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## Abstract

The primary goals of this collaborative program were to compare small mammal community composition in remnant prairies in Wisconsin and establish a base-line inventory program for grassland-associated species of conservation interest. Small mammal surveys were carried out at 16 preserves over a two-year period in southern Wisconsin. During this period, trapping was carried out twice during the growing season using a combination of three different live trap types. Five species considered of Special Concern by the Wisconsin Natural Heritage Inventory Working List were trapped: the pygmy shrew (*Sorex hoyi*), arctic shrew (*Sorex arcticus*), prairie vole (*Microtus ochrogaster*), western harvest mouse (*Reithrodontomys megalotis*) and Franklin's ground squirrel (*Spermophilus franklinii*). Of these species, prairie voles and western harvest mice were only captured in dry upland sites, whereas pygmy shrews were only recorded in wet prairie sites. Although the scope of this study was limited in duration, differences in species composition and abundance between seasons and community types were evident. In addition, long-tailed shrews (*Sorex* spp.), harvest mice and white-footed/deer mice (*Peromyscus* spp.) showed significant differences in abundance between three stages of post-burn vegetation (<1 year; 2-4 years; 5+ years since last burn). Data from this study as well as other records compiled by the Wisconsin Natural Heritage Program have been used to adjust the ranks of all eight small mammal species of Special Concern. In order to evaluate the importance of native grassland preserves to small mammals, inventories of other grassland habitats outside protected areas are needed.


## Introduction

Tallgrass prairie is one of the most endangered habitats in North America (Noss and Peters 1995). In Wisconsin, it has been estimated that as much as 99.9% of original prairie habitat has been lost (Henderson and Sample 1995). As a result, native prairie remnants have become the focus of intense conservation and inventory efforts in Wisconsin (e.g. Hoffman and Sample 1988, Panzer 1988, Sample and Hoffman 1989, Henderson and Sample 1995, Leach and Givnish 1996, Swengel 1996). However, since the publication of Jackson's "The Mammals of Wisconsin" in 1961, there has been little systematic sampling of grassland-associated small mammals in Wisconsin. Moreover, at the inception of this project in 1995, only limited information was then available in the Natural Heritage Inventory database for small mammals listed as Special Concern and therefore of conservation interest at the state level (Wisconsin Department of Natural Resources Natural Heritage Program Working List, 1995).

In response to this need to update and to revise our current understanding of grassland small mammals, a collaborative small mammal survey program was initiated in 1995, in collaboration with biologists and natural resource specialists in the Wisconsin Chapter of The Nature Conservancy (TNC) and the Wisconsin Department of Natural Resources (DNR). Due to the lack of base-line data from benchmark sites, sampling focused on high-quality remnants where inventory data from other groups had already been gathered. Study sites were located across the two natural divisions within the state where native prairie historically occurred (Hole and Germaine 1994). Species composition and structure of tall grass prairie communities varies greatly with soil moisture content (Curtis, 1959; Cochrane and Iltis, 2000), so study sites were classified into either dry or wet community types and their respective small mammal communities were compared.

Nearly all of the sites examined in the present study are divided into discrete management units that are subject to prescribed burning on a rotational basis. Given the popular use of fire in these preserves (Henderson and Statz 1995) and its influence on small mammal local population dynamics (Kaufman et al. 1990), the present study also set out to investigate differences in small mammal abundance between three stages of succession in post-burn vegetation (< 1 year, 2-4 years, 5+ years) and examine how these differences might vary between seasons (late spring/early summer versus late summer/early fall) and between principal (dry and wet) community types.

## Study Areas

The twelve sites examined in the present study were located within the two southern-most natural divisions recognized in the state of Wisconsin (Hole and Germaine 1994): southwestern uplands and southeastern ridges and lowlands. With the exception of Chiwaukee prairie and adjacent lakeshore, these two natural divisions broadly correspond to the "Driftless" and southeastern Wisconsin Till Plains level III ecoregions described by Omernik et al. (2000). Figure 1 illustrates the location of each site in relation to these natural divisions. Each site was selected to represent the predominant dry (N=7) or wet (N=5) grassland community types characteristic of the southwestern uplands and southeastern lowland divisions of the state, respectively. All sites were contained within designated State Natural Areas or TNC preserves. A pilot study was also conducted in 1995 surveys where six sites were sampled once over a period of two to four nights. Of these sites, three were subsequently rejected for further work (Lulu Lake (LL), Waukesha County; Oakfield Ledge (OL), Fond du Lac County; Walking Irons County Park (WI), Dane County). However, three remaining pilot sites (Spring Green, Schluckebier Prairie and Westport Drumlin) were all systematically re-assessed in 1996 (see below). Although data gathered for these preliminary surveys was not included in the present study, records of Special Concern species were noted (Table 1). Further details on study sites included in this survey are described in Anthony (1999).

The southwestern uplands of Wisconsin are dominated by a loess-capped, un-glaciated landscape, otherwise referred to as the "Driftless" region. In pre-settlement times, this natural division was dominated by oak savanna with upland prairie occurring on the ridge tops and some of the dry west and south facing slopes. Wet to mesic lowland prairie was present in the wider valley bottoms. Forests of mostly oak and some maple-basswood were found on moister, more protected north and east facing slopes. Today, the Driftless region is subject to heavy agricultural use and only small scattered prairie remnants and isolated wood lots persist in less productive areas. Sites sampled within this natural division are characteristic of the dry upland slopes of the Driftless region and areas of thin-soiled glacial till found in parts of southern Wisconsin (Sample and Hoffman 1989) and will be referred to as "dry" prairie communities. Within the Driftless region, surveys were carried out at Rettenmund Black Earth Prairie (BE), Dane County; Barneveld Prairie (BV), Iowa County; Spring Green Preserve (SG), Sauk County; Schluckebier Prairie (SK), Sauk County; Thomson Prairie (TP), Dane/Iowa County border. Both SG and SK are sand prairies which developed on the deep, sandy terraces deposited by the outwash from the face of the glacier at the western edge of the Green Bay lobe of the Wisconsin glaciation (Martin 1974). Two additional dry sites located in areas bordering the Driftless region were also included in the present study: Muralt Bluff Prairie State Natural Area (MB), in Green County and Westport Drumlin Prairie State Natural Area (WD) in Dane County.

