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MAMMALS OF THE FREEMAN RANCH, HAYS COUNTY, TEXAS

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During Recent time, disturbance has become a major factor in the ecology of grasslands of North America. The grazing guild (herbivory) composed of domestic livestock: cattle, sheep, goats, and horses are important grazers of grasslands because of their size and abundance, but other organisms also function in this guild: insects, small mammals, native ungulates, and birds. Thus, a synergistic effect results from this multiplicity of species functioning as grazers that has ramifications in the composition and structure of an ecosystem. The mammal community is constructed around a paradigm of herbivores being the prey for carnivores. Although discussions of detrimental effects of grazing on plant community composition and structure generally center on domestic livestock, insects and small mammals may be the most important grazers in some communities. By cropping grass to a short height, jackrabbits (*Lepus*) and prairie dogs (*Cynomys*) cause structural and compositional changes to the plant community of prairies. The effect of grazing by domestic livestock at a proper stocking rate usually does not result in such alteration of the landscape (Holecek et al., 1982).

An important issue for private and public land managers is grazing by domestic livestock. This has become a contentious issue, especially in western states, because of competing economic, social, and conservation interests. However, grazing by domestic livestock is not unique because herbivory by indigenous hoofed mammals has been an important natural ecological and evolutionary process in grassland ecosystems. Grasslands developed under a regime of disturbance by fire, drought, and ungulate grazing. In some cases, rather severe perturbations have occurred through time. Even today, grazing is an integral part, or tool, in the management of grasslands.

The intermediate disturbance hypothesis fits well into a discussion of grasslands, grazing, and species diversity. This hypothesis states that highest diversity is maintained at intermediate levels of disturbance (Huston, 1979; 1993). It is a dynamic model, demonstrating that diversity is not a stagnant concept when applied to an ecosystem. Species diversity may change within a short period, in ecological time. The frequency of disturbance is an important factor affecting maximum diversity. A major premise of the hypothesis is that maximum diversity will oscillate around an intermediate level of disturbance within an ecosystem. Major disturbances cause an initial reduction of species diversity. Only those species that have adaptive plasticity (generally those species with rapid life cycles) survive, while species lacking adaptive plasticity become extinct. Through time, environmental changes induced by disturbance may result in speciation events.

In any environment without disturbance, dominant species are the major modifiers of community structure. Because of the competitive superiority of dominant species, those less adapted or competitively inferior species have lower populations or may be eliminated from a community (Huston, 1993). Therefore, because of competitive exclusion, species diversity diminishes.

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There is an interplay between periodic, intense disturbances that cause a decrease in species diversity and periods of small disturbances in which, over time, competitive inhibition increases and species diversity decreases (Huston, 1993). Somewhere between the two extremes, circumstances favor maximum species diversity. The intensity and frequency of disturbances are important factors. Species with low growth rates may only occur under low disturbance conditions. Species diversity for species with low growth rates will decrease under high disturbance regimes. Such species are not adapted to disturbance modified environments. In environments with a high frequency and intensity of disturbance, only species with high growth rates will survive. The greatest species diversity is at an intermediate level of disturbance (Huston, 1993).

Three factors are important in the grazing management of domestic livestock: intensity, frequency, and duration. These three in concert will determine range conditions and forage yields in standing crop biomass (above ground) vegetation (Holecek et al., 1982). High numbers of grazing animals can cause community disturbance by reducing the carrying capacity for herbivores and causing changes in species composition, species diversity, primary productivity, and vegetational cover of the plant community and soil characteristics. General guidelines on grazing, grazing systems, and affects of large herbivores on grasslands are available from the United States Department of Agriculture, Natural Resource Conservation Service, Texas Agricultural Extension Service, and Texas Parks and Wildlife Department.

Mammalian species assemblage of an area is a reflection of the successional status and the diversity of habitats in the plant community. Small mammals are especially sensitive to decreases in available vegetative cover resulting from excessive grazing by livestock. Not only does the abundance of small mammals decrease because of intense grazing, the overall species richness, a component of diversity, also decreases. As small mammalian herbivores decrease and small to intermediate size predators are affected by a loss of their prey base, there is a downward cascading effect on species diversity. To judge the effect of grazing and other land management practices on small mammals, it is important to establish a baseline of the abundance and diversity of mammals in different habitat types in a geographic area.

Changes induced by ungulate grazing on the local environment have been documented across a wide range of North American grassland types (Grant et al., 1982). Grazing alters the structure of native biotic communities, affecting changes in plant species composition and diversity, primary productivity, and standing crop biomass. Abiotic components of grassland ecosystems, such as soil characteristics, erosion potential, and sediment build-up in waterways, are impacted as well (Grant et al., 1982). Differences in plant species composition and vegetative structure are apparent on grazed versus ungrazed sites on grasslands of the Southwest (Smeins and Merrill, 1988; Holechek et al., 1994; Bich et al., 1995; Scholl and Kinucan, 1996; Bock and Bock, 1997). Heavy grazing of grasslands of the Edwards Plateau, for example, inhibits succession from a shortgrass to a midgrass rangeland (Smeins and Merrill, 1988). Holechek et al. (1994) determined that intermediate grazing of Chihuahuan Desert rangeland caused an increase of noxious plant species. Conservative grazing allowed perennial grass cover to increase to twice the amount of standing crop at season’s end compared to sites with intermediate grazing.

In addition to assessing effects on native floras, several studies have quantified the effects of grazing on wildlife populations and community structure of native faunas (Grant et al., 1982; Bich et al., 1995; Brooks, 1995; Rosenstock, 1996). Effects on wildlife communities can include changes in species composition, diversity, and abundance. The impact of grazing on small rodent populations in particular may be significant because of their functional role in grassland ecosystems (Carey and Johnson, 1995). Rodents are a prey source for reptiles, raptors, and other mammals, but also are predators. Some species are herbivorous, consuming herbage, seeds, and berries, while others are omnivorous and include insects in their diets. Thus, monitoring small rodent communities may provide insights into the effects of grazing on higher trophic levels and biodiversity in general (Rosenstock, 1996).

Small mammal faunas are less affected by changes in plant species composition resulting from grazing than by alterations in the physiognomy of the plant community (Grant et al., 1982). Vegetative structure (i.e., the horizontal and vertical distribution of plants within a habitat) provides a variety of cover opportunities for small mammals. In a study of North American grasslands, Grant and Birney (1979) demonstrated that aboveground plant biomass, or cover, had a direct influence on the composition the of small mammal community in grasslands. Available cover influences the total biomass of small mammals, species diversity, and taxa composing a community. Functional roles within the community, for example, reproductive strategies, diet, and seasonality of activity, also are influenced by the amount of available cover. Because grazing reduces the density of aboveground plant biomass, small mammal faunas are necessarily affected.

Over the last 150 years, the landscape of the Edwards Plateau has been altered by human activities, including overgrazing by livestock, suppression of fire, and urbanization (Diamond et al., 1987). Historically, grasslands or open savannahs of the Edwards Plateau were subjected to a series of disturbance factors: climate, periodic grazing by large, migratory herds of bison (*Bos bison*) and pronghorn antelope (*Antilocapra americana*), and frequent wildfires. Later with the arrival of Europeans, chronic overgrazing by domestic livestock (cattle, sheep, and goats), fencing of land, and fire suppression resulted in degradation of grasslands and the replacement of palatable grass species with less palatable grasses and weeds. The ecosystem shifted from a grassland/savanna to Ashe juniper (*Juniperus ashei*) woodland. These vegetational changes likely changed the biological diversity of the region.

To date no systematic study of habitat use by terrestrial vertebrates has been conducted on the Freeman Ranch, and anecdotal accounts continue to indicate a paucity of wildlife. An inventory of mammalian species could provide important information about wildlife use of ranch lands and thus assist the ranch manager and wildlife biologist in developing effective management plans. A biological survey for mammals was conducted to determine which species occur on ranch lands. The results of the survey are contained in an annotated list of mammal species (Appendix 1).

Several questions about small mammals and habitat interactions need investigation for ranch personnel to make informed land use decisions. These questions address specifically livestock grazing and the influence of grazing on the small rodent community. We posed four questions. Most of this monograph provides answers to these questions. What is the relative abundance of small rodent species in each habitat type? How has grazing influenced the small mammal community and the habitat in which these mammals live? Which habitats are the most diverse? How does the small mammal community of the Freeman Ranch compare to those of other areas of the Edwards Plateau (Parren and Capen, 1985; Schwertner, 1996; Schwausch, 1997)?

ENVIRONMENT OF THE FREEMAN RANCH

The Freeman Ranch is a 1,701-ha (4,204 acres) Hill Country ranch located 4.8 km west of San Marcos in Hays County, Texas (N 29° 56’ 18’’, W 98° 00’ 29’’). The ranch has been a working cattle/sheep ranch since the early to mid 1900s. In 1981, Southwest Texas State University assumed management of the ranch. Before the university’s involvement in managing the ranch, a continuous grazing system resulted in an overgrazed, degraded rangeland. Since 1981, range management practices on the ranch have changed. The animal stocking rate has been reduced. Cattle graze the rangeland in a rotational grazing system. Prescribed burning has been instituted to invigorate the rangeland. Fire and mechanical control of Ashe juniper is being used to restore the rangeland. Wildlife management techniques have been used to promote the use of ranch lands by wildlife. A high fence was constructed to manage white-tailed deer (*Odocoileus virginianus*) populations on a part of the ranch, a deer census was started, food plots were planted, and turkey feeders installed.

The ranch is located on the eastern edge of the Edwards Plateau Ecological Region of Texas, the southernmost extension of the Great Plains Physiographic Province (Hunt, 1967), and falls within the Balconian Biotic Province (Blair, 1950). Shallow mollisol soils overlain on Cretaceous limestone rock characterize the region. The eastern edge of the Edwards Plateau is hilly and dissected by streams and steep canyons. An Ashe juniper-live oak woodland association dominates on slopes and in canyons. Uplands are grasslands or savannahs with an interspersion of live oak (*Quercus virginiana*) mottes. The encroachment of both Ashe juniper and honey mesquite (*Prosopis glandulosa*) onto upland sites is evident on the ranch.

