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16. Abstract

Abstract

Many species of wildlife occur along roads. Most rodents spend their entire lives within the rights-of-way (ROWs); larger species are transients which feed within ROWs. Mowing affects abundance of rodents. Species preferring denser cover were more plentiful in unmowed ROWs than in mowed ROWs. Species preferring sparse cover were more abundant in mowed ROWs than in unmowed ROWs. Rodent diversity was greater in less-disturbed habitats (old fields). The types of vegetation occurring in an area influence rodent diversity and abundance.

Less than one percent of the rodent community living within ROWs died on the highways. Relative impact of highway mortality on populations of larger animals is probably greater than on rodents, but is probably still negligible. Number of fatalities decreased as traffic volume increased.

Fewer than 6 percent of the marked rodents crossed roadways under normal conditions. Immediately following mowing greater proportions of populations crossed pavements. Because of this migration, highways do not constitute barriers to gene flow between animal populations on opposite sides of the facility.

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COMPOSITION OF SMALL MAMMAL POPULATIONS ON HIGHWAY RIGHTS-OF-WAY IN EAST TEXAS

by

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

Little is known concerning the effects of highways on small mammals and other wildlife species. To define this relationship, three pairs of mark-recapture grids (one of each pair mowed, the other unmowed) were established along three eastern Texas highways having different traffic volumes and patterns.

Populations dynamics of rodents occurring within unmowed and mowed highway rights-of-way and in adjacent old fields, pastures, and cultivated fields were studied for one annual cycle, and the effects of land management practices (especially mowing) on rodents were examined. Rodent densities and diversities were directly related to plant diversity and amount of cover characterizing each habitat. The fewest rodent species and least species abundance occurred in the cultivated fields (the most highly impacted habitat). The least disturbed habitat (old fields) supported the greatest amount of cover and the most diverse plant and rodent communities. Rodent densities were greatest in the unmowed ROWs where cover was nearly as dense as in the old fields. Before mowing, cover and rodent densities in the unmowed and mowed ROWs were similar. After mowing, cover in the mowed ROWs was significantly less than in the unmowed ROWs. Population densities of cotton rats in the mowed ROWs were not significantly affected by mowing.

Movements of marked rodents across pavements were followed. The effectiveness of highways as barriers to dispersal of wildlife populations is discussed. At least 5 percent of the cotton rat populations and 2 percent of the pygmy mouse populations crossed roads. Most cotton rat crossings (63 percent) were movements across one lane of pavement, although crossings of two, three, and four lanes occurred. Nearly equal numbers of males and females dispersed across pavements, although their seasonal crossing patterns were asynchronous. Seventy percent of the cotton rats traversing roads were adults; another 29 percent were subadults. Due to migration of individuals across roadways, highways probably do not inhibit gene flow.

The impact of highway mortality on wildlife populations was assessed. Animal carcasses found along regularly surveyed stretches of these highways were counted. A total of 286 carcasses was observed within the 1,768 km (1,105 mi.) of highway surveyed. Mammals comprised 65 percent of the casualties; birds and herptiles (reptiles and amphibians) each comprised approximately 17 percent. More mammals and herptiles were killed during spring than during other seasons; birds were most susceptible during summer. The relationship between highway mortality and traffic volume suggests that susceptibility is greatest at the intermediate traffic volume, least at the highest volume, and intermediate at the lowest volume. Less than 1 percent of the rodent community died on roadways.

IMPLEMENTATION

Trends in intensive agricultural and industrial land use are accelerating, and suitable wildlife habitat is rapidly being destroyed. Man's progress is jeopardizing the survival of many species, and is in some way influencing the well-being of most other species. Numerous refugia have been established by both public and private concerns to preserve a natural habitat and perpetuate our wildlife species. Federal and state governments have established parks and wilderness areas within which all wildlife is protected. Privately-endowed foundations in many states have taken similar steps towards protecting these resources.

With millions of acres of vegetated ROWs at their disposal, highway department have an opportunity to aid in perpetuation of our wildlife heritage. In the near future, roadsides could constitute virtually the only other habitat available for wildlife in some parts of the United States. Mowing of vegetation within ROWs is a form of land management which, if approached properly, can benefit wildlife and, at the same time, possibly reduce roadside maintenance costs. In this study, changes in plant diveristy and amount of cover within ROWs were found to influence diversity and abundance of small mammals therein.

Rodent densities were generally greater in the more densely covered ROWs. Hence, reducing the frequency of mowing from two or three times per season to once or twice per season should result in larger populations of rodent species which prefer more densely covered habitat. Another way to benefit wildlife is to abandon the policy of full-width mowing in favor of strip-mowing. Full-width mowing every third or fourth year should be sufficient to prevent woody vegetation from encroaching upon the ROWs. Although not directly evaluated during this study, the effects of strip-mowing on wildlife populations appear to be negligible. Opportunity for observation of these effects resulted from accidental cutting of strips of vegetation in two sections of an otherwise unmowed study grid. Fluctuations of small mammal population densities in these grid sections corresponded to those in other unmowed sections of ROWs which were not strip-mowed.

Other practices (based on habitat preferences of wildlife species) can be adopted to control the species occurring in a given area. Selective seeding of areas along new or reworked roadways can promote establishment of habitat which is favorable to one species but not to another. For example, consider cotton rats and pygmy mice, two species sampled in this study and found to have different preferences (see Table 5). Cotton rats strongly preferred areas covered by Johnsongrass and Bermudagrass; pygmy mice densities were negatively correlated with these grasses. Forbs were important cover plants for pygmy mice but not for cotton rats. By seeding sections of ROWs to establish preferred habitat, ROWs could even be used as field laboratories for studying rare species. Larger species (deer) can probably be discouraged from utilizing ROWs as feeding areas by planting vegetation which is not palatable to these animals. Since bare ground surfaces must be seeded anyway, choosing one seed type over another should not substantially affect landscaping costs. In fact, seeding roadsides with grasses (i.e.: low-growing native grasses) which naturally grow to limited heights will reduce necessity of frequent mowing and subsequently decrease maintenance costs.

Establishing more suitable habitat along roads should result in increased populations of rodents. In turn, this will probably attract predators (raccoons, foxes, skunks, etc.) to the roadside in greater numbers. Numbers of animal-vehicle encounters might then increase; however, the impact of increased highway mortality on wildlife will probably still be insignificant. A five-fold increase in rodent highway mortality would extirpate less than 5 percent of the total rodent community--still a seemingly negligible figure. As relatively few motorist injuries occur in collisions with smaller animals, it seems doubtful that motorist safety would be jeopardized by instituting such programs to benefit wildlife.

Most of the above statements and recommendations are rather general in nature, and to implement many of these concepts, additional study is needed. For example, it is not yet known what roadside seeding strategies (which species to seed, when to seed, etc.) should be pursued. The dates of mowing from which wildlife would reap optimal benefits are not precisely known. However, areas should be mowed only after young rodents, rabbits, and ground-nesting birds have left their nests and after plants have produced seeds. For eastern Texas, mowing in mid to late June is recommended. The height at which grass is cut is another point of uncertainty. Wildlife benefits from greater amounts of cover; maintenance programs are more economical when grass is cut as close to the surface as possible without promoting erosion. These positions must be carefully weighed and compromised such that benefits to both parties are maximized.

Stability of wildlife populations is dependent upon presence of vegetation which provides dense cover not subject to great artificial fluctuations. Stability in amount of cover along roadways can be achieved by reducing the frequency and intensity of mowing. Two recommendations for immediate implementation of study findings can be presented. First, mow any given section of ROW fewer times per year--perhaps only once. Second, adopt the strip-mowing program statewide. Mowing of a single strip adjacent to the pavements should allow sufficient visibility for motorists to note and avoid roadside hazards. Strip-mowing apparently does not adversely affect wildlife, since tall vegetation in which animals may live remains within the ROWs.

Careful planning of ROW maintenance programs with the above considerations in mind will simultaneously benefit wildlife and possibly permit more efficient application of highway maintenance budgets.

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INTRODUCTION

Highway roadsides have traditionally been one of mammalogists' favorite collecting sites. Habitats occurring within highway Rights-of-Way (ROWs) of any geographic region are frequently reminiscent of the once widespread native habitats characterizing that region. The diversity of vegetation and density of cover within highway ROWs are oftentimes greater than in contiguous grazing and farming lands. More diverse habitats generally support more diverse assemblages of wildlife.

In spite of the prevalence of collecting along highway ROWs, little is known of the effects of the construction, maintenance, and mere presence of highways on small mammals. The purpose of this study is to define the relationship between highway facilities and rodent communities occurring both within the ROWs and in adjacent pastures, old fields, and cultivated fields in eastern Texas. Specifically, the objectives of this study are:

(1) to determine if stable small mammal (rodent) communities exist along and in properties adjacent to highway ROWs in eastern Texas, and if so, to determine the species composition of these communities;

(2) to elucidate population dynamics of these species including seasonal variation in population densities, reproductive activities, and age class frequencies;

(3) to determine the effects of highway department maintenance practices (mowing) on the stability of these populations;

(4) to evaluate the effect of highway pavements on dispersal of animals;

(5) to determine identity and numbers of wildlife species killed on the road by vehicles, and estimate the effect of highway mortality on population size and stability.

Literature Review

The occurrence of animals along roadsides has been noted by numerous authors whose attention was attracted by the presence of dead animals along pavements. Numerous emotional accounts of birds struck by vehicles on the highways exist in the literature (e.g.: Cottam, 1931; Robertson, 1929; Spiker,1927). The number of woodpecker[1] carcasses sighted along Iowa highways was so great that Dill (1926) feared possible extermination of the species by the automobile. Davis (1940), Hodson (1966), and Stoner (1935) reported mammalian casualties observed along highways in Texas, England, and the midwestern United States, respectively. Game species, primarily deer, were the most frequent subjects of the major publications concerning highway mortality in mammals (Bellis and Graves, 1971a, b; Peek and Bellis, 1969; Reilly and Green, 1974). Few papers dealt exclusively with reptiles and amphibians (herptiles). The primary recognition accorded herptiles was among casuality lists of birds or mammals except for one note correlating nocturnal behavior of iguanid lizards with roadkill frequency (Mays and Nickerson, 1968).

Although living close to a highway is often dangerous for animals, the advantages apparently outweigh the disadvantages. Mankind is presently engaged in large-scale destruction of native habitat. In time, quite possibly, the only areas supporting stands of native vegetation (especially grasses) will be the unpaved segments of highway ROWs. Due to intensive land use practices, many species of wildlife are being displaced into the ROWs. For example, in Illinois the only habitat suitable for nesting pheasants is along highway ROWs where reduced mowing schedules were instituted (Joselyn, 1968).

In other situations, some species occur more abundantly within ROWs than in adjacent areas outside ROWs, not because the later is

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[1] Appendix A lists common and scientific names of animals.

unsuitable, but because the former is more attractive vegetationally and edaphically. Huey (1941) recognized that the easiest way to obtain a large series of southern pocket gophers in the California desert was to search for burrows within highway ROWs rather than in the desert away from the roadway. The attractiveness of the ROWs resulted from the presence of both more friable soil (a result of roadbuilding activities) and a dependable food supply in the form of more luxuriant vegetation (a result of abnormally moist soil conditions due to runoff of water from the pavement). Another example of favorable edaphic factors attracting large numbers of animals to roadsides was reported by Doucet et al. (1974) who noted that the texture of the substrate and good drainage of the slopes of overpass embankments in Canada were conducive to high densities of woodchucks.

Highways are an excellent source of food for predaceous, insectivorous, granivorous, and herbivorous species. Michael (1976) noted that grass-eating rodents (prairie voles), occurred in greater numbers within ROWs than outside of them. Granivorous birds and mammals benefit from the fruits of numerous seeding plants as well as grain which falls from passing feed trucks. Insectivorous species also benefit by an existence along highways since countless insects are drawn towards vehicle headlights and killed (Finnis, 1960). Flesh and carrion eaters (including coyotes, ground squirrels, skunks, opossums, raccoons, badgers, ringtails, weasels, owls, buzzards, and hawks) thrive on carcasses comprised primarily of individuals of the aforementioned categories (Bebb, 1937, 1935; Martin, 1935). Rainwater accumulated in shallow puddles constitutes a source of drinking water for many species (Finnis, 1960). Where rock salt is used for de-icing pavements, many animals (especially deer) frequent roadsides to obtain this essential material (Joselyn, 1969). Birds often bathe in dust which accumulates on or along roadways (Finnis, 1960). In order to maintain a constant body temperature, many reptiles lie on road pavements to absorb heat.

Ground squirrels have also been observed basking on sunwarmed pavements (Hawbecker, 1944).

Another function of highways is to offer avenues for dispersal of individuals and entire populations. According to Pienaar (1968), many species, such as porcupines and elephants, use roads as daily "routes of communication" between feeding and watering areas. On a larger scale, the existence of roads contributes to extensions of geographic ranges of some species. Bridges over large, otherwise impassable rivers or other barriers afford access to new areas which may or may not be suitable for colonization (Pienaar, 1968). Significant range extensions of pocket gophers across southern California have resulted from highway construction across the desert (Huey, 1941). Prior to construction of a concrete highway spanning the 80 kilometer (km) or 50 mile (mi.) wasteland, no gopher activity was evident along the sand-silt roadway. During the ensuing 12 years, gophers advanced along the roadside 59 km (37 mi.) into the desert.

Concern for motorist safety has prompted highway departments in several states (particularly Pennsylvania and Michigan) to at least partially fund studies of deer behavior along highways (Bellis and Graves, 1971a, b; Peek and Bellis, 1969; Reilly and Green, 1974). Awareness of deer activity patterns permits highway departments to initiate new or to modify existing programs in efforts to decrease the number of vehicle-deer encounters.

Egler (1953a, b, 1957) was among the first to recognize that American highway ROWs contained over 4 million hectares (ha) or 10 million acres of land which could be managed to benefit numerous wildlife species (particularly game species) while actually reducing the cost of maintaining the facilities. Joselyn (1969) also realized that special consideration should be given wildlife in establishing policies for roadside maintenance. One study evaluated the effects of differential seeding and mowing of ROWs on population densities and nesting success of ring-necked pheasants in Illinois (Joselyn et al., 1968).

Only two studies have been conducted to assess and quantify the effects of highways on non-game species. In Ontario, Oxley et al. (1974) investigated road crossing and highway mortality in small to medium-sized mammals as influenced by various factors including type of road (number of lanes and surfacing material), traffic volumes and patterns, and habitat type adjacent to the thoroughfare. Population data (numbers of animals trapped and movements of individuals) collected during two summers of field work were presented in this study. Michael (1976) surveyed diversity and abundance of vertebrates present along a highway in West Virginia before, during, and after highway construction. However, neither highway mortality nor movements across pavements was monitored.

The studies by Oxley et al. (1974) and Michael (1976) did not investigate in detail the population dynamics of small rodents along highways. Furthermore, many of their conclusions likely do not apply to small mammal populations along eastern Texas roadways since both fauna and habitat here differ from those in Canada and West Virginia.

METHODS AND MATERIALS

Study Areas

General Description of Eastern Texas

Brazos County and Madison County (Fig. 1) are situated within the Texan biotic province (Blair, 1950) and within the oak-hickory vegetational region of Texas (Tharp, 1926). Topography of this region is gently rolling to hilly with elevations ranging from 120 meters (m) or 200 feet (ft.) to 240 m (400 ft.). The mean annual rainfall of approximately 102 centimeters (cm) or 40 inches (in.) is nearly equally distributed throughout the seasons. The mean January minimum temperature ranges from 4°C (40°F) to 6°C (42°F) while the mean maximum temperature for July is 35°C or 95°F (Texas Almanac, 1976). Post oak[1] and blackjack oak are the climax overstory species. Climax grasses include little bluestem, Indiangrass, switchgrass, purpletop, silver bluestem, Texas wintergrass, and chasmanthium (Thomas, 1975).

Location of Study Area

Two sites along each of three highways differing in design and usage patterns were selected as locations for establishment of rodent study grids (Fig. 1). Two grids, hereafter referred to as "6 North" and "6 South", were located along Highway 6, the east bypass around Bryan and College Station, Brazos County. The "2818 North" and "2818 South" sites were established along Farm to Market 2818, the west bypass around Bryan and College Station. Two other grids, "45 North" and "45 South", were situated near Madisonville, Madison County along Interstate 45. The northern site along each highway was mowed according to regular highway department maintenance schedules while the southern sites were not mowed or in any other way maintained during the study period.

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[1]Appendix B lists common and scientific names of plants.

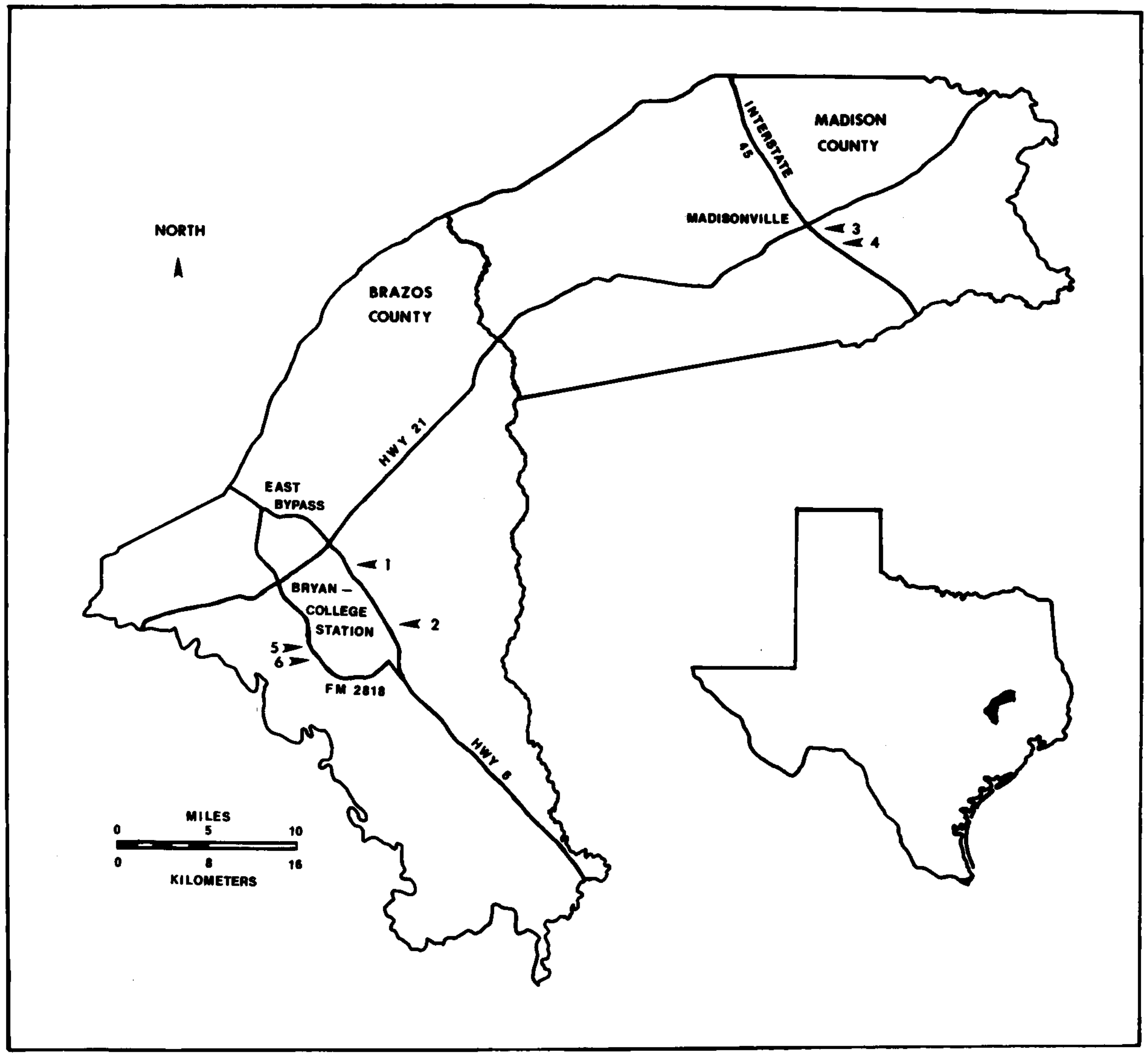

Fig. 1.--Map of Brazos County and Madison County. Arrows indicate locations of study sites: (1) 6 North grid, (2) 6 South, (3) 45 North, (4) 45 South, (5) 2818 North, and (6) 2818 South.

