RIPARIAN HABITATS OF THE CENTRAL PLATTE AS A CORRIDOR FOR DISPERSAL OF SMALL MAMMALS IN NEBRASKA

by

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Riparian Habitats of the Central Platte as a Corridor

for Dispersal of Small Mammals in Nebraska

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University of Nebraska, 1995

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Trends in diversity of small mammals were examined in six grassland and six forested habitats along a 140 km (Clarks to Elm Creek) portion of the central Platte River, Nebraska in 1993 and 1994. The primary objective of the study was to provide baseline data to define the role of riparian habitats of the central Platte as a corridor for dispersal of small mammals that were formerly or are currently restricted to the climax-hickory forest along the Missouri River in extreme eastern Nebraska (Missouri Distributional area). Secondary objectives examined 1) effects of microvegetative structure on relative abundance of species and 2) efficiencies of capture of two different baits and traps. Thirteen species (1,562 individuals) were collected; all were from expected distributional ranges. No trends in indices were found with the exception of evenness in grassland habitats in 1993. Proportions among species at a site (evenness) were more similar at greater distances from the easternmost grassland site sampled ($r_s = 0.943$, $p \leq 0.010$). Ranks of relative abundances of masked shrews (*Sorex cinereus*) and meadow jumping mice (*Zapus hudsonius*) were positively correlated with vertical density in grassland habitats in 1993 ($p \leq 0.100$). Meadow voles (*Microtus pennsylvanicus*) were positively correlated with total canopy cover ($p \leq 0.100$). In forested sites in 1994, abundances of white-footed mice (*Peromyscus leucopus*) showed a negative rank correlation with total canopy cover ($p < 0.010$). The six most common species in 1993 and 1994 were captured at a significantly higher rate with snap traps baited with a mixture of peanut butter and oats compared to ground beef. In sites sampled with two different traps, snap traps

outperformed live traps in measuring richness ($p = 0.0844$) but showed no difference in overall relative abundance ($p = 0.3362$). Mean relative abundance of meadow voles was higher using snap traps compared to live traps ($p < 0.025$). Thirty-eight non-target individuals (including birds, amphibians, and reptiles) were also captured in snap traps.

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I would like to thank my advisor Dr. Ron Case for giving me the opportunity to further my experience in the field of wildlife biology. His guidance and input for ideas and goals in this project are greatly appreciated. Dr. Case also encouraged me to present my research at scientific meetings, which helped me gain confidence in myself as well as my research. My committee members, Dr. Patricia Freeman and Dr. Linda Young, provided a great deal of advice on writing, research questions, and statistical analysis. They also helped me realize how valuable the study was and how important it would be to document further changes in small mammal distributions in Nebraska. To this I owe them a great deal of gratitude.

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INTRODUCTION

The Platte River habitat was once treeless and consisted primarily of native grasslands. Tallgrass prairies and wetland meadows were the dominant forms of riparian vegetation before pioneer settlement in the 1840s. This environment was disturbed by herds of grazing buffalo (*Bos bison*) and fires set by Native Americans and lightning (Currier *et al.* 1985). These disturbances kept the prairie ecosystem essentially treeless. Early accounts of the channel of the Platte described it as being wide and not very deep. But changes occurred following the arrival of European settlers.

The channel width of the 115-km portion between Overton and Grand Island, Nebraska, within what is known as the "Big Bend" region (Lexington to Chapman) of the Platte River, was significantly reduced in the past 100 years (Williams 1978). Portions of other river systems in the state also encountered dramatic changes in channel morphology and vegetative composition. Roedel (1992) found net increases in coverage of woody vegetation from 1952 through 1990 in his research along the Republican River in southwestern Nebraska. Encroachment of woody vegetation began in the smaller, North and South Platte Rivers and spread downstream to the Platte River proper around 1900 (Johnson 1994). Diversion of water for irrigation and (Jones *et al.* 1983) the intentional planting of trees as shelterbelts and ornamentals influenced the expansion of trees in the region. Water was a necessary and valuable resource for farmers and ranchers as they converted prairies and wetland meadows to croplands. Later, the construction of upstream dams for recreation and hydropower assisted the encroachment process by reducing the flow of the water in the channel.

The reduced scouring effect of winter ice flows on sandbars and banks allowed the establishment of many species of trees and shrubs. Johnson (1994) showed that succession of sandbar to woodland (*Populus-Salix*) was regulated primarily by ice flows, rates of channel flow in June, and summer drought. Cottonwood (*Populus deltoides*), rough-leaf dogwood (*Cornus drummondii*), peach-leaf willow (*Salix amygdaloides*), and red cedar (*Juniperus virginiana*) are just a few of the species that appear dominant (pers. obsv.). Currier *et al.* (1985) has a detailed account of woody species in the Big Bend region of the Platte River.

Sidle *et al.* (1989) described substantial increases of cropland as well as woody vegetation since the late 1930's. Associated with this increase was the decrease in the number of active river channels and wetland meadows found along the Platte and North Platte Rivers. McDonald and Sidle (1992) showed that extensive conversions of aquatic to dry-land habitats occurred along the North and South Platte Rivers over the past half-century. However, the dominant trend of loss in channel area and gain in woodland area has apparently ceased in recent years (Johnson 1994). In active channels, survivorship of tree seedlings has been reduced since 1969.

There is increasing concern with the effect of changes in riparian habitats of central Platte on wildlife. Knopf and Scott (1990) stated that impacts of invasion of exotic species, such as the Russian-olive (*Elaeagnus angustifolia*), will be difficult to interpret because so little is known on the ecology of this species. Fragmentation of grasslands, changes in channel morphology, and sandbar succession already have had an impact on certain species. The Platte River is considered critical habitat for many species. Avian species such as whooping (*Grus americana*) and sandhill cranes (*Grus canadensis*), least tern (*Sterna antillarum*), and piping plover (*Chorarius melodus*), are highly dependent on this ecosystem. Suitable habitat for these species has declined most likely as a result of the expansion of woody vegetation and changes in channel morphology. Several agencies in Nebraska are involved in examining strategies for survivorship of these birds and managing riparian habitats according to the birds' life history requirements. These strategies may ensure survival of these species. However, little attention has been focused on mammals and their distributions in this changing system.

LITERATURE REVIEW

Distributions of mammals in Nebraska

The development of riparian forest adjacent to the Platte facilitated westward range expansion of several mammals characteristic of the eastern deciduous forest. Freeman and Benedict (1993) reported that several mammals expanded their ranges westward as a result of this developing forest. One mammal in particular, the white-footed mouse (*Peromyscus leucopus*), is especially interesting because of its preference for wooded habitats. It occurs throughout most of the plains region and is increasingly restricted to riparian woodlands as it moves west along major rivers (Jones *et al.* 1985). Roedel (1992) showed westward expansion of white-footed mice along the Republican River nearly 100 km west of the species' 1959 distributional range. The expansion is believed to be a result of an increase in woody vegetation along the river.

Small mammals have limited dispersal abilities and can take several years to pass through a corridor of suitable habitat. Our understanding of the riverine habitat and how it serves as a dispersal corridor for small mammals is limited. Such a long-term phenomenon may not be easily recognized in a short-term study. The knowledge that is required will depend on data from the past, present, and future. Unfortunately, research on these "corridor dwellers" and their use of corridors has been largely neglected (Beier and Loe 1992).

Corridors and their role in population biology

"Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth" (Naiman *et al.* 1993). Corridors are valuable to many forms of wildlife because they connect substantive patches of habitat (Beier and Loe 1992). Animals can move safely between patches as they disperse through natural highways (Odum 1978). Movement and gene flow between populations using a corridor can promote genetic diversity and prevent inbreeding. Catastrophic events such as fires and floods can cause local extinctions of populations in isolated habitats. But recolonization is more likely to occur if these habitats are connected by corridors (Meffe and Carroll 1994).

Corridors vary considerably in their size and function. Regional corridors several kilometers wide connecting large nature reserves as well as fencerows connecting isolated woodlots can provide dispersal routes for a wide range of species. Fencerows allow localized dispersal of small mammals to more suitable habitats. Henderson *et al.* (1985) showed that fencerows were extremely important in dispersal of chipmunks between woodlots in an agricultural mosaic. In some cases, chipmunks survived and reproduced in the corridor itself. Fahrig and Merriam (1985) developed, tested, and supported models that predicted lower growth rates of white-footed mice in isolated woodlots than those in connected woodlots. Mice in isolated woodlots were more prone to extinction. Merriam and Lanoue (1990) examined white-footed mice in three types of structurally diverse fencerows (simple, intermediate, and complex). They found that these mice used all three as corridors for movement and preferred fencerows that were structurally complex.

Meffe and Carroll (1994) describe a landscape corridor as a riparian forest along a stream where daily, seasonal, and more permanent movements of wildlife are established. Wooded riparian corridors are important to mammalian distributions in Nebraska because they extend westward into arid habitats where species would not normally occur (Jones *et al.* 1983). These forests, commonly known as northern floodplain forests, are productive corridors supporting a diversity of mammals (Jones *et al.* 1985). Classification of corridors does not depend exclusively on its length or width but how it serves several ecological functions. The riparian forest of the Platte River serves many functions to many species: as a corridor or simply as an increase of available habitat.

Although there is controversy involving the value of corridors to wildlife, they provide many benefits. But these benefits depend largely on what function it serves for a particular species. Corridors have disadvantages and may facilitate the spread of fire and disease, (Meffe and Carroll 1994) serve as death traps or sink corridors, (Knopf 1986) or allow hybridzation of formerly isolated congeneric species that may reverse 10,000 years of speciation. Density and diversity of species tends to be higher at land-water ecotones than in adjacent uplands (Odum 1978). This edge effect can attract generalists, predators, and edge species because corridors often have high edge to interior ratios. As a result, area-sensitive species passing through corridors may encounter higher rates of competition and predation.

Effects of fragmentation

Fragmentation of landscapes has occurred at an alarming rate. Human activity is largely responsible and habitat degradation has resulted. Meffe and Carroll (1994) describe it as a disruption of extensive habitats into smaller, isolated patches. Local and total extinctions can be the most significant consequence of fragmentation. Some organisms have the ability to adapt to a rapidly changing environment. But others are unsuccessful, and adaptation is not compatible with the rate at which habitat loss and anthropogenic disturbances are occurring.

As fragmentation of areas increases, higher dispersal rates are required to maximize the survival of a species (Burkey 1989). Special requirements of area must be met to ensure survival of a species. Forman and Godron (1981) discuss effects of area of islands and how in most cases larger islands have more structural diversity and therefore can support more species. Gottfried (1978) tested predictions of MacArthur and Wilson's model of island biogeography on populations of small mammals in isolated woodlots. He found that mainland communities contained a significantly higher diversity than islands and that species richness was positively related to size.

Fragmentation on small and large scales can affect movements of small mammals. Merriam *et al.* (1989) found that roads as little as 3.3 m to 6.4 m wide were effective quantitative barriers for white-footed mice dispersal between fragmented forests. Bierregaard *et al.* (1992) showed that an 80 m expanse of sparsely vegetated landscape in a tropical rainforest was enough of a barrier to prevent the dispersal of small mammals. Examining effects of fragmentation in riparian grasslands and forests should be given close attention because of important consequences on small mammals and their distributions.

Goals

The principal goals of this research project were to 1) provide baseline data to define the role of riparian habitats of the central Platte as a corridor for dispersal of small mammals that were formerly or are currently restricted to the climax-hickory forest along the Missouri River in extreme eastern Nebraska (Missouri Distributional area) (Jones 1964), 2) examine the effects of microvegetative structure on the relative abundance of species, and 3) evaluate efficiencies of capture of two different baits and traps.