Topography of the ranch is hilly with elevations ranging from 204 to 287 m along a gradient from east to west. Annual precipitation ranges from 81 to 91 cm with peak rainfall in May, June, and September. The mean annual temperature is 19.5° C.

Predominant soils include those of the Comfort and Rumple series (USDA, 1984). Rumple and Comfort soils are shallow to moderately deep upland soils, undulating, with a slope of 1 to 8%. Rumple soil is cherty clay loam; its surface layer comprises 20% rocks or gravel. Comfort soil is extremely stony clay. Mesquite, Ashe juniper, and Texas persimmon (*Diospyros texana*) commonly invade soils of the Rumple-Comfort association where overgrazing occurs. The Comfort-Rock outcrop complex consists of shallow, clay soils and rock outcroppings. This soil complex is typically located on slopes and hilltops in upland areas of the ranch. Horizontal bands of rock outcrop with Comfort soil in between are found on slopes and near drainages. At the surface, up to 45% of Comfort soil is rock. Like the Rumple-Comfort association, soils in this complex are mildly alkaline, well drained, have low water capacity, and shallow rooting zones. The Low Stony Hills range site occurs on the dominant soil types found on the ranch.

Five habitats, each representing major vegetational communities of the ranch, were considered important potential mammalian environments on the ranch. Each community was somewhat distinctive in plant species composition and physical structure of the vegetation. Habitat types included live oak savannah, live oak woodland, mesquite savannah, riparian woodland, and Ashe juniper-live oak forest. Common woody plants included live oak, mesquite, and Ashe juniper. Cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* sp.), Texas persimmon, and greenbriar (*Smilax bona-nox*). On upland savannahs, shortgrasses and a variety of forbs dominate the herbaceous community. Important grasses include Texas winter grass (*Stipa leucotricha*), Texas grama (*Bouteloua rigidseta*), King Ranch bluestem (*Bouthriochloa ischaemum*), and common curly mesquitegrass (*Hilaria belangeri*). Important forbs include doveweed (*Croton* sp.) and violet sida (*Meximalva filipes*). Together these habitat types make up the majority of vegetative cover on the ranch.

SAMPLING

Woody Vegetation Sampling

To describe and compare habitat types, an inventory of woody plants was conducted using the line-intercept method (Simpson et al., 1996). From these data, relative density, percent cover, dominance, and frequency were calculated for each woody species. Vegetational sampling occurred in March, April, and May of 1998, allowing for comparison of different habitats within one season (Nudds, 1977). Five permanent points (T-posts) within each habitat type were established and used as sampling stations. T-posts were randomly placed (at least 250 m apart) within an area of relatively uniform habitat. One line transect, 50 m in length, was extended from each sampling station in a randomly chosen cardinal direction. Woody canopy and understory species that intercepted the line or were above or below the line were recorded, along with their intercept lengths. The taxonomy of woody plants follows Correll and Johnson (1996).

Vertical structure refers to the density of vegetative cover at various heights in the understory (Nudds, 1977) and includes both woody and herbaceous plant species. To quantify this feature, a vegetation profile board 2.5 m in height was used. The profile board was used to estimate the percent of visual obstruction created by vegetation at different heights (Mitchell and Glenn, 1995). Increments of 0.5 m were delineated on the board, and percent of visual obstruction was assigned to one of five classes: 0-20% = 1; 21-40% = 2; 41-60% = 3; 61-80% = 4; and 81-100% = 5 (Nudds, 1977). Four sampling points in the four cardinal directions were used at each sampling station with the T-post as the center point. The board was placed 15 m from the station. The reader estimated the amount of visual obstruction for each height increment. For each habitat type, 20 sampling points were recorded.

Small Rodent Sampling

Between 6 January and 29 March 1998, small rodent populations were systematically sampled in the five habitat types described above. In each habitat, Sherman live traps (23 x 8 x 8 cm) were arranged in a 10,000 m^2 grid with traps aligned in a 10 x 10 trap-station pattern and spaced approximately 10 m apart. In order to stay within uniform habitat, some grids were broken into two or three adjacent subgrids with a different trap-station pattern. Each habitat type was trapped for 1,500 trap nights with a total trap effort in all habitat types of 7,500 trap nights. Traps were open on consecutive nights, except in the Ashe juniper-live oak forest, where traps were open for six nights, then temporarily closed for 17 nights and reopened again to finish trapping. All traps were baited and refreshed every three days with a combination of rolled oats and birdseed with peanut butter. Traps were checked for rodents late each evening and again in early morning to prevent mortality by red imported fire ants (*Solenopsis invicta*). Rodents were identified and released at point of capture. Taxonomy for small rodents follows Hall (1981).

Bat Sampling

Bat detectors were used to locate favorable sites for possible collection of bats. Mist nets were used at the following locations to sample chiropterans: Crawford Pond (9 nights), Quail Station (4 nights), 100-acre Pond (1 night), and dry creek (1 night). Bats were caught in mist nets from February to May 1998.

Intermediate to Large Size Mammal Sampling

Information on intermediate to large size mammals was collected by several different methods. Date, time, and habitat type were recorded for any observation of a mammal. Much of the information on large mammals was observational, either through field observation while trapping small mammals or during spotlight counts for white-tailed deer. Intermediate size carnivors were trapped using Tomahawk live traps. Some data were obtained for carnivores at scent stations on the ranch and their presence recorded at the scent station by a camera. Any mammal tracks or scats found were tentatively identified to the species of origin. Transects for tracks and scats were established in the different habitat types.

GRAZING DURING THE STUDY

Grazing continued during the study. Study sites were sampled after cattle had been rotated out of a pasture. The only habitat where grazing did not occur during the study was the live oak woodland. Grazing had been curtailed in this area 31 months prior to the study.

DATA ANALYSIS

Woody Vegetation Analysis

Data derived from the line-intercept survey were used to compute relative density, percent cover, dominance, and frequency of woody plants in each habitat type (Cox, 1996). Relative density was calculated as the number of individuals of species (i) divided by the total number of individuals of all species present. Percent cover was calculated as the sum of all intercept lengths for species (i) divided by total transect length (250 m). Frequency was obtained by dividing the number of 10 m intervals in which species (i) occurred by the total number of intervals (n = 25) on the transect. Dominance was calculated by multiplying percent cover by 107,636.76 m^2/ha. A Relative Importance Value (RIV) was calculated for each species by summing relative density, relative frequency, and relative cover values and dividing by three. Species richness was a count of the number of species present in each habitat type.

Vertical structure data were used to construct frequency distribution tables of cover classes for each habitat type. Classes correspond to the percent of visual obstruction created by woody and herbaceous vegetation at various height increments in the understory. To facilitate comparisons of the vertical arrangement of woody and herbaceous vegetation, a histogram was generated for each habitat type.

Small Rodent Trapping Analysis

Abundance of small rodent species was calculated as total number of individuals captured per 100 trap nights (Carey and Johnson, 1995). Species richness was determined by summing the number of species trapped in each habitat type. Because trap effort was equal in all five-habitat types, species richness values for the five study sites were comparable. Brillouin's index (Krebs, 1989) was used to determine community diversity and evenness for each habitat type:

$$H = (1/N) \log_2 \frac{N!}{n_1!n_2!n_3!\ldots}$$

Where:
N = total number of individuals of all species in the collection,
n_i = number of individuals belonging to species 1, 2, 3….

Like the Shannon-Wiener Index, Brillouin's index (H) measures the degree of uncertainty in predicting into which category a randomly drawn sample from a community will fall (Zar, 1996). The value of H increases with increasing uncertainty (i.e., increasing diversity in a community). The minimum value for H is zero, indicating no uncertainty (i.e., all samples fall into one category). Both diversity measures tend to underestimate actual community diversity, especially with small sample sizes, as rare species are left undetected (Krebs, 1989; Zar, 1996). For the field sampling conducted in this study, the Brillouin's Index is a more appropriate measure than the Shannon-Wiener Index, the application of which should be restricted to a large number of random samples drawn from a large community where the total number of species in the community is known (Krebs, 1989). This was not the case in any of the habitat types sampled. The individuals captured in each habitat type can be viewed instead as finite collections.

An evenness statistic (J) (Krebs, 1989) also was calculated for each community:

$$J = \frac{H}{H_{max}}$$

Where:
H = observed diversity, based on Brillouin's index,
H_{max} = maximum possible diversity, given sample size N and number of species observed (k).

Evenness statistics measure diversity as a proportion of the maximum possible diversity for a given community. Evenness values range from 0 to 1. A value of 1 indicates that, in the community sample, observations are distributed equally among all categories. The evenness statistic is biased in that it represents an overestimate of equitability (Krebs, 1989; Zar, 1996). That is, if H is an underestimate of diversity, then J must be an overestimate, because H_{max} is based on the number of categories observed ($H_{max} = \log k$, k is the number of categories or species). Therefore, caution should be used when interpreting evenness values. Heterogeneity and evenness measures were estimated using the software program DIVERS (Krebs, 1988). Rodent communities were compared across habitat types by calculating total abundance of all species in a habitat, species richness (k), species diversity (H), and evenness (J). To compare small rodent diversity of Freeman Ranch with other study sites, data from all habitat types were pooled, and diversity recalculated using the Shannon-Wiener Index with a logarithmic base of 10. In this way, both a single diversity (H') and a single evenness value (J') was obtained for the entire ranch.

