AN ABSTRACT OF THE THESIS OF

Virleen Bailey for the Master of Science Degree

in Biology presented on August 3, 1984

Title: Seasonal Roadside Ditch Use by Microtus and Sigmodon

Abstract Approved: Dwight L. Spencer

During late fall and winter, rural roadside ditches support numerous small mammal species regardless of the type of adjacent habitat. The extent of ditch utilization as small mammal winter habitat is influenced by the effect of agricultural use of adjoining land and by factors associated with competition, predation and weather. This two year study examined the use of *Microtus ochrogaster* and *Sigmodon hispidus* of ditches and adjoining agricultural land, marginal pasture, and native grassland.

Vegetative cover in all ditches studied remained relatively constant during the study, except for the native-grassland ditch (ditch R) which was burned the first spring. Where ditch and adjacent area vegetative cover were homogenous and constant (ditch R), separate rodent populations appeared to be established in the ditch and on the adjoining land. Where agricultural treatment of adjoining land resulted in cover that varied with season of the year, evidence suggested that roadside ditches may represent primary habitat with adjacent land serving as forage and dispersal areas for ditch populations. However, some use of ditches for winter habitation by a small number of rodents from the adjoining lands was indicated.

# SEASONAL ROADSIDE DITCH USE
# BY <u>MICROTUS</u> AND <u>SIGMODON</u>

A Thesis
Submitted to
the Division of Biological Sciences
Emporia State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Virleen Bailey
August, 1984

Approved for Major Department

Approved for Graduate Council

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## ACKNOWLEDGEMENTS

This investigation was carried out under the guidance of my major professor, Dr. Dwight L. Spencer, and I am grateful for his advice. I also wish to thank my graduate committee members, Dr. John W. Parrish and Dr. James M. Mayo, for their suggestions and interest. Each contributed to my progress in a special way.

I am indebted to Dr. John Ransom for assistance with statistical analyses, and to Roger Ferguson for constructing traps. I also thank the Division of Natural and Mathematical Sciences of Tabor College for use of a computer. And for devoting many weekends to setting traps and walking transects, I thank my son, Brendan.

I have from the beginning regarded my master's research as a continuing learning process rather than an educational finale--a perspective inspired and encouraged by my long-time friend and mentor, Dr. Max R. Terman, to whom this work is dedicated.

# INTRODUCTION

Vegetative cover is probably the most important feature in the environment of small mammals (Dice, 1952). Small mammals, especially rodents, are usually dependent upon vegetation type rather than on particular plant species for nest materials and sites, food, shelter, and protection from weather and predation. Because much rural land in Kansas has long been put to agricultural uses, adequate sized areas of rodent-preferred cover vegetation are scarce to the point of limiting and altering social and demographic aspects of small mammal populations (Fleharty and Navo, 1983).

Roadside ditches frequently exhibit density and diversity of vegetative cover, particularly during late fall and winter, in contrast to that found on adjacent fields, and provide suitable habitat for numerous small mammal species. Eadie (1953), Frydendall (1969), and others underscored the importance of adequate cover for successful overwintering of small mammals. Agricultural practices on adjacent land influence the extent of ditch utilization, and thus, have some bearing on small mammal species diversity (Phillips, 1954; Johnson, 1982; Yahner, 1982). Microclimate (Vickery and Bider, 1981), competition for available resources (Terman, 1973, 1978; Rose and Spevak, 1978; Gaines and McClenaghan, 1980; Glass and Slade, 1980) and the presence of predators (Baker and Brooks, 1982) cannot be excluded as factors that influence the overwintering potential of roadside ditches for small mammals.

While numerous studies have been conducted on winter habitat characteristics and overwintering of small mammal populations, little attention has focused on specific use of roadside ditches as small mammal winter refugia. Getz et al (1978) investigated the role of roadside cover in their study of vole dispersal but did not mention seasonal use. Do roadside ditches provide a winter refuge for some rodents, and if so, to what extent are ditches utilized? Given such winter ditch utilization, do the animals disperse into adjacent agricultural areas once winter is past, and if so, do they retreat into ditches with the coming of cold weather? To what extent does vegetative cover influence seasonal movement patterns?

These questions suggest certain testable hypotheses: (1) rural roadside ditches, because of the relatively constant vegetative cover as compared with the cover on adjacent agricultural land, serve as winter refugia for rodent populations from adjacent agricultural land; (2) vegetative cover of both ditch and adjacent land determines the extent to which ditches are utilized.

A study designed to test these hypotheses was conducted from November, 1982 through May, 1984, on three sites located approximately 25 kilometers northwest of Emporia, Lyon County, Kansas. Populations of two small mammal species, prairie vole (Microtus ochrogaster) and cotton rat (Sigmodon hispidus), were monitored on each site relative to seasonal ditch usage.

## DESCRIPTION OF STUDY SITES

The three ditches selected for study were located approximately 25 kilometers northwest of Emporia, Lyon County, Kansas. Lyon County lies along the eastern edge of the Flint Hills, a region of rolling tallgrass prairie 66 to 83 kilometers wide extending from north to south through east-central Kansas. Each ditch was bordered on the south by a regularly maintained, moderately traveled, gravel surface, east-west road. Criteria for selection included similar vegetation type, similar slope exposure, potential for rodent habitat, and difference in agricultural treatment of adjacent land. In this study the term "agricultural" as applied to land use signified land intended for the practice of agriculture, whether for cropland or grazing (pasture). Ungrazed native grassland was designated as rangeland.

Vegetation composition and density were determined on each site and comparisons made between ditches and adjacent lands. Vegetation types, determined by the step-point method along a 50 m transect on each site (after Cook, 1962) were recorded as either grasses or forbs. Also included were the cover-related categories: litter, and bare ground (Table 1).

### Site P

Ditch site P (pasture), T 18 S, R 10 E, S 30, was 50 m long and contained the following most frequently occurring plant species: switch grass (*Panicum virgatum*), little bluestem (*Schyzacchrium scoparius*), Indian grass (*Sorghastrum nutans*), dropseed (*Sporobolus vaginiflorus*), and prairie cordgrass (*Spartina pectinata*). Forbs were Arkansas rose (*Rosa arkansana*), common ragweed (*Ambrosia artemisiifolia*), and heath aster (*Aster ericoides*). Pasture vegetation was considered

Table 1. Relative frequency of occurrence of predominant plant species and cover-related categories per 50 m transect for each of three study sites.

| Vegetation type | Pasture Ditch | Pasture In-fence | Field Ditch | Field In-fence | Rangeland Ditch | Rangeland In-fence |
|---|---|---|---|---|---|---|
| *Panicum virgatum* | 14 % | | 28 % | | 27 % | 2 % |
| *Andropogon gerardi* | 6 | | | | 8 | 2 |
| *Schyzacchrium scoparius* | 16 | 10 | | | | 4 |
| *Bromus inermus* | 6 | | 16 | 8 | 10 | 4 |
| *Sorghastrum nutans* | 6 | | | | 6 | 16 |
| *Sporobolus vaginiflorus* | 16 | 32 | 12 | | 4 | 4 |
| *Spartina pectinata* | 12 | | | | 1 | |
| *Elymus villosus* | 8 | | | | | |
| Forbs | 8 | 36 | 16 | | 4 | 4 |
| *Bouteloua curtipendula* | | 4 | | | 2 | 4 |
| *Triticum* spp. | | | | 38 | | |
| *Carex* spp. | | | | | 2 | 2 |
| Litter | 8 | 12 | 28 | 8 | 40 | 6 |
| Bare ground | | 6 | | 46 | 20 | 52 |

to be overgrazed because of the amount of invader-type plant species present (Table 1). Dropseed was the most frequently occurring pasture grass while common ragweed, broom weed (Xanthocephalum dracunculoides) and heath aster were most numerous among the forbs. A small farm pond situated in the pasture a short distance north of the study site was important to small rodents only as it attracted predators to the area.

Soil types were Martin (silty clay loam) and Clime (silty clay) (Soil Survey of Lyon County, Kansas, 1981). Ditch site P cover components, rated as a percentage of the 50 total basal "hits" recorded on the transect (Cook, 1962), consisted of 84 % grasses, 8 % forbs, and 8 % litter; percentages were extrapolated to represent the total area cover. Cover approximately six m inside the fence away from the ditch consisted of 46 % grasses, 36 % forbs, and 12 % litter. These percentages were obtained and treated in the same manner as ditch percentages. Ditch grasses (switch grass, little bluestem, Indian grass, and dropseed) were primarily those preferred by voles and cotton rats (Mossman, 1955; Goertz, 1964; Fleharty and Mares, 1972; Kaufman and Fleharty, 1974; Grant, 1975; Kincaid et al, 1983). Absence of these grasses inside the fence, together with large populations of such coarse-stemmed forbs as common ragweed, heath aster, and broom weed indicated the area as one from which any wintering small mammal residents might move into the more dense cover of the adjacent roadside ditch.

Site F

Ditch F (field), T 18 S, R 10 E, S 19, was located one mile north of Site P. Ditch cover appeared to be optimum small rodent habitat (Mossman, 1955; Carroll and Getz, 1976; Phillips, 1936). Predominant plant species were switchgrass, smooth brome (<u>Bromus inermus</u>) and dropseed. Brome appeared to be dominant beyond the fence except during the wheat growing season. Giant ragweed (<u>Ambrosia trifida</u>) and annual sunflower (<u>Helianthus annuus</u>) were the most numerous forbs. Grasses comprised 56 % of the total ditch F cover, with 16 % forbs and 20 % litter. Approximately six m into the field, wheat (during growing season) comprised 38 % of the vegetative cover, brome grass was 16 %, and forbs the remaining 46 %. During late summer, fall and much of the winter, tillage practices reduced cover growth on the wheat field. Site F soil type were Martin (silty clay) and Ladysmith (silty clay loam) (Soil Survey of Lyon County, Kansas, 1981). A high voltage power line crossed the east end of the trapline.

<u>Site R</u>

Site R (native grass, or rangeland as it will be referred to hereafter), T 18 S, R 10 E, S 7, was selected as being representative of tallgrass prairie although grass species growing inside the fenceline resulted from a 1962 range management reseeding program (Spencer, 1980). Ample time had elapsed between reseeding and the current study for litter and cover to provide adequate rodent habitat. Ditch vegetation was not altered by the reseeding. Ditch cover, as well as that of the adjacent land, consisted mainly of big bluestem (<u>Andropogon gerardi</u>), little bluestem, switch grass, Indian grass, smooth brome, and dropseed. Predominant forbs were heath aster, common ragweed, and rosinweed (<u>Silphium lacinaiatum</u>). Vegetative cover of the ditch and adjacent area presented a homogenous appearance. Site R ditch cover was composed of 36 % grasses, 4 % forbs, and 40 % litter. This transect and its parallel counterpart six m inside the fenceline were run on fall vegetation after an early spring range fire. Approximately one third of the ditch sampling area did not burn and nearly all the litter basal "hits" were made on this protion of the vegetation transect. Grass and other plant debris inside the fence burned completely. Therefore, the percentage of bare ground hits inside the fence was relatively high (52 %) and litter was low (6 %). Grasses accounted for 30 % of the site R in-fence cover. Soil type was a Labette-Dwight complex characterized as deep to moderately deep, well-drained upland loam (Soil Survey of Lyon County, Kansas, 1981).

# MATERIALS AND METHODS

The purpose of this study was to determine the seasonal use of roadside ditches by small rodents. The research was designed to monitor movement between ditches and adjacent lands, and involved selection of three study sites of comparable cover, microclimate, and food resources but with different agricultural treatment of the adjacent lands. The capture-mark-recapture technique, one of several field methods frequently employed for studying small mammal movements, was used. DeBlase and Martin (1981) mentioned a number of studies using variations of mark and recapture techniques for population studies of small mammals.

