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17 Deer Populations and the Widespread Failure of Hemlock Regeneration in Northern Forests

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This chapter describes our attempts to determine whether the widespread regenerative failure of eastern hemlock (*Tsuga canadensis* L.) in remnant eastern hemlock and hemlock-hardwood stands in the Upper Great Lakes region can be justly attributed to browsing by white-tailed deer, a native mammal whose populations now commonly occur at two to four times the density of pre-European settlement (e.g., Garrott et al. 1993). These forest types and their resident biota were once widespread and common in the Upper Great Lakes region. Eastern hemlock was a dominant or important canopy component in approximately two-thirds of Wisconsin's northern forest area at the time of European colonization but was reduced by timber harvest and bark extraction to remnant stands covering only 0.5% of the landscape (Curtis 1959; Rogers 1978; Eckstein 1980).

The causes of direct reduction of these forest types are not mysterious but, in contrast, the mechanism of eastern hemlock's regenerative failure remains controversial. Wisconsin Department of Natural Resources and U.S. Forest Service employees have proposed that climatic fluctuations, limited seed dispersal, and lack of appropriate seedbed conditions are better predictors of hemlock regeneration than are deer population densities (summarized in Mladenoff and Stearns 1993), but these hypotheses have not yet been tested.

In a previous paper (Alverson et al. 1988), we evaluated the evidence then available that deer contribute to the widespread lack of regeneration of canopy trees within stands of eastern hemlock and white cedar (*Thuja*

occidentalis L.) in northern Wisconsin and the Upper Peninsula of Michigan. In that paper, we cited an abundance of anecdotal information, descriptive data, and historical exclosure studies that indicated that elevated deer populations could greatly alter the composition and structure of several forest types on a local basis. A subsequent pilot field study on Nicolet National Forest and adjacent Menominee tribal lands indicated that regional variation in hemlock regeneration also was strongly correlated with deer abundance (E. J. Judziewicz, S. L. Solheim, D. M. Waller, and W. S. Alverson, unpublished data).

State and federal silviculturalists in our region often suggest that snowshoe hare (*Lepus americanus*) population densities could explain much of the variation in hemlock regeneration, but few data have been available to support or reject this hypothesis. For example, many historical exclosures were fenced to exclude both deer and snowshoe hare (e.g., Alverson et al. 1988: Figure 2), thus confounding their experimental effects. Furthermore, historical exclosures were often erected without replication and subjectively placed within deer yards, maximizing their demonstrative value but minimizing their experimental worth at a regional scale.

In this chapter, we contrast the effects of deer browsing on eastern hemlock seedlings with the effects of browsing by snowshoe hare to test the hypothesis that hare, rather than deer, population levels can best predict hemlock regeneration. We compare descriptive data from demographic plots and experimental data from exclosure plots on a small-scale basis here and on a large-scale basis elsewhere (Waller et al. 1996).

METHODS

Our broad study is based on 190 sites in northern Wisconsin and the Upper Peninsula of Michigan that were selected randomly from lists of eastern hemlock and hemlock-component stands provided by the staffs of county, state, and national forests and Native American reservation lands. At each site, all hemlock juveniles between 2 and 200 cm in height were measured within two randomly selected 7-m × 7-m subquadrats within a randomly placed 14-m × 21-m study quadrat during the summer of 1990. We assessed the recent browsing history of each site by counting the number of browsed and unbrowsed twigs of 10 or more randomly selected sugar maple (*Acer saccharum* L.) seedlings between 30 and 200 cm in height (where these were available).

