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INTRODUCTION

Although fires are an integral part of prairie ecology (Bragg and Hulbert 1976, Daubenmire 1968, Rice and Parenti 1978, Zimmerman and Kucera 1977), there is evidence that mowing can serve at least some of the functions of fire (Hover and Bragg 1981) in prairies. Mowing, in fact, has two major advantages over burning. First there is no need for large crews to control the fire, and second the hay produced can be used as a cash crop. Because mowing is an attractive alternative to burning for prairie preserves it is important to determine the effects of mowing on the prairie. In this paper we report our findings on the effects of mowing on the community of rodents in a natural tallgrass prairie near Lincoln, Nebraska. Although there has been some work on the reaction of rodents to prairie fires (LoBue and Darnell 1959, Tester and Marshall 1962, Schramm 1970, Cook 1959, Moreth and Schramm 1972), not much work has been done on the effects of mowing (LoBue and Darnell 1959, Tester and Marshall 1962). The general finding from burning and mowing in the tallgrass prairies of North America is that populations of *Microtus* decline dramatically after the removal of the vegetation, and the numbers of *Peromyscus maniculatus* increase. The populations of rodents return to pre-fire levels as the vegetation above ground grows back. Even though mowing and burning have similar effects on aboveground material, there are differences. First, mowing leaves a stubble of vegetation, and second, mowing is typically done on a yearly basis, in the late summer or early fall. The result of yearly mowing is that fields are left as stubble for long periods of time every year, and it is not known whether this cover is sufficient to maintain the population of *Microtus* at high density.

Our results indicate that mowing, like burning, greatly reduces the use of an area by *Microtus* and increases the density of *P. maniculatus* until the grass can grow back. Depending on the rate of growth of the grass this process can take more than a year. If the prairie is mowed every year to maximize the production of hay, populations of *Microtus* cannot be maintained at high densities.

MATERIALS AND METHODS

The study site, Nine Mile Prairie, is one of the few natural tallgrass prairies remaining in eastern Nebraska. It covers about 240 acres and is located 5 km north and 9 km west of Lincoln, Nebraska. The area used in this study has never been plowed and for the last 75 years has been mowed. The vegetation of Nine Mile Prairie has been extensively studied by Steiger (1930).

When we arrived in the early spring of 1981, plant growth had not yet started. In one area of approximately 8 hectares there were three mowing treatments: an area last mowed in the fall of 1978, an area last mowed in the fall of 1979, and an area last mowed in the fall of 1980. In the spring of 1981 these different mowing treatments were quite distinct. The area mowed late in 1980 was still only stubble. The 1979 area had one year's growth and the 1978 area had two years' growth.

A total of 20 trapping areas was set out in this 8-hectare area, five in the 1978 area, nine in the 1979 area and six in the 1980 area. In the fall of 1981 we returned and trapped again: at that time all areas had one additional season of growth.

Each trapping site consisted of a total of 22 Sherman live traps (7.5x23 cm). These traps were set out in two parallel transects that were 15 m apart. The trap interval on each transect was 7m. Each site was trapped for two nights and the total number of rodents captured was recorded.

The above-ground vegetation was quantified using 0.1 m^2 clip plots. All the above-ground vegetation, live and dead, was removed, dried and weighed. In the spring we took two samples from each trapping site, and in the fall we took four more.

The rodents captured in this study are *Microtus pennsylvanicus* (meadow vole), *M. ochrogaster* (prairie vole), *Reithrodontomys megalotis* (western harvest mouse), and *Peromyscus maniculatus* (deer mouse). On the first night of trapping all animals were released.

RESULTS

The results of the vegetative sampling are analyzed with a one way analysis of variance to determine if time since mowing has an effect on vegetation above ground. The analysis indicates that there are significant differences in vegetative cover in both the spring ($F = 81.5$, $p < 0.0001$) and fall $F = 85.3$, $p < 0.0001$. Using the Newman-Kuels multiple range test we find that the area mowed in 1978 has significantly more material above ground than the 1979 and 1980 areas in both the spring and fall of 1981. Likewise the 1979 areas have significantly more above-ground material than the 1980 areas in both sampling periods.

A paired t-test can be used to compare the amount of vegetation above ground in the spring and fall of 1981 to determine if there are significant increases in vegetation during the 1981 growing season. This test shows that the 1978 areas did not experience a significant increase in material ($t = 0.81$, $p > 0.10$). However both the 1979 and the 1980 areas had statistically significant increases in vegetation (1979 paired $t = 13.55$, $p < 0.001$; 1980 paired $t = 8.13$, $p < 0.001$).