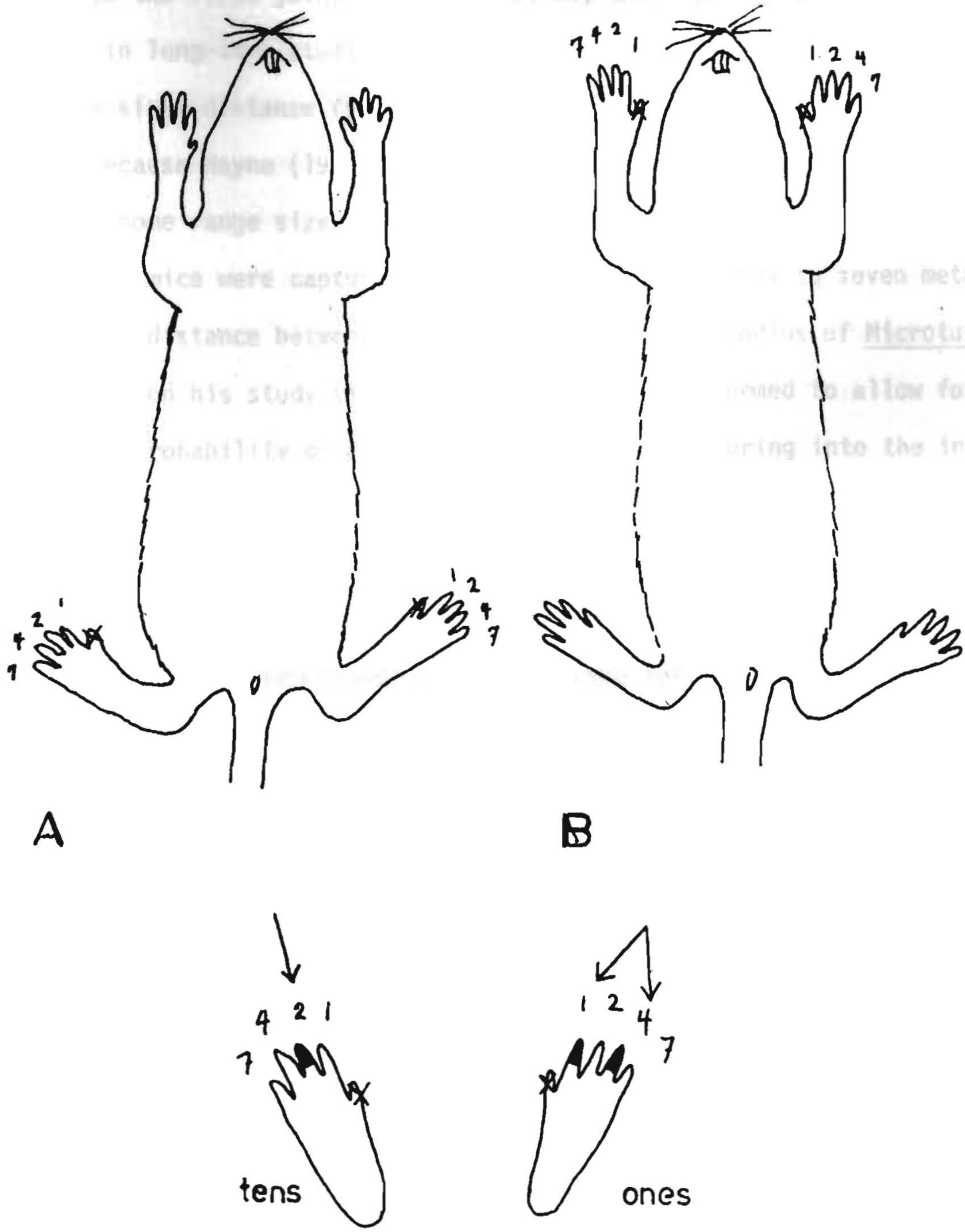
A 50 m trapline was established in each of three ditches. Seven stations approximately seven m apart were located on the south-facing slope of each ditch. They were approximately 0.5 m from the ditch bottom or as near that as possible given the location of an established runway on which to position a trap. The seven m distance between stations was selected because distances (15-20 m) most often reported in the literature for trapping grids (Terman, 1973; Kaufman and Fleharty, 1974; Abramsky et al, 1979; and others) were deemed too far apart for the single row of stations restricted by ditch dimensions: more animals might be captured if the space between the traps was not excessive. Getz (1970) used a five m distance between traps; however, Martin (1956) reported little difference in capture rate after his traps were repositioned five m farther apart than the 6 m initially placed, several weeks after he began trapping.

All live traps were Fitch-type (Fitch, 1950). Clayton (1952), Terman (1973) and Glass and Slade (1980) reported favorable results using modification of this type live trap. A mixture of peanut butter and oatmeal was used as bait the first fall, winter, and spring; whole oats were used the second year. As success had been reported with both baits (Clayton, 1952; Weigert and Mayenschein, 1966; Johnson, 1968; Krebs et al, 1969), difference, if any, in effectiveness of one bait over the other was questionable. Comparison of an equal number of trapping sessions for each bait indicated no significant difference ($p > 0.05$) in their effectiveness.

Traps were baited and set late in the afternoon and checked early the following morning, since rodent activity is generally concentrated in the predawn and after-dusk hours, although some species such as Microtus and Sigmodon are known to be active throughout the 24 hour day (Spencer, pers. comm.). Each session ran from Friday afternoon through Monday morning, a session length suggested by Martin (1956) and also used by Krebs et al (1969), Getz (1970), Glass and Slade (1980), Birney et al (1976), and Fleharty and Navo (1983). Each captured animal was marked by toe clipping, weighed to the nearest gram, sexed, and checked for reproductive condition and general health. The trap number in which the animal was caught and the animal's status at capture (i.e. newly captured or recaptured) also were recorded. Two toe-clip marking codes (Figure 1) were used to differentiate among animals captured in ditches from those taken on adjoining land. As animals from both ditch and in-fence areas were expected to be captured on a given site, two codes were considered necessary.

The numbering system necessitated the clipping of no more than two toes per foot, a number which apparently does not affect the animal's ability to move about (Terman, pers. comm.). Toes were clipped well

Figure 1. Toe clipping codes used in the present study (after Terman, pers. comm.). A. Ditch code. B. In-fence code. C. example.




C Number 25 (hind feet)

behind the first joint. Borgens (1982) found that mouse digits clipped distal to the first joint tended to regrow, thus rendering the animal useless in long-term studies.

The six m distance from fenceline to in-fence trap stations was chosen because Hayne (1950), in his study of the relationship between Microtus home range size and distance between traps, found greatest numbers of mice were captured in traps approximately six to seven meters apart, the distance between traps approximating the radius of Microtus home range on his study site. Thus, this distance seemed to allow for increased probability of capture of any rodents venturing into the in-fence area from the adjacent ditch.

Central to the questions was the extent to which ditch cover was occupied by rodent populations. Estimates of occupancy by such species as Microtus and Sigmodon were made by looking for burrows and runways, fecal pellets, and piles of recent grass clippings. Runway systems of a 10 m section in each ditch were mapped (after Martin, 1956). Carroll and Getz (1976) also mapped vole runway systems in their study of Microtus ochrogaster runway utilization. Occurrence of additional species was determined by snaptrapping early the first winter. Museum special traps were set in each ditch on a line continuous with the live trapline, with an intervening space of approximately 50 m between the last live trap and the first snap trap. This space was intended to reduce the possibility of killing marked animals from the live-trapping area.

Vegetation was identified and the percentage of occurrence of plant species was determined by the step-loop method (Table 1). Light probe-oriented light meter (Enviro-line Environmental Meter). Mossman (1955) and Getz (1970) also evaluated vegetative cover density in this manner. Burrow, runway, and ambient temperatures were determined with a Tele-thermometer (Yellow Springs Instr. Co.). Table 2 shows mean burrow and runway temperatures taken between 8:00 and 9:00 a.m. on each site three days of each November, January, and April during the study.

Several authors (Goertz, 1964; Martin, 1956; Yahner, 1982) suggested ways to avoid excessive trap mortality due to winter weather conditions. The method utilized in this study gave complete protection during two winters. Hardware cloth traps were first wrapped in several layers of newspaper, then in a layer of heavy aluminum foil, being careful to allow for the proper functioning of the trap mechanism. A generous handful of polyester fiber was placed in the trap as nest material. Polyester fiber was preferred to cotton because cotton readily absorbs moisture, thereby contributing to rapid heat loss by the captured animal. With careful handling, traps were used for an entire session without rewrapping.

As the weather warmed and spring vegetation growth began, traps were set approximately six m inside the fence on the land adjacent to the ditches, with five subsequent in-fence sessions carried out into late spring. This procedure was designed to monitor movement, if any, away from the ditch into the adjoining land. Trapping was resumed in the fall to determine the extent to which earlier, outward "flow" (from ditch to field) may have reversed. Trapping was discontinued for the summer months because of the reduced trappability demonstrated by many small rodent species in July, August, and September. Goertz (1964) in a two year study of habitat quality upon <u>Sigmodon</u> density, did not

Table 2. Mean burrow and runway temperatures in °C recorded during the 3-day trapping sessions for each November, January, and April of the study.

| Month | Burrow (ditch) | | | Runway (ditch) | | | Runway (in-fence) | | | Ambient temp. (8:00 a.m. 1 m above ground) |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | F | R | P | F | R | P | F | R | |
| November | 5 | 4 | 6 | 15 | 7 | 11 | 10 | 8 | 9 | 7 |
| January | 4 | 4 | 8 | 10 | 5 | 11 | 4 | 5 | 10 | 4 |
| April | 14 | 12 | 12 | 19 | 22 | 26 | 28 | 30 | 30 | 8 |

P = Pasture
F = Field
R = Rangeland

trap from July 3 through September 30 the first summer and, when trapping the same period the second summer, recorded the lowest number of captures for the year. Fleharty et al (1972) also noted population "lows" during summer months in a four year study of Sigmodon population fluctuations.

Sigmodon and Microtus were the most abundant species taken in live traps. Small numbers of deer mice (Peromyscus maniculatus) and white footed mice (P. leucopus) were captured alive on all sites but were not recorded in total capture data because it was thought that the ability of these small species to move freely in and out of the traps would result in distortion of population density values.

Seasonal ditch occupancy by Sigmodon and Microtus, as revealed by capture data, was compared using Student's t test. Capture data also were analyzed for significant habitat utilization differences among the ditch populations using Friedman's two way analysis of variance. Vegetative cover was analyzed and correlated with rodent population density. Population densities were estimated by minimum number known to be alive (Krebs, 1966) and recorded as number of animals per unit area (unit area: 50 m X 4 m = 200 $m^2$). Krebs' (1966) estimation method reveals the minimum number of animals on each area at time $t$. The resulting figure is a summation of two counts: (1) the actual number of individuals caught at time $t$, and (2) the number of individuals marked previous to time $t$ but caught after time $t$, and not at time $t$ (Terman, 1973).

## RESULTS AND DISCUSSION

Habitat-related factors influencing rodent occupancy appeared to be (1) the quality of available cover on ditch sites compared to the adjoining lands (as revealed by the runway systems), and (2) the rangeland fire. This study was designed to investigate movement of Sigmodon hispidus and Microtus ochrogaster between roadside ditches and adjacent agricultural lands. Therefore, the research was carried out by live-trapping the two species in roadside ditches and areas adjacent to the ditches. Sessions began in November, 1982, and were repeated in December, 1982, January, 1983, April, 1983, May, 1983, and early June, 1983. Trapping was discontinued during the summer of 1983 but resumed in September and November, 1983, with subsequent sessions in January, March, and April, 1984. Sessions extended over three nights except where severe weather conditions might have presented survival problems for trapped animals. One hundred ninety-three animals were captured in 1158 trap nights, a rate of 167 per 1000 trap nights. Of the total caught, 50 were recaptures. As the number of animals trapped was relatively small, captures were counted per 1000 trap nights to provide a standard for comparisons (Navo and Fleharty, 1983).

The effect of cover quality on Sigmodon and Microtus populations was reflected in the capture data for each site. Numbers of animals caught are shown in Table 3. Data were grouped by season because it was believed that rodent movements recorded from fall through winter into spring would most accurately reflect cover-related changes in rodent location, if any. Each fall, winter, and spring season was represented in the total capture data. Species and numbers of animals

Table 3. Total fall, winter, and spring live-captures of *Microtus* and *Sigmodon* at each site.

| | Ditch | | | In-fence | | |
|---|---|---|---|---|---|---|
| Site | Fall | Winter | Spring | Fall | Winter | Spring |
| Pasture | 20 | 32 | 11 | 19 | no trap | 8 |
| Field | 10 | 20 | 3 | 18 | --- | 2 |
| Rangeland | 9 | 34 | 9 | 3 | --- | 5 |

snaptrapped as a means of determining each site's small mammal diversity are listed in Table 4.

Table 4. Number of individuals of each species snaptrapped during a three day session, winter, 1982-1983.

| Site | *Peromyscus maniculatus* | *Microtus ochrogaster* | *Neotoma floridana* | *Sigmodon hispidus* | *Blarina hylophaga* |
|---|---|---|---|---|---|
| Pasture | 1 | 1 | 1 | | |
| Field | | 4 | 1 | 1 | 2 |
| Rangeland | | 6 | | 1 | |

Table 5 summarizes the seasonal captures by year for each ditch site. No significant seasonal difference was found ($p > 0.05$) due to agricultural treatment of adjoining lands. However, a trend toward larger fall and winter populations than were noted in spring in all ditches seemed apparent (Figure 2).

