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# EFFECTS OF WOODCHUCK ACTIVITY ON WOODY PLANTS NEAR BURROWS

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**ABSTRACT.**—The relationship between woodchuck (*Marmota monax*) activity and characteristics of woody plants was examined at two woodlands in Connecticut. Areas within 3 m of main burrow entrances were characterized by a lower number of live stems and greater mortality of stems than were areas of the same size located 13 m from burrows. These and other differences were not related to either plant age or edaphic or light characteristics. We attribute the observed vegetation changes to behaviors associated with burrowing and scent marking by woodchucks, and conclude that woodchucks in wooded areas can promote localized, long-term changes in the abundance, and possibly the distribution, of woody plants.

Fossorial and semifossorial herbivorous mammals can alter dramatically the abundance and composition of plants near burrows, either directly by consuming plants (Agnew et al., 1986; Mallory and Heffernan, 1987; Reichman and Jarvis, 1989) or indirectly by altering soil and nutrient characteristics that affect plant growth (Grant et al., 1980; Hobbs and Mooney, 1985; Inouye et al., 1987; Koide et al., 1987; Merriam and Merriam, 1965; Reichman and Jarvis, 1989; Spencer et al., 1985; Tilman, 1983). Such disturbances ultimately can influence rates of plant succession (Hobbs et al., 1988; Inouye et al., 1987; Williams et al., 1986).

Woodchucks (*Marmota monax*) are semifossorial sciurids that construct extensive burrows in early successional and woodland habitats (Grizzell, 1955; Hamilton, 1934). They are selective herbivores (Hamilton, 1934; Swihart, 1990), and their feeding can reduce the biomass of selected foods in the vicinity of burrows (Merriam and Merriam, 1965). In addition, changes in woody vegetation may occur as a consequence of behavior associated with chemical communication. Woodchucks scent mark numerous substrates, including wood (Hébert and Prescott, 1983), and gnawing often precedes scent marking of woody plants (Ouellet and Ferron, 1988; Swihart, 1991). This presumably facilitates retention of scent (Ouellet and Ferron, 1988) or serves as a visual marker of scent stations (Halpin, 1984). Gnawing by woodchucks is a common cause of mortality of young fruit trees in orchards in New England (Swihart and Conover, 1988). Hence, gnawing associated with scent marking may affect survival of trees in natural habitats. Our objectives were to examine the influence of *M. monax* on survival, species composition, and growth of woody plants near burrows in woodland habitat.

## METHODS

Burrows of woodchucks were selected for study in two woodlots in central Connecticut. One woodlot located in Hamden, New Haven Co., was 1.3 ha, whereas the other woodlot in Southington, Hartford Co., was 5.6 ha. Woody vegetation was examined at each site in September 1989. Burrows within woodlots were chosen for study only if in current use by woodchucks as indicated by freshly excavated soil, or capture, observation, or radiotelemetry location of woodchucks, and if they were >10 m from the edge of woods and >15 m from other active burrows. All burrows were present since 1987. Woody plants  $\geq 1$  m in height and with diameters  $\leq 7.5$  cm at 0.5 m above ground were examined at each burrow.

To examine stem density as a function of distance from burrows, stems were counted within 2-m-wide transects beginning at the main entrance of a burrow and extending 5 m in each of the cardinal directions.

Each stem was identified to species, inspected for gnawing by woodchucks (Swihart and Conover, 1988), and the size of the area gnawed ( $\text{cm}^2$ ) was measured.

Of all scent marking by woodchucks, 96% occurs  $\leq 6$  m from a burrow (Ouellet and Ferron, 1988). Thus, we hypothesized that stems 10–15 m from burrows would be relatively unaffected, but would occupy sites with characteristics of soil and light similar to those observed at burrows. To assess the impact of woodchuck activity on abundance and composition of woody plants near burrows, stems within a 3-m radius centered on the main entrance of a burrow were compared with stems in a 3-m radius centered on a point located 13 m away. Each 13-m point was located in a randomly chosen direction from the burrow with which it was paired, subject to the constraints that it was  $> 10$  m from the edge of the woodlot and  $\geq 13$  m from any other burrow. A distance of 13 m was chosen so no stem within a paired circle was  $< 10$  m from its paired burrow. For each plant occurring within one of the circles, we recorded species, condition (alive or dead), size of area gnawed ( $\text{cm}^2$ ) by woodchucks, diameter (cm) at 0.5 m above ground, current linear annual growth (cm), and age of plant (years) as determined by counts of bud-scale scars (Harlow, 1946).

