FINAL REPORT

GRANT TITLE: **ECOLOGY OF THE NORTHERN GRASSHOPPER MOUSE (ONYCHOMYS LEUCOGASTER) AND PRAIRIE VOLE (MICROTUS OCHROGASTER) IN CLAY COUNTY, MINNESOTA**

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SUBMITTAL DATE:
1 December 1995

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Abstract:

During the summers of 1994 and 1995, study sites in Clay County, Minnesota, were live-trapped for small mammals with the main objective of studying the ecology of the northern grasshopper mouse (Onychomys leucogaster) and the prairie vole (Microtus ochrogaster) in grassland habitats. In 1994, 8 sites were studied including sites at Bluestem, Felton, and Bicentennial Prairies, Buffalo River State Park, and Ames Gravel Quarry (T.141N, R.46W., S.36). Quite a few prairie voles were trapped at Bicentennial Prairie (n = 23) and a few were trapped at Ames Gravel Quarry (n = 5), but northern grasshopper mice were not captured on any of the sites during 1994. During our 1995 field season, we intensified our trapping efforts and concentrated our efforts on Ames Gravel Quarry where we had captured northern grasshopper mice in the past. We also retrapped Bicentennial Prairie in the area where we had captured prairie voles in 1994. During 1995, we were successful at capturing both prairie voles (n = 17) and grasshopper mice (n = 5) at Ames Gravel Quarry and prairie voles (n = 8) at Bicentennial Prairie. Prairie voles were associated with dense grass cover and a considerable layer of grass litter. Therefore, we suggest that prescribed burns be kept relatively small and carried out on a rotational basis. This would provide at least some nearby unburned areas to which the prairie voles could escape and find suitable grass litter cover. Grasshopper mice were associated with sandy "hillocks" which we defined as the sandy spoil piles or topsoil piles left from previous excavations at the quarry. Weedy vegetation often grew on these hillock areas. One adult male and 1 adult female grasshopper mouse at Ames Gravel Quarry were fitted with radiocollars and released at the location of capture. Although the female lost her radiocollar within the first few days, we radiotracked the male from 17 August to 7 September 1995. Radiotelemetry position readings were taken during daytime and nighttime hours. We found that he was strictly nocturnal and always spent the daytime hours in a burrow within a hillock. Soon after sunset, he left his burrow and moved about, often traveling great distances. He paused periodically in his forays, and we assumed he was stopping to feed. He returned to his burrow prior to sunrise. We think that excavation activities could be planned in advance to minimize the danger to the grasshopper mice. Hillocks in the area of a planned excavation could be searched in advance and flagged if burrow systems appeared present. Because the northern grasshopper mouse seems to be limited in its distribution, has specific habitat requirements (i.e., sandy hillocks), and sparsely populates an area due to its extremely large home range, we suggest that it be considered for inclusion on Minnesota's List of Special Concern Species. A wide variety of nontarget species were also captured during the study. Most notably, we captured meadow jumping mice (Zapus hudsonius) at Ames Gravel Quarry for the first time in Clay County since we began our small mammal studies in 1990. Small mammal diversity was quite high at Ames Gravel Quarry, probably due in part to the great heterogeneity of the habitat.

Introduction:

The prairie vole (Microtus ochrogaster) and the northern grasshopper mouse (Onychomys leucogaster) reach the northeastern edge of their distribution in western Minnesota (Jones and Birney 1988). Both species are associated with grassland habitats and are prey species for a variety of mammalian and avian predators (Jones et al. 1983).

The northern grasshopper mouse is a very unique species for several reasons. This species has unusual carnivorous feeding habits (Bailey and Sperry 1929, Egoscue 1960, Jahoda 1970). Plant material found in their gut has been attributed to the arthropods they consume (Hansen 1975). They form male-female social bonds with both parents contributing to the care of the offspring (Ruffer 1965a). They are highly aggressive and territorial (Ruffer 1968) and have large home ranges (Blair 1953, as reported by Ruffer 1968). They also have complex communication systems (Hafner and Hafner 1979, Hildebrand 1961, Ruffer 1966). Grasshopper mice are found in a variety of grassland habitats, often associated with sandy, coarse soils (McCarty 1978). They live in burrows which they excavate themselves. The substrate is scattered away from the hole leaving little or no raised area around the burrow (Ruffer 1965b), a feature which is characteristic of northern grasshopper mice burrows.

Prairie voles seem to be especially adapted for living in dry prairies (DeCoursey 1957, Getz 1963, Miller 1969). In Minnesota, it is believed that the prairie vole's habitat has been so altered that the prairie vole is now being displaced by the meadow vole (Hazard 1982). Further research has shown that the prairie vole's mating system is basically monogamous and both parents care for the young which is relatively rare among microtines (Thomas and Birney 1979).

Our extensive literature review has indicated that the northern grasshopper mouse has been relatively unstudied in Minnesota prior to our studies beginning in 1990. Consequently, little is known about its life history in this area. In 1988, the Minnesota County Biological Survey captured 8 grasshopper mice (Wilkin County: 1 capture, Lac Qui Parle County: 7 captures) (Birney and Nordquist 1991) with snap-trap surveys of Norman, Clay, Wilkin, Traverse, Big Stone, Lac Qui Parle, and Washington Counties. Specimens have also been found in Kittson, Lincoln, and Otter Tail Counties (Dickerman and Tester 1957). In our 1990-91 studies, we captured 7 northern grasshopper mice at 3 sites in Clay County and 6 at 1 site in Lac Qui Parle County (Stockrahm 1991). During our 1993 study (Harper et al. 1994) sponsored by the Zoological Society of Minnesota, Moorhead State University, and the Moorhead State University Foundation, we captured 7 northern grasshopper mice at a commercial gravel quarry (Ames Gravel Quarry) and 2 at Bluestem Prairie, both sites in Clay County, Minnesota. In addition to these captures, Clay County has past records of grasshopper mice captures (Hazard 1982, Heaney and Birney 1975).

Prairie voles have also not been extensively studied in Minnesota. They were collected shortly after the turn of the century in Sherburne County, Minnesota (Bailey 1929). Allen (1936) and Heaney and Birney

(1975) mentioned the distribution of the prairie vole in Minnesota, but Clay County was not listed as part of the distribution. Swanson et al. (1945) listed the prairie vole as being found in Minnesota, but again, Clay was not among the counties listed. In Hazard's (1982) comprehensive and more recent work, prairie voles were reported in Clay County. Frederick J. Jannett, Jr., Ph.D., Department of Biology of The Science Museum of Minnesota, has trapped prairie voles in Clay County for a number of years in his ongoing studies (personal communication, phone call on 22 November 1995).

During the summer of 1994, we initiated our new 2-year study in Clay County, Minnesota, to obtain more information about northern grasshopper mice and prairie voles in this geographic region. Our specific objectives and tasks included:

Objective 1:

Characterize the distribution, habitat affinities, and demography of target species within study sites.

Tasks:

a) Use transect arrangement of live-traps to sample study sites for target species.

b) As time permits, conduct intensive grid trapping at any sites at which target species are found.

c) For all individuals of target species captured, collect data on weight, sex, age class, location of capture, and type of habitat. Mark all target species individuals by toe-clipping.

Objective 2:

Describe response of target species to excavation within occupied habitat.

Tasks:

a) Prior to excavation, conduct intensive grid trapping at quarry site. Collect data and mark individuals of target species as described under Objective 1.

b) During excavation, monitor dispersal by intensively trapping in vicinity of excavation.

c) As funding permits, monitor dispersal by use of radiotelemetry.

Acknowledgements:

We are deeply grateful for the financial support from the Minnesota Chapter of The Nature Conservancy, the Minnesota Nongame Wildlife Tax Checkoff, and the Reinvest in Minnesota Program through the Minnesota Department of Natural Resources, Section of Wildlife, Natural Heritage and Nongame Research Program. A Moorhead State University Faculty Research Grant supplemented the above funds for our 1995 field season. We also thank the Moorhead State University Foundation, Moorhead State University Biology Department, and the Zoological Society of Minnesota for past and/or present support for our ongoing studies on the northern grasshopper mice and prairie voles. Your support has helped us learn more about these species in western Minnesota, and you have helped provide the opportunity for enthusiastic, Moorhead State University undergraduate Biology Majors to gain valuable hands-on research experience. We also want to thank all of those student volunteers who helped with various aspects of the project while receiving no monetary compensation. Your efforts helped make the completion of this study possible. We also thank Rich J. Baker, Grants Coordinator of the Natural Heritage and Nongame Research Program for the Minnesota Department of Natural Resources for his assistance and helpful comments throughout the study. We thank The Bell Museum of Natural History, especially Elmer C. Birney, Ph.D., for specimen identification. We are grateful to the Buffalo River State Park, The Nature Conservancy, and the Minnesota Department of Natural Resources' SNA Program for allowing us access to land under their stewardship. Last, and perhaps most importantly, we thank Daniel G. Ames, President of Ames Sand and Gravel, for his complete cooperation throughout the study and for allowing us access to his gravel quarry and its resident northern grasshopper mice and prairie voles.

Materials and Methods:

1994 Trapping Methods

During 1994, 8 study sites were live-trapped with 1 of the sites being a retrapped gravel quarry in Clay County where both target species had been captured during the summer of 1993 (Table 1; Appendix A: Maps). Study sites were trapped using Sherman live-traps baited with dog food and/or a mixture of peanut butter and rolled oats. For the preliminary trapping, traps were prebaited and locked open for 2 nights prior to setting them. At Sites 1 through 7, 25 traps were placed in a transect at 10-m intervals to give a 250-m (effective size) transect. All transects were straight lines except on Site 5 where an "L" configuration was formed (due to the presence of a pond). After prebaiting, the traps were set at sunset for 2 nights and checked the following mornings at sunrise (Table 2).

Intensive trapping was conducted only on Sites 3 and 8 (Tables 3, 4). Site 3 was retrapped using a 7-by-7 (3600 m^2 actual size, 4900 m^2

effective size) grid arrangement centered around 2 of the 3 stations where prairie voles had been captured during the preliminary trapping session. During this intensive trapping session, dog food was the only bait used (in the hope of attracting northern grasshopper mice) and trapping took place during daylight hours due to cold evening temperatures. As a prelude to the anticipated habitat destruction (excavation) study at Ames Gravel Quarry, Site 8 was intensively live-trapped using 2, 7-by-7 grids superimposed over areas where northern grasshopper mice and prairie voles had been captured in 1993. After prebaiting, traps were set for 4 and 3 nights, respectively, for these 2 grids, i.e., Grids C and D.

The following information was collected for each captured small mammal: trap station number, habitat, species, sex, age, weight (Pesola scale), tail length, and breeding condition (Appendix B: Field Forms). Captured animals were toe-clipped for individual recognition and released at the site of capture. Animals were aged as adult or subadult based on weight, pelage color, and reproductive condition. Because subadults and juveniles were often difficult to distinguish, the "juvenile" age category was used only when an animal was obviously extremely young. Scientific and common names for small mammals were taken from Whitaker (1980).

