18,400 versus 20,900). The impact of deer is more apparent if only stems over 5 feet tall are considered. Unfenced areas averaged 36 percent fewer stems of this size than the fenced areas (4,600 versus 7,200). If only commercial species are considered, the figures are 3,200 versus 5,300; and this difference was statistically significant.

The reduction in number of stems over 5 feet tall as a result of browsing occurred in

Table 5.—Regeneration stocking of commercial species was judged by various stocking criteria

Plots	Age 15 to 16 years: proportion of plots satisfactorily stocked[1]	Age 4 to 5 years[2]							
		Total stems	Stems over 3 feet tall	Proportion of plots stocked with at least--					
				5 stems	10 stems	100 stems	2 stems over 3 feet tall	2 stems over 3 feet or 100 stems	5 stems over 3 feet tall
	Percent	*Thousands per acre*		*Percent*					
Fenced:									
Chappel Fork	100	61.8	2.4	100	100	75	67	83	58
Cherry Grove	78	9.6	3.7	64	45	9	64	64	45
Silver Creek	78	4.7	2.0	67	42	0	67	67	33
Unfenced:									
Chappel Fork	67	76.6	1.1	100	100	92	42	92	25
Cherry Grove	55	3.5	.3	75	33	0	25	25	0
Silver Creek	31	2.6	.1	50	25	0	8	8	0
Coefficient of determination (R^2) on stocking at age 15 to 16 years		0.66 *	0.87 **	0.50	0.67 *	0.60	0.95 **	0.87 **	0.87 **

[1] A satisfactorily stocked plot is one containing at least 5 stems of commercial species over 5 feet tall.
[2] * Significant at 0.05 level; ** significant at 0.01 level.

Figure 1.—Deer browsing has completely eliminated tree regeneration outside (left of this photo) this fenced deer exclosure.

all species except striped maple and aspen. Pin cherry and sugar maple were browsed especially hard; large stems of both these species were virtually eliminated in the unfenced areas (table 6).

Stocking levels, as measured by a variety of criteria, differed significantly between fenced and unfenced areas (table 7). Although the different criteria produced slightly different results, somewhere between 10 and 40 percent of the areas studied have failed to regenerate satisfactorily as a direct result of deer browsing. That is, regeneration is satisfactory inside the exclosure and unsatisfactory outside the exclosure in 10 to 40 percent of the clearcuts.

Deer browsing had a greater impact on the preferred timber species than on all commercial species. For example, the proportion of clearcuts on which 60 percent of the plots were stocked with at least 2 stems over 3 feet tall was reduced by browsing from 90 to 50 percent on preferred species, but was reduced only from 90 to 70 percent if all commercial species are counted (table 7).

Data in table 7 also indicate that somewhere between 40 and 80 percent of the clearcuts will regenerate satisfactorily in spite of deer browsing (outside the exclosure). There are no data available for these stands before cutting, so the factors responsible for the success of some stands and the failure of others cannot be determined. However, extensive surveys performed by Grisez and Peace *(1973)* have shown that stands containing abundant advance regeneration before cutting have a high probability of regenerating satisfactorily even in the presence of deer browsing, while those with sparse advance regeneration are likely to fail. Much of the difference in stands observed here can probably be attributed to such differences in advance regeneration.

Average height of the tallest stem of all preferred species was reduced 38 percent in the unfenced areas, from 9.2 to 5.7 feet. Average height of the tallest stem of all commercial species was reduced 41 percent, from 11.6 to 6.8 feet (table 8). Both of these differences were statistically significant.

The average area occupied by groundcover vegetation did not differ appreciably

Table 6.—Average number of stems in 5- to 6-year-old clearcuts

(Thousands of stems per acre)

Species	Fenced			Unfenced		
	Over 5 feet	Under 5 feet	All sizes	Over 5 feet	Under 5 feet	All sizes
Black cherry	2.2	7.4	9.7	1.8	7.5	9.3
Suger maple	.3	.7	1.0	.0	.7	.7
Red maple	.4	1.8	2.3	.3	1.8	2.0
White ash	.4	1.0	1.4	.1	.6	.7
Beech	1.0	.9	1.9	.3	.4	.6
Birch	1.0	.7	1.6	.8	.9	1.7
Aspen	.2	.1	.3	.2	.1	.3
Pin cherry	1.2	.2	1.5	.1	.5	.6
Striped maple	.2	.1	.3	.7	.4	1.1
Others	.3	.8	.9	.3	.9	1.4
All species	7.2	13.7	20.9	4.6	13.8	18.4