To determine whether physical characteristics of the environment differed between the burrow and 13-m sites, we measured ambient light intensity ( $\text{W}/\text{m}^2$ ) at ground level and 2 m above ground by use of a Lambda LI-185 photometer. Light was measured between 1230 and 1430 h on a cloudless day at a burrow and its paired 13-m site within 3 min of each other. The angle of the slope within 3 m of each site also was measured. Soil pH was recorded with a Corning Model 12 pH meter for soil samples collected to a depth of 20 cm with a hand auger. Woodchucks excavate subsurface soil and deposit it at the entrance to burrows, and as a result pH values of excavated soil may not be representative of values for surface soil. To permit comparison of surface and subsurface soil near burrows with surface soil at 13-m sites, we collected samples of excavated soil at the entrance of each burrow and surface soil 1.5 m and 13 m from each burrow. Mean soil pH at these three locations was compared by use of analysis of variance, with burrows as a blocking factor.

For each woodlot, a nonparametric two-way analysis of variance (Quade test—Conover, 1980) was computed to determine whether stem density varied as a function of distance from a burrow, with burrows as a blocking factor. The abundance of stems within circles of 3-m radius centered at burrows and 13-m points was compared with the Wilcoxon matched-pairs test (Conover, 1980), as were incidence of gnawing, light intensity, and slope. Species composition at burrows and 13 m was compared by use of a chi-square analysis. Species of woody plants with  $\geq 50$  stems measured in a woodlot had growth characteristics (diameter, current annual growth) analyzed separately by analyses of covariance, with location (burrow or 13 m) as a fixed effect and age as a covariate. In addition, we calculated an index of damage severity, defined as the proportion of surface area of stems from 0 to 0.5 m in height gnawed by woodchucks.

## RESULTS

In general, density of live woody stems increased as a function of distance from a burrow, although at the Southington site this relation was not monotonic (Fig. 1). Moreover, extent of gnawing damage was correlated negatively with distance from a burrow at the Southington site ( $r = -0.46$ ,  $d.f. = 39$ ,  $P < 0.01$ ) and at the Hamden site ( $r = -0.30$ ,  $d.f. = 40$ ,  $P < 0.05$ ). The proportion of stem surface area gnawed exhibited similar trends ( $r = -0.50$  and  $-0.38$  at Southington and Hamden, respectively;  $P < 0.01$  at both sites). Thus, live stems became less abundant near burrows, and gnawing was more severe on stems near these entrances.

Comparison of live stems within 3-m radii indicated that significantly fewer stems occurred at burrows than at a distance of 13 m (Table 1; Southington,  $z = 2.09$ ,  $P = 0.037$ ; Hamden,  $z = 2.65$ ,  $P = 0.008$ ). Despite the relative scarcity of stems  $< 3$  m from burrows, the mean number of stems gnawed by woodchucks was greater within 3 m of a burrow than at a distance of 13 m (Table 1; Southington,  $z = -2.31$ ,  $P = 0.021$ ; Hamden,  $z = -2.04$ ,  $P = 0.042$ ).

The number of dead stems within each 3-m radius was too small to permit statistical analysis, hence, we present only pooled proportions. Of stems examined at the Southington site ( $n = 113$  at burrows, 204 at 13-m sites), the proportion of dead stems was 1.6 times greater at burrows than at 13-m sites, whereas for stems at the Hamden site ( $n = 149$  at burrows, 366 at 13-m sites), the proportion of dead stems was 2.8 times greater at burrows. Moreover, the greater mortality evident near burrows was correlated with damage by gnawing. The proportion of dead stems damaged by gnawing was 10.6 and 5.7 times greater near burrows than at 13-m sites at the Southington and Hamden sites, respectively.

Thirty species of woody plants grew near burrows. The mean number of species occurring at burrows and at 13-m sites at Southington did not differ ( $\bar{X} = 3.2$  species at both sites,  $z = -0.51$ ,  $P = 0.61$ ). At Hamden, though, the mean number of species  $\leq 3$  m from burrows ( $\bar{X} = 3.4$ ) was