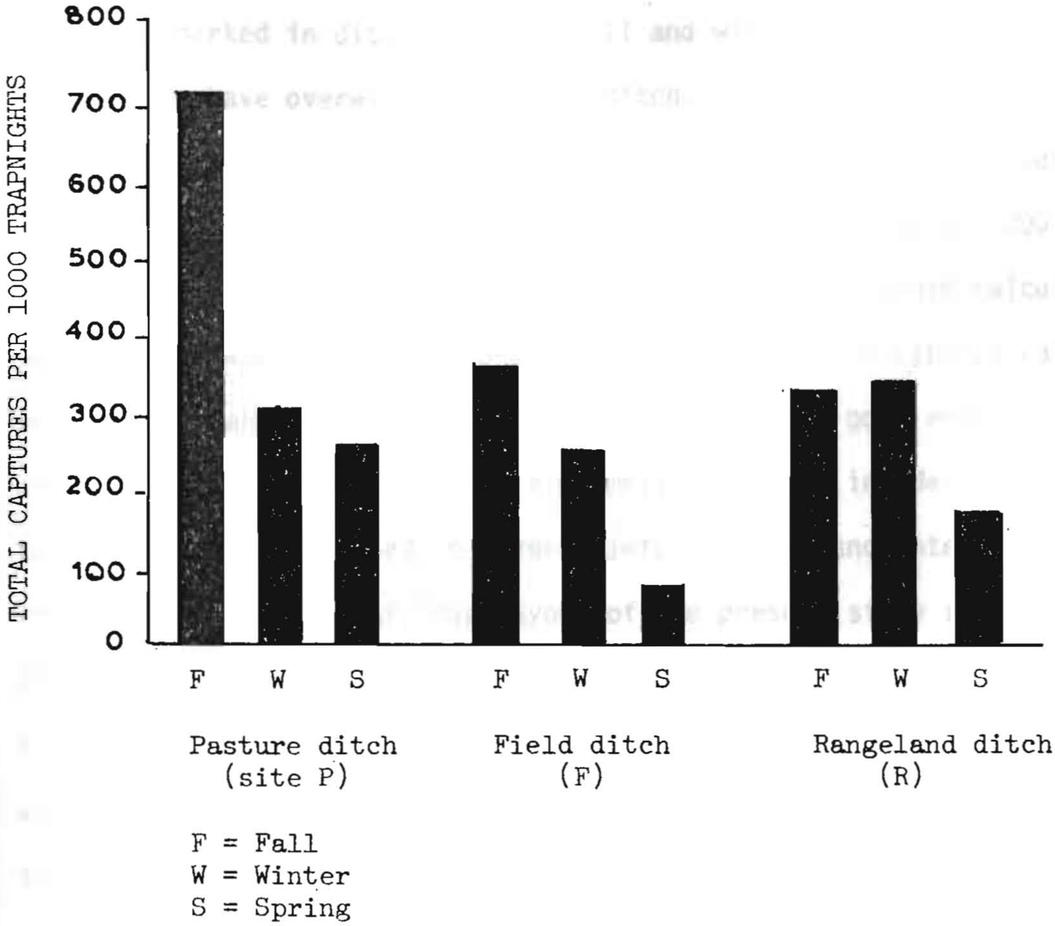
Site P (Pasture)

The total fall capture rate was 714 animals per 1000 trap nights of which 30 % were recaptures. Total winter capture rate was 305 animals per 1000 trap nights, 31 % were recaptures. Seven recaptured animals had been marked and released in the ditch in late autumn, while the remaining three were originally taken in the early fall inside the

Table 5. Combined yearly seasonal captures and recaptures of Microtus and Sigmodon for each of three ditch sites.

| Site | Season | No. Captures Year 1 (Nov.-June) | No. Captures Year 2 (Sept.-April) | No. recaptures Year 1 | No. recaptures Year 2 | No. cross-fence Year 1 | No. cross-fence Year 2 | No. overwintered Year 1 | No. overwintered Year 2 |
|---|---|---|---|---|---|---|---|---|---|
| Ditch P (Pasture) | Fall | 11 | 9 | 5 | 6 | | 0 | 2 | 0 |
| | Winter | 19 | 13 | 10 | 2 | | 2 | 0 | 0 |
| | Spring | 6 | 5 | 2 | 2 | | 1 | 0 | 0 |
| Ditch F (Field) | Fall | 5 | 5 | 0 | 0 | | 0 | 0 | 0 |
| | Winter | 20 | 0 | 2 | 0 | | 0 | 0 | 0 |
| | Spring | 5 | 4 | 0 | 0 | | 0 | 0 | 0 |
| Ditch R (Rangeland) | Fall | 5 | 4 | 1 | 0 | | 0 | 2 | 2 |
| | Winter | 30 | 4 | 9 | 3 | | 1 | 0 | 0 |
| | Spring | 5 | 0 | 2 | 2 | | 0 | 0 | 0 |

Figure 2. Seasonal use by Microtus and Sigmodon of three ditch sites as indicated by calculated numbers of rodents captured per 1000 trap nights.


800
700
600
500
400
300
200
100
0
TOTAL CAPTURES PER 1000 TRAPNIGHTS
F
W
S
F
W
S
F
W
S
Pasture ditch (site P)
Field ditch (F)
Rangeland ditch (R)
F = Fall
W = Winter
S = Spring

fence adjacent to ditch P. This suggests that those three animals may have moved to the ditch with the onset of colder weather.

Spring capture rate for ditch P was 262 animals per 1000 trap nights; with a recapture rate of 20 %. All recaptures were originally taken and marked in ditch P in the fall and winter. The recaptured animals may have overwintered in the ditch.

Microtus and Sigmodon density in ditch P was estimated at seven per unit area (200 $m^2$) the first fall and winter, and two per 200 $m^2$ the second spring. Lack of sufficient recapture data precluded calculating density estimates for the second winter and spring. Recapture rates were lower than expected, with 50-70 % considered a good return (Krebs et al, 1969). Terman (1973) also experienced a low incidence of recaptures which he attributed to severe winter weather and interspecific interaction. The linear trap layout of the present study rather than the standard grid customarily used in live-trapping would also result in low recaptures because of fewer opportunities (i.e. less traps per unit area) for recapture. This would hold true for each of the three study sites.

When seasonal ditch captures were compared (Table 5), no significant difference was found in ditch P between the winter and spring periods ($p > 0.05$), although the difference between fall and winter levels was significant ($p < 0.05$).

Two animals trapped and marked in ditch P in January, 1983, were subsequently recaptured inside the fence in May, 1983. While this is not conclusive evidence that the center of rodent activity (as defined by Hayne, 1949) moved to the area inside the fence with the spring regrowth of vegetation, these recaptures did indicate that the increase in vegetative cover may have facilitated animal movement to the pasture side of the fence.

Site F (Field)

Fall capture rate of ditch site F totaled 357 animals per 1000 trap nights (Figure 2). There were no fall recaptures in the ditch (Table 5). Total winter catch rate was 256 animals per 1000 trap nights, with a 10 % recapture rate. No animals marked on ditch F were found to have overwintered either year of the study. However, one male *Microtus* first captured inside the fence as an adult was recaptured inside the fence the following March.

There was a significant difference between winter and spring captures at ditch F ($p < 0.05$), the difference was possibly due to variation in population density. Predation may have exerted an unusually strong influence on the site F spring population. All animals taken in one snaptrapping session were partially eaten, and on two occasions, several live traps were disturbed. The proximity of an occupied badger den and a nearby farmstead suggested possible predator sources.

An extended period of extreme cold during January, 1984 (night time lows frequently ranged below -20° over three weeks) also may have affected the total winter capture from ditch F. The 1982-1983 winter temperatures during the sampling periods were less severe than 1983-1984, as was duration of snow cover, and the first winter's capture rate was greater than for the second winter. This suggests that intense cold of January, 1984, may have been a factor in the lower capture rate for ditch F the second winter. However, extensive digging through heavy, packed snow along the 50 m ditch trapline revealed a number of runways with undecomposed fecal pellets as well as relatively fresh stem cuttings.

The January, 1984, cold spell might also have been responsible in part for the low total 1984 spring capture rate for ditch F: only 69 animals per 1000 trap nights were taken, with no recaptures. Two adult _Microtus_ were captured the second spring, which indicated that they might have overwintered in the ditch under the snow.

Another factor which may have negatively influenced the 1983-1984 winter capture rate was the drouth and high temperatures during late summer and autumn of 1983. Both _Microtus_ and _Sigmodon_ are primarily herbivores whose preferred food consists of the succulent portions of grass stems (Martin, 1956), although Cole and Batzli (1978) reported dicots as preferred _Microtus ochrogaster_ food in Illinois. Since much of the non-metabolic water utilized by the two species is derived from their food source, the effect of dry, hot weather on plant growth would produce a correspondingly negative effect on _Microtus_ and _Sigmodon_ survival. This may have been the case on site F. With the wheat harvested and the adjacent land fall-plowed and reseeded, little cover and food would be available on the land adjacent to the ditch. Ditch F population density was estimated at two per 200 $m^2$ the first fall and winter. Thereafter, estimates could not be made due to insufficient recapture data.

Site R (Rangeland)

Ditch R fall trapping rate was 321 animals per 1000 trap nights (Figure 2), with an 11 % rate of recapture. Winter trapping prior to the grass fire in April, 1983, yielded a relatively high number of captures: 539 per 1000 trap nights with a recapture rate of 14 %. Captures for the winter following the fire, however, were reduced to 95 animals per 1000 trap nights with a 27 % recapture rate.

Data from site R (ditch plus in-fence area) were affected by two distinct types of vegetative cover: before and after the management-related grass fire of April, 1983. Fall versus winter ditch captures were significantly different ($p < 0.05$), with 74 % more animals captured in the winter than in the fall (Table 5). The winter-spring difference also was significant ($p < 0.05$). However, of the total winter-caught animals (i.e. first winter captures plus second winter captures) only 12 % were caught during the second winter, approximately nine months after the range fire that destroyed several years' accumulation of litter on two thirds of the ditch study area. The low second winter capture rate might have been indicative of a slow recovery of population density after the fire due to vegetative cover alteration. Whether these animals were permanent ditch inhabitants or whether they had recently moved into the ditch from the adjoining grassland is unknown. Only one animal initially captured inside the R fence was subsequently taken in the ditch.

Ditch R population density was estimated at two animals per 200 $m^2$ the first autumn, three that winter, and four, the following spring. The second winter, three animals per 200 $m^2$, and spring, two animals per 200 $m^2$ were estimated on ditch R.

Trans-season Survival

Table 6 gives the mean residence time (as a measure of trans-season survival) in weeks for Microtus and Sigmodon on each site. Greater survival rates are indicated where vegetative cover was most dense.

Unless detered by such factors as predation and intra-or inter-specific agressive interaction which is more apt to occur at higher

Table 6. Mean residence time in weeks of Microtus and Sigmodon on each of the study sites.

| | DITCH | | | IN-FENCE | | |
|---|---|---|---|---|---|---|
| Species | Pasture | Field | Rangeland | Pasture | Field | Rangeland |
| Microtus | | | 35 | 32.5 | 18 | 21 |
| Sigmodon | 10.8 | 8 | | 36.0 | | |

density levels where greater potential exists for contact between individuals (Terman, 1974), animals in marginal habitat will seek better cover, such as that presented by the ditches on each of the three study sites as compared with the cover on the adjoining land. And, because of the trapline's linear design, animals could readily bypass the in-fence traps to range into outlying areas. It is possible that some individuals may have crossed the roads, although a number of authors, investigating the role of roads as natural barriers to dispersing rodents, have found that rodents probably do no voluntarily cross roads (Kozel and Fleharty, 1979) but utilized roadside grass cover as dispersal routes (Getz et al, 1978). Cole (1978) situated a trapping grid alongside a graveled rural road in Illinois to take advantage of the road's function as a natural barrier to dispersing rodents.

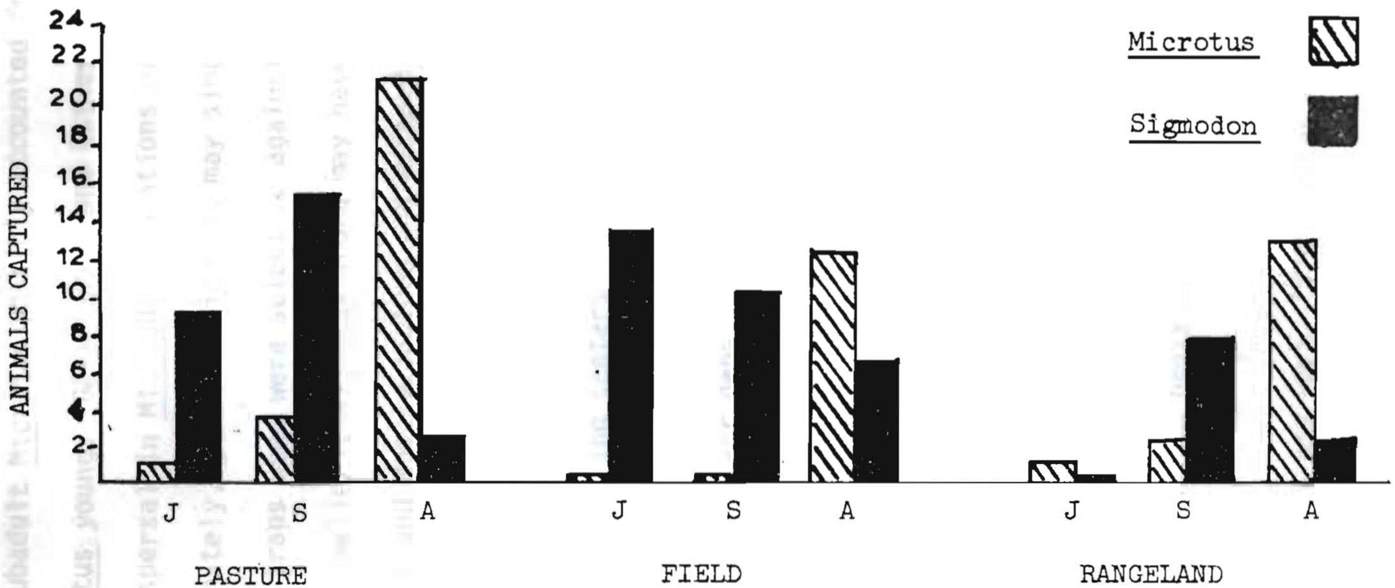
Trans-season survival was indicated the first year but not the second year for some ditch P animals. Marked specimens living through the first winter were all Sigmodon. Mild late fall weather, which would encourage late-season breeding, probably accounted for the relatively large number of young Sigmodon captured in the second winter on ditch P. However, none of the marked young on ditch P were recaptured the second spring. Furthermore, only one adult Sigmodon was caught the second spring, suggesting that the severe January cold of the second winter may have increased mortality in ditch P Sigmodon. Dunaway and Kaye (1961), Fleharty et al (1972), and Vickery and Bider (1981) mention the vulnerability of Sigmodon hispidus to severe weather conditions. This supposition is supported by the fact that only the cold-hardy Microtus were captured during the second spring in the ditch and inside the fence on site P. Sigmodon are essentially southern rodents while Microtus are found well into Canada (Hall, 1981). This fact may indicate a tolerance for cold weather in Microtus that has yet to evolve in Sigmodon as the species continues to extend its range northward.

Neither Sigmodon nor Microtus were known to overwinter on ditch site F although one marked adult Microtus survived the second winter inside the fence. With little or no cover on the site F field, this animal, captured in early March, may have overwintered in the adjacent heavy ditch cover.