In the fall of 1990, we initiated an exclosure experiment at a randomly

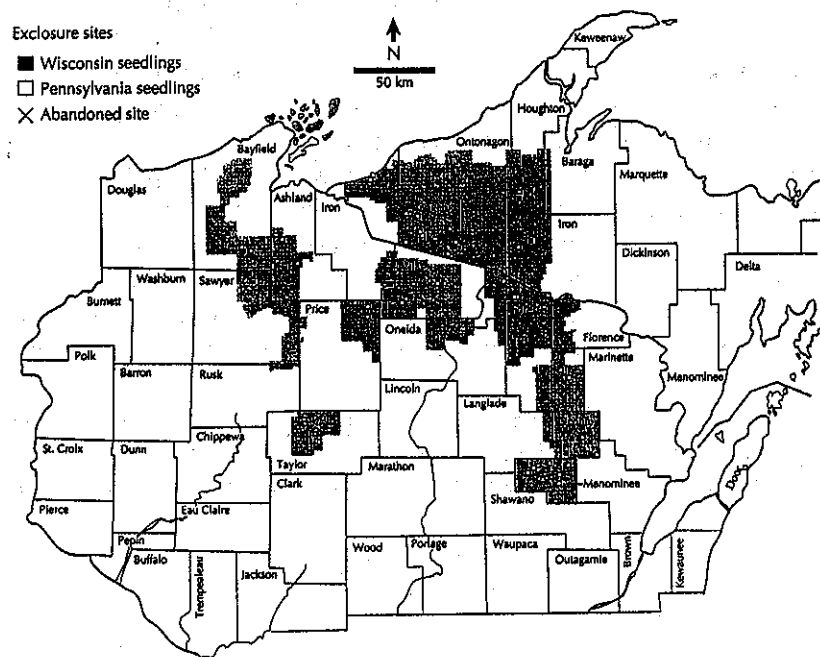


FIGURE 17.1. Map of study sites with mini-exlosures. The sites were located in northern Wisconsin and the Upper Peninsula of Michigan. Shaded areas indicate public forests and Native American lands sampled by the study. The 60 pairs of enclosure plots were planted with either native, wild-collected eastern hemlock seedlings or seedlings transplanted from a Pennsylvania nursery; one enclosure was later vandalized and abandoned.

selected subset of 60 of these study sites (Figure 17.1); one site was subsequently lost to vandalism. At each site, we selected two 9-m² plots as alike as possible with respect to slope, moisture, and canopy and subcanopy cover. We then randomly selected one as the experimental plot and erected a deer-proof cage over it. The other plot was left uncaged as a control. These "mini-exclosure" cages were 2.4 m on a side and 1.3 m tall. Their sides and tops were constructed of rigid cattle panels with 15-cm × 20-cm mesh, thus excluding deer but allowing snowshoe hare and other small herbivores to enter the cages.

We used transplanted eastern hemlock seedlings from two different sources in our experiment. Thirty-nine sites contained large, fertilized, bare-root seedlings from a commercial nursery in Pennsylvania. The other 20 sites received smaller, unfertilized, native Wisconsin seedlings with

root balls. The 20 sites with Wisconsin seedlings were chosen randomly from the original list of 60 enclosure sites and represent five ownerships, including three national forests and two Native American reservations (Figure 17.1). The Pennsylvania seedlings were much easier to obtain and transplant in large quantities than were the native Wisconsin seedlings, but we used both types of seedlings to address concerns that the nursery seedlings might be significantly more attractive to deer than wild-collected seedlings, possibly biasing our results. Here we report data on seedling growth and survival for the sites receiving Wisconsin transplants, along with site data (e.g., browse indices and pellet counts) for all 59 nonvandalized sites receiving transplanted hemlocks.

In the spring of 1991, we randomly assigned nine transplanted hemlock seedlings to each of the two enclosure plots at the 59 study sites. We recorded each seedling's height (maximum elevation from substrate) and length (longest distance along stem from base to any branch tip) immediately after transplantation. We then revisited the sites in early spring 1992 and 1993 to record height, length, recent browse, and mortality data. Our experimental design did not require us to distinguish snowshoe hare from deer browse on individual hemlock twigs during censuses, although we routinely did so, because the enclosures were specifically designed not to exclude hare.

At each site, we recorded the number of new deer-pellet groups in eight circular 0.01-acre sample points (which totaled 323.9 m² per site; Figure 17.2) during early spring 1991–93. We also noted the number of these circular plots that contained any new hare pellets. Both counts reflect the number of pellets deposited during the winter season between leaf fall (October) and snowmelt (mid-April to mid-May). Although we used methods similar to those employed regionally to estimate deer densities in large management units of 500–1,000 km² or more in size (e.g., Thompson 1978), our intent was to provide estimates of the relative intensity of deer visitation to our study sites rather than to estimate absolute numbers of deer in larger areas, a much more problematic task. We used multiple plots per site to minimize sampling errors (Eberhardt and Van Etten 1956; Van Etten and Bennett 1965; Neff 1968; Smith 1968; Ryel 1971; Creed et al. 1984), and meticulous pellet counts for all years were made by a single field worker to minimize observer error.