Establishment of Grids and Trap Deployment

The grids along FM 2818, a two-lane undivided highway, were divided into four sections: (1) and (2), the east and west ROWs, respectively (hereafter referred to as EROW and WROW), including the areas extending from the pavement to the fence lines; and (3) and (4), the east and west fields or pastures, respectively (EP and WP), consisting of the trapping areas extending from the fence line away from the roadway.

Highway 6 and Interstate 45 are four-lane divided highways bounded on either side by two-lane access roads (Fig. 2). The presence of four strips of pavement and two fence lines permitted recognition of seven distinct areas in each grid: (1) the median, situated between the northbound and southbound lanes; (2) and (3), the east and west frontage areas, respectively (EF and WF), located between the northbound lane and east access road, and southbound lane and west access road, respectively; (4) and (5), the east and west rights-of-way (EROW and WROW), located between the east access road and adjacent property line or fence line, and west access road and adjacent property line or fence line; (6) and (7), the east and west fields or pastures (EP and WP), extending from property or fence lines into a field or pasture.

The above highway designs dictated the manner in which trapping stations were established. On each of the Highway 6 and Interstate 45 grids, folding Sherman live traps (7.6 cm × 8.9 cm × 22.9 cm) were deployed in 11 parallel lines of 10 traps per line for a total of 110 traps per grid. Distance between traps in a given line was 15 m (50 ft.); length of an entire trap line was 135 m (450 ft.). Trap lines were placed as follows (Fig. 2): one line centered in the median; two each in the EF and WF; one each in the EROW and WROW and two each in the EP and WP. Distance between adjacent trap lines was 15 m (50 ft.) in trapping areas outside the access roads (EROW, WROW, EP, and WP). Distances between trap lines in other grid sections varied according to the width of respective grid sections.

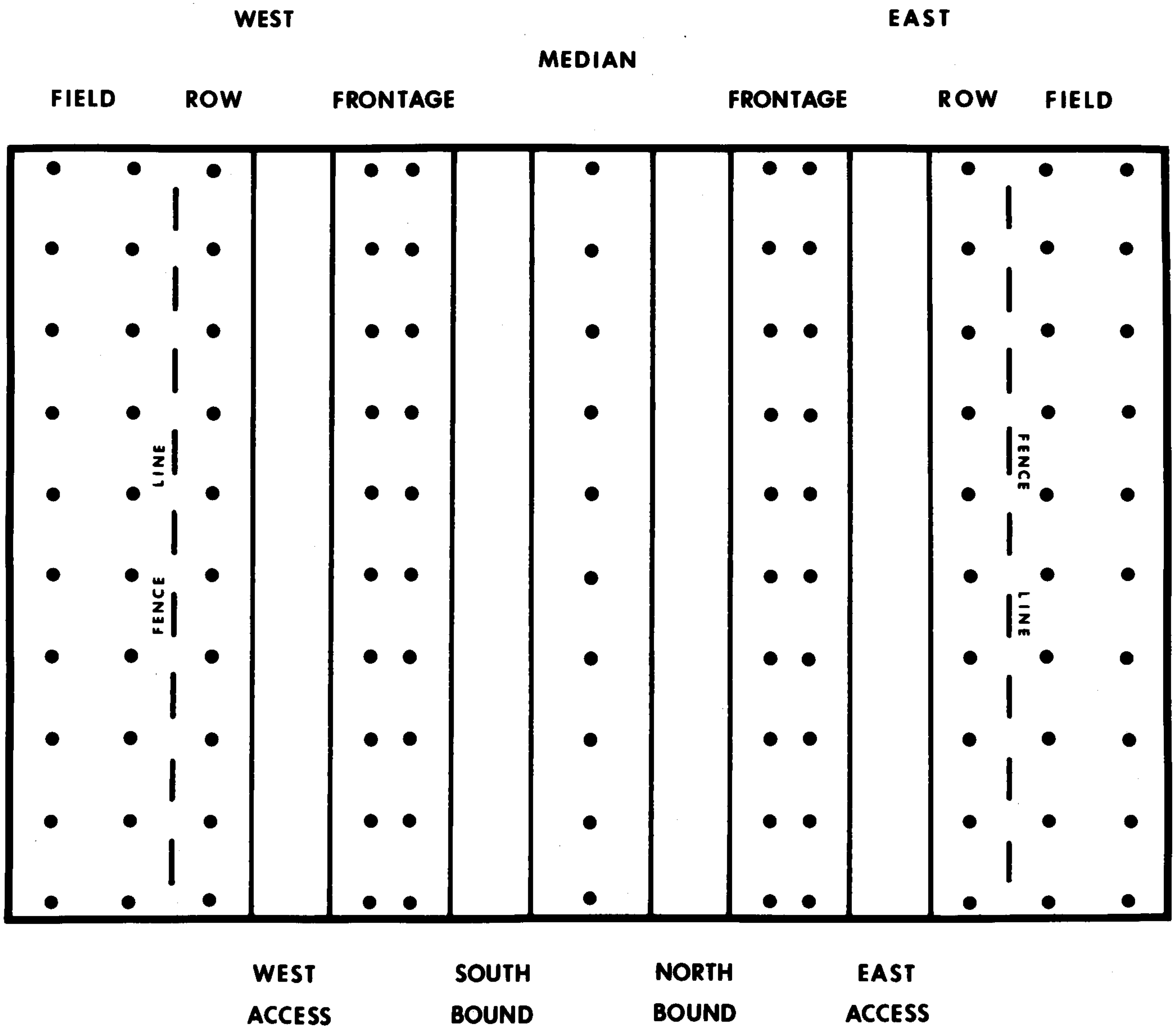

Fig. 2.--Diagram of Highway 6 and Interstate 45 grids. Dots represent trap stations.

Within the FM 2818 grids, a single line of 10 traps was placed within each EP and WP. Thirty trap stations were located in the WROW and EROW of 2818 North and in the WROW of 2818 South; due to the narrowness of the EROW of 2818 South, only 20 trap stations were established there. The total number of trap stations for 2818 North was 80; for 2818 South, 70. Distance between adjacent trap lines on a given side of the roadway was 15 m (50 ft.).

Due to variation in design of the highways (particularly the width of unpaved areas between adjacent lanes of pavement), considerable variation exists in the areas of grid sections situated within the ROWs both within and between grids. The smallest sections sampled, the EROW and WROW of 45 North, each included an area of only 0.18 ha. The largest section, the WROW of 2818 North, was 1.23 ha while the mean area of sections within the ROW was 0.41 ha. Area for all EP and WP was 0.89 ha. Average total grid size was 3.14 ha with extremes of 2.64 ha (2818 South) and 3.64 (6 South). The total area trapped was 18.84 ha.

Habitat Description

Study areas were selected with the intention of minimizing habitat variability within the ROWs while sampling areas outside the ROWs which were subject to diverse land management practices. Table 1 presents the plant species or categories comprising the vegetational community of the five habitat types designated below.

One of the three habitat types occurring outside of the ROWs is the "old field" habitat which is comprised of the EP and WP of 6 North, WP of 6 South, and WP of 45 North for a total area of 3.66 ha. These areas represent the least disturbed habitat investigated in this study. These are the only grid sections in which post oak and blackjack oak occur in large numbers; bluestem grasses and dewberry are the predominant members of the understory (Table 1). A total of 80 trap stations was placed in the old field grid sections.

Table 1.—Checklist of plants and plant categories characterizing each of the habitat types. Only those species or categories comprising a major component of the plant community are indicated.

	Old Field	Pasture	Cultivated Field	Unmowed ROWs	Mowed ROWs
Grasses					
Johnsongrass	X			X	X
Bermudagrass	X	X		X	X
Bluestems	X	X		X	X
Knotroot Bristlegrass	X			X	X
Paspalum	X	X		X	X
Sandbur				X	X
Other	X	X	X	X	X
Forbs	X	X	X	X	X
Vines					
Dewberry	X				
Woody					
Post Oak	X	X			
Blackjack Oak	X	X			
Honey Mesquite		X			
Elms	X				
Others	X				

Moderately to heavily grazed "pastures" represent the second habitat located outside the highway ROWs. Six grid sections (EP of 6 South, 45 North, 45 South, and 2818 South), and WP of 45 South and 2818 South) comprise the pasture habitat. Within this 5.34 ha area, 100 trap stations were established. All of these areas were grazed during all or part of the study period. Primary vegetation includes an assortment of grasses with honey mesquite and a few post oaks comprising a minor component of the plant community.

The EP and WP and 2818 North, representing an area of 1.78 ha, are the only two grid sections comprising the "cultivated fields" habitat. Sorghum is the dominant plant although other grasses and forbs of lesser importance are present. Twenty traps were located in this habitat.

The "unmowed ROWs" habitat, consisting of all unmowed grid sections located within the ROWs, is represented by the EROW, EF, M, WF and WROW of 6 South and 45 South, and the EROW and WROW or 2818 South. Corresponding sections of the three North grids comprise the "mowed ROWs" habitat. Johnsongrass and Bermudagrass and, to a lesser degree, bluestem grasses are the dominant plants occurring within the ROWs, although forbs and a few low shrubs are also present. Species composition of the plant community of both the mowed and unmowed ROWs are essentially identical. Total areas of mowed and unmowed habitats are 4.71 ha and 5.15 ha, respectively. The number of trap stations situated in the former was 200; in the latter, 190. Appropriate sections of the 6 North grid were mowed on two occasions: 18 May and 14 July 1976. The 2818 North and 45 North grids were mowed only once, on 25 May and 15 June 1976, respectively.

Field Techniques

Rodent Population Study

A mark-recapture technique similar to those employed by Blair (1941) and Hayne (1949) was utilized to gather data from which population estimates were calculated and movements of individual animals were followed. Both Highway 6 grids were operated monthly for the 11 month trapping period beginning in October 1975 and ending in August 1976. The four remaining grids were run for five sessions, once each in fall, winter, and spring, and twice during summer, immediately following mowing. All sessions consisted of five nights of trapping, except the December 1975 session for both Highway 6 grids which were trapped for three evenings. Total number of trap nights for the Highway 6 grids was 11,660; that for the other grids was 8,500. Total number of trap nights for the entire study was 20,160.

Traps were set during the late afternoon prior to each night of trapping, and baited with scratch grain and rolled oats. During the colder months, cotton was placed in the traps to serve as nesting material for the rodents. Traps were run the next morning approximately 1 hour after daybreak.

Each rodent was uniquely marked on its initial capture using a toe-clipping method modified from Martof (1953). For each captured animal, the following data were recorded: (1) species identity, (2) toe number, (3) trap station, (4) sex, (5) reproductive condition, (6) weight, and (7) age. Animals were then released at the point of capture.

Two hand-held Pesola scales, a 30 gram (g) capacity scale graduated at 1 g intervals and a 300 g capacity scale graduated at 2 g intervals, were used to weigh rodents. Age of individuals of smaller species was estimated by examining pelage coloration and by noting the relative size of the individual. Weight was the criterion used to designate age class assignments for Sigmodon hispidus: juveniles of both sexes, less than 35 g; subadults, males 35-84 g, females 35-79 g; adults, males in excess of 85 g, females in excess of 80 g (Meyer and Meyer, 1944). Reproductive condition, either pregnant, lactating, scrotal or inactive, was determined by examining the genitalia and mammae of the rodents.

Several biases are inherent to the mark-recapture technique. Several authors (including Young, Heess, and Einlem, 1952; Dice, 1938;

and Overton, 1972) have acknowledged the problem presented by trap-happy or trap-shy individuals. This phenomenon represents a failure of animals to be equally subject to capture (a violation of the assumption of random sampling), and may be due to any of several factors including: (1) a behavioral trait of the animal, (2) a peculiarity of the trap itself, or (3) the spatial placement of the trap.

Larger, older cotton rats tend to be sampled at a higher frequency than they occur in the populations (Joule and Cameron, 1974). Therefore, population densities may be underestimated (Ricker, 1975), and age class distributions incorrectly defined using conventional mark-recapture techniques. To alleviate this distortion of demographic parameters, Joule and Cameron (1974) suggested that animals captured each night be temporarily removed from the grid and returned at the end of the trapping session. Due to manpower and time limitations, their recommendations were not followed in this study. Assuming that biases act equally in all habitats, however, the relative differences in population parameters between habitats can still be recognized.

Vegetation Analysis

The Daubenmire method of canopy cover analysis (Daubenmire, 1959) was employed to quantify the amount of ground surface covered by vegetation. Cover provided by 10 categories of plants was evaluated at varying heights above the soil surface: (1) litter, fallen dead material at 10 cm (4 in.); (2) middlestory, standing dead material at 25 cm (10 in.); (3) maximum herbaceous overstory, standing dead material at 50 cm (20 in.); (4) live forbs; live graminoids including (5) bluestem grasses; (6) Johnsongrass; (7) Bermudagrass; (8) sedges and all other grasses; (9) dewberry; and (10) woody species. Cover for categories (4) through (9) was assessed at 25 cm (10 in.); for category (10), 1 m (39 in.).

Four "summary" categories of vegetation were obtained by summing coverage provided by several of the above 10 categories as follows: (1) "all dead material", categories 1 through 3; (2) "all forbs", categories 4 and 9; (3) "all grasses", categories 5 through 8; and (4) "all woody material", category 10.[1]

Vegetation analysis was performed four times during the study period: winter, spring, early summer (within 5 days of mowing), and late summer (from 4 to 6 weeks after mowing). Such scheduling permitted assessment of seasonal changes in cover as well as changes effected by mowing. Cover analysis was conducted during trapping periods. Cover of both grids along a given highway was analyzed during the same trapping period. Appendix E lists dates of trapping sessions and vegetation sampling.

Vegetation within a 0.2 m × 0.5 m quadrat (area of 0.1 m^2) was observed 1 m from each trap station. The number of quadrats sampled seasonally for the 2818 North grid was 80; for 2818 South, 70; for all other grids, 110. The percent of ground covered by plants of each of the initial 10 categories was visually assessed and recorded as coded values: code 1, 0-5 percent of ground covered; 2, 6-25 percent; 3, 26-50 percent; 4, 51-75 percent; 5, 76-95 percent; and 6, 96-100 percent. Use of midpoint values of these percentage intervals, rather than the code values themselves, allowed application of parametric statistical analyses.

For several reasons, the Daubenmire cover analysis technique was well-suited to this study. The procedure is designed for sampling large numbers of quadrats in a relatively short time using unsophisticated equipment (only a 0.2 m × 0.5 m wooden frame and a meter stick). Structure of the vegetation as it contributed to cover was the prime subject of analysis. Hence, plants were categorized by growth form; specific identification of most plants was not necessary.

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[1]Cover contributed by standing dead plants at least 50 cm tall was evaluated at 25 cm and at 50 cm. Hence, some overlap exists between categories (2) and (3).

Highway Mortality Study

To estimate the impact of highway mortality on wildlife, particularly small rodents which had been marked within the grids, a survey line was established along each highway where grids were located. The Highway 6 line included the entire 22.4 km (14.0 mi.) east bypass; the Interstate 45 and FM 2818 lines were 15.2 km (9.5 mi.) and 9.6 km (6.0 mi.) in length, respectively. Lines were surveyed for carcasses of all types of wildlife killed during the previous 24 hours each morning during which the corresponding grids were operated. To minimize overlooking carcasses, survey lines were driven at speeds of 25-32 km (15-20 mi.) per hour when traffic was light. During heavier traffic, driving on the shoulder at similar speeds permitted frequent abrupt stops without impeding traffic flow. This approach was apparently quite effective as a number of small frogs about 5 cm (2 in.) in length were observed. The identity, locality, and lane in which a carcass was found were recorded for each victim. If discernable, sex, age, and reproductive condition of individuals were recorded.

Data Analysis

Population estimates.—Seasonal and, where appropriate, monthly rodent population estimates were calculated for each species for each section of each grid using the Schnabel formula which assumes that the ratio of marked to unmarked animals in the sample closely approximates that of the population. The Schnabel formula (Overton, 1972) is as follows:

$$N = \frac{\Sigma M_i \times n_i}{\Sigma\, \chi_i}$$

where N = population estimate;

M_i = number of marked animals in population on i^{th} occasion;

n_i = number of animals in sample on i^{th} occasion;

χ_i = number of marked (recaptured) animals in sample on i^{th} occasion.

Since these estimates reflect population size of grid sections varying greatly in area, estimates were standardized by dividing the area of the grid section into the corresponding Schnabel estimate to yield species densities (number of individuals per hectare). To obtain densities for a given species for a given habitat, the mean of density values for that species from all grid sections representing that habitat was calculated. Seasonal densities for those grids which were operated monthly (Highway 6 grids) were derived by taking the means of appropriate monthly densities as follows: fall, October and November; winter, December through February; spring, March and April; early summer, May and June; and late summer, July and August.

The effect of varying trap densities in different sections of the grid on population estimates was considered negligible. Having more traps in one grid section than another (for example, the old field had 22 traps/ha whereas the mowed ROW had 42 traps (ha) merely increases the potential sample size of captured and recaptured animals. However, this would not affect the ratio of these two measures (as used in the Schnabel formula) if, in those grid sections with fewer traps, large numbers of animals are captured and recaptured. Since this was the case in our study, we do not feel variation in trap densities by grid sections significantly influenced our data.

Diversity.—Monthly or seasonal indices of general diversity, richness, and evenness were generated for each grid section, and then seasonally for each habitat in the same manner described above for obtaining seasonal population densities. The Shannon index of general diversity (Odum, 1971), $\overline{H}$, is computed from

$$\overline{H} = -\Sigma(\frac{n_i}{N}) \log_e (\frac{n_i}{N})$$

where n_i = importance value for each species (population densities);
N = sum of importance values for all species.

Community diversity depends on both richness (a function of the number of species present) and the evenness with which the individuals are apportioned among the species. Since a community composed of many, unevenly represented species can have the same diversity index as one with only a few, evenly represented species, it is desirable to present measures of evenness and richness along with those of diversity (Pielou, 1975). Evenness (Odum, 1971), e, may be estimated by

$$e = \frac{\overline{H}}{\log_e S}$$

where H = Shannon index of general diversity;

S = number of species present.

Richness (Odum, 1971), d, may be derived from

$$d = \frac{S-1}{\log_e N}$$

where S = number of species present;

N = total number of individuals present.

The above indices are especially useful in tracing changes in both community species composition and individual species abundance during the course of development of an ecosystem (eg.-forest, grassland, desert). The time frame involved for maturation of such habitats spans from several decades up to a few hundred years. In early stages of succession (approximately the first 10 years), values for these indices are often subject to fluctuations sometimes of large magnitude in such a manner that no obvious pattern is discernable. However, long term studies (see Odum, 1971) indicate that diversity ($\overline{H}$) increases with increasing age of the ecosystem. In younger habitats, fewer species are present whereas greater numbers of species occur in mature ecosystems; therefore, species richness (d) increases with maturity. Similarly, evenness (e) increases with maturity. Of the species present in early stages, a few (usually 1 or 2) occur in large numbers, while the remaining species are represented by relatively few individuals. Ideally, in older stages, all species are present in approximately equal numbers.