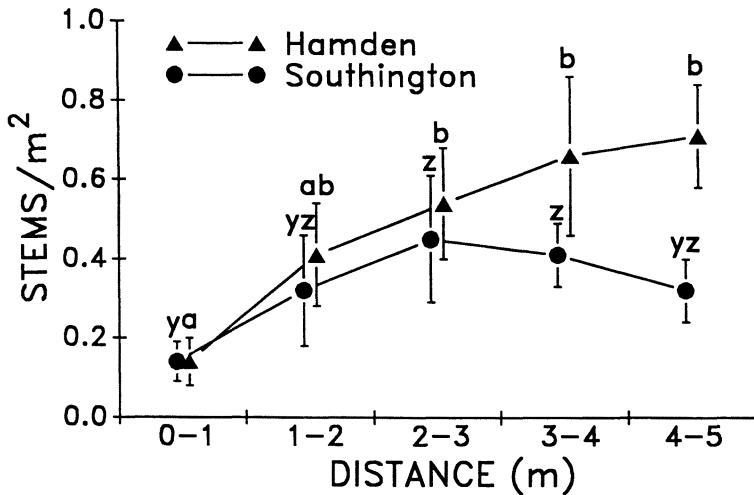


FIG. 1.—Mean density ( $\pm$ SE) of live woody stems as a function of distance from burrows of *Marmota monax* in two woodlots in Connecticut. Means were calculated from 10 burrows in each woodlot. Within woodlots, means with different letters differ significantly ( $P < 0.05$ , Quade test—Conover, 1980).

significantly less than at 13-m sites ( $X = 4.5$ ;  $z = 2.03$ ,  $P = 0.04$ ). At Southington, hornbeam (*Ostrya virginiana*) and common witch-hazel (*Hamamelis virginiana*) were proportionately more abundant at burrows than at 13-m sites, whereas spicebush (*Lindera benzoin*) was less abundant at burrows ( $\chi^2 = 30.9$ ,  $d.f. = 7$ ,  $P < 0.001$ ). At Hamden, sugar maple (*Acer saccharum*) and burningbush (*Euonymus atropurpureus*) were more abundant at burrows than at 13-m sites, whereas mapleleaf viburnum (*Viburnum acerifolium*) and white ash (*Fraxinus americana*) were significantly less abundant near burrows ( $\chi^2 = 92.1$ ,  $d.f. = 9$ ,  $P < 0.001$ ).

Analyses of covariance were conducted for growth characteristics of mapleleaf viburnum at Southington and for mapleleaf viburnum and sugar maple at Hamden. Significant interactions between age and location (burrow or 13-m site) precluded an assessment of the relation between location and growth of mapleleaf viburnum. For sugar maple, plants at burrows exhibited less current annual growth, corrected for age effects, than conspecifics at 13-m sites ( $F = 8.59$ ;  $d.f. = 1,57$ ;  $P = 0.005$ ). No significant difference in stem diameter was evident for this species ( $F = 0.67$ ;  $d.f. = 1,57$ ;  $P = 0.417$ ). Sugar maple was damaged most by gnawing, with an index of damage severity of 0.86, compared with the three other most common species, witch-hazel (0.57), hornbeam (0.54), and mapleleaf viburnum (0.16).

Mean light intensity ( $W/m^2$ ) at Southington did not differ at burrows and 13-m sites when measured at ground level ( $\bar{X}$  at burrow = 50.7, at 13 m = 24.9;  $z = 0.51$ ,  $P = 0.61$ ) or at a height of 2 m ( $\bar{X}$  at burrow = 48.2, at 13 m = 41.2;  $z = 0.51$ ,  $P = 0.61$ ). Likewise, light intensity at Hamden did not differ either at ground level ( $\bar{X}$  at burrow = 19.1, at 13 m = 21.3;  $z = -0.89$ ,  $P = 0.37$ ) or at 2 m above ground ( $\bar{X}$  at burrow = 54.5, at 13 m = 34.6;  $z = 0.46$ ,  $P = 0.65$ ). Mean slope did not differ between burrows and paired, 13-m sites either at Southington ( $\bar{X}$  at burrow = 21.5°, at 13 m = 22.4°;  $t = 0.52$ ,  $P = 0.63$ ) or at Hamden ( $\bar{X}$  at burrow = 13.6°, at 13 m = 14.0°;  $t = 0.28$ ,  $P = 0.80$ ). Mean soil pH at Hamden did not differ ( $P = 0.73$ ) among samples collected at burrow entrances ( $\bar{X} = 5.1$ ), 1.5 m from burrows ( $\bar{X} = 5.1$ ), or 13 m from burrows ( $\bar{X} = 5.2$ ). At Southington, Student-Newman-Keuls multiple comparisons indicated that pH of soil 1.5 m from burrow entrances ( $\bar{X} = 5.4$ ) did not differ ( $P > 0.05$ ) from the pH of soil 13 m away ( $\bar{X} = 5.3$ ). However, pH of subsurface soil deposited by woodchucks at burrow entrances ( $\bar{X} = 5.7$ ) was significantly ( $P < 0.05$ ) greater than that of soils sampled at 13-m sites.