1995 Trapping Methods

We were unable to locate northern grasshopper mice during our 1994 field season despite much trapping effort. We became very concerned that if we used our 1994 trapping scheme, it would again fail to locate this target species during our 1995 field season. Therefore, during our 1995 field season, we concentrated our trapping efforts in areas where northern grasshopper mice and/or prairie voles had been captured in our past studies to maximize our chances of locating populations of the target species, i.e., Bicentennial Prairie, Bluestem Prairie, and especially Ames Gravel Quarry (Table 5). We implemented a very intensive trapping scheme which essentially doubled the size of our trapping grids from 7-by-7 (49 traps) to 10-by-10 (100 traps) and increased our trapping effort (Tables 6, 7). We decided not to spend extra days on preliminary trapping with transects, but to implement a 10-by-10 grid trapping scheme immediately (with 10 m between traps along a transect and 10 m between transects).

When August 1995 arrived and even this intensive trapping scheme failed to locate northern grasshopper mice, we decided to cluster traps on the hillocks scattered around the Ames Gravel Quarry because our previous studies (Stockrahm 1991 and Harper et al. 1994) had indicated that this species seemed to be associated with these microhabitats. We defined "hillocks" as the sandy spoil piles scattered around the quarry, presumably made by previous excavation activities. Some of the hillocks, especially in the southern portion of Ames Gravel Quarry, seemed to be sandy loam topsoil stockpiled for future use. Daniel G. Ames, President of Ames Sand and Gravel, verified that the hillocks in

the southern area were topsoil piles that had been set aside for the future reclamation of the area after the sand and gravel had been removed (personal communication, phone call on 30 November 1995). These topsoil piles had been there for approximately 3 years. To the north, most of the hillocks were very sandy and he again verified that they were spoil piles left by previous excavating activities. He said that he thought some of them had been around for approximately 30 years. We attempted to cover the entire area of each hillock with traps. During these widespread trapping efforts, we trapped hillocks from nearly all areas of Section 36. After this hillock trapping proved successful at locating northern grasshopper mice, we superimposed a 10-by-10 trapping grid over the hillocks where the grasshopper mice had been initially trapped.

During our 1995 field season, we also experimented with the timing of trap checks to determine what scheme produced maximal data and also to learn more about the diurnal versus nocturnal movement behavior of different small mammal species. Early in the summer (June) on Sites 1, 2, 3 (Round 1 only), Site 4 (first day of trapping only), and Site 10, we set traps in the evening, conducted an early-morning trap check, then continued checking traps approximately every 3 hours until sunset. When daytime trap checks indicated that very few additional animals were caught after the early-morning check (i.e., most of the animals captured in the daytime were recaptures of those caught in the early-morning check), we conducted only the early-morning checks throughout the rest of the summer.

The same information collected on each captured small mammal in 1994 was also collected during 1995 (Appendix B: Field Forms).

1995 Radiotelemetry and Powdertracking Methods

We used radiotelemetry on an experimental basis on 2 northern grasshopper mice in August/September 1995. Two collars were purchased from Wildlife Materials, Inc. (SOM 2028 MVS XMTR; Frequency 150.944 MHz and 151.727 MHz) with estimated battery lives of 58 and 62 days, respectively, and weighing between 1.9 and 2.1g. Tracking was done using a TRX-2000S radioreceiver with a 3-element Yagi folding antenna (Wildlife Materials, Inc.) (Fig. 1).

An adult male northern grasshopper mouse (#2230) weighing 26 g was radiocollared on 17 August 1995 and tracked until 7 September 1995, after which date it could no longer be located. An adult female (#3430) weighing 27 g was radiocollared on 18 August 1995 and released. She was tracked that evening which turned out to be the only time because she did not have her collar when she was recaptured on 20 August.

Powdertracking was also used to monitor movements of 4 of the northern grasshopper mice, using the methods of Lemen and Freeman (1985). The 2 radiocollared grasshopper mice were dusted with fluorescent powder before their release. Therefore, they could be tracked by the 2 methods simultaneously until the powder wore off. Two additional grasshopper mice, 1 adult male (#3450, 32 g) and 1 adult

female (#0010, 30g) were also dusted. The paths of the movements of these 4 dusted mice were then tracked at night using an ultraviolet light.

1995 Excavation Methods

Excavations at Ames Gravel Quarry did not proceed exactly as planned for a number of reasons (see Results). The initial plan was to locate a population of northern grasshopper mice and intensively trap the area using a trapping-grid arrangement. We would then ask the quarry owner to excavate the area, after which we would monitor dispersal movements by trapping around the edge of the excavation area. If financially possible, we were also hoping to place radiotelemetry collars on several animals and monitor their movements during and after excavation. Although it sounded simple on paper, we quickly found out that our original plan was impossible to implement.

The following describes what actually happened. In order to explain the excavations and our change in plans, a few results must also be presented here. We finally located several northern grasshopper mice on 17-18 August 1995 by trapping the hillocks at Ames Gravel Quarry; we had tried trapping the hillocks because the grid trapping regime had been unsuccessful up to that point in time. We immediately put radiotelemetry collars on a male and a female and powdertracked them because we were afraid we would never retrap them and the opportunity would be lost. We then superimposed a 10-by-10 trapping grid (i.e., Site 5) over the hillocks where we initially captured the grasshopper mice in order to intensively trap that area prior to excavation. While trapping this new grid, we also radiotracked the animals to see where they were going. Although the literature says that this species has a large home range, we were surprised to find out how enormous their home ranges were in the gravel quarry habitat. The radiocollared male completely moved off the trapping grid to an area over 0.25 km away and eventually made a short reappearance back on Site 5. In the meantime, someone other than the owner of the gravel quarry moved equipment into the area (without our prior knowledge) and started to excavate a highwall on approximately 30 August 1995 just to the northwest of our hillock where we had initially captured the male that we radiocollared. The excavation might have begun slightly before this, but 30 August was the day we noticed it and recorded it in our records. (A highwall excavation removes sand/gravel in such a manner as to leave a vertical wall.) The excavation did not destroy the tunnel system of the grasshopper mice within the hillock, but the machinery excavated up to a few meters from the northwestern end of the hillock. While all of this was going on, large gravel trucks and excavation equipment were being driven all over our trapping grid (i.e., Site 5), preventing further intensive trapping. To complicate matters even more, additional grasshopper mice were trapped in the area and the radiocollared female grasshopper mouse died. At the time, we thought that the dead female was the mate of the radiocollared male. The male started moving around

with another female grasshopper mouse after the death of the radiocollared female. All of our trapping and radiotelemetry results were indicating that their movements and behaviors were more complex than we had anticipated. It was difficult to tell if the movements of the radiocollared male were due to the excavation activities, the death of the female, and/or the fact that pair bonds might be changing. Therefore, after consultation with Rich J. Baker, our DNR Grant Coordinator, we decided not to completely excavate and destroy the known tunnel systems in the hillocks that the grasshopper mice were currently using. We decided we could learn more and gather baseline data on movements and space use by continuing the tracking of the lone radiocollared male grasshopper mouse without further excavation.

During the week of 13 October 1995, the entire area on Ames Gravel Quarry approximately 0.25 to 0.50 km south of our grasshopper mouse 10-by-10 trapping grid (i.e., Site 5) was completely excavated and flattened. With the exception of 1 hillock that was too close to the fence to be excavated (i.e., where Burrow #2 was located), all the hillocks containing burrows and used by the radiocollared male in this southern area were "smoothed off". The entire area where Burrows #4 and #5 used to be located were flattened and no longer exist (Fig. 5). A phone convervation with Daniel G. Ames revealed that these activities were part of the reclamation of the area (personal communication, 30 November 1995).

Habitat Data Collection Methods

During the 1994 field season, general habitat conditions were noted at each small mammal capture location and a general plant species list was compiled for the entire study site (Appendix C: Plant Species List). Scientific and common names were taken from Great Plains Flora Association (1986). During the 1995 field season, we compiled only a limited plant species list because we spent more time collecting quantitative habitat data on our study sites. We were especially interested in the habitat structure, and we collected data on parameters such as vegetation density, percent ground cover (i.e., grass, forbs, litter, bare), and litter type and density. Characteristics of the hillocks used by the northern grasshopper mice were also noted, e.g., approximate length, width, and height of the hillock, and plant species present (Appendix B: Field Forms).

Results:

Because the trapping effort and trapping methods varied considerably between our 1994 and 1995 field seasons, we are reporting our findings separately for each year when appropriate and combining data from the 2 years when appropriate.

During the 1994 field season, 8 study sites in Clay County were live-trapped (Table 1). Additional locations with suitable habitat were

unable to be trapped due to difficulties procuring permits and/or time limitations.

During the 1995 field season, we concentrated our efforts on 10 study "sites" (Table 5). Note that the study sites were different from 1994 to 1995, even though the site numbers were repeated. Also note that all of the "sites" during 1995 at Ames Gravel Quarry were not necessarily mutually exclusive. Sites 2, 3, and 4 were in very close proximity and several trap stations overlapped on the sites (Fig. 2). This was done intentionally because there were some animals near the study site edges that we wanted to further monitor; in several instances, these overlapping trapping stations were also in the vicinity of hillocks and we wanted to further increase our chances of detecting the grasshopper mice if they were present. Further overlap occurred between Site 5 and 7; Site 7 consisted of groups of trapped hillocks and Site 5 was a 10-by-10 trapping grid superimposed over 2 of the hillocks which were part of Site 7 on which 4 northern grasshopper mice had been captured. Site 8 included those hillocks where the radiocollared grasshopper mice had been known to use in an attempt to retrieve the remaining radiocollar at the end of the study. The "site" designation during 1995 for Sites 6, 7, 8, and 10 was mainly for the purpose of being able to separate and analyze the small mammal captures rather than to designate a particular 10-by-10 trapping "grid".

Target Species - 1994

Northern grasshopper mice were not captured on any of the 8 study sites. A combined total of 28 prairie voles, 11 males and 17 females, were captured on Site 3 (Bicentennial Prairie) and Site 8 (Ames Gravel Quarry) (Tables 8, 9). On Site 3, these captures included 1 adult male, 6 subadult males, 1 adult female, 14 subadult females, and 1 juvenile female, for a total of 7 males and 16 females (Table 10). On Site 8, these captures included 2 adult males, 2 subadult males, and 1 subadult female, for a total of 4 males and 1 female (Table 10).

Target Species - 1995

Both prairie voles and northern grasshopper mice were captured in 1995 (Table 11). A total of 25 individual prairie voles were trapped during our 1995 season, with captures at both Bicentennial Prairie (Site 9) and Ames Gravel Quarry (Sites 3, 4, 6) (Table 12). Sites 2, 3, and 4 were adjacent to each other and some prairie voles were captured on more than 1 site. Five northern grasshopper mice were trapped at Ames Gravel Quarry (Table 12), 3 adult males and 2 adult females. Take note that some of the northern grasshopper mice trapped during the hillock trapping (Site 7) were also trapped on Site 5 which was superimposed over the hillocks. It was interesting to note that although prairie vole subadults and 1 juvenile were captured, only adult and no young northern grasshopper mice were captured (Tables 13, 14).