The areas surveyed in this study are all in very early stages of development towards the climax oak-hickory forest characteristic of eastern Texas. Index values presented are not meant to infer varying degrees of maturity to the five habitat types (although the cultivated fields are obviously the most disturbed and the old fields are the least disturbed). Instead, they provide insight into seasonal fluctuation in activity of the rodent community within each habitat type. Reliability in values of $\overline{H}$, d, and e increases as sample size increases. Because of this relationship, care must be exercised when attempting to compare index values between habitats. Comparisons of habitats where population estimates are based on captures of very few rodents (eg.-cultivated fields) with habitats where numerous rodents were trapped (eg.-unmowed ROWs) can be misleading and biologically unsound. For contrasting different habitats, perhaps the best parameter to consider is simply the number of species present; here, too, reasonably large sample size is an important consideration.

Statistical treatment.—Pearson's product-moment correlation coefficients were calculated using the computerized statistical analysis system (SAS) of Barr *et al.* (1976) to elicit relationships between rodent species and vegetation categories. This method of analysis permits determination of habitat preferences for those rodent species represented by eight or more individuals (*Sigmodon hispidus*, *Baiomys taylori*, *Reithrodontomys fulvescens*, and *Mus musculus*). Other species were taken in such low numbers that application of statistical techniques would not be biologically meaningful. Correlation coefficients were computed by comparing the population density of a given rodent species for a given grid section with the mean value of each of the 14 vegetation categories for that grid section. Sample size varied between habitats according to the number of grid sections comprising each habitat (old field, N = 16); pasture, 24; cultivated field, 8; unmowed ROWs, 48; mowed ROWs, 48).

Mean values of cover provided by each of the 14 vegetative categories and of population densities for each rodent species in the mowed ROWs habitat were tested against corresponding means of the unmowed ROWs habitat (using the ANOVA test of the SAS programs) to test for differences between the habitats before and after mowing.

Probability levels were calculated for Pearson's product-moment correlations, Chi-squared tests, and t-tests. Unless stated otherwise, all significance values are at P = .05.

RESULTS

Presenting data by habitat is biologically more meaningful than presentation by grid. Two or three habitats are represented within each grid. Consolidating data from sections within any given grid would distort the effects caused by different land management practices, and possibly lead to erroneous conclusions. Only areas of homogeneous habitat (i.e.: areas characterized by similar plant communities and subject to similar management practices) were consolidated for statistical analysis. Desirability of clarity and brevity also dictates that results not be presented in a grid by grid, section by section fashion.

Grid Studies

Habitats Outside Highway Rights-of-Way

Old Fields

Vegetation Analysis

A greater diversity of plant species occurred in the old fields than in any other habitat. Bluestems and knotroot bristlegrass, the most prominent grasses found in these areas, had a mean annual ground surface cover of 15 percent (Fig. 3). Johnsongrass and Bermudagrass provided less than 1 percent of the mean annual canopy cover. About 10 percent of the surface was covered by woody plants (mesquite, elm, post oak, cedar, and coralberry) ranging in height from 1 m (3.3 ft.) to 5 m (16.5 ft.). Total dead plant material was more important in the old fields (33.4 percent) than in other habitats. Dewberry provided approximately 10 times more cover in old fields (9.4 percent) than in any other areas. The greatest seasonal cover (87 percent) occurred during spring. Mean height of herbaceous vegetation was about 40 cm (16 in.).

The relative importance of each plant category with regard to cover varied seasonally (Fig. 3). Dead material was most prominent

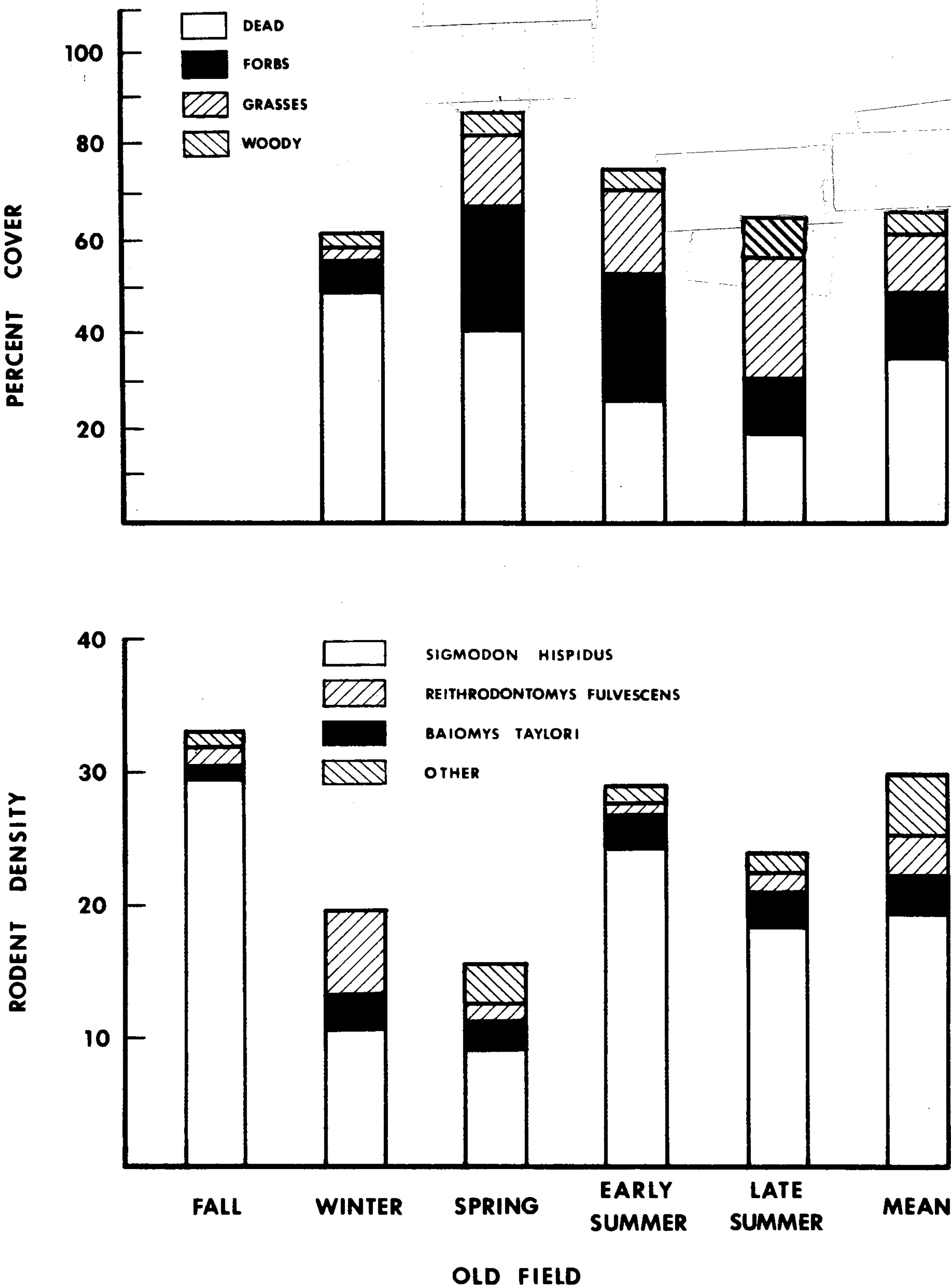

Fig. 3.--Seasonal variation in plant cover and rodent densities in the old field habitat.

(48.6 percent) during the winter dormant season, and of least importance (25.5 percent in early summer, 18.7 percent in late summer) during the growing season. The opposite trend was observed in most other categories since these plants are inactive in winter but produce leaves during spring and summer. Forbs were most important during early summer (9.0 percent) and late summer (7.4 percent). Dewberry covered approximately 8 percent of the surface in all seasons except spring when cover was 13.7 percent. Table 1 of Appendix C contains seasonal cover values for vegetation in the old field.

Rodent Diveristy

Eight rodent species (Sigmodon hispidus, Baiomys taylori, Mus musculus, Reithrodontomys fulvescens, Reithrodontomys montanus, Peromyscus leucopus, Peromyscus maniculatus, and Oryzomys palustris), as represented by 546 recaptures of 377 different individuals, were sampled in the old field habitat. The greatest number of species trapped during any season (six) was caught during spring when richness (1.846) and diversity (1.297) were highest; during the same season, the second-greatest evenness value occurred (0.724). Evenness was greatest (0.887) during winter when the least richness value (0.667) and the second-largest diversity (0.974) was recorded; only three species (S. hispidus, B. taylori, R. fulvescens) were captured during winter. Minimum diversity values (0.623 and 0.631) were obtained during early summer and fall, respectively, when four rodent species were trapped. Least community evenness occurred in early summer (0.449) and fall (0.455). Index values for total old field rodent catch for the entire study period are as follows: diversity, 1.316; evenness, 0.633; richness, 2.058. Seasonal values for the above indices as well as population densities of the rodents present are presented in Table 1 of Appendix D. Seasonal population densities of each rodent species in the old field are illustrated in Fig. 3.

Sigmodon hispidus.—Cotton rats, the most abundant rodent species during all seasons, occurred at a mean density of 19 individuals per hectare (Fig. 3). Densities ranged from lows of 9/ha during spring and 11/ha in winter to peaks of 24/ha and 29/ha in early summer and fall, respectively. During late summer, population density was 18/ha. Population estimates were based on 518 recaptures of 306 individuals.

Cotton rats were trapped within the old fields at a ratio of 174 males to 132 females. This ratio is significantly different ($\chi^2 = 5.76$; $P < .025$) from the expected 50 : 50 ratio.

Reproductive activity was observed in 54 (18 percent) cotton rats as follows: pregnant females, 21; lactating, 13; scrotal males, 20. Pregnancies were most frequent during spring and early summer although at least one pregnant female was trapped during each of the other seasons. Peak breeding activity occurred just before the increase in numbers of pregnancies as indicated by the capture of 7 scrotal males during winter; three scrotal males were trapped in both spring and early summer. The majority of lactating females was taken during early summer (46 percent) and fall (38 percent); only one lactating female was captured during late summer. Seasonal distribution of lactating females suggests the existence of two primary parturition periods, one in early summer (May and June) and another in late summer and early fall (late August into October). Mature individuals and subadults from early summer litters apparently bred during mid-summer.

Juveniles were present in all seasons. The greatest numbers of juveniles were observed during late summer (11) and fall (15); the fewest (one), during winter. Mean overall frequency of subadults in the population was 31 percent. During spring, subadults comprised only 18 percent of the population, suggesting that juveniles from the fall breeding season had matured to adult status. Four juveniles taken during spring were probably from the earliest spring litters.

Baiomys taylori.—Populations of pygmy mice exhibited remarkable stability in density throughout the study period. During fall and spring, density figures were 2/ha; densities were 3/ha during other trapping sessions. Ten recaptures were made of 35 marked mice.

Experimental design was not suited for accurate determination of age class distribution of B. taylori as Sherman traps were not sensitive enough to catch animals smaller than adults. Consequently, most pygmy mice captured were adults, although occasionally a subadult was trapped. Sexing pygmy mice was difficult especially when they were not in breeding condition or not obviously pregnant or lactating. Therefore, sex ratios for pygmy mice may not be as accurate as those for cotton rats. Cumulative sex ratio for B. taylori was 14 males to 20 females.

No reproductive activity was observed during winter. No scrotal males were taken during any season in the old field habitat. Pregnant females occurred during spring (one individual) and both summer trapping periods (two individuals each). Lactating females were taken during early and late summer and during fall. Lactating females first appeared one season after pregnancies were first noted (spring), and last appeared one season following last observations of pregnancies (summer).

Mus musculus.—One adult male house mouse of unknown reproductive status was captured in the EP of the 6 North grid during October. This species was assigned a population density of 1/ha because the Schnabel formula, which requires recaptures of previously marked animals, could not be employed.

Reithrodontomys fulvescens.—Population estimates of fulvous harvest mice were based on 17 recaptures of 32 individuals. The greatest density (6/ha) occurred during winter. During all other seasons, except for fall when the density was 3/ha, harvest mice occurred at the rate of only 1/ha.

Nearly twice as many males as females (sex ratio, 21 : 11) were trapped in the old fields. No males showed signs of reproductive activity. One pregnant female was captured during each season except early summer when none were taken. One lactating adult was observed during all seasons except spring when none were trapped. Breeding seems to occur throughout most of the year.

Reithrodontomys montanus.—One montane harvest mouse, a lactating adult, was collected from the EP of the 6 North grid during March. Population density for this uncommon species was designated as 1/ha during the spring and 0/ha during other seasons.

Peromyscus leucopus.—One male white-footed mouse was captured twice (once in June as a juvenile and again in July as a subadult) at the only trap station situated within a narrow extension of post oak woodland into the old field habitat in the EP of the 6 North grid. Population densities for both early and late summer were 1/ha; none were taken during other seasons.

Peromyscus maniculatus.—Two deer mice, a lactating adult and a reproductively inactive male, were taken during March and May, respectively, at the same trap station as the white-footed mouse. Population densities of 1/ha were assigned P. maniculatus for the spring and early summer periods; density for other seasons was 0/ha.

Oryzomys palustris.—Prior to this study, marsh rice rats were unknown from Brazos County (Davis, 1974). One female carrying four embryos was collected in the WP of the 6 North grid during early May. This species was assigned a density of 1/ha for spring.

Pastures

Vegetation Analysis

Average height of non-woody plants in the pastures was less than 10 cm (4 in.). At 10 cm above ground surface, the mean seasonal cover provided by all plant categories combined was approximately 25 percent (Fig. 4). Litter contributed an average cover of 9.8 percent. Bluestems, paspalum, and smutgrass covered an average of 8.1 percent of the surface. Johnsongrass was absent from the pastures during all seasons while Bermudagrass occurred in traces (1.5 percent).

As in most other habitats, all dead material contributed more cover in winter (21 percent) than in other seasons; least cover afforded by this category (3 percent and 8 percent) was during

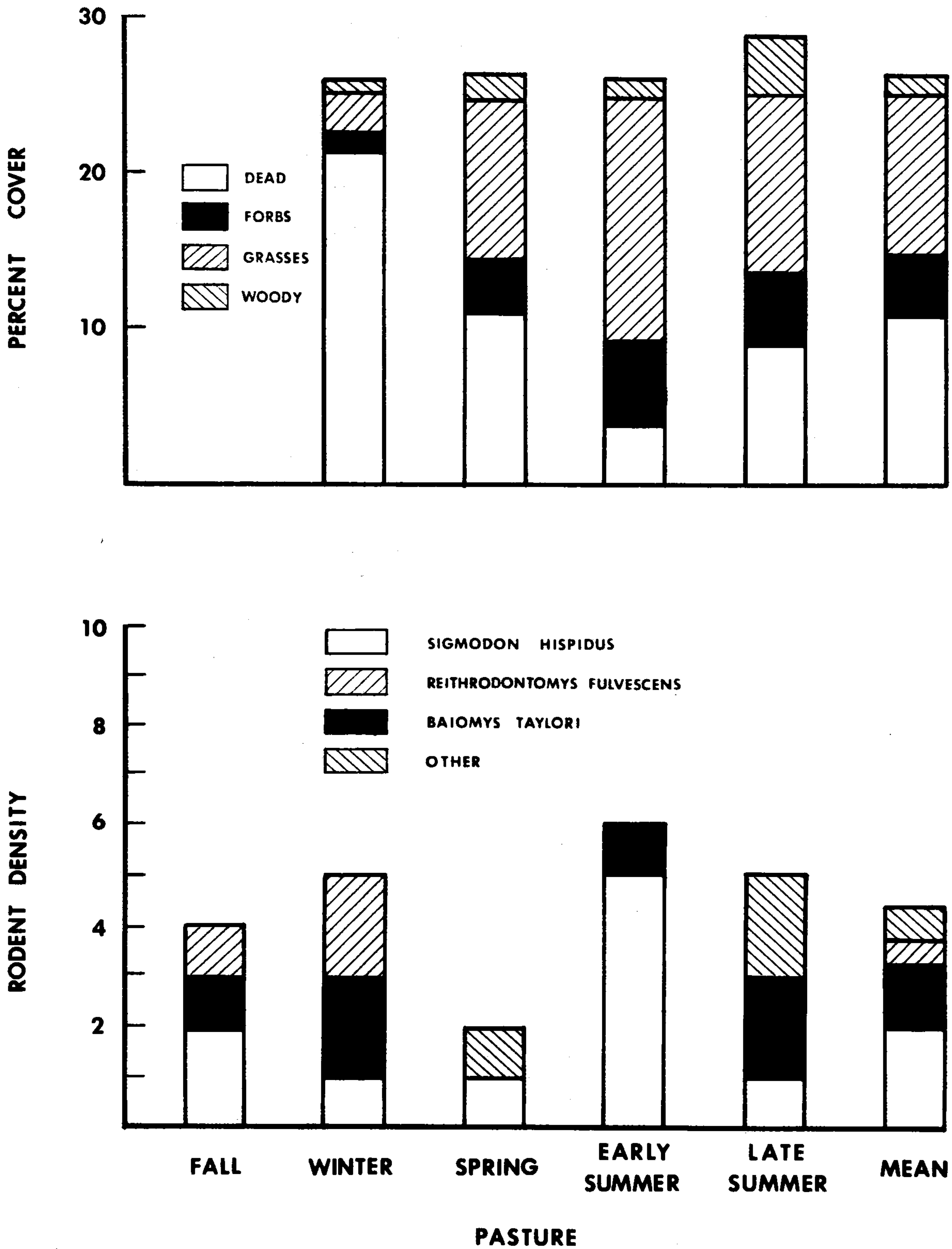

Fig. 4.--Seasonal variation in plant cover and rodent densities in the pasture habitat.

early and late summer. Maximum coverage contributed by forbs during any season was 5 percent. Grazing pressure probably caused low cover values for forbs since many forbs are favored forage plants. Similarly, seasonal cover values of each of the favored forage grasses analyzed separately (Johnsongrass, Bermudagrass, and blustems) were less than 5 percent. Due to light grazing pressure, smutgrass, paspalum, and other unpalatable grasses fared better, and provided at least twice the cover (up to 8 percent) of the favored forage species. All living plant categories reflected a seasonal pattern with minimal cover occurring in winter and maximum cover occurring during summer. Table 2 of Appendix C contains seasonal coverage values for vegetation in the pasture habitat.

Rodent Diversity

Fifty-eight individuals of six species (Sigmodon hispidus, Baimoys taylori, Mus musculus, Reithrodontomys fulvescens, Reithrodontomys montanus, and Perognathus hispidus) were recaptured a total of 15 times in the pasture habitat. Four species (S. hispidus, B. taylori, M. musculus, and P. hispidus) were taken during late summer when the highest diversity (1.332) occurred. The lowest diversity values (0.450 and 0.693) were observed in early summer and spring when only two species were taken. Evenness index values ranged between 0.9 and 1.0 during all seasons except early summer when the lowest value (0.650) occurred due to the overwhelming predominance of cotton rats. The least richness value (0.558) occurred in early summer when only S. hispidus and B. taylori were captured. During other seasons richness values ranged between 1.242 and 1.864. Index values for the cumulative rodent catch are as follows: diversity, 1.732; evenness, 0.967; richness, 2.402. Seasonal values for the above indices and population densities of rodents present are presented in Table 2 of Appendix D. Fig. 4 illustrates seasonal variation in population densities of rodent species discussed in the following accounts.

Sigmodon hispidus.—Cotton rats were the only rodents trapped during all seasons in the pasture habitat. The mean density was 2/ha. The early summer density (5/ha) was the highest recorded; the lowest densities were recorded during winter, spring, and late summer when cotton rats occurred at a density of only 1/ha. Cotton rats were present at 2/ha during fall. Nine recaptures were recorded for the 29 cotton rats marked.