Vegetation of dry to dry-mesic prairie community types is typically composed of little bluestem (*Andropogon scoparius*), interspersed with pockets of big bluestem (*Andropogon gerardii*), side-oats grama grass (*Bouteloua curtipendula*), northern dropseed (*Sporobolis heterolepis*), and porcupine grass (*Stipa spartea*). Prevalent forbs include flowering spurge (*Euphorbia corollata*), birdfoot violet (*Viola pedata*), leadplant (*Amorpha canescens*), several golden rod species (*Solidago* species), silky aster (*Aster sericeus*), rough blazing star (*Liatris aspera*), and purple prairie clover (*Petalostemum purpureum*) (Curtis 1959, Sample and Hoffman 1989, Wisconsin Natural Heritage data files 1999).

In contrast, sites sampled within the southeastern ridges and lowlands of the state contained high quality examples of wet-mesic to wet prairie community types and will be referred to throughout as "wet" prairie communities. These sites were Chiwaukee Prairie (CP), Kenosha County; Kettle Moraine Low Prairie and Fen State Natural Area (KM), Waukesha County;

Scuppernong Prairie State Natural Area (SC), Waukesha County; Snapper Prairie State Natural Area (SN), Jefferson County; Young Prairie State Natural Area (YP), Walworth County. Historically, this region of the state was a matrix of southern-mesic forest and savanna, with large prairie, sedge meadows and fens embedded in the savanna landscape (Sample and Mossman 1997). Alongside marshes and wet meadows, these prairies were the major wetlands occupying drainage-ways and glacial depressions within the pre-settlement oak savanna/forest matrix (Hoffman and Sample 1988, Albert 1995). These prairies are subject to periodic flooding because the water table is near the ground surface, and ground water is often raised above the soil surface by precipitation. This up welling of mineral rich ground water contributes to the accumulation of peat and a soil that is nutrient and oxygen rich (Curtis 1959). Consequently, these lowland areas are high in moisture content and are characterized by particularly lush and rapid vegetative growth (Curtis 1959, Hoffman and Sample 1988). Wet sites typically support a larger biomass of insects than drier sites and provide highly suitable habitat for shrews. Although generally flat, lowland prairies may have a shallow undulating surface. Chiwaukee Prairie is a unique site in this respect, as it formed as a series of parallel beach ridges as glacial Lake Chicago receded from its maximum extent 6 miles inland from the current Lake Michigan shoreline (Martin 1974).

Dominant, tallgrass species in wet prairie communities include big blue-stem, blue-joint grass (*Calamagrostis canadensis*), and cordgrass (*Spartina pectinata*). Typical lowland forbs include prairie dock (Silphium terebinthinaceum), common milkweed (*Asclepias syriaca*), New England Aster (*Aster novae-angliae*), wild strawberry (*Fragaria virginiana*), yellow coneflower (*Ratibida pinnata*), golden-alexanders (*Zizia aurea*), bottle gentian (*Gentiana andrewsii*), yellow star grass (*Hypoxis hirsuta*), and prairie blazing star (*Liatris pycnostachya*) (Curtis 1959, Hoffman and Sample 1988).

## Methods

With the exception of Barneveld Prairie, which was heavily grazed until 1996, all prairie reserves examined in this study were subject to prescribed burning management regimes. Three separate study grids (A, B, C) were laid out within discrete management units at each site and were defined on the basis of the time elapsed since the last burn: <1 year; 2-4 years; 5+ years. Each study grid was laid out in a 5 x 5 format, with 25 trap stations to a grid. Trap stations were marked with removable flags and were placed 15 m apart on the grid. As no single trap type is likely to provide an unbiased estimate of overall community structure (e.g. Wiener and Smith 1972, Williams and Braun 1983, Handley and Kalko 1993), we used three of the most commonly used models: 2-piece Longworth traps (tunnel 4.44cm x 6.06 cm x 12.7cm; nestbox 6.35 x 8.57 x 13.97cm; Penlon Ltd., Oxford, England), small, non-folding Sherman traps (5.08 x 6.35 x 16.15cm), and large, folding Sherman traps (7.62 x 8.89 x 22.89 cm; H.B. Sherman Inc., Florida). One of each of these trap types was placed within a 3m radius of each trap station.

Pitfall traps were also incorporated into the present study as they have been shown to be a highly efficient means of sampling shrews (e.g. Pucek 1969, Williams and Braun 1983, Kalko and Handley 1993, Kirkland and Sheppard 1994). Individual pitfalls were placed in the center and the four-corners of each grid. Pitfalls consisted of two #10 cans taped together and sunk into the ground with a raised rain and sun-proof cover. In addition to the traps located within the grid, two 15.24 x 15.24 x 48.26cm Tomahawk traps (Tomahawk, Wisconsin) and three large non-folding Sherman traps of equivalent size (15.24cm x 15.24cm x 45.72cm) were placed in areas showing evidence of high ground-squirrel activity, such as burrows or runways. Overall, 225 conventional live traps, 15 squirrel-sized traps, and 15 pitfalls were used per study area at any one time.

As seasonal fluctuations are commonly observed in small mammal communities (e.g., Birney et al., 1976; Briese and Smith, 1979; Anthony et al., 1981; Swihart and Slade, 1990), two rounds of trapping were conducted at each site with an interval of at least six weeks between trapping rounds. The first round of trapping was conducted in early to mid summer (late May to mid-July) and the second round during late summer to early fall (late July-end August). Each round of trapping extended over four consecutive nights. Trapping effort, summed over both sampling sessions for each site, amounted to 1800 trap nights for conventional live traps and 360 trap nights for pitfall or large squirrel-sized traps.