Two marked Microtus survived the first winter on ditch R and another, caught the first winter, was last captured the second spring. Evidence of similar longevity in Sigmodon was not apparent on ditch R. This may have been due to adverse weather or to natural population fluctuation. The absence of Sigmodon the second year could be explained by the impact of the severe January temperatures as well as the spring grassfire's effect on site R in-fence vegetation.

Figure 3 shows the number of captured Microtus and Sigmodon in each of the following age groups: Juvenile, sub-adult, and adult (ages assessed by body weight, after Krebs et al, 1969; Gaines and McClenaghan, 1980; Glass and Slade, 1980). Adult Microtus outnumbered adult Sigmodon on each site. The relatively numerous juvenile and subadult Sigmodon

Figure 3. Numbers of *Microtus* and *Sigmodon* in each age group at time of capture in three different ditch sites.




J = Juvenile
S = Subadult
A = Adult

may have been indicative that Sigmodon had a higher reproduction rate than that of Microtus, although the large number of adult Microtus would suggest that the data may have misrepresented Microtus reproduction. Dispersal of subadult Microtus possibly accounted for the limited captures of Microtus young. Getz (1978) and Gaines et al (1979), suggested that dispersal in Microtus populations occurs mainly among subadults. Alternately, juvenile Microtus may simply have eluded capture. Since the live traps used were selective against small animals (Peromyscus or smaller), Microtus young may have gnawed through the trap's newspaper and foil wrappings and escaped.

Alteration in either diversity or size of microhabitat results in alteration of resident rodent populations structure. This change is characterized by shifting centers of activity, and interspecific competition for space and food resources (Grant, 1971). Seasonally related alteration in cover density, measured in the present study in foot candles of light penetrating to the runway floors (Table 7), appeared to coincide positively with seasonal rodent population density although lack of sufficient data prevented testing for a positive correlation. Mossman (1955) and Goertz (1964) stressed the effect of habitat quality and reported a positive correlation between cover and rodent population density. In this study, however, more animals were trapped in medium than in heavy cover, and greater capture rates were recorded in winter than in fall as would be expected (Krebs et al, 1969; Weigert, 1972; Gaines and Rose, 1976; Gaines et al, 1979). Carroll and Getz (1976) suggested that less dense cover facilitates small mammal movement which might explain the greater numbers of captures in medium than in heavy cover, while the increase in winter over fall captures

Table 7. Numbers of animals captured per 1000 trap nights and runway vegetative cover density in ditch habitat expressed in foot candles (f.c.) of light at ground level.

| Site | Season | Heavy cover (0-5 f.c.) | Medium cover (6-10 f.c.) | Light cover (11-15 f.c.) |
|---|---|---|---|---|
| Pasture | F | | 714 | |
| | W | 305 | | |
| | S | | | 262 |
| Field | F | | 357 | |
| | W | 256 | | |
| | S | | | 69 |
| Rangeland | F | | 321 | |
| | W | 324 | | |
| | S | | | 160 |

F = Fall
W = Winter
S = Spring

may have been due to moderation of severe temperatures in burrows and runways by heavy snow cover (Table 8). Weather conditions, as stated earlier, affect rodent population density and, consequently, rodent trappability and habitat utilization (Barbehenn, 1958).

Population fluctuation factor

Population density might possibly be determined by factors inherent in the population, and therefore might fluctuate independently of the environment (Martin, 1956; Errington, 1946). Normal population fluctuation was recognized as a factor in rodent movements within the ditches and between ditch and in-fence sites. Figure 4 shows separation of the total captures for each site into specific (Microtus and Sigmodon) components, with the degree of fluctuation and the potential for competition clearly evident. The phenomenon of cycling, widely known to occur among some small rodent populations (Chitty, 1960; Krebs et al, 1973; Krebs, 1970; Fleharty et al, 1972), is usually characterized by greater population densities in the fall than at other seasons due to recruitment of the young of the year as well as possible immigration. However, populations on each of the present study sites exhibited winter peaks, but by spring, capture rates on each site were reduced to a point suggesting the characteristic downward trend of a population density "cycle." The apparent reduction in Sigmodon numbers was characteristic of the "crash" described by Fleharty et al (1972).

Interspecific Competition and Population Density

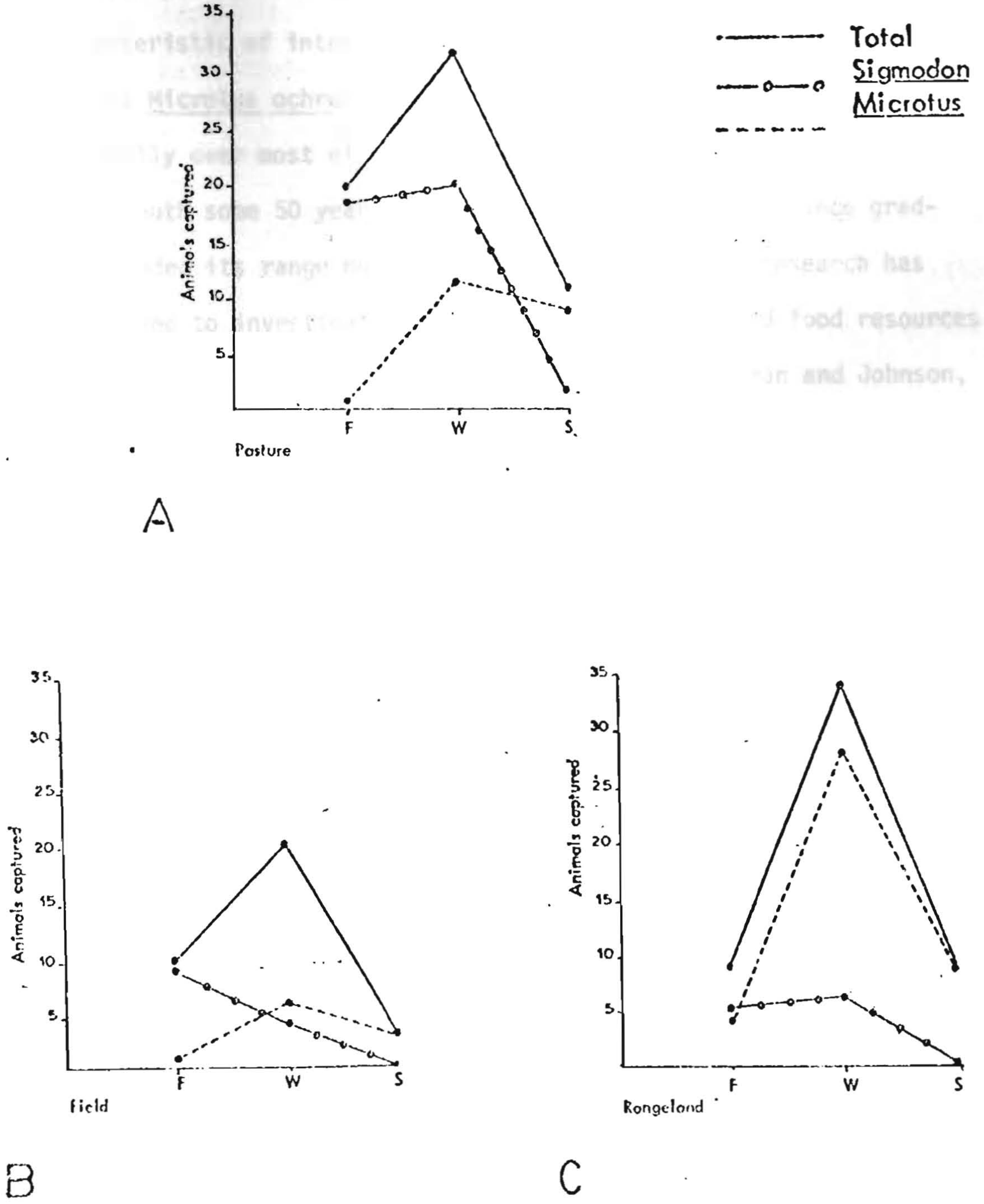
Capture data from the present study appeared to agree with Martin (1956), Frydendall (1959), Baker (1969) and Terman (1973; 1974) who contended that competition for space may be a major factor in small mammal population fluctuation. This suggested that competition was

Table 8. Number of well-defined runways crossing three 10-meter transects on fence line, April, 1983.

<table>
<tr><th rowspan="2">Transect</th><th colspan="2">Pasture (P)</th><th colspan="2">Field (F)</th><th colspan="2">Rangeland (R)*</th></tr>
<tr><th>Dense cover (ditch)</th><th>Patchy cover (in-fence)</th><th>Dense cover (ditch)</th><th>New wheat (in-fence)</th><th>Patchy to dense (ditch)</th><th>Dense cover (in-fence)</th></tr>
<tr><td>A</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">2</td></tr>
<tr><td>B</td><td colspan="2">6</td><td colspan="2">2</td><td colspan="2">4</td></tr>
<tr><td>C</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">1</td></tr>
<tr><td>$\overline{X}$</td><td colspan="2">5.67</td><td colspan="2">3.67</td><td colspan="2">2.33</td></tr>
</table>

*One week before burning

Figure 4. Fall (F), Winter (W), and Spring (S) captures of *Microtus* and *Sigmodon* in ditches adjacent to *pasture* (A), *field* (B), and rangeland (C).


Total
Sigmodon
Microtus
Animals captured
35
30
25
20
15
10
5
F
W
S
Pasture
A
Field
B
Rangeland
C

likely a casual factor in the movement between ditch and adjoining land. Demonstrated dominance of one species over another (even to the point of the exclusion of one species) where the niches of the two overlap is characteristic of interspecific competition for space.

While Microtus ochrogaster and Sigmodon hispidus presently occur sympatrically over most of Kansas, Sigmodon first moved into the state from the south some 50 years ago (Cockrum, 1948) and has since gradually extended its range northward and westward. Much research has been designed to investigate competition for habitat and food resources between the two species (Fleharty and Olson, 1969; Terman and Johnson, 1971; Terman, 1973, 1974, 1978; Weigert, 1972; Glass and Slade, 1978, 1980; Prochaska and Slade, 1980). Terman (1974) found that Microtus reduced their use of areas occupied by Sigmodon. Figure 4 indicates possible competition for space between Microtus and Sigmodon on each study site.

The greatest numbers of Ditch P Sigmodon captured the first year were trapped at those stations yielding the fewest Microtus. Traps were not set inside the fence at any of the sites until the second year. Few Sigmodon were caught on either side of the ditch P fence the second year, while Microtus captures increased at most stations. Conditions in the ditch may have been more favorable for Sigmodon than in-fence conditions. Apparently, as long as Sigmodon were present on the site in appreciable numbers, Microtus avoided the area. Terman (1973, 1974) noted similar behavior in his studies of Sigmodon-Microtus competitive exclusion. He also suggested that in the absence of Sigmodon, Microtus moved in from the marginal habitat to which Sigmodon occupancy of the most favorable habitat had relegated them. This seems to have occurred on site P, while site F conditions appeared to promote some degree of co-existance, and on site R, Microtus captures outnumbered Sigmodon. In each instance, the apparent interaction between the two species within the ditches probably influenced movement between ditch and adjoining land.

Runway Systems

Before the fire, density of ditch R cover and cover inside the fence were similar. This would suggest an equitable rate of habitation in both areas by both species. The mean number (2.33) of well-defined runways crossing a 10 m fence line transect on site R (Table 8) indicated little movement occurred between ditch R and the adjacent land. It would also suggest separate ditch and in-fence rodent populations, while the ditch P runway systems, with a mean of 5.67 runways crossing from ditch into pasture indicated, though not significantly ($p > 0.05$), more travel between ditch and adjacent land than on the F or R ditch sites. Ditch P cover appeared to be optimum small mammal habitat, whereas adjacent pasture cover did not. Lidicker and Anderson (1962) suggested a positive correlation between the number of Microtus californicus runways crossing a transect and M. californicus population density, and Fitzgerald (1983) noted that the relative abundance of runways may be a rough Sigmodon population index. The greater number of runway crossings on sites P (5.67) and F (3.67) than on R (2.33) might possibly indicate larger Microtus and Sigmodon populations on P and F than on R. Or, it could indicate heavier vegetative cover on ditches P and F, than on ditch R, which was the case as shown by Table 1). Carroll and Getz (1976) observed that more runways were necessary to facilitate movement of resident voles in dense cover than in sparse cover. They also found a positive correlation between Microtus density and the number of active runways crossing a transect in dense cover.

The runway networks were visible evidence of preferred habitat as well as indicators of limited movements and directions of movement by small mammals. A 10 m segment of runway system in each of the three study ditches was mapped in April, 1983 (Figures 5-7). Martin (1956) and Carroll and Getz (1976) mapped runway systems in their studies of runway use by Microtus ochrogaster. Similar concentrations of interconnecting runways were not apparent on the inside fence areas on any of the study sites. Passages from the ditch systems crossed the fence lines and from there continued onto the adjoining land, connecting occasionally with other runways but without forming the network of trails found in the ditches. Although more land area was available inside the fences for wider population dispersion, the runway pattern together with the readily apparent sparseness of cover inside the fences on sites P and F, and the fact that all discernable in-fence runways radiated from and converged on the mapped crossing, suggested that the animals may have occupied the ditch as primary habitat and foraged on the adjacent lands.

Martin (1956) did not consider a runway system as a complete unit but rather as part of a larger network of systems, reasoning that rodent home range size would indicate larger area use than the area covered by each individual runway system. However, Carroll and Getz (1976) suggested that the space used by an individual vole may be limited to an easily defined small part of the total habitat. They found that while the number of individuals using a particular runway segment did not increase with an accompanying increase in population density, the number

Figure 5. Runway system, Ditch P, covering approximately a 10 m X 4 m segment of the 50 m trap line. Mapped late April, 1983.