Nontarget Species - 1994

Only 2 nontarget species were captured in quantity in 1994, i.e., deer mice (Peromyscus maniculatus) and meadow voles (Microtus pennsylvanicus). Over twice as many deer mice as meadow voles were captured (Tables 8, 15, 16). Both of these species were captured in close proximity to capture locations of prairie voles (i.e., on both Sites 3 and 8). More specifically, 4 deer mice (1 subadult male and 3 adult females) and 1 adult female meadow vole were captured on Site 3 (Tables 15 and 16, respectively); 29 deer mice (4 adult males, 12 subadult males, 8 adult females, and 5 subadult females) and 17 meadow voles (2 adult males, 2 subadult males, 6 adult females, and 7 subadult females) were captured on Site 8 (Tables 8, 15, 16). Additionally, 1 arctic shrew (Sorex arcticus) was captured on Site 8 (Table 8), but it died in the trap.

No small mammal captures occurred on Site 1 (Bluestem Prairie), Site 5 (Buffalo River State Park), or Site 6 (Buffalo River State Park) (Tables 1, 9).

Nontarget Species - 1995

Three species of shrews and 7 species of rodents were captured at Ames Gravel Quarry (Table 12), the highest small mammal diversity in 1 general location that we have found to date in our studies in Clay County. When data from all study sites were combined, deer mice were the most numerous, followed by meadow voles (Table 11, 12). Meadow jumping mice (Zapus hudsonius) were also captured at Ames Gravel Quarry during 1995, the first time since we began our small mammal studies in 1990.

Deer mice and meadow voles were not only the most numerous, they also were the most widely distributed. Deer mice were captured on 9 of the 10 sites in 1995, and meadow voles were captured on 8 of the sites (Tables 17, 18). Meadow jumping mice were not exceedingly dense, but they were widely scattered over many of the trapping sites at Ames Gravel Quarry (Table 19). It was interesting to note that the sex ratios were fairly balanced for deer mice and meadow voles, but they were greatly skewed in favor of females for meadow jumping mice (Tables 12, 17, 18, 19).

Shrews were not as numerous as rodents, but they occurred at a number of sites at Ames Gravel Quarry (Tables 20, 21, 22). Franklin's and thirteen-lined ground squirrels were both known to occur at Ames Gravel Quarry (Tables 23, 24). They were rather large to be captured in our small mammal live-traps, but several of them were caught by their foot in the door. Because they were usually highly agitated when they saw us approaching the trap, we usually just released them without further processing (i.e., sex, age, and reproductive condition were usually not recorded).

Interestingly, we even captured a horned toad (not identified to species) in one of our traps at Ames Gravel Quarry. At Bicentennial

Prairie, large numbers of millipedes entered our traps, presumably attracted by the peanut butter.

Spatial and Habitat Relationships Between Small Mammal Species - 1995

Spatial and habitat relationships were mainly analyzed from 1995 data because comparable data were not collected in 1994. Unless noted otherwise, the following information is from 1995. It was a relatively rare event for more than 1 species of small mammal to be captured at the same trap station on a study site. Usually only 1 species was captured at a particular station indicating that either different habitat preferences were separating the species or that behavioral interactions were causing the spatial separation. When captures were analyzed on those sites where a 10-by-10 trapping grid was utilized, i.e., on Sites 1-5 and Site 9, both meadow voles and prairie voles were trapped at the same trap station a total of 9 times (Site 9, n = 1; Site 4, n = 2; Site 3, Round 1, n = 6). Although we could have made some errors in field identification of these 2 vole species, we believe that we were fairly accurate overall and that some overlap in space/habitat use between the 2 species really existed.

On Site 5 during the regular grid trapping, no other species were captured at the trap stations where the northern grasshopper mice were captured. However, during the Retrieval Trapping (i.e., Site 8), some deer mice were captured very near the hole that the grasshopper mice had been using on Site 5. Deer mice were also captured during the Retrieval Trapping on a number of the hillocks which grasshopper mice were known to have used during the radiotelemetry sessions. When hillock trapping (Sites 6 and 7), Site 5 trapping, and Retrieval Trapping (Site 8) data were combined, we noted 2 instances of meadow voles, 2 instances of meadow jumping mice, and 1 instance of a thirteen-lined ground squirrel being captured on the same hillock where at least 1 grasshopper mouse had been captured.

In general, deer mice seemed to be caught in association with the widest variety of other species. The following associations of deer mice with other species were noted: meadow jumping mouse (Site 3, Round 1, n = 1), meadow voles (Site 3, Round 1, n = 2; Round 2, n = 3), thirteen-lined ground squirrel (Site 3, Round 1, n = 1), short-tailed shrew (Site 3, Round 2, n = 1), Franklin's ground squirrel (Site 4, n = 1). In addition to the above associations, meadow voles were also occasionally captured at the same trap station as meadow jumping mice (Site 2, n = 2; Site 3, Round 1, n = 1; Site 4, n = 2). One trap station had a recorded capture of a meadow vole, a prairie vole, and a deer mouse (Site 3, Round 1).

Some definite habitat associations were noted. Meadow voles were usually associated with ground covers dominated by grasses. Vegetation at both ground level and approximately 30-50 cm above the ground was quite dense, usually rated 4 or 5 on our 5-point scale with 5 being the

most dense (Appendix B: Field Forms). Some grass litter, and often a considerable amount of grass litter, was present.

Prairie vole habitat seemed to be quite similar to that of meadow voles, i.e., dense vegetation dominated by grasses with a relatively thick grass litter layer. We could not discern if prairie voles were choosing drier sites than meadow voles because most sites were fairly well-drained during the time we were trapping. We did note that both vole species seemed to occur in areas dominated by little bluestem. However, meadow voles seemed to also be found in grassy areas that were not dominated by little bluestem, whereas prairie voles did not seem to utilize these areas as readily. Prairie voles did not seem to use habitats dominated by brome, whereas meadow voles were readily found in these habitats. It was also noteworthy that almost no grass litter was present on Site 1 (1995: Bluestem Prairie) and neither vole species was captured on that site. We also noted a lack of runways on this site.

Ames Gravel Quarry offered a very interesting mosaic of habitats. A band of prairie/grassland, consisting mainly of grasses including little bluestem and a fairly thick grass litter cover, extended along a portion of the eastern edge of the quarry. Daniel G. Ames said that this grassland area was usually only cut for hay (personal communication, phone conversation on 30 November 1995). Although he was not sure if it was virgin prairie (i.e., never having been plowed), he did not think it had been plowed recently to any great extent. Along the western edge of this grassland band, the area was very disturbed from former and ongoing excavations. Site 3 (in 1995) was covered by a large portion of the prairie/grassland in the central and western areas of the site, but the southern and northern edges were dominated by thistles and sweet clover. Several hillocks were also on the site, mainly along the western edge. The great diversity in microhabitats probably contributed to the great species diversity in small mammals on this site (Table 12). Sites 2, 4, and 5 (in 1995) had relatively large portions of sandy, disturbed soil with weedy species (e.g., thistles and sweet clover) and corresponding lower numbers of voles.

Both radiotelemetry and trapping data indicated that northern grasshopper mice seemed to prefer the hillocks in which to make their tunnel systems. These hillocks were usually composed of very sandy soils with high to sparse vegetation density, depending on the plant species that comprised the ground cover. Weedy species, such as thistles, Russian thistle, and sweet clover, were often the dominant plant species. However, even if the vegetation density was relatively high in areas above the ground level, at ground level, the vegetation density was somewhat sparse, with spaces between individual plants. In the southern area of Ames Gravel Quarry where the radiocollared male spent much of his time (Fig. 5), grasses often covered at least a portion of the hillocks utilized, but the grasses were usually brome and seldom little bluestem. Apparently, grasshopper mice preferred a more open habitat, at least at the base of the plants, in which to maneuver.

The hillocks used by the northern grasshopper mice varied in dimensions, varying in length, width, and height (Table 25). The radiocollared male grasshopper mouse spent the daylight hours in

hillocks that were less than a meter high to those that were 2.4 m high (Table 25). The initial capture location of the radiocollared male was on a rather large, sandy hillock (Fig. 3).

Deer mice seemed to be associated with a fairly wide range of habitat parameters, but they were usually associated with areas of vegetation density and litter considerably less than that associated with the voles. Deer mice habitat seemed to be similar to that of northern grasshopper mice, but deer mice were not necessarily associated with the hillocks.

Meadow jumping mice were associated with areas of medium vegetation density. The ground cover was sometimes dominated by grasses and sometimes by forbs. Litter depth usually was not very great. Thistles were often present at the capture sites.

Activity Patterns Based on Trapping Records

Early in the summer of 1995 (i.e., June), on Sites 1, 2, 3 (Round 1 only), Site 4 (only the first day of trapping), and Site 10, we checked the traps in the early morning, then continued checking traps throughout the day at approximately 3-h intervals. We wanted to make sure we were not missing any species by only conducting the overnight trapping with an early-morning trap check. We also wanted to determine if we obtained appreciably more data by trapping around-the-clock. We found that all of the species were represented in the early-morning checks. During the daytime checks, we captured mainly voles (meadow and prairie) and occasionally a shrew. Northern grasshopper mice and meadow jumping mice were never captured during the daytime, and deer mice were seldom captured during the daytime. Because the daytime checks could result in higher trap mortality during the hotter summer months and because we had primarily recaptures during the daytime checks, we decided to conduct all of our later-summer trapping using only early-morning trap checks.

We want to point out that if one were mainly interested only in voles and their movements, etc., daytime checks might be very worthwhile. We found that the voles were active around-the-clock in both our 1994 and 1995 field seasons. If nights got too cold for overnight trapping, such as might happen in the fall or early spring, daytime trapping could be preferable to overnight trapping. In our 1994 field season, trapping at Bicentennial Prairie in September during the daytime was very successful at capturing both prairie and meadow voles. The September nights were too cold for overnight trapping.

Comparisons of Round 1 and Round 2 Trapping on Site 3

Overall, rodent capture numbers seemed to be lower during Round 2 trapping (August 1995) than Round 1 trapping (June 1995) on Site 3, with the exception of deer mice (Tables 13, 17, 18). It is especially interesting to note that 8 meadow jumping mice were captured in June, but none were captured in August. We were a bit surprised because we

thought numbers would be higher by the end of the summer after several months of the breeding season had elapsed. We were unsure of the cause. However, we did conduct only
early-morning checks during Round 2 and absolute number of captures would probably be down slightly due to the lower trapping effort. Weather factors might have played a role because it rained heavily during Round 2.