The sexes occurred at the anticipated 50 : 50 ratio in the pastures (15 males : 14 females). The only rats exhibiting reproductive activity, one pregnant female and one scrotal male, were both trapped during late summer. Two juveniles were taken during spring and early summer. Subadults and adults occurred in the area during each season.

Baiomys taylori.—Spring was the only season during which no pygmy mice were captured in the pastures. During the other seasons, densities were 1 or 2/ha with the overall mean of 2/ha. Eighteen individuals were marked; four recaptures were recorded.

The sexes occurred in a ratio of 10 males to 8 females. Reproductive status was recorded for only three individuals as follows: one pregnant female (winter), one lactating female (autumn), and one scrotal male (late summer). All individuals trapped were adults.

Reithrodontomys fulvescens.—Densities of 1 and 2/ha for fall and winter were calculated on the basis of two recaptures of eight marked individuals. Since no fulvous harvest mice were taken during other seasons, the mean annual density was 1/ha. The sex ratio for the six specimens of known sex was one male : five females ($\chi^2 = 2.66$, not significant). One subadult was taken during each of the fall and winter sessions; the remaining individuals were adults. These data suggest that young are born during summer and fall.

Reithrodontomys montanus.—The 1/ha density for montane harvest mice results from the capture of one individual in the EP of the 45 North grid. This specimen, a non-scrotal adult male, represents the first record of occurrence of the montane harvest mouse in Madison

County. The previously recognized eastern limit of range for this species was 64 km (40 mi.) westward in Brazos County (Davis, 1974).

Mus musculus.—One subadult female taken during July in the WP of the 45 South grid constitutes the only record of the house mouse in the pasture habitat. This animal showed no sign of reproductive activity. A population density figure of 1/ha was assigned this species during late summer.

Perognathus hispidus.—Hispid pocket mice are the third species whose presence in the pasture habitat was documented by a single specimen. This individual, a reproductively inactive, subadult female, was captured in the EP of the 45 South grid during July. Since no recaptures of this rodent were made, the species was assigned a late summer and overall density of 1/ha.

Cultivated Fields

Vegetation Analysis

No woody plants or dewberry vines were observed at any time in the cultivated fields (Fig. 5). The primary grasses observed were the crop plants, although other grasses were present at less than 1 percent cover during all seasons. Recently germinated sorghum provided 7.8 percent ground cover in spring and a maximum coverage of 71.8 percent in late May just prior to harvest. Cover provided by the year's second sorghum crop in mid-July was 26.4 percent. The winter coverage value for sorghum was 0.0 percent as the fields had only recently been plowed.

Dead material, comprised primarily of the remains of crop plants, exhibited cover values of less than 8 percent except during winter (30.5 percent). An average of less than 1 percent of the ground was covered by forbs. Height of vegetation varied from ground level immediately following plowing to 1.5 m (5 ft.) prior to harvest. The greatest seasonal cover (73 percent) occurred in early summer. Seasonal differences in cover provided by each category do not reflect changes caused by climate; instead differences represent

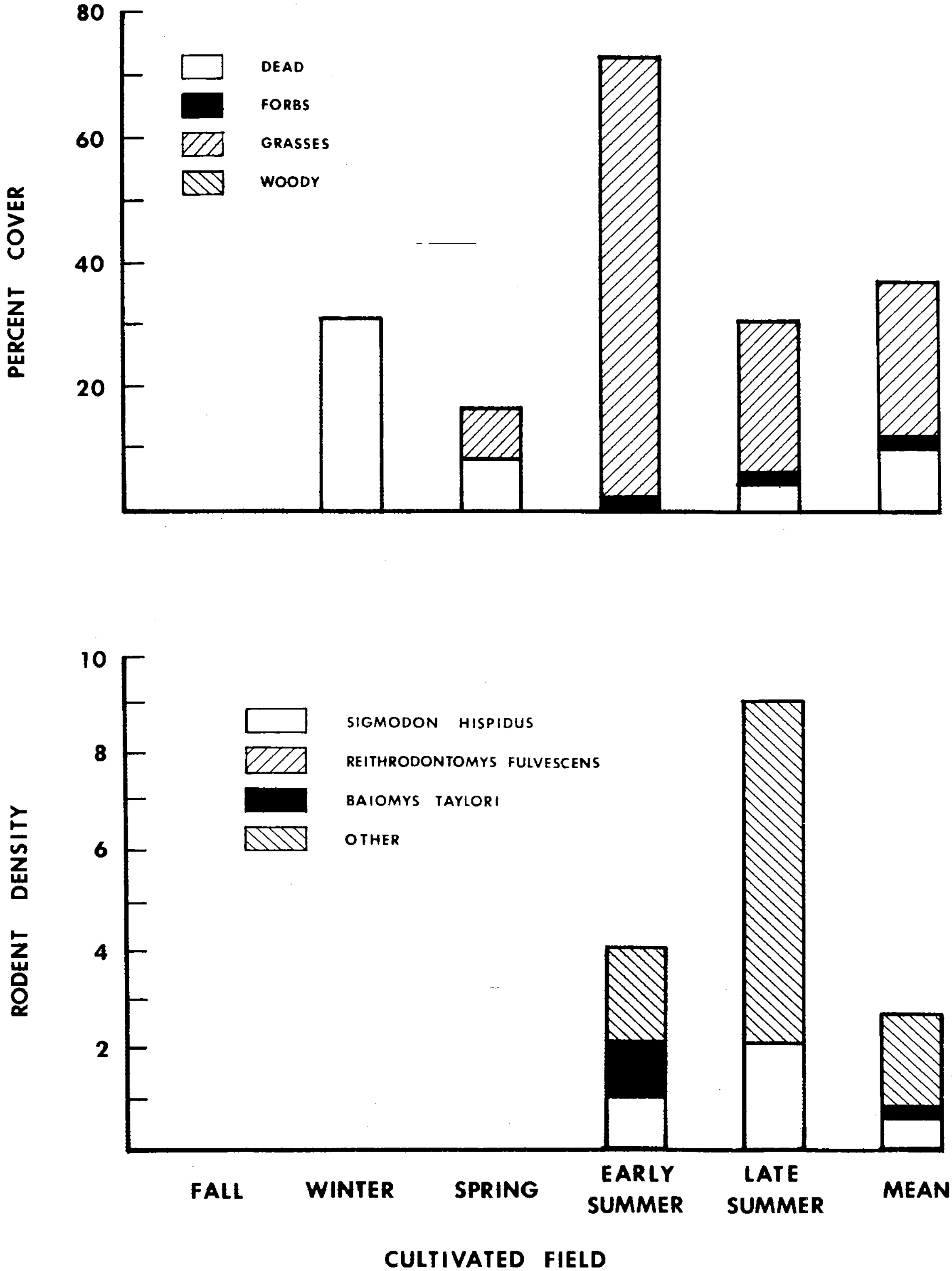

Fig. 5.--Seasonal variation in plant cover and rodent densities in the cultivated field habitat.

artifacts of the planting and harvest schedule. Table 3 of Appendix C presents seasonal cover values for vegetation in the cultivated fields.

Rodent Diversity

Only two out of 10 animals of three species (Sigmodon hispidus, Baiomys taylori, and Mus musculus) marked in the cultivated field habitat were recaptured. No rodents were taken in this habitat during fall, winter, or spring; hence, indices of community diversity, evenness, and richness were not computed. Higher values of these indices (diversity, 1.039; evenness, 0.946; richness, 1.442) characterized the early summer community when three species were present. Corresponding values for late summer, when only S. hispidus and M. musculus were observed, were 0.529, 0.764, and 0.455, respectively. Index values for the cumulative rodent catch in this habitat are identical to those computed for the early summer session. Table 3 in Appendix D presents seasonal variation in index values as well as population densities of rodent species. Fig. 5 illustrates seasonal variation in rodent densities in the cultivated field habitat.

Sigmodon hispidus.—This habitat is the only one in which cotton rats were not the predominant species. No rodents were taken here during fall, winter, or spring; hence, rodent population densities for those seasons were 0/ha. Cotton rats were present at densities of 1 and 2/ha during early and late summer, respectively. These estimates are based on the captures of six adult rats, three of which were initially trapped in the adjacent grid section (WROW). Following mowing of the WROW of the 2818 North grid, many of these rats crossed the fence line into the sorghum fields.

One of the two females marked in these fields was pregnant; the other was sexually inactive. None of the four males showed signs of reproductive activity.

Baiomys taylori.—Pygmy mice were captured only during the early summer session at a density of 1/ha. This density was based on the recapture of one pregnant female in the WP of the 2818 North grid; this individual was originally marked in the WROW of the same grid during February.

Mus musculus.—House mice, four males and two females, occurred in the cultivated field habitat at densities (early summer, 2/ha; late summer, 7/ha) greater than those of any other species during corresponding trapping sessions. None of the six individuals marked were recaptured.

Habitats Within Highway Rights-of-Way

Unmowed Rights-of-Way

Vegetation Analysis

Areas comprising the unmowed ROWs habitat were not mowed from early August 1975, about two months before the beginning of trapping, through the end of the study in August 1976. By October, the date of the first trapping session, vegetation in this habitat had recovered to a mean height of 50 cm (20 in.).

More ground surface (seasonal mean of 30 percent) was covered by dead plant material than any other category (Fig. 6). The great majority of dead material, most of which was dead grasses, was found within 10 cm (4 in.) of the surface. Forbs provided a mean cover of 9 percent. Dewberry and woody vegetation occurred in almost undetectable traces (< 1 percent). Grasses covered a mean of 25 percent of the surface. While bluestems and Johnsongrass were of only minor importance (mean < 3 percent), Bermudagrass contributed as much cover (mean = 10 percent) as did all species in the "sedges and all other grasses" category. A diverse assemblage of forbs covered over 9 percent of the ground.

Cover provided by dead material showed the expected seasonal trend by shading 42 percent of the surface during winter and 18

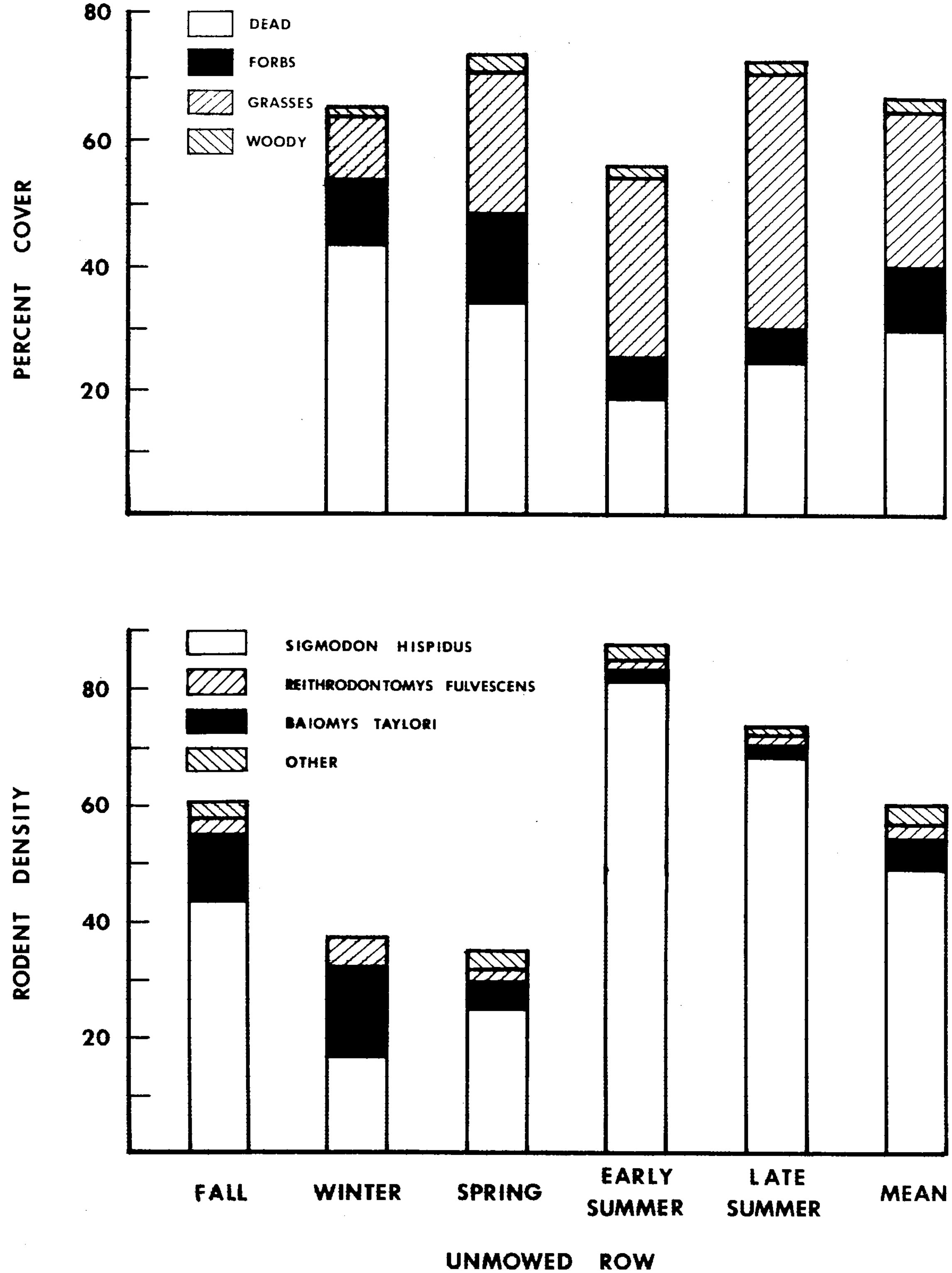

Fig. 6.--Seasonal variation in plant cover and rodent densities in the unmowed ROWs habitat.

percent in early summer before rising to 24 percent in late summer. At no time did dead material at a height of 50 cm (20 in.) contribute as much as one percent coverage. Forbs covered more area (15 percent) during spring than any other season; least cover was during late and early summer (5 percent and 7 percent, respectively), while the winter value was 9 percent.

Total grass cover increased as the seasons progressed from winter (11 percent) to late summer (39 percent). Bermudgrass paralleled this trend with winter and late summer cover values of 0 and 21 percent, respectively. Cover contributed by bluestems (seasonally ranging between 1 and 2 percent) was nearly constant. Peak cover values for Johnsongrass occurred during spring (4 percent) and late summer (6 percent); low values occurred in winter (0 percent) and early summer (2 percent). Species of the "sedges and all other grasses" category exhibited a slightly different trend; low coverage (8 percent) occurred in early summer, high coverage (14 percent) in spring, and intermediate values (10 percent) in both winter and late summer. Table 4 of Appendix C presents seasonal cover values for vegetation in the unmowed ROWs.

Rodent Diversity

A total of 1,008 recaptures was recorded for the 1,012 rodents of seven species (Sigmodon hispidus, Baiomys taylori, Mus musculus, Reithrodontomys fulvescens, Reithrodontomys montanus, Perognathus hispidus, and Rattus rattus) trapped in the unmowed ROWs habitat. Individuals of seven species were taken during spring when indices of diversity (0.997) and richness (1.701) were highest. During early and late summer, community diversity (0.187 and 0.128, respectively) and evenness (0.135 and 0.157) were at their lowest values as a result of the overwhelming numbers of cotton rats present as compared to the other species (B. taylori, M. musculus, and R. fulvescens). The greatest evenness (0.795) occurred in winter when B. taylori almost equalled S. hispidus in population density;

R. fulvescens, the only other species taken during winter, was of minor importance. Intermediate evenness values occurred during fall (0.517) and spring (0.512). Richness (0.567) was least in spring when evenness was greatest. Index values for the total rodent catch are as follows: diversity, 0.795; evenness, 0.408; richness, 1.465. Seasonal values for these indices and rodent population densities are presented in Table 4 of Appendix D. Seasonal trends in rodent densities are depicted in Fig. 6.

Sigmodon hispidus.—Cotton rats, the predominant rodents present during each season, comprised as much as 96 percent of the rodent community during early summer and as little as 50 percent during winter when nearly as many B. taylori were present. Population lows occurred in winter (17/ha) and spring (25/ha). However, numbers increased abruptly during early summer (84/ha) with the influx of newborn juveniles. Densities decreased to 69/ha during late summer and 43/ha during fall. These densities were derived from Schnabel estimates based on 951 recaptures of 844 individuals.

Of the 822 cotton rats of known sex, 398 were males and 424 were females. Nearly one-third of the females (131 individuals) were pregnant at least once during the study period. Only two pregnancies occurred during winter. During all other seasons at least 21 (fall) and as many as 36 (late summer) and 45 (early summer) animals were pregnant. Twenty-seven pregnant females were captured during spring. No lactating females were seen during winter although 20 and 22 such individuals were observed during fall and early summer, respectively. Five lactating females were trapped during both spring and late summer.

Seasonal distribution of scrotal males indicates two peaks in breeding efforts--one in winter (nine individuals) and another during early summer (six individuals). Only one breeding male was taken during spring and late summer.

The fewest juveniles occurred in winter (none) and spring (two). During late summer, the number of juveniles peaked at 55 individuals; the second highest numbers of juveniles occurred during early summer and fall (44 and 40 individuals, respectively). The smallest proportion of subadults (8 percent as compared to a mean of 36 percent) occurred during spring. Only during the winter did subadults (103) exceed adults (70) in number. Adults comprised approximately 55 percent of the cumulative rodent catch.

Baiomys taylori.—A total of 134 pygmy mice, for which 48 recaptures were recorded, was marked in the unmowed ROWs habitat. Populations of these mice exhibited seasonal density trends almost opposite those of S. hispidus. Pygmy mice density was greatest (15/ha) during winter when that of cotton rats was least. Whereas cotton rat populations peaked during summer, pygmy mice were least abundant (1/ha) during this time. Intermediate densities of the latter were observed during fall (11/ha) and spring (4/ha).

Of the 70 females marked, 24 exhibited evidence of breeding. Pregnant mice were trapped during all seasons with peak periods being winter (five females) and spring (seven females). Two females were carrying young during both the fall and early summer seasons; only one pregnancy was recorded during late summer. Six lactating females were captured during fall whereas only one was taken during spring. No scrotal males were detected.

Reithrodontomys fulvescens.--Six recaptures were recorded for the 22 fulvous harvest mice marked in grid sections comprising the unmowed ROWs habitat. A density estimate of 3/ha during fall was the highest recorded for this species. Their winter density was 2/ha; during the three remaining seasons, density was 1/ha.

The sex ratio of this species was 14 males to 8 females. One pregnant female was trapped during early summer. No lactating females were observed. Fall was the only season during which scrotal males (two) were detected. One juvenile and one subadult were marked during fall. Adults were taken during all seasons.

Mus musculus.—Nine individuals, two of which were recaptured one time each, were marked in the unmowed ROWs habitat. As indicated by density estimates (only 1/ha during each season except winter when none were trapped), house mice comprised a minor segment of the rodent community. One of the four females marked during winter was pregnant. None of the five males were in breeding condition.

Reithrodontomys montanus.—One montane harvest mouse, a sexually inactive female, was trapped during spring in the WROW of the 6 South grid. None were taken during other seasons.

Perognathus hispidus.—This was another uncommon species comprising a minor portion of the rodent community in the unmowed ROWs. No hispid pocket mice were taken during winter or summer. Initial capture of one female in the WF of the 6 South grid during October and subsequent recapture of the same individual in March documented presence of this species at a density of 1/ha during the fall and spring.

Rattus rattus.—One black rat, the only one taken during this study, was trapped in the EF of the 6 South grid in April. This reproductively inactive, subadult male was never recaptured.