To test for habitat selection, a chi-square value was calculated using raw data for the sample distributions of three of the four species captured across all five habitat types (Holbrook, 1978; Songer et al., 1997). Habitat selection would be supported by a statistically significant difference between the number of individuals captured of species (i) in a given habitat and the expected number captured of this species if it were distributed randomly across all habitats. Because all habitat types were sampled equally (time and area covered), expected frequency values were calculated as the total number of individuals (n) of species (i), divided by the number of habitats sampled (k). Thus, the null hypothesis states that the sample distribution of species (i) comes from a population having a trap frequency of n / k. Conversely, the alternate hypothesis states that the sample distribution comes from a population having a trap frequency not equal to n / k. A significant chi-square value indicates that the species is not randomly distributed across habitat types (Holbrook, 1978; Songer et al., 1997). According to Zar (1996), the chi-square test is robust if values meet the following guidelines. One is testing for uniform distribution, i.e., expected frequency = n / k, where n is the sample size, and k is the number of classes or habitats; and in addition, $k \geq 3$, $n \geq 10$, and $n^2 / k \geq 10$. Values for three of the four rodent species captured (*Baiomys taylori*, *Peromyscus pectoralis*, and *Sigmodon hispidus*) met these criteria. A chi-square test was inappropriate for *Reithrodontomys fulvescens* because of the low sample size.

To ascertain if a significant chi-square value was the result of discrepancies between observed and expected frequencies in certain classes or the result of the observed frequencies in all classes combined, the chi-square analysis can be subdivided (Zar, 1996). In subdividing the analyses for the sample distributions of *P. pectoralis*, S. hispidus, and *B. taylori*, relevant habitat types were isolated in the calculations, and new chi-square values were calculated. The Yates correction for continuity was used when degrees of freedom (v) equaled 1 (Zar, 1996). Chi-square table values are based on a continuous distribution, whereas the distribution of possible values from the actual data used is a discrete or discontinuous distribution. A correction becomes necessary only when the number of classes being tested equals two. The Yates correction was made to avoid inflated chi-square values, which would result in an increase in Type I errors (i.e., rejecting the null hypothesis when it should be accepted).

Geographic Information System Analysis

All data collected on mammals were used to develop a GIS-data set on mammalian fauna at Freeman Ranch using Arcview software from ESRI. Trap grids, mist net captures, and indices of larger mammals were located on a DOQQ of Freeman Ranch with an accuracy of +/- 10 m. These locations were recorded in real-world units along with their attributes (date, species, method of sampling, etc.). The data set was designed to be integrated into a larger database containing soil and topography data, as well as vegetation information gathered from remotely sensed data. The database can serve as a tool for future study and analysis of wildlife and their habitats at Freeman Ranch.

RESULTS AND DISCUSSION

Habitat Types

Species composition of woody plants was similar from one habitat type to the next, and the same woody plant species dominated all habitat types. However, there were wide discrepancies for total available woody and herbaceous cover. Only five species of trees constituted the entire canopy in three of the five habitats: live oak, cedar elm, hackberry, Ashe juniper, and honey mesquite. Excluding mesquite, these same canopy species also were found in the Ashe juniper-live oak forest. In the fifth habitat type, the riparian woodland area, Spanish oak (*Quercus buckleyi*) was present, in addition to the aforementioned species. Greenbriar and Texas persimmon dominated understory vegetation in all habitat types except the Ashe juniper-live oak forest. Species richness values for woody plants ranged from 11 to 16 for four of the habitat types. The fifth habitat type, riparian woodland, had a richness of 25 (Table 1). The riparian woodland community had the highest percent cover (144.8%), as well as the highest density of individual woody plants. The live oak savannah and mesquite savannah habitat types had the lowest total cover (53.9% and 59.8%, respectively) and the lowest density of individuals (137 and 121, respectively).

There was a high degree of variation in the density of woody and herbaceous cover at different heights in the understory (vertical structure), both within and between habitat types (Table 2). In both the mesquite savannah and live oak savannah habitat types, cover class 1 (0-20% visual obstruction) most often was recorded at all height increments in the understory. The riparian woodland community exhibited the greatest variability in vertical structure, especially between 0.0 and 1.5 m. This habitat was the most structurally diverse of all habitat types because of its ecotonal quality. In the Ashe juniper-live oak forest and the live oak woodland habitat types, the distribution of cover classes at all height increments was bimodal.

Live Oak Savannah: Live oak and mesquite trees dominated the woody vegetation of the oak savannah habitat type. Relative cover values were 20% and 13%, respectively (Table 3). Ashe juniper also was present (9% relative cover). The understory was dominated by Texas persimmon saplings and greenbriar (relative cover values of 14% and 17%, respectively). The total percent cover of all woody plant species was 54%. This habitat type is an upland savannah interspersed with oak mottes with extensive encroachment by honey mesquite. As expected for savannah habitats, the most frequent cover class for all height increments in the understory was cover class 1, corresponding to 0–20% visual obstruction created by vegetation.

Live Oak Woodland: The live oak woodland habitat type comprised relatively open woodlands juxtaposed with large patches of open grassland where shortgrass and midgrass species dominated (Table 4). Live oak constituted 36% relative cover. Ashe juniper was the second most important canopy species with 12% relative cover. Common understory species included Texas persimmon, greenbriar, and elbow bush (*Forestiera pubescens*). The patchy landscape probably explains the bimodal distribution of cover classes for vegetation at all heights, with cover class 1 (0–20% visual obstruction) recorded most often in grassland areas and cover class 5 (81–100% visual obstruction) recorded most frequently in wooded areas. The total percent cover of 125% was twice that of the live oak savannah habitat type.

Mesquite Savannah: Mesquite trees and hackberry saplings dominated the woody plant community in the mesquite savannah habitat type (relative cover values of 23% and 18%, respectively; Table 5). Important understory species were Texas persimmon and greenbriar, as well as a number of thorny species, such as prickly pear cactus (Opuntia engelmannii), agarita (Berberis sp.), and tasajillo (O. leptocaulis). Vegetative cover was sparse (60%) compared to other habitats. As with the live oak savannah habitat type, cover

Table 1. Comparison of woody plant communities across five habitat types at the Freeman Ranch, Hays County, Texas, March to May, 1998. Species richness (k), total number of individuals (n), total intercept length (m) for all species recorded, and total percent cover of woody plants are given for each habitat type.

Habitat Type	k	n	Total Intercept *Length*	Percent Cover
Live Oak Savannah	15	137	134.7	53.9
Live Oak Woodland	15	260	313.4	125.0
Mesquite Savannah	16	121	149.5	59.8
Riparian Woodland	25	296	361.9	144.8
Juniper-Oak Forest	11	167	302.9	121.0

Table 2. Frequency distribution of cover classes at five height increments (m) in the understory for five habitat types at the Freeman Ranch, Hays County, Texas, March – May, 1998. Cover classes correspond to percent of visual obstruction created by vegetation: 1 = 0–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, 5 = 81–100%.

		Height Increments (m)					
Habitat Type	Class	0.0–0.5 0.5	0.5–1.0 1.0	1.0–1.5 1.5	1.5–2.0 2.0	2.0–2.5 2.5	Total
Live Oak Savannah	1	12	14	13	15	15	69
	2	2	2	3	0	1	8
	3	1	1	1	2	0	5
	4	0	0	0	0	2	2
	5	5	3	3	3	2	16
Live Oak Woodland	1	5	8	11	12	13	49
	2	2	1	0	0	0	3
	3	0	2	0	1	0	3
	4	1	1	1	0	0	3
	5	12	8	8	7	7	42
Mesquite Savannah	1	8	11	14	14	14	61
	2	2	4	1	1	2	10
	3	1	2	1	4	3	11
	4	3	1	2	0	0	6
	5	6	2	2	1	1	12
Riparian Woodland	1	3	5	4	8	7	27
	2	2	6	3	1	2	14
	3	3	2	3	2	1	11
	4	3	2	4	5	3	17
	5	9	5	6	4	7	31
Juniper-Oak Forest	1	5	6	7	8	7	33
	2	0	3	0	0	1	4
	3	2	2	1	1	0	6
	4	2	2	3	2	1	10
	5	11	7	9	9	11	47

Table 3. Species composition, percent cover, dominance, relative cover, percent frequency, relativefrequency and relative importance values (RIV) for woody vegetation in the live oak savannah habitat type at the Freeman Ranch, Hays County, Texas, March to May, 1998.

Species	Relative Density	Percent Cover	Dominance	Relative Cover	Percent Frequency	Relative Fre-quency	RIV
Trees							
Celtis sp.	3.6	0.3	344.4	0.6	20	7.2	3.8
Juniperus ashei	7.3	4.9	5295.7	9.1	12	4.3	6.9
Prosopis glandulosa	2.9	7.2	7706.8	13.3	24	8.7	8.3
Quercus fusiformis	5.1	10.8	11667.8	20.1	16	5.8	10.3
Ulmus crassifolia	0.7	1.2	1291.6	2.2	8	2.9	2.0
Shrubs and vines							
Berberis sp.	5.8	2.2	2325.0	4.0	20	7.2	5.7
Diospyrus texana	10.9	7.6	8223.4	14.2	32	11.6	12.2
Eysenhardtia texana	0.7	0.4	387.5	0.7	4	1.4	0.9
Opuntia engelmannii	2.9	1.8	1937.5	3.3	12	4.3	3.5
O. leptocaulis	5.1	1.9	2066.6	3.6	20	7.2	5.3
Forestiera pubescens	5.1	1.7	1851.4	3.2	12	4.3	4.2
Parthenocissus quinquefolia	10.9	2.6	2841.6	4.9	24	8.7	8.2
Rubus trivialis	8.0	1.5	1593.0	2.7	16	5.8	5.5
Smilax bona-nox	27.7	9.0	9687.3	16.7	48	17.4	20.6
Vitis sp.	2.9	0.7	775.0	1.3	8	2.9	2.4
Total	100	53.9	57988.7	100	276	100	100

Table 4. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and relative importance values (RIV) for woody vegetation in the live oak woodland habitat type at the Freeman Ranch, Hays County, Texas, March to May 1998.