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ARTICLE: RIPARIAN HABITATS OF THE CENTRAL PLATTE AS A CORRIDOR FOR DISPERSAL OF SMALL MAMMALS IN NEBRASKA

ABSTRACT

This study provided baseline data to define the role of riparian habitats as a corridor for dispersal of small mammals that were formerly or are currently restricted to the climax-hickory forest along the Missouri River in extreme eastern Nebraska (Missouri Distributional area). Five indices of small mammals were measured in two different riparian habitats (grassland and forested) adjacent to the central Platte in 1993 and 1994. Distance from the easternmost grassland site sampled, microvegetative structure, baits, and traps influenced indices. Thirteen species (1,562 individuals) were collected in snap traps; all were from expected distributional ranges. Proportions among species at a site (evenness) were more similar at greater distances from the easternmost grassland site sampled in 1993 ($r_s = 0.943$, $p \leq 0.010$). Four other indices were examined but no trends were found. In grassland sites in 1993, rank correlations showed that meadow voles (*Microtus pennsylvanicus*) were positively correlated with canopy cover ($p \leq 0.100$). In forested sites in 1994, abundances of white-footed mice (*Peromyscus leucopus*) were negatively correlated with canopy cover ($p < 0.010$). The six most common species in 1993 and 1994 were captured at a significantly higher rate with snap traps baited with a mixture of peanut butter and oats compared to ground beef. I found no difference in captures of northern short-tailed shrews (*Blarina brevicauda*) using the two baits in 1993. Snap traps outperformed live traps in measuring richness ($p = 0.0844$) but not in overall relative abundance ($p = 0.3362$). Mean relative abundance of meadow voles was higher using snap traps compared to live traps ($p < 0.025$). Thirty-eight non-target individuals (including birds, amphibians, and reptiles) were also captured in snap traps.

INTRODUCTION

"Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth" (Naiman *et al.* 1993). Corridors are valuable to many forms of wildlife because they connect substantive patches of habitat (Beier and Loe 1992). Animals can move safely between patches as they disperse through natural highways (Odum 1978). Movement and gene flow between populations using a corridor can promote genetic diversity and prevent inbreeding. However, Knopf (1986) discussed how corridors allow hybridzation of formerly isolated congeneric species and may reverse 10,000 years of speciation. Catastrophic events such as fires and floods can cause local extinctions of populations in isolated habitats. But recolonization is more likely to occur if these habitats are connected by corridors (Meffe and Carroll 1994).

Corridors vary considerably in their size and function. Regional corridors several kilometers wide connecting large nature reserves may be necessary for large animals. Fencerows allow localized dispersal of small mammals to more suitable habitats. Henderson *et al.* (1985) showed that fencerows were important in dispersal of chipmunks between woodlots in an agricultural mosaic. In some cases, chipmunks survived and reproduced in the corridor itself. Fahrig and Merriam (1985) developed, tested, and supported models that predicted lower growth rates of white-footed mice in isolated woodlots than those in connected woodlots. Mice in isolated woodlots were more prone to extinction. Merriam and Lanoue (1990) examined white-footed mice in three types of structurally diverse fencerows (simple, intermediate, and complex). They found that these mice used all three as corridors for movement and preferred fencerows that were structurally complex.

Meffe and Carroll (1994) describe a landscape corridor as a riparian forest along a stream where daily, seasonal, and more permanent movements of wildlife are established. Wooded riparian corridors are important to mammalian distributions in Nebraska because they extend westward into arid habitats where some species would not normally occur (Jones *et al.* 1983). These forests, commonly known as northern floodplain forests, are productive corridors supporting a diversity of mammals (Jones *et al.* 1985). Classification of corridors does not depend exclusively on its length or width but how it serves several ecological functions. The riparian forest of the Platte River serves many functions to many species: as a corridor or simply as an increase of available habitat. Density and diversity of species tends to be higher at land-water ecotones than in adjacent uplands (Odum 1978). This edge effect can attract generalists, predators, and edge species because corridors often have high edge to interior ratios. As a result, area-sensitive species passing through corridors may encounter higher rates of competition and predation.

The Platte River habitat was once treeless and consisted primarily of native grasslands. Tallgrass prairies and wetland meadows were the dominant forms of riparian vegetation before pioneer settlement in the 1840s. This environment was disturbed by herds of grazing buffalo (*Bos bison*) and fires set by Native Americans and lightning (Currier *et al.* 1985). These disturbances kept the prairie ecosystem essentially treeless.

The habitat is now fragmented from the encroachment of woody vegetation and agriculture and is a mosaic of grasslands and gallery forests. Diversion of water for irrigation and (Jones *et al.* 1983) the intentional planting of trees as shelterbelts and ornamentals influenced the expansion of trees in the region. The construction of upstream dams for recreation and hydropower assisted the process by reducing the flow of water in the channel. The scouring effect of winter ice flows on sandbars and banks was diminished and this allowed the establishment of many species of trees and shrubs. Johnson (1994) showed that succession of sandbar to woodland (*Populus-Salix*) was regulated primarily by ice flows, rates of channel flow in June, and summer drought.

As a result of the invasion of trees, forest-dwelling mammals that were formerly characteristic of the climax-hickory forest along the Missouri River in extreme eastern

Nebraska, (Jones 1964) expanded their ranges westward. Mammals such as the white-footed mouse (*Peromyscus leucopus*) and opossum (*Didelphis virginiana*) responded to these anthropogenic disturbances that provided suitable habitat where these species did not historically occur. Jones (1964) stated that the opossum "expanded its range northward and westward, utilizing as avenues of travel the deciduous riparian communities of river systems." Freeman and Benedict (1993) reported that several other mammals expanded their ranges westward as a result of this developing forest. Range expansion of mammals has occurred along other river systems in the state. Roedel (1992) showed westward expansion of white-footed mice along the Republican River nearly 100 km west of the species' 1959 distributional range. The expansion is believed to be a result of an increase in woody vegetation along the river.

Other types of habitats may be providing dispersal routes for small mammals in neighboring regions. Choate *et al.* (1991) hypothesized that roadsides containing tallgrass habitats as well as riparian corridors containing tallgrass vegetation were routes of dispersal for meadow jumping mice (*Zapus hudsonius*). The mouse expanded its range westward in Kansas and was not known to inhabit areas where it had been recently captured. Although it is not yet supported, Frey and Moore (1990) speculated that the sides of two-lane U.S. highways provided dispersal routes for meadow voles (*Microtus pennsylvanicus*) and that these routes may explain the recent southward range extension for the species in Kansas.

There is increasing concern with the effect of changes in riparian habitats of the central Platte on wildlife. Knopf and Scott (1990) stated that impacts of invasion of exotic species, such as the Russian-olive (*Elaeagnus angustifolia*), will be difficult to interpret because so little is known on the ecology of this species. Fragmentation of grasslands, changes in channel morphology, and sandbar succession have already had an impact on certain species. The central Platte River is considered critical habitat for avian species such as whooping (*Grus americana*) and sandhill cranes (*Grus canadensis*), least tern (*Sterna* *antillarum*), and piping plover (*Chararius melodus*). Suitable habitat for some of these species has declined most likely as a result of the expansion of woody vegetation and changes in channel morphology. Several agencies in Nebraska are involved in examining strategies for survivorship of these birds and managing riparian habitats according to the birds' life history requirements.

Many of the strategies involve grazing, burning, and clear-cutting to prevent encroachment of woody vegetation. Potential impacts of these practices on mammals, their distributions, and dispersal is unknown. The value of the habitat is equivocal and disturbances may positively or negatively influence dispersal of some species.

The presence of specific plants may not be as important as vegetative structure at influencing populations of small mammals (Hayslett and Danielson 1994). Edge *et al.* (1995) reported that removal of cover by mowing reduced gray-tailed vole (*Microtus canicaudus*) populations by half. In a study on the effects of mowing on a rodent community, Lemen and Clausen (1984) found that an increase in vegetative cover and the number of *Microtus* caught were positively correlated.

White-footed mice are common in forested habitats. Jones *et al.* (1983) stated that *P. leucopus* "invariably are found in woodlands or in brushy areas such as shelterbelts and fencerows." McMillan and Kaufman (1994) stated that white-footed mice "selectively used wooded habitat" where trees with large and small shrubs were present.

The type of bait and trap used, weather conditions, season, and vegetative structure are a few factors that influence trapping of small mammals. Presence or absence of bait can explain part of the variation in terms of responses of small mammals to traps (Smith *et al.* 1975). Baits are important because in many studies of small mammals, (Call 1986) it is often the objective to catch as many species (richness) as well as individuals (abundance) of each species in a community.

Qualities of baits for successful trapping include: an attraction to a diversity of small mammals, easy procurement, application, and resistance to spoilage and foraging by invertebrates (Patric 1970). Smith *et al.* (1969) stated that trapping mammals should involve baits that adhere adequately to pedals if snap traps are used. Failure of traps in capturing certain animals can often be explained by ineffectiveness of the bait (Smith *et al.* 1975). It is apparent that a mixture of peanut butter and oats is an effective bait for trapping a variety of small mammals. However, reports on success of trapping shrews in studies using the mixture as well as ground meat were conflicting.

Sealander and James (1958) stated that traps are selective with respect to the size of specimen captured. This selectivity is largely based on the mechanical sensitivity of the trap. In surveys of biodiversity, a complete inventory of the species inhabiting an area is, in most cases, the primary objective. But this is not always obtainable because of limited resources. Williams and Braun (1983) stated that the type of trap used, as well as the numbers of traps set, is influenced by available time and money. Because resources are often limited, inaccurate estimates of richness, relative abundance, and other indices are the result.

The principal goals of this study were to 1) provide baseline data to define the role of riparian habitats of the central Platte as a corridor for dispersal of small mammals that were formerly or are currently restricted to the climax-hickory forest along the Missouri River in extreme eastern Nebraska (Jones 1964), 2) examine the effects of microvegetative structure on the relative abundance of species, and 3) evaluate efficiencies of capture of two different baits and traps.

STUDY AREAS AND METHODS

Research was conducted in Merrick, Hall, Buffalo, and Dawson counties in Nebraska (Figure 1). I selected six grassland and six forested sites along a 140 km portion of the central Platte River. Most sites were located within the "Big Bend" (Lexington to Chapman) region of the Platte River. Homogeneous vegetation of at least 750 x 100 m (7.5 ha) was required at each site. One grassland site did not meet the dimensional requirement but vegetation was homogeneous for at least 7.5 ha. Areas where vegetation was fragmented by channels, roads, or other management practices (edge effects) were avoided. Sites varied in relation to management or had no specific management practice (Appendix A and B).

I censused small mammals using 7.6 x 7.6 x 25.4 cm non-collapsible H.B. Sherman live traps and 14.0 x 6.7 cm ("Victor"-Woodstream Co.) Museum Special snap traps. In 1993, five sites (three grassland; two forested) were selected for live-trapping within an 86 km portion (Alda to Elm Creek) of the river. Sampling occurred from 14 May to 11 July 1993 and this produced a total of 1,600 trap-nights. All sites were sampled using snap traps from 18 May to 7 November and 14 May to 8 July in 1993 and 1994, respectively, for a total of 23,040 trap-nights. Relative abundance was expressed as catch per 100 trapping units and calculated using the method described by Nelson and Clark (1973).

In each of 11 study areas, there were four, 500-m trap lines. Lines were parallel to the channel edge and spaced 50 m apart with the first line 12.5 m from the edge. Stations were spaced evenly along trap lines. In grassland site # 1, there were eight 250-m trap lines. Intervals between lines and stations were as above.

One live trap was placed every 12.5 m along trap lines, baited with rolled oats, and locked open for one night prior to sampling. For sampling, traps were baited with a mixture of peanut butter and rolled oats wrapped in packets of waxed paper for two consecutive nights. I started baiting and setting live traps approximately three hours before sunset. Traps were checked starting approximately one hour after sunrise. Mammals were ear-tagged with a size 1 Monel tag (National Band and Tag Co.) in the right ear and released at the point of capture. Where needed, bait was replaced for the second trap-night. Date, species identification, point of capture, tag number, and number of incidentally sprung traps were recorded. Recaptured animals marked on the first trap-night were "removed" in the relative abundance measures.

One snap trap was placed at a 2-m interval on either side of the stations and baited following the live-trapping protocol. Traps placed 2 m east and west of each station were baited with a mixture of peanut butter and rolled oats and 72% lean ground beef, respectively, for three consecutive nights (Appendix C). Data recorded, time of baiting, setting, and checking traps were as above. All live and snap traps were intentionally sprung and snapped, respectively, after each sampling period to avoid accidental capture of diurnal animals (Ad hoc committee 1987). Collected specimens were tagged and double-bagged with ties and immediately placed on dry ice in coolers. All prepared skins and skeletons were deposited in the collection of the University of Nebraska State Museum.