To assess the reliability of our counts, we marked 207 deer-pellet groups at 34 study sites in the spring of 1991. During site revisitations in 1992, we incorrectly scored old pellet groups (from the previous year) as new pellet groups (from the preceding 6 months) in only 7 of 207 in-

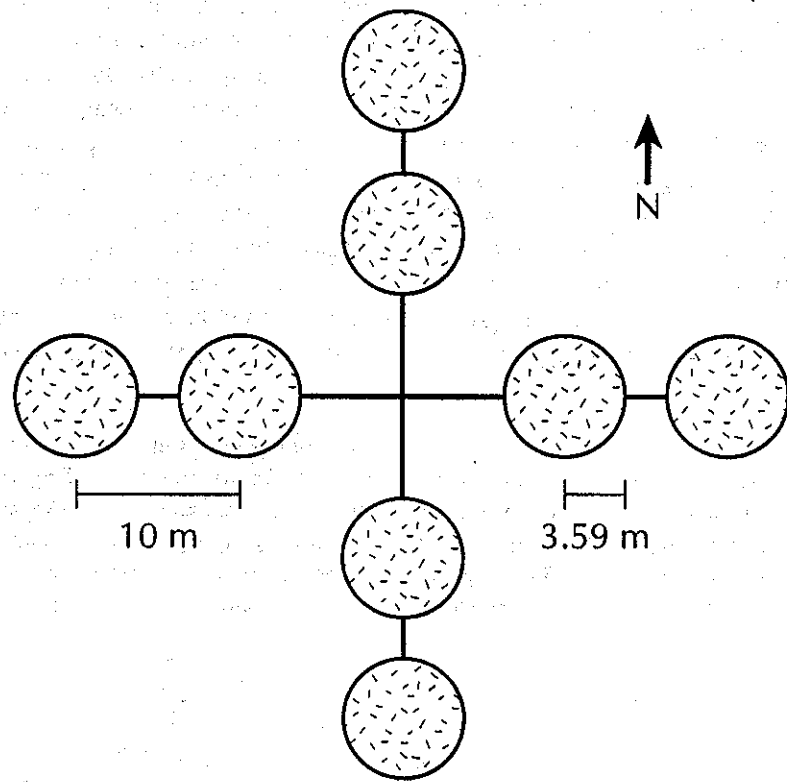


FIGURE 17.2. Layout of sampling points for deer and hare pellets within exclosure sites. The center of this array of eight 0.01-acre points was randomly sited at one of the two ends of the randomly sited study quadrat.

stances (3.4%) with our pellet scoring criteria. In spring 1991, we also removed pellet groups from 136 sample points at these sites for comparison with an equal number of points from which pellets were left unmanipulated. The number of pellet groups scored as new during the 1992 census in all points from which deer-pellet groups had been removed in 1991 was not significantly different from the number of pellet groups scored as new in an equal number of points from which pellets were not removed. Thus, our methods had no significant bias towards misidentification of new pellet groups as old ($t = 0.350$, $P = 0.729$, for respective means of 4.8 and 4.5).

We estimated the relative abundance of showshoe hare at each site during these spring visits in two ways. First, we recorded the number of

the eight circular 0.01-acre sample points containing any hare pellets at each site ("hare points"). Second, we counted the total number of hare pellets at least 0.5 m distant from any other hare pellet within each sample point ("independent hare pellets") to differentiate between sites with high and very high population densities of hare.

All analyses were carried out in SYSTAT (Wilkinson 1990; SYSTAT 1992) and InStat (Motulsky et al. 1994).

RESULTS

Occurrence of Hemlock Seedlings

Naturally occurring hemlocks between 4 and 200 cm tall occurred in one or both of the 49-m² subquadrats at 62.6% of our 190 study sites; the average was 9.7 juveniles per site (Table 17.1). Seedlings 2–3 cm tall and mostly 1 year old or less (Eckstein 1980) were found within at least one of the subquadrats at 26% of the sites. We did not analyze data for the 2–3-cm size class further because the majority of these individuals were highly ephemeral and differences in abundance between sites reflect, in part, the month of site visitation.

Measures of Deer and Hare Abundance

The number of deer-pellet groups deposited within the eight sample points at individual sites during any winter season ranged from 0 to 66; the 3-

TABLE 17.1
Naturally occurring hemlock seedlings by size class

Size class (height)	Number per 98 m ²		Frequency (fraction of sites)
	Mean	s	
2–3 cm	12.1	65.2	0.26
4–9 cm	3.3	10.0	0.38
10–29 cm	3.0	7.3	0.46
30–200 cm	3.4	10.0	0.40
4–200 cm	9.7	23.2	0.63

Note: Data are from 190 sites in eastern hemlock and hemlock-component stands in northern Wisconsin and the Upper Peninsula of Michigan, 1990.

TABLE 17.2
Relative abundance of deer and snowshoe hare at 59 enclosure sites

Year	Number of deer-pellet groups in sample points			Number of sample points with hare pellets			Number of independent hare pellets in sample points ^a		
	Mean	s	Median	Mean	s	Median	Mean	s	Median
1991	8.6	12.1	5	1.5	2.4	0	4.2	7.9	0
1992	8.7	11.0	4	1.4	2.5	0	5.9	16.5	0
1993	5.9	8.2	2	1.2	2.1	0	3.9	9.8	0

Notes: In total, 323.9 m² within eight sample points were censused at each site in early spring. Values estimate the relative abundance of deer and hare at study sites during the previous winter season.