Radiotelemetry/Powdertracking/Excavations

The radiocollared male northern grasshopper mouse was tracked from 17 August 1995 (when it was collared) until 7 September 1995, the last day we could pick up a signal. We tried to relocate him by telemetry and retrapping the hillocks he was known to frequent (Retrieval Trapping = Site 8) until 12 October 1995, but we were unsuccessful. At the times we did recapture him during the grid trapping at Site 5 (i.e., on 25 and 26 August), he appeared to be in good health and the radiocollar did not seem to have any ill effects on him. He weighed 30 g with his collar, so apparently he had not lost any weight. The cause of his disappearance is not known. Possible reasons included: he moved away from the area and out of the range of our radiotelemetry receiver, he was predated upon, or he was still in the vicinity, but the battery (or another part of the collar) was not functioning properly. We believe that battery failure played some role because we noticed an erratic signal several days before 7 September 1995. In any case, he also was not retrapped during our extensive retrieval trapping effort (trapping occurred 5 different nights starting the evening of 27 September and ending the morning of 12 October).

Unfortunately, the radiotelemetry data on the collared female was not nearly as extensive as that for the male. She was tracked only for a portion of 1 day, i.e., 18 August 1995, after which we could not relocate her radiosignal. She was retrapped on 20 August 1995 at which time she no longer was carrying her radiocollar. Although she was alive in the trap, she died during processing (i.e., weighing, handling, etc.). We were unsure of the cause of death. Between 18-20 August, she had been radiocollared, powdertracked, and retrapped. The stress of so much human interference might have affected her adversely, but she did not exhibit any dramatic weight loss as might be expected with stress. She weighed 27 g when first captured and weighed 26.5 g at death.

Possibly the manner in which her radiocollar came off of her neck was responsible for her demise. Perhaps some predator had tried to capture her and succeeded only in taking off her collar and injuring her in the process. We saw no external injuries, however, so it was probably unlikely that interactions with a predator played a role. We think the radiocollar was probably attached too loosely and she simply slipped it over her head. Although we searched extensively for her lost radiocollar, it was never recovered. We do not know if the radiocollar was damaged in the process of being removed from her neck, if a predator carried it away, or if some other cause was to blame for our lack of

radiocollar retrieval.

Activity Period:

Radiotelemetry data indicated that the northern grasshopper mouse at our study sites was strictly nocturnal (Tables 26, 27, 28). The radiocollared male left his burrow before 2140 h, between 2010 and 2130 h, and at 2105 h on 4, 6, and 7 September 1995, respectively. These times corresponded to sunset. All-night tracking indicated that he re-entered 1 of his burrows between 0415 h and 0710 h on 4 September and at 0610 h on 5 September (Table 26), i.e., approximately at sunrise. Numerous radiotelemetry spotchecks during the daylight hours always indicated that he was inactive in 1 of his burrows (Table 27). These daytime checks (when he was in his burrow) extended from as early as 0700 h on 18 August to as late as 2130 h on 17 and 23 August (Table 27).

Home Range and Movements:

The radiocollared male had a very large homerange. He was originally trapped on Site 7 (Hillock Trapping) (which later became Site 5) on 17 August. On 18 August he was approximately 85 m northwest of his original capture location, and on 23 August he was relocated approximately 240 m nearly due south of his original capture location (Figs. 4, 5). On 25 and 26 August, he was again trapped on the 10-by-10 trapping grid on Site 5 (near his original capture site. Subsequently, he then moved south again, off of Site 5. On 29 August he was relocated in a burrow even further south than on 23 August. Between 26 August and 7 September (our last day of contact), he seemed to spend his time in the area approximately 0.25-0.50 km south of Site 5 (Fig. 5).

Evidence of Pair Bonds:

The radiocollared male (#2230) and radiocollared female (#3430) were believed to be a mated pair based on 4 lines of evidence. They were both trapped at the same trap station on Site 5, but 1 day apart; their fluorescent powder trails indicated they used the same trail for a while; they entered the same burrow; and the radiotelemetry positions on the night of 18 August indicated that they were hunting together. On 25 August, the male was recaptured on Site 5 near his original capture location.

We believed that a second male (#3450) and female (#0010), both of which were powdertracked, also shared a pair bond (at least for a while) based on the fact that they were caught in the same trap, 1 day apart. However, we never recaptured male #3450 again, so we were unsure of what happened to him.

With the death of the radiocollared female (#3430) on 20 August, it appeared that pair bonds were in the process of changing. They could possibly have been in a state of flux before, but we had no radiotelemetry data prior to 17 August to determine this. On 26 August, the radiocollared male (#2230) and female (#0010) were both trapped in close proximity to each other (1 transect over and 1 trap station further down the transect). When released, they both ran down the same hole. After this time, we only captured female #0010 1 more time on Site 5, so we do not know if she accompanied the radiocollared male in his movements south of Site 5 as described above.

To make things even more interesting, we also captured a new adult male northern grasshopper mouse on 28 September in the vicinity of where female #0010 had been captured on 26 August.

An alternative explanation for some of the associations described above could be that the animals were family members, possibly undispersed siblings. However, all 5 grasshopper mice captured appeared to be adults based on pelage, reproductive condition, and weight; therefore, we thought the sibling explanation was unlikely.

Response to Excavations and Management Implications:

The planned excavation portion of our study was somewhat disappointing. As explained earlier in the methods, it was nearly impossible to tell if the movements of the radiocollared male were due to the excavation in the area of the hillock where he was first captured, if they were due to the death of the female which we believed to be his mate, or if he normally moved as much as we recorded.

In any case, one thing we noted was that the grasshopper mice had burrow systems in a number of widely-spaced hillocks. In the event that excavations did occur to annihilate 1 system of burrows, the mice could move to another burrow system. The hillocks with burrows, however, would have to be widely enough spaced to escape the excavation activities. The mice would also have to avoid getting crushed during the excavation process because excavations would most likely take place during the day when the nocturnal mice were in their burrows. It would be unlikely that all excavations would involve the hillocks which often were old spoil piles that had been left behind by prior excavation activities. Many of the current excavation activities were in areas other than the spoil piles. Some of the hillocks seemed to be of topsoil, but they seemed to be in the minority.

All in all, excavation activities might not be totally devastating to northern grasshopper mice with a little prior planning by the excavators. If researchers knew which areas were to be excavated, they could quickly search the hillocks in the area for signs of the burrow systems and flag those that looked likely to be grasshopper mouse habitat. Depending on the magnitude and type of excavation, at least some of these hillocks could be avoided to provide refugia for the mice that are displaced and to give some mice the chance to escape the

excavation. Again, the cooperation of the landowner and excavator would be required.

Evaluation of Radiotelemetry as a Method for Studying Northern Grasshopper Mice:

We used radiotelemetry on an experimental basis during our 1995 field season to monitor the movements of northern grasshopper mice. To the best of our knowledge, we are the first researchers to use radiotelemetry methods to study this species. Although our sample size was small, n = 2, we think that radiotelemetry is probably one of the best methods of studying this species for several reasons. First of all, this species has such a large home range that it can easily move off of a trapping grid. Without radiotelemetry, one would never know to where the mouse had traveled. Also, even though we had recaptures, trapping requires that the mouse actually encounters the trap in its wide-ranging movements and then goes into it; this is not necessary with radiotelemetry. The researcher can go to the mouse and not have to wait for the mouse to re-appear.

Radiotelemetry is not without its drawbacks, however. Expense is a major factor because each radiocollar costs in the vicinity of $150, with $35 for the replacement of 1 battery. The receiver and antenna will run approximately $1000 for even a basic model. It is not always possible to retrieve the radiocollars at the end of the study (as we found out), so this financial loss probably should be built into the study budget. Also, northern grasshopper mice are strictly nocturnal, so researchers must be able to maneuver in the dark.

The model of radiocollar we used supposedly had a battery life of approximately 60 days, but we got an erratic signal from the male's radiocollar in less than a month. A signal from the female's radiocollar was not detected after the first day. We are unsure if the collar became nonfunctional after it was removed from the female or if it was carried off by a predator. In any case, it was nonfunctional from our standpoint in 1 day.

We found that it was very difficult to place the radiocollars on the mice, partly due to the style of the collar. The part of the radiocollar that actually goes around the neck of the animal is the antenna. The ends of the antenna are placed around the neck and then stuck through a tiny metal sleeve. The sleeve (approximately 5 mm in length and 1.5mm in width) is then crimped with a small pair of pliers in order to secure the ends of the antenna around the mouse's neck. The sleeve is so tiny that it is difficult to manipulate. The pliers have to be placed between the neck and the radiocollar to get a good crimp, and this makes it difficult to get the radiocollar tight enough. If it is not crimped tightly enough, the ends of the antenna pull out of the sleeve. To further complicate matters, the animal is squirming about. We decided not to anesthetize the animals because it is too easy to overdose and kill them. If we were to do this kind of study again, we

would try to get the company to come up with a better design for attaching the collar to the animal. Some sort of adjustable collar, providing it could be made to weigh no more than 2 g, would be preferable. We have talked to the radiocollar manufacturers, and weight is a major consideration. Supposedly it might be difficult to come up with an adjustable collar without adding extra weight.

Discussion:

Trapping success was much greater in 1995 than 1994 probably due to several reasons, the most obvious one being that more trapping effort was exerted in 1995 than 1994. Additional reasons, however, could include the fact that there was a lot of rainy, damp weather in 1994 during the times we were trapping. In 1995, we also conducted a considerable amount of trapping in June. Actually, we expected to capture only low numbers of animals at this time because rodent populations were just coming out of their winter population lows. We were surprised to capture so few specimens at the Buffalo River State Park in 1994 and at the Bluestem Prairie in 1995. We are unsure of the reason for low trapping success in Buffalo River State Park. However, at Bluestem Prairie in 1995, the reason seemed to be poor habitat conditions on the site we trapped, especially for voles. Litter cover was practically nonexistent and the area had a number of weedy species as opposed to grass cover. Brian Winter, Director of Science and Stewardship, Northern Tallgrass Prairie, for the Nature Conservancy (personal communication, phone conversation on 22 November 1995), mentioned that this site was essentially an old field habitat that had not yet received any restoration efforts. Some recolonization of prairie plants had occurred naturally since the cessation of farming a number of years ago, but he did not consider it a prime prairie habitat.

The number of small mammal captures during 1994 was relatively low in comparison to our former trapping seasons (Stockrahm 1991, Harper et al. 1994). In phone conversations during the summer of 1994, Frederick J. Jannett, Jr., Ph.D., Department of Biology at The Science Museum of Minnesota, reported that he had captured lower than usual numbers of both prairie voles and northern grasshopper mice, especially the latter, during the summer of 1994. He suggested that the low abundance of grasshoppers might be a major factor in low small mammal densities. Dr. Jannett has conducted ongoing small mammal snap-trap studies in several areas of Minnesota, including a strip from Kittson County to Lac Qui Parle County, with a study plot in Clay County. We noted some grasshoppers and crickets at most of our study sites, but the species diversity was limited. Another phone conversation with Dr. Jannett (personal communication on 22 November 1995) indicated that he had also captured lower-than-usual numbers of both prairie and meadow voles during the summer of 1995.