My initial objective was to examine estimates of population and capture efficiencies of two different traps in 12 study sites. However, the use of live traps was discontinued after five sites. The decision was made because of logistic demands as well as the relative inefficiency of live traps in capturing some small mammals. My comparison involved only those sites sampled with the different traps. I used the first two trap-nights of snap-trapping and only those individuals collected on the mixture of peanut butter and oats for the analysis.

I characterized ground cover in the grassland sites by measuring 12 variables (Table 1) in five and six grassland sites from 16 June to 23 October and 12 May to 5 July, in 1993 and 1994, respectively, using a rectangular frame (0.80 x 0.45 m) to measure percent cover of canopy, live and dead vegetation, grass, forbs, wood, litter, and bare ground within the frame. Visual obstruction (vertical density) and maximum height of both live and dead vegetation were measured using a Robel pole (Robel *et al.* 1970). Variables were measured at odd and even-numbered stations on alternating, trap lines, respectively. The Robel pole was placed 4 m from trap stations at a randomly selected cardinal point. Readings were made 1 m above ground and 4 m from the pole. Measurements of visual obstruction were made to the nearest half decimeter as an index to vertical density. The rectangular frame was systematically positioned 1 m away from the Robel pole in the same cardinal direction and one reading taken. Measurements of litter depth were taken 2.54 cm (1 in.) away from a premarked location on the frame.

I characterized ground cover in the six forested sites from 14 May to 27 June in 1994 only, by measuring 16 variables (Table 2). A square meter frame was used to measure percent cover of canopy, live and dead vegetation, grass, forbs, shrub, tree, litter, and bare ground within the frame. Density of trees and shrubs within and touching the square and maximum height of non-woody vegetation touching a tape measure placed in the center of the square were also recorded. The frame was placed approximately 2 m north of odd and even-numbered stations on alternating trap lines, respectively. Litter depth was measured as above. Woody debris was counted to indicate additional litter in contact with or within the frame. A detailed description of all methods is also given (Appendix D).

Statistical analysis

I measured richness (total number of species), overall relative abundance (see Nelson and Clark 1973), Shannon-Wiener diversity, and evenness indices of small mammals (see Magurran 1988) at each site in 1993 and 1994 (Appendix E and F). Relative abundance of each species was also calculated in each habitat and year (Appendix G, H, I, and J). Rank correlations were performed to examine any significant relationships between an index and distance (km) from the easternmost site sampled. This was done for each type of habitat in both 1993 and 1994 using SYSTAT (1992) software.

Estimates of the mean and standard error were calculated for each vegetative variable ($n = 80$) at each site (Appendix K, L, and M). If vegetative variables were correlated ($p \leq 0.100$), discussion of results was limited to one variable of a correlated pair. Relationships between relative abundances of small mammals and mean vegetative variables were examined using a rank correlation. I limited the analysis to species that occurred at three or more grassland sites in 1993 and 1994. Rank correlations between relative abundances of small mammals (those occurring at three or more sites) and vegetative variables were analyzed in forested sites in 1994 only.

For each species in each year, I tested the null hypothesis that no difference existed between total captures with different baits. A Chi-square test using Yates' correction for continuity (Zar 1984) was used for each species where a total of 10 or more individuals was collected in each year. Because the number of traps set for each type of bait was initially equal for every trapping occasion, the total number of each species collected on each type of bait was used as opposed to a measure of relative abundance. This is valid only under the assumption that the traps baited with different baits had equal probabilities of being snapped incidentally or by adverse weather conditions. A Chi-square test was also used in the comparison of mean relative abundances of species in two different traps. I limited the analysis to the four most common species captured ($\geq$ 10.0 / 100 total trapping units).

RESULTS AND DISCUSSION

Trends in indices of small mammals

I collected 1,562 specimens representing 13 species (Table 3). Twelve (573 individuals) and seven (600 individuals) species were collected in six grassland and six forested sites in 1993, respectively (Appendix N and O). In 1994, 10 (123 individuals) and seven (266 individuals) species were collected in six grassland and six forested sites, respectively (Appendix P and Q). No trends in diversity indices were found with the exception of evenness in grassland habitats in 1993. Evenness among species at a site increased east to west and showed a positive rank correlation with distance of site from the easternmost grassland site sampled ($r_s = 0.943$, $p \leq 0.010$) (Figure 2). No east to west trends were evident in forested habitats in either year (Figure 3). Relative abundances of each species showed no rank correlation with intersite distances.

In 1993, several study sites were temporarily inundated with heavy rains. Relative abundances of nearly all species showed a decrease from 1993 to 1994. Reasons for this are speculative but flooding of burrows in 1993 may have affected populations the following year. Because they often construct burrows that may be up to 9" deep (Jones *et al.* 1983), masked shrews may have been most susceptible. A total of 136 and 45 masked shrews was collected in 1993 and 1994, respectively. White-footed mice may be less sensitive to flooding because they are more arboreal. Ruffer (1961) found that flooding was not detrimental to numbers of white-footed mice. Mice may have been forced to utilize "more above-ground nest sites and peripheral portions of their home range." McCarley (1959) also reported *Peromyscus* survived flooding well and that they utilized trees during this disturbance. I collected 292 and 181 *Peromyscus* in 1993 and 1994, respectively. Populations of meadow voles are cyclical (Jones *et al.* 1985), and it is no surprise that there were fewer (232 vs. 16) in the second year of the study. Meadow voles were the second most abundant mammal in the two-year study.

Effects of microvegetative structure on relative abundance of species

In 1993, relative abundances of four species in grassland habitats showed significant rank correlations with vegetative variables (Table 4). Abundance of meadow voles was positively correlated with total canopy cover ($p \leq 0.100$) and negatively correlated with dead canopy cover ($p \leq 0.100$). Abundance of deer mice (*Peromyscus maniculatus*) was also negatively correlated with dead canopy cover ($p \leq 0.100$). Abundances of masked shrews (*Sorex cinereus*) and meadow jumping mice were positively correlated with vertical density ($p \leq 0.100$). In 1994, abundance of western harvest mice (*Reithrodontomys megalotis*) was negatively correlated with litter cover ($r_s = -0.943$, $p \leq 0.010$).

Relative abundances of two species showed significant rank correlations with vegetative variables in forested habitats in 1994 (Table 5). Abundance of white-footed mice was negatively correlated with total canopy cover ($p < 0.010$) and positively correlated with cover of bare ground ($p < 0.100$). Abundance of western harvest mice was positively correlated with shrub cover ($p < 0.100$).

My results indicated that canopy cover, vertical density, ground litter, and shrub cover influenced the relative abundance of some species positively or negatively. Meadow voles showed a positive rank correlation with total canopy cover. This is consistent with results reported by Edge *et al.* (1995) and Lemen and Clausen (1984).

Jones *et al.* (1983) and McMillan and Kaufman (1994) stated that white-footed mice typically inhabit forests. I collected 448 and 25 in forested and grassland habitats, respectively. Relative abundance of white-footed mice was positively correlated with cover of bare ground. This variable is likely to have been positively correlated with density and canopy cover of trees.

Evaluation of two baits for trapping shrews and other small mammals

In 1993, 209 (17.8%) and 964 (82.2%) small mammals of 10 and 12 species were collected on ground meat and a mixture of peanut butter and oats, respectively. In 1994, 46 (11.8%) and 343 (88.2%) of 7 and 11 species were collected on ground meat and the mixture, respectively. My justification for using ground meat was to attract shrews.

Two species of shrews were collected in the study. I collected 136 and 45 masked shrews in 1993 and 1994, respectively. Northern short-tailed shrews were less common and only 32 and 1 were collected in 1993 and 1994, respectively. This was the only small mammal that was collected more frequently on traps baited with ground meat (19 individuals) than the mixture (13 individuals) in 1993. Masked shrews were collected in higher numbers with the mixture compared to ground meat in both years ($p < 0.001$). Northern short-tailed shrews showed no difference in 1993 ($p > 0.100$) and too few were caught in 1994 for analysis. White-footed mice, deer mice, meadow voles, and western harvest mice, were collected in higher numbers with the mixture ($p < 0.005$) in both years. More meadow jumping mice were also caught with the mixture in 1993 ($p < 0.001$) and 1994 ($p < 0.050$) (Tables 6 and 7).

One of the most effective baits used in the trapping of small mammals is a mixture of peanut butter and rolled oats. Smith *et al.* (1969) stated that this mixture could be used for trapping mammals but that its dispensing qualities from plastic squeeze bottles were slightly inferior to peanut butter alone. Beer (1964) tested 12 baits with an unbaited trap as a control and found that "the best bait, when considering all animals captured, was the peanut butter and rolled oats mixture." The mixture was particularly effective at trapping white-footed mice and meadow voles. Mihok (1982) recommended several baits for trapping deer mice that included peanut butter and oats used separately or in combination. The mixture of peanut butter and oats has been used in studies by Stickel (1948), Sullivan and Sullivan (1980), Seagle (1985), Clark and Kaufman (1989), Medin and Clary (1989), Kaufman *et al.* (1993), and many others with various trapping objectives with small mammals.

Shrews are known to prefer other types of baits. Call (1986) stated that shrews are not commonly captured with traditional trapping methods. The commonly used peanut butter and oat mixture often fails at capturing shrews. This is probably attributable to the shrew's insectivorous and carnivorous food habit. He suggested using baits such as sardines, earthworms, rodent brains or liver, or other meat. Patric (1970) found that ground meat, bacon, and a mixture of seven baits attracted *Blarina* and *Sorex*. However, Beer (1964) reported that peanut butter alone gave the best results for shrews. He caught no shrews with traps baited with ground meat. Northern short-tailed shrews, masked shrews, and arctic shrews (*S. arcticus*) were caught, but none of the 54 captures were reported by type of bait.

My results are both consistent and contradictory to reports of other authors. Beer (1964) stated that the mixture of peanut butter and oats was effective at capturing a variety of small mammals. I also found this to be true when compared to ground meat. The mixture was effective at capturing white-footed mice, meadow voles, and deer mice, and was consistent with Beer's (1964) study and Mihok's (1982) suggestions. Call (1986) stated that the mixture often fails at capturing shrews. I found it effective for trapping masked shrews as well as northern short-tailed shrews although 59% of the short-tailed shrews were captured with ground meat in 1993. Contrary to Patric's (1970) conclusion, traps baited with ground meat captured only 12.7% of masked shrews.

Efficiency of two traps for sampling of small mammals

A total of 10 species (523 individuals) was captured in five sites sampled with two different traps. Live and snap traps captured seven (189 individuals) and nine (334 individuals) species, respectively. I caught more species on four of five sites and the same number of species on the other site, using snap traps (Figure 4). Richness was higher with snap traps compared to live traps (ANOVA, $p = 0.0844$, 1 df). Overall relative abundance was higher for snap traps at all five sites (Figure 5), but not different from live traps (ANOVA, $p = 0.3362$, 1 df). Mean relative abundance of meadow voles was significantly higher using snap traps compared to live traps (Table 8). Mean relative abundance of western harvest mice, white-footed mice, and deer mice did not differ between the types of traps ($p > 0.100$). Relative abundances of meadow jumping mice, masked shrews, and four other species were not analyzed because of low sample sizes. However, 15 of 16 (93.8%) meadow jumping mice and all masked shrews (11 individuals) were captured in snap traps.

Meadow voles may have been reluctant to enter live traps. Geier and Best (1980) did not attempt to estimate populations of meadow voles captured in live traps. Their study indicated that meadow voles, masked shrews, and three other species could not be estimated accurately because of low susceptibility to or complete avoidance of live traps when compared to snap traps. Kale (1972) used Museum Special snap traps, Victor mouse traps, and 7.6 x 7.6 x 25.4 cm Sherman live traps baited with a mixture of peanut butter and oats. His study addressed concentrations of least shrews (*Cryptotis parva*) in a forest in Florida. Only 16 least shrews were captured in 10 nights of live-trapping. However, 180 were caught in only five nights of snap-trapping. Mean live weight of the species (185 individuals) was 5.19 grams. He reported that "this value was close to, or below, the limit of sensitivity" of the Sherman live traps. I collected masked shrews, which are similar in weight (3-6 g) to least shrews.