Immediately before each survey period, live-traps other than pitfalls were left open and pre-baited for 2 days with peanut butter. Tomahawk and squirrel-sized Sherman traps were pre-baited with whole peanuts and slices of apple. Following this pre-baiting interval, all traps were baited once more and set to trap. Traps were checked once in the morning and once in the evening and were periodically shut down during the day to avoid heat stress to the animals. Following capture, each animal was identified, sexed, weighed, and ear-tagged. Data were also recorded for the trap type and location of each capture and whether an animal was new or previously tagged. Rodents were ear-tagged using Fingerling Monel tags (National Band and Tag Co., Kentucky). Shrews were marked with a dab of non-toxic paint behind the ear and were color coded for different days during the trapping period. Standard museum measurements were taken on all Special Concern species. We made no distinction between white-footed mice (*Peromyscus leucopus*) and prairie deer mice (*P. maniculatus*), as differentiation between these two species in the field is difficult without analyzing salivary amylase variation (Aquadro and Patton 1980, Feldhammer et al. 1983, Palas et al. 1992). Stromberg (1979) attempted to separate white-footed mice from the prairie deer mice using a discriminate analysis based on external morphology. Previous experience with this method and discussions with Frank Iwen (pers. comm.) has shown that this method can sometimes fail to separate these two species. Juvenile and sub-adult mice cannot reliably be identified in the field although adult prairie deer mice have a number of characteristics that distinguish them from white-footed mice and can often be recognized in the field by a trained observer (Oliver Pergams pers. comm.). Similarly, separation of the masked shrew (*Sorex cinereus*) and the pygmy shrew (*S. hoyi*) is also impossible in the field so records of these species were recorded as long-tailed shrews. Examination of the dentition of incidentally taken specimens did, however, allow a limited inventory of these two species. We distinguished prairie voles and meadow voles in the field based on pelage, tail length, and number of plantar tubercles on the hind foot. Verification of voucher specimens was confirmed at the University of Wisconsin Zoological Museum, Madison, WI. Animal handling and safety techniques were carried out according to a protocol approved by the University of Wisconsin-Madison. Field personnel used latex gloves and facial respirators when in direct contact with captured animals. All incidentally taken or voucher specimens were frozen and deposited at the UW Zoological museum.

## Data Analysis

The number of individual captures of each species was pooled by grid for each trapping session. Diurnal data were used to establish presence or absence of species that might otherwise have been missed in nocturnal trapping. Statistical analyses were carried out on nocturnal trapping data. Animal abundance data (defined as the total number of new individuals captured) were transformed using the square root transformation X' = square root [X + 0.5], as recommended for count data that follows a Poisson distribution (Zar 1984, Sokal and Rohlf, 1995). Reported means and their respective confidence limits in Tables 2 and 3 were back-transformed from the square root transformed data (Sokal and Rohlf, 1995).

For each of the six most frequently encountered species, differences in small mammal abundance between dry and wet community types were tested using a nested analysis of variance where grids were nested within sites. Repeated measures analysis of variance was carried out to test the effects of time since burn and seasonal change on species abundance as well as interactions between these two effects. Time since burn was the grouping variable and season was the within group variable. As the repeated measures only involved two measures, this analysis is the mathematical equivalent of a paired-t test. Where a significant interaction term was observed, one way analysis of variance was used to assess the effects of burn treatment within the first and second trapping rounds. Bon Ferroni *post hoc* tests were used to compare between means. Significance was assessed at $P < 0.05$. For interaction terms in the repeated measures analysis, significance was assessed at $P < 0.1$. Residuals from ANOVA analyses were visually inspected for homogeneity of variance and standard checks were carried out to test that the data were normally distributed. All statistical analyses were carried out using SYSTAT 6.0 for Windows (SPSS, Chicago, IL).

## Results

### Inventory data

A total of 12 native small mammal species were captured over two years of this study (Table 1). Of the total 1,583 individuals captured over all sites, the most frequently encountered species in dry sites were white-footed/prairie deer mice (relative abundance n = 305/583; 52%), meadow voles (n = 139/583; 24%), and western harvest mice (n = 52/583; 8.9%). In contrast, meadow voles (n = 575/1000; 58%) and long-tailed shrews (n = 246/1000; 25%) dominated wet sites. Five of the species captured in the present study are currently considered as Special Concern: the pygmy shrew, arctic shrew, western harvest mouse, prairie vole and Franklin's ground squirrel (*Spermophilus franklinii*). With the exception of the western harvest mouse, captures of Special Concern species were rare. The arctic shrew and Franklin's ground squirrel were encountered only once in the entire study. Additional records of western harvest mice and prairie voles were also recorded in 1995 (Table 1).

### Community-type association

Although there was no overall difference in species richness between dry and wet prairies, small mammal community composition differed considerably between these habitats. Several species of Special Concern were consistently found in only one community type. Pygmy shrews were captured exclusively in wet sites, whereas prairie voles and western harvest mice were only found in dry sites. Of the six most abundant species present in both dry and wet prairies, three species were significantly more abundant in wet prairie (Table 2). These species were: long-tailed shrews ($F_{1,10}$= 131.817, $P < 0.001$), short-tailed shrews ($F_{1,10} = 14.816$, $P < 0.001$) and meadow voles ($F_{1,10} = 52.362$, $P < 0.001$). Western harvest mice were absent in wet prairie so no statistical test was required. In contrast, neither white-footed/deer mice species ($F_{1,10} = 2.136$, $P = 0.157$) or meadow jumping mice ($F_{1,10} = 2.339$,

$P = 0.139$) showed any significant differences in abundance between dry and wet sites. Captures of thirteen-lined ground squirrels and eastern chipmunks were biased towards day time captures and were therefore not included in our statistical analyses.