In our current studies as well as our past studies on northern grasshopper mice (Stockrahm 1991, Harper et al. 1994, Goertel et al. 1992, Canfield et al. 1994), the species has always been difficult to

locate. Even when populations had been located, they were difficult to trap on a consistent basis. In light of our new radiotelemetry findings, both of the above are probably due to their wide-ranging movements. They might leave an area for days, only to return sometime in the future. They are known to be associated with sandy soils (McCarty 1978), so in our past and present studies we have looked for them in areas with sandy soils. In Clay County, many areas with sandy soils have been converted into commercial sand/gravel quarries. Our past studies made us suspect that the hillocks were important components of the habitat of northern grasshopper mice, at least in Clay County. Our radiotelemetry studies during 1995 verified this. All of the burrow systems for the radiocollared male were located inside hillocks of varying sizes. Although the literature mentions that sandy soils are necessary for this species (McCarty 1978), a habitat component similar to a hillock does not seem to be documented.

Radiotracking during the nighttime hours indicated that the grasshopper mice seem to use the sandy, flat stretches between the hillocks as hunting grounds, but they do not spend the daytime hours in these flat areas. We are not sure why the hillocks seem to be so important to this species in Clay County. We do not know what makes these hillocks so attractive for burrow construction, but perhaps drainage is important in the spring when the snow melts. Perhaps burrows on the flat areas would be flooded during the melt. Another reason could be that hillock soil conditions make burrowing efforts easier. Because the soil has already been dug up by machinery and piled to the side, perhaps it is not so compact, thereby facilitating digging efforts. It is also possible that the vegetation on the hillocks is involved with this habitat preference, but it is difficult to pinpoint which parameters are involved. For example, maybe the disturbed nature of the hillocks insures that early-successional stage vegetation will be present. The weedy species that colonize these hillocks, e.g., thistles, Russian thistle, and sweet clover, are often widely spaced at their base (even it they are dense above ground level), facilitating movements of the grasshopper mice at ground level. Grasshopper mice also feed on grasshoppers, and perhaps these weedy conditions offer a good habitat for grasshoppers. Whatever the reason(s) for this preference for hillocks by the grasshopper mice, the association seems to be real. Because of this association, "reclamation" efforts to restore old quarry/excavation sites to a "more natural" contour could have an enormous effect on local populations of this species. Before any reclamation efforts are begun, we believe that it is important for researchers to examine any hillocks in the area for signs of grasshopper mice burrowing activities. Perhaps these active hillocks could be made exempt from the "reclamation" or other measures could be taken to lessen the impact on the species.

The northern grasshopper mice in our current and past studies seldom have exceeded 30 g. This seems a little light when compared to the averages given in the literature: 27-52 g (Whitaker 1980), 42.1 g (Hazard 1982), and 40 g (Jones et al. 1983). We believed that all 5 animals captured during our 1995 field season were adults based on

pelage, reproductive condition, and weight, but perhaps they were really only large subadults. If this was the case, then maybe the associations between the animals were that of undispersed siblings rather than mated pairs. In our studies since 1990, we have never captured a juvenile animal. However, they might not be trappable at a young age. In any case, the reproductive rate seems to be rather low.

The prairie voles in our study have been associated with little bluestem and other (usually non-brome) species. On our study sites, we did not notice obvious habitat separation between meadow voles and prairie voles. Habitat separation between these 2 species has been found to exist in a number of studies (DeCoursey 1957, Miller 1969, Zimmerman 1963). During 1995, occasionally both species were trapped at the same trap station, but on different days. Supposedly the prairie voles are associated with dryer prairies and meadow voles with more moist habitats, but those relationships did not always seem obvious on our study sites. The prairie voles were usually associated with relatively dry prairie/grassland (especially where little bluestem was present), but the meadow voles seemed to be able to use both kinds of habitats more readily than could prairie voles.

We were very pleased that we were able to experiment with radiotelemetry methods to study grasshopper mouse movements. Without radiotelemetry, we would only have a few isolated spots where we had trapped the animals, but we would have no idea where the animals traveled between their sequential captures. We would also have no idea how important the hillocks are to this species, at least in a gravel quarry habitat such as that found at Ames. Despite its drawbacks (see results section above), we think radiotelemetry has great potential for use in future studies. We would also like to experiment with this method on prairie voles, but the radiocollar would have to weigh even less than the collars we used in this study because prairie voles weigh less, on average, than northern grasshopper mice. Based on our trapping records only, it was impossible to tell if any of the prairie voles we captured were mated pairs. When more than 1 prairie vole was captured at a particular trap station in 1995, they were often subadult animals indicating they were siblings rather than mates. Pair bonds between mated prairie voles would probably have a better chance of detection if we used radiotelemetry techniques.

Using the fluorescent powdertracking technique indicated that some information about burrow locations and specific movement patterns could be gathered. However, this method had some drawbacks also. The powder trail was not discernible for long distances, and a few hours of heavy rain seemed to diminish the fluorescent properties of the powder.

We are not sure why we have never captured meadow jumping mice in Clay County until 1995. They seem to frequent areas that, at least superficially, resemble those used by northern grasshopper mice. However, we are not sure if hillocks are important to them or not. Trapping records indicate that hillocks probably are not as critical to them as they are to the northern grasshopper mice. We are also not sure why we captured quite a few meadow jumping mice in June on Site 3 and none during August. Weather conditions might have played a part, but

other unknown factors probably played a part as well.

With a definite shortage of native prairie remnants in Clay County, we think that it would be interesting as well as beneficial to the ecology of the area to investigate how land in the CRP (Conservation Reserve Program) could be enhanced or improved to provide quality habitat for species like the prairie vole. When information from all of our studies since 1990 was compiled (Stockrahm et al. 1995; Appendix D), we found that meadow voles can readily use grass habitats of brome, but prairie voles did not seem to thrive in these habitats. The future of CRP is unclear at this time, but if the program is continued, perhaps experiments could be done where the CRP land is seeded to species like little bluestem instead of other, nonnative species. Prairie vole pairs could then be introduced into these areas and monitored via radiotelemetry. Of course, the soils and drainage would have to be able to support this kind of vegetation.

Management Recommendations and Concluding Remarks:

Summary Statements:

** Prairie voles were associated with grassland habitats, especially those with some little bluestem and relatively dense grass litter cover.

** Northern grasshopper mice burrows were associated with sandy spoil piles and sandy topsoil piles (which we termed "hillocks") from previous excavations in sand/gravel quarries. Weedy vegetation was often present. Vegetation density at ground level was usually low. Nocturnal foraging seemed to occur in the sandy, flat areas between hillocks.

** Prairie voles and northern grasshopper mice seemed to have completely different habitat requirements. Although some of our past studies have captured both species on the same trapping grid, our current studies evaluating habitat use indicate that the 2 species would probably seldom come into contact with each other except perhaps in the areas where little bluestem prairie meets a gravel quarry (such as was the case at Ames Gravel Quarry). Even then, the grasshopper mice's home range and movements are so great, the grasshopper mice would probably only momentarily move through areas used by prairie voles. The grasshopper mice would be unlikely to stay in the heavily vegetated habitats required by the prairie vole for very long.

** Prairie voles seemed to be much more common than the northern grasshopper mice in the areas studied. However, they were not very common with respect to other species present, e.g., deer mice and meadow voles. They were sometimes locally abundant in areas with little bluestem as long as thick grass litter was also present.

Meadow voles were also sometimes found in the habitats used by prairie voles, but meadow voles also were found in other kinds of grassy habitats that were not necessarily dominated by little bluestem.

** Northern grasshopper mice have quite a large home range. Although they seem to eventually return to the same hillocks which contain their burrow systems, this return might take several days or weeks. They seem to have a series of hillocks which they use on a rotational basis. These movements often make it difficult to recapture the mice using live-traps on a grid system because the animals move off of the grid. Because of these wide-ranging movements, we think that using radiotelemetry to study northern grasshopper mice is more productive than using a grid trapping system.

** Meadow jumping mice were captured in June 1995, the first time since our small mammal studies began in Clay County in 1990. However, retrapping of 1 of the sites (i.e., Site 3) in August 1995 resulted in no captures. We are unsure of the cause, but the weather was quite rainy during the August trapping.

Management Recommendations:

** Due to its rarity in all areas studied, its specific habitat requirements (i.e., sandy hillocks), and its required large home range, we think the northern grasshopper mouse should be assessed further as a possible candidate for Minnesota's List of "Special Concern Species".

** Before old quarry sites, especially "hillocks" are reclaimed, they should be checked for the presence of northern grasshopper mice to ensure an ecologically-sound decision.

** Before burning, prairies should be assessed for small mammal community structure because prairie voles seem to require grass litter while other species do not. Indiscriminant burning could have great impact on local small mammal community structure. Burning a series of small units would probably be less detrimental to prairie voles than burning 1 large unit. The unburned habitats with their grass litter could possibly serve as refugia for the prairie voles until the new vegetation grew on the burned sites.

** Small mammal studies on CRP (Conservation Reserve Program) land need to be conducted to evaluate its value as suitable habitat for such species as the prairie vole (providing the CRP program continues in the future and that some land stays in CRP after 1995).

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Table 1: List of locations trapped during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota.

STUDY SITE NUMBER	STUDY SITE	T	R	S
1	Bluestem Prairie	139N	46W	S1/2 of NW1/4 of S15
2	Felton Prairie Shrike Unit	142N	45W	SW1/4 of S30
3	Bicentennial Prairie	141N	45W	NW1/4 of SW1/4 of S5
4	Buffalo River State Park	139N	46W	N1/2 of SW1/4 of S11
5	Buffalo River State Park	139N	46W	S1/2 of NW1/4 of S14
6	Buffalo River State Park	139N	46W	NE1/4 of NW1/4 of S14
7	Buffalo River State Park and Bluestem Prairie	139N	46W	NE1/4 of S15
8	Ames Gravel Quarry	141N	46W	N1/2 of NE1/4 of S36

Table 2: Schedules of prebaiting, setting, and checking traps for the preliminary trapping sessions of the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota.

	ACTIVITY				
TIME	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Sunrise	---	---	---	Check	Check
Sunset	Prebait	Prebait	Set	Set	Close down[a]

[a] At this time, traps were locked open and left in place for further trapping, or they were removed from the site.

Table 3: Schedules of prebaiting, setting, and checking traps for the intensive trapping sessions on Sites 3 and 8 of the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota.

	ACTIVITY						
TIME	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Sunrise	---	---	---	Check	Check	Check	Check[a]
Sunset	Prebait	Prebait	Set	Set	Set	Set	Close down[b]

[a] Intensive trapping on Grid D at Site 8 was conducted only for 3 consecutive nights.

[b] At this time, traps were locked open and left in place for further trapping, or they were removed from the site.

Table 4: Dates of prebaiting, preliminary trapping, and intensive trapping for the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. All traps were prebaited in the evenings. The dates for the preliminary and intensive trapping refer to the dates when the traps were actually checked; traps were set open the evening before each of these dates. Preliminary and intensive traps were checked in the morning, except 17 and 18 September at Site 3 which was checked during the daytime hours. Preliminary trapping was a transect of 25 traps, 1 set every 10 m. If a target species was captured on a site during preliminary trapping, a 7-by-7 grid was set up for intensive trapping.