Getz (1982) recommended using Victor traps baited with peanut butter or rolled oats for measuring the relative abundance of meadow voles. Kirkland (1982) recommended use of Museum Special snap traps over Sherman live traps because of their higher sensitivity to smaller shrews. And Weiner and Smith (1972) concluded that in most cases, Museum Specials more effectively sampled populations of small mammals compared to other types of traps. My results support the aforementioned recommendations and conclusions.

Captures of non-target species

I trapped 1,562 small mammals and 38 non-target individuals including six gray catbirds (*Dumetella carolinensis*), six unidentified sparrows (Family Emberizidae), five Swainson's thrushes (*Catharus ustulatus*), two swamp sparrows (*Melospiza georgiana*), and one American robin (*Turdus migratorius*), song sparrow (*Melospiza melodia*), rufous-sided towhee (*Pipilo erythrophthalmus*), house wren (*Troglodytes aedon*), yellow-breasted chat (*Icteria virens*), and barn swallow (*Hirundo rustica*). In addition, eight leopard frogs (*Rana* spp.), three toads (*Bufo* spp.), and two red-sided garter snakes (*Thamnophis sirtalis*) were collected. All were captured in Museum Special snap traps. Relative abundance of non-target species was low (0.2 / 100 trapping units; 2.4%) compared to small mammals (8.1 / 100 trapping units; 97.6%). One of the swamp sparrows was a juvenile and G.R. Lingle (pers. comm.) stated that this was a possible nesting record for the species at the Mormon Island Crane Meadows on 24 June, 1994 (Sec. 35, 36, T10N, R10W).

There has been extensive research related to trapping small mammals. But little attention is given to the capture of non-target species in these studies. Schmidt and Peters (1981) captured 85 individuals which accounted for 1.1 non-target organisms / 100 trap-nights compared to 3.5 small mammals / 100 trap-nights. Several species of birds, reptiles, and insects were captured. Taulman and Thill (1991) captured four species of birds (11 individuals) while comparing capture efficiences of bottles and three types of snap traps for short-term sampling of small mammals.

Some of the captures of non-targets in my study may have been incidental; others may have been attracted by the baits. Color of baits or traps may have influenced the capture of the avian non-targets. Gionfriddo (1994) reported that house sparrows (*Passer domesticus*) and northern bobwhites (*Colinus virginianus*) consistently consumed grit of specific colors. The birds were offered equal amounts of eight colors and often chose yellow, green, or white grit. He stated that "both species generally used very little black and blue grit." Baits in my study were red (ground meat) and tan speckled with white (mixture of peanut butter and rolled oats). Interestingly, all plastic bait pedals on snap traps were yellow.

A large proportion of the avian and amphibian species collected were ground feeders and insectivorous and the presence of insects may have facilitated their capture. The two baits used readily attracted insects. Insects began to forage on baits within ten minutes on some occasions (pers. obsv.). Anderson and Ohmart (1977) experimented with chemicals that repelled insects but did not significantly alter trapping success of small mammals. They suggested using dimethylpthalate mixed in with oats and peanut butter. No difference in total catches of mammals using untreated versus treated baits was indicated ($p > 0.30$). Their repellent was successful at preventing insects from foraging on the bait. Of 1,660 traps for each, bait was removed from 61 (3.7%) treated traps and from 388 (23.4%) untreated traps ($\chi^2 = 359.7$, 1 d.f., $p < 0.001$). However, they did not report captures of non-target species.

Treating baits or areas around traps has advantages. Chabreck *et al.* (1986) tested the effects of insect poisons at repelling ants from baits and specimens. Specimens collected from treated areas were free from ant damage and easily identified. A chemical repellent should be considered if study skins are to be deposited in museum collections. It also may reduce the number of non-targets attracted by insects and increase trapping success of small mammals because of retention of bait. However, captures of shrews may decrease when using a repellent-treated bait. Shrews are insectivorous and trapping success may be based on the type of bait used as well as the presence of insects foraging on the bait.

CONCLUSIONS

Small mammals have limited dispersal abilities and species can take several years to pass through a corridor of suitable habitat. Our understanding of riparian habitats and their role in this unique system will require a long-term investigation. This may involve repetition of the study in 10-year increments as well as other investigations of small mammals in riparian habitats east and west of the central Platte River. The knowledge that is required will depend on data from the past, present, and future. Evenness among species was more similar at greater distances from the easternmost grassland site sampled, but I have no biological explanation as to why this occurred. In addition, no east to west trends of relative abundance of species were observed along the corridor. Analysis may have been confounded by management practices, removal effects, sampling time and effort, or extreme variation in weather patterns between sites and years. Examination of a longer portion of the channel with additional sites may be necessary to determine trends. Some species such as the white-footed mouse have already dispersed through the corridor and are found west of the area sampled. Impacts of management practices in this environmentally critical area may affect dispersal of this mouse and other small mammals that are filtering in from adjacent habitats.

Indices varied considerably between sites and years and were most likely related to factors such as distance from the easternmost site sampled, microvegetative structure, weather patterns, and different baits and traps. I found that vegetative structure positively or negatively influenced the relative abundance of some species. Ground meat was unnecessary for capturing shrews although sample size was probably too small to detect a difference in northern short-tailed shrews. A mixture of peanut butter and rolled oats successfully attracted shrews as well as several other small mammals in central Platte riparian habitats. My results suggest that meadow voles, meadow jumping mice, and masked shrews were not as easily captured by live traps. In addition, sensitivity of treadles in live traps is likely inadequate for capturing masked shrews; a result supported by my findings as well as others. Because estimates of populations and richness of small mammals by live traps may be biased and could result in underestimates, I recommend Museum special snap traps over Sherman live traps in surveys of biodiversity. However, if resources involving preparation of specimens are not available, then use of snap traps is not advised.

I concur with Schmidt and Peter's (1981) statement that "specialization of both traps and bait, trap location and placement, and seasonal trapping schedules" may help reduce the incidence of captures of non-targets. More research should be conducted on the capture efficiencies of repellent-treated baits versus non-treated for small mammals as well as non-target species. In addition, experimentation with different colored baits and traps should be given closer attention in order to reduce the incidence of captures of non-targets.

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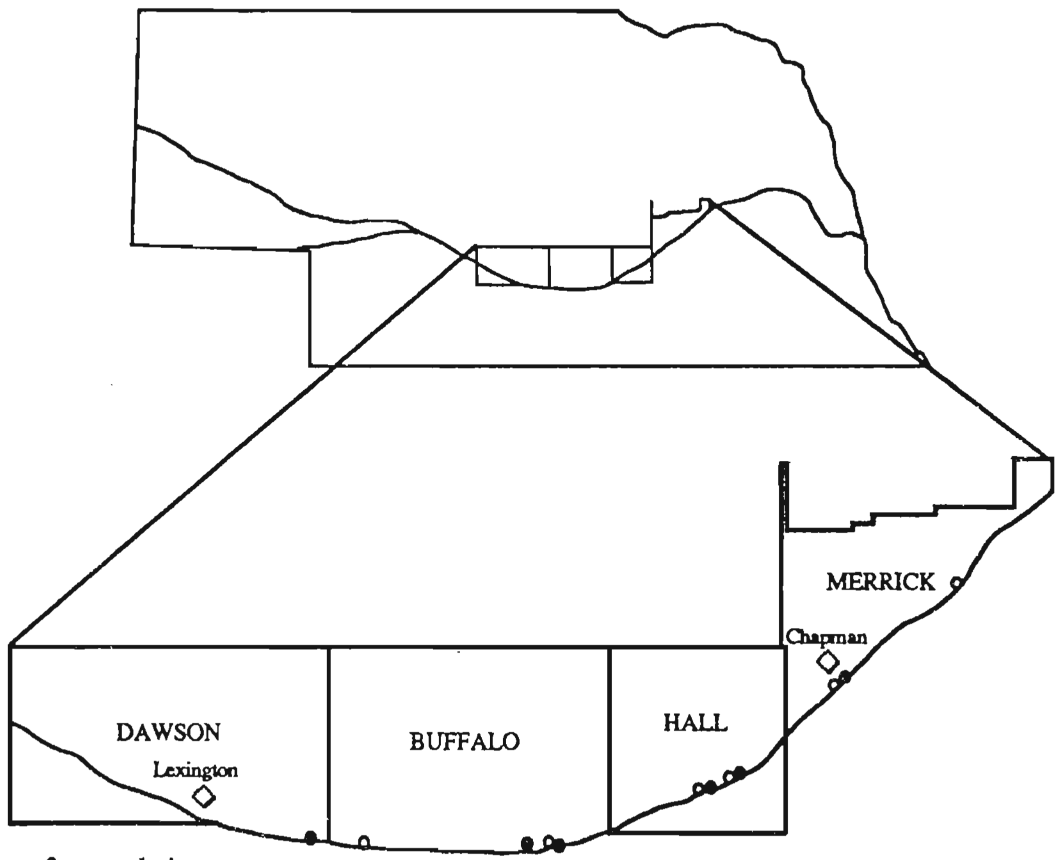


- forested sites
- grassland sites

Figure 1. Enlarged view of four counties and locations of 12 study sites in south-central NE. Most sites lie along the "Big Bend" (Lexington to Chapman) region of the Platte River.

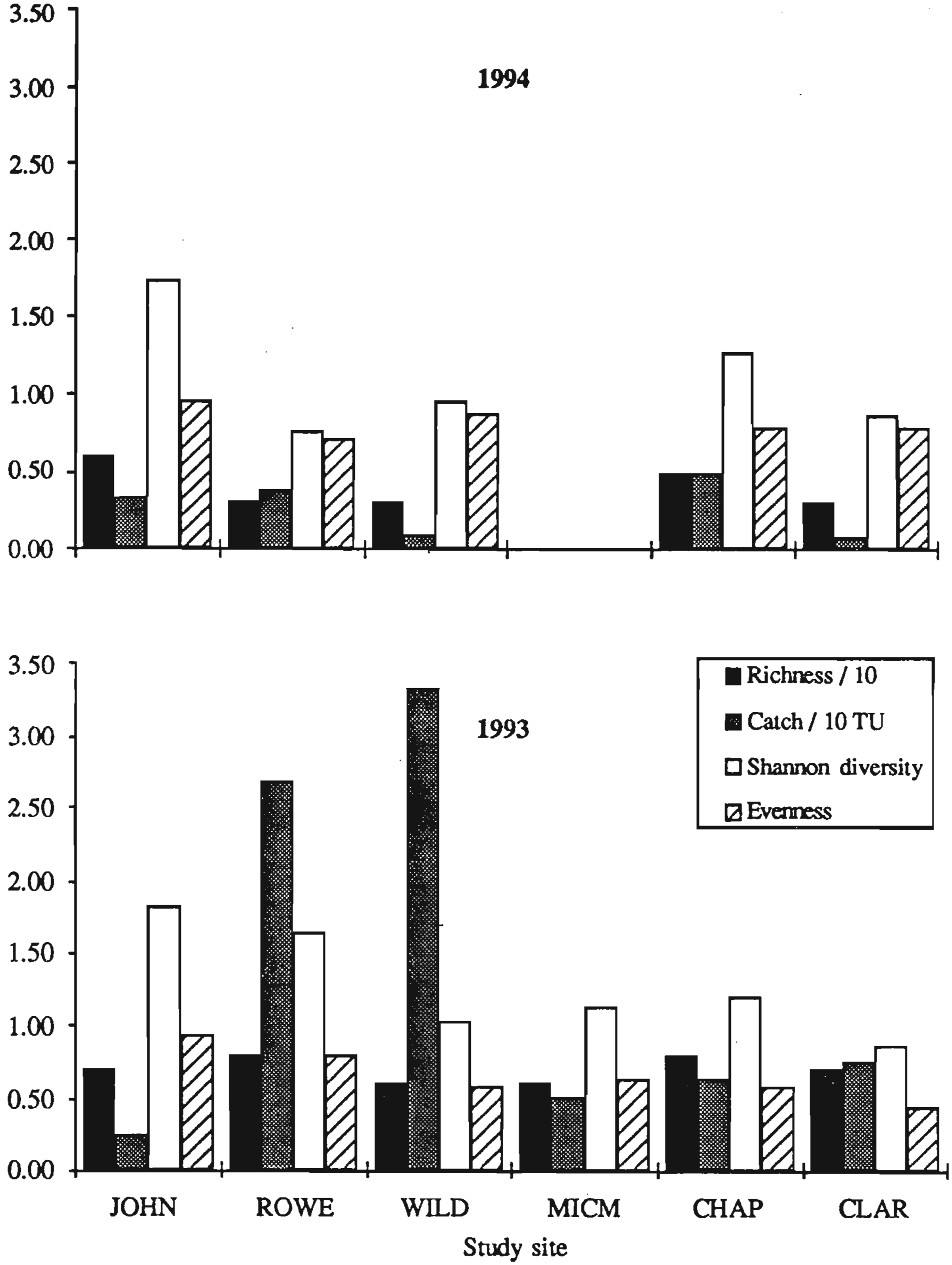


Figure 2. Indices for small mammals in six grassland sites along a 130 km portion of the central Platte River in south-central NE, 1993 and 1994. Study sites are arranged west to east (JOHN - CLAR).