Species	Relative Density	Percent Cover	Dominance	Relative Cover	Percent Frequency	Relative Frequency	RIV
Trees							
Celtis sp.	6.9	3.5	3788.8	2.8	40	7.8	5.8
Juniperus ashei	10.0	15.5	16705.2	12.4	48	9.4	10.6
Prosopis glandulosa	0.4	2.4	2540.2	1.9	4	0.8	1.0
Quercus fusiformis	11.9	45.5	48953.2	36.3	68	13.3	20.5
Ulmus crassifolia	6.5	3.6	3918.0	2.9	28	5.5	5.0
Shrubs and vines							
Berberis sp.	5.4	5.0	5381.8	4.0	40	7.8	5.7
Bumelia lanuginosa	3.8	1.4	1463.9	1.1	20	3.9	2.9
Diospyrus texana	12.3	14.8	15973.3	11.8	64	12.5	12.2
Forestiera pubescens	5.0	8.7	9342.9	6.9	28	5.5	5.8
Parthenocissus quinquefolia	4.6	1.7	1851.4	1.4	24	4.7	3.6
Rubus trivialis	6.5	1.6	1722.2	1.3	36	7.0	4.9
Smilax bona-nox	23.5	19.5	21010.7	15.6	88	17.2	18.7
Toxicodendren radicans	0.8	0.1	86.1	0.1	8	1.6	0.8
Vitis sp.	0.8	1.1	1205.5	0.9	12	2.3	1.3
Yucca rupicola	1.5	0.9	990.3	0.7	4	0.8	1.0
Total	100	125.4	134933.4	100	512	100	100

Table 5. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the mesquite savannah habitat type at the Freeman Ranch, March to May 1998.

Species	Relative Density	Percent Cover	Dominance (m2/ha)	Relative Cover	Percent Frequency	Relative Frequency	RIV
Trees							
Celtis sp.	10.7	10.8	11581.7	18.0	44	13.3	14.0
Juniperus ashei	5.0	3.9	4219.4	6.6	20	6.0	5.8
Prosopis glandulosa	13.2	13.8	14810.8	23.0	48	14.5	16.9
Quercus fusiformis	0.8	1.6	1722.2	2.7	4.0	1.2	1.6
Ulmus crassifolia	9.1	3.3	3573.5	5.6	28	8.4	7.7
Shrubs and vines							
Acacia farnesiana	0.8	0.6	645.8	1.0	4.0	1.2	1.0
Berberis sp.	7.4	4.2	4563.8	7.1	24	7.2	7.3
Bumelia lanuginosa	1.7	0.2	258.3	0.4	8.0	2.4	1.5
Cercis canadensis	0.8	0.1	86.1	0.1	4.0	1.2	0.7
Colubrina texensis	0.8	0.2	258.3	0.4	4.0	1.2	0.8
Condalia hookeri	1.7	1.0	1119.4	1.7	8.0	2.4	1.9
Diospyrus texana	13.2	6.5	6974.9	0.8	28	8.4	10.8
Forestiera pubescens	5.0	1.2	1334.7	2.1	16	4.8	4.0
Opuntia engelmannii	18.2	4.7	5037.4	7.8	44	13.3	13.1
Opuntia leptocaulis	4.1	2.0	2109.7	3.3	16	4.8	4.1
Smilax bona-nox	7.4	5.6	6070.7	9.4	32	9.6	8.8
Total	100	59.8	64366.8	100	3.32	100	100

class 1 was the most frequent value at all height increments in the understory. However, for the increment 0.0–0.5 m, the distribution of cover classes for the mesquite savannah was skewed slightly to higher cover classes, reflecting the abundance and interspersion of low shrubs.

Riparian Woodland: The riparian woodland habitat type is a lowland forest dominated by Ashe juniper, cedar elm, and live oak (Table 6). Other canopy species included hackberry, Spanish oak, and mesquite. Greenbriar and Texas persimmon dominated the understory. *Vitis* sp. and elbow bush also were important understory components. Species richness (k = 25), total percent cover (145%), and the density of woody plants (296) were higher in the riparian woodland area than in any other habitat type. The riparian woodland area exhibited the greatest heterogeneity in vegetative structure of all habitat types sampled. At the lowest elevations, where Orif soils occur and flooding potential is high, woody vegetation was absent. Elsewhere, limestone bluffs and dense woody vegetation characterized the landscape along narrow creek drainages. The creek bed along a north-facing bluff supported a compositionally diverse understory and canopy, presumably due to higher available moisture. In one area, large live oaks were found with no understory development, and at slightly higher elevations, dense associations of large cedar elm, hackberry, and live oak trees occurred. This heterogeneity was reflected in measures of vertical structure. The distribution of cover classes for understory vegetation was highly variable and there was no obvious overall pattern.

Ashe Juniper-Live Oak Forest: The Ashe juniper-live oak forest was dominated by two species (Ashe juniper 51% of relative cover, live oak 32%; Table 7). Cedar elm was less common (7% relative cover). Understory species constituted only 7% of woody vegetation. Greenbriar and Texas persimmon (1% and 2% relative cover, respectively) were found in the closed, densely forested areas dominated by junipers. In the small, enclosed pockets of open grassland, prickly pear cactus was the dominant woody plant (3% relative cover). Total percent cover for woody vegetation was 121%. Species richness was 11. As with the live oak woodland habitat type, the bimodal distribution of cover classes for understory vegetation can be explained by the patchiness of this habitat. Open patches had 0–20% vegetative cover at all heights, while densely forest areas had 81–100% vegetative cover at all height increments.

Small Rodents

One hundred forty-nine white-ankle mice (*Peromyscus pectoralis*), 44 cotton rats (*Sigmodon hispidus*), 19 northern pygmy mice (*Baiomys taylori*), and one fulvous harvest mouse (*Reithrodontomys fulvescens*) were trapped during this study. Species abundance (Carey and Johnson, 1995) and total abundance of small rodents for each habitat type are presented in Table 8. The Ashe juniper-live oak forest had the highest total abundance of small rodents (5.27 individuals captured/100 trap nights), whereas the riparian woodland forest had the lowest total abundance (0.94). The mean total abundance for all five habitat types was 2.85 individuals/100 trap nights.

The highest species richness (k = 4) occurred in the mesquite savannah habitat type (Table 9). This was the only habitat type in which *Reithrodontomys fulvescens* occurred. *Peromyscus pectoralis* was the only species trapped in the Ashe juniper-live oak forest. This habitat type had the lowest species richness (k = 1).

Diversity of small rodents in the five habitat types ranged from 0.00 to 1.37 (Table 9). The live oak savannah had both the highest diversity value and the highest evenness value. The mesquite savannah also had high diversity (1.33), but a low evenness value. The Ashe juniper-live oak forest habitat type had the lowest diversity (0), as only *P. pectoralis* was caught. Evenness for this community was also 0.

The frequency of captures across the five habitat types was significantly different from what would be expected due to random chance for *Peromyscus pectoralis* ($\chi^2 = 108.6$, d.f. = 4, $P < 0.001$), *Baiomys taylori* ($\chi^2 = 18.1$, d.f. = 4, $0.001 < P < 0.005$), and *Sigmodon hispidus* ($\chi^2 = 24.6$, d.f. = 4, $P < 0.001$). There was a significant non-random association of the white-ankled mouse, *Peromyscus pectoralis*, and the Ashe

Table 6. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values (RIV) for woody vegetation in the riparian habitat type at the Freeman Ranch, March to May, 1998.

Species	Relative Density	Percent Cover	Dominance	Relative Cover	Percent Frequency	Relative Frequency	RIV
Trees							
Celtis sp.	4.7	5.8	6242.9	4.0	40	7.4	5.4
Juniperus ashei	18.9	30.0	32334.1	20.8	64	11.8	17.1
Prosopis glandulosa	1.7	2.3	2454.1	1.6	8.0	1.5	1.6
Quercus fusiformis	3.4	27.4	29449.4	18.9	40	7.4	9.9
Q. buckleyi	3.0	3.0	3229.1	2.1	12	2.2	2.4
Ulmus crassifolia	14.9	28.4	30568.8	19.6	68	12.5	15.7
Shrubs and vines							
Baccharis neglecta	0.3	0.2	258.3	0.2	4.0	0.7	0.4
Berberis sp.	1.0	0.5	559.7	0.4	8.0	1.5	0.9
Bernardia myricifolia	0.7	0.3	344.4	0.2	8.0	1.5	0.8
Bumelia lanuginosa	0.3	0.1	86.1	0.1	4.0	0.7	0.4
Ehretia anacua	0.3	0.4	473.6	0.3	4.0	0.7	0.5
Diospyrus texana	8.8	12.2	13174.7	8.5	44	8.1	8.4
Forestiera pubescens	4.7	4.0	4262.4	2.7	20	3.7	3.7
Ilex decidua	2.0	2.0	2195.8	1.4	24	4.4	2.6
I. vomitoria	0.3	0.2	172.2	0.1	4.0	0.7	0.4
Juglans sp.	1.4	3.8	4047.1	2.6	16	2.9	2.3
Mimosa borealis	0.3	0.4	387.5	0.2	4.0	0.7	0.4
Opuntia engelmannii	0.7	0.6	602.8	0.4	4.0	0.7	0.6
O. leptocaulis	1.0	0.4	387.5	0.2	12	2.2	1.2
Parthenocissus quinquefolia	1.4	0.4	473.6	0.3	12	2.2	1.3
Ptelea trifoliata	0.3		43.1		4.0	0.7	0.4
Rubus trivialis	6.1	1.6	1765.2	1.1	36	6.6	4.6
Smilax bona-nox	16.6	10.5	11323.4	7.3	60	11.0	11.6
Ungnadia speciosa	3.0	2.8	3013.8	1.9	16	2.9	2.6
Vitis sp.	4.1	7.4	7965.1	5.1	28	5.1	4.8
Total	100	144.8	155815.0	100		100	100

Table 7. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values (RIV) for woody vegetation in the Ashe juniper-live oak forest habitat type at the Freeman Ranch, Hays County, Texas, March to May, 1998.