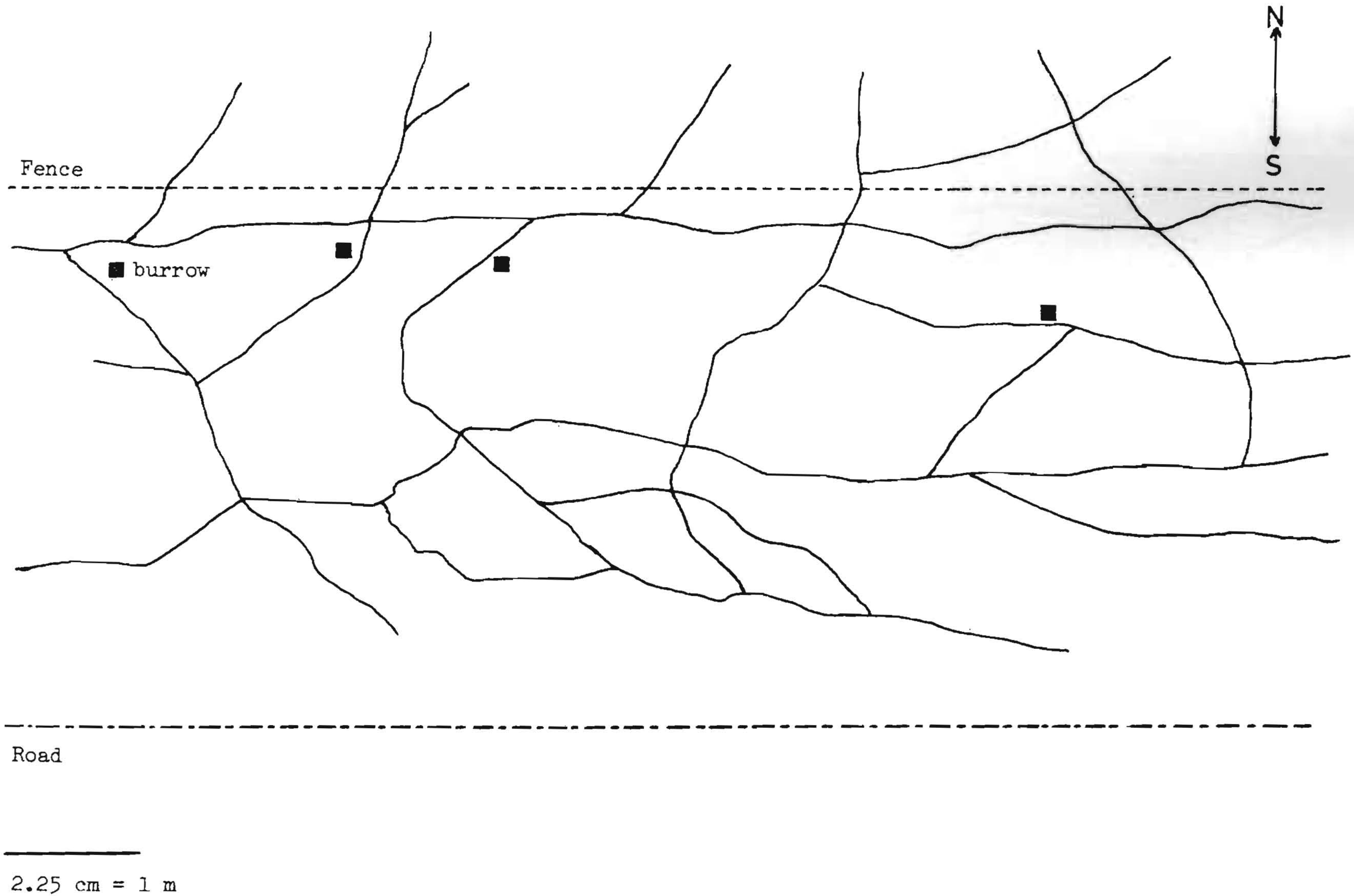

N
S
Fence
burrow
Road
2.25 cm = 1 m

Figure 6. Runway system, Ditch F, covering approximately a 10 m X 4 m segment of the 50 m trap line. Mapped late April, 1983.

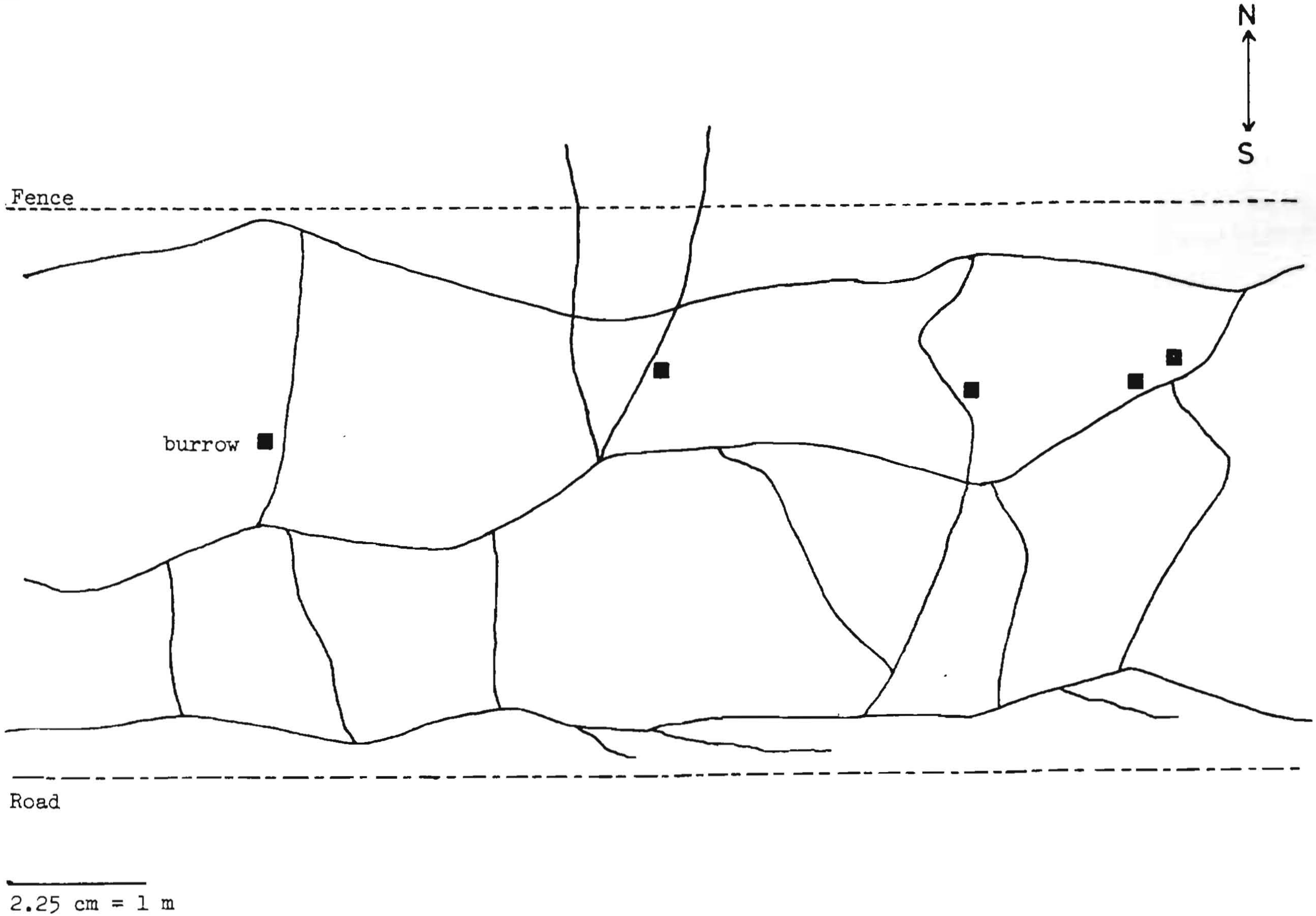
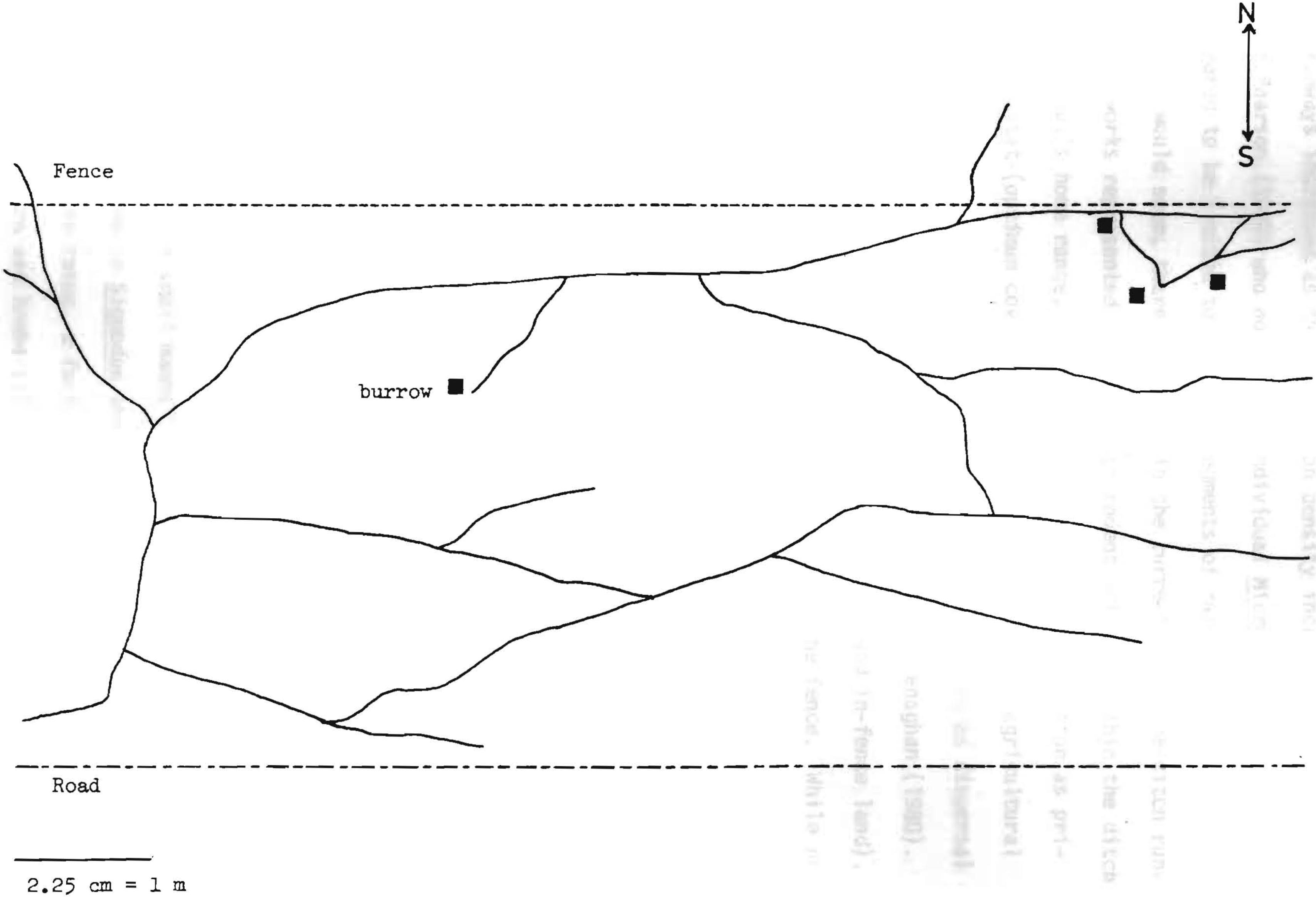

N
S
Fence
burrow
Road
2.25 cm = 1 m

Figure 7. Runway system, Ditch R, covering approximately a 10 m X 4 m segment of the 50 m trap line. Mapped late April, 1983.


N
S
Fence
burrow
Road
2.25 cm = 1 m

of runways increased as the population density increased. This agreed with Pearson (1960) who noted that individual Microtus californicus appeared to be limited to specific segments of runway systems.

It would seem, therefore, that in the current study the ditch runway networks represented the center of rodent activity within the ditch individual's home range, suggesting general ditch utilization as primary habitat (optimum cover/habitat) with the adjoining, agricultural land (marginal cover/habitat) serving as forage areas and as dispersal sinks as defined by Tamarin (1978) and Gaines and McClenaghan (1980). Site R, with its equitable vegetative cover (ditch and in-fence land), may have had resident populations on each side of the fence. While not conclusive evidence, the capture inside the fence of an adult, lactating female Microtus in April, 1984, which had been previously captured and marked inside the fence in November, 1983, at the same station, suggests that this mouse was an in-fence resident. Certainly, the possibility exists that it may have moved from the ditch onto the adjoining land on both occasions, but the similarity of ditch and in-fence rangeland cover also precludes the need for a cross-fence move.

The Site R Grass Fire

Low capture and recapture rates on site R in the late spring trapping sessions may have been partly attributable to weather conditions. Sidorowicz (1960), Gentry and Odum (1957), and Vickery and Rider (1981) experienced similar limited trapping success in studies dealing with the effect of weather on small mammal live-trapping. Normal seasonal population fluctuation in Sigmodon and Microtus could have negatively influenced capture rates, a factor also noted by Getz (1970), Birney et al (1976), Hilborn and Krebs (1976), and Boonstra and Krebs (1979).