Effects of season and fire history

Variation in species composition and relative abundance was evident between trapping sessions across both dry and wet prairies (Tables 1, 3). At all sites except BV, some species were present in one but not both trapping sessions (Table 1). Owing to differences in small mammal communities between dry and wet sites, the effects of both season and fire history were examined separately. Within dry prairies, five of the six most common species did not show any significant change in abundance between the first and second trapping sessions. White-footed/deer mouse spp. abundance, however, did increase significantly with season ($F_{1,15} = 6.658$, $P = 0.021$). With respect to time since burn, white-footed/deer mice were the only species to show a significant response to different post-burn stages across both seasons ($F_{2,15} = 16.023$, $P < 0.001$). *Post hoc* comparisons indicated that white-footed/deer mouse abundance was always significantly greater in the earliest (< 1 year) post-burn stage ($P = 0.006$). A significant interaction between post-burn category and season ($F_{2,15} = 4.525$, $p = 0.029$) was observed for western harvest mice. Closer examination of this interaction revealed a significant difference in abundance between stages in the first ($F_{2,12} = 85.516$, $P < 0.001$) but not second round of trapping. Comparisons among means indicated that abundance was greatest in the oldest post-burn category ($P = 0.023$).

In wet prairies, long-tailed shrew spp. ($F_{1,12} = 85.516$, $P < 0.001$), short-tailed shrews ($F_{1,12} = 22.996$, $P < 0.001$) and meadow voles ($F_{1,12} = 38.667$, $P < 0.001$) were all significantly more abundant in the second round of trapping. In contrast, white-footed/deer mouse abundance decreased ($F_{1,12} = 4.852$, $P = 0.048$) with season. A significant interaction term between fire treatment and season was also observed for long-tailed shrews ($F_{2,12} = 8.232$, $P < 0.006$) and white-footed/deer mice ($F_{2,12} = 3.060$, $P = 0.084$). Long-tailed shrew abundance differed significantly between stages within the second ($F_{2,12} = 4.220$, $P = 0.001$) but not the first round of trapping. Comparison among means indicated that the oldest stage of post-burn vegetation supported a significantly greater abundance of long-tailed shrews ($P = 0.02$). However, this result was only significant when a severe outlying point was removed. White-footed/deer mouse abundance also differed between burn stages in the first ($F_{2,12} = 4.849$, $P = 0.029$) round of trapping and was significantly greater in the early ($P = 0.029$) versus middle stage comparisons of post-burn vegetation.

## Discussion

### Inventory data

One of the principal aims of this study was to establish base-line data across a range of key grassland preserves in Wisconsin. Despite surveys of other important community types within Wisconsin (e.g. Johnson 1978, Kantak 1981, Pitts 1983, Evrard 1998), systematic small mammal surveys across a broad range of grassland communities are needed in order to assess the distribution and conservation status of many of Wisconsin's rare small mammals. Despite the small size of the majority of the preserves included in this study (ranging from 5 to 230 acres of continuous prairie or up to 380 acres of prairie/woodland), most appeared to contain many of the commonly associated grassland species, including several of conservation interest. Five species of Special Concern were trapped in surveys over the two-year duration of this study. Excluding two species that were only captured once (Franklin's ground squirrel, arctic shrew), the remaining species were only trapped in either dry (western harvest mouse, prairie vole) or wet (pygmy shrew) habitat types. In terms of perceived rarity, the Wisconsin Department of Natural Resources used data from this and other studies as well as data gathered from the major zoological collections around Wisconsin to assign state ranks to a number of species (Wisconsin Department of Natural Resources Natural Heritage Program Working List 2002). The changes in rank for grassland-associated species of Special Concern, along with their definitions, are listed in Table 4. Additional sampling in other grassland habitats outside protected areas is needed in order to elucidate the present distribution and abundance of many of the target species in the present study as well as the conservation importance of these preserves to small mammals.

In the present study, pygmy shrews were recorded at four wet sites, all of which are within the southeastern lowland division of the state: YP, SC, KM and CW. Historically, this shrew has been documented in the southeastern and northwestern corners of the state (Jackson 1961). More recent inventory work has also recorded pygmy shrews in the central plains natural division in Colombia and Sauk counties (Wisconsin Atlas Database in preparation). Of all the long-tailed shrew species identified to species level (N = 189), pygmy shrews made up a sizeable component (19/189 = 10%) of the total number captured. Previous studies have suggested that the apparent rarity of pygmy shrew could be the result of its avoidance of conventional small-mammal traps or the fact that it ordinarily occurs at lower densities than other shrews (Edwards 1952, Brown 1967, Kurta 1995). However, with one exception, all identified pygmy shrews in the present study were captured in live traps and not pitfall traps indicating that trap type alone may not have necessarily biased abundance estimates. Although traditionally viewed as a boreal species, further work may help define the southern range limits of the pygmy shrew and aid in clarifying its habitat requirements.

Only one arctic shrew was recorded in the grassland surveys carried out in this study. This apparent rarity is likely to be an artifact of our methods since the location and size of the grids used in this study fail to address local variation in the spatial distribution of apparently rare species. The occurrence of this species in the southeastern corner of the state, at SC in Waukesha County, however, is interesting and does represent a new county record. Although artic shrews are historically believed to be restricted to the northern half of the state, Jackson (1961) has also documented this shrew in Dane and Dodge counties in south central Wisconsin. This shrew has also been recently documented in wet pasture in Colombia County in south central Wisconsin (Chapman 1999) and along marsh edges in eastern Columbia County (Bautz pers. obs.). Although we do not currently know the southern range limit of this species, it is highly probable that arctic shrews may be found further south and east along the Curtis Tension Zone (Curtis, 1969) where ever suitable habitat exists and that further work should focus on clarifying the southern range limits of this species.

According to Jackson (1961), the western harvest mouse is limited to the Driftless region and its bordering areas in Wisconsin although specimens have also been captured in Racine County in the 1960s (Iwen, pers. obs.). Although this species is generally believed to be common in grassland habitats (Peterson et al. 1985, Finck et al. 1986, McMillan and Kaufman 1994), it is also found in a variety of other mid-west habitats including riparian areas with lush vegetation (Kaufman and Fleharty 1974) and irrigated croplands (Fleharty and Navo 1983). Recent studies within southwestern Wisconsin have also found western harvest mice in grassy edges and agricultural fields adjacent to riparian areas (Chapman 1999). Although the present study only found this species in dry upland sites in southwestern and south-central Wisconsin, it is likely to be much more of a habitat generalist than our findings suggest, as evidenced by its presence at most sites in this study within its known range (Jackson 1961), as well as its reported recent eastward invasion into Illinois and Indiana (see Whitaker and Mumford 1972).