Species	Relative Density	Percent Cover	Dominance	Relative Cover	Percent Frequency	Relative Frequency	RIV
Trees							
Celtis sp.	1.2	1.8	1894.4	1.5	8	3.3	2.0
Juniperus ashei	58.1	62.4	67208.4	51.5	84	35.0	48.2
Quercus fusiformis	18.6	39.6	42581.1	32.7	64	26.7	26.0
Ulmus crassifolia	4.2	8.8	9472.0	7.3	20	8.3	6.6
Shrubs and vines							
Condalia hookeri	0.6		43.1		4	1.7	0.8
Diospyrus texana	3.0	2.6	2841.6	2.2	12	5.0	3.4
Forestiera pubescens	0.6	0.4	387.5	0.3	4	1.7	0.9
Opuntia engelmannii	6.6	3.8	4133.3	3.2	16	6.7	5.5
O. leptocaulis	0.6	0.1	129.2	0.1	4	1.7	0.8
Smilax bona-nox	6.0	1.4	1506.9	1.2	20	8.3	5.2
Yucca rupicola	0.6	0.2	215.3	0.2	4	1.7	0.8
Total	100	121.2	130412.7	100	240	100	100

Table 8. Species relative abundance for small rodents for five habitat types at the Freeman Ranch, Hays County, Texas, January to March, 1998. Abundance in habitat type equals individuals captured per 100 trap nights. Total individuals taken (n) of each species is given. Trap effort for each habitat type equaled 1500 trap nights.

		Habitat Types				
Species	n	Live Oak Savannah	Live Oak Woodland	Mesquite Savannah	Riparian Woodland	Ashe Juniper Live Oak Forest
Baiomys taylori	19	0.67	0.34	0.27		
Peromyscus pectoralis	149	0.87	1.87	1.34	0.6	5.27
Reithrodontomys fulvescens	1			0.07		
Sigmodon hispidus	44	0.47	0.87	1.27	0.34	
Relative abundance		2.01	3.08	2.95	0.94	5.27

Table 9. Small rodent species richness, species diversity, and evenness for five habitat types at the Freeman Ranch, January to March, 1998. Species diversity and evenness were calculated using Brillouin's index ($\log_2$).

Habitat Type	Species Richness	Species Diversity	Evenness
Live Oak Savannah	3	1.369	0.970
Live Oak Woodland	3	1.183	0.812
Mesquite Savannah	4	1.327	0.732
Riparian Woodland	2	0.783	0.934
Juniper-Live Oak Forest	1	0.000	0.000

juniper-live oak forest habitat type ($\chi^2_{0.01,1}$ = 81.7). The relative paucity of the white-ankled mouse in the riparian woodland forest and live oak savannah habitat types also was significant $\chi^2_{0.01,1}$ = 15.9; $\chi^2_{0.01,1}$ = 11.0, respectively). The frequency of captures of the white-ankled mouse in the live oak woodland and mesquite savannah habitat types was not significantly different from what would be expected due to chance.

There was a significant non-random association between *B. taylori* and the live oak savannah habitat type ($\chi^2_{0.01,1}$ = 10.7). The observed frequency of captures of *B. taylori* in all other habitat types was not significantly different from the expected frequency of captures. The observed frequency of captures of *Sigmodon hispidus* in the mesquite savannah habitat type ($\chi^2_{0.001,1}$ = 10.7) and in the Ashe juniper-live oak forest habitat type ($\chi^2_{0.01,1}$ = 7.9) differed significantly from expected frequency. Live oak woodland, riparian woodland, and live oak savannah habitat types were not significant factors affecting the test statistic for this species.

Based on the sampling in this study, four species of small rodents were found on the Freeman Ranch: *Peromyscus pectoralis*, *Sigmodon hispidus*, *Baiomys taylori*, and *Reithrodontomys fulvescens*. One species, the fulvous harvest mouse, was unique to a single habitat; it occurred only in the mesquite savannah habitat type. In contrast, the white-ankled mouse was found in all five habitats and was the most abundant rodent species in each, accounting for 70% of all captures.

Savannah habitats (mesquite and live oak) had higher small rodent diversity than woodland or forest habitats. Similar results were reported in two contemporary studies of small rodent diversity on the Edwards Plateau in Lampasas/San Saba counties and Edwards/Kinney counties (Table 10) (Schwertner, 1996; Schwausch, 1997). An exception is the river riparian woodland habitat studied by Schwausch (1997) which had a diversity value comparable to grassland habitats.

On the Freeman Ranch, the mesquite savannah habitat type had the highest rodent species richness of all habitats sampled. All four small rodent species found on the ranch occurred there. This habitat type also had the second highest diversity and relatively high small rodent abundance. Thorny scrub species offered concealment for cotton rats, while pygmy mice were caught in open areas with sparse cover. White-ankled mice were found near clumps of vegetation that always included Ashe juniper, and the single harvest mouse was trapped in an area with dense, overgrown, woody vegetation along a barbed wire fence. Although all four rodent species occurred in this habitat type, diversity was lower in this habitat type due to the small number of captures of *B. taylori* and *R. fulvescens*.

The live oak savannah habitat type had the highest diversity of all habitat types and high species richness, but far fewer captures than the mesquite savannah habitat type. Species diversity was highest of any habitat type, in part because captures were evenly distributed among species categories. Low vegetative cover may have limited small rodent abundance. Captures of *P. pectoralis* were restricted to oak mottes that were widely scattered throughout the study site. Cotton rats were trapped near large clumps of thorny vegetation. Pygmy mice were more abundant in this habitat type than in any other and were often trapped out in the open, in sparse grass, far from any other cover.

The riparian woodland habitat type had the second lowest diversity value and the lowest total abundance of any habitat type. In addition, of the two species present, *P. pectoralis* and *S. hispidus*, the latter was entirely localized to a man-made brush pile, which provided more cover than would otherwise have been available in this habitat. Other studies have suggested cotton rats to be absent from creek riparian woodland habitats elsewhere on the Edwards Plateau (Schwertner, 1996; Schwausch, 1997). The Ashe juniper-live oak forest habitat type was unique in that only one rodent species occurred here. However, it also supported the greatest abundance of small rodents.

The live oak woodland habitat type had a relatively high diversity and species richness compared to other habitats. Species richness and species composition were the same as in the live oak savannah habitat type. However, captures of rodents were less evenly distributed in the live oak woodland habitat. Diversity and evenness values for the two habitats reflect these differences in equitability. Total small rodent abundance

Table 10. A comparison of small rodent diversity in grassland/savannah habitats and woodland/shrubland habitats. Sampling was conducted at Kickapoo Caverns State Park in Edwards and Kinney counties, 1994-1995; Colorado Bend State Park in San Saba and Lampasas counties, 1995-1996; and the Freeman Ranch, Hays County, 1998. Diversity values (H') are derived using the Shannon-Wiener Index ($\log_{10}$).

Habitat Type	Kickapoo Caverns	H'	Colorado Bend	H'	Freeman Ranch	H'
Grassland/Savannah	King Ranch bluestem	0.38	King Ranch bluestem	0.41	Live oak savannah	0.46
	Little bluestem	0.24	Stipa grassland	0.20	Mesquite savannah	0.45
	Sparse grassland	0.14				
	Intermediate grassland	0.51				
	Dense grassland	0.36				
Shrubland/Woodland	Creek riparian		Creek riparian		Riparian woodland	0.28
	Vasey oak association		Oak-juniper woodland	0.11	Live oak woodland	0.39
	Pine-oak-juniper woodland		Juniper forest		Juniper-oak forest	
	Guajillo shrubland	0.11	River riparian	0.21		
	Mixed brushland	0.15	Oak-persimmon-cactus scrub			

for the live oak woodland habitat type was similar to the mesquite savannah habitat type. Only the juniper-oak forest had a higher abundance of small rodents.

Vegetative Features and Small Rodent Community Characteristics

Species richness of woody plants was not a good predictor of species abundance of small rodents or diversity. Other habitat features apparently play a more important role. The habitat type with the lowest richness of woody plant species, the Ashe juniper-live oak forest, had the highest abundance of small rodents. On the other hand, it also had the lowest small rodent diversity. The riparian woodland habitat type had the highest species richness of woody plants and the most cover; notwithstanding, it had the lowest rodent abundance, species richness, and diversity.

The amount of available herbaceous and woody plant cover between ground level and 1.0 m above ground seemed more important in determining small rodent faunal characteristics than overall vegetative cover, plant species richness, or vegetative composition. Although overall available cover was relatively low in the mesquite savannah habitat type, grasses provided cover near ground, as did thorny shrubs, especially tasajillo and prickly pear cactus. Compared to the other four habitat types, small rodent abundance was relatively high.

Thorny scrub plant species may be the reason for the abundance of cotton rats in the mesquite savannah habitat type. Cattle were unable to graze areas with dense thorny shrubs; thus, dense patches of grasses grow in and around their bases, providing concealment and escape cover from predators. Cotton rats, and occasionally pygmy mice, were trapped in similar locations in the live oak savannah habitat type, although the abundance of thorny shrubs is less.

Patchiness of the landscape may explain the high diversity, abundance, and richness of small rodents in the live oak woodland habitat type. Open woodlands are juxtaposed with large patches of grassland with transition zones at varying stages of seral development. Open grassland areas support shortgrass and midgrass species. The population of cotton rats in this habitat type was localized to a large, dense patch of midgrass that had flourished in the absence of grazing. This patchiness, as well as curtailed grazing, may have influenced the diversity of small rodents in this habitat type.

One might expect a similar diversity value for the Ashe juniper-live oak forest habitat type, which is also characterized by patchy vegetation. However, there is little transition between forested and open areas. Small-interspersed pockets of open grassland are completely enclosed on all sides by a dense wall of junipers and live oaks. This arrangement probably precludes colonization by *Baiomys taylori*, otherwise found in open grassland areas on the ranch. Furthermore, grazing has reduced the amount of herbaceous vegetation in this habitat type such that sufficient cover for larger rodents is lacking.

