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INFLUENCE OF *MARMOTA MONAX* ON VEGETATION IN HAYFIELDS

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ABSTRACT.—Examination of vegetation around 29 woodchuck (*Marmota monax*) burrows in two hayfields in Connecticut revealed that grass biomass decreased, and forb biomass increased, as a function of distance from burrows. In addition, orchard grass (*Dactylis glomerata*) <2 m from burrows was more lush and exhibited significantly greater levels of crude protein than orchard grass 15 m away. Over an entire field, woodchucks caused an increase in biomass of orchard grass an average of 7.4% and reduced the biomass of alfalfa (*Medicago sativa*) by 2.5%. Differential selection of orchard grass and alfalfa as food, release of grass from competition with alfalfa, and enhanced levels of nitrogen from feces all were plausible factors responsible for the distance-dependent differences in growth of vegetation.

Burrowing and feeding by mammals such as Arctic ground squirrels (*Spermophilus parryii*), prairie dogs (*Cynomys ludovicianus*), and pocket gophers (*Geomys bursarius, Thomomys bottae*), can modify abundance and growth rates of plants (Archer et al., 1987; Hobbs and Mooney, 1985; Hobbs et al., 1988; Inouye et al., 1987; Koide et al., 1987; Mallory and Heffernan, 1987; Tilman, 1983). Disturbances related to burrowing also can alter patterns of species richness, and spatial and temporal aspects of plant succession (Archer et al., 1987; Inouye et al., 1987; Mallory and Heffernan, 1987; Platt, 1975; Tilman, 1983). Woodchucks (*Marmota monax*), because of their relatively large size (adult mass of 2–5 kg, Snyder et al., 1961) and extensive burrow systems, could have a substantial impact on characteristics of vegetation and soil near burrows. To date, only Merriam and Merriam (1965) and Thompson (1971) examined effects of woodchucks on vegetation and soil surrounding their burrows. Herein, I report on the influence of woodchucks on composition and biomass of plant species and on nutrient characteristics of vegetation and soil near burrows in hayfields.

STUDY AREAS

Two adjacent hayfields in Cheshire, Connecticut, were studied during May–August 1989. The fields were similar in topography and aspect, but differed in vegetative composition. Hayfield 1 was 3.7 ha and dominated by alfalfa (*Medicago sativa*) and orchard grass (*Dactylis glomerata*), with lesser amounts of campion (*Lychnis alba*), winter cress (*Barbarea vulgaris*), curled dock (*Rumex crispus*), and Kentucky bluegrass (*Poa pratensis*). Hayfield 2 was 1.5 ha and was vegetated almost exclusively by orchard grass and sweet vernal grass (*Anthoxanthum odoratum*), with minor amounts of campion, curled dock, and narrow-leaved plantain (*Plantago lanceolata*).

METHODS

Both hayfields were censused for woodchuck burrows in early May. At the time of vegetative sampling, only burrows with freshly excavated soil at the main entrance and separated by >10 m (Henderson and Gilbert, 1978) were included in the analyses. Vegetative variables in each hayfield were measured within a 5-day period to reduce the effect of changes related to weather, plant phenology, or farming operations. The percent of herbaceous cover in 1-m^2 plots was estimated visually 2 and 5 m from the main entrance to all burrows at the cardinal points of a compass. For plots along the north-south axis, the number of herbaceous species in each 1-m^2 plot was recorded. An estimate of aboveground biomass was obtained by oven-drying 100-cm^2 samples clipped at ground level from the center of these four plots. Biomass of grasses also was measured 0.5 m from each burrow in hayfield 2, because grasses there were visibly more lush in the immediate vicinity of burrows. To permit comparison of vegetation near burrows with areas of the hayfield supposedly unaffected by woodchuck activity, measurements at 0.5, 2, or 5 m from burrows were compared with values of the same variables measured 15 m from the burrow at a random heading, subject to the constraint that the point was >15 m from any other burrow.