In contrast to the relatively widespread meadow vole, only a handful of prairie voles were documented at four of the sites examined in this study. All of these individuals were captured in dry and dry-mesic prairie remnants in south-central Wisconsin. Prairie voles have also been recently recorded on grazed sites (rotational and continuous) but not in riparian buffer sites in southwestern Wisconsin (Chapman and Ribic 2002). The prairie vole is typically associated with grassland habitats and is distributed throughout central North America (Stalling 1990). In many states, this species appears to be a common rodent in prairie habitat (e.g. Finck et al. 1986, Meserve 1971, Schramm and Wilcutts 1983). In Wisconsin, the prairie vole is at the periphery of its range, where it is broadly sympatric with the meadow vole (Long 1989). Although earlier studies by Hanson (1944) claim that the prairie vole is "the most abundant over the uplands and sand prairies of the driftless region", findings from the present study would suggest that the prairie vole is now relatively uncommon in Wisconsin. Some studies suggest that where prairie and meadow voles are found, the prairie vole tends to occupy drier habitat and may compete directly with the more ubiquitous meadow vole (Findley 1954, Miller 1969, Wrigley et al. 1991, Bowles and Copsey 1992), although inter-specific competition may only result in areas of high population density (Krebs 1977, Haken and Batzli 1996). Moreover, reports also indicate that the prairie vole may be in decline in Iowa (Bowles 1981, Bowles and Copsey 1992). Anecdotal evidence from Wisconsin would also suggest the same (Long C., pers. comm). This apparent decline of the prairie vole could in part be attributed to landscape changes in Wisconsin over the past 200 years (Schroger 1937) whereby the progressive increase in tree and shrub cover in southern Wisconsin could in part explain the loss of suitable habitat for this species. The absence of the prairie vole from sites encompassing suitable habitat, and its very low numbers in the present study, indicates that there may be reasonable cause for concern for this species.

The range of Franklin's ground squirrel is believed to have extended throughout the tall-grass and mid-grass prairie states of North America (Hall 1981). In Wisconsin, its distribution is known to extend from Kenosha and Racine counties in the southeast to Polk County in the northwest of the state. Hall (1981) revised Jackson's distribution in the northwest further north into Douglas County, an observation later confirmed by Lewis and Rongstad (1981). Two relatively recent studies have shown that this animal is in severe decline in the more eastern portion of its range in the Mid-West (Lewis and Rongstad 1992, Johnson and Choromanski 1992). In Indiana, trapping studies at 370 survey sites have shown that the current distribution of this squirrel is now limited to nine of the most western counties in north-western Indiana and that it is now apparently extirpated from eight more eastern counties where it previously occurred (Johnson and Choromanski 1992). In another survey in Wisconsin and Illinois, sightings by survey respondents indicated that the current range of this squirrel has extended into north-western Wisconsin but appears to have receded from south-west Wisconsin and the north-western corner of Illinois (Lewis and Rongstad 1992). A number of factors have been suggested as causes of decline in the range of this squirrel, including land use changes, demographic fluctuations and the fragmentation of suitable habitat. Clearly, more research is needed to better understand this species and develop appropriate management strategies in the future.

Several species that historically occurred in southern Wisconsin were completely absent in our surveys. Most notably, these are the least shrew *Cryptotis parva* and the pine vole *Microtus pinetorum*. The least shrew has not been recorded in Wisconsin for over 50 years (see Jackson 1961, A. Wydeven pers. comm.), so its absence from our surveys is not entirely unexpected. The pine vole is semi-fossorial in nature, so that the trapping methods used in this study could have potentially overlooked this animal. However, the capture of a pine vole in two recent studies in southwestern Wisconsin using pitfall traps has been noted (Chapman 1999, Bautz, pers. obs.). Jackson (1961) documents the occurrence of a handful of specimens of this vole in Dane and Colombia counties, but notes that this animal has probably been overlooked in other counties. Pine voles also appear to favor woodland habitats with well-drained sandy soils in the Great Lakes region (Kurta 1995), and so may be extremely rare or uncommon in grasslands.

While it is tempting to view our results within the context of species-area relationships, the nature of land-use patterns surrounding each preserve varied considerably between sites, making any analysis of species-area relationships difficult. Small mammal use of non-native grassland vegetation, replanted prairie and agricultural areas is well documented (Navo and Fleharty 1983, Fleharty and Navo 1983, Schwartz and Whitson 1986, Hall and Willig 1994, Hayslett and Danielson, 1994, Sietman et al. 1994, Kirsch 1997). Nevertheless, the influence of roads, the degree of isolation of individual preserves from other grassland habitat, and the effects of edge habitat are likely to affect small mammal populations (e.g., Garland and Bradley 1982, Bennett 1990). In particular, habitat use and dispersal through adjacent agricultural areas and corridors present intriguing prospects for further research.

### Community type association

Numerous studies have demonstrated that vegetation structure is one of the most important determinants of small mammal community structure (e.g. Rozensweig and Winakur 1969, Kaufman and Fleharty 1974, Snyder and Best 1988). In the present study, differences in small mammal species composition and abundance between dry and wet community types were apparent and to a large extent reflected the habitat preferences and distribution of the species included in this analysis. Meadow voles prefer moist, grassy conditions with a well-developed cover layer (Getz 1961a, Snyder and Best 1988, Kurta 1995, Getz et al. 2001) and in this study appeared to dominate the small mammal community in wet sites. Shrews are also generally associated with moist environments with dense cover (Getz 1961b, Wrigley 1979, Kurta 1995, Kaufman et al. 2000), and were abundant in wet sites in this study. In contrast, the prairie vole was only captured in dry, upland habitat, in keeping with what is presently known of its habitat associations in the Great Lakes region (Meserve 1971, Long 1989, Kurta 1995). The western harvest mouse also appears associated with dry sites contained within its present range in Wisconsin (see Jackson 1961). However, the documented occurrence of this species in a variety of other habitats across its range (e.g. Kaufman and Fleharty 1974, Fleharty and Navo 1983, Hayslett and Danielson 1994) as well as its recent invasion into the Great Lakes region (Kurta 1995), would indicate that it is more of a habitat generalist than our data suggest.