Habitat Selection

Peromyscus pectoralis, *Sigmodon hispidus*, and *Baiomys taylori* were non-randomly distributed across the landscape, exhibiting differential use of available habitats. White-ankled mice selected Ashe juniper-live oak forest habitat types. Throughout its distribution, the white-ankled mouse is associated with a variety of rocky environments (King, 1968). On the Edwards Plateau, the white-ankled mouse often is found in rocky, oak-juniper woodlands (Davis and Schmidly, 1994). Baccus and Horton (1984) found this species to be highly correlated with ledges, slopes, and brushpiles. Ledges and brushpiles were used for escape, while 26.6% of the mice observed were noted to climb juniper or oak trees upon release. Thus, the distribution of *P. pectoralis* was highly associated with habitat features that could be used as escape cover.

On the Freeman Ranch, the white-ankled mouse always was trapped near Ashe juniper trees, which occur in all habitat types. It is not clear if *P. pectoralis* is responding to juniper trees or some other covariate. It was noted during this study that *P. pectoralis* is an agile climber and frequently used juniper trees for escape. Its diet includes juniper berries, as well as seeds and insects (Davis and Schmidly, 1994). Another structural feature that *P. pectoralis* may be selecting for is the rocky substrate. The three habitat types where the white-ankled mouse was most abundant were dominated by soils of the Comfort-Rock outcrop complex.

Peromyscus pectoralis also showed habitat avoidance of the riparian woodland and live oak savannah habitat types. In the riparian woodland area, only 0.60 individuals per 100 trap nights were captured. This is relatively low compared to 13.7 white-ankled mice per 100 trap nights in the creek riparian woodland habitat at Colorado Bend State Park (Schwausch, 1997) and 7.4 individuals per 100 trap nights in a riparian woodland habitat at Kickapoo Caverns State Park (Schwertner, 1996). Reasons for avoidance of this habitat type at the Freeman Ranch by the white-ankled mouse are unclear. However, the low abundance of small rodents may be explained by the impact of heavy grazing in this habitat type, a conclusion supported by Schulz and Leininger (1991). In the live oak savannah habitat type, *P. pectoralis* was captured only in or at the edge of oak mottes that were widely scattered, hence the relative paucity of white-ankled mice in this habitat type.

The distribution of *Sigmodon hispidus* showed an affiliation for the mesquite savannah habitat type. This larger rodent usually is found in tallgrass habitats that provide an ample food supply and enough cover for concealment. In the absence of tallgrasses, cotton rats will form dens at the base of low clumps of thorny plant species (Davis and Schmidly, 1994). On the Freeman Ranch, where shortgrasses dominate and grazing reduces available cover, thorny shrubs provided the necessary cover. Thorny shrubs were most abundant in the mesquite savannah habitat type. *S. hispidus*, a grassland-adapted species, avoided the densely forested Ashe juniper-live oak habitat type. A lack of sufficient cover probably precludes its colonization of the interspersed, grassy patches.

Baiomys taylori preferred the live oak savannah habitat type. Shortgrass species predominate on upland savannahs on the ranch, and pygmy mice seem well adapted to the sparse cover conditions. *B. taylori* frequently was trapped amid closely grazed shortgrasses with little or no other cover nearby in all habitat types where it occurred. At Colorado Bend State Park, the pygmy mouse also was most abundant in a shortgrass habitat dominated by *Stipa* sp. It was less common in the grassland habitat dominated by King Ranch bluestem, a midgrass species (Schwausch, 1997).

Structural attributes of the environment largely determine habitat selection by small mammals, resulting in a non-random, patchy distribution of species across a heterogeneous landscape (Baccus and Horton,1984). Habitat selection (and conversely, habitat avoidance) is defined as use of habitat resources disproportional to habitat availability (Litvaitis et al., 1996). In order to support the hypothesis of habitat selection, one must demonstrate significant and interpretable differences between rodent microhabitats (M’Closkey and Fieldwick, 1975). Research on habitat selection among small mammals has proliferated in the last two decades. The standard approach has been to test for differential use of quantitatively defined microhabitats (Kaufman and Kaufman, 1989). Many studies have focused on the genus *Peromyscus*, especially *P. leucopus* and *P. maniculatus*. Habitat features have been identified (at macrohabitat and microhabitat levels) that correlate significantly with species presence (Rosenzweig and Winakur, 1969; Holbrook, 1978; Kantak, 1996; Songer et al., 1997). Selection for certain structural features of the environment also can explain niche separation of sympatric rodents (M’Closkey and Fieldwick, 1975; Stahl, 1980; Parren and Capen, 1985).

The specific features that elicit a response in the selection of habitat often remain unidentified due to the complexity of the environment (Kantak, 1996). For example, the white-ankled mouse, *Peromyscus pectoralis*, is associated with rocky substrates throughout its distribution (King, 1968), suggesting selection for this habitat feature. However, it may be responding to untested covariates. Certainly, other factors also influence the realized niche of a species, including physiology, genetic predisposition, interspecific competition, and predation (M’Closkey and Fieldwick, 1975; Holbrook, 1978; Baccus and Horton, 1984).

Grant and Birney (1979) delineated the ecological patterns in the geographic distribution of North American grasslands and small mammal community characteristics then compared these ecological patterns with the structural attributes of different grassland types. Nine grassland types were grouped into three broad categories based on available cover: those with high cover (characteristic of midgrass and tallgrass prairies), those with intermediate cover (characteristic of southern shortgrass prairies), and those having low cover (bunchgrass or desert grasslands). Small mammal faunal communities at grassland sites with high cover were characterized by high total small mammal biomass, low faunal diversity, and litter-dwelling herbivores. Sites with intermediate cover conditions had low total small mammal biomass, low faunal diversity, and consisted mainly of surface-dwelling omnivores. Grasslands with low cover had high small mammal biomass, high diversity, and specialized, surface-dwelling granivores. Thus, there was no simple trend in small mammal diversity or evenness as aboveground plant biomass decreased from one grassland type to the next.

Small mammal faunas are less affected by changes in plant species composition resulting from grazing than by alterations in the physiognomy of the plant community (Grant et al., 1982). Vegetative structure (i.e., the horizontal and vertical distribution of plants within a habitat) provides a variety of cover opportunities for small mammals. In a study of North American grasslands, Grant and Birney (1979) demonstrated that aboveground plant biomass, or cover, had a direct influence on the characteristics of small mammal grassland communities. Available cover influences total biomass of small mammals, species diversity, and specific taxa represented. Functional roles within the community, for example, reproductive strategies, diet, seasonality of activity, also are influenced by the amount of available cover. Because grazing reduces the density of above ground plant biomass, small mammal faunas are necessarily affected. However, not all grassland faunas are influenced equally or in the same way, i.e., reductions in cover do not yield predictable patterns across grassland types (Grant et al., 1982).

When grazed and ungrazed sites were compared within the same grassland type, significant differences in total biomass of small mammals, faunal diversity, evenness, and proportional species and functional group compositions were evident at tallgrass and montane grassland sites (Grant et al., 1982). Small mammal communities of shortgrass and bunchgrass sites, however, were not significantly affected by different grazing treatments. Reduced cover caused by grazing less impacted species adapted to shortgrasses or sparse cover conditions. This differential response was explained by Grant et al. (1982) as due to the greater impact grazing had on cover at tallgrass and montane sites. The greater the changes in available cover, the greater the impact on native small mammal faunas. One can conclude that cover plays a large role in determining small mammal community characteristics in grassland ecosystems.

Studies that are more contemporary have elucidated significant changes induced by grazing on small mammal faunas of arid, desert grasslands. Brooks (1995) found that rodent density and diversity of grasslands of the western Mojave Desert were significantly higher in areas protected from grazing. A significant increase in seed bank biomass, resulting from increased above ground plant biomass, was also evident in exclosure areas. Rosenstock (1996) reported that herbaceous vegetation recovered more quickly on sites with curtailed grazing relative to sites continuously grazed on semi-arid grasslands in south central Utah. Species richness and abundance of rodents also were significantly higher at the macrohabitat level.

Bich et al. (1995) suggested that intensive grazing altered the richness of the grassland community in the Glen Canyon region of Utah. Heavily grazed pastures exhibited a significant decrease in plant densities. The basal area of some plant species decreased as well. Although total abundance of rodents was not significantly different between sites with different grazing intensities, two rodent species in particular, *Perognathus longimembris* and *Peromyscus maniculatus* responded differentially to grazing. *Perognathus longimembris*, a species of particular importance in the seed dispersal of *Oryzopsis hymenoides*, declined significantly in abundance on heavily grazed sites, negatively impacting rangeland recovery.

Few studies of grassland faunas have assessed the influence of grazing on small mammals in associated riparian habitats. Riparian areas are characterized by high vegetative heterogeneity and support a higher diversity of wildlife than adjacent uplands (Schulz and Leininger, 1991). Riparian grazing can cause extensive damage to the plant community through overgrazing, trampling of vegetation, and compaction of soils. Increased erosion of soils along stream banks and the build-up of sediment in waterways also can result from riparian grazing (Baccus, in press). Schulz and Leininger (1991) demonstrated that although small mammal diversity did not differ significantly between grazed and ungrazed riparian habitats, there was little overall similarity in the species composition of small mammal communities. *Zapus princeps* was the most abundant small mammal in ungrazed riparian areas, but was not well represented in grazed riparian sites, which lacked sufficient cover. Species adapted to sparse cover conditions, such as *Peromyscus maniculatus*, were abundant in the grazed riparian areas and rare in exclosure sites. Thus, if riparian and adjacent upland sites are assessed together at the landscape level, there is a net decrease in diversity where grazing occurs.

Intensive grazing may well have deleterious effects on wildlife communities; however, some studies provide evidence that conservative, well-managed grazing may benefit wildlife diversity (Hall and Willig, 1994; Smith et al., 1996; Baccus, in press). Grazing can be used as an effective management tool in maintaining and even restoring grasslands (Smeins and Merrill, 1988; Holechek et al., 1994). Since the Oligocene, North American grasslands have been shaped by a myriad of ecological processes. Grazing by ungulates represents but one of a number of natural disturbances in grassland ecosystems that influenced an ever-changing assemblage of plants and animals over time (Baccus, in press). Intermediate levels of disturbance that allow for maintenance of mid-successional seral stages may maximize wildlife diversity. For example, Smith et al. (1996) found that on good condition rangeland (72% of climax vegetation remaining), wildlife diversity was higher than on rangeland in excellent condition (86% of climax vegetation remaining). They ascribed this difference to the higher mix of grasses, forbs, and shrubs on grasslands in good condition; this heterogeneity provided a greater variety of food and cover opportunities for wildlife. In short, whether a site is grazed or not is less critical to wildlife diversity than the kind of disturbance, whereby intensity, duration, and frequency of disturbance are decisive factors (Baccus, in press).