Mowed Rights-of-Way

Vegetation Analysis

Mean height of vegetation on mowed grid sections was about 50 cm (20 in.) during winter and spring analyses prior to mowing. Immediately following mowing, vegetation height decreased to approximately 10 cm (4 in.). In some areas, especially those sections mowed only once, plants recovered to a mean height of approximately 30 cm (12 in.) by late summer. Overall mean height during the two summer sessions was about 20 cm (8 in.).

Amount of available cover before mowing ranged from 56 percent in winter to 80 percent in spring (Fig. 7). Although dead vegetation at 50 cm (20 in.) was equally unimportant in both seasons (< 1 percent), litter and middlestory categories contributed to cover differently in winter (sum of both categories, 39 percent) than in spring (17 percent). Cover contributed by forbs increased from 8 percent in winter to 13 percent during spring. All grasses showed

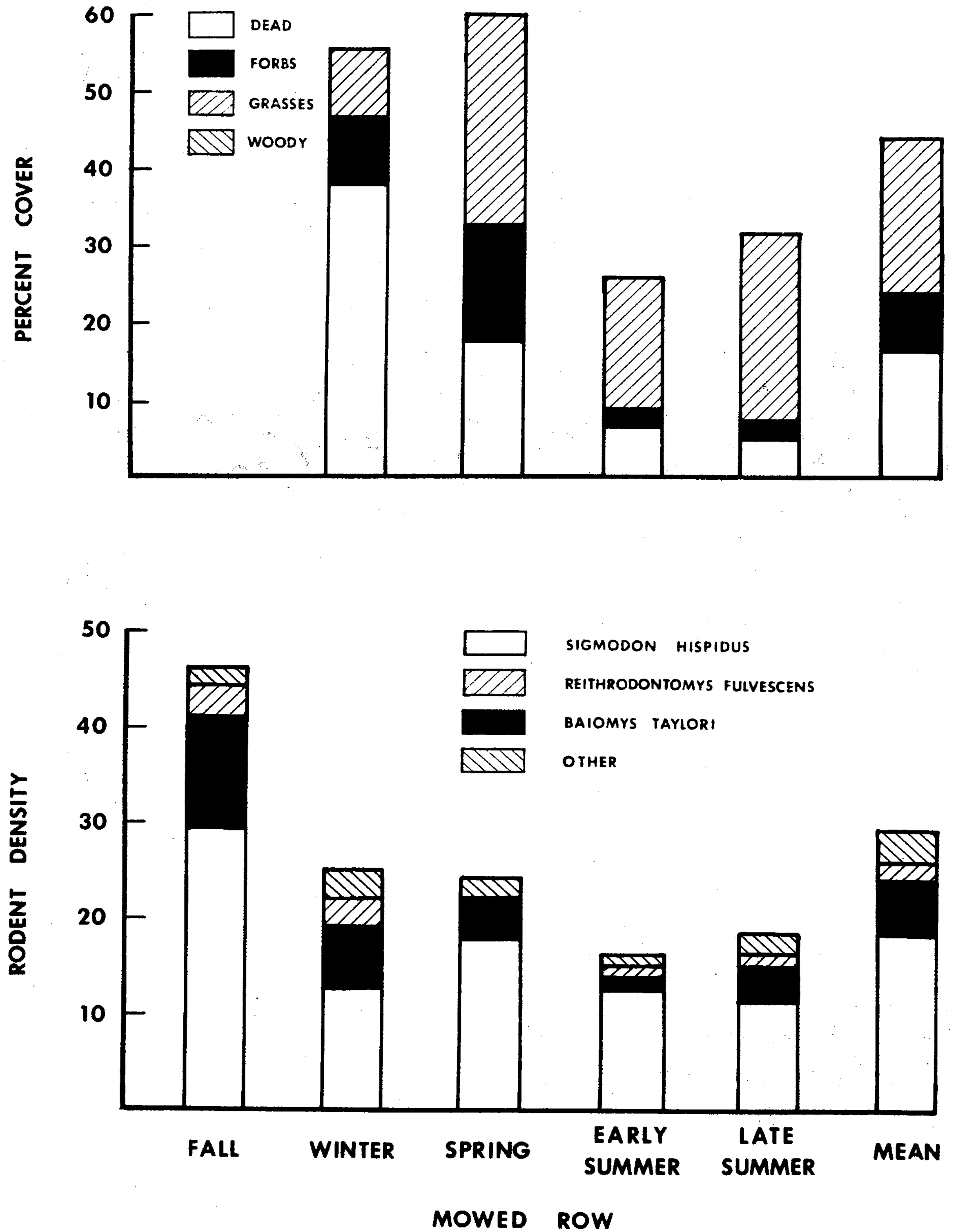

Fig. 7.—Seasonal variation in plant cover and rodent densities in the mowed ROWs habitat.

an increase in cover from winter (10 percent) into spring (28 percent), due primarily to increasing importance of Bermudagrass, bluestems, and Johnsongrass. Dewberry covered less than 2 percent of the habitat; woody vegetation was absent.

Mowing resulted in a marked reduction in total cover during early summer (26 percent) and late summer (31 percent). Mean cover for dead material during the two summer sessions was 6 percent. Material belonging to the "maximum overstory" category was absent; less than 1 percent of the cover provided by "all dead material" was contributed by the middlestory category. Both forbs and dewberry were unimportant contributors to cover (< 2 percent). All grasses collectively shaded from 17 percent to 24 percent of the surface during early and late summer, respectively. Little or no change was exhibited in cover values between early and late summer by bluestems (1 to 2 percent), Johnsongrass (1 percent both sessions) and Bermudagrass (11 to 9 percent). "Sedges and all other grasses", however, increased coverage from 4 percent in early summer to 11 percent in late summer. No woody vegetation occurred in the mowed ROWs habitat. Seasonal cover values for the 14 vegetation categories in the mowed ROWs are presented in Table 5 of Appendix C.

Rodent Diversity

Six species (*Sigmodon hispidus*, *Baiomys taylori*, *Mus musculus*, *Reithrodontomys fulvescens*, *Reithrodontomys montanus*, and *Perognathus hispidus*), represented by 560 recaptures of 495 individuals, were trapped in the mowed ROWs habitat (Fig. 7). *S. hispidus* was the predominant species during all seasons. The presence of *B. taylori* in winter at slightly less than half the density of *S. hispidus* results in the highest evenness index (0.803) recorded in this habitat. Immediately following mowing in early summer, the lowest evenness value (0.519) was observed, but by the late summer session it reached 0.725. Intermediate evenness values occurred during spring (0.602) and fall (0.612). Prior to mowing, the diversity index ranged from 0.835 in spring to 1.293 in winter. In early summer, the diveristy index dropped to its least observed value (0.720) but increased to 1.006 during late summer. Richness values exhibited reasonable stability throughout the study. The greatest value before mowing (1.242) occurred in winter; the least (0.943), in fall. Following mowing, richness values were 1.107 and 1.058 for early and late summer, respectively. Index values for the total rodent catch in the mowed ROWs are as follows: diversity, 1.240; evenness, 0.692; richness, 1.484. For seasonal values of the above indices and rodent densities see Table 5 of Appendix D.

Sigmodon hispidus.—As was the case in most other habitats, S. hispidus was the predominant rodent species present; cotton rats comprised as much as 80 percent of the community in early summer and as little as 48 percent during winter. During the three seasons prior to mowing, population densities ranged from a low of 12/ha in winter to 17/ha in spring and a high of 29/ha during fall. Little variation was observed between densities of the early summer session (12/ha) immediately following mowing, and late summer (11/ha). Prior to mowing, the mean of seasonal densities was 20/ha; following mowing, 12/ha. Population estimates were computed from 514 recaptures of 352 cotton rats.

Of the 272 marked rats for which sexes were known, 139 were males and 133 were females. Forty-three of these females were reproductively active. Eighteen of the 33 pregnant females were trapped during the spring whereas three were taken in each of the summer sessions. The second greatest number of pregnancies (six) was observed during fall. As in the other habitats, no pregnant cotton rats were captured during winter. Lactating females were observed only during the fall, spring, and early summer; these were represented by nine, three, and one individuals, respectively. Scrotal males were observed during fall, winter, and early summer at the rate of three per season.

Eighteen of the 33 juveniles marked were trapped during the fall session. The fewest juveniles (one) were caught during winter. As many as five juveniles were captured during the other seasons.

Subadults and adults comprised the majority of the cotton rat populations throughout the year. Cumulative juvenile : subadult : adult ratio for the mowed ROWs was 33 : 154 : 193.

Baiomys taylori.—Thirty recaptures were recorded for 84 pygmy mice marked in the mowed ROWs habitat. Mean population density prior to mowing was 8/ha with extremes of 5/ha in spring and 12/ha in fall; the winter density was 7/ha. After mowing, densities were 1/ha for early summer and 3/ha for late summer.

Thirteen of the 42 females captured within the mowed ROWs were pregnant. The majority (62 percent) of the pregnancies occurred during the spring; three were noted during winter and one each during fall and late summer. No pregnant females were taken during early summer. Pygmy mice were taken at a density of only 1/ha during early summer. A total of five lactating females was observed (fall, 2; winter, 1; spring 2); none were trapped during summer. Late summer was the only season during which reproductively active males were evident. Only one of the 41 males trapped was scrotal.

Mus musculus.—House mice were relatively unimportant in the mowed ROWs as they comprised only 7 percent of the rodent community. Thirty-five individuals were marked with 12 recaptures recorded. Mean population density during the seasons immediately before and after mowing was 2/ha. Density for winter and late summer was 2/ha; for all other seasons, density was 1/ha.

Male house mice significantly ($\chi^2 = 5.45$, $P < .025$) outnumbered females by 22 : 9. Although the only pregnancy recorded occurred in winter, two lactating females were taken during the fall and one during late summer. Single breeding males were taken in fall and late summer.

Reithrodontomys fulvescens.—Only two recaptures were recorded for 18 individuals marked. Mean population density before mowing was 2/ha. No fulvous harvest mice were trapped during spring. Densities for both fall and winter were 3/ha, whereas densities for both summer sessions were 1/ha.

None of the 11 males showed signs of breeding activities. The only two lactating females observed were trapped during the fall. No pregnancies were observed. The proportion of the sample participating in reproductive activities was only 11 percent.

Subadults were taken in the study area during fall, winter, and late summer, whereas adults were seen only during fall and winter. One juvenile was trapped during the late summer. However, young (as well as mature individuals) were present in the mowed ROWs during May, June, and July. I observed and apprehended as many as 10 individuals running through grass cuttings during observation of mowing of the 45 North and 2818 North grids.

Reithrodontomys montanus.—One montane harvest mouse collected in the median of the 6 North grid during May constitutes the only record of this species from the mowed ROWs habitat. Density for the spring season was 1/ha; for all others, 0/ha.

Perognathus hispidus.—Two recaptures were made of four hispid pocket mice marked. All activity of *P. hispidus*, as indicated by trapping records, occurred during fall and winter for which population densities were 1/ha. None were trapped during the spring or following mowing. These four mice, all males, exhibited no signs of recent breeding behavior.

Comparison of Unmowed and Mowed Rights-of-Way

Before mowing, cover provided by only one category (litter) differed significantly between the unmowed and mowed ROWs habitats. No significant differences were found between population densities of any rodent species occurring in these areas. Marked differences between the mowed and unmowed ROWs in both cover and rodent densities were evident following treatment of the mowed habitat. Only four vegetation categories (bluestem grasses, sedges and all other grasses, woody, and all woody material) were not significantly different between the areas. As woody plants were present along the roadside only in trace amounts, those categories probably have little bearing on diversity and abundance of rodents. Only S. hispidus occurred at significantly different densities between the habitats; densities of the other species (B. taylori, R. fulvescens, and M. musculus) were not significantly different.

Cover in both areas was similar before mowing (total cover for unmowed and mowed ROWs was 67 and 58 percent, respectively), but was markedly different between the two habitats after mowing (total cover for unmowed and mowed ROWs was 62 and 29 percent, respectively). Whereas overall rodent population density on the unmowed area increased from 35/ha (the mean of fall, winter, and spring values) to 80/ha during summer, a decrease from 23/ha to 17/ha was observed in the mowed ROWs during the corresponding period. During summer the two habitats differed in cover by 33 percent (62 percent in unmowed area as compared to 29 percent in mowed area) and in abundance of rodents by 63/ha (80/ha in unmowed ROWs as compared to 17/ha in mowed ROWs). Hence, a 53 percent reduction in cover resulted in a 79 percent reduction in density of the rodent community.

Fewer species were trapped in both unmowed and mowed ROWs during summer than during preceding seasons. The number of species trapped in the mowed areas decreased from six during winter and spring to four during summer. The number sampled in the unmowed ROWs dropped from seven during spring to four during summer (the same four species present on the mowed area during summer).

Differences were noted in the relative proportion of the rodent community comprised by each species in the two areas. Prior to mowing, approximately 60 percent of the community in both unmowed and mowed ROWs was comprised by S. hispidus. B. taylori comprised about 25 percent of the community while the other species each comprised 3 to 4 percent. The proportion of the rodent community comprised by S. hispidus in the unmowed ROWs increased to 96 percent during summer. A smaller increase (to 73 percent) occurred in the mowed ROWs following mowing. Both B. taylori and M. musculus occurred in greater absolute numbers in the mowed habitat after mowing than in the unmowed ROWs during the corresponding time interval.

Habitat of Preferences of Rodents

Old Fields

Cotton rat densities were negatively correlated with all categories of dead material (significantly with maximum herbaceous overstory) and woody material (Table 2). Although a positive correlation for all grasses is indicated, cotton rats appeared to avoid areas characterized predominantly by bluestem grasses. Positive correlations with forbs and dewberry were demonstrated.

B. taylori was negatively correlated with the all forbs and woody categories. Pygmy mice favored most grassy situations except bluestems.

Negative correlations were exhibited by *R. fulvescens* for all vegetation categories except dewberry for which correlation was positive. Significant positive correlations were obtained for the three categories of dead material.

One *R. montanus* was collected in a field supporting tall, dense stands of bluestems, a diverse array of forbs, and a moderate amount of dead material. Very little Johnsongrass or Bermudagrass grew in this area. One white-footed mouse and two deer mice were trapped within a stand of post oaks where the ground was covered with litter. The rice rat (*Oryzomys*) was captured in a low-lying field overgrown with dewberry vines and lesser amounts of forbs and bluestems.

Pasture

Densities of *S. hispidus* correlated significantly with the all forbs, all grasses, and woody categories (Table 2). Negative r-values were generated only for the dead material categories.

B. taylori habitat preferences were almost opposite those of cotton rats. The three dead material categories were rated as preferred habitat components. Pygmy mice avoided situations comprised of forbs, Bermudagrass, dewberry, and woody plants in the pasture habitat.

Table 2.—Correlation coefficients of population densities of rodent species with each of 14 vegetation categories for the old field and pasture habitats.

	Old Field			Pasture		
	Sigmodon hispidus	*Baiomys taylori*	*Reithrodontomys fulvescens*	*Sigmodon hispidus*	*Baiomys taylori*	*Reithrodontomys fulvescens*
Litter	-0.411	0.191	0.743**	-0.244	0.453*	0.569**
Middlestory	-0.385	0.181	0.753**	-0.153	0.487*	0.397*
Maximum herbaceous overstory	-0.491*	0.081	0.558*	0.000	0.414*	0.751**
Forbs	0.270	-0.134	-0.325	0.335	-0.091	-0.110
Bluestem grasses	-0.446	-0.174	-0.056	0.298	0.178	0.077
Johnsongrass	0.238	0.095	-0.164	0.000	0.000	0.000
Bermudagrass	0.189	0.066	-0.235	0.260	-0.203	-0.103
Sedges and all other grasses	0.296	0.092	-0.380	0.230	0.155	-0.186
Dewberry	0.047	-0.024	0.096	0.621**	-0.122	-0.081
Woody	0.042	-0.192	-0.242	0.394*	-0.118	-0.128
Summary Categories						
All dead material	-0.462	0.191	0.773**	-0.239	0.477**	0.570**
All forbs	0.045	-0.113	-0.127	0.456*	-0.109	-0.115
All grasses	0.150	0.030	-0.378	0.492**	0.157	-0.146
All woody material	-0.042	-0.192	-0.242	0.394*	-0.118	-0.128

*Significant at $P < .05$.

**Significant at $P < .01$.

Correlations of vegetation parameters with densities of *R. fulvescens* indicate that this species actively seeks habitat rich in dead plant material. In pastures, maximum overstory was more important for this species than any other. Negative correlations existed for all other categories except bluestem grasses.

Statistical correlations of vegetation with densities of three other species were not conducted due to small sample size. One *R. montanus* was collected in a pasture supporting paspalum, bluestems, a few mesquite trees, and moderate amounts of dead material. Bluestems, paspalum, and post oaks characterized the pasture in which the one *P. hispidus* was captured. One *M. musculus* was taken in an overgrazed pasture where smutgrass and forbs were the predominant vegetation.

Cultivated Fields

Too few rodents were taken in the cultivated fields for application of statistical techniques. *S. hispidus*, *B. taylori*, and *M. musculus* were present only during the two summer sessions, the only season during which sorghum was growing. A few other grasses and forbs were also present.

Unmowed Rights-of-Way

S. hispidus densities correlated positively with Johnsongrass and Bermudagrass (significant, $P < .01$) and negatively (significant) with "sedges and all other grasses" (Table 3). Positive r-values were calculated for the "all grasses" (significant) and "all dead material" categories. Correlations with other categories were negative.

B. taylori habitat preference was nearly opposite those of cotton rats. Vegetation of the all dead material category (significant, $P < .01$) as well as dewberry (significant) and forbs correlated positively with densities of pygmy mice. The only grasses to be positively correlated were those belonging to the "sedges and all other grasses" group.

Table 3.—Correlation coefficients of population densities of rodent species with each of 14 vegetation categories for the unmowed ROWs habitat.

	Sigmodon hispidus	*Baiomys taylori*	*Mus musculus*	*Reithrodontomys fulvescens*
Litter	-0.138	0.413**	-0.021	0.098
Middlestory	-0.166	0.223	-0.133	0.221
Maximum herbaceous overstory	-0.058	0.253	-0.126	-0.022
Forbs	-0.233	0.241	0.004	-0.094
Bluestem grasses	-0.139	-0.076	-0.071	0.240
Johnsongrass	0.253	-0.205	0.098	-0.137
Bermudagrass	0.461**	-0.300*	0.077	-0.195
Sedges and all other grasses	-0.301*	0.250	0.281*	0.052
Dewberry	-0.121	0.318*	-0.041	0.842*
Woody	-0.107	-0.051	-0.055	0.114
Summary Categories				
All dead material	0.142	0.404**	-0.043	0.117
All forbs	-0.246	-0.274*	0.001	-0.012
All grasses	0.328*	-0.249	0.147	-0.126
All woody material	-0.107	-0.051	-0.055	0.114

*Significant at $P < .05$.
**Significant at $P < .01$.

Negative r-values were computed for correlations of M. musculus densities with all dead material, bluestems, dewberry, and woody plants. The only significant, positive correlation was with the "sedges and all other grasses" category.

Dewberry is a primary component (significant, $P < .01$) of favored fulvous harvest mouse habitat. Dead plant material, woody plants, bluestems, and "sedges and all other grasses" were less important segments of the preferred habitat of R. fulvescens. Johnsongrass and Bermudagrass were the only negatively correlated grass categories.

Single specimens of three additional species (P. hispidus, R. montanus, and R. rattus) were captured in the unmowed ROWs habitat where the predominant plants were Johnsongrass, Bermudagrass, and forbs.