Certainly, the trappable population was affected by the loss of vegetation from the range fire. Cover before the fire was apparently good Sigmodon-Microtus habitat, similar to that described by Martin (1956), Randall (1978), and Goertz (1964). The present study revealed a significant difference between first year (pre-fire) and second year total capture rates ($p < 0.05$).

An earlier study by Johnson (1968) in the same section 0.5 km northwest of the present site R, examined the effect of burning on small mammal populations and indicated that some small mammal species such as deer mice (Peromyscus maniculatus) and harvest mice (Reithrodontomys megalotis) survived the fire and were captured on the burned area three days following the fire. Species dependent on vegetative cover for runways and nests, as well as for food (Microtus and Sigmodon), were either absent immediately after the fire or present in greatly reduced numbers. Post-fire trapping data for the remaining trapping sessions (the second year) of the present study tend to agree with Johnson's (1968) observations to determine the recolonization rate of the area by Microtus and Sigmodon.

Baker (1940) concluded that fire seriously affects small rodent populations and based his conclusion on 20 post-fire captures per 1000 trap nights compared with 140 per 1000 trap nights on the same site before the fire. Howard et al (1959) observed that many small rodents are able to survive grassland burning. The alteration in habitat may cause a shift in population centers of activity, with a negative effect on population density. They also found that the immediate effect of fire on small mammals depended largely on the animal's ability to find refuge. Although instances have been reported where animals panic and run directly into the flames (Tevis, 1956), most animals apparently move ahead of the fire. Some, such as Sigmodon, seek refuge in burrows (Komarek, 1969). Spencer (per. comm.) noticed rodents emerging from burrows in the burned area shortly after the fire studied by Johnson (1968).

Peripheral trapping in the unburned grass one week after the April, 1983, fire resulted in no captures of any rodent species. Cook (1959) found that Microtus movement into a burned area seemed restricted largely by reduction in cover and their subsequent vulnerability to predation. Ryback (1976) agreed with Beck and Vogl (1972) who suggested that small mammal response to fire is not a direct response to fire as such, but rather a reaction to vegetation change in the habitat relative to structure, food, and microhabitat. The lack of litter for cover resulting from grassland burning severely limits burned prairie as rodent habitat (Gaines et al, 1979). Birney et al (1976) reported the necessity of a threshold level of vegetative cover for normal Microtus population behavior. Therefore, destruction of litter on site R was probably in part responsible for the low, post-fire Microtus density. As annual vegetation regrowth supplies a source for litter accumulation, Microtus and Sigmodon population densities should return eventually to pre-fire levels.

Conclusion

Whether roadside ditches serve as winter refugia for small rodent populations appears to remain equivocal. Certainly, the present data showed that the relatively constant ditch vegetation compared to the manipulated cover on adjacent agricultural areas was found to be preferred by the combined populations of Microtus and Sigmodon in the winter (Figure 4). However, only Microtus in the rangeland ditches showed a several-fold higher population level in the winter than both fall and spring. It is probable that the exceptionally low recapture rates observed may have contributed to the inability to find similar results in the other ditch sites. That a moderate number of animals initially trapped, marked, and released inside the study site fences were later captured in the late fall or winter supports this contention. Unfortunately, the exceptionally low recapture rate precluded statistical validation of these results. Further support for the contention was suggested by the finding that the majority of the overwintering marked animals had been captured originally in the ditches in the fall, and was subsequently recaptured in the ditches in the spring. This implies that animals from adjacent, outlying areas may move into the ditches with the onset of cold weather. Yet, strong evidence of the apparent manner of runway utilization by Microtus and Sigmodon, such as networks of ditch runways connecting with passages widely diverging from the fence line into cover-poor adjoining land, suggests that ditches are used by rodents as year-round rather than seasonal habitat. This agrees with a similar finding of Fleharty and Navo (1983).

Seasonally related alteration in cover density such as occurs on agricultural land (including grazing land) has a pronounced negative effect on small mammal population density, according to Navo and Fleharty (1983). They reported significantly fewer species on cropland than on native, ungrazed rangeland. Neither Sigmodon nor Microtus were among species captured on tilled land in their study of cropland small mammal diversity. Both species, however, were captured in significant numbers on native grass. Fleharty and Navo (1983) pointed out that even in areas of extensive cultivation, small areas of essentially native habitat such as roadside ditches persist where small mammals can survive.

Since Sigmodon-Microtus preferred cover consists largely of litter and dense vegetation, conditions not usually found on tilled land, and only marginally on heavily grazed pasture, neither Sigmodon nor Microtus are likely to be found in significant numbers where vegetative cover is either marginal (over-grazed pasture) or subject to sharp seasonal alteration (cropland). This seems to support the second hypothesis that vegetative cover of both ditch and adjacent land determines the extent to which ditches are utilized by small mammals, specifically, Microtus and Sigmodon.

A possibility of separate populations (both Microtus and Sigmodon) inhabiting the similar vegetative cover of R fence and R ditch with little apparent intersite contact was mentioned earlier. Existence of such parallel populations in close proximity needs to be examined, along with a more complete investigation of seasonal ditch use by small mammal species in addition to Microtus and Sigmodon. Future research in these areas should be designed to focus on trapping regimes, including numbers, types, and placement of traps. Probably more complete data would be realized from concurrent monthly trapping sessions over a multiple-year study period on ditch and adjoining lands, with additional two-trap stations positioned to insure adequate sampling of each site. Furthermore, findings from two or more "sets" of study sites would tend to lessen distortion of data due to such factors as population fluctuations, climate effect, and vegetative cover differential.

## SUMMARY

1. Vegetative cover apparently determined the extent of utilization of roadside ditches adjacent to a pasture, field or rangeland. Rodent population density of Microtus and Sigmodon appeared to be directly dependent upon the degree and character of vegetative growth, regardless of ditch type.
2. Social interaction of the dominant rodent species reflected the influence of weather conditions on vegetative growth as well as the effectiveness as cover of locally occurring vegetation types.
3. Vegetative cover in roadside ditches remained relatively constant during the two year study, while seasonal cover change on adjacent lands was reflected in lower rodent population densities. As spring growth increased on those agricultural areas, the number of animals trapped inside the fences increased, although not significantly.
4. Where ditch cover appeared to be constantly similar to that on adjoining land, rodent populations were apparently established on each side of the fence. Travel between ditch and adjacent agricultural areas where vegetative cover exhibited some homogeneity was statistically less significant than travel between ditch and adjoining land where the agricultural treatment created a cover differential. In these areas, évidence suggested that roadside ditches, rather than acting as winter refugia, may indeed represent primary year-round habitat with adjacent land serving as forage and dispersal areas for the ditch populations. Evidence of cross-fence runway usage (i.e. forage and dispersal routes onto adjacent land where the agricultural treatment has rendered cover less desirable for rodents than that of the associated ditch) appears to support the present author's

hypothesis that vegetative cover of both ditch and adjoining land determines the extent to which the ditches are utilized.

5. The question as to whether roadside ditches, because of their relatively constant year-round vegetative cover, serve as winter refugia to rodent populations from adjacent agriculturally utilized land appears to be answered negatively. However, some qualification seems allowable. Animals initially trapped, marked, and released inside the fences were later recaptured, in late fall or winter, in the ditches but at a rate too low to quantify statistically. This suggests that under some conditions rodents from the outlying areas may move into the ditches with the onset of cold weather.

# LITERATURE CITED

## LITERATURE CITED


Abramsky, A., N.I. Dyer, and P.D. Harrison. 1979. Competition among small mammals in experimentally perturbed areas of the shortgrass prairie. Ecology 60:530-536.

Baker, R.H. 1940. Effects of burning and grazing on rodent populations. J. Mamm. 22:223.

________. 1969. Cotton rats of the Sigmodon fulviventor group. Misc. Publ. Mus. Nat. Hist. University of Kansas. 51:177-232.

Baker, J.A. and R.J. Brooks. 1982. Impact of raptor predation on a declining vole popualtion. J. Mamm. 63:297-300.

Barbehenn, K.R. 1958. Spatial and population relationships between Microtus and Blarina. Ecology. 39:293-304.

Beck, A. and R. Vogl. 1972. The effects of spring burning on rodent populations in a brush prairie savanna. J. Mamm. 53:336-346.

Birney, E.C., W.E. Grant, and D.D. Baird. 1976. Importance of vegetative cover to cycles of Microtus populations. Ecology. 57:1043-1051.

Boonstra, R. and C.J. Krebs. 1979. Viability of large and small-sized adults in fluctuating vole populations. Ecology. 60:567-573.

Borgens, R.B. 1982. Mice regrow the tips of their foretoes. Science. 217:747-750.

Carroll, Diane and L.L. Getz. 1976. Runway use and population density in Microtus ochrogaster. J. Mamm. 57:772-776.

Chitty, D. 1960. Population processes in the vole and their relevance to general theory. Can. J. Zool. 38:99-113.

Clayton, Kenneth. 1952. Some phases of the winter ecology of some small mammals in a bluestem, bluegrass meadow of Lyon County, Kansas. Unpubl. MS thesis, Emporia State University. 157 pp.

Cockrum, E.L. 1948. Distribution of the hispid cotton rat in Kansas. Trans. Kansas Acad. Sci. 51:306-312.

Cole, F.R. 1978. A movement barrier useful in population studies of small mammals. Am. Mid. Nat. 100:480-482.

________, and G. Batzli. 1978. Influence of supplemental feeding on vole populations. J. Mamm. 59:809-819.

Cook, C.W. (ed.). 1962. Basic problems and techniques in range research. National Academy of Sciences, National Research Council, Washington, DC. 342 pp.

Cook, S.F., Jr. 1959. The effects of fire on a population of small rodents. Ecology. 40:102-108.

DeBlase, A.F. and R.E. Martin, 1981. A Manual of Mammalogy. Wm. C. Brown Co. Dubuque. 436 pp.

Dice, L.R. 1952. Measure of the spacing between individuals within a population. Cont. Lab. Verb. Bio. 55:1-23.

Dunaway, P.B. and S.V. Kaye. 1961. Cotton rat mortality during a severe winter. J. Mamm. 42:265-268.

Eadie, W.R. 1953. Response of Microtus to vegetative cover. J. Mamm. 34:263-264.

Errington, P. 1946. Predation and vertebrate populations. Quart. Rev. Biol. 21:144-147.

Fitch, H.S. 1950. A new style live trap for small mammals. J. Mamm. 31:364-365.

Fitzgerald, V.J. 1983. Observations of runway construction by cotton rats (Sigmodon hispidus). Georgia J. Sci. 41:79-82.

Fleharty, E.D., J.R. Choate, and M.A. Mares. 1972. Fluctuations in population density of the hispid cotton rat: factors influencing a crash. Bull. Southern Calif. Acad. Sci. 71:132-138.

______________, and M.A. Mares. 1972. Habitat preference and spatial relations of Sigmodon hispidus on a remnant prairie in west-central Kansas. Southwestern Naturalist. 18:21-29.

______________, and K.W. Navo. 1983. Irrigated cornfields as habitat for small mammals in the sandsage prairie region of western Kansas. J. Mamm. 64:367-379.

______________, and L.E. Olson. 1969. Summer food habits of Microtus ochrogaster and Sigmodon hispidus. J. Mamm. 50:475-486.

Frydendall, M.J. 1969. Rodent populations of four habitats in central Kansas. Trans. Kansas Acad. Sci. 72:213-222.

Gaines, M.S. and L.R. McClenaghan. 1980. Dispersal in small mammals. In: Annual Review of Ecology and Systematics. 11:163-196.

____________ and R. Rose. 1976. Population dynamics of Microtus ochrogaster in eastern Kansas. Ecology. 57:1147-1161.

____________, A.M. Vivas, and C.L. Baker. 1979. An experimental analysis of dispersal in fluctuating vole populations: demographic parameters. Ecology. 60:814-828.

Gentry, J.B. and E. Odum. 1957. The effect of weather on the winter activity of old-field rodents. J. Mamm. 38:72-77.

Getz, L.L. 1970. Habitat of the meadow vole during a population low. Am. Midl. Nat. 83:455-461.

_________. 1978. Speculation on social structure of population cycles of Microtine rodents. The Biologist. 60:134-137.

_________, F.R. Cole, and D.L. Gates. 1978. Interstate roadsides as dispersal routes for Microtus pennsylvanicus. J. Mamm. 59:208-212.

Glass, G.E. and N.A. Slade. 1978. The effect of Sigmodon hispidus on spatial and temporal activity of Microtus ochrogaster: evidence for competition. Ecology. 61:358-370.

_________. 1980. Population structure as a predictor of spatial association between Sigmodon hispidus and Microtus ochrogaster. J. Mamm. 61:473-585.

Goertz, J.W. 1964. The influence of habitat quality upon density of cotton rat populations. Ecological Monographs. 34:359-381.

Grant, P.R. 1971. The habitat preference of Microtus pennsylvanicus and its relevance to the distribution of this species on islands. J. Mamm. 52:351-361.

_________. 1975. Population performance of Microtus pennsylvanicus comfined to woodland habitat and a model of habitat occupancy. Can. J. Zool. 53:1447-1465.

Hall, E.R. 1981. The Mammals of North America. Vol. II. John Wiley and Sons. New York.

Hayne, Don. 1949. Calculation of home range size. J. Mamm. 30:1-18.

Hilborn, Ray and C.J. Krebs. 1976. Fates of disappearing individuals in fluctuating populations of Microtus townsendii. Can. J. Zool. 54:1507-1518.

Howard, W.E., R.L. Fenner, and H.E. Childs. 1959. Wildlife survival on bush burns. J. Range. Manag. 12:230-234.