To determine whether protein content of alfalfa and orchard grass differed as a function of distance from burrows, vegetation samples were collected <2 m and 15 m from each of six burrows in hayfield 1 in mid-July 1989, 3 weeks after the first cutting of the year. In mid-August 1989, orchard grass also was sampled at six burrows in hayfield 2. Duplicate samples from each site were dried at 40°C for 24–36 h, ground to pass through a 20-mesh screen, and analyzed for nitrogen content by use of a Tecator® Kjeltec Auto 1030 Analyzer. Results for subsamples were averaged and expressed as percent dry mass comprised of crude protein (nitrogen × 6.25). Paired *t*-tests were used to compare mean levels of crude protein at the two distances for each species.

To examine surface-soil characteristics in areas of woodchuck excavation, a hand auger was used to collect soil samples to a depth of 20 cm. A sample was collected at <1 m and at 15 m from the main entrance of each burrow. Soil samples were collected within a 2-day period in early May. Samples were weighed within 4 h of collection, and oven-dry masses subsequently were recorded to calculate percent soil moisture. Soil pH was determined by use of a pH meter. For soil samples collected at 10 of the burrows in hayfield 1, levels of nitrate nitrogen, ammonia nitrogen, phosphorus, potassium, calcium, and magnesium were classified by colorimetric assays (Lunt et al., 1950). In addition to soil characteristics, the percent of ground covered by rocks within 2 m of the main entrance was estimated visually.

Analysis of variance, with burrows as a blocking factor, and Student-Newman-Keuls multiple comparisons were used to test for differences in mean levels of variables measured in hayfields (Zar, 1974). Mineral content of soils collected <1 m and 15 m from burrows was tested with the Wilcoxon matched-pairs test. Because values of zero were sometimes recorded for biomass, abundance, and species richness of plants, statistical analyses were performed on variables subjected to a $\log_{10}(X + 1)$ transformation, where X = the original variable (Zar, 1974). Measures of herbaceous cover and rock cover were arcsine-square root transformed before analysis (Zar, 1974). Statistical significance was assessed at the 0.05 level.

To determine whether food selection of woodchucks could influence the distribution and abundance of alfalfa and orchard grass in hayfield 1, feeding trials were conducted with captive woodchucks. Nine woodchucks (five males, four females) were captured in agricultural areas in central and western Connecticut during March and April 1989. Woodchucks were housed individually in 1.5- by 1.5- by 0.9-m pens constructed of galvanized-wire mesh and provided with rodent chow and water ad lib. During mid-May, each woodchuck was presented with two 100-g bundles collected from hayfield 1, one consisting of alfalfa and the other consisting of orchard grass. Chow was available ad lib. during this trial. After 24 h, all remaining vegetation was removed and weighed. The biomass of alfalfa and orchard grass consumed was determined by subtraction, after correcting for loss of moisture as determined from control bundles placed in empty cages. The feeding trial was repeated, and mean values of daily biomass ingested were calculated for each animal. Differences in the levels of daily ingestion of alfalfa and orchard grass were compared by use of a paired *t*-test.

To assess whether palatability of vegetation was correlated with its location relative to a burrow, 50-g bundles of alfalfa collected <2, 5, and 15 m from the main entrance of burrows in hayfield 1 were collected in mid-July and presented to captive woodchucks. Bundles were secured with twist-ties of different colors to permit identification. After 4 h, bundles were removed and consumption was calculated as in the earlier trial. A similar trial was conducted with orchard grass, except that the trial lasted 16 h, and rodent chow was unavailable to woodchucks for 20 h immediately preceding the trial and during the trial.

Results

I examined 20 and nine woodchuck burrows in hayfields 1 and 2, respectively. Mean soil moisture <1 m from burrows (14.0%) was significantly ($P = 0.02$) less than 15 m from burrows (15.8%). Soils near burrows did not differ from soils 15 m away in percent of rock cover, pH, or concentration of nitrate nitrogen, ammonia nitrogen, phosphorus, potassium, calcium, or magnesium ($P > 0.05$ for all tests).