According to this paradigm, shortgrass prairies of the Edwards Plateau would have low small mammal diversity with a few opportunistic, omnivorous species. A comparison of diversity at the Freeman Ranch with a range of grassland types surveyed by Grant and Birney (1979) reveals that small mammal diversity is much lower at the Freeman Ranch than at any other grassland site, including a comparable southern shortgrass prairie (Table 11). A diversity value of 0.35 for the ranch falls well outside the range of diversity values (0.66-1.24) for other grasslands. The evenness value (0.59), however, is within the range of values (0.42–0.81) for nine grasslands in Table 11. The southern shortgrass site located in Carson County, Texas in the High Plains Vegetative Region, was an association of *Bouteloua gracilis* and *Aristida longiseta*. This site had annual precipitation that ranged from 50 to 61 cm. A diversity value of 1.06 for this grassland was higher than the value calculated for the Freeman Ranch. Grant and Birney (1979) based all diversity values on sampling of small mammals at ungrazed grassland sites.

There are a number of limitations to this comparison. We did not replicate sampling intensities and methods in the Freeman Ranch study. In addition, Grant and Birney (1979) sampled insectivores and rodents; whereas, diversity values for the Freeman Ranch are based on sampling of the small rodent community only with no captures of insectivores. Finally, wooded and forested habitats, which tend to have a lower small rodent diversity than savannah or grassland habitats (see Table 10) were pooled with savannah habitats to arrive at a single H' value for the Ranch. Sampling sites in Grant and Birney (1979), on the other hand, were restricted solely to representative grassland habitats.

Keeping these disparities in mind, one may ask whether lower diversity at the Freeman Ranch is simply characteristic of grasslands of the Edwards Plateau or if some other factor, or combination of factors, is impacting small rodent diversity. A study of small rodent community characteristics conducted at the Colorado Bend State Park (CBSP) offers an apt comparison (Schwausch, 1997). CBSP also is located on the Edwards Plateau, and both sites are similar in terms of plant communities and small rodent species composition. Grazing at CBSP was curtailed nine years prior to the study. Not-withstanding, diversity measures indicate that CBSP had a lower small rodent diversity than the Freeman Ranch for three comparable habitat types (Table 12). These differences may or may not be statically significant. Comparison of diversity values is limited for several reasons. First, sampling intensities, which do affect H' values, were not the same in the two studies or for all habitat types sampled at CBSP. In addition, rodent sampling at the Freeman

Ranch was conducted within one season (January–March), whereas at CBSP, sampling was conducted over one year. Given these dissimilarities in methods and the fact that rodent populations fluctuate widely from

Table 11. Comparison of small rodent diversity at the Freeman Ranch, Hays County, Texas, a southern shortgrass grassland type, with other grassland types of North America. Aboveground plant biomass is given, along with diversity (H') and evenness (J') values. North American grassland data adapted from Grant and Birney (1979). H' and J' were derived using the Shannon-Wiener Index ($\log_{10}$).

Grassland type	Aboveground plant biomass (g dry weight/m^2)	Diversity (H')	Evenness (J')
Freeman Ranch		0.35	0.59
Bunchgrass	225	0.66	0.53
Montane	300	0.75	0.73
Northern Tallgrass		0.84	0.65
Southern Tallgrass	850	0.75	0.42
Northern Midgrass	900	0.76	0.54
Southern Midgrass	600	0.78	0.81
Northern Shortgrass	275	0.90	0.75
Southern Shortgrass	475	1.06	0.65
Desert Grassland	150	1.24	0.78

Table 12. A comparison of small rodent community characteristics at two sites on the Edwards Plateau: Freeman Ranch, Hays County, January-March, 1998; and Colorado Bend State Park (CBSP), Lampasas County, 1995-1996. Sampling intensity (trap nights), diversity (H'), and abundance (individuals ca-tured/100 trap nights) are given for three comparable habitat types.

Habitat Type	Site	Trap nights	Diversity (H')	Abundance
Stipa grassland/ savannah	Freeman Ranch	1,500	0.46	2.01
	Colorado Bend State Park	540	0.20	10.00
Riparian (creek)	Freeman Ranch	1,500	0.28	0.94
	Colorado Bend State Park	168	0.00	13.70
Live oak-Ashe juniper woodland	Freeman Ranch	1,500	0.39	3.08
	Colorado Bend State Park	1,108	0.11	2.71

season to season, no firm conclusions can be drawn from these data. Finally, nine years may be an insufficient amount of time for a rangeland with a history of chronic overgrazing to recover, much less for the small rodent fauna dependent on that rangeland. Data for the Welder Wildlife Refuge indicate a period of 10-15 years are necessary for the rangeland to go from 20% of climax to 60% (Lynn Drawe, personal communication).

A comparison of small rodent abundance data for the Freeman Ranch and CBSP reveals the opposite trend of diversity: mean small rodent abundance for all habitat types at Colorado Bend SP was much higher (7.33 individuals/100 trap nights) than at the Freeman Ranch (2.84 individuals/100 trap nights; Table 12). Species richness was slightly higher at CBSP, as well (k = 5 at CBSP, k = 4 at Freeman Ranch). For two out of three comparable habitat types, abundance was much higher at Colorado Bend SP than at the Freeman Ranch. For the third habitat type, live oak-juniper woodland, abundance was only slightly higher at the Freeman Ranch (Table 12). Because sampling times were different in the two studies, seasonality is a factor affecting abundance results. Thus, even comparisons between similar habitat types are limited. Differences may or may not be significant.

That small rodent abundance may be negatively affected by intensive grazing is a conclusion supported by Rosenstock (1996) in his study of semi-arid grasslands. Chronic overgrazing reduces potential cover, and as ground cover is removed, soils tend to loose moisture more rapidly, and desertification of rangeland can occur. Increased aridity leads to a decrease in primary productivity and finally, to a decreasing food supply for herbivores. Grant and Birney (1979) suggested that the essential element linking above ground plant biomass and small mammal faunal characteristics in grasslands is the food supply. For example, at grassland sites with intermediate cover, characteristic of southern shortgrass prairies, both herbage and seed supplies are marginal. This situation favors only a few generalist species. Leaf-litter is likewise minimal, precluding habitat utilization by litter-dwellers. The minimal quantity and quality of the food supply results in low small mammal biomass. In this scenario, the effect of overgrazing would be to further reduce a marginal food supply.

CONCLUSIONS AND FUTURE RESEARCH

Given the functional role of small rodent populations in grassland ecosystems, decreasing abundance of rodents is certain to impact the structure of the native biotic community. Caution must be used when interpreting diversity or abundance data as ecological indicators of the health of a community. Populations of small rodents are extremely variable, both spatially and temporally (Rosenstock, 1996). Shortgrass prairies in particular are highly variable from season to season in total small mammal biomass (Grant et al., 1982). Thus, the findings of one study are limited, but can be interpreted within a larger research context.

Research conclusions on the effects of grazing on small rodent communities on shortgrass prairies are far from unanimous. Experimental results often are contradictory. Grant et al. (1982) found no significant difference in small mammal diversity on lightly versus heavily grazed shortgrass sites. Brooks (1995), however, found that both diversity and density of small rodents were significantly affected by different grazing treatments. Rosenstock (1996) reported significant differences in species richness and abundance between grazed versus ungrazed sites. Yet, Bich et al. (1995) found that neither diversity nor abundance was affected significantly by heavy grazing, but rather, the proportion of species composition varied based on grazing intensity.

Confounding these contradictions, research on small rodent communities of the Edwards Plateau is extremely limited. A few studies of diversity and habitat use have been conducted (Schwertner, 1996; Schwausch, 1997). However, no studies have tested specifically for differences in small rodent faunal characteristics on grazed and ungrazed grasslands on the Edwards Plateau in this specific area. Research on the effects of grazing on grasslands of the Edwards Plateau would be particularly valuable, as overgrazing of rangeland in Central Texas is widespread. Overgrazing of this region is a condition that has been further exacerbated by changes brought on by the suppression of wildfire and by urbanization and urban sprawl, which has resulted in habitat loss and habitat fragmentation. Clearly, the impact of heavy grazing on small mammal faunas of shortgrass prairies merits further study

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APPENDIX 1. ANNOTATED CHECKLIST OF RECENT MAMMMALS OF THE FREEMAN RANCH, HAYS COUNTY, TEXAS.

The occurrence of 26 species of mammals was verified for the Freeman Ranch. Classification follows Davis and Schmidly (1994).

Didelphis virginiana (Virginia Opossum)
The opossum is a common mammal in all habitats on the ranch.

Myotis velifer (Cave Myotis)
Twenty-six (4 males and 29 females) cave myotis were captured in mist nests over stock ponds on the ranch. This species was collected in March, April, May and August 1998. Two males captured in March and April had descended testes. Twenty-three females collected and released in April were pregnant. Davis and Schmidly (1994) listed Hays County as being within the distribution of this species.

Pipistrellus subflavus (Eastern Pipistrelle)
Only one female eastern pipistrelle was collected at the ranch in March. There is no county record listed for Hays County for this species (Davis and Schmidly, 1994). This female and 50 individuals collected at a sinkhole on McCarty Lane represent a new county record.

Lausiurus borealis (Eastern Red Bat)
Four female eastern red bats were captured at the ranch in April and May. This bat is a common resident at the ranch in the summer. This is a new county record for Hays County (Davis and Schmidly, 1994).

Lasiurus cinereus (Hoary bat)
Ten female hoary bats were collected in April and May at the ranch. The hoary bat is a spring migrant in North America with females migrating prior to males. It is possible the skewed number of females represented individuals involved in migration. This is a new county record for Hays County (Davis and Schmidly, 1994).