Johnson, J.G. 1968. The effects of burning on some small mammal populations at the Ross Natural History Reservation, Lyon County, Kansas. Unpubl. MS project report, Emporia State Univ. 29 pp.

Johnson, M.K. 1982. Response of small mammals to livestock grazing in south central Idaho. J. Range. Manag. 35:51-53.

Kaufman, D.W. and E.D. Fleharty. 1974. Habitat selection by nine species of rodents in north central Kansas. Southwestern Nat. 18:433-452.

Kincaid, W.B., G.N. Cameron, and B.A. Carnes. 1983. Patterns of habitat utilization in sympatric rodents on the Texas coastal prairie. Ecology. 64:1471-1480.

Komarek, E.V. 1969. Fire and animal behavior. Tall Timbers Fire Ecology Conf. 9:161-207.

Kozel, R.M. and E.D. Fleharty. 1979. Movements of rodents across roads. Southwestern Nat. 24:239-248.

Krebs, C.J. 1966. Demographic changes in fluctuating populations of Microtus californicus. Ecol. Monogr. 36:239-273.

_________. 1970. Microtus population biology: behavioral changes associated with the population cycle in Microtus ochrogaster and Microtus pennsylvanicus. Ecology. 51:34-52.

_________, B. Keller, R. Tamarin. 1969. Microtus population biology: demographic changes in fluctuating populations of Microtus ochrogaster and Microtus pennsylvanicus in southern Indiana. Ecology. 50:587-607.

_________, M. Gaines, B. Keller, J. Myers, R. Tamarin. 1973. Population cycles in small rodents. Science. 179:35-41.

Lidicker, W.Z., Jr. and P.K. Anderson. 1962. Colonization of an island by Microtus californicus, analyzed on the basis of runway transects. J. Anim. Ecol. 31:503-517.

Martin, E.P. 1956. A population study of the prairie vole (Microtus ochrogaster) in northeastern Kansas. Univ. Kansas Publ., Mus. Nat. Hist. 8:361-416.

Mossman, A.S. 1955. Light penetration in relation to small mammal abundance. J. Mamm. 36:564-566.

Navo, K.W. and E.D. Fleharty. 1983. Small mammals of winter wheat and grain sorghum cropland in west-central Kansas. Prairie Nat. 15: 159-172.

Pearson, O.P. 1969. Habits of Microtus californicus revealed by automatic photographic recorders. Ecol. Monogr. 30:231-249.

Phillips, Paul. 1936. The distribution of rodents in overgrazed and normal grasslands of central Oklahoma. Ecology. 17:673-679.

Phillips, M.O. 1954. A study of small mammals in areas adjacent to Garden City, Kansas. Unpubl. MS thesis, Emporia State Univ. 93 pp.

Prochaska, M. and N. Slade. 1979. The effect of Sigmodon hispidus on summer diel activity patterns of Microtus ochrogaster in Kansas. Transactions Kansas Academy Science. 84:134-138.

Randall, Jan. 1978. Behavioral mechanisms of habitat segregation between sympatric species of Microtus: habitat preference and interspecific dominance. Behav. Ecol. and Sociobiol. 3:187-202.

Rose, R.K. and A. Spevak. 1978. Aggressive behavior in two sympatric microtine rodents. J. Mamm. 59:213-216.

Ryback, Elaine. 1976. The effects of fire on mammal populations. Abstract, Zoological seminar, Michigan State University.

Sidorowicz, J. 1960. Influence of the weather on capture of micromammalia. I. Rodents. Acta Theriologica. 4:139-158.

Soil Survey of Lyon County, Kansas. U.S. Dept. Agriculture. 1981. 70 pp.

Spencer. D.L. 1980. Ross Natural History Reservation, The First Twenty Years, 1959-1979. Emporia State University. 64 pp.

Tamarin, R.H. 1978. Dispersal, population regulation and K selection in field mice. Amer. Nat. 112:545-555.

Terman, M.R. 1973. Interactions between sympatric Microtus and Sigmodon (Rodentia: Cricetidae). Unpubl. Ph.D. dissertation, Michigan State University. East Lansing. 98 pp.

__________. 1974. Behavioral interaction between Microtus and Sigmodon: a model for competitive exclusion. J. Mamm. 55:705-719.

__________. 1978. Population dynamics of Microtus and Sigmodon in central Kansas. Trans. Kans. Acad. Sci. 81:337-351.

__________ and D.I. Johnson. 1971. The effects of Sigmodon hispidus on Microtus pennsylvanicus in a confined area. Trans. Kansas. Acad. Sci. 74:217-220.

Tevis, L., Jr. 1956. Effect of slash burn on forest mice. J. Wildlife Manag. 20:405-409.

Vickery, W.L. and J.R. Bider. 1981. The influence of weather on rodent activity. J. Mamm. 62:140-145.

Weigert, R.G. 1972. Population dynamics of cotton rats (Sigmodon hispidus) and meadow voles (Microtus pennsylvanicus) in field enclosures in South Carolina. Georgia Acad. Sci. Bull. 30:103-110.

__________ and J.C. Mayenschein. 1966. Distribution and trap response to a small wild population of cotton rats (Sigmodon hispidus). 47:118-120.

Yahner, R.H. 1982. Microhabitat use by small mammals in farmstead shelterbelts. J. Mamm. 63:440-445.

APPENDIX A

Table 1. Time interval between earliest and latest captures of Ditch P *Microtus* and *Sigmodon*.

| Animal: Age Class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| S | M | 0001 | S | X*------- | ---------- | -------X | No trap set in ditch | | |
| S | F | 0002 | S | X-------- | -X* | | | | |
| S | M | 0003 | S | X-------- | -X | | | | |
| A | F | 0004 | S | X** | | | | | |
| S | M | 0005 | S | X | | | | | |
| S | F | 0006 | S | X | | | | | |
| S | F | 0007 | S | X**------ | -X | | | | |
| J | F | 0008 | S | X* | | | | | |
| S | F | 0009 | S | X-------- | -X | | | | |
| S | F | 0010 | S | X | | | | | |
| S | M | 0011 | S | X-------- | -X* | | | | |
| S | M | 0012 | S | X-------- | -X--------- | -X | | | |
| J | M | 0013 | S | X | | | | | |
| A | F | 0001 | M | X | | | | | |
| A | M | 0002 | M | | X* | | | | |
| S | F | 0014 | S | | X | | | | |
| S | M | 0015 | S | | X* | | | | |
| A | F | 0003 | M | | X | | | | |
| A | F | 0004 | M | | X | | | | |
| A | M | 0005 | M | | | X | | | |

Table 1. (Continued)

| Animal: Age Class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| A | F | 0006 | M | | | X | | | |
| A | F | 0007 | M | | | X | | | |
| J | M | 0016 | S | | | | | X | |
| A | F | 0008 | M | | | | | X | |
| A | F | 0009 | M | | | | | X | |
| J | M | 0017 | S | | | | | X | |
| S | M | 0018 | S | | | | | X | |
| J | F | 0019 | S | | | | | X | |
| S | F | 0020 | S | | | | | X | |
| S | F | 0021 | S | | | | | X | |
| J | F | 0022 | S | | | | | X | |
| J | F | 0023 | S | | | | | X | |
| J | M | 0024 | S | | | | | X | |
| A | F | 0006+ | S | | | | | | X |
| A | M | 0010 | M | | | | | | X |
| A | M | 0011 | M | | | | | | X |
| A | M | 0012 | M | | | | | | X |

Age: S = subadult, A = adult, J = juvenile
* = Recapture
Species: S = Sigmodon, M = Microtus
+ mismarked, earmarked

Table 2. Time interval between earliest and latest captures of site P in-fence *Microtus* and *Sigmodon*.

| Animal: Age class | Sex | Number | Species | Winter, 82 ditch | Spring, 83 | Fall, 83 | Winter, 83-84 | Spring, 84 |
|---|---|---|---|---|---|---|---|---|
| A | F | 0012 | S | #------------ | X | X** | No traps set in-fence | |
| A | F | 0001 | M | | X------------ | X**------ | #(initially in ditch)-------- | X |
| J | F | 0001 | S | | X------------ | X | | |
| A | F | 0002 | M | | | X | | |
| Z | M | 0003 | M | | | X*** | | |
| J | M | 0004 | M | | | X | | |
| A | F | 0005 | M | | | X | | |
| S | M | 0006 | M | | | X | | |
| S | M | 0007 | M | | | X | | |
| A | F | 0008 | M | | | X-------- | #(initially in ditch)-------- | X |
| S | F | 0009 | M | | | X | | |
| A | F | 0010 | M | | | X | | |
| S | F | 0012 | M | | | X | | |
| A | F | 0013 | M | | | X | | |
| A | M | 0014 | M | | | X | | |
| A | M | 0015 | M | | | | | X |
| A | M | 0016 | M | | | | | X |

Table 2. (Continued)

| Animal: Age class | Sex | Number | Species | Winter, 82 ditch | Spring, 83 | Fall, 83 | Winter, 83-84 | Spring, 84 |
|---|---|---|---|---|---|---|---|---|
| A | M | 0017 | M | | | | | X |

# = Caught previously in adjacent area
* = Recaptures
Age class: S = subadult, A = adult, J = juvenile
Species: S = Sigmodon, M = Microtus

Table 3. Time interval between earliest and latest captures of Ditch F *Microtus* and *Sigmodon*.

| Animal: Age class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| S | M | 0001 | S | X | | | No trap set in ditch | | |
| J | F | 0002 | S | X-------- | X | | | | |
| S | M | 0003 | S | X | | | | | |
| A | F | 0004 | S | X | | | | | |
| S | M | 0005 | S | X | | | | | |
| J | F | 0006 | S | X | | | | | |
| A | M | 0007 | S | X | | | | | |
| A | M | 0001 | M | X | | | | | |
| J | F | 0008 | S | X | | | | | |
| S | F | 0009 | S | X-------- | X | | | | |
| A | F | 0002 | M | X | | | | | |
| S | F | 0010 | S | | X | | | | |
| A | F | 0003 | M | | X | | | | |
| A | M | 0004 | M | | X | | | | |
| S | F | 0011 | S | | X | | | | |
| A | F | 0005 | M | | X | | | | |
| A | M | 0006 | M | | X | | | | |
| A | F | 0007 | M | | X | | | | |
| A | F | 0008 | M | | X | | | | |
| A | F | 0009 | M | | X | | | | |

Table 3. (Continued)

| Animal: Age class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| A | F | 0010 | M | | | X | | | |
| A | F | 0011 | M | | | | | | X |
| A | M | 0012 | M | | | | | | X |

Age: S = subadult, A = adult, J = juvenile
* = Recapture
Species: S = Sigmodon, M = Microtus

Table 4. Time interval between earliest and latest captures of site F in-fence *Microtus* and *Sigmodon*.

| Animal: Age class | Sex | Number | Species | Winter, 82 ditch | Spring, 83 | Fall, 83 | Winter, 83-84 | Spring, 84 |
|---|---|---|---|---|---|---|---|---|
| A | F | 0001 | S | | | X | | |
| A | M | 0003 | M | | | X------------- | ------------- | -------------X |
| S | M | 0003 | S | | | X | | |
| S | M | 0004 | S | | | X | | |
| J | M | 0005 | S | | | X | | |
| J | M | 0006 | S | | | X | | |
| J | M | 0007 | S | | | X | | |
| S | F | 0008 | S | | | X | | |
| J | F | 0009 | S | | | X | | |
| J | M | 0010 | S | | | X | | |
| J | F | 0012 | S | | | X | | |
| A | F | 0013 | S | | | X | | |
| J | M | 0014 | S | | | X | | |
| J | M | 0015 | S | | | X | | |
| A | M | 0016 | S | | | X | | |
| S | F | 0017 | S | | | X | | |
| J | F | 0018 | S | | | X | | |
| A | M | 0002 | M | | | | | X |

Age class: S = subadult, A = adult, J = juvenile
Species: S = *Sigmodon*, M = *Microtus*

Table 5. Time interval between earliest and latest captures of Ditch R _Microtus_ and _Sigmodon_.

| Animal: Age class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| S | F | 0001 | S | X | | | No trap set in ditch | | |
| A | F | 0001 | M | X-------- | X---------- | X | | | |
| A | M | 0002 | S | X | | | | | |
| S | F | 0003 | S | X | | | | | |
| S | M | 0004 | S | X | | | | | |
| A | M | 0005 | S | X | | | | | |
| A | F | 0002 | M | X*------- | X***-------- | X | | | |
| A | F | 0003 | M | X | | | | | |
| S | F | 0006 | S | | X* | | | | |
| S | M | 0007 | S | | X* | | | | |
| A | F | 0004 | M | | X** | | | | |
| A | M | 0005 | M | | X | | | | |
| S | M | 0008 | S | | X | | | | |
| A | M | 0006 | M | | X | | | | |
| A | M | 0007 | M | | X | | | | |
| A | F | 0008 | M | | X | | | | |
| S | M | 0009 | S | | X | | | | |
| A | M | 0009 | M | | X | | | | |
| A | M | 0010 | M | | X---------- | ---------- | ---------- | X---------- | X |
| A | M | 0011 | M | | | X-------- | -------- | X | |

Table 5. (Continued)

| Animal: Age class | Sex | Number | Species | Fall 1982 | Winter 82-83 | Spring 1983 | Fall 1983 | Winter 83-84 | Spring 1984 |
|---|---|---|---|---|---|---|---|---|---|
| S | F | 0012 | M | | | | | X | |
| S | M | 0013 | M | | | | | | X |
| J | F | 0014 | M | | | | | | X |
| A | F | 0015 | M | | | | | | X |

Age: S = subadult, A = adult, J = juvenile
* = Recapture
Species: S = Sigmodon, M = Microtus