Therefore our analysis of the vegetation indicates that there are significant differences in vegetative cover in all the mowing treatments in both the spring and fall of 1981. The 1978 area appears to have come to an equilibrium and there was no increase in above-ground material in this area in the 1981 growing season. The 1979 and 1980 areas were still accumulating material during 1981.

The most common species of rodents captured in both trapping periods were *Microtus pennsylvanicus* and *M. ochrogaster.* Using an ANOVA with ranked data we found a statistically significant effect of the year of last mowing on the density of *Microtus* (spring $F=20.9$, $p<0.0001$; fall $F=10.8$, $p<0.0009$). Using a Duncan's multiple range test we found that all mowing treatments were statistically different from one another in the density of *Microtus* in the spring. However, by the fall there was not a statistical difference between the 1979 and 1980 mowing areas. Another way to view the effect of mowing on the density of *Microtus* is to correlate vegetative cover and number of rodents (Fig. 1). This correlation is significant for both the spring ($r=0.86$, $p<0.0001$) and the fall ($r=0.81$, $p<0.0001$) sampling periods. The positive relationship between

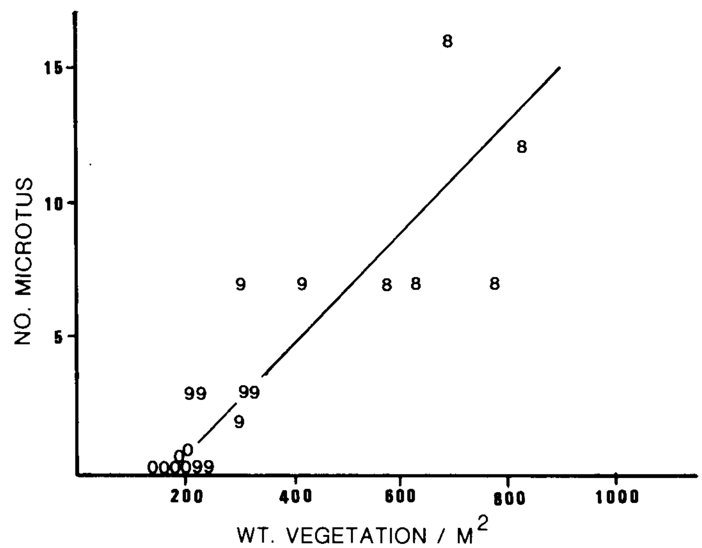

Fig. 1. The numbers of *Microtus* caught during the two nights of trapping in the spring sampling period are plotted against the average amount of vegetative cover at each of the trapping sites. The sites last mowed in 1980 are plotted as 0's, the 1979 sites as 9's and the 1978 sites as 8's. Using the weight of vegetative cover as the independent variable a regression analysis indicates there is a statistically significant relationship for the spring data set ($x=0.175y-2.354$, $F=49.58$, $p<0.0001$) and the fall data as well ($x=0.116y-3.162$, $F=34.09$, $p<0.0001$; note that the fall data are not shown in this figure). Further analysis indicates that the intersept and slope values for both regressions are statistically different from 0.0 at the 0.05 level.

vegetative cover and the number of *Microtus* caught is summarized in Fig. 2. One of the interesting things that can be seen in Fig. 2 is the general decline in the numbers of *Microtus* caught in the fall. Therefore, the line for the fall is below the line for the spring in Fig. 2. However, while the average number of *Microtus* caught declined on the 1978 and 1979 areas in the fall, there is a five-fold increase in the density of *Microtus* on the 1980 areas. This difference in response to the decline in rodent numbers indicates that there is a threshold effect between vegetative cover and the density of voles. The threshold can be seen by noting the x-axis intercept of about 150 g/m^2 in Fig. 1. In Fig. 2, the threshold effect is manifested as the steep portion of the spring line between 180 and 280 g/m^2. If this threshold is truly indicative of the relationship between vole density and cover, we can predict that when cover falls below a critical value (around 150 g/m^2) *Microtus* will disappear from the area, or conversely if the vegetation increases above about 150 g/m^2 there should be a great increase in the relative abundance of *Microtus*. This is the case in the fall data, while other areas experienced an average loss of 50% in the numbers of *Microtus*, the 1980 areas averaged a 500% increase.