#### DISCUSSION

Although edaphic and light characteristics at burrow and 13-m sites did not differ, a longitudinal study is needed to determine whether nonrandom selection of burrow sites by woodchucks

TABLE 1.—Abundance ( $\bar{X} \pm SE$ ) of live and gnawed woody stems occurring within 3 m of burrows of *Marmota monax* or within a 3-m radius 13 m from burrows. Data are from 10 burrows in each of two woodlots in central Connecticut.

Woodlot	Site	Live stems		Gnawed stems	
		$\bar{X}$	SE	$\bar{X}$	SE
Southington	Burrow	10.1*	2.4	4.2*	1.2
	13 m	19.1	3.1	1.1	0.5
Hamden	Burrow	13.3**	2.6	6.6*	0.9
	13 m	35.2	7.8	3.8	0.7

\*  $P < 0.05$ ; test of equality of means for burrow and 13-m sites.

\*\*  $P < 0.01$ .

could at least partially explain differences in the abundance of woody stems. However, the 1.8- to 3.8-fold increase in number of gnawed stems near burrows compared to 13-m sites (Table 1), the 1.6–2.8-fold increase in the proportion of dead stems near burrows, the 5.7–10.6-fold increase in dead stems gnawed near burrows, and the reduction in current annual growth associated with sugar maple (the most severely gnawed species of plant) indicate that woodchucks modify woody vegetation by gnawing plants in the immediate vicinity of burrows.

Merriam and Merriam (1965) documented a gradient in density of herbaceous stems near woodchuck burrows in meadows similar to the gradient we observed for woody stems (Fig. 1). Their gradient in stem counts was attributed to distance-dependent effects of feeding and trampling by woodchucks. In our study, trampling, excavation of soil, and root damage related to burrowing may have contributed to the low density of woody stems <1 m from burrows (Fig. 1). However, the inverse relationship between severity of gnawing and distance from a burrow suggests that gnawing also may contribute to the reduced abundance of stems near burrows.

Gnawing appears to be related to scent marking in woodchucks (Hébert and Prescott, 1983; Ouellet and Ferron, 1988), and variation in frequency of scent marking is related to dominance status (Hébert and Barrette, 1989). Thus, interburrow variation in damage to and mortality of plants caused by gnawing conceivably could be related to socially mediated differences in burrow occupancy. We doubt that this explanation is correct, because woodchucks move freely among burrow systems (Merriam, 1971) and damage invariably is accrued over more than one generation at most burrows. More likely, cumulative effects of gnawing at burrows are related positively to the age of the burrow.

Although scent marking of woody substrates often is preceded by gnawing (Ouellet and Ferron, 1988), earlier researchers attributed gnawing to feeding (Grizzell, 1955; Hamilton, 1934) or as a means of wearing down incisors and exercising jaw muscles (Grizzell, 1955). On numerous occasions we detected the characteristic odor from oral glands of woodchucks on gnawed areas of woody plants; hence, scent marking apparently was related to gnawing in our study. However, we cannot rule out other explanations. For instance, sugar maple was the most severely gnawed species in our study. Most gnawing occurs during spring (Swihart, 1991), thus availability of sap from sugar maple may have led to its disproportionate use as a gnawing site.

Densities of woodchuck burrows were 5.4 and 10.8/ha at the Southington and Hamden woodlots, respectively. Using a 3-m radius to delimit the area within which woody plants were significantly influenced by woodchucks, 1.5% and 3.0% of each woodlot was affected. Proportionately larger areas are known to be affected by the burrows and mounds of pocket gophers (Geomysidae, 2.2–9.9%—Reichman et al., 1982; Spencer et al., 1985; Tilman, 1983) and mole-rats (Bathyergidae, 28.2%—Reichman and Jarvis, 1989), and these fossorial herbivores continuously construct new burrows during foraging.

Burrows of *M. monax* remain functional for many years, and few new burrows are constructed annually in undisturbed areas (Henderson and Gilbert, 1978). For instance, of 345 active burrows identified at or near the Southington and Hamden study sites from 1987 to 1989, only nine (2.6%) of the burrows were excavated initially in 1988 or 1989. Similarly, Merriam (1971) noted that <4% of the burrow systems he examined ( $n = 114$ ) were added during a 4-year period.

Taken together with our findings, the perennial nature of burrows and their slow rates of turnover suggest that the presence of woodchucks promotes relatively small-scale but long-term changes in the abundance and distribution of woody plants in deciduous woodlands of the eastern United States.

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