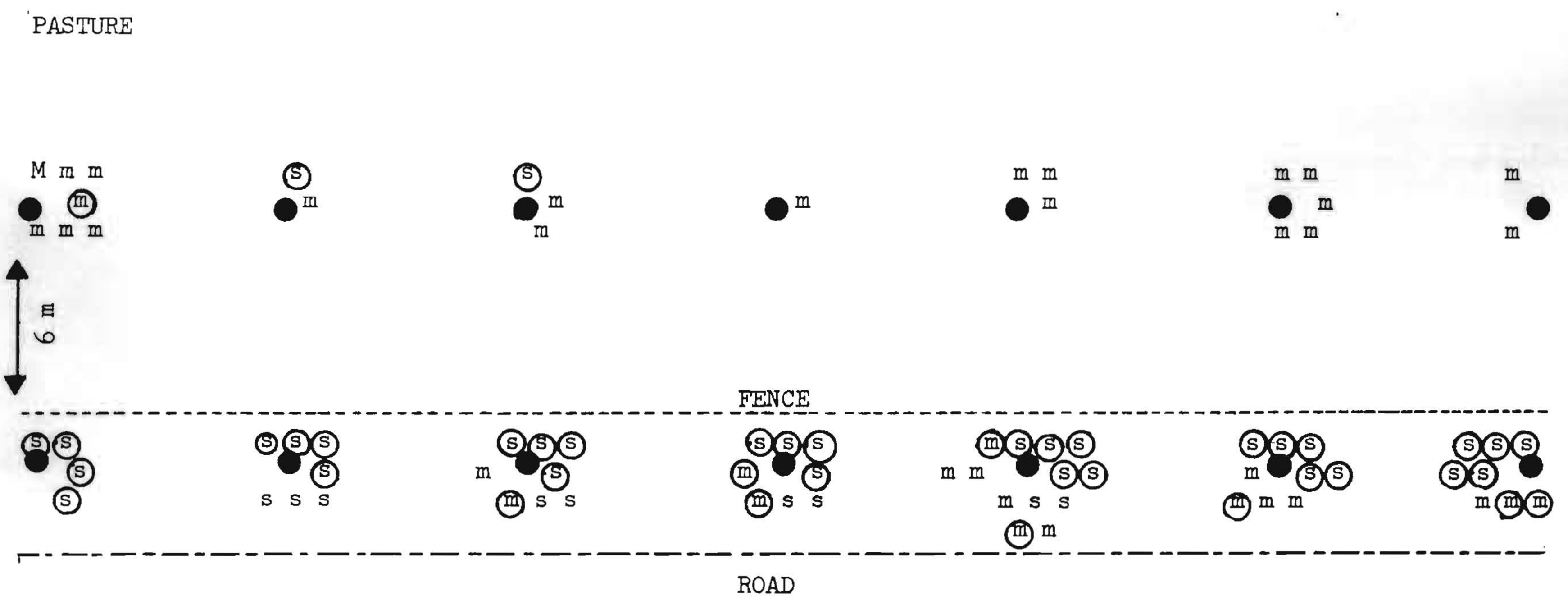
Table 6. Time interval between earliest and latest captures of site R in-fence <u>Microtus</u> and <u>Sigmodon</u>.

| Animal: Age class | Sex | Number | Species | Winter, 82 ditch | Spring, 83 | Fall, 83 | Winter, 83-84 | Spring, 84 |
|---|---|---|---|---|---|---|---|---|
| J | F | 0002 | M | | X | | | |
| J | F | 0003 | M | | | X | | |
| A | M | 0004 | M | | | X | | |
| A | F | 0005 | M | | | X | | |
| A | F | 0015 | M | | | | #(in ditch initially)------ | X* |
| S | M | 0006 | M | | | | | X |

Age class: S = subadult, A = adult, J = juvenile
Species: S = <u>Sigmodon</u>, M = <u>Microtus</u>
# = Caught previously in adjacent area

# APPENDIX B

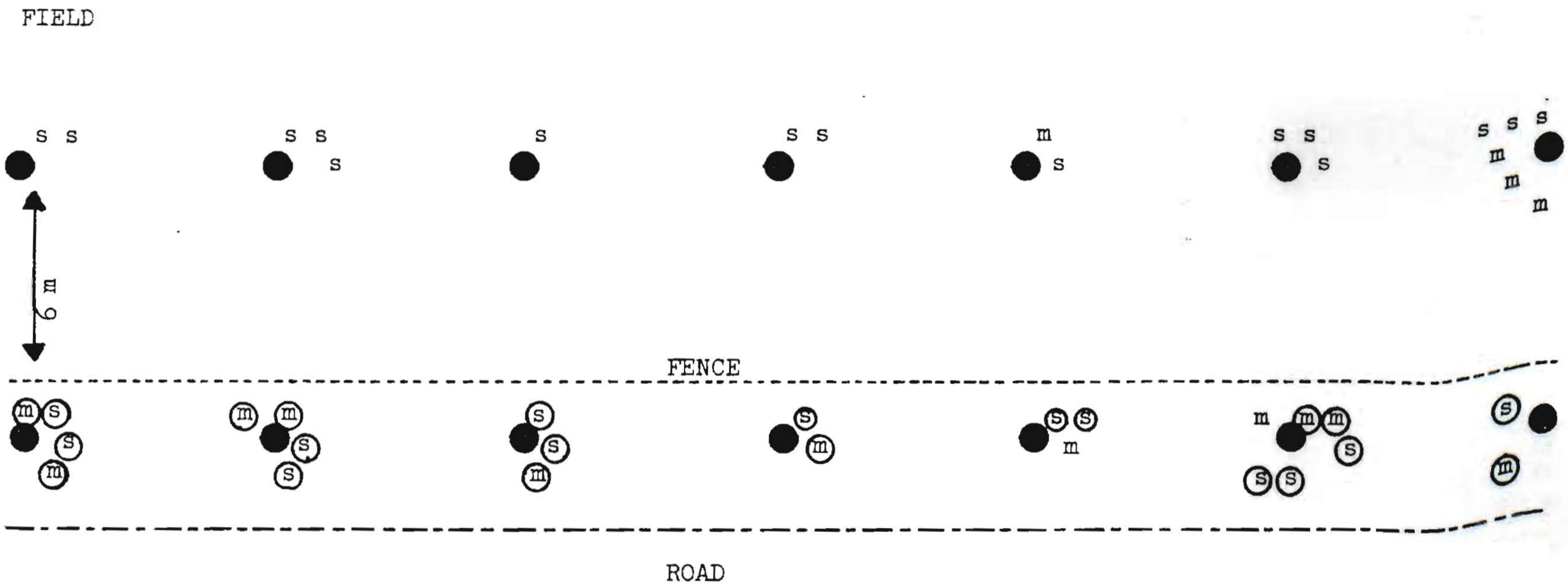
Figure 1. Location of all captures of *Microtus* (m) and *Sigmodon* (s) for Site P (Pasture) for entire two year study period.




Sigmodon (s) = year 1; s = year 2

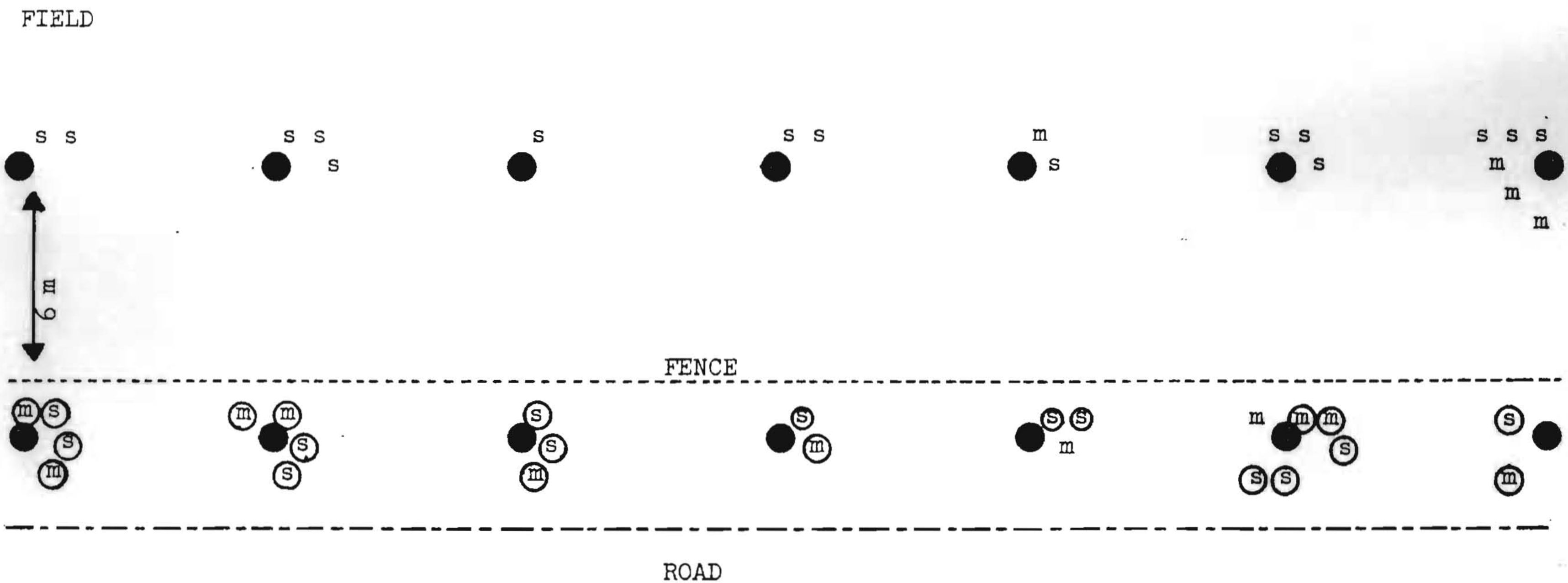
Microtus (m) = year 1; m = year 2

Figure 2. Location of all captures of *Microtus* (m) and *Sigmodon* (s) for Site F (Field) for entire two year study period.




Sigmodon (s) = year 1;  s = year 2

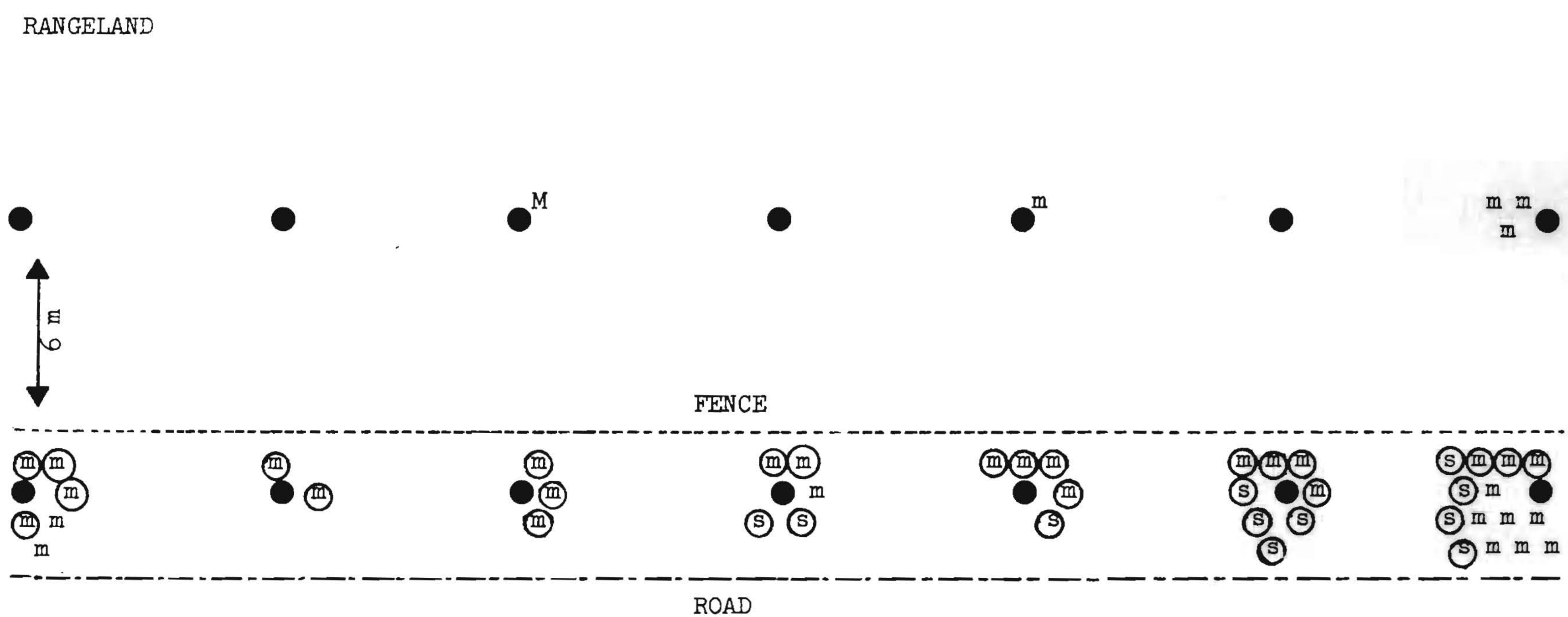
Microtus (m) = year 1;  m = year 2




Sigmodon Ⓢ = year 1; s = year 2

Microtus Ⓜ = year 1; m = year 2

Figure 3. Location of all captures of *Microtus* (m) and *Sigmodon* (s) for Site R (Rangeland) for entire two year study period.




*Sigmodon* (s) = 1 year; s = year 2

*Microtus* (m) = 1 year; m = year 2