Mowed Rights-of-Way

All correlations of S. hispidus densities with vegetation parameters were positive except for Bermudagrass (Table 4). Significant positive correlations of cotton rat densities were observed with Johnsongrass ($P < .01$), forbs, and "sedges and all other grasses".

B. taylori preferred habitat in which both dead material (significant, $P < .01$) and forbs (significant) were major components. Dewberry and all grasses except the "sedges and all other grasses" category were negatively correlated.

No significant correlations between vegetation and population densities were observed for M. musculus. The following categories were positively correlated: middlestory, maximum herbaceous overstory, bluestems, and "sedges and all other grasses".

The three classes of dead material were significantly correlated to population densities of R. fulvescens. Positive correlations included "sedges and all other grasses", forbs, and bluestems.

One R. montanus was collected in an area sparsely covered by forbs and a variety of low-growing grasses. Four P. hispidus were trapped in an area densely covered by Johnsongrass, Bermudagrass, other grasses, and a diverse assemblage of forbs.

Table 4.—Correlation coefficients of population densities of rodent species with each of 14 vegetation categories for the mowed ROWs habitat.

	Sigmodon hispidus	*Baiomys taylori*	*Mus musculus*	*Reithrodontomys fulvescens*
Litter	0.023	0.361**	-0.010	0.279*
Middlestory	0.029	0.361**	0.256	0.464**
Maximum herbaceous overstory	0.141	0.325*	0.089	0.520*
Forbs	0.298*	0.426*	-0.029	0.128
Bluestem grasses	0.058	-0.103	0.022	0.016
Johnsongrass	0.591**	-0.002	-0.039	-0.116
Bermudagrass	-0.011	-0.078	-0.158	-0.145
Sedges and all other grasses	0.295*	0.263	0.055	0.226
Dewberry	0.015	-0.035	-0.025	-0.074
Woody	0.000	0.000	0.000	0.000
Summary Categories				
All dead material	0.017	0.411**	0.072	0.305*
All forbs	0.280*	0.363*	0.022	0.086
All grasses	0.258	0.022	-0.117	-0.044
All woody material	0.000	0.000	0.000	0.000

*Significant at $P < .05$.
**Significant at $P < .01$.

All Habitats Combined

Examination of results of correlations of overall rodent densities with overall cover provided by the various vegetative categories permits definition of habitat preferences of *S. hispidus*, *B. taylori*, *R. fulvescens*, and *M. musculus* (Table 5).

Cotton rats favored areas abundant in Johnsongrass and Bermudagrass; wooded areas were uncharacteristic of prime cotton rat habitat. Cover of favored pygmy mouse habitat was comprised predominantly of dead material, forbs, and species included in the "sedges and all other grasses" category. Generally, *B. taylori* avoided prime cotton rat habitat. Significant r-values indicate that *R. fulvescens* preferred areas covered by dead material and dewberry vines. Harvest mice avoided areas of Johnsongrass and Bermudagrass, but did show some preference for areas covered by bluestems. Characteristics of the habitats in which individuals of the less abundant species were caught are related in the preceding habitat accounts.

Highway Mortality

Combining all highways and all seasons, a total of 1,768 km (1,105 mi.) of roadway was observed for roadkilled animals. During all seasons, mammals comprised the vast majority of highway mortality victims, representing 186 individuals or 65 percent of the highway mortality (Table 6). The remaining 35 percent was apportioned nearly evenly between birds (49 individuals) and reptiles and amphibians (50 individuals). Both mammals and herptiles (reptiles and amphibians) exhibited similar patterns of seasonal variation, occurring least frequently as casualties during winter and most frequently during spring. Numbers of fatalities observed for birds increased steadily from a minimum during fall to a maximum during summer.

Table 5.—Correlation coefficients of population densities of rodent species with each of 14 vegetation categories for all habitats combined.

	Sigmodon hispidus	*Baiomys taylori*	*Mus musculus*	*Reithrodontomys fulvescens*
Litter	0.159	0.394**	-0.101	0.310**
Middlestory	-0.050	0.120	0.036	0.244**
Maximum herbaceous overstory	-0.036	0.155*	-0.024	0.352**
Forbs	0.093	0.315**	-0.052	-0.027
Bluestem grasses	-0.111	-0.069	-0.019	0.104
Johnsongrass	0.393**	-0.075	-0.007	-0.095
Bermudagrass	0.361**	-0.115	-0.113	-0.130
Sedges and all other grasses	-0.047	0.133	0.222**	0.038
Dewberry	-0.070	-0.003	-0.066	0.180*
Woody	-0.128	-0.093	-0.110	-0.014
Summary Categories				
All dead material	0.126	0.379**	-0.077	0.328**
All forbs	0.029	0.253**	-0.061	0.062
All grasses	0.318**	-0.037	-0.065	-0.067
All woody material	-0.128	-0.093	-0.110	-0.014

*Significant at $P < .05$.
**Significant at $P < .01$.

Table 6.—Total numbers of each species fallen victim to highway mortality along stretches of three highways in eastern Texas.

Species	Highway 6	Interstate 45	FM 2818	Total	Species	Highway 6	Interstate 45	FM 2818	Total
Mammals									
Armadillo	30	8	3	41	Mourning Dove	2	1	1	4
Opossum	37	9	5	51	Cardinal	2			2
Striped Skunk	13	4	3	20	Crow	1			1
Cottontail Rabbit	14	2	1	17	Green Winged Teal	1			1
Jackrabbit	1			1	Brown Thrasher	1			1
Cat	12	1	1	14	Painted Bunting		1		1
Dog	8	2		10	Domestic Chicken			1	1
Coyote	3			3	Unknown	6	1	1	8
Gray Fox	1			1	Total Birds	37	6	6	49
Raccoon	6	2		8	Reptiles and Amphibians				
Deer	6			6					
Cattle			1	1	Frogs and Toads	13	1	2	16
Gopher	1			1	Box turtle	8	3	5	16
Fox Squirrel	2			2	Other Turtles	7	2	2	11
Cotton Rat	11	1		12	Speckled Kingsnake	2			2
Total Mammals	145	29	14	188	Prairie Kingsnake	2			2
Birds					Coachwhip	2			2
Mockingbird	10			10	Copperhead	1			1
Meadowlark	3	1	1	5	Total Reptiles and Amphibians	35	6	9	50
Robin	4	1		5					
Sparrow	4	1	1	6					
Scissortail Flycatcher	3		1	4	Total All Animals	217	41	30	286

Frequency of Occurrence and Seasonal Variation

Mammals

Armadillos and opossums accounted for nearly half (49 percent) of the mammalian casualties. An additional 33 percent was comprised by striped skunks, cottontail rabbits, and domestic dogs and cats. The 11 cotton rats found dead composed 6 percent of the kill, while seven other species represented the remainder.

Table 7 presents seasonal mortality totals for each species of mammal found as highway casualities. Mammals suffered their fewest fatalities in winter and their greatest number during spring. Individuals of five species (opossum, striped skunk, cottontail rabbit, deer, and cotton rat) died on the roadways during all seasons. Armadillos, cats, and raccoons were killed in all seasons except winter. Fox squirrels were fatalities during summer and fall. Four species occurred as fatalities during only one season: jackrabbit, winter; gray fox, spring; gopher and cattle, fall. Dogs were killed during fall and spring; coyotes were struck by vehicles in fall and winter.

At this time, it is pertinent to note that the highway mortality data may not reflect a totally accurate assessment of the situation. Our data indicate that armadillos and opossums comprise about half of the road kill. Work by Dr. Aelred Geis of the U.S. Fish and Wildlife Service (personal communication) indicates that species such as opossums and skunks are not picked up by scavengers as quickly as other species. Another complicating factor is that many of the animals, especially small mammals and birds, may be totally obliterated before they can be discovered, or they could be easily missed. These types of problems should be considered in analyzing road kill data.

Birds

Mockingbirds were the most frequently (20 percent) observed avian casualities. Sparrows, meadowlarks, robins, scissortail

Table 7.—Total numbers of each species of mammal found dead on roadways by season. Data from Highway 6, Interstate 45, and FM 2818 survey lines combined.

Species	Fall	Winter	Spring	Summer	Total
Armadillo	9		19	13	41
Opossum	8	12	23	8	51
Striped Skunk	7	2	5	5	19
Cottontail Rabbit	3	6	3	5	17
Jackrabbit		1			1
Domestic Cat	7		2	5	14
Domestic Dog	5		5		10
Coyote	2	1			3
Gray Fox			1		1
Raccoon	4		2	2	8
Deer	2	1	2	1	6
Cattle	1				1
Gopher	1				1
Fox Squirrel	1			1	2
Cotton Rat	2	1	5	4	12
Totals	52	24	67	44	187

flycatchers, and mourning doves each occurred at approximately 10 percent. Birds of six other species comprised 14 percent; 16 percent was represented by individuals of unknown identity.

Both the number of species and number of carcasses increased steadily from fall, when three individuals of two species (mockingbird and meadowlark) died, into spring, when 15 individuals of seven species (sparrows, meadowlark, cardinal, mourning dove, mockingbird, brown thrasher, and painted bunting) died. The winter fatalities included nine birds of four species (robin, meadowlark, crow, and green-winged teal). The upward trend in numbers (18 individuals) continued into the summer although fatalities were of only four species (mockingbird, mourning dove, scissortail flycatcher, and sparrow).

Reptiles and Amphibians

Over half (54 percent) of the reptile and amphibian victims were turtles. An additional 32 percent was comprised of frogs and toads. Four species of snakes (speckled kingsnake, prairie kingsnake, eastern coachwhip, and southern copperhead) completed the list of herptile fatalities.

The fewest herptile casualties (one frog) occurred during winter. Frogs and toads died on the road during all seasons; half of the kill (eight individuals) occurred during spring. No turtles or snakes were killed during winter; 26 of the 27 turtle fatalities were divided evenly between the spring and summer. Three snakes died on the highway during spring and four during summer.

Comparison of Fatalities by Highway

The Highway 6 survey line was driven on 53 occasions for a total distance of 1,187 km[1] (742 mi.) during which 145 mammal, 37 bird,

[1] One km of highway refers to a cross-section of the ROW 1 km in length. For Highway 6 and Interstate 45, each 1 km segment includes 4 km of pavement--1 km each of the east and west access lanes and the north and southbound lanes; for FM 2818, a 1 km cross-section of ROW includes 1 km of pavement.

and 35 herptile carcasses were noted. "Susceptibility frequencies" (the number of dead per km of highway) for the three groups were 0.12, 0.03, and 0.03, respectively. The Interstate 45 and FM 2818 lines were surveyed 25 times each for cumulative distances of 381 km (238 mi.) and 200 km (125 mi.), respectively. Fatalities totaled 29 mammals (susceptibility frequency of 0.08), 6 birds (0.02), and 6 herptiles (0.02) along Interstate 45. Mammals (14 individuals), birds (6), and herptiles (9) died at rates of 0.07, 0.03, and 0.05 per km, respectively, on FM 2818.

Relationship of Traffic and Highway Mortality

The numbers of animals killed per km of ROW differed between facilities just as did traffic volumes. The mean daily traffic volume for the section of FM 2818 surveyed for carcasses was 2,800 vehicles; for Highway 6, 8,000 vehicles; for Interstate 45, 20,000 vehicles.[1] The susceptibility indices for birds and for reptiles and amphibians decreased steadily with increasing traffic volume. The least susceptibility of mammals was at the lowest traffic volumes; the intermediate value occurred at the highest volume. Most mammals died at the intermediate traffic densities. The general trend observed for all animals was that susceptibility was greatest at the intermediate traffic volume, least at the greatest volume, and intermediate at the lowest volume.

Distribution of Carcasses by Lane

Chi-squared statistics were calculated to test for evenness of distribution of carcasses between strips of pavement defined as the west access road, southbound lane, northbound lane, and east access road (ratios follow preceding lane sequence). Distribution of mammal carcasses on Highway 6 (32 : 34 : 49 : 26) deviated slightly

[1]Sources of figures are Texas State Department of Highways and Public Transportation traffic maps and use of traffic counters.

(χ^2 = 8.2, significant) from the expected 1 : 1 : 1 : 1 ratio. Much greater deviation was observed on Interstate 45 where the ratio was 1 : 11 : 14 : 2 (χ^2 = 17.7, significant, $P < .005$). It is questionable whether a 1 : 1 : 1 : 1 ratio should be expected for the access roads and main lanes of the major routes. The main lanes are bound by relatively narrow strips of vegetation while the access roads are bounded on one side by a large vegetated area; therefore, the number of species which have access to the road will vary. In addition, drainage characteristics might be expected to be different, thereby causing a difference in response by the animals due to the difference in habitat.

Avian carcasses were distributed evenly across the lanes. Ratios for both Highway 6 (13 : 7 : 9 : 5, χ^2 = 4.3) and Interstate 45 (1 : 2 : 2 : 1, χ^2 = 0.16) were not significantly different from the expected proportion.

Distribution of reptiles and amphibians on Highway 6 (12 : 7 : 2 : 11) differed significantly (χ^2 = 12.6) from the expected. However, the 2 : 3 : 0 : 1 proportion (χ^2 = 3.3, non-significant) recorded for Interstate 45 fit the expected 1 : 1 : 1 : 1 ratio.

Dispersal Across Pavements

Although 10 species of rodents were sampled during the study, trapping records indicated that only cotton rats and pygmy mice crossed highway pavements. This does not, however, preclude road crossings by the remaining eight species.

Baiomys taylori

According to trapping records, only five (2 percent) of the 272 pygmy mice trapped crossed roadways. All were crossings of one lane within the 6 South grid. An adult female traversed the east access road sometime between early November and late January in relocating from the EF to the EROW. Four adults, two males and two females, crossed the west access road. A pair of these mice moved from the

WF to the WROW; the male relocated during February whereas the female moved sometime between February and August. During October a female migrated to the WP from the WF. The fourth pygmy mouse crossed from the WROW to the WF between mid-November and late January.

Sigmodon hispidus

Fig. 8 depicts highway crossings for cotton rats with data compiled and analyzed so the effects of (1) habitat treatment (mowed vs. unmowed), (2) sex (male vs. female), and (3) age classification (juvenile vs. subadult vs. adult) on dispersal can be visualized. The upper graph shows percentages of populations involved in crossings; the lower graph shows numbers of rodents involved in crossings. Of the 1,532 S. hispidus marked, only 86 (5 percent) were known to cross pavements. Six of these dispersing cotton rats crossed the northbound lane from the EF to the median of the 6 South grid following an unauthorized mowing of the EF during November. These six rats (representing 30 percent of the EF population) apparently established residences in the median because they were continuously recaptured there for several months.

Differences between unmowed and mowed Rights-of-Way.—During all seasons, at least twice as many cotton rats crossed roadways within the unmowed grids (60 individuals) as in the mowed grids (26 individuals). The rodents crossing in the unmowed grid consistently represented a greater percentage of the population than did those crossing in the unmowed grid (Fig. 8). The season during which the greatest proportion of the populations in both the unmowed and mowed habitat crossed highways was spring. Summer dispersal involved more individuals in both areas than during any other season. However, smaller percentages of populations in both unmowed and mowed ROWs crossed during summer than in spring. The smallest seasonal percentage of the unmowed ROWs populations crossed roads during summer; during the same season, the second largest seasonal percentage of unmowed ROWs populations traversed pavements.

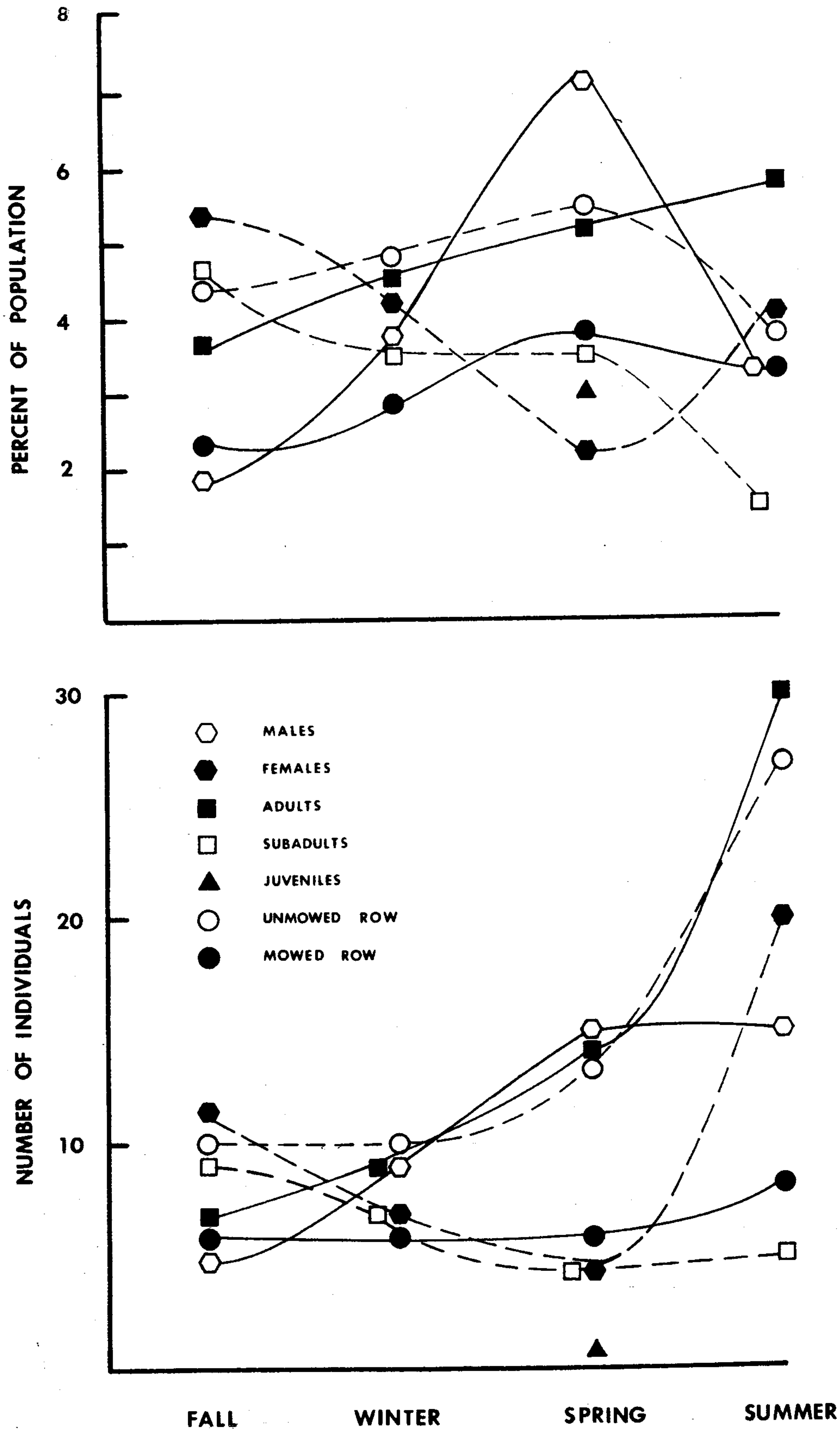

Fig. 8.--Seasonal variation in movements of <u>Sigmodon hispidus</u> across highway pavements. Differences by sex and age class of animals as well as differences between unmowed and mowed ROWs are depicted. Percent of population crossing (upper graph) corresponds with numbers of individuals crossing (lower graph) from one grid section to another.