STUDY SITE NUMBER	DATE		
	PREBAITING	PRELIMINARY TRAPPING	INTENSIVE TRAPPING
1	5, 6 July	8, 9 July	
2	9, 10 July	12, 13 July	
3	11, 12 July	14, 17 July	
	15 September		17, 18 September
4	17, 18 July	20, 21 July	
5	23, 24 July	26, 27, 31 July	
6	21, 22 July	24, 25, 31 July	
7	2, 3 August[a]	6, 7 August	
8 Grid C	4, 6 August[a]		8, 9, 13, 14 August
8 Grid D	17, 18 August		20,21, 24 August

[a] 2 grids, C and D, were trapped at Site 8.

Table 5: List of locations trapped during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. Trapping at Bicentennial Prairie occurred in both 1994 (Site 3) and 1995 (Site 9) with the trapping grid in approximately the same area. However, in 1995, the trapping effort was much greater and the trapping grid comprised of 10-by-10 traps compared to 7-by-7 traps (with 10 m between transects and 10 m between traps along a transect) in 1994. During 1995, many areas of Ames Gravel Quarry were trapped, covering representative areas from nearly the entire section.

STUDY SITE NUMBER	STUDY SITE	T	R	S
1[a]	Bluestem Prairie	139N	46W	W 1/2 of S23
2	Ames Gravel Quarry	141N	46W	36
3	Ames Gravel Quarry	141N	46W	36
4	Ames Gravel Quarry	141N	46W	36
5	Ames Gravel Quarry	141N	46W	36
6[b]	Ames Gravel Quarry (Hillocks - Round 1)	141N	46W	36
7[b]	Ames Gravel Quarry (Hillocks - Round 2)	141N	46W	36
8[c]	Ames Gravel Quarry (Radiotelemetry Collar Retrieval Trapping)	141N	46W	36
9	Bicentennial Prairie	141N	45W	NW 1/4 of SW 1/4 of S5
10[d]	Ames Gravel Quarry (Random Trapping)	141N	46W	36

[a] Sites 1 through 5 and Site 9 were all trapped with a 10-by-10 trapping grid with 10 m between transects and 10 m between traps along a transect.

b

Sites 6 and 7 each consisted of a group of hillocks at Ames Gravel Quarry. Hillocks comprising Site 6 were trapped simultaneously and hillocks comprising Site 7 were trapped simultaneously in an attempt to locate northern grasshopper mice. Traps were placed on individual hillocks in a manner to cover most of the area of the hillock, but especially around holes which where approximately 3-4 cm in diameter and resembled those used by northern grasshopper mice. Site 6 ("Round 1") consisted of 11 hillocks where some hillocks had 10 traps/hillock and some hillocks had 20 traps/hillock for a total of 180 traps; on those hillocks with 20 traps, there were 2 traps per hole or per station. Site 7 ("Round 2") consisted of 12 hillocks where some hillocks had 10 traps/hillock and some hillocks had 20 traps/hillock; on those hillocks with 20 traps, there were 2 traps per hole or per station for a total of 200 traps.

c

Trapping at "Site 8" consisted of placing small groups of traps in the areas where the radiocollared mice had been known to frequent, especially on the hillocks where they had been known to use the burrows on a consistent basis. Trapping was done in an (unsuccessful) attempt to retrieve the radiocollar on the remaining radiocollared male.

d

"Random Trapping" refers to the placing of traps on 1 particular set of hillocks that initially looked promising as northern grasshopper mouse habitat.

Table 6: Schedule of prebaiting, setting, and checking traps for the intensive trapping sessions of the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota.

	ACTIVITY					
TIME	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6
Sunrise	---	---	Check[b]	Check[b]	Check[b]	Check[b]
Sunset	Prebait[a]	Set	Set	Set	Set	Close down[c]

a
Traps were prebaited in the evening after the trapping grid was set up.

b
Early in the summer, traps on Sites 1, 2, 3 (Round 1 only), Site 4 (only the first day of trapping), and Site 10 were checked every 3 hours between sunrise and sunset. When this intensive trapping yielded only minimal additional information, traps on the other sites were checked only at sunrise, closed during the day, and reset that evening.

c
At this time, traps were locked open and left in place for further trapping, or they were removed from the site.

Table 7: Schedule of dates for trap checks in the intensive trapping sessions of the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The first date listed below for each site refers to the morning of the first trap check. The traps were baited and set open the evening before this date. Prebaiting occurred for approximately a 24-hr period before the traps were set open. Site 3 was trapped twice during the summer, i.e., Round 1 and Round 2.

STUDY SITE NUMBER	DATES TRAPPED
1	7-11 June[a]
2	7-11 June
3	15-18 June (Round 1); 23-26 August (Round 2)
4	23-26 June
5	23-26 August
6	12-15 August
7	17-20 August
8	28-29 September and 1, 7, 12 October
9	31 August and 1-3 September
10	15-18 June 1995

[a] Trapping on Sites 1 and 2 began on 7 June, but severe rainstorms caused us to close the traps for approximately 24 h. When we re-set the traps open on 8 June, we decided to run the trap checks a few extra times. Therefore, Sites 1 and 2 had slightly more trapping effort than most of the other sites.

Table 8: Age and sex structure of all species captured at all sites during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The numbers below are the combined data from the preliminary and intensive trapping sessions.

ORDER SPECIES	MALE	FEMALE	TOTAL
INSECTIVORA			
ARCTIC SHREW	-	-	1[a]
RODENTIA			
DEER MICE			
Adult	8	14	22
Subadult	15	7	22
Total	23	21	44
MEADOW VOLES			
Adult	2	8	10
Subadult	2	7	9
Total	4	15	19
PRAIRIE VOLES			
Adult	3	1	4
Subadult	8	15	23
Juvenile	-	1	1
Total	11	17	28

[a] Sex could not be determined.

Table 9: Summary of all species live-trapped during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. At study numbers 1, 5, and 6, no animals were captured. The numbers below are the combined data from the preliminary and intensive trapping sessions. M = male, F = female.

ORDER	STUDY SITE NUMBER					
	2	3	4	7	8	TOTAL
	M/F	M/F	M/F	M/F	M/F	M/F
INSECTIVORA						
ARCTIC SHREW	-	-	-	-	1[a]	1[a]
RODENTIA						
DEER MICE	2/0	1/3	4/5	-	16/13[b]	23/21
MEADOW VOLES	-	0/1	-	0/1	4/13	4/15
PRAIRIE VOLES	-	7/16	-	-	4/1	11/17

[a] Sex could not be determined.

[b] 1 adult female might have been a recaptured animal, but we were unsure because the toe-clip might have been read incorrectly. It is included in the total.

Table 10: Age and sex structure of prairie voles (Microtus ochrogaster) captured at all sites during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The numbers below are the combined data from the preliminary and intensive trapping sessions. On Site 8, data are combined for Grids C and D. A = adult, SA = subadult, J = juvenile, M = male, F = female.

STUDY	MALE	FEMALE	TOTAL		
NUMBER	A/SA/J	A/SA/J	A/SA/J	M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3	1/6/0	1/14/1	2/20/1	7/16	23
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	2/2/0	0/1/0	2/3/0	4/1	5
TOTAL	3/8/0	1/15/1	4/23/1	11/17	28

Table 11: Age and sex structure of all species captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. Site 3 was trapped twice in 1995 (June and August); the data were combined in this table from the 2 trapping rounds, but each animal was counted only once even if it was captured during both rounds. In some instances, the same animals moved between several sites and were captured on more than 1 site. In this table, each animal is counted only once, i.e., it is recorded on the site on which it was first captured.

ORDER SPECIES	MALE	FEMALE	TOTAL
INSECTIVORA			
ARCTIC SHREWS			
Adult	-	3	3
Subadult	-	-	-
Total	-	3	3 a
MASKED SHREWS			
Adult	-	2	2
Subadult	-	-	-
Total	-	2	3 b
SHORT-TAILED SHREWS			
Adult	1	6	7
Subadult	-	1	1
Total	1	7	9 c
RODENTIA			
DEER MICE			
Adult	43 d	52	95
Subadult	32 e	19	51 e
Total	75 f, e	71	148 g, e
FRANKLIN'S GROUND SQUIRREL			
Adult	-	-	-
Subadult	-	-	-
Total	-	-	3 h
MEADOW JUMPING MICE			
Adult	5 j	18 i	23
Subadult	2	2	4
Total	7	20	27

ORDER SPECIES	MALE	FEMALE	TOTAL
MEADOW VOLES			
Adult	30 f	35 k	65
Subadult	22 l	16 m	38
Total	52	51	103
NORTHERN GRASSHOPPER MICE			
Adult	3	2	5
Subadult	-	-	-
Total	3	2	5
PRAIRIE VOLES			
Adult	3	6	9
Subadult	8	8	16
Total	11	14	25
THIRTEEN-LINED GROUND SQUIRRELS			
Adult	2	1	3
Subadult	-	-	-
Total	2	1	4 n

a
1 animal died in the trap.

b
1 animal died in the trap. It is still awaiting processing so sex and age is unknown at this time. It is included in the total only.

c
1 animal escaped before it was sexed and is included only in the total. Also, 3 animals were identified only as shrews in the field; however, based on their weights and measurements, they were probably short-tailed shrews.

d
2 animals were possibly subadults.

e
1 subadult male was tentatively identified in the field as a western harvest mouse (Reithrodontomys megalotis) based on its tail which was not as strictly bicolored as most of the deer mice in the area. However, its teeth were not examined in the field, and this animal probably was really a deer mouse and not a western harvest mouse. This animal is included in the numbers above as a deer

mouse.

f

1 male was later identified as a female. It is included in the totals as a male.

g

2 animals had serious botfly infestations in the genital area and could not be sexed. They are included only in the total.

h

2 animals were caught only by the front foot in the trap door; they were released without processing due to their agitated state. The other was seen running on the trapping grid, but it was not captured.

i

1 animal was later aged as a subadult female, another as a subadult male.

j

1 adult male was found dead in trap and a light brown animal (approximately 12 cm long) was seen fleeing from the scene. It is included in the above numbers.

k

1 animal was later aged as a subadult. On Site 3, 1 of these adult females was later recaptured on Site 4 and field identified as an adult female prairie vole. We have counted it as an adult female meadow vole in all of our tables.

l

2 animals were later aged as adults.

m

1 animal was later aged as an adult.

n

1 animal was caught only by the back foot in the trap door; it was released without processing due to its agitated state. It is included only in the total.