Tadarida brasiliensis (Brazilian Free-tailed Bat)
Twelve (5 males and 7 females) Brazilian free-tailed bats were collected at the ranch in April. This bat is the most common bat in Central Texas. The species migrates into Texas from Mexico in January-February and large populations do not occur in caves until May-June. Davis and Schmidly (1994) listed a record of this bat for Hays County.

Dasypus novemcinctus (Nine-banded Armadillo)
The nine-banded armadillo is a common mammal on the ranch in all habitats. Davis and Schmidly (1994) listed a record of this mammal for Hays County.

Sylvilagus floridanus (Eastern Cottontail)
The eastern cottontail inhabits all habitat types on the ranch. It is most common in areas with thicker, higher stands of grass and uncommon in heavily grazed areas. Davis and Schmidly (1994) listed a record of this rabbit for Hays County.

Lepus californicus (Black-tailed Jackrabbit)
L. californicus typically is found in habitats on the ranch with limited brush and sparse vegetation. Although most plant communities of the ranch fit this profile, the black-tailed jackrabbit is uncommon. Only five specimens have been collected on the ranch. This is a new county record for Hays County (Davis and Schmidly, 1994).

Spermophilus variegatus (Rock Squirrel)
The rock squirrel occurs along Sink Creek and other areas of the ranch with outcropping of rock. It is not a common species on the ranch. Only one specimen was collected. This is a new county record for Hays County (Davis and Schmidly, 1994).

Sciurus niger (Eastern Fox Squirrel)
With live oak trees being the dominant tree species in most habitats on the ranch, the eastern fox squirrel is a common mammal on the ranch. Davis and Schmidly (1994) listed a record of this squirrel for Hays County.

Reithrodontomys fulvescens (Fulvous Harvest Mouse)
One fulvous harvest mouse was collected on the ranch in the mesquite savannah habitat. Davis and Schmidly (1994) listed a record of this mouse for Hays County.

Peromyscus pectoralis (White-ankled Mouse)
The white-ankled mouse was the only small rodent collected in all habitat types on the ranch. It was the most common mammal on the ranch. Davis and Schmidly (1994) listed a record of this mouse for Hays County.

Baiomys taylori (Northern Pygmy Mouse)
Dense ground cover is an important habitat variable for this species. The greatest number of captures for B. taylori was in the live oak savannah in the open with a sparse grass cover, far from any other type of cover. This is a new county record for Hays County (Davis and Schmidly, 1994).

Sigmodon hispidus (Hispid Cotton Rat)
Hispid cotton rats were most often associated with patches of prickly pear cactus in the mesquite savannah habitat type. The patches of prickly pear cactus protected grasses from grazing by providing a thorny barrier between grasses and cattle. This allowed the development of small, but dense areas of grass that provided an optimum habitat for this species. This is a new county record for Hays County (Davis and Schmidly, 1994).

Canis latrans (Coyote)
The coyote is uncommon on the ranch. Most records have been during spotlight population surveys for white-tailed deer. Davis and Schmidly (1994) listed a record of this canid for Hays County.

Vulpes vulpes (Red Fox)
Two red foxes were sighted in the spring near the boundary fence with Country Estates in one of the larger creeks on the ranch. This is a new county record for Hays County (Davis and Schmidly, 1994).

Urocyon cinereoargenteus (Common Gray Fox)
The population density of the gray fox is cyclic on the ranch. Some years the species is common; whereas, in other years the gray fox is uncommon. The cyclic nature of the population density may be associated with canine distemper and rabies epizootics in canine species. The gray fox digs dens along rock outcrops of Sink Creek and in Crawford Pasture. Davis and Schmidly (1994) listed a record of this canid for Hays County.

Bassariscus astutus (Ringtail)
The ringtail is an uncommon small predator on the ranch. Most sightings of this species have been during spotlight population surveys for white-tailed deer. *B. astutus* is most common near riparian woodland habitats. Davis and Schmidly (1994) listed a record of this procyonid for Hays County.

Procyon lotor (Raccoon)
Like the gray fox, raccoon populations are cyclic. Some years the species is common; whereas, in other years the raccoon is uncommon. The cyclic nature of the population density may be associated with canine distemper and rabies epizootics. Davis and Schmidly (1994) listed a record of this procyonid for Hays County.

Mephitis mephitis (Striped Skunk)
The striped skunk has a similar pattern of abundance as that of the raccoon and gray fox. The same ecological factors that influence the gray fox and raccoon populations probably control striped skunk populations. Davis and Schmidly (1994) listed a record of this mustelid for Hays County.

Conepatus mesoleucus (Common Hog-nosed Skunk)
The common hog-nosed skunk is uncommon on the ranch. Most records have been observations during spotlight population surveys for white-tailed deer. This is a new county record for Hays County (Davis and Schmidly, 1994).

Felis concolor (Mountain Lion)
The mountain lion is uncommon on the ranch. Footprints were found at the small pond near Ranch Road 12. Davis and Schmidly (1994) listed a record of this felid for Hays County.

Lynx rufus (Bobcat)
The bobcat is uncommon on the ranch. Most records have been observations during spotlight population surveys for white-tailed deer. Davis and Schmidly (1994) listed a record of this felid for Hays County.

Sus scrofa (Feral Hog)
A small population of feral hogs inhabits the ranch. A substantial increase in the population of this species on the ranch has the potential to cause ecological havoc.

Odocoileus virginianus (White-tailed Deer)
The white-tailed deer is a common ungulate in Hays County. Historical information indicates the deer population on the ranch was harvested heavily. When the data for the spotlight line used to estimate white-tailed deer density for Hays County and specifically the spotlight line on County Road 213 are compared to spotlight line and helicopter data for the ranch, the deer density is less than the county average. Plant analyses on the ranch indicate a limited abundance of forbs, preferred by white-tailed deer, growing on the rangeland. The rare melanistic white-tailed deer occurs on the ranch. It is estimated that about 2% of the deer on the ranch are melanistic (Baccus and Posey, 1999).

UNVERIFIED SPECIES ON FREEMAN RANCH

Cryptotis parva (Least Shrew)
The least shrew has been collected in Travis County north of Hays County and Bexar County to the south (Davis and Schmidly, 1994). There is an unpublished record from the Settlement Subdivision across Ranch Road 12 from the ranch.

Eptesicus fuscus (Big Brown Bat)
There is a record of this bat from Comal County to the south of Hays County (Davis and Schmidly, 1994). Davis and Schmidly (1994) indicated in the range map for this species that Hays County is within the western distribution of the big brown bat in Central Texas.

Lasiurus intermedius (Northern Yellow Bat)
The northern yellow bat has been collected in Travis County north of Hays County and Bexar County to the south (Davis and Schmidly, 1994). Hays County is located at the westernmost edge of the distribution for this species.

Nycticeius humeralis (Evening Bat)
There is no record for the evening bat in Hays County, but there is a record for Travis County to the north (Davis and Schmidly, 1994).

Spermophilus mexicanus (Mexican Ground Squirrel)
The Mexican ground squirrel has been collected in Hays County in the City Park and cemetery. Davis and Schmidly (1994) listed records for all surrounding counties. The overgrazed habitat at the ranch should be optimum habitat for this ground squirrel, but none were collected or observed.

Perognathus merriami (Merriam’s Pocket Mouse)
The species has been recorded in Travis and Burnet counties to the north of Hays County (Davis and Schmidly, 1994). The stony, gravelly soil with scattered patches of grass should provide habitat for Merriam’s pocket mouse.

Chaetodipus hispidus (Hispid Pocket Mouse)
Davis and Schmidly (1994) recorded the species in all counties surrounding Hays County. This pocket mouse might occur on the ranch.

Reithrodontomys montanus (Plains Harvest Mouse)
Davis and Schmidly (1994) reported the plains harvest mouse from Travis and Bexar counties. The plains harvest

mouse often occurs in the same habitat with Baiomys taylori. This harvest mouse might occur on the ranch.

Peromyscus attwateri (Texas Mouse)
The Texas mouse has been collected at the Pollard Refuge in habitat similar to the Ashe juniper-live oak forest habitat on the ranch. Davis and Schmidly (1994) listed the species range as including all of Central Texas.

Peromyscus leucopus (White-footed Mouse)
Davis and Schmidly (1994) listed the species range as including all of Central Texas. The species occurs in riparian woodland habitat in Hays County along the San Marcos and Blanco Rivers and their major tributaries. Suitable habitat for this species occurs on the ranch in the riparian woodland habitat along Sink creek.

Peromyscus maniculatus (Deer Mouse)
Davis and Schmidly (1994) showed the distribution of this species to include all of Central Texas. The deer mouse might occur on the ranch in grassland habitat.

Neotoma floridana (Eastern Woodrat)
Davis and Schmidly (1994) included Hays County within the range of the eastern woodrat in Central Texas. The species has been collected in Travis and Caldwell counties adjacent to Hays County.

Erethizon dorsatum (Porcupine)
The porcupine has been collected south of Wimberly in Hays County. The species has been observed in the Country Estates Subdivision adjoining the ranch.

Myocastor coypus (Nutria)
Davis and Schmidly (1994) included Hays County and all surrounding counties within the range of the nutria in Central Texas. The nutria is common in Spring Lake in San Marcos. Sink Creek, a tributary of the San Marcos River, crosses the ranch. The species might inhabit the stock ponds on the ranch.

Mustela vison (Mink)
The mink inhabits the Sink Creek drainage complex in Hays County south of the Freeman ranch. Sink creek is the major drainage crossing the ranch. The mink might occur on the ranch.

Taxidea taxus (American Badger)
The American badger has been collected in Travis County, and Davis and Schmidly (1994) included Hays County within the range of this species in Central Texas. However, the rocky soil on the ranch probably may preclude the occurrence of the badger on the ranch.

Spilogale putorius (Eastern Spotted Skunk)
Davis and Schmidly (1994) included a record for this mustelid in Hays County. This rare species may occur on the ranch.