Differences between the sexes.—Annual mean percentage of population involved in dispersal across roadways was 4 percent for both sexes although each sex showed different patterns of seasonal variation. The proportion of crossing males peaked at 7.1 percent (15 individuals) during spring with the least frequent crossing (five rodents representing 1.9 percent) during fall. Intermediate values, 3.8 percent (nine individuals) and 3.3 percent (15 individuals), were recorded for winter and summer, respectively. The greatest percentage of females (11 individuals representing 5.4 percent) migrated during fall when the fewest males traversed pavements. During the spring, when the greatest percentage of males crossed, the fewest females (four individuals representing 2.2 percent) crossed. Proportions of crossing females for summer and winter were 4.0 percent (20 individuals) and 4.2 percent (seven individuals), respectively. Annual totals of crossing individuals were nearly evenly divided between the sexes as follows: males, 44; females, 42.

Differences between age classes.—Even distribution between age classes of animals engaged in crossing activities was not observed. The one juvenile (representing 3.0 percent of the population of the grid section from which it migrated) determined to have crossed the roadway did so during spring. A total of 25 subadults ventured across pavements during the study. The highest percentage activity (4.5 percent) occurred during fall when nine subadults traversed the roadway. Seven subadults crossing during winter and four dispersing during spring represented 3.5 percent of the populations present during these seasons. Although the number of subadults present during the summer was at least 50 percent greater than during any other season, the smallest proportion of same (four individuals representing 1.9 percent of subadult population) were involved in crossing efforts. Adults comprised 70 percent of all cotton rats traversing highway lanes. Both absolute numbers and percentages of crossing adults increased from minimum values in fall (seven individuals representing 3.7 percent) to maximum values in summer (30 individuals representing 5.9 percent). Mean proportion of individuals of each age class participating in road crossing activities was as follows: juveniles, less than 1 percent; subadults, 3.3 percent; adults, 4.9 percent.

Magnitude of crossings.—Crossings of four magnitudes were recognized on the basis of the number of lanes traversed. An inverse relationship existed between the magnitude of a crossing and the number of crossings of a given magnitude, that is, the fewer the number of lanes crossed, the greater the number of crossings. A total of 47 of the 86 crossings (55 percent) entailed traversing one lane of traffic while an additional 18 (21 percent) were of the two-lane variety. The remaining 24 percent of the migrations included 16 crossings involving three lanes and five involving four lanes.

Multiple crossings.—Nine cotton rats engaged in multiple road crossings. Eight of these crossed pavements on two occasions which were separated by as little as one or two days or as much as six months. Another rat, an adult female, migrated between the EF and the median of the 6 South grid on four separate instances between early November and late January. Multiple crossings seem to be the exception rather than the rule.

DISCUSSION

Grid Studies

Habitats Outside Highway Rights-of-Way

Separate presentation of results for the old fields, pastures, and cultivated fields illustrates the effects of different habitat management practices on plant and animal communities. Both plant diversity and cover were greatest in the old fields. Only two plant groups (grasses and forbs) characterized the cultivated fields which was the least densely covered habitat. Cover and plant diversity in the pastures were intermediate to the other two habitats. Similar trends were observed between these habitats in species richness and species densities of rodent communities. The fewest species and lowest densities characterized the cultivated field habitat. The number of species and community density were greatest in the old fields.

Odum (1971) noted that diversity of herbivorous animals (rodents) which depend on plants for food and shelter fluctuates according to the diversity of the plant community. Generally, cultivation and severe overgrazing reduce plant species richness from more species in undisturbed areas (old fields) to fewer species in disturbed areas (cultivated fields and pastures).

Habitats Within Highway Rights-of-Way

Effects of Mowing on Vegetation and Wildlife

One manner in which mowing affected vegetation along highway ROWs is obvious. The plants were uniformly cut at 7 cm (3 in.) to 10 cm (4 in.) above the ground to achieve an attractive lawn-like appearance. However, cutting plants before they flower and produce seeds interrupts their reproductive cycles. Some plants may recover sufficiently to re-initiate and complete reproductive activities before the next mowing. To survive, annual plants must produce seeds since the entire plant dies at the end of the growing season.

Alteration of habitat by mowing roadside vegetation has more far-reaching effects than simple modification of plant height. Either directly or indirectly, all species of wildlife are influenced by changes in habitat. Cover provided by plants is essential to wildlife in several respects. Cover provides wildlife with sites in which to locate shelters. Entrances to dens of such animals as armadillos, opossums, carnivores, and rodents can be easily disguised in thickets or tall grass. Many ground-nesting birds (meadowlarks, pheasants, etc.) as well as numerous species of small rodents (S. hispidus, B. taylori, O. palustris, and R. montanus) utilize dense cover on the ground surface for nesting sites. Other species, particularly R. fulvescens, P. leucopus, and P. maniculatus, build nests in shrubs and trees. Cover also aids in protection of prey species from predators either by obstructing the vision of the predator or by providing a safe retreat from predators.

Many species of wildlife, including all rodents trapped during this study, feed almost entirely on plant material. S. hispidus is primarily a grass-eater while P. leucopus, P. maniculatus, P. hispidus, and B. taylori feed mainly on seeds. The diet of the other rodents surveyed along the roadsides consists of both seeds and the vegetative parts of a variety of plants (Davis, 1974). Hence, when attempting to assess the impact of habitat disturbances on the surrounding biotic community, the logical group of animals to monitor is that trophically most closely associated with the segment of the habitat being disturbed.

The observed decrease in number of species present in both unmowed and mowed ROWs from winter into summer is probably related to seasonal activity patterns of rodents as influenced by food and water availability and body temperature regulatory mechanisms (Davis, 1974). This phenomenon is commonly observed by mammalogists. This statement should not be construed as meaning that mowing has no effect on the species present or on rodent densities. Data collected in this study suggest that S. hispidus is adversely affected by mowing, while B. taylori and M. musculus are favorably affected by mowing. The amount of cover and diversity of vegetation in an area determines which species will inhabit an area as well as their population densities (Odum, 1971).

Habitat Preferences of Rodents

Davis (1974) described prime S. hispidus habitat as areas supporting tall stands of bluestem grasses. In this study, bluestems appeared to be the least important of the three major grass species. More cotton rats were trapped in areas densely covered by Johnsongrass and Bermudagrass than in stands of bluestems. Forbs also seem to be a minor component of prefered cotton rat habitat.

The plant species present in any habitat are undoubtedly important in determining the diversity and abundance of rodents residing therein. However, the plant structure as it contributes to cover is probably more important. Hence, cotton rats occur in tall stands of many grass species.

Pygmy mice are more generalized in their habitat tolerances. Pygmy mice were taken in all habitats including the most densely covered grid sections as well as the most sparsely covered areas. Davis (1974) reports their preferred habitat to be low areas supporting stands of grasses (especially bluestems) and weeds. In this study, they were taken on well-drained roadside embankments as well as in low-lying areas.

Fulvous harvest mice locate their nests within shrubs and clumps of bluestems which dot grassy or weedy areas (Davis, 1974). More R. fulvescens were taken in habitats characterized by bluestems, paspalum, and forbs than in other areas. Like B. taylori, harvest mice occurred in a variety of habitats.

House mice are usually associated with buildings although they may occur anywhere vegetation is dense enough to afford concealment (Davis, 1974). This species occurred in all habitats sampled in this study. *M. musculus* was plentiful in only one grid (2818 North) where dense cover was provided by dead material, forbs, a variety of grasses (including Johnsongrass, Bermudagrass, and bluestems), and dewberry.

Highway Mortality

Frequency of Occurrence and Seasonal Variation

Mammals

Most seasonal variation in frequency of fatalities of animals can be explained by examining general aspects of their life history. A reduction in activity during winter is characteristic of many species of mammals although winter climate in eastern Texas is generally not severe enough to induce prolonged periods of torpor in those species most frequently found as roadkill victims. Raccoons are among the species which Davis (1974) reports to "hibernate" or "hole up" duringwinter; no raccoon carcasses were observed during winter. Year around activity patterns characterize the four most frequently killed mammals: armadillos, opossums, striped skunks, and cottontail rabbits. Individuals of the latter three species became victims of traffic throughout the year while armadillos succumbed to traffic in all seasons except winter. This represents an interesting correlation of the winter lifestyle of the armadillo with roadkill frequency. During the warmer months armadillos are active at night, the hours when most animal-vehicle collisions occur. Their peak activity period in winter is daytime. This interesting reversal of behavior is a response to an inability of the armadillo to retain body heat (due to an almost complete lack of hair) during cold winter nights (Davis, 1974).

Ten of the 12 mammalian species observed as roadkills breed at sometime during the period between late January and April or May (Davis, 1974). Only armadillos and white-tailed deer mate during fall and early winter. Only three species (gray fox, oppossum, and cotton rat) which breed during spring experienced highs in highway mortality during the same season. The only fall-breeding species to suffer its highest seasonal roadway casualties during fall was the white-tailed deer. Periods of greatest roadkill frequency were asynchronous with breeding seasons in the remaining eight species. This observation disagrees with those of numerous authors who have postulated that highway mortality was greatest for a species during its breeding season (Bellis and Graves, 1971a; Brockie, 1960; Davis, 1946; Haugen, 1944; Jahn, 1959).

Of those remaining eight species, five (striped skunk, coyote, raccoon, fox squirrel, and gopher) experienced their highest seasonal mortality during fall, when young of the year disperse in search of their own individual territories. Davis (1940) wrote of this occurrence in opossums in Brazos County. Armadillos, opossums, and gray foxes died more frequently on the pavements during spring than any other season. Cottontails and jackrabbits, both year around breeders, died on the roads most frequently during winter when food was in minimal supply. Being denizens of grassy areas, rabbits come into direct competition with livestock in grazed areas. Hence, they may often relocate to the highway ROWs where greater amounts of forage are available. Existence in close proximity to the pavements enhances chances of becoming a road fatality (Davis, 1940).

Birds

Seasonal tallies of bird losses were commensurate with specific migratory patterns (McClure, 1951); that is, only during those seasons when a species was present in the area did members of that species become highway casualties. Reckless behavior of breeding birds during the mating season doubtless accounts at least partially for increased fatalities during spring (Hodson, 1960). Cottam (1931), Flint (1926), and Shadle (1930) noted that oftentimes as many as 50 percent of the summer bird casualties are the awkward, slow, and inexperienced juveniles. Species most frequently observed as fatalities in this study (mockingbirds, sparrows, mourning dove, meadowlark, robin,and scissortail flycatcher) were frequently observed feeding along roadsides. Although crows and vultures frequented the roadsides, they rarely died on the highways.

Reptiles and Amphibians

Herptiles occurred least often as roadkills during winter. Being poikilotherms, herptiles are inactive during the winter months, although during warmer winter days they occassionally arouse to forage (Porter, 1972). During the spring breeding season many individuals travel outside their normal territories in search of mating partners (Goin and Goin, 1971; Porter, 1972). For those herptiles residing near highways, answering mating calls of individuals on the other side of they highway places them in potentially hazardous situations. Hodson (1966) reported that 130 of 191 frogs (*Rana temporaria*) killed on an English roadway in 1959 died during March and April at the height of the spawning season (see also Hodson, 1960 and McClure, 1951). Hence, highway casualties for herptiles were greatest during spring. Their second greatest losses occurred during summer when young born in spring were dispersing to establish their own territories.

Comparison of Fatalities by Highway

Susceptibility frequencies can be used to compute projected annual wildlife kills for each of the highways surveyed. If the Highway 6 line were surveyed daily for a year (total distance of 8,176 km or 5,110 mi.), the estimated mortality would be 1,511 individuals broken down as follows: 999 mammals; birds, 256; herptiles, 256. Daily observation of the Interstate 45 transect (5,549 km or 3,468 mi.) would likely include 444 mammals, 111 birds, and 111 herptiles for a total of 666 individuals. By surveying the

FM 2818 line daily for a year (3,504 km or 2,190 mi.), approximately 507 carcasses (245 mammals, 105 birds, and 157 herptiles) should be observed. These projected losses are based on sampling during all seasons and under a variety of weather conditions. Some deviation would be expected.

Relationship of Traffic and Highway Mortality

A direct relationship between vertebrate susceptibility and traffic volume at low and intermediate volumes was observed. Assuming equal numbers of animal crossings at the two traffic volumes, an increase in animal-vehicle encounters with increasing traffic volume would be expected. However, an inverse relationship was observed between these parameters at moderate and high traffic volumes. These data suggest that the number of road crossings did not increase or remain constant with increasing traffic volume.

Two explanations may be postulated to explain these observations. First, animals are cognizant of the increasing danger concomitant with increasing traffic volume, and therefore, they make conscious efforts to avoid ROWs,or those that cross are more successful in dodging vehicles. Second, certain characteristics of highway design necessitated in construction of roadways which handle varying traffic loads may influence the numbers of individuals of a given species occurring along roadsides, and,consequently, their frequency of occurrence as fatalities. For example, the greater the traffic volume, the more lanes are present and the wider the ROWs. Wider ROWs enhance the separation of the once continuous native habitat into two discontinuous areas by what may be a complete barrier to some species and which, to some extent, probably discourages road crossing by most others. Generally, more intense maintenance practices, and, consequently, continuous setbacks in attempts of the habitat to return to its natural state, are associated with the major thoroughfares.

Because most species of mammals are nocturnal, a logical conclusion would be that the greatest number of fatalities would occur along highways characterized by heaviest nighttime traffic. This relationship was observed when considering only FM 2818 (a highway characterized by heavy rush hour traffic and light nighttime volumes) and Interstate 45 (a highway with nearly equal hourly traffic volumes throughout the day and night). Comparison of fatalities along Highway 6 (also characterized by heavy rush hour and light nighttime traffic) with Interstate 45, however, shows the opposite relationship. Hence, the number of animals killed appears to be more dependent on traffic volume than traffic patterns.

Distribution of Carcasses by Lane

Distribution of carcasses across the four lanes of pavement on the Highway 6 and Interstate 45 survey sections correlated with both traffic volume and locomotary ability of the animals. Snakes, frogs, and turtles travel slowly and awkwardly in comparison with other vertebrates. Along Highway 6, more herptiles died on each access lane than on the two main lanes combined, whereas on Interstate 45 the combined losses for the access lanes equalled that of the main lanes. The probable cause for the difference is that the Highway 6 access roads are much more heavily travelled (mean of about 500 vehicles/day) than are those along Interstate 45 (about 100 vehicles/day).

Since mammals are generally much more agile and mobile than herptiles, a more even distribution of carcasses was expected for mammals. This expected relationship was observed on Highway 6 where use of access roads is heavy. The occurrence of the overwhelming majority of mammal carcasses on the main lanes of Interstate 45 was probably because markedly fewer vehicles utilize access roads as compared to main lanes.

Bird carcasses were distributed evenly between lanes. Their ability to fly enables them to reach any area of the ROWs without walking across the pavements. Nevertheless, many low-flying and inattentive birds were killed.

Impact of Highway Mortality on Wildlife

An expected benefit of marking rodents was that rodents killed on the roadway within the grids could be identified and the impact of their deaths on the population could be quantified. This benefit was never realized as none of the nearly 2,000 marked rodents and no unmarked rodents were found dead on sections of roadway within the grids. Cotton rats, the only censused rodent species observed as fatalities, died at a rate of 0.007 individuals per km (0.011 individuals per mi.) along stretches of road outside the grids (calculated from 12 dead rats found in 1,768 km or 1,105 mi. of driving). The six grids combined bounded 0.81 km (0.50 mi.) of roadway. At the rate of 0.007 dead rats per km, the number of rodents expected to die within the 0.81 km of road enclosed within the grids would be 0.006. Rounding to the next higher integer, the loss of one individual from about 2,000 known to be present represents an annual mortality loss of 0.05 percent of the population--almost certainly a negligible portion of the population.

Because population estimates were not made for species other than rodents, the absolute effect of highway mortality on those species cannot be assessed. Some observations of impact of highway mortality on other species, particularly other mammals, can be made based on population densities known for those species in relation to those of rodents in this study. Whereas rodents may occur in densities of about 50/ha, larger species are less abundant. In eastern Texas, opossums occur in densities ranging from one individual/2ha to one individual/13ha (Davis, 1974). Densities of cottontail rabbits are about 1/2 ha (Betsill, 1976). Although rodents were by far the most abundant vertebrate group present in the trapping areas, rodents experienced less absolute loss to highway mortality (12 individuals) than did most other groups of animals, and probably less proportionate loss than any species. A total of 56 carnivores died on the road as did 51 opossums, 59 birds, 41 armadillos, 27 turtles, 18 rabbits, 16 frogs, 7 snakes, and 7 ungulates. Hence, highway mortality probably impacts populations of animals which are more wide-ranging and less abundant more than it does rodents.

Dispersal Across Pavements

Sigmodon hispidus

Differences between unmowed and mowed Rights-of-Way.—Analysis of dispersal data indicates that cotton rats living in sparsely covered areas (mowed ROWs) are as likely to cross roads as rodents residing in densely covered areas (unmowed ROWs). Support for this statement derives from examination of mowed and unmowed ROWs curves in the percentage graph in Fig. 8. Percentage involvement in crossing during summer decreased to nearly equal values in both areas. Hence, amount of cover in an area does not appear to influence movements of rodents. Crossing behavior may be regulated by tendencies inherent to the individual, by pressures exerted by the population on individuals, or by some other source.

However, abrupt reduction in amount of cover (e.g.: unauthorized mowing of EF of 6 South grid) promotes dispersal of large proportions (30 percent) of populations across roadways. For mowing to promote dispersal, rodents must be present in the area subjected to mowing. Therefore, mowing schedules should be arranged in such a manner that, between mowings, habitat is permitted to recover to produce sufficient cover and food supply to attract and harbor large numbers of rodents.

Difference between sexes.—The asynchronous male and female road crossing behavior may be related to reproductive activity patterns. As shown in this study, two major mating seasons exist — one in late winter and early spring and another in early summer. During these periods equal percentages of males and females crossed roadways. However, during spring when females began to drop young, very few females crossed pavements. They probably remained closer to their nests during this time to protect their young. Although more pregnancies were noted in early summer than in spring, female involvement in crossings increased during summer possibly as an indication of efforts to mate again. Why such a large portion of the male population (7.1 percent) crossed highway lanes in spring is not understood.

Differences between age classes.—Intuitively, more young and subadults than adults might be expected to cross roadways in their efforts to establish their own territories. Since nearly twice as many crossings were made by adults than by other age classes combined, it appears that such is not the case. An alternative hypothesis, not tested in this study, is that crossing activities are prompted by urges to locate mating partners.

Comment.—Acceptance of results and discussion concerning dispersal across pavements must be tempered with the following thoughts. In most cases, the exact date of crossing was unknown; hence, the date assigned to each crossing was the month midway between the final capture in one grid section and the initial capture in another. An error of one month might result in the incorrect seasonal placement of a crossing event. The second reason for caution is that the number of individuals found to be crossing pavements may be a function of nothing more than the cumulative number of animals marked at a given point in time. This is a plausible explanation for the occurrence of fewest dispersals in fall and most during summer.

Effectiveness of Highways as Barriers to Dispersal

Road crossing in animals other than rodents was not monitored in this study. However, the presence of carcasses on roads indicates that other species attempt crossings. Incidental observations of various animals (deer, armadillos, opossums, dogs, turtles, etc.) crossing pavements show that highways do not effectively isolate populations of larger species of wildlife. The effectiveness of highways as barriers to dispersal of mammals is probably inversely proportional to size of the animal.