Table 12: Summary of all species live-trapped during the 1995 northern

grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. At Study Site 1, no animals were captured. Site 3 was trapped twice in 1995 (June and August); the data were combined in this table from the 2 trapping rounds, but each animal was counted only once even if it was captured during both rounds. In some instances, the same animals moved between several sites and were captured on more than 1 site. In this table, each animal is counted only once, i.e., it is recorded on the site on which it was first captured. Site 1 = Bluestem Prairie; Sites 2 through 8 and Site 10 = Ames Gravel Quarry; Site 9 = Bicentennial Prairie. M = male, F = female, TOT = total.

ORDER / SPECIES	STUDY SITE NUMBER 2 M/F	3 M/F	4 M/F	5 M/F	6 M/F	7 M/F	8 M/F	9 M/F	10 M/F	TOT M/F
INSECTIVORA										
ARCTIC SHREW	-	0/1	-	0/1	0/1	-	-	-	-	0/3
MASKED SHREW	-	0/1	0/1	-	-	1/0	-	-	-	[a] 1/2
SHORT-TAILED SHREW	-	0/2	-	-	1/4	0/2	-	-	-	[b] 1/8
RODENTIA										
DEER MICE	[c, d] 2/3	10/8	[g] 3/1	[g] 4/4	[g] 16/26	[g] 22/18	8/5	9/5	1/1	77/71
FRANKLIN'S GROUND SQUIRREL	-	1/0	1/0	-	1/0	-	-	-	-	[h] 3/0
MEADOW JUMPING MICE	[g] 3/4	[g] 1/5	0/1	1/1	0/5	2/4	-	-	-	7/20
MEADOW VOLES	[e,f] 11/7	20/26	[g] 3/2	[g] 1/2	7/2	[g] 8/9	-	1/3	1/0	52/51
NORTHERN GRASSHOPPER MICE	-	-	-	[g] -	-	2/2	[g] 1/0	-	-	3/2

ORDER SPECIES	STUDY SITE NUMBER									
	2 M/F	3 M/F	4 M/F	5 M/F	6 M/F	7 M/F	8 M/F	9 M/F	10 M/F	TOT M/F
PRAIRIE VOLES	-	4/8[g]	2/1[g]	-	0/2	-	-	5/3	-	11/14
THIRTEEN LINED GROUND SQUIRRELS	-	-	1/1	-	-	1/0[i]	1/0	-	-	- 3/1[i]

a
On Site 7, unsure of the sex of the animal. It is counted as a male in this table.

b
On Site 3 (Round 2), unsure of sex of 1 animal because it escaped. It is included as a female.

c
On Site 5, 2 additional deer mice were captured, but sex could not be determined due to botfly infestation. These 2 animals are included as males only in the "TOT" column.

d
On Site 7, 1 subadult male was tentatively identified in the field as a western harvest mouse (Reithrodontomys megalotis) based on its tail which was not as strictly bicolored as most of the deer mice in the area. However, its teeth were not examined in the field, and this animal probably was really a deer mouse and not a western harvest mouse. This animal is included in the numbers above as a deer mouse.

e
On Site 7, 1 additional meadow vole was capture, but sex could not be determined. This animal is included in the numbers above as a male.

f
On Site 3, 1 of these adult females was later recaptured on Site 4 and field identified as an adult female prairie vole. We have counted it as an adult female meadow vole in all of our tables.

g

At least 1 additional animal was recaptured on this site that had formerly been captured at another site. See individual species tables for details.

h

2 animals were caught only by the front foot in the trap door; they were released without processing due to their agitated state. The other was seen running on the trapping grid, but it was not captured. All 3 animals are included under the male total, but we are unsure of sex.

i

1 animal was caught by the back foot in the trap; it was released without processing because it was agitated. This animal is included under the male total, but we were unsure of sex.

Table 13: Age and sex structure of prairie voles (Microtus ochrogaster) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995),
Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3	(Rd 1) 2/0/0	3/3/0	5/3/0	2/6	8
3	(Rd 2) 0/2/0	2/1/0 a	2/3/0	2/3	5
4	1/1/0	0/1/0	1/2/0	2/1	3
5	-	-	-	-	-
6	-	2/0/0	2/0/0	0/2	2
7	-	-	-	-	-
8	-	-	-	-	-
9	0/5/0	0/2/1	0/7/1	5/3	8
10	-	-	-	-	-
TOTAL					25 b

a
1 of these adult females was originally captured on Site 3.

b
Only 25 different animals were actually captured; 1 animal was recaptured on another site.

Table 14: Age and sex structure of northern grasshopper mice (Onychomys

leucogaster) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female.

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	-	-	-	-	-
5	1/0/0	1/0/0	2/0/0	1/1	2 a
6	-	-	-	-	-
7	2/0/0	2/0/0 b	4/0/0	2/2	4
8	1/0/0	1/0/0 c	2/0/0	1/1	2
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					5 d

a Both animals were originally captured on Site 7.

b 1 adult female was radiocollared and powdertracked; she died before the end of the study. She is included in the numbers above.

c This adult female was originally captured on Site 7.

d Only 5 different animals were actually captured; 3 animals were recaptured on other sites.

Table 15: Age and sex structure of deer mice (Peromyscus maniculatus) captured at all sites during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The numbers below are the combined data from the preliminary and intensive trapping sessions. On Site 8, data are combined for Grids C and D. A = adult, SA = subadult, J = juvenile, M = male, F = female.

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	1/1/0	-	1/1/0	2/0	2
3	0/1/0	3/0/0 a	3/1/0	1/3	4
4	1/3/0	3/2/0	4/5/0	4/5	9
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	4/12/0	8/5/0	12/17/0	16/13	29
TOTAL	6/17/0	14/7/0	20/24/0	23/21	44

a 1 adult female might have been a recaptured animal, but we were unsure because the toe-clip might have been read incorrectly. It is included in the numbers above.

Table 16: Age and sex structure of meadow voles (Microtus pennsylvanicus) captured at all sites during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The numbers below are the combined data from the preliminary and intensive trapping sessions. On Site 8, data are combined for Grids C and D. A = adult, SA = subadult, J = juvenile, M = male, F = female.

STUDY	MALE	FEMALE	TOTAL		
NUMBER	A/SA/J	A/SA/J	A/SA/J	M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3	-	1/0/0	1/0/0	0/1	1
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	1/0/0	1/0/0	0/1	1
8	2/2/0	6/7/0	8/9/0	4/13	17
TOTAL	2/2/0	8/7/0	10/9/0	4/15	19

Table 17: Age and sex structure of deer mice (Peromyscus maniculatus)

captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	TOTAL ALL
1	-	-	-	-	-
2	1/1/0	1/2/0	2/3/0	2/3	5
3 (Rd 1)	3/1/0	3/0/0	6/1/0	4/3	7
3 (Rd 2)	5/3/0 a	3/3/0	8/6/0	8/6	14
4	3/2/0 b	4/0/0 c	7/2/0	5/4	9
5	4/3/0 d	4/4/0 e	8/7/0	7/8	17 f
6	12/5/0 g	24/4/0 h	36/9/0	17/28	45
7	9/13/0	13/5/0	22/18/0	22/18	40 i
8	6/2/0	4/1/0	10/3/0	8/5	13
9	6/2/1	4/0/1	10/2/2	9/5	14
10	1/0/0 j	1/0/0 k	2/0/0	1/1	2
TOTAL					148 l

a
1 of these adult males was originally captured on Site 6;
1 of these subadult males was originally captured on Site 7.

b 1 of these adult males was originally captured on Site 3;
1 of these adult males was originally captured on Site 2.

c
3 of these adult females were originally captured on Site 3.

d
2 of these adult males were originally captured on Site 7;
1 of these adult males was originally captured on Site 2.

e
3 of these adult females and 1 of these subadult females were originally captured on Site 7.

f
2 animals had serious botfly infestations in the genital area and could not be sexed. They are included in the "ALL" column and in the final total.

g 1 of these adult males was originally captured on Site 4.

h 1 of these adult females was originally captured on Site 3 and later recaptured on Site 4.

i On Site 7, 1 subadult male was tentatively identified in the field as a western harvest mouse (Reithrodontomys megalotis) based on its tail which was not as strictly bicolored as most of the deer mice in the area. However, its teeth were not examined in the field, and this animal probably was really a deer mouse and not a western harvest mouse. This animal is included in the numbers above as a deer mouse.

j 1 of these adult males was originally captured on Site 2.

k 1 of these adult females died during the study.

l Only 148 different animals were actually captured; the other 18 captures refer to recaptures on other sites. (Note that 1 animal was captured on 3 sites).

Table 18: Age and sex structure of meadow voles (Microtus pennsylvanicus) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	6/5/0	4/3/0	10/8/0	11/7	18
3	(Rd 1) 13/7/0a	11/10/0 b,c	24/17/0	20/21	41
3	(Rd 2) 3/2/0	7/3/0 d	10/5/0	5/10	15
4	2/2/0 e	2/3/0 f	4/5/0	4/5	9
5	0/1/0	2/0/0	2/1/0	1/2	3
6	5/2/0	3/0/0 g	8/2/0	7/3	10
7	7/2/0 h	9/0/0	16/2/0	9/9	18
8	-	-	-	-	-
9	0/0/1	3/0/0	3/0/1	1/3	4
10	1/0/0	-	1/0/0	1/0	1
TOTAL					103 i

a 5 of these adult males were originally captured on Site 2 (1 of which died).

b 2 of these adult females and 2 of these subadult females were originally captured on Site 2.

c 1 of these adult females was later recaptured on Site 4 and field identified as an adult female prairie vole. We have counted it as an adult female meadow vole in all of our tables.

d 1 of these adult females was originally captured on Site 2.

e 1 of these adult males was originally captured on Site 3.

f 2 of these adult females and 1 of these subadult females were originally captured on Site 3.

g 1 of these adult females was originally captured on Site 3.

h 1 of these adult males was originally captured on Site 6.

i Only 103 different animals were actually captured; 16 animals were recaptured on other sites.

Table 19: Age and sex structure of meadow jumping mice (Zapus hudsonius) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	TOTAL ALL
1	-	-	-	-	-
2	1/2/0	2/2/0	3/4/0	3/4	7
3 (Rd 1)	1/0/0 a	7/0/0 b	8/0/0	1/7	8
3 (Rd 2)	-	-	-	-	-
4	-	2/0/0 c	2/0/0	0/2	2
5	1/0/0	1/0/0	2/0/0	1/1	2
6	-	5/0/0	5/0/0	0/5	5
7	2/0/0	4/0/0	6/0/0	2/4	6
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					27 d

a This adult male died.

b 2 of these adult females were originally captured on Site 2.

c 1 of these adult females was originally captured on Site 3.

d Only 27 different animals were actually captured; 3 animals were recaptured on other sites.

Table 20: Age and sex structure of short-tailed shrews (Blarina brevicauda) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	TOTAL ALL
1	-	-	-	-	-
2	-	-	-	-	-
3 (Rd 1)	-	-	-	-	-
3 (Rd 2)	-	1/0/0	1/0/0	0/1	2 a
4	-	-	-	-	-
5	-	-	-	-	-
6	1/0/0	4/0/0	5/0/0	1/4	5
7	-	1/1/0	1/1/0	0/2	2
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					9

a 1 animal escaped before it could be sexed or aged; it is counted only in the "ALL" column and in the final total.