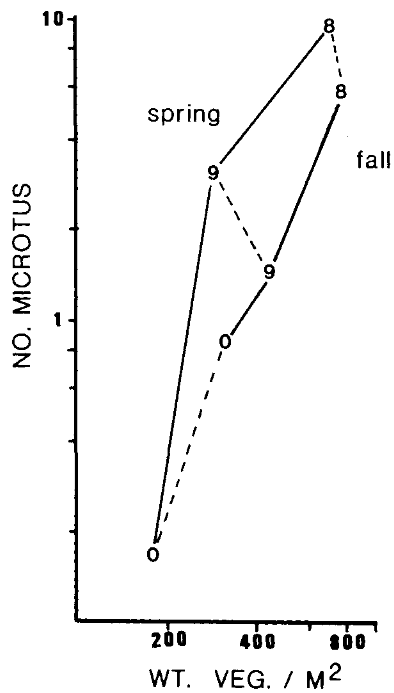

Fig. 2. This scattergram summarizes the *Microtus* numbers and the average vegetative cover for each mowing treatment are plotted for both the spring and fall. The solid lines connect different mowing treatments in the same season and the dotted lines connect the same mowing treatments in the spring and fall.

The two other species of rodents caught are *Peromyscus maniculatus* and *Reithrodontomys megalotis*. *Peromyscus maniculatus* is more common on the most recently mowed areas (1980) than on the areas with at least one year's growth of vegetation (1980 area $n = 6$; 1979 and 1978 areas $n = 14$; Mann-Whitney $U = 68.5$, $p < 0.03$). This finding is in agreement with other studies of *P. maniculatus* after burning or mowing. The positive response of *P. maniculatus* may be a direct response to the loss of vegetation, a response to the absence of the larger and more aggressive *Microtus*, or both. Grant (1972) demonstrated that the removal of *Microtus* alone can cause the immigration of *Peromyscus* into an area.

DISCUSSION

Our finding that the density of *Microtus* is significantly related to cover is consistent with the patterns found by workers studying fire ecology (Schramm 1970), mowing effects (LoBue and Darnell 1959) and habitat structure (Birney et al., 1976). Birney et al. (1976) discussed the need of heavy cover for high densities of *Microtus*. Our results produce a similar prediction and we conclude from both these studies that the above-ground cover of grass must reach around 700 g/m^2 to support populations of *Microtus* at high densities. How quickly this much vegetation accumulates on a tallgrass prairie is dependent on rainfall. However, at least one growing season would be necessary under ideal situations, and it might take several years with low rainfall. Perhaps of equal interest is the response of *Microtus* to the lower end of vegetative cover. We find that when vegetative cover is lower than 280 g/m^2 there is a precipitous drop in vole density. Mowing reduces the cover below this level and therefore will make an area temporarily unsuitable for *Microtus*.

We can conclude from our study that the density of *Microtus* is affected by vegetative density. Because mowing cuts the vegetative cover below levels acceptable for the voles, the animals must leave the area until the grass grows back in one or more years. Because mowing is typically done in the late summer and early fall, this will leave the prairie uninhabitable for the entire winter and spring at the minimum.

To mow or not to mow is a complex management decision. First, native prairies do not have to exist to maintain the community of rodents. There are habitats along roadsides and in old fields that can support these species. Therefore, after the vegetation begins to grow there are source areas of immigrants to re-colonize the prairie. Of course, the sensitivity of *Microtus* to mowing may be paralleled in other organisms. These other forms may be specifically tied to native prairies, and yearly mowing will eliminate them from the community. Likewise, other components of the prairie community, such as predators of rodents, may depend on populations of *Microtus* at natural levels.

Another difficult point is to define the goals of management programs for prairies with respect to rodents. As already stated there is no need to have prairies to preserve the species, they are already abundant. However, if the goal is to maintain natural populations the problem is still complex. Natural fires have been a regular source of disturbance on the prairie. These fires must have had a profound effect on the density and population cycles of the rodents inhabiting the tallgrass prairie. The problem with reconstructing the effects of fire with mowing (or man-made fires for that matter) is that the frequency, season, and area of natural fires are not known.

A more modest goal would be to manage the prairie so that the vegetation builds up to acceptable levels for high densities of *Microtus*. Our data indicate that mowing every year or two will not allow voles to reach maximal densities. A cycle of mowing every three to five years may be a reasonable compromise between maintaining the voles and preventing the invasion of woody plants or the senescense of the prairie.

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