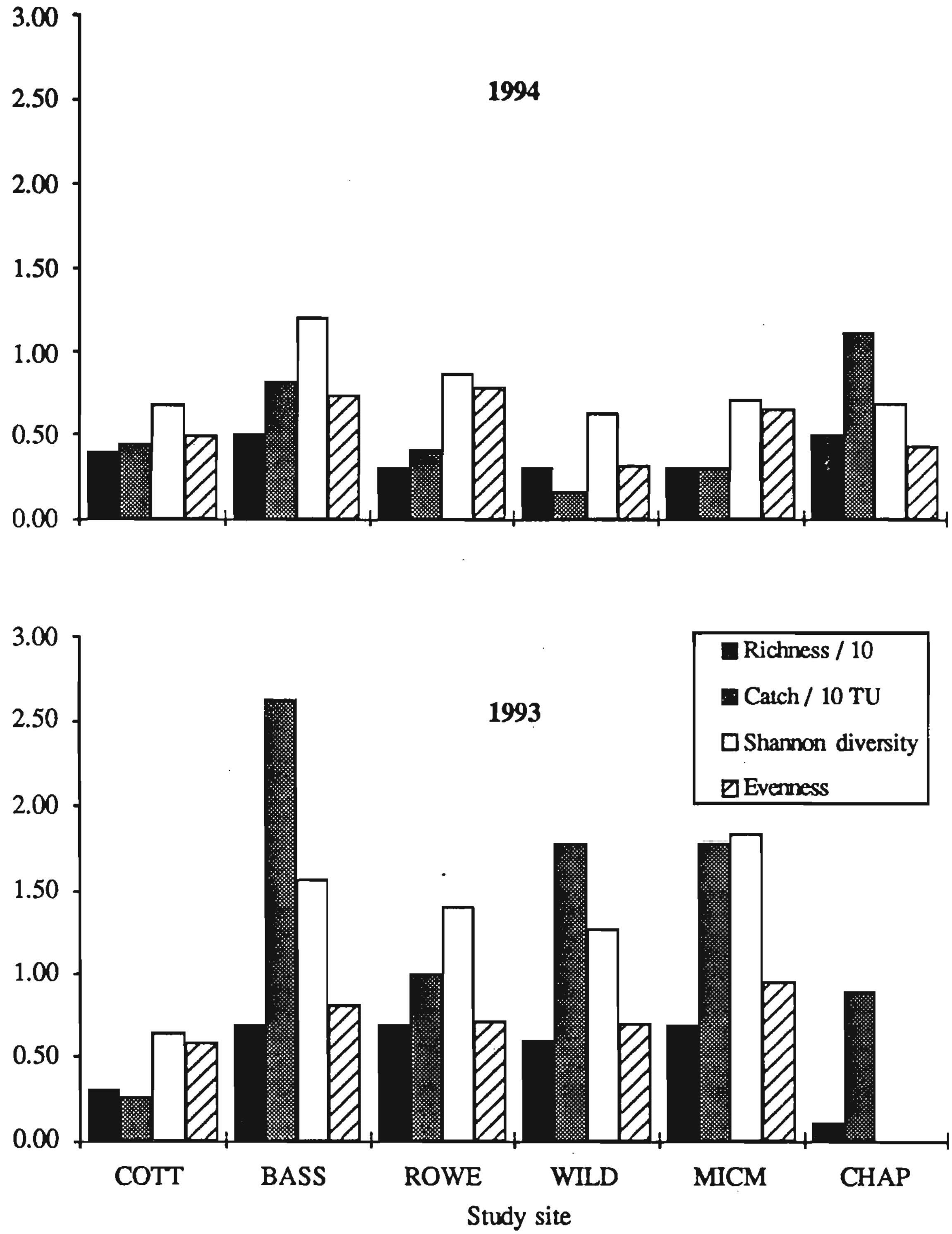


Figure 3. Indices of small mammals in six forested sites along a 110 km portion of the central Platte River in south-central NE, 1993 and 1994. Study sites are arranged west to east (COTT - CHAP).

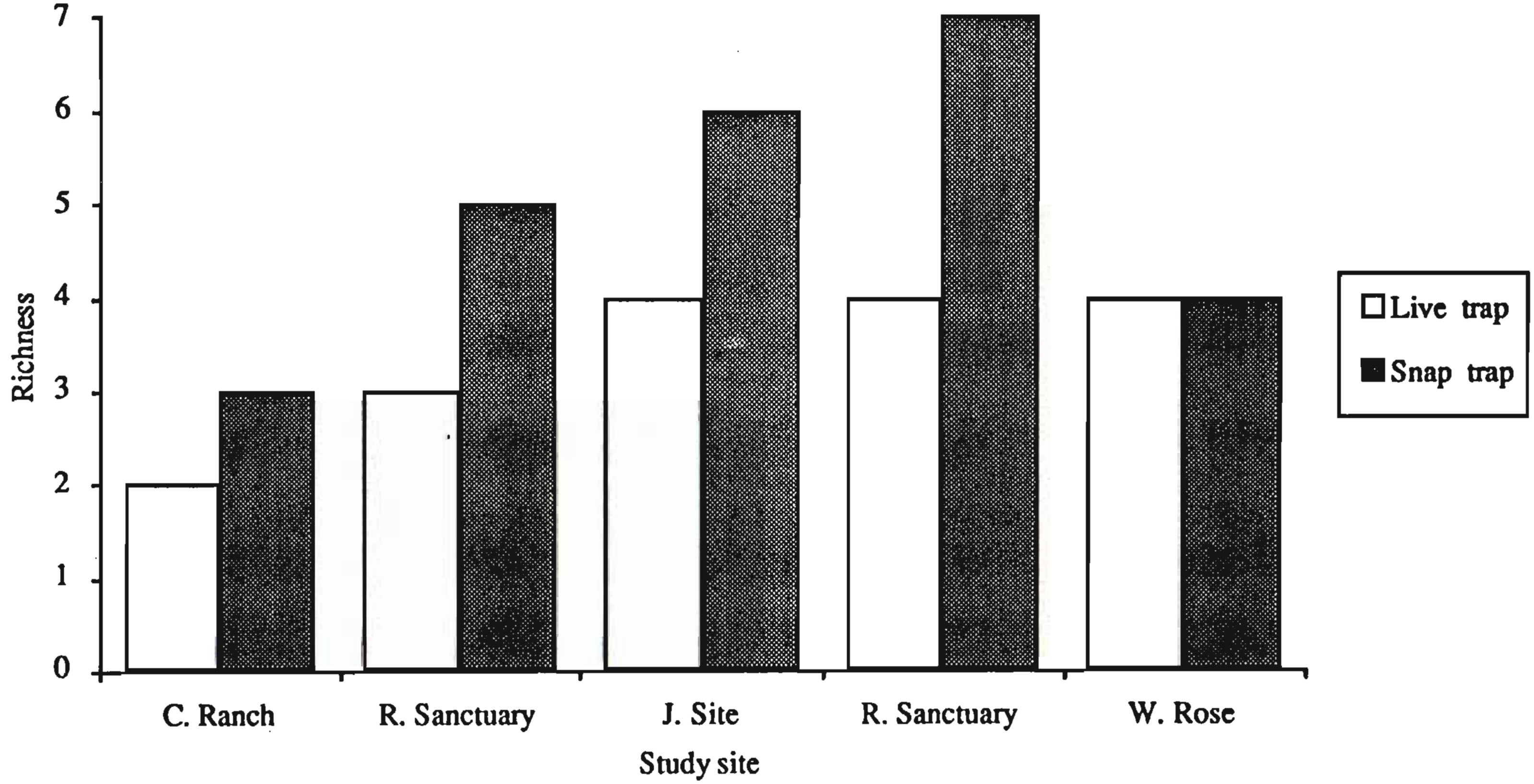


Figure 4. Comparison of species richness of live and snap traps in five study sites in south-central NE, 1993.

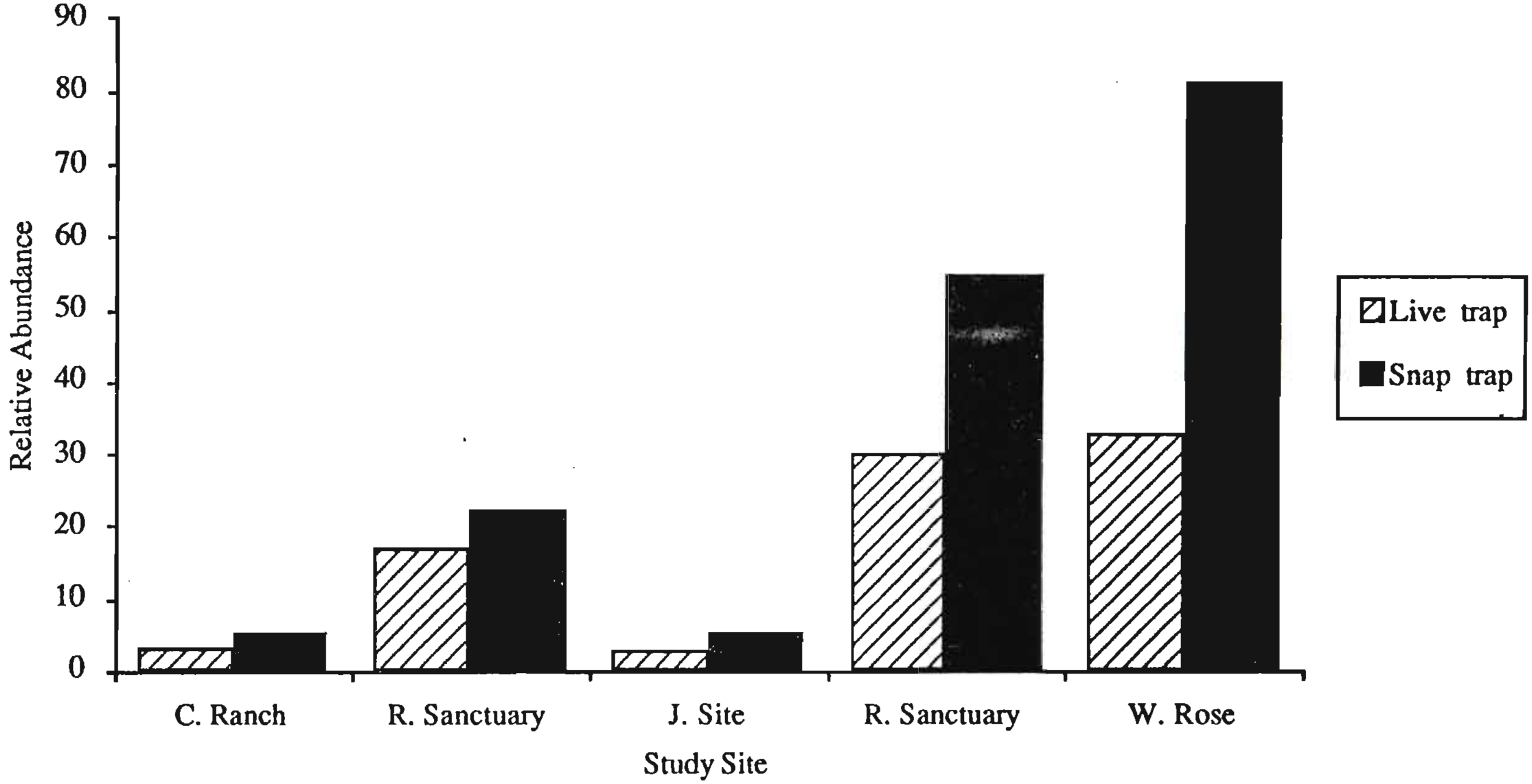


Figure 5. Comparison of relative abundance (catch per 100 trapping units) of live and snap traps in five study sites in south-central NE, 1993.