^aTotal number of hare pellets at least 0.5 m from any other hare pellet within each sample point.

year mean was 7.7 ($s = 9.0$, $n = 59$; Table 17.2). Local deer abundances by this index were significantly correlated between years ($r = 0.571$, $P < 0.0001$, comparison of 1992 with 1991; $r = 0.779$, $P < 0.0001$, 1993 with 1992).

Hare pellets were relatively scarcer in our study area, occurring in 0 to 8 sample points per study site (3-year mean = 1.4, $s = 2.2$, $n = 59$; Table 17.2). The number of independent hare pellets deposited within the sample points at individual sites during any winter season ranged from 0 to 111; the 3-year mean was 4.7 ($s = 10.6$; Table 17.2). We report further results based on only data for hare points (the number of sample points with hare pellets) because the two indices of hare abundance were highly correlated ($r = 0.864$, $P < 0.001$, $n = 59$ for 3-year means) and consistent among years (Table 17.3) and because they produced similar results in most comparative analyses.

In contrast, we found no significant association between the number of deer-pellet groups and the number of points with hare pellets per site ($r = -0.052$, $P = 0.694$, $n = 59$; Figure 17.3).

Sugar maple seedlings were present at 102 of the 190 sites used for our broad study (Waller et al. 1996). At these sites, the browse index averaged 0.44 (range 0–0.93), slightly but nonsignificantly greater than the mean for the subset of sites with exclosures and with sufficient sugar maple seedlings to calculate this index (mean = 0.39, $n = 38$; $P = 0.373$ for t -test).

Our independent estimates of deer abundance were positively correlated. The browse index, an indicator of browsing at sites prior to 1990,

TABLE 17.3
Pearson correlation values for two indices of local hare abundance

Correlation variable	Hare points			Independent hare pellets		
	1991	1992	1993	1991	1992	1993
Hare points						
1991	1.000	—	—	—	—	—
1992	0.814	1.000	—	—	—	—
1993	0.708	0.773	1.000	—	—	—
Independent hare pellets						
1991	0.936	0.829	0.787	1.000	—	—
1992	0.651	0.761	0.706	0.762	1.000	—
1993	0.621	0.632	0.862	0.720	0.835	1.000

Notes: Hare point values represent the number of 0.01-acre census points per site (eight census points at each of 59 sites) containing new hare pellets in an early spring census. Independent hare pellet values represent the total number of hare pellets at least 0.5 m from any other found in the census points. Each individual comparison is significant at the $P < 0.001$ level.

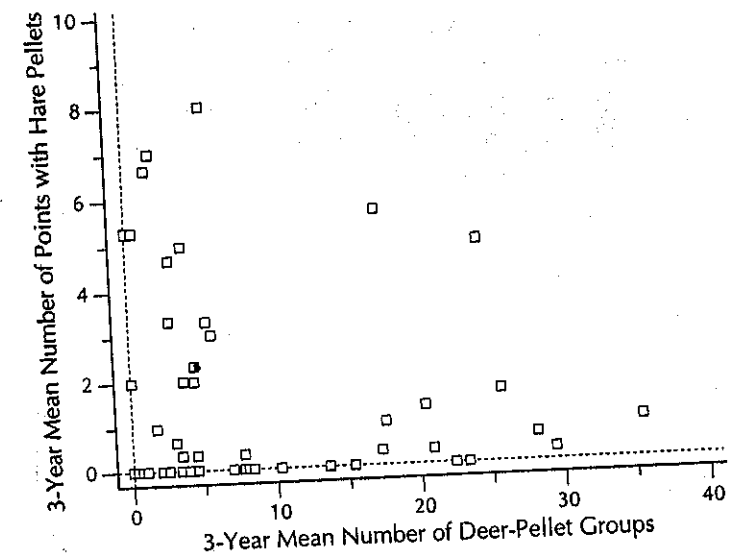


FIGURE 17.3. Association between deer and hare pellets at enclosure sites. Three-year mean number of sample points with hare pellets per site (eight sample points in each of 59 enclosure sites) and the 3-year mean number of deer-pellet groups per site, 1991–93, are compared.