The mean percent of herbaceous cover was significantly less at 2 m from the main entrance than at 5 or 15 m for hayfield 1 ($P < 0.01$), but not for hayfield 2 ($P = 0.51$; Table 1). Species richness decreased with increasing distance from burrows in hayfield 1, although not significantly ($P = 0.06$; Table 1). No trends or differences in species richness occurred in hayfield 2 ($P = 0.53$; Table 1). Grass biomass varied with distance from burrows in hayfield 1 ($P < 0.01$) and hayfield 2 ($P < 0.05$), generally decreasing as a function of distance from the main entrance (Table 1). Hayfield 1 exhibited greater biomass of forbs ($P < 0.01$), almost exclusively alfalfa,

TABLE 1.—*Means (±SE) of vegetative variables measured at several distances from woodchuck burrows in two hayfields in Connecticut, spring 1989.*

Variable[a]	n	0.5 m	2 m	5 m	15 m
		$\bar{X} \pm SE$	$\bar{X} \pm SE$	$\bar{X} \pm SE$	$\bar{X} \pm SE$
Hayfield 1	20				
Herbaceous cover (%)			89.1 ± 1.4^x	95.3 ± 1.5^y	97.5 ± 1.2^y
Number of species			3.0 ± 0.2	2.7 ± 0.1	2.5 ± 0.1
Grass biomass (g/m^2)			505 ± 80^x	235 ± 50^y	120 ± 30^y
Forb biomass (g/m^2)			250 ± 40^x	400 ± 45^y	585 ± 35^z
Hayfield 2	9				
Herbaceous cover (%)			66.8 ± 2.0	64.7 ± 2.2	63.2 ± 2.5
Number of species			2.2 ± 0.2	2.4 ± 0.2	2.2 ± 0.1
Grass biomass (g/m^2)		400 ± 50^x	260 ± 40^{xy}	280 ± 55^y	200 ± 25^y

[a] For a given field, values of a variable followed by different letters differ significantly ($P < 0.05$).

at greater distances from a burrow (Table 1); hayfield 2 did not contain enough forbs for statistical analysis.

Content of crude protein ($\bar{X} \pm SE$) of alfalfa collected <2 m (33.3 ± 0.8%) and 15 m (34.1 ± 1.0%) from burrows did not differ significantly ($P = 0.72$). However, content of crude protein of orchard grass collected <2 m (21.8 ± 1.1%) from burrows was greater than for samples collected 15 m (19.7 ± 1.1%) from burrows ($P = 0.01$).

Feeding trials indicated that alfalfa was selected more often than orchard grass from hayfield 1 ($P < 0.001$). Mean daily consumption ($\pm SE$) of alfalfa (34.2 ± 3.2 g) was 10 times greater than levels of consumption of orchard grass (3.4 ± 1.3 g).

Mean consumption ($\pm SE$) of alfalfa collected <2 m (3.6 ± 0.5 g/h), 5 m (4.4 ± 0.4 g/h), and 15 m (2.9 ± 0.5 g/h) from burrows in hayfield 1 did not differ significantly ($P = 0.06$). Likewise, no significant differences occurred in mean consumption of orchard grass collected <2 m (0.9 ± 0.1 g/h), 5 m (1.0 ± 0.1 g/h), and 15 m (1.0 ± 0.1 g/h) from burrows ($P = 0.69$).

DISCUSSION

Like other burrowing mammals, woodchucks may alter habitat near burrows either indirectly, by bringing soil to the surface from lower horizons, or directly, by feeding, trampling, and elimination of feces and urine in the vicinity of burrows. The effect of excavation-related disturbance on vegetative composition apparently depends on the nutrient content of excavated soil and the level of competition among plants (Inouye et al., 1987; Williams et al., 1986). In hayfield 1, nutrient content of soils at burrows did not differ from samples 15 m away. Although this suggests that excavation had little impact, an extremely wet May (26.1 cm of precipitation, 2.7 times greater than normal—National Oceanic and Atmospheric Administration, 1989) might have hastened the rate at which recycled nutrients were leached, thereby obscuring an effect of excavation. Thompson (1971) simulated mounds of excavated soil similar to those from woodchuck burrows and observed greater aboveground production around the mounds, and increased levels of soil phosphorous. Conversely, other investigators showed that soils excavated by pocket gophers contained less nitrogen and phosphorous than surface soils, and plant growth was reduced in soil from gopher mounds relative to non-mound soil (Inouye et al., 1987; Koide et al., 1987; Spencer et al., 1985).