Genetic considerations.—Prior to highway construction, all rodents of a given species in the vicinity of the proposed highway site probably comprised one large population. Following construction and re-vegetation of the ROWs, pavements divided the large population into five less-widely ranging subgroups situated in the median, the east and west frontage areas, and the areas outside each access road. Assuming random mating, the large population was at equilibrium. This implies that no change in genotypic proportion or gene frequencies occurs from generation to generation (from the Hardy-Weinbery Law, p. 3 in Li, 1955). Assuming uniformity of habitat, selection pressures, and mutation rates as well as absence of geographic barriers within the range of that population, any sizable subgroup of that population would have the same gene frequencies as the population. After one generation of random mating, each subgroup would exhibit the same genotypic proportions as the population. Therefore, gene frequencies and genotypic proportions of all subgroups should be identical. Various selective pressures associated with the highway could affect the equilibrium of any of those subgroups residing adjacent to the highway if two conditions were met. First, there must be no individuals migrating between subgroups so that each subgroup is genetically isolated from the others. Second, the number of breeding individuals in each subgroup must be small. Under such conditions, random mating of N individuals would eventually result in loss of heterozygosity at the rate of 1/2N per generation. The fewer the number of mating individuals, the more quickly complete homozygosity would be attained.

The two above conditions are not representative of the present situation, however. A large number of individuals (at least 155 cotton rats occurring with a mean density of 48/ha in the unmowed habitat) occurred in each of the three areas (median and east and west frontage areas) whose boundaries are defined by adjacent pavements (mean width of 20 m) and by consecutive overpasses or crossovers (mean length of about 1.6 km or 1 mi.). In those areas outside of the access roads, N is much greater than 155 individuals since width of the areas is practically unlimited. Although the areas are physically separated, the subgroups are not genetically isolated since approximately 5 percent of the animals migrated between subgroups. After one generation, the variance in gene frequency ($\sigma^2 q$) among the subgroups of the population will reduce to (1-m) $\sigma^2 q$ where m is the portion of the population involved in migration (p. 302, in Li, 1955). So, the greater the involvement in migration, the fewer are the number of generations required before all subgroups achieve equal gene frequencies.

These considerations seem to suggest that, although highways serve as partial barriers to dispersal, flow of genes between semi-isolated segments of the entire population continues due to migration.

SUMMARY

Numerous species of wildlife occur along highways investigated in this study. Many medium and large sized animals frequent the roadsides during the course of their daily or nightly activities, although their dens or nests are often situated away from the highway. Some of these transient species (especially predators and scavengers) utilize the roadway as a feeding area since carrion comprises a major part of their diets. Smaller species (especially rodents) apparently spend their entire lives within the bounds of ROWs since the habitat present adequately supplies their food and shelter needs.

Since vegetative cover is important to all wildlife species, habitat management has profound effects on the diversity and abundance of animals in a given area. In areas with less cover (mowed ROWs), fewer species were present and species densities were lower than in areas with greater amounts of cover (unmowed ROWs). However, those species preferring sparse cover were often more abundant in the mowed ROWs than in the unmowed ROWs. Similarly, the unmowed ROWs supported greater numbers of species favoring denser cover. Both unmowed and mowed ROWs supported more species of rodents than did highly impacted areas outside the ROWs (pastures and cultivated fields). The greatest number of species occurred in the least impacted habitat (old fields). Densities of those rodent species occurring in all habitats were greatest within the unmowed ROWs.

The types of vegetation occurring in an area influence the diversity and abundance of wildlife. For example, forest-dwelling species were never trapped within the ROWs since no trees grow there. Species preferring habitat characterized by bluestem grasses were taken less often in stands of Johnsongrass or Bermudagrass. The knowledge of such habitat preferences permits modification of land management practices (mowing) to regulate the diversity and abundance of wildlife in a given area.

Less than 1 percent of the rodent community living along the highway died due to highway mortality. Intuitively, loss of such a small portion of the community would have little impact on the stability of the community. Relative impact of highway mortality on populations of mammals larger than rodents is probably greater than impact on rodents. Correlation of fatalities with traffic volumes indicated that the number of fatalities decreases as traffic volume increases.

Fewer than 6 percent of the marked rodents crossed roadways under normal conditions. Under stress conditions (immediately following mowing), however, greater proportions of populations crossed pavements in search of suitable habitat in which to re-establish residence. As a result of this migration, highways do not constitute a barrier to gene flow between populations of rodents or the larger species on opposite sides of the facility.

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APPENDIX A. Common and scientific names of vertebrates used in text.

Common Name	Scientific Name
	Reptiles and Amphibians[1]
Common Frog	*Rana temporaria*
Snapping Turtle	*Chelydra serpentina*
Mud Turtles	*Kinosternon* sp.
Iguanid Lizards	Family Iguanidae
Eastern Coachwhip	*Masticophis flagellum flagellum*
Prairie Kingsnake	*Lampropeltis calligaster calligaster*
Speckled Kingsnake	*Lampropeltis getulus holbrooki*
Southern Copperhead	*Akistrodon contortrix contortrix*
	Birds[2]
Green-winged Teal	*Anas carolinensis*
Buzzards or Vultures	Family Cathartidae
Hawks	Family Accipitridae
Ring-necked Pheasant	*Phasianus colchicus*
Domestic Chicken	*Gallus gallus*
Mourning Dove	*Zenaidura macroura*
Owls	Families Tytonidae and Strigidae
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Scissortail Flycatcher	*Muscivora forfic*
Common Crow	*Corvus brachyrhynchos*
Mockingbird	*Mimus polyglottos*
Brown Thrasher	*Toxostoma rufum*
Robin	*Turdus migratorius*
Eastern Meadowlark	*Sturnella magna*
Cardinal	*Richmondena cardinalis*
Painted Bunting	*Passerina ciris*
Sparrows	Family Fringillidae
	Mammals[3]
Virginia Opossum	*Didelphis virginiana*
Nine-banded Armadillo	*Dasypus novemcinctus*
Eastern Cottontail	*Sylvilagus floridanus*
Black-tailed Jackrabbit	*Lepus californicus*
Woodchuck	*Marmota monax*
Ground Squirrels	*Spermophilus* spp.
Fox Squirrel	*Sciurus niger*
Southern Pocket Gopher	*Thomomys umbrinus*
Plains Pocket Gopher	*Geomys bursarius*
Hispid Pocket Mouse	*Perognathus hispidus*

APPENDIX A. Continued.

Common Name	Scientific Name
Marsh Rice Rat	Oryzomys palustris
Plains Harvest Mouse	Reithrodontomys montanus
Fulvous Harvest Mouse	Reithrodontomys fulvescens
Deer Mouse	Peromyscus maniculatus
White-footed Mouse	Peromyscus leucopus
Northern Pygmy Mouse	Baiomys taylori
Hispid Cotton Rat	Sigmodon hispidus
Meadow Vole	Microtus pennsylvanicus
Black Rat	Rattus rattus
House Mouse	Mus musculus
Old World Porcupines	Thecurus spp., Hystrix spp., Atherurus spp., and Trichys spp.
Coyote	Canis latrans
Domestic Dog	Canis familiaris
Gray Fox	Urocyon cinereoargenteus
Ringtail	Bassariscus astutus
Raccoon	Procyon lotor
Weasels	Mustela spp.
Badger	Taxidea taxus
Striped Skunk	Mephitis mephitis
Other Skunks	Spilogale spp., Mephitis spp., and Conepatus spp.
Domestic Cat	Felis domestica
African Elephant	Loxodont africana
White-tailed Deer	Odocoileus virginianus
Domestic Cattle	Bos sp.

[1]Nomenclature of reptiles and amphibians follows Conant (1975).

[2]Avian nomenclature follows Peterson (1963).

[3]Mammalian nomenclature follows Jones et al. (1973) except for Old World species where Walker (1975) is followed.

APPENDIX B. Common and scientific names of plant species used in text.

Common Name	Scientific Name[1]
Cedar or Juniper	*Juniperus* sp.
Sedges	Family Cyperaceae
Chasmanthium	*Chasmanthium* sp.
Texas Wintergrass	*Stipa leucotricha*
Purpletop	*Tridens flavus*
Smutgrass	*Sporobolus indicus*
Bermudagrass	*Cynodon dactylon*
Switchgrass	*Panicum virgatum*
Dicanthelium	*Dicanthelium* spp.
Paspalum	*Paspalum* spp.
Knotroot Bristlegrass	*Setaria geniculata*
Sandbur	*Cenchrus* spp.
Sorghum	*Sorghum bicolor*
Johnsongrass	*Sorghum halepense*
Indiangrass	*Sorghastrum* sp.
Little Bluestem	*Schizachyrium scoparium*
Silver Bluestem	*Bothriochloa saccharoides*
Other Bluestems	*Andropogon* spp.
Elms	*Ulmus* spp.
Dewberry	*Rubus trivialis*
Honey Mesquite	*Prosopis glandulosa*
Hickory	*Carya* spp.
Post Oak	*Quercus stellata*
Blackjack Oak	*Quercus marilandica*
Coralberry	*Symphoricarpos orbiculatus*

[1]Plant nomenclature follows Reeves (1972) and Gould (1975).

APPENDIX C

Seasonal percent ground surface covered by each of the 14 vegetative categories in each of the habitat types.

Table 1.—Percent of ground surface covered by each of 14 vegetation categories in the old field habitat.

Plant Categories	Winter	Spring	Early Summer	Late Summer	Mean
Litter	39.2	33.4	23.6	17.5	28.4
Middlestory	7.3	4.1	1.6	1.0	3.5
Maximum herbaceous overstory	2.2	1.4	0.4	0.1	0.9
Forbs	0.6	5.6	8.9	7.4	5.6
Bluestem grasses	0.4	7.8	1.9	1.2	2.8
Johnsongrass	0	0.1	0	0.1	0.1
Bermudagrass	0	0.4	0.2	0.2	0.2
Sedges and all other grasses	1.1	10.5	16.2	21.2	12.2
Dewberry	8.2	13.7	8.4	7.2	9.4
Woody	0.8	3.7	3.8	5.5	3.4
Summary Categories					
All dead material	48.6	40.8	25.5	18.7	33.4
All forbs	8.8	26.8	17.3	14.6	16.9
All grasses	1.5	15.6	18.4	27.6	14.6
All woody material	0.8	3.7	3.8	5.5	3.4

Table 2.—Percent of ground surface covered by each of 14 vegetation categories in the pasture habitat.

Plant Categories	Winter	Spring	Early Summer	Late Summer	Mean
Litter	17.9	10.0	3.1	8.1	9.8
Middlestory	2.5	0.5	0.1	0.1	0.8
Maximum herbaceous overstory	0.2	0	0	0	0.1
Forbs	1.6	2.9	5.1	4.2	3.4
Bluestem grasses	1.5	4.2	3.5	0.4	2.4
Johnsongrass	0	0	0	0	0
Bermudagrass	0	0.1	3.1	2.7	1.5
Sedges and all other grasses	1.3	5.5	7.6	8.5	5.7
Dewberry	0.1	0.6	0.6	0.3	0.4
Woody	0.7	1.0	1.1	3.2	1.5
Summary Categories					
All dead material	20.7	10.5	3.1	8.2	10.6
All forbs	1.6	3.4	5.7	4.5	3.8
All grasses	2.8	9.8	14.2	11.6	9.6
All woody material	0.7	1.0	1.1	3.2	1.5

Table 3.—Percent of ground surface covered by each of 14 vegetation categories in the cultivated field habitat.

Plant Categories	Winter	Spring	Early Summer	Late Summer	Mean
Litter	1.3	7.8	0	3.6	3.1
Middlestory	27.7	0	0	0	6.9
Maximum herbaceous overstory	1.6	0	0	0	0.4
Forbs	0	0	1.3	0.4	0.4
Bluestem grasses	0	0	0	0	0
Johnsongrass	0	0	0	0	0
Bermudagrass	0	0	0	0	0
Sedges and all other grasses	0	7.8	71.8	26.4	26.5
Dewberry	0	0	0	0	0
Woody	0	0	0	0	0
Summary Categories					
All dead material	30.5	7.8	0	3.6	10.4
All forbs	0	0	1.3	0.4	0.4
All grasses	0	7.8	71.8	26.4	26.5
All woody material	0	0	0	0	0

Table 4.—Percent of ground surface covered by each of 14 vegetation categories in the unmowed ROWs habitat.

Plant Categories	Winter	Spring	Early Summer	Late Summer	Mean
Litter	36.3	32.4	16.4	22.6	26.9
Middlestory	4.9	1.5	1.8	0.8	2.3
Maximum herbaceous overstory	0.6	0.1	0.1	0.1	0.2
Forbs	9.5	15.3	6.8	4.8	9.1
Bluestem grasses	0.3	1.3	2.0	1.8	1.3
Johnsongrass	0	3.7	2.4	5.7	2.9
Bermudagrass	0	3.0	16.6	21.5	10.3
Sedges and all other grasses	10.4	14.2	7.7	9.5	10.5
Dewberry	0.5	0.1	0	0.1	0.1
Woody	0.1	0.1	0.1	0.1	0.1
Summary Categories					
All dead material	42.3	33.4	18.3	24.2	29.5
All forbs	9.9	15.4	6.8	4.8	9.2
All grasses	10.6	22.6	28.6	39.5	25.3
All woody material	0.1	0.1	0.1	0.1	0.1

Table 5.—Percent of ground surfact covered by each of 14 vegetation categories in the mowed ROWs habitat.

Plant Categories	Winter	Spring	Early Summer	Late Summer	Mean
Litter	32.9	15.9	6.6	4.9	15.1
Middlestory	6.3	1.4	0.8	0.1	2.1
Maximum herbaceous overstory	0.8	0.2	0	0	0.2
Forbs	8.2	12.8	1.4	1.6	5.9
Bluestem grasses	0.7	5.5	1.2	2.5	2.5
Johnsongrass	0	3.1	0.9	1.3	1.3
Bermudagrass	0	7.4	11.4	9.2	7.0
Sedges and all other grasses	9.2	11.7	3.6	10.7	8.8
Dewberry	0.2	1.6	0.3	0.8	0.7
Woody	0	0	0	0	0
Summary Categories					
All dead material	38.2	17.6	6.8	5.0	16.9
All forbs	8.3	14.8	2.1	2.4	6.9
All grasses	9.9	27.8	17.4	23.7	19.7
All woody material	0	0	0	0	0

APPENDIX D

Seasonal rodent population densities and rodent community diversity, evenness, and richness indices for each of the habitat types.

Table 1.—Rodent population densities (numbers per hectare) and rodent community diversity, evenness, and richness indices by season for the old field habitat.

Species	Fall	Winter	Spring	Early Summer	Late Summer	Annual Mean
Sigmodon hispidus	29	11	9	24	18	19
Baiomys taylori	2	3	2	3	3	3
Mus musculus	1	0	0	0	0	1
Reithrodontomys fulvescens	3	6	1	1	1	3
Reithrodontomys montanus	0	0	1	0	0	1
Perognathus hispidus	0	0	0	0	0	0
Peromyscus leucopus	0	0	0	1	1	1
Peromyscus maniculatus	0	0	1	0	0	1
Oryzomys palustris	0	0	1	0	0	1
Rattus rattus	0	0	0	0	0	0
All species (Σ)	35	20	15	29	23	30
Diversity	0.631	0.974	1.297	0.623	0.730	0.851
Evenness	0.455	0.887	0.724	0.449	0.526	0.608
Richness	0.843	0.667	1.846	0.890	0.956	1.040

Table 2.—Rodent population densities (numbers per hectare) and rodent community diversity, evenness, and richness indices by season for the pasture habitat.

Species	Fall	Winter	Spring	Early Summer	Late Summer	Annual Mean
Sigmodon hispidus	2	1	1	5	1	2.0
Baiomys taylori	1	2	0	1	2	1.2
Mus musculus	0	0	0	0	1	0.2
Reithrodontomys fulvescens	1	2	0	0	0	0.6
Reithrodontomys montanus	0	0	1	0	0	0.2
Perognathus hispidus	0	0	0	0	1	0.2
Peromyscus leucopus	0	0	0	0	0	0
Peromyscus maniculatus	0	0	0	0	0	0
Oryzomys palustris	0	0	0	0	0	0
Rattus rattus	0	0	0	0	0	0
All species (Σ)	4	5	2	6	5	4.4
Diversity	1.039	1.054	0.693	0.450	1.332	0.914
Evenness	0.946	0.960	1.000	0.650	0.960	0.903
Richness	1.442	1.242	1.442	0.558	1.864	1.310

Table 3.—Rodent population densities (numbers per hectare) and rodent community diversity, evenness, and richness indices by season for the cultivated field habitat.

Species	Fall	Winter	Spring	Early Summer	Late Summer	Annual Mean
Sigmodon hispidus	0	0	0	1	2	0.6
Baiomys taylori	0	0	0	1	0	0.2
Mus musculus	0	0	0	2	7	1.8
Reithrodontomys fulvescens	0	0	0	0	0	0
Reithrodontomys montanus	0	0	0	0	0	0
Perognathus hispidus	0	0	0	0	0	0
Peromyscus leucopus	0	0	0	0	0	0
Peromyscus maniculatus	0	0	0	0	0	0
Oryzomys palustris	0	0	0	0	0	0
Rattus rattus	0	0	0	0	0	0
All species (Σ)	0	0	0	4	9	2.6
Diversity				1.039	0.529	0.784
Evenness				0.946	0.764	0.855
Richness				1.442	0.455	0.949

Table 4.—Rodent population densities (numbers per hectare) and rodent community diversity, evenness, and richness indices by season for the unmowed ROWs habitat.

Species	Fall	Winter	Spring	Early Summer	Late Summer	Annual Mean
Sigmodon hispidus	43	17	25	84	69	48
Baiomys taylori	11	15	4	1	1	6
Mus musculus	1	0	1	1	1	1
Reithrodontomys fulvescens	3	2	1	1	1	2
Reithrodontomys montanus	0	0	1	0	0	1
Perognathus hispidus	1	0	1	0	0	1
Peromyscus leucopus	0	0	0	0	0	0
Peromyscus maniculatus	0	0	0	0	0	0
Oryzomys palustris	0	0	0	0	0	0
Rattus rattus	0	0	1	0	0	1
All species (Σ)	59	34	34	87	72	60
Diversity	0.833	0.874	0.997	0.187	0.218	0.662
Evenness	0.517	0.795	0.512	0.135	0.157	0.423
Richness	0.980	0.567	1.701	0.671	0.701	0.924

Table 5.—Rodent population densities (numbers per hectare) and rodent community diversity, evenness, and richness indices by season for the mowed ROWs habitat.

Species	Before Mowing			After Mowing		
	Fall	Winter	Spring	Early Summer	Late Summer	Annual Mean
Sigmodon hispidus	29	12	17	12	11	17
Baiomys taylori	12	7	5	1	3	6
Mus musculus	1	2	1	1	2	2
Reithrodontomys fulvescens	3	3	0	1	1	2
Reithrodontomys montanus	0	0	1	0	0	1
Perognathus hispidus	1	1	0	0	0	1
Peromyscus leucopus	0	0	0	0	0	0
Peromyscus maniculatus	0	0	0	0	0	0
Oryzomys palustris	0	0	0	0	0	0
Rattus rattus	0	0	0	0	0	0
All species (Σ)	46	25	24	15	17	29
Diversity	0.985	1.293	0.835	0.720	1.006	0.968
Evenness	0.612	0.803	0.602	0.519	0.725	0.652
Richness	1.004	1.242	0.943	1.107	1.058	1.071

APPENDIX E.—Dates of rodent trapping sessions. Asterisks indicate trapping sessions during which vegetation was sampled.

Season	Highway 6	Interstate 45	FM 2818
Fall 1975	7-9, 11, 12 Oct. 6-10 Nov.	30 Nov. 1, 5-6 Dec.	10, 12-15 Dec.
Winter 1976	27-29 Dec. 23-26, 30 Jan. 23-27 Feb.*	8-12 March*	4, 5, 9-11 Feb.*
Spring 1976	25-28, 30 March 28-30 April, 1, 2 May*	5-9 May*	9-13 April*
Early Summer 1976	19-23 May* 27-30 June, 1 July	28-30 June, 1, 2 July*	3-7 June*
Late Summer 1976	21-23, 26, 27 July * 10-14 August	4-8 August*	11-15 July*