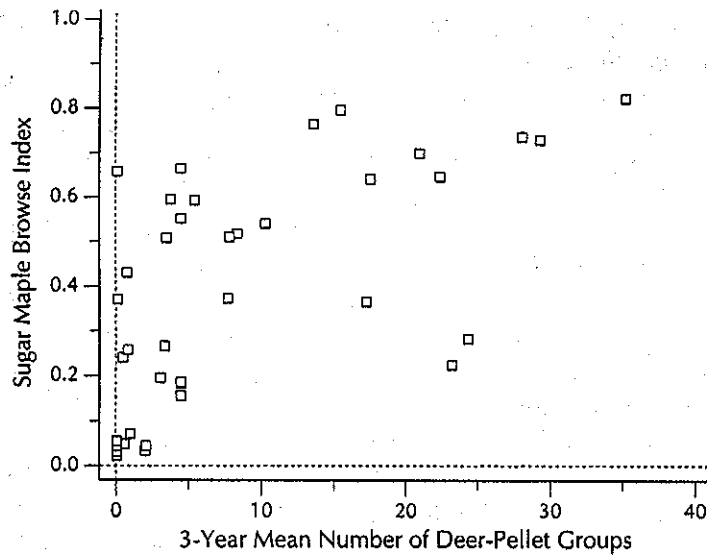


FIGURE 17.4. Association between browse index and deer pellets at exclosure sites. The sugar maple browse index, taken in 1990, was compared with the 3-year average number of deer-pellet groups counted at exclosure sites during early spring, 1991-93 ($n = 38$).

was significantly and positively correlated with the average number of new deer-pellet groups counted during the spring surveys of 1991-93 ($r = 0.602$, $P < 0.001$, $n = 38$; Figure 17.4). In contrast, the browse index varied independently of estimated hare density ($r = -0.027$, $P = 0.873$, $n = 38$ for hare points). Thus, the sugar maple browse index reflects cumulative browsing by deer, not hare.

Correlations of Hemlock Abundance and Height with Deer and Hare Abundance

The average height of eastern hemlock seedlings showed a significant, negative relationship with the browse index at demographic sites at which sugar maple seedlings were sampled ($r = -0.270$, $P = 0.006$, $n = 102$; Figure 17.5). In addition, the variance in average hemlock seedling height was notably reduced at high values of the browse index. The correlation between average heights and the browse index was also negative and of a similar magnitude for the subset of sites with both exclosures and browse index values, but sample size limited the statistical significance ($r = -0.314$, $P = 0.055$, $n = 38$).

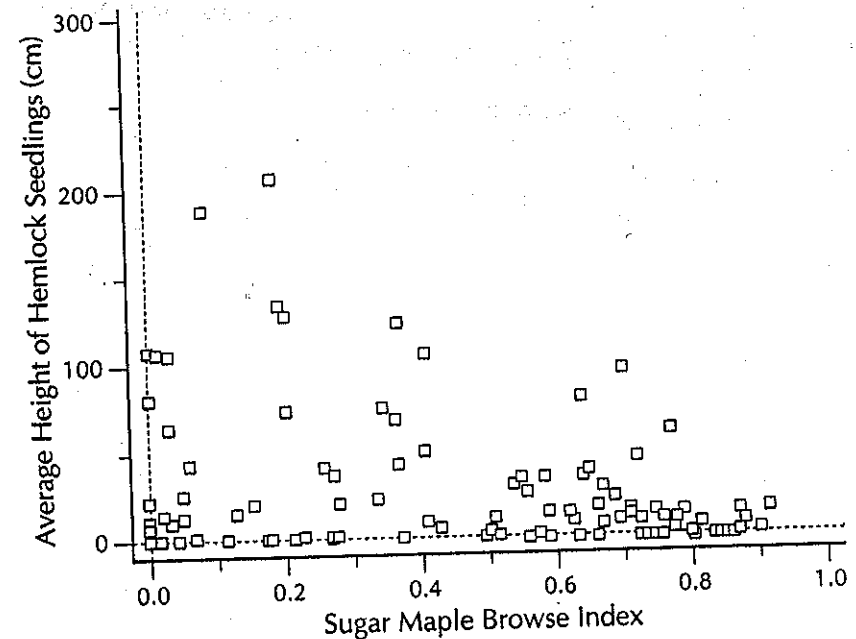


FIGURE 17.5. Average height of eastern hemlock seedlings and the sugar maple browse index. Data are for all demographic sites at which the browse index was scored ($n = 102$).

The abundance and average heights of naturally occurring nontransplanted hemlock seedlings at study sites with exclosures was consistently negatively correlated with the 3-year mean number of deer-pellet groups, but again small sample size limited statistical significance (Table 17.4). In contrast, comparisons of numbers and heights of hemlock seedlings at exclosure sites showed consistently positive correlations with snowshoe hare abundance among sites, which reached statistical significance for the 4-200-cm combined size class (Table 17.4). To insure that these relationships were not an incidental artifact of some other factor preventing hemlock regeneration, we reanalyzed these data by removing sites without hemlock seedlings. These reanalyses did not substantially change the patterns of correlation (Table 17.5).