Table 1. Twelve habitat variables measured in grassland sites in south-central NE, 1993 and 1994.

Variable	Description
TOCA	Percent cover of live and dead attached vegetation within 0.80 x 0.45 m frame
TOLI	Percent cover of live vegetation within frame
TODE	Percent cover of dead attached vegetation within frame
TOGR	Percent cover of grass within frame
TOFO	Percent cover of forbs within frame
TOWO	Percent cover of live or dead wood within frame
GRLI	Percent cover of dead unattached herbaceous vegetation (litter) within frame
GRBA	Percent cover of bare ground within frame
VIOB	Visual obstruction (dm) of vegetation between trap station and Robel pole (4 m)
MALI	Maximum height (dm) of live vegetation touching Robel pole
MADE	Maximum height (dm) of dead attached vegetation touching Robel pole
LIDE	Maximum height (mm) of dead unattached herbaceous vegetation (litter) taken 2.54 cm outside of premarked location on frame

Table 2. Sixteen habitat variables measured in forested sites in south-central NE, 1994.

Variable	Description
TOCA	Percent cover of live and dead attached vegetation within square meter frame
TOLI	Percent cover of live vegetation within frame
TODE	Percent cover of dead attached vegetation within frame
TOGR	Percent cover of grass within frame
TOFO	Percent cover of forbs within frame
TOSH	Percent cover of shrubs (< 31 cm height) within frame
TOTR	Percent cover of trees (≥ 2.0 m height) within frame
GRLI	Percent cover of dead unattached herbaceous vegetation (litter) within frame
GRBA	Percent cover of bare ground within frame
SHDE	Number of shrubs (< 2.0 m height) within frame
TRDE	Number of trees (≥ 2.0 m height) within frame
MALI	Maximum height (dm) of live herbaceous vegetation touching tape measure positioned in center of frame
MADE	Maximum height (dm) of dead herbaceous vegetation touching tape measure positioned in center of frame
WOBR	Number of branches (≥ 1 and < 3 cm in diameter) within and/or touching frame
WOLO	Number of logs (≥ 3 cm in diameter) within and/or touching frame
LIDE	Maximum height (mm) of dead unattached herbaceous vegetation (litter) taken 2.54 cm outside of premarked location on frame

Table 3. Number (%) of each mammal species captured in south-central NE, 1993 and 1994.

Species	Total	(%)
White-footed mouse (*Peromyscus leucopus*)	473	(30.3)
Meadow vole (*Microtus pennsylvanicus*)	248	(15.9)
Deer mouse (*Peromyscus maniculatus*)	247	(15.8)
Western harvest mouse (*Reithrodontomys megalotis*)	245	(15.7)
Masked shrew (*Sorex cinereus*)	181	(11.6)
Meadow jumping mouse (*Zapus hudsonius*)	111	(7.1)
Northern short-tailed shrew (*Blarina brevicauda*)	33	(2.1)
Prairie vole (*Microtus ochrogaster*)	8	(0.5)
House mouse (*Mus musculus*)	8	(0.5)
Plains harvest mouse (*Reithrodontomys montanus*)	4	(0.3)
Ord's kangaroo rat (*Dipodomys ordii*)	2	(0.1)
Northern grasshopper mouse (*Onychomys leucogaster*)	1	(0.1)
Thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*)	1	(0.1)
TOTAL	1,562	(100.1)

Table 4. Spearman rank correlations between relative abundances of common species (present at ≥ 3 sites) of small mammals and mean vegetative characteristics in grassland sites (n = 5) in south-central NE, 1993 (TOCA = total canopy cover, TOLI = live canopy cover, TODE = dead canopy cover, GRLI = litter cover, VIOB = vertical density, and MALI = maximum height of live vegetation).

Species	TOCA	TOLI	TODE	GRLI	VIOB	MALI
M. pennsylvanicus	0.900 *	0.900 *	-0.900 *	-0.900 *	0.800	0.800
P. maniculatus	0.600	0.600	-0.900 *	-0.600	0.700	0.700
S. cinereus	0.821	0.821	-0.462	-0.821	0.975 *	0.975 *
Z. hudsonius	0.872	0.872	-0.718	-0.872	0.975 *	0.975 *

* $p \leq 0.100$

Table 5. Spearman rank correlations between relative abundances of common species (present at ≥ 3 sites) of small mammals and mean vegetative characteristics in forested sites (n = 6) in south-central NE, 1994 (TOCA = total canopy cover, TOLI = live canopy cover, TOSH = shrub cover, GRLI = litter cover, and GRBA = cover of bare ground).

Species	TOCA	TOLI	TOSH	GRLI	GRBA
P. leucopus	-0.986 ***	-0.986 ***	0.406	0.928 **	0.841 *
R. megalotis	-0.577	-0.577	0.880 *	0.334	0.820

* $p < 0.100$

** $p < 0.050$

*** $p < 0.010$

Table 6. Occurrences of each species collected by types of bait in south-central NE, 1993. Chi-square tests compare differences between captures of types of bait (df = 1) (TC = total captures, PBO = mixture of peanut butter and oats, and GM = ground meat).

Species	TC	PBO	GM	$\chi^2_{0.001} = 10.828$
P. leucopus	292	234	58	104.880
M. pennsylvanicus	232	194	38	103.556
P. maniculatus	199	156	43	63.035
R. megalotis	189	177	12	142.307
S. cinereus	136	123	13	87.360
Z. hudsonius	77	55	22	13.299
B. brevicauda	32	13	19	0.781 *
M. musculus	7	5	2	
M. ochrogaster	4	3	1	
D. ordii	2	2	0	
R. montanus	2	1	1	
O. leucogaster	1	1	0	
TOTAL	1,173	964	209	
%	100.0	82.2	17.8	

* $p > 0.100$

Table 7. Occurrences of each species collected by types of bait in south-central NE, 1994. Chi-square tests compare differences between captures of types of bait (df = 1) (TC = total captures, PBO = mixture of peanut butter and oats, and GM = ground meat).

Species	TC	PBO	GM	$\chi^2_{0.001} = 10.828$
P. leucopus	181	165	16	121.017
R. megalotis	56	55	1	50.161
P. maniculatus	48	42	6	25.521
S. cinereus	45	35	10	12.800
Z. hudsonius	34	24	10	4.971 *
M. pennsylvanicus	16	15	1	10.563 **
M. ochrogaster	4	2	2	
B. brevicauda	1	1	0	
R. montanus	2	2	0	
M. musculus	1	1	0	
S. tridecemlineatus	1	1	0	
TOTAL	389	343	46	
%	100.0	88.2	11.8	

* $p < 0.050$
** $p < 0.005$

Table 8. Chi-square analysis testing the null hypothesis that no difference exists in mean relative abundances (catch per 100 trapping units) of species captured in live traps and collected in snap traps in south-central NE, 1993.

Species	Total	Live	Snap	χ^2
M. pennsylvanicus	28.2	7.3	20.9	5.630 *
R. megalotis	13.9	5.4	8.5	0.065
P. leucopus	13.1	7.5	5.6	0.062
P. maniculatus	12.5	6.2	6.3	0.097
Z. hudsonius	2.7	0.5	2.2	
M. musculus	2.0	0.0	2.0	
S. cinereus	1.9	0.0	1.9	
D. ordii	1.0	0.3	0.7	
B. brevicauda	0.5	0.5	0.0	
M. ochrogaster	0.4	0.0	0.4	

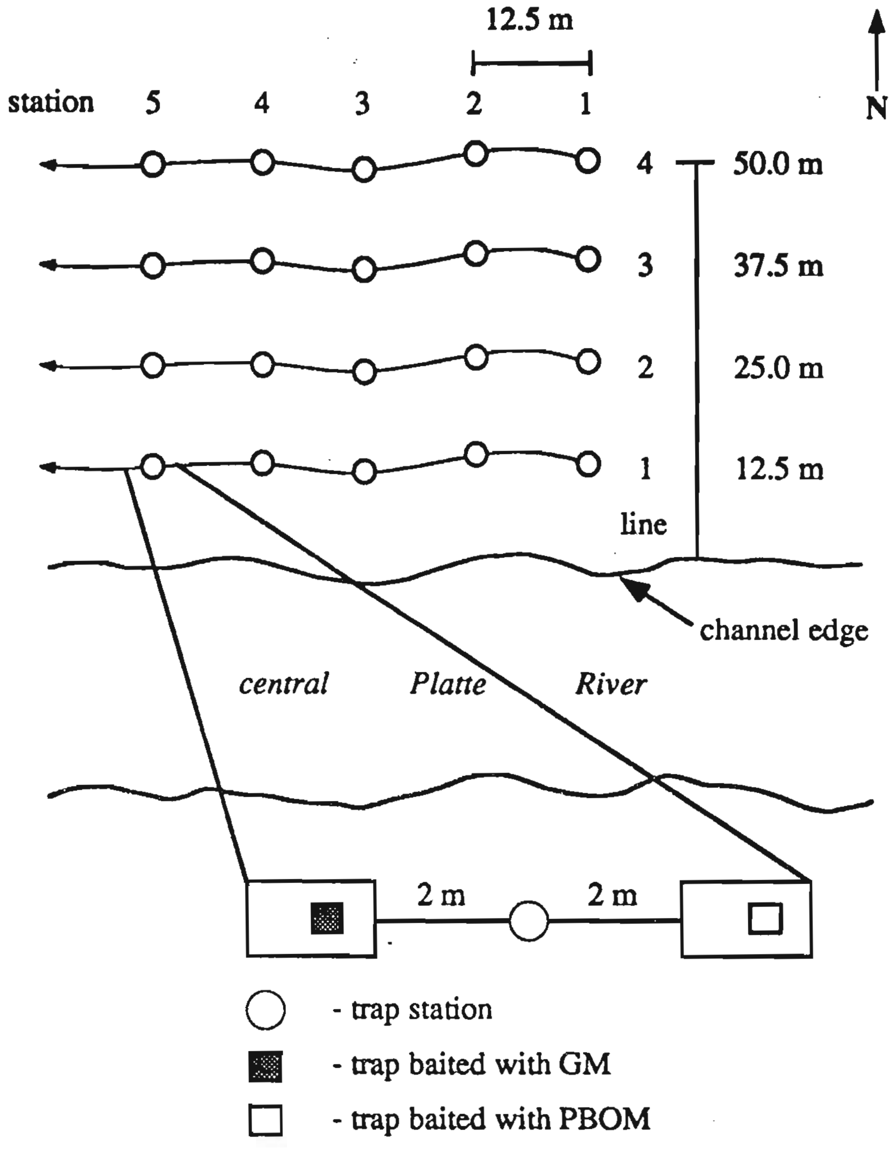
* $p < 0.025$

Appendix A. Study sites of central Platte grasslands, owner, location and management in 1993 and 1994.