The inventory data and perceived community type associations derived from this study are limited in their scope and can only be taken as a preliminary assessment of Wisconsin grassland-associated mammals. As is the case for many other states, much of the original coverage of tall grass prairie in Wisconsin has been lost and is likely to have forced many small mammals into other forms of grassland habitat. A number of studies in the prairie states have examined small mammal composition in a variety of modified grassland habitats including roadside ditches, prairie plantings, old field, pastures, hayfields, and Conservation Reserve Program lands plantings (Schwartz and Whitson 1986, Bowles and Copsey 1992, Hall and Willig, 1994, Hayslett and Danielson 1994, Sietman et al. 1994, Kirsch 1997). Clearly further work needs to be directed towards other grassland habitats in Wisconsin in order to clarify the current distribution of Special Concern species and determine the importance of protected areas as habitat for rare small mammals.

Effects of season and fire history

With respect to overall seasonal changes in abundance, significant differences in small mammal abundance between trapping sessions were observed for many species in wet sites. The observed increase in small mammal abundance with advancing season in these habitats could be a result of greater shifts in vegetation productivity and increases in the dead vegetation layer or duff layer, as has been observed in vegetation studies at these sites (Anthony, pers. obs.). Previous studies have shown that vegetation productivity can influence small mammal communities (Brown 1973, Grant et al. 1977, Abramsky et al. 1979, Abramsky 1988). However, other factors such as inter-specific competition (Grant 1972, Redfield et al. 1977, Abramsky et al. 1979), population fluctuations (Swihart and Slade 1990, Getz and Hofmann 1999), and disturbance regimes (Schwartz and Whitson 1987, Hall and Willig 1994) could also be operating at these sites so that interpretation of these patterns need to be made with caution. However, the fact that the grassland-associated species known to favor dense cover, all showed a similar increase in abundance with season, suggests that shifts in productivity and vegetative cover may be important factors influencing small mammal abundance.

The availability of burn histories for all the sites examined in the present study did allow a limited analysis of the effects of fire on small mammal abundance and examine how these responses may vary with season. Numerous studies have demonstrated that fire has profound effects on both vegetation structure and composition. More importantly, changes in habitat structure brought about by fire will also affect microhabitat choice and movements of small mammals in areas affected by a burn (e.g. Beck and Vogl 1972, Schramm and Willcutts 1983; Kaufman et al. 1983, Vacanti and Galuso 1985, Clark and Kaufman 1990; Henderson and Statz 1995, McMillan et al. 1995).

In the present study, white-footed/deer mice were the only species to show greater apparent abundance in recently burned areas. This is probably due to immigration from surrounding areas and a preference for relatively open habitat. Interestingly, this species group showed no significant differences in abundance between dry and wet community types, suggesting that post-burn changes in vegetation are more important than structural differences between dry and wet habitat types. Although the present study made no distinction between white-footed and deer mice, increased capture rates in recently burned sites reflects the fire positive responses commonly observed in deer mice (Kaufman et al. 1988, Kaufman et al. 1990). Removal of ground litter has been cited as a factor likely to favor deer mouse abundance and may account for the perceived prevalence of these mice in recently burned sites.

Seasonal differences in response to burn stage were evident in long-tailed shrew species inhabiting wet prairie indicating a potential shift towards older, more established vegetation with a well-developed duff layer. Western harvest mice also appeared to be significantly more abundant in the later rather than earlier vegetation stage. However, this effect was only observed in the first round of trapping, indicating that the apparent avoidance of recently burned sites in this species is relatively short-lived. Previous studies have shown that although harvest mouse mortality and emigration is high following a burn, these mice have been found to immigrate back into a recently burned area towards the end of the growing season and can thus recover relatively rapidly (Kaufman et al. 1998, 1990).

## Conclusions

The results from the present base-line study indicate that many of the preserves assessed in the present study are species-rich and contain one or more species of Special Concern. Seasonal differences in the composition and relative abundance of small mammal species in this study highlight the problems of reliably detecting uncommon species and underline the importance of multiple survey efforts at any given site. The apparent dry or wet habitat preferences of Special Concern species, while requiring further study, emphasize the need to preserve a variety of different habitats for effective small mammal conservation. Responses to fire-induced changes in habitat structure were apparent in several small species and may vary with season. Increases in small mammal capture rates were pronounced in wet prairie habitats and may be associated with increased productivity and better developed duff layers in these habitats. For animals requiring a substantial duff layer such as voles and shrews, short term fire responses are likely to be tied very closely to the initial loss and gradual accumulation of the duff layer. We postulate that higher rates of vegetative growth would lead to faster rates of accumulation of duff layer in wet rather than dry prairie habitats. However, further work is needed to examine fully the effects of season and fire frequency on vegetation structure and small mammal population dynamics through time. Long-term studies are also needed to fully evaluate species richness and community composition in a variety of grassland habitat types and to monitor the effects of management regimes in grassland preserves over longer time frames. Although limited in scope, baseline data generated from this short-term study can provide a valuable starting point for more systematic surveys in other grassland areas.