Exclosure Seedlings

Browsing by deer and snowshoe hare significantly increased the mortality rate of hemlock seedlings. Only 9.3% of the 280 unbrowsed, transplanted

TABLE 17.4

Pearson correlation values of the abundance and mean height of naturally occurring hemlock seedlings with 3-year mean measures of deer and snowshoe hare abundance

Abundance of eastern hemlock seedlings by size class	Deer pellets	Hare points
4-9 cm	-0.132	0.290
10-29 cm	-0.171	0.325
30-200 cm	-0.078	0.160
4-200 cm	-0.152 ^a	0.314 ^b
Average height	-0.236 ^c	0.130 ^d

Notes: Data are from 59 sites with two subquadrats totaling 98 m² per site for years 1991-93. Tests for the statistical significance of the four summary comparisons are given.

^aP = 0.251.

^bP = 0.015.

^cP = 0.071.

^dP = 0.325.

TABLE 17.5

Pearson correlation values after removal of sites without juvenile hemlocks in either sampled subquadrat

Abundance of eastern hemlock seedlings by size class	Deer pellets	Hare points
4-9 cm (25 sites)	-0.273	0.347
10-29 cm (37 sites)	-0.246	0.334
30-200 cm (34 sites)	0.133	0.067
4-200 cm (48 sites)	-0.162 ^a	0.274 ^b
Average height (50 sites)	-0.268 ^c	0.079 ^d

Notes: The number of sample sites with juvenile hemlocks of a given size class are noted in parentheses. Tests for significance of the four summary comparisons are given.

^aP = 0.271.

^bP = 0.059.

^cP = 0.06.

^dP = 0.587.

TABLE 17.6

Growth of browsed versus unbrowsed and caged versus uncaged transplanted Wisconsin hemlock seedlings

Treatment	Growth in height (cm)			Growth in length (cm)		
	Mean	s	n	Mean	s	n
Unbrowsed	2.18	4.82	247	3.00	5.12	247
Browsed	0.11	6.98	59	0.18	8.53	59
		(P = 0.007)			(P = 0.001)	
Caged	2.13	4.29	150	2.90	4.84	148
Uncaged	0.79	3.39	156	1.29	4.31	156
		(P = 0.003)			(P = 0.002)	

Notes: Over the 2-year period, spring 1991 to spring 1993, uncaged seedlings were exposed to browsing by deer and snowshoe hare but caged seedlings were exposed only to hare. The P-values given are for t-tests of equality of means.

Wisconsin seedlings died between spring 1991 and spring 1993 versus 27% of the 74 browsed seedlings (t-test, $P < 0.001$). Browsing also significantly decreased height and length growth (Table 17.6).

We observed no significant differences in mortality between caged seedlings and uncaged seedlings during the 2-year period ending in spring 1993 (mean mortality caged seedlings = 0.156, $s = 0.202$, $n = 150$; mean mortality uncaged seedlings = 0.131, $s = 0.156$; $n = 156$; $P = 0.226$, t-test).

Despite this similarity in overall survivorship, the additional browse sustained by seedlings surviving in the uncaged plots significantly reduced their height and length growth (Table 17.6). The mean height of seedlings within the exclosures was significantly greater than that of uncaged seedlings after 2 years (Figure 17.6; mean height of seedlings within exclosure = 14.6 cm, outside exclosure = 12.6 cm, $P = 0.017$; respective spring 1991 means, 12.1 and 11.7 cm, $P = 0.517$). Likewise, the mean length of seedlings protected within the exclosures also became significantly greater by spring 1993 (mean length of seedlings within exclosure = 20.2 cm, outside exclosure = 17.3 cm, $P = 0.005$).

Inside the exclosures, growth in neither height nor length of seedlings was significantly related to the average number of deer-pellet groups ($r = 0.418$ and 0.215 , respectively) nor to the average number of hare points ($r = -0.318$ and -0.162 , respectively). Likewise, outside the exclosures, the average number of deer-pellet groups did not significantly predict