Table 21: Age and sex structure of arctic shrews (Sorex arcticus) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	TOTAL ALL
1	-	-	-	-	-
2	-	-	-	-	-
3 (Rd 1)	-	1/0/0	1/0/0	0/1	1
3 (Rd 2)	-	-	-	-	-
4	-	-	-	-	-
5	-	1/0/0	1/0/0	0/1	1
6	-	1/0/0	1/0/0	0/1	1 a
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					3

a This animal died in the trap.

Table 22: Age and sex structure of masked shrews (Sorex cinereus)

captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3 (Rd 1)	-	1/0/0	1/0/0	0/1	1
3 (Rd 2)	-	-	-	-	-
4	-	1/0/0	1/0/0	0/1	1
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	1 a
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					3

a This animal was found dead in the trap. It is still awaiting processing and is not yet sexed or aged.

Table 23: Age and sex structure of thirteen-lined ground squirrels (Spermophilus tridecemlineatus) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3 (Rd 1)	1/0/0	1/0/0	2/0/0	1/1	2
3 (Rd 2)	-	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	1 a
7	1/0/0	-	1/0/0	1/0	1
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL					4

a 1 animal was caught by the back foot in trap; it was released without processing because it was agitated. This animal is included under the "All" column and the final total.

Table 24: Age and sex structure of Franklin's ground squirrels (S. franklinii) captured at all sites during the 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. A = adult, SA = subadult, J = juvenile, M = male, F = female, Rd 1 = results from Round 1 trapping (June 1995), Rd 2 = results from Round 2 trapping (August 1995).

STUDY SITE NUMBER	MALE A/SA/J	FEMALE A/SA/J	TOTAL A/SA/J	TOTAL M/F	ALL
1	-	-	-	-	-
2	-	-	-	-	-
3 (Rd 1)	-	-	-	-	1 a
3 (Rd 2)	-	-	-	-	-
4	-	-	-	-	1 a
5	-	-	-	-	-
6	-	-	-	-	1 a
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-
TOTAL	-	-	-	-	3 a

a 2 animals were caught only by the front foot in the trap door; they were released without processing due to their agitated state. The other was seen running on the trapping grid, but it was not captured. All 3 animals are included only in the "ALL" column and the final total because we were unsure of sex or age.

Table 25: Chi-square analysis of sex ratios for the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. The degrees of freedom = 1. P = probability, DM = deer mice, MV = meadow voles, PV = prairie voles. At study numbers 1, 5, and 6, no animals were captured.

SPECIES	STUDY NUMBER	MALE	FEMALE	CHI-SQUARE VALUEVALUE	P
DM	2	2	0	2.000	<0.50
DM	3	1	2	0.333	<0.90
DM	4	4	5	0.111	<0.90
DM	8	16	12	0.571	<0.50
MV	3	0	1	2.000	<0.50
MV	7	0	1	2.000	<0.50
MV	8	4	13	4.765	<0.05
PV	3	7	16	3.520	<0.10
PV	8	4	1	1.800	<0.50

Table 26: Recapture data for each study site from the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. C/A is the number of captures per total number of animals of a species captured. C/R is the number of captures per total number of animals of a species that were recaptured. DM = deer mice, MV = meadow voles, PV = prairie voles.

STUDY	DM				MV		PV	
	NUMBER	C/A	C/R		C/R	C/A	C/R	C/A
1	0	0	0	0	0	0		
2	2/2	0	0	0	0	0		
3	3/3	0	1/1	0	0	0		
4	10/9	2/1	0	0	0	0		
5	0	0	0	0	0	0		
6	0	0	0	0	0	0		
7	0	0	1/1	0	0	0		
8	53/28	38/16	19/17	4/2	9/5	7/3		

Table 27: Weight mean (X), sample size (n), standard deviation (S.D.), and standard error of the mean (S.E.M.) of all species trapped during the 1994 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. DM = deer mice, MV = meadow voles, PV = prairie voles, A = adult, SA = sub-adult, J = juvenile, M = male, F = female. At study numbers 1, 5, and 6 no animals were captured.

SPECIES	STUDY NUMBER	SEX	AGE	WEIGHT			
				X	n	S.D.	S.E.M.
DM	2	M	A	18.0	2	1.414	1.000
	3	M	SA	15.5	1	0	0
	3	F	A	21.8	3	3.329	1.922
	4	M	A	21.0	1	0	0
	4	M	SA	14.0	3	2.000	1.545
	4	F	A	20.5	3	2.838	1.639
	4	F	SA	9.5	2	0	0
	8	M	A	17.5	4	3.109	1.555
	8	M	SA	13.9	11	2.979	0.898
	8	F	A	23.8	7	5.438	2.055
	8	F	SA	12.8	5	3.233	1.446
MV	3	F	A	24.0	1	0	0
	7	F	A	30.0	1	0	0
	8	M	A	34.8	2	3.182	2.250
	8	M	SA	19.3	2	1.768	1.250
	8	F	A	26.5	6	7.328	2.990
	8	F	SA	15.3	7	4.122	1.558
PV	3	M	A	12.5	1	0	0
	3	M	SA	11.9	6	1.609	0.657
	3	F	A	25.0	1	0	0
	3	F	SA	12.3	14	1.440	0.385
	3	F	J	7.5	1	0	0
	8	M	A	18.5	2	1.414	1.000
	8	M	SA	10.8	2	1.768	1.250
	8	F	A	15.0	1	0	0

Appendix C: Plant species list for sites studied during the 1994 and 1995 northern grasshopper mouse/prairie vole study conducted in Clay County, Minnesota. This list is not comprehensive, especially during the 1995 field season when habitat structure was studied more than plant species composition. Common and scientific names were taken from Great Plains Flora Association (1986). Numbers refer to the study site number in which that species was noted for each field season. Study sites varied from year-to-year even though they have same number. They do not refer to the same site. Tables 1 and 5 give the location of each site.

FAMILY	SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER	
			1994	1995
ASCLEPIADACEAE				
	Asclepias sp. L.	milkweed	6	
	Asclepias speciosa Torr.	showy milkweed	1,2,3,4	
ASTERACEAE				
	Achillea millefolium L.	yarrow	4	
	Ambrosia sp. L.	ragweed		3,4,5
	Artemisia sp. L.	wormwood	2,3,4	5,6,7, 8,9
	Artemisia frigida Willd.	sage	3,4,5 6,7,8	2,3,5,9
	Artemisia ludoviciana Nutt.	white sage	3,4,5, 6,7	
	Aster spp. L.	wild aster	3,4,5, 6,7,8	2,3
	Cirsium spp. P. Mill.	true thistle	1,2,5	2,3,4,5 6,7,8, 10
	Cirsium arvense (L.) Scop.	Canada thistle	3,8	
	Cirsium flodmanii (Rydb.) Arthur	Flodman's thistle	1,4, 5,6,7,8	

FAMILY	SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER	
			1994	1995
	Cirsium vulgare (Savi) Ten.	bull thistle	8	
	Echinacea angustifolia DC.	purple coneflower	1,3,4,5,7	
	Liatris sp. Schreb.	blazing star	4,5	
	Liatris punctata Hook.	blazing star	3,7	
	Ratibida sp. Raf.	prairie coneflower	7	
	Ratibida columnifera (Nutt.) Woot. & Standl.	prairie coneflower	1,3,4, 5,6,7	
	Solidago spp. L.	goldenrod	5,6	2,3,4, 5,6,7, 8,9,10
	Solidago rigida L.	rigid goldenrod	2,3,4, 5,6,7	
CAMPANULACEAE				
	Campanula rotundifolia L.	harebell	1,3,4, 5,6,7	
CAPRIFOLIACEAE				
	Symphoricarpos occidentalis Hook.	western snowberry	3,4,5, 6,8	
CHENOPODIACEAE				
	Salsola iberica Senn. and Pau	Russian-thistle	2,3,4, 5,6,7, 8,10	
FABACEAE				
	Amorpha canescens Pursh	lead plant	2,3,4, 5,6	3
	Astragalus crassicarpus Nutt.	ground-plum	3	

FAMILY SCIENTIFIC COMMON NAME STUDY SITE

NAME		NUMBER	
		1994	1995
Dalea candida Michx. ex Willd.	white prairie-clover	3,4,5,6	
Dalea purpurea Vent.	purple prairie clover	1,2,3, 4,5,6,7	3
Petalostemum candidus (Willd.) Michx.-Rydberg	white prairie-clover	3,4,5,6	
Melilotus spp. P. Mill.	sweet clover		a 2,3,4, 5,6,7, 8,9,10
Melilotus alba Medic.	white sweet clover	1,2,3,4, 5,6,7,8	
Melilotus officinalis (L.) Pall.	yellow sweet clover	3,4,5	
Psoralea argophylla	silver-leaf scurf Pursh pea	2,3,4,5,6	
LILIACEAE			
Allium vineale L.	wild garlic	4,5,6	
Lilium philadelphicum L.	wild lily	1,2,3	
POACEAE			
Agropyron sp. Gaertn.	wheatgrass	5,6,7	
Agropyron smithii Rydb.	western wheatgrass	4	
Andropogon gerardii Vitman	big bluestem	2,3,4, 5,6,7	9
Andropogon scoparius Michx.	little bluestem	1,2,4, 5,7	3,4,9
Bouteloua curtipendula (Michx.) Torr.	sideoats grama	2,4,6,7	9

FAMILY	SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER	
			1994	1995
	Bouteloua gracilis (H. B. K.) Lag. ex Griffiths	blue grama	2,4,5, 6,7	4
	Bromus spp. L.	brome grass	6	2,3,4,5
	Bromus inermis Leyss. inermis	smooth brome	1,4,5,6	
	Bromus tectorum L.	downy brome	6	
	Koeleria pyramidata (Lam.) Beauv.	Junegrass	4,7	
	Muhlenbergia pungens Thurb.	sand muhly	5	
	Panicum virgatum L.	switchgrass	5,6,7	
	Poa sp. L.	bluegrass	4,5,6,7	
	Stipa comata Trin. & Rupr.	needle-and-thread	3,5,7	
	Stipa spartea Trin.	porcupine-grass	1,2,3,4	
POLYGONACEAE				
	Rumex crispus L.	curly dock	2	
ROSACEAE				
	Rosa arkansana Porter	prairie wild rose	4,5,6,7	2,3,4
SALICACEAE				
	Populus sp. L.	aspen		4
SCROPHULARIACEAE				
	Verbascum thapsus L.	common mullein		2,5

FAMILY	SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER	
			1994	1995
SOLANACEAE				
	Physalis sp. L.	ground cherry	5	

a Both yellow and white sweet clover were widespread at Ames Gravel Quarry; in 1995 it was not recorded which of the species (or both) occurred on each site because it was too late in the season to differentiate between the 2 species. Some type of sweet clover was present at Bicentennial Prairie in the sandy, disturbed part of the plot; likewise, it could not be identified to species.