(#) and field name	Owner / Manager	Location	Management
(1) Clarks (CLAR)	Private landowner	Sec. 13 T14N R5W Se 1/4	Grazed from June 1, 1993 - Jan. 1, 1994 Grazed from May 10 - Oct. 15, 1994
(2) Chapman (CHAP)	Private landowner	Sec. 20 T12N R7W Nw 1/4	Grazed from June 1 - Sept. 15, 1993 Grazed from June 1 - Sept. 15, 1994 Thistle spray and cut in 1994
(3) Mormon Island Crane Meadows (MICM)	Platte River Whooping Crane and Maintenance Trust	Sec. 34 T10N R10W Se 1/4	Grazed from June 21 - August 4, 1993 Grazed from May 1 - June 21, 1994
(4) Wild Rose Ranch (WILD)	Platte River Whooping Crane and Maintenance Trust	Sec. 33 T10N R10W Ne 1/4	Grazed from Sept. 15 - Oct. 15, 1993 Grazed from August 8 - Sept. 14, 1994
(5) Audubon Rowe Sanctuary (ROWE)	Audubon Society	Sec. 17 T8N R14W Ne 1/4	Burned April 15, mowed late June, 1993 No management in 1994
(6) Johns Site (JOHN)	Platte River Whooping Crane and Maintenance Trust	Sec. 11 T8N R16W Nw 1/4	No management in 1993 No management in 1994

Appendix B. Study sites of central Platte forests, owner, location and management in 1993 and 1994.

(#) and field name	Owner / Manager	Location	Management
(1) Chapman (CHAP)	Private landowner	Sec. 17 T12N R7W Sw 1/4	Grazed from June 1 - Sept. 15, 1993 Grazed from June 1 - Sept. 15, 1994
(2) Mormon Island Crane Meadows (MICM)	Platte River Whooping Crane and Maintenance Trust	Sec. 35, 36 T10N R10W Ne, Nw 1/4	No management in 1993 No management in 1994
(3) Wild Rose Ranch (WILD)	Platte River Whooping Crane and Maintenance Trust	Sec. 27, 28, 33, 34 T10N R10W Sw Se, Ne, Nw 1/4	No management in 1993 No management in 1994
(4) Audubon Rowe Sanctuary (ROWE)	Audubon Society	Sec. 11 T8N R14W Se 1/4	Tree clearing on south bank June, 1993 No management in 1994
(5) Bassway Strip (BASS)	Nebraska Game and Parks Commission	Sec. 6 T8N R14W Se 1/4	No management in 1993 No management in 1994
(6) Cottonwood Ranch (COTT)	Nebraska Public Power District	Sec. 2 T8N R19W Sw 1/4	Grazed entire growing season in 1993 Grazed entire growing season in 1994



Appendix C. Design for sampling small mammals and enlarged view of placement of snap traps.

Appendix D.

DETAILED METHODS

Trapping of small mammals

I censused small mammals using 7.6 x 7.6 x 25.4 cm non-folding H.B. Sherman live traps and 14.0 x 6.7 cm ("Victor"-Woodstream Co.) Museum Special snap traps in 1993. I sampled five (three grassland; two forested) study sites with live traps and sampled all (six grassland; six forested) sites with snap traps. All sites were sampled using snap traps only in 1994. Study sites for both grassland and forested sites were along a 140 km portion of the river. Sampling occurred from 14 May to 7 November and 14 May to 8 July in 1993 and 1994, respectively, for a total of 24,640 trap-nights.

In each of 11 study areas, there were four, 500-m trap lines. Each line consisted of 40 trap stations for a total of 160 stations per study area. Survey flags marked trap stations indicating trap line and station in order to record point of capture. Lines were parallel to the channel edge and spaced evenly over 50 m with line one, 12.5 m from the channel edge. Stations were spaced evenly over 500 m. In grassland site # 1, small mammals were sampled on eight, 250-m trap lines. Each line consisted of 20 trap stations for a total of 160 trap stations. Intervals between lines and stations were as above.

One live trap was placed on a flattened ground surface and positioned with the back door facing east at every station. I started prebaiting traps approximately three hours before sunset one night prior to sampling. A small handful of rolled oats was used as prebait and placed in and outside the trap. Traps were locked open during prebaiting and were set not to spring. The following day, I started baiting, repositioning, and setting traps at approximately three hours before sunset. Traps were repositioned with front doors eastward. A mixture of peanut butter and rolled oats wrapped in packets of waxed paper was the bait. Packets were held securely inside by the back door of the trap (Appendix R) and two cotton balls were placed in each trap to provide bedding. A small amount of oats was replaced in and outside the trap if needed and traps were set for two consecutive nights.

I checked live traps starting approximately one hour after sunrise. Mammals were ear-tagged with a size 1 Monel tag (National Band and Tag Co.) in the right ear and released at the point of capture. Date, species identification, point of capture, tag number, and number of incidentally sprung traps were recorded. Traps were closed to avoid sampling during the day and were reset in early evening. Bait was replaced for the second trap-night if needed.

After two consecutive nights of live-trapping on five study areas, one snap trap was placed at a 2 m interval on either side (east and west) of the stations along trap lines (Appendix C). All traps were positioned on a flattened surface with plastic bait pedals eastward. Traps east and west of each station were baited with a mixture of peanut butter and oats and 72% lean ground meat (beef). I started baiting and setting traps approximately three hours before sunset and checking one hour after sunrise over three consecutive nights. Traps baited with the mixture were kept separate from traps baited with ground meat during transport. Date, species identification, point of capture by type of bait, number of incidentally snapped traps, and traps snapped due to non-target species were recorded. Traps were snapped intentionally after each occasion to avoid sampling during the day.

Collected specimens were tagged and double-bagged with ties and immediately placed on dry ice in coolers. Measurements for specimens included weight, sex, nose to base of tail length, tail length, ear length, and hind foot length. All prepared skins and skeletons were deposited at the University of Nebraska-Lincoln State Museum.

Vegetation-grassland sites

I characterized ground cover in the grassland sites by meassuring 12 variables (Table 1) in five and six open sites from 16 June to 23 October and 12 May to 5 July, in 1993 and 1994, respectively, using a rectangular (0.80 x 0.45 m) frame, made from 1.9 cm polyvinyl chloride (PVC) pipe, to measure percent cover of canopy, live and dead vegetation, grass, forbs, wood, litter and bare ground within the frame. The frame was marked in five and two equally spaced segments on long and short sides, respectively, and was modified from the 0.50 x 0.20 m frame suggested by Daubenmire (1959). A larger frame was more easily placed because of the clumped structure of vegetation in some study areas. A Robel pole was used to measure visual obstruction (vertical density) and maximum height of both live and dead vegetation touching the pole. The wooden pole is round, 3 cm in diameter, and is marked in alternating decimeters of white and brown. Readings were made 1 m above ground and 4 m from the pole. Measurements of visual obstruction were made to the nearest half decimeter as an index to vertical density (Robel *et al.* 1970).

Vegetation variables were measured at odd and even-numbered stations on alternating, trap lines, respectively. This provided 80 readings for each variable on each study area. The Robel pole was placed 4 m from trap stations at a randomly selected cardinal point. The rectangular frame was systematically positioned 1 m away from the Robel pole in the same direction. An undisturbed area was sampled adjacent to each station in all open and forested sites. This prevented the sampling of trampled vegetation on east and west sides of stations resulting from placement of snap traps. Measurements of litter depth were taken 2.54 cm (1 in.) away from a premarked location on the frame. A small area was cleared for ground-level placement of a ruler. The maximum height where litter touched the ruler was the depth recorded. Vegetation that was dead and unattached was defined as litter.

Forested sites

I characterized ground cover in six forested sites from 14 May to 27 June in 1994 only, by measuring 16 variables (Table 2). A square meter frame, made from 1.9-cm polyvinyl chloride (PVC) pipe, was used to measure percent cover of canopy, live and dead vegetation, grass, forbs, shrub, tree, litter, and bare ground within the frame. A larger sized frame allowed placement around trees if necessary. Density of trees and shrubs in contact with or within the frame and maximum height of non-woody vegetation touching a tape measure placed in the center of the square were also recorded. Woody vegetation < 2 m and ≥ 2 m tall was classified as shrubs and trees, respectively. The frame was placed approximately 2 m north of odd and even-numbered stations on alternating trap lines, respectively. I sampled 80 stations distributed evenly over each study area. Litter depth was measured as above. Woody debris ≥ 1 and < 3 cm in diameter (branches) and ≥ 3 cm in diameter (logs) was counted to indicate additional litter in contact with or within the frame.

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Robel, R.J., J.N. Briggs, A.D Dayton and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management. 23:295-298.

Appendix E. Species richness, overall relative abundance, species diversity and evenness of small mammals collected with snap traps in grassland sites in 1993 and 1994.

	J. Site		R. Sanctuary		W. Rose		C. Meadows		Chapman		Clarks	
Indices	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Richness (S)	7	6	8	3	6	3	6	0	8	5	7	3
Catch / effort *	2.4	3.3	26.8	3.8	33.3	0.9	5.1	0.0	6.3	5.0	7.5	0.7
Shannon-Wiener (H')	1.81	1.73	1.64	0.77	1.03	0.96	1.13		1.19	1.28	0.86	0.87
Evenness (E)	0.93	0.96	0.79	0.71	0.58	0.88	0.63		0.57	0.79	0.44	0.79

S = number of species

* (Nelson and Clark 1973).

$H' = -\Sigma p_i \ln p_i$

$E = H' / \ln S$

Appendix F. Species richness, overall relative abundance, species diversity and evenness of small mammals collected with snap traps in forested sites in 1993 and 1994.

	C. Ranch		B. Strip		R. Sanctuary		W. Rose		C. Meadows		Chapman	
Indices	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Richness (S)	3	4	7	5	7	3	6	3	7	3	1	5
Catch / effort *	2.6	4.5	26.3	8.2	10.0	4.1	17.8	1.6	17.8	3.1	8.9	11.2
Shannon-Wiener (H')	0.65	0.68	1.57	1.20	1.40	0.87	1.27	0.63	1.84	0.72	0.00	0.69
Evenness (E)	0.59	0.49	0.81	0.74	0.72	0.79	0.71	0.32	0.95	0.66	0.00	0.43

S = number of species

* (Nelson and Clark 1973).

$H' = -\Sigma p_i \ln p_i$

$E = H' / \ln S$

Appendix G. Relative abundance (catch per 100 trapping units) of each species collected with snap traps in grassland sites in 1993.

Species	J. Site	R. Sanctuary	W. Rose	C. Meadows	Chapman	Clarks
M. pennsylvanicus	0.6	3.9	21.1	2.8	0.2	0.1
R. megalotis	0.3	9.7	5.0	0.1	0.0	5.9
P. maniculatus	0.7	6.7	6.1	1.3	4.0	0.6
S. cinereus	0.1	2.1	0.6	0.6	0.1	0.2
Z. hudsonius	0.3	2.9	0.4	0.1	0.0	0.0
P. leucopus	0.0	0.2	0.0	0.0	1.5	0.5
M. musculus	0.0	1.0	0.0	0.0	0.1	0.0
B. brevicauda	0.0	0.3	0.1	0.0	0.2	0.1
M. ochrogaster	0.2	0.0	0.0	0.2	0.0	0.0
R. montanus	0.0	0.0	0.0	0.0	0.1	0.1
D. ordii	0.2	0.0	0.0	0.0	0.0	0.0
O. leucogaster	0.0	0.0	0.0	0.0	0.1	0.0
TOTAL	2.4	26.8	33.3	5.1	6.3	7.5

Appendix H. Relative abundance (catch per 100 trapping units) of each species collected with snap traps in forested sites in 1993.

Species	C. Ranch	B. Strip	R. Sanctuary	W. Rose	C. Meadows	Chapman
P. leucopus	2.0	12.3	4.6	7.1	2.2	8.9
S. cinereus	0.0	3.5	0.3	7.7	3.8	0.0
P. maniculatus	0.5	1.3	1.1	1.1	4.8	0.0
Z. hudsonius	0.0	4.7	0.9	0.6	2.0	0.0
R. megalotis	0.1	1.5	2.9	0.0	1.7	0.0
M. pennsylvanicus	0.0	1.2	0.1	0.6	2.2	0.0
B. brevicauda	0.0	1.8	0.1	0.7	1.1	0.0
TOTAL	2.6	26.3	10.0	17.8	17.8	8.9

Appendix I. Relative abundance (catch per 100 trapping units) of each species collected with snap traps in grassland sites in 1994.