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| Site | Habitat | Species | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1996* | | LTS | ACS | STS | WHM[a] | WDM | MDV | PRV[b] | MJM | TLG | FGS | ECH |
| SG S1 | Dry | | | | 5 | 6 | | | | | | |
| SG S2 | | | | | | 4 | | 1 | | | | |
| SN S1 | Wet | 1 | | 2 | | 25 | 76 | | | 2 | | |
| SN S2 | | 13 | | 19 | | 4 | 137 | | 1 | 4 | | |
| SK S1 | Dry | | | | 5 | 7 | 17 | | 1 | 1 | | |
| SK S2 | | 3 | | 2 | 6 | 14 | 23 | | | 2 | | |
| TP S1 | Dry | 1 | | | 11 | 14 | 19 | | | X | | |
| TP S2 | | 24 | | 10 | 11 | 9 | 32 | | 1 | 1 | | |
| WD S1 | Dry | 3 | | | | 39 | 6 | | | 1 | | X |
| WD S2 | | | | 2 | 3 | 83 | 1 | | | 3 | | 2 |
| YP S1 | Wet | 1 | | | | 3 | 12 | | | 1 | | X |
| YP S2 | | 23 | | 14 | | 1 | 48 | | 3 | X | | |
| *1997* | | LTS | ACS | STS | WHM | WDM | MDV | PRV | MJM | TLG | FGS | ECH |
| BE S1 | Dry | | | | | 30 | 5 | 3 | | X | | |
| BE S2 | | | | | | 32 | 24 | 1 | 9 | 4 | | |
| BV S1 | Dry | | | | | 6 | 3 | | | X | | |
| BV S2 | | | | | | 12 | 7 | | | X | | |
| MB S1 | Dry | 1 | | 2 | 4 | 19 | 2 | | | 3 | | 2 |
| MB S2 | | | | 1 | 7 | 36 | | | 1 | 2 | | |
| CW S1 | Wet | 4 | | | | 12 | 31 | | X | 2 | | X |
| CW S2 | | 62 | | 1 | | 8 | 98 | | 1 | 3 | X | X |
| KM S1 | Wet | 7 | | | | 7 | 1 | | | | | |
| KM S2 | | 51 | | 5 | | 11 | 25 | | 13 | | | X |
| SC S1 | Wet | 2 | | | | 7 | 19 | | | | | X |
| SC S2 | | 83 | 1 | 9 | | 6 | 128 | | 14 | | | |

**Table 1** Total number of individuals captured of each species. Captures are listed by site in 1996 and 1997 surveys. Trapping results are presented for two discrete trapping sessions (S1 late spring/early summer and S2 mid-summer/early fall). (X): diurnal species captures only. For full study site names see the methods section.

Species key: LTS: Long-tailed shrew spp. (pygmy and masked); ACS: Arctic shrew; STS: short-tailed shrew; WHM: Western harvest mouse; WDM: White-footed/deer mouse spp.; MDV: Meadow vole; PRV: Prairie vole; MJM: Meadow jumping mouse; TLG: Thirteen-lined ground squirrel; FGS: Franklin's ground squirrel; ECH: Eastern Chipmunk. Several species of special concern were recorded in 1995 pilot surveys. These were: [a]Western harvest mice, recorded in dry prairie at SK, TP, WD and WI in 1995 pilot surveys; [b]Prairie voles, recorded in dry prairies at SK and WI.

| Species | Dry Prairie | Wet Prairie |
|---|---|---|
| *Long-tailed shrew spp.* ** | 0.80 (0.053/1.863) | 14.5 (8.997/21.25) |
| *Short-tailed shrew*** | 0.52 (0.073/1.090) | 2.64 (1.179/4.559) |
| *Western harvest mouse* ‡ | 1.59 (0.517/3.053) | |
| *White-footed/deer mice spp.* | 9.28 (3.735/17.10) | 4.13 (1.621/7.604) |
| *Meadow vole* ** | 4.08 (1.447/7.812) | 32.8 (19.13/50.16) |
| *Meadow jumping mouse* | 0.36 (0.006/0.804) | 1.21 (0.071/2.954) |

**TABLE 2** Mean number of individuals/grid and 95% confidence limits (parentheses) for the six most frequently encountered small mammal species in each community type.

‡ Species of Special Concern. ** Significant differences at $P < 0.01$

**Table 3** Mean number of new captures/grid (95% confidence limits) in 3 stages of post-burn succession: early (<1 year), middle (2-4 years) and late (5+ years) stages. Data are partitioned by (a) dry and (b) wet prairie and by season (first and second trapping sessions).

(a) Dry prairie

| Post-burn Stage | Grids Total=18 | Species | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Short-tailed shrew spp.* | *Long-tailed shrew* | *Western harvest mouse* | *White-footed/deer mouse spp.* | *Meadow vole* | *Meadow jumping mouse* |
| *Session 1* | N | | | | | | |
| Early | 4 | 0.00 | 0.00 | 0.00 | 16.87 (10.1/25.3) | 0.00 | 0.00 |
| Middle | 9 | 0.30 (-0.14/0.90) | 0.15 (-0.10/0.45) | 0.31 (-0.14/0.95) | 1.56 (0.32/3.37) | 3.36 (0.60/7.78) | 0.00 |
| Late | 5 | 0.16 (-0.08/0.45) | 0.00 | 3.33 (-0.86/7.07) | 2.87 (0.58/6.41) | 1.22 (0.13/2.86) | 0.16 (-0.08/0.45) |
| *Session 2* | N | | | | | | |
| Early | 4 | 0.00 | 0.00 | 0.20 (-0.09/0.56) | 29.51 (16.9/45.5) | 0.36 (-0.14/1.07) | 1.05 (-0.01/2.72) |
| Middle | 9 | 0.93 (-0.20/2.91) | 0.77 (-0.18/2.35) | 1.46 (0.06/3.71) | 2.38 (0.18/6.12) | 4.82 (0.20/13.7) | 0.25 (-0.16/0.81) |
| Late | 5 | 1.16 (-0.15/3.44) | 0.59 (-0.09/1.59) | 0.98 (-0.13/2.84) | 3.36 (2.04/4.96) | 1.32 (-0.22/4.19) | 0.16 (-0.08/0.45) |