Table 7.—Proportion of 5- to 6-year-old clearcuts satisfactorily stocked

Clearcuts in which at least 60 percent of plots are stocked with--	Fenced	Unfenced
	Percent	*Percent*
Preferred species:		
5 stems over 3 feet tall	70	40
2 stems over 3 feet tall	90	50
10 stems any size	70	60
5 stems any size	90	60
2 stems over 3 feet *or* 100 stems any size	90	50
2 stems over 3 feet *or* 25 stems any size	90	50
Commercial species:		
5 stems over 3 feet tall	90	50
2 stems over 3 feet tall	90	70
10 stems any size	90	60
5 stems any size	90	80
2 stems over 3 feet *or* 100 stems any size	90	70
2 stems over 3 feet *or* 25 stems any size	90	70

between the fenced and unfenced areas, but there were shifts in species abundance. Browsing reduced *Rubus* spp. considerably in the unfenced areas, while grasses and sedges spread to fill this void. These differences between fenced and unfenced areas were significant at the 10 percent level. Coverage of ferns and other ground-cover species was similar both inside and outside the exclosure (table 9). However, these average figures conceal some large differences that occurred in the individual areas. For example, the two areas in which tree seedlings were almost completely eliminated outside the exclosures had been taken over completely by herbaceous plants; primarily grasses and sedges, ferns, and tall plants such as goldenrod and aster (fig. 2).

All Clearcuts Combined

To provide a measure of the impact of deer browsing on Allegheny hardwood regeneration, all 13 clearcuts were grouped together, and stocking was evaluated on the basis of the most promising criterion. Those in which at least 60 percent of the plots were stocked with at least 2 stems over 3 feet tall, or 100 stems of any size at age 4 to 6 years, were judged to have regenerated satisfactorily;

Figure 2.—This 10-year old clearcut has failed to regenerate to tree species. This area is completely dominated by herbaceous plants such as grasses, ferns, goldenrod, and aster.

Table 8.—Average heights of tallest stem per plot in 5- to 6-year-old clearcuts

Species	Fenced	Unfenced
	Feet	*Feet*
Black cherry	9.0	4.1
Sugar maple	3.4	1.0
Red maple	4.8	3.6
White ash	3.4	2.5
Any preferred species	9.2	5.7
Any commercial species	11.6	6.8

Table 9.—Ground cover in 5- to 6-year-old clearcuts

Ground cover	Fenced	Unfenced
AVERAGE COVERAGE (percent)		
Rubus	46	27
Ferns	14	16
Grasses, sedges	6	15
All species	63	58
PROPORTION OF PLOTS WITH OVER 30-PERCENT COVERAGE (percent)		
Rubus	57	39
Ferns	23	20
Grasses, sedges	6	20
All species	91	83

those with lower stocking were judged unsatisfactory:

	Preferred species	*Commercial species*
Fenced	92	92
Unfenced	50	67

On this basis, deer browsing has resulted in unsatisfactory stocking of preferred species on 42 percent of the clearcuts examined. It has resulted in unsatisfactory stocking of any commercial timber species on 25 percent of the clearcuts examined (table 10).

A few areas (8 percent) failed to regenerate satisfactorily even where protected

Table 10.—Summary of regeneration success or failure

Success or failure	Preferred Species	Commercial Species
	Percent	*Percent*
Clearcuts successful in spite of deer browsing	50	67
Clearcuts failed because of deer browsing	42	25
Clearcuts failed because of other causes	8	8

from deer browsing (inside the exclosure). However, deer browsing may be responsible for these failures, too, to the extent that browsing may have reduced the number of advance seedlings present before cutting, and thus contributed to the failure before the fence was erected.

CONCLUSIONS

The following conclusions seem warranted:

- Browsing by white-tailed deer reduces the stocking of tree species in clearcut areas on the Allegheny Plateau of Pennsylvania and New York. Regeneration failures can be attributed directly to deer browsing in 25 to 40 percent of those areas in which no special attention has been given to advance reproduction.

- Successful regeneration can be obtained on many areas in spite of deer browsing; between ½ and ⅔ of the areas studied here have regenerated satisfactorily without protection from deer. Although not demonstrated here, other studies have shown that the stands most likely to regenerate satisfactorily are those with abundant advance regeneration *(Grisez and Peace 1973)*. These same studies show that over 90 percent of the areas clearcut will regenerate satisfactorily in spite of deer browsing if advance reproduction is abundant before cutting.

- Pin cherry is the species most severely affected by deer browsing. In unfenced clearcuts, pin cherry has been nearly eliminated by browsing. Sugar maple is also selectively reduced by browsing, while beech, birch, and striped maple often increase in proportion to other species in clearcuts subjected to deer browsing.

- Regeneration in areas cut 4 to 5 years previously can be judged satisfactory if 60 percent of the 6-foot-radius sample plots examined are stocked with at least 2 desirable stems over 3 feet tall *or* at least 100 desirable stems of any size.

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