Species	J. Site	R. Sanctuary	W. Rose	C. Meadows	Chapman	Clarks
R. megalotis	0.9	1.4	0.4	0.0	2.0	0.5
P. maniculatus	0.7	2.3	0.1	0.0	1.8	0.0
P. leucopus	0.0	0.0	0.0	0.0	0.9	0.0
Z. hudsonius	0.3	0.0	0.4	0.0	0.0	0.0
S. cinereus	0.7	0.0	0.0	0.0	0.0	0.0
M. pennsylvanicus	0.3	0.0	0.0	0.0	0.2	0.0
M. ochrogaster	0.4	0.0	0.0	0.0	0.0	0.0
R. montanus	0.0	0.1	0.0	0.0	0.0	0.1
M. musculus	0.0	0.0	0.0	0.0	0.1	0.0
S. tridecemlineatus	0.0	0.0	0.0	0.0	0.0	0.1
TOTAL	3.3	3.8	0.9	0.0	5.0	0.7

Appendix J. Relative abundance (catch per 100 trapping units) of each species collected with snap traps in forested sites in 1994.

Species	C. Ranch	B. Strip	R. Sanctuary	W. Rose	C. Meadows	Chapman
P. leucopus	3.6	2.6	2.6	1.3	2.3	9.3
S. cinereus	0.0	4.2	0.0	0.1	0.0	0.1
Z. hudsonius	0.6	0.3	1.1	0.0	0.5	0.9
M. pennsylvanicus	0.2	0.8	0.0	0.2	0.0	0.0
R. megalotis	0.0	0.3	0.4	0.0	0.0	0.5
P. maniculatus	0.0	0.0	0.0	0.0	0.3	0.4
B. brevicauda	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	4.5	8.2	4.1	1.6	3.1	11.2

Appendix K. Vegetative characteristics in grassland sites in 1993.

	J. Site * X̄ ± SE	R. Sanctuary X̄ ± SE	W. Rose X̄ ± SE	C. Meadows X̄ ± SE	Chapman X̄ ± SE	Clarks X̄ ± SE
Percent Canopy Cover						
TOCA		74.5 (1.4)	84.2 (1.1)	51.6 (1.8)	20.4 (2.5)	45.4 (2.0)
TOLI		70.9 (1.5)	82.9 (1.2)	46.7 (2.0)	16.0 (2.0)	35.2 (2.1)
TODE		3.6 (0.7)	1.3 (0.3)	4.9 (0.4)	4.4 (1.4)	10.3 (1.4)
TOGR		41.8 (2.9)	66.8 (2.6)	51.1 (1.9)	17.4 (2.3)	42.8 (1.9)
TOFO		32.7 (2.8)	17.4 (2.3)	0.4 (0.2)	2.3 (1.0)	2.7 (0.6)
TOWO		0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.4 (0.3)	0.0 (0.0)
Percent Ground Cover						
GRLI		15.9 (1.2)	15.6 (1.1)	46.2 (1.8)	70.8 (2.7)	48.8 (2.0)
GRBA		9.6 (1.2)	0.2 (0.1)	2.3 (0.5)	8.8 (1.6)	5.8 (1.4)
Visual Obstruction (dm)						
VIOB		6.4 (0.4)	4.4 (0.2)	1.2 (0.1)	0.1 (0.0)	0.2 (0.1)
Vegetation Height (dm)						
MALI		6.0 (0.3)	5.6 (0.3)	0.9 (0.1)	0.1 (0.0)	0.2 (0.1)
MADE		0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Litter (mm)						
LIDE		8.5 (1.1)	18.2 (1.5)	18.0 (0.9)	10.5 (0.9)	13.4 (1.0)

* not sampled

Appendix L. Vegetative characteristics in grassland sites in 1994.

	J. Site	R. Sanctuary	W. Rose	C. Meadows	Chapman	Clarks
	X̄ ± SE	X̄ ± SE	X̄ ± SE	X̄ ± SE	X̄ ± SE	X̄ ± SE
Percent Canopy Cover						
TOCA	45.9 (2.7)	39.6 (1.5)	54.0 (1.6)	38.0 (1.4)	56.9 (1.9)	57.2 (1.6)
TOLI	32.9 (2.2)	32.8 (1.4)	50.5 (1.6)	34.2 (1.2)	45.9 (2.5)	38.3 (1.9)
TODE	13.0 (1.8)	6.8 (0.7)	3.5 (0.6)	3.8 (0.6)	11.0 (1.8)	18.9 (1.9)
TOGR	40.8 (2.8)	36.3 (1.8)	41.6 (2.0)	38.0 (1.4)	45.5 (2.6)	48.2 (2.0)
TOFO	4.9 (1.5)	3.3 (0.7)	12.4 (1.7)	0.0 (0.0)	11.4 (2.0)	9.0 (1.5)
TOWO	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Percent Ground Cover						
GRLI	42.5 (2.5)	36.3 (2.5)	44.2 (1.5)	57.8 (1.5)	34.1 (1.5)	37.5 (1.6)
GRBA	11.2 (2.7)	24.1 (3.0)	1.8 (0.4)	4.3 (0.7)	9.0 (1.6)	5.3 (1.3)
Visual Obstruction (dm)						
VIOB	1.3 (0.1)	1.4 (0.1)	2.0 (0.1)	0.5 (0.1)	2.4 (0.1)	1.8 (0.1)
Vegetation Height (dm)						
MALI	1.2 (0.2)	1.7 (0.1)	2.2 (0.2)	0.6 (0.1)	2.6 (0.2)	0.7 (0.2)
MADE	0.8 (0.2)	0.1 (0.1)	0.3 (0.1)	0.3 (0.1)	0.4 (0.1)	1.6 (0.2)
Litter (mm)						
LIDE	27.6 (2.2)	11.2 (1.0)	20.1 (1.5)	18.9 (1.3)	9.7 (0.7)	11.7 (0.9)

Appendix M. Vegetative characteristics in forested sites in 1994.

	C. Ranch $\bar{X} \pm SE$	B. Strip $\bar{X} \pm SE$	R. Sanctuary $\bar{X} \pm SE$	W. Rose $\bar{X} \pm SE$	C. Meadows $\bar{X} \pm SE$	Chapman $\bar{X} \pm SE$
Percent Canopy Cover						
TOCA	27.6 (1.9)	32.2 (1.8)	35.4 (2.3)	54.3 (2.4)	45.1 (2.5)	25.6 (3.1)
TOLI	24.6 (1.8)	29.9 (1.7)	33.3 (2.3)	54.2 (2.4)	45.1 (2.5)	24.3 (3.0)
TODE	3.1 (0.3)	2.3 (0.4)	2.2 (0.5)	0.1 (0.1)	0.0 (0.0)	1.3 (0.6)
TOGR	23.2 (1.5)	22.3 (1.8)	20.4 (2.0)	11.4 (1.8)	15.9 (2.0)	14.3 (2.9)
TOFO	1.5 (0.3)	5.3 (0.9)	10.3 (1.2)	39.6 (2.4)	26.9 (2.7)	6.7 (1.3)
TOSH	0.5 (0.3)	4.0 (1.1)	3.3 (0.8)	1.4 (0.4)	2.2 (0.6)	4.5 (0.9)
TOTR	2.7 (0.7)	0.6 (0.4)	1.5 (0.8)	1.9 (1.2)	0.1 (0.1)	0.4 (0.1)
Percent Ground Cover						
GRLI	67.6 (2.1)	64.1 (1.8)	57.6 (2.2)	42.3 (2.2)	52.6 (2.5)	65.8 (3.4)
GRBA	4.8 (1.4)	3.7 (0.8)	7.0 (1.6)	3.5 (1.2)	2.4 (0.8)	8.7 (1.8)
Vegetation Density						
SHDE	2.0 (0.3) *	2.2 (0.2)	2.5 (0.3)	0.8 (0.1)	2.3 (0.2)	2.8 (0.4)
TRDE	**	0.4 (0.1)	1.0 (0.2)	0.5 (0.1)	0.2 (0.1)	0.4 (0.1)
Vegetation Height (dm)						
MALI	2.7 (0.1)	2.1 (0.2)	3.1 (0.3)	2.8 (0.2)	3.9 (0.3)	1.6 (0.2)
MADE	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Wood Litter Density						
WOBR	1.6 (0.2)	2.0 (0.2)	2.2 (0.2)	2.6 (0.3)	1.6 (0.2)	3.4 (0.3)
WOLO	0.7 (0.1)	0.4 (0.1)	0.4 (0.1)	1.0 (0.2)	0.6 (0.1)	1.0 (0.2)
Litter (mm)						
LIDE	19.1 (1.1)	24.6 (1.6)	28.6 (2.1)	24.6 (1.5)	38.8 (2.1)	18.2 (1.6)

* 40 observations at this site only

** not measured

Appendix N. Frequency of each species collected with snap traps in grassland sites in 1993.

Species	J. Site *	R. Sanctuary **	W. Rose	C. Meadows	Chapman *	Clarks	Total
M. pennsylvanicus	5	23	148	24	2	1	203
R. megalotis	3	57	35	1	0	51	147
P. maniculatus	6	39	43	11	32	5	136
S. cinereus	1	12	4	4	1	2	24
Z. hudsonius	3	17	3	1	0	0	24
P. leucopus	0	1	0	0	12	4	17
M. musculus	0	6	0	0	1	0	7
B. brevicauda	0	2	1	0	2	1	6
M. ochrogaster	2	0	0	2	0	0	4
R. montanus	0	0	0	0	1	1	2
D. ordii	2	0	0	0	0	0	2
O. leucogaster	0	0	0	0	1	0	1
TOTAL	22	157	234	43	52	65	573
# snapped traps	119	593	285	135	267	132	
# total trap-nights	841	367	675	825	693	828	

* - one night inclement weather

** - two nights inclement weather

Appendix O. Frequency of each species collected with snap traps in forested sites in 1993.

Species	C. Ranch *	B. Strip **	R. Sanctuary **	W. Rose *	C. Meadows *	Chapman	Total
P. leucopus	17	74	32	57	16	79	275
S. cinereus	0	21	2	62	27	0	112
P. maniculatus	4	8	8	9	34	0	63
Z. hudsonius	0	28	6	5	14	0	53
R. megalotis	1	9	20	0	12	0	42
M. pennsylvanicus	0	7	1	5	16	0	29
B. brevicauda	0	11	1	6	8	0	26
TOTAL	22	158	70	144	127	79	600
# snapped traps	181	562	449	159	367	65	
# total trap-nights	779	398	511	801	593	895	

* - one night inclement weather

** - two nights inclement weather

Appendix P. Frequency of each species collected with snap traps in grassland sites in 1994.

Species	J. Site	R. Sanctuary	W. Rose *	C. Meadows *	Chapman *	Clarks *	Total
R. megalotis	8	13	4	0	17	4	46
P. maniculatus	6	21	1	0	15	0	43
P. leucopus	0	0	0	0	8	0	8
Z. hudsonius	3	0	4	0	0	0	7
S. cinereus	6	0	0	0	0	0	6
M. pennsylvanicus	3	0	0	0	2	0	5
M. ochrogaster	4	0	0	0	0	0	4
R. montanus	0	1	0	0	0	1	2
M. musculus	0	0	0	0	1	0	1
S. tridecemlineatus	0	0	0	0	0	1	1
TOTAL	30	35	9	0	43	6	123
# snapped traps	82	51	104	342	164	387	
# total trap-nights	878	909	856	618	796	573	

* - one night inclement weather

Appendix Q. Frequency of each species collected with snap traps in forested sites in 1994.

Species	C. Ranch	B. Strip	R. Sanctuary *	W. Rose	C. Meadows *	Chapman *	Total
P. leucopus	32	23	19	12	18	69	173
S. cinereus	0	37	0	1	0	1	39
Z. hudsonius	5	3	8	0	4	7	27
M. pennsylvanicus	2	7	0	2	0	0	11
R. megalotis	0	3	3	0	0	4	10
P. maniculatus	0	0	0	0	2	3	5
B. brevicauda	1	0	0	0	0	0	1
TOTAL	40	73	30	15	24	84	266
# snapped traps	111	82	407	38	344	348	
# total trap-nights	849	878	553	922	616	612	

* - one night inclement weather