(b) Wet prairie

| Post-burn Stage | Grids Total= 15 | Species | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Short-tailed shrew spp.* | *Long-tailed shrew* | *Western harvest mouse* | *White-footed/deer mouse spp.* | *Meadow vole* | *Meadow jumping mouse* |
| *Session 1* | N | | | | | | |
| Early | 3 | 0.27 (-0.08/0.73) | 0.50 (-0.13/1.42) | 0.00 | 8.80 (5.13/13.4) | 12.93 (8.03/18.9) | 0.00 |
| Middle | 5 | 1.52 (0.10/3.79) | 0.00 | 0.00 | 0.74 (-0.11/2.08) | 10.97 (2.91/23.8) | 0.00 |
| Late | 7 | 0.36 (-0.04/0.90) | 0.00 | 0.00 | 2.15 (0.24/5.23) | 2.74 (0.25/6.98) | 0.00 |
| *Session 2* | N | | | | | | |
| Early | 3 | 7.17 (0.90/18.5) | 4.80 (3.09/6.85) | 0.00 | 2.22 (0.54/4.69) | 44.1 (32.8/57.0) | 3.16 (-0.08/9.59) |
| Middle | 5 | 8.96 (5.18/13.7) | 2.54 (0.76/5.09) | 0.00 | 0.34 (-0.06/0.85) | 23.1 (14.7/33.4) | 0.97 (-0.33/3.60) |
| Late | 7 | 21.4 (15.2/28.6) | 1.81 (0.05/4.80) | 0.00 | 2.30 (-0.64/4.68) | 20.2 (4.78/45.7) | 0.74 (-0.08/1.99) |

| Species | Common Name | SRANK in June 1995 | SRANK in December 2002 |
|---|---|---|---|
| *Sorex arcticus* | Arctic shrew | SU | S2 |
| *Sorex hoyi* | Pygmy shrew | SU | S3 |
| *Cryptotis parva* | Least shrew | SH | SX* |
| *Reithrodontomys megalotis* | Western harvest mouse | SU | S2 |
| *Microtus ochrogaster* | Prairie vole | SU | S2 |
| *Microtus pinetorum* | Woodland/pine vole | SU | S1 |
| *Spermophilus franklinii* | Franklin's ground squirrel | SU | S2S3 |

**TABLE 4** Changes in state rarity rankings of grassland-associated small mammal species. (After the Wisconsin Natural Heritage Inventory Working List, 1995-2002).

SRANK refers to the State element rank given by the Wisconsin Natural Heritage Inventory program. This ranking system used by all state heritage programs, is designed to reflect the knowledge of a species rarity in a given state. The SRANKs used here are defined as follows: S1= Critically imperiled in WI (generally 5 or fewer extant occurrences ), S2 = Imperiled in WI because of rarity (generally 6 to 20 extant occurrences) or because some factor(s) make it very vulnerable to extirpation from the state, S3 = Rare or uncommon in Wisconsin (21 to 100 occurrences), SH = Of historical occurrence in WI not having been verified in the past 20 years and suspected to be still extant, SU = Possibly in peril in WI, but the status is uncertain. More information is needed, SX= Apparently extirpated from the state. *In the case of *Cryptotis parva,* the SX listing refers to the SRANK listing in Jan 2001.

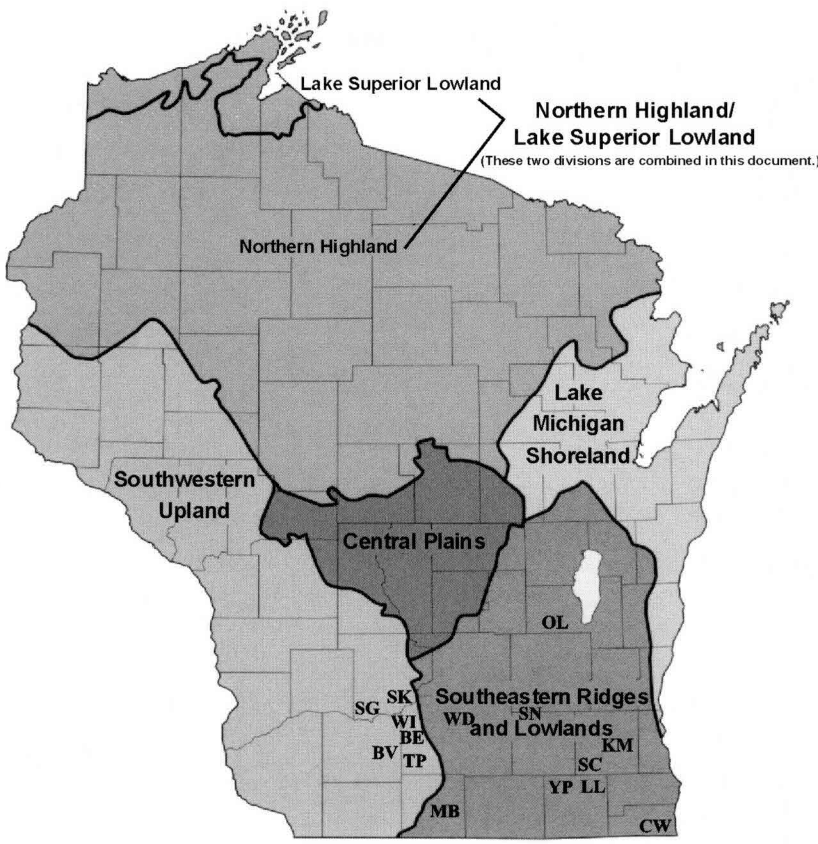


**FIGURE 1** Location of Wisconsin Small Mammal Survey study sites in relation to the natural divisions of Wisconsin (see Hole and Germain, 1994). Study sites are as follows: BE: Rettenmund Black Earth Prairie, Dane Co.; BV: Barneveld Prairie, Iowa Co.; CP: Chiwaukee Prairie, Kenosha Co.; KM: Kettle Moraine Low Prairie and Fen State Natural Area, Waukesha Co.; MB: Muralt Bluff Prairie State Natural Area, Green Co.; SG: Spring Green Preserve, Sauk Co.; SK: Schluckebier Prairie, Sauk Co.; SC: Scuppernong Prairie State Natural Area, Waukesha Co.; SN: Snapper Prairie State Natural Area, Jefferson Co.; TP: Thomson Prairie, Dane/Iowa Co.; WD: Westport Drumlin Prairie State Natural Area, Dane Co.; YP: Young Prairie State Natural Area, Walworth Co. Map modified from Sample and Mossman (1997).