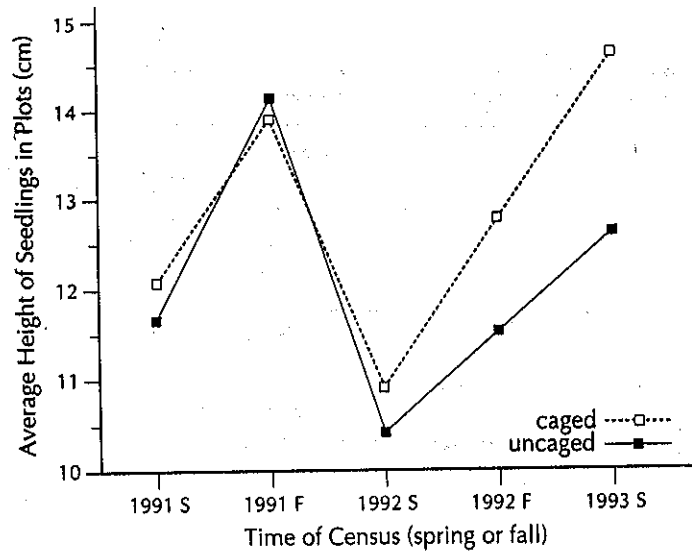


FIGURE 17.6. Average height growth of caged and uncaged transplanted native hemlock seedlings. The reduction in mean height from 1991 to 1992 was caused by dieback and branch repositioning after transplantation.

height or length growth of seedlings ($r = -0.216$ and -0.251 , respectively) nor did the average number of hare points ($r = -0.147$ and -0.210 , respectively).

To assess the effect of deer browse alone, we compared the difference between the height increment values of the caged and uncaged plots at each site (height excess) against measures of deer abundance. The height excess shows a highly significant correlation with the 3-year mean of deer-pellet groups per site during this 2-year period of seedling growth ($r = 0.756$, $P < 0.0001$). Deer-pellet group counts from the 1992-93 winter season alone predicted the height excess even better ($r = 0.85$; Figure 17.7). Calculations for the difference between the length increment values of caged and uncaged plots at each site (the length excess) indicate a similar relationship. This variable was highly significantly correlated with the 3-year average number of deer-pellet groups ($r = 0.667$, $P < 0.0001$) and with pellet counts from the 1992-93 winter season ($r = 0.648$, $P < 0.0001$).

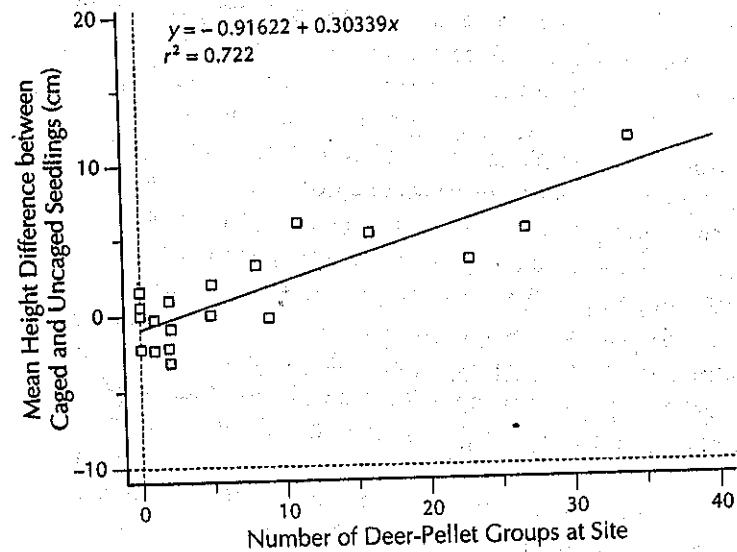


FIGURE 17.7. Seedling height excess versus deer abundance. Height excess, the mean difference in height of seedlings within the exclosure cage and those outside (on a per site basis), was regressed against the number of deer-pellet groups deposited at that site during the 1992-93 winter season.

Overall Effects of Deer and Hare Browsing

On average, browsed seedlings increased in height 2.07 cm (95.0%) less than did unbrowsed seedlings from spring 1991 to spring 1993 (Table 17.6). As a consequence, browsed seedlings were 14.1% shorter, on average, than were unbrowsed seedlings by spring 1993. Of this reduction in height growth, 64.7% can be attributed to deer, as evidenced by the additional growth (mean height excess) of 1.34 cm shown by caged seedlings during this 2-year period.

Likewise, browsed seedlings increased in length 2.82 cm (94%) less, on average, than did unbrowsed seedlings during this same 2-year period. Thus, the average length of browsed seedlings became 14% less than that of unbrowsed seedlings by spring 1993. Of this reduction in length growth, 57.2% can be attributed to deer, as evidenced by the additional growth (mean length excess) of 1.61 cm shown by seedlings protected within the exclosures.

DISCUSSION

This study provides evidence that browsing significantly increases mortality and significantly decreases height and length growth of native eastern hemlock seedlings. The results also suggest that deer have a greater effect on the growth and survival of hemlock seedlings than do snowshoe hare in hemlock stands of the Upper Great Lakes region.

Data from the demographic plots suggest that increased deer abundance reduces the number and size of hemlock seedlings, as evidenced by the consistently negative correlations between our measures of hemlock regeneration and deer abundance. In contrast, we found no support for the hypothesis that snowshoe hare populations significantly reduce hemlock abundance or height within these habitats on a regional basis, though such an effect occurs at some local sites.