Disturbance by mammals also favors plant species capable of rapid colonization or incapable of competing successfully in dense vegetation (Hobbs and Mooney, 1985; Hobbs et al., 1988; Inouye et al., 1987; Tilman, 1983). In hayfield 1, biomass of alfalfa was greater than biomass of orchard grass 5 and 15 m from burrows, but the situation reversed dramatically within 2 m of burrows (Table 1). Feeding trials indicated that woodchucks selected alfalfa over orchard grass, consistent with the observation that woodchucks typically select other leguminous species over grasses (Swihart, 1990). Moreover, palatability of alfalfa did not vary predictably as a function of its distance from a burrow. These results suggest that heavier grazing of alfalfa relative to orchard grass near burrows resulted in reduced biomass of alfalfa and competitive release of orchard grass in hayfield 1. Nutrient levels of alfalfa and orchard grass can vary temporally (Miller, 1958), and silica content of grasses varies with maturational stage (Howe and Westley, 1988). Hence, the relative consumption of alfalfa and orchard grass by woodchucks may vary during the growing season and as a function of cutting of hay. However, grasses generally are less palatable to woodchucks than forbs (Hamilton, 1934), and any temporal differences in consumption that might have occurred in the present study were too small to cause a trend in biomass for orchard grass comparable to that observed for alfalfa in hayfield 1. Moreover, Mullen and Rongstad (1979) used exclosures to demonstrate differential consumption of alfalfa by white-tailed deer (*Odocoileus virginianus*) grazing in hayfields. Inouye et al. (1987) noted that abundance and composition of plants near pocket gopher burrows could be influenced by selective feeding, and Reichman and Smith (1985) hypothesized that the greater growth of vegetation observed adjacent to pocket gopher burrows occurred because of competitive release.

Differential grazing on alfalfa does not account for the greater biomass of grasses near burrows in hayfield 2, where alfalfa was absent, or for the greater height and darker green color of grasses observed near burrows in both hayfields. Merriam and Merriam (1965) noted that higher levels of nitrate nitrogen in soil near eight woodchuck burrows in pastures coincided with lusher vegetation, leading to the hypothesis that enrichment of soil with fecal nitrogen enhanced the growth of individual plants. Thompson (1971) found that presence of feces in woodchuck mounds significantly increased aboveground production relative to simulated mounds without feces. In my study, crude-protein content of orchard grass growing near burrows was greater than for grass growing 15 m away, indicating that enhancement of nitrogen levels occurred near burrows. Woodchucks frequently deposit feces near burrows (Hamilton, 1934); hence, it is possible that supplemental fecal nitrogen produced the differences I observed.

My results suggest that woodchucks can significantly alter composition and abundance of vegetation within 5 m of burrows in hayfields. Because woodchucks select alfalfa over orchard grass, they may reduce the quality and quantity of hay produced. Based on the values in Table 1, I estimated the change in overall biomass resulting from the activities of woodchucks. A linear relation between biomass and distance was assumed within 5 m of a burrow, and biomass values 15 m from burrows were used to estimate vegetative production independent of woodchuck activities. Numerical integration within 5 m of a burrow in hayfield 1 revealed that biomass/m^2 of orchard grass was 3.2 times greater than 15 m from a burrow, whereas biomass/m^2 of alfalfa was 0.5 times the level 15 m away. For hayfield 2, grass biomass within 5 m was 1.5 times greater than at 15 m. The density of burrows in both fields was ca. seven/ha. On a unit-area basis, then, woodchucks in hayfield 1 increased biomass of orchard grass by 12.2% and reduced biomass of alfalfa by 2.5%. In hayfield 2, grass biomass was increased 2.6% by woodchucks. Clearly, the impact of woodchucks on vegetation in an area is linked to the density of burrows. Densities of burrows in hayfields generally are greater than in other agricultural habitats. Henderson and Gilbert (1978) found 8.4 burrows/ha in hayfields, but only 4.7 burrows/ha in pastures and wheat fields. Two orchards I surveyed in Connecticut exhibited an average density of 3.6 burrows/ha. Because these areas also differ from hayfields in plant composition and biomass, detailed studies are required to determine the extent to which feeding and burrowing of woodchucks affect plants in other habitats.

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