The weak correlations between our estimates of deer and hare abundance and hemlock variables probably reflect the relatively small areas and consequent high sampling variation for demographic profiles of hemlock regeneration at study sites. Although 62.6% of these sites contained some hemlock seedlings between 4 and 200 cm tall within the randomly sited 98-m² sampling area, such small spatial samples probably underestimated the frequency of hemlock regeneration at larger scales within sites.

As the Wisconsin seedlings transplanted into our study sites continue to grow larger while being differentially exposed to deer over additional winters, we expect the differences in growth and mortality reported here to become more pronounced. Indeed, such larger differences have already been observed in exclosure plots in which larger hemlock seedlings from a Pennsylvania nursery have been planted (W. S. Alverson, personal observation, spring 1995). Data from censuses during the spring of 1997 should allow us to evaluate further how well our indices of deer and hare abundance predict seedling growth. The passage of time will also allow us better to understand mortality, a demographic event that appears to be strongly linked to browsing but more delayed in effect than growth, as well as the biological significance of differences in growth rates between browsed and unbrowsed seedlings.

Ultimately, if we are to build a chain of evidence indicating that deer are responsible for a failure of hemlock regeneration within hemlock and hemlock-component stands in the Upper Great Lakes region, a number of interconnecting links must be established. To discuss these links, we must carefully distinguish between two aspects of hemlock regeneration: reproduction and recruitment. Reproduction is defined here as the input of

seeds and small seedlings (<4 cm tall) into forest stands. Recruitment refers instead to the subsequent survival of these young seedlings to sapling and adult size. Successful regeneration of canopy trees clearly requires both adequate reproduction and at least intermittently satisfactory recruitment. That is, both are necessary conditions but neither alone is sufficient.

This study and other published and unpublished studies support three of the evidential links connecting deer and eastern hemlock regeneration. First, we note that hemlock stands in our region frequently produce large seed crops with 25% viability and that there is no evidence that reproduction in any recent decade is limited by availability of seeds (Eckstein 1980). Our studies and observations indicate that seedlings 2–3 cm tall are present within a minimum of 25.6% of our randomly selected 98-m² study quadrats and that the local heterogeneity of seedling reproduction results in an even greater frequency of occurrence of small seedlings at larger scales within sites. Thus, it appears doubtful that the number of seeds or small seedlings within these hemlock stands often limits regeneration in the Upper Great Lakes region, as postulated by Mladenoff and Stearns (1993).

Second, our studies also indicate that although the abundance of 2–3-cm-tall hemlock seedlings varies locally in response to many factors, such as snowshoe hare abundance, seedbed conditions, coarse woody debris, and canopy conditions, this variance is less predictive of the abundance of juveniles in larger size classes in remnant hemlock stands than are regionally varying indicators of deer abundance (Waller et al. 1996). Third, these same studies indicate that measures of local deer population density predict growth and survival rates of hemlock seedlings better than do hare abundance or other predictors.

In future studies, we intend to investigate whether browsing by deer directly precludes hemlock seedlings from growing into subadult size classes or if it prevents regeneration indirectly by reducing the growth and survival of hemlock seedlings so that they lose competitive advantages over other woody species (or both). We are also pooling local (study site) data into classes based on ownership, management, and deer population densities (e.g., national forests versus reservation lands; Table 17.7) to investigate how the pattern of missing size classes of juvenile hemlocks characterizing some ownerships, or other classes, will translate into replacement of senescent canopy hemlocks on a regional scale (Waller et al. 1996). Our eventual goal is to determine whether some threshold deer density exists for our region and how long (and often) densities must re-

TABLE 17.7

Population levels of deer and snowshoe hare at exclosure sites by land ownership

Ownership (# sites)	Number of deer-pellet groups		Number of census points with hare pellets	
	Mean	s	Mean	s
Chequamegon National Forest (12 sites)	11.00	9.08	2.75	2.68
Lac du Flambeau Reservation (8 sites)	0.50	0.67	2.63	3.18
Menominee Reservation (13 sites)	3.90	6.24	0.80	1.63
Nicolet National Forest (10 sites)	6.27	7.14	0.60	0.98
Ottawa National Forest (16 sites)	12.85	10.57	0.60	1.23

Notes: Values are 3-year means for eight census points per site, fall 1990 to spring 1993. The Chequamegon National Forest and the Lac du Flambeau Reservation are adjacent, as are the Nicolet National Forest and the Menominee Reservation.

main below this threshold density to allow episodes of successful eastern hemlock reproduction in our region.

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