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FINAL REPORT

GRANT TITLE: ECOLOGY OF THE NORTHERN GRASSHOPPER MOUSE (*Onychomys leucogaster*) IN WESTERN MINNESOTA

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ABSTRACT

During the summer of 1993, 6 study sites in Clay County, Minnesota, were live-trapped in order to determine the distribution of populations of the northern grasshopper mouse (Onychomys leucogaster). Sites were generally examined for the presence of northern grasshopper mice using a preliminary trap-line of 25 traps placed 10 m apart. Traps were pre-baited for two nights and set on the third and fourth nights. Traps were checked for two consecutive mornings. If preliminary trapping resulted in the capture of a northern grasshopper mouse, the area was intensively trapped using a 7 X 7 trap grid with traps 10 m apart. This grid was centered around the location of the northern grasshopper mouse capture(s). Traps were pre-baited for two nights, and set on the third through the sixth nights. Traps were checked for 4 consecutive mornings. A total of 9 northern grasshopper mice were captured: 5 males and 2 females at a commercial gravel pit (Site 1: T141N, R46W, NE 1/4 of S36) and 1 male and 1 female at Bluestem Prairie (Site 4: T139W, R46W, W1/2 of S23). A northern grasshopper mouse was believed to have been sighted at Bicentennial Prairie (Site 2: T141N, ROW, SW 1/4 of S5), but none were captured at this site. All northern grasshopper mice in this study were associated with sandy or gravelly soils and sparse vegetation. Although all males were fully or partially scrotal and all females appeared pregnant or perforate, no juveniles were captured. Nontarget species captured included 72 deer mice (Peromyscus maniculatus), 1 white-footed mouse (Peromyscus leucopus), 24 meadow voles (Microtus pennsvlvanicus), and 9 prairie voles (Microtus ochrogaster). Presently, the biggest threat to northern grasshopper mice in western Minnesota appears to be habitat destruction due to sand/gravel excavation. Northern grasshopper mouse numbers appeared low in Clay County, MN, and it is recommended that the northern grasshopper mouse be considered for inclusion on Minnesota's "List of Special Concern Species" which currently includes the prairie vole.

INTRODUCTION

The northern grasshopper mouse reaches the most northeastern edge of its distribution in western Minnesota (Jones and Birney 1988). An extensive literature review has indicated that the northern grasshopper mouse has been little studied in Minnesota. Consequently, little is known about its life history in this area. The Minnesota County Biological Survey captured 8 grasshopper mice (Wilkin Co. - 1 capture; Lac Qui Parle Co. - 7 captures) (Birney and No dquist 1991) with snap-trap surveys of Norman, Clay, Wilkin, Traverse, Big Stone, Lac Qui Parle, and Washington Counties in 1988. ,Specimens of northern grasshopper mice have also been found in Kittson, Lincoln, and Otter Tail Counties (Dickerman and Tester 1957).' In 1990, 7 grasshopper mice were captured at 3 sites in Clay 9ounty and 6 at 1 site in Lac Qui Parle County (Stockrahm 1991).; In addition to these captures, Clay County has past records of grasshopper mouse captures (Hazard 1982, Heaney and Birney 1975)., However, all of these studies were primarily surveys dealing with presence/absence of animals.

The grasshopper mouse is a very unique species for several reasons. They have a carnivorous diet (Bailey and Sperry 1929, Egoscue 1960, Flake '1973, Jahoda 1970a), and plant material found in their gut has been attributed to the diet of the arthropods which the grasshopper mice consume (Hansen 1975). They form male-female social) bonds with both parents contributing to the care of the young (Ruffer 1965a), are highly aggressive and territorial (Ruffer 1968), and have large home ranges (Blair 1953 as reported by Buffer 1968). They also have a complex communication system (Hafner and Hafner 1979, Hildebrand 1961, Ruffer 1966). Grasshopper mice are found in a variety of grassland habitats, often with sandy, coarse soils (McCarty 1978) and live in burrows which they excavate themselves. These burrows are characteristic of northern grass topper mice because the substrate is scattered, leaving little or no raised area around the burrow (Ruffer 1965b).

Because this species seems to be rare in western Minnesota and little is known about its ecology in its northeasternmost range, this study was undertaken to locate and study populations of northern grasshopper mice in Clay County, Minnesota. We addressed the following objectives:

Objective 1: To determine distributions and habitat affinities of the northern grasshopper mouse in selected grasslands of western Minnesota (primarily in Clay County) using live-trapping techniques.

Objective 2: To estimate population densities and sex and age ratios of northern grasshopper mice and associated small mammals.

Objective 3: To record any sightings/signs of predators on/near the study grids.

Objective 4: To use the data gathered in this study in Conjunction with the data gathered in 1990 and 1991 to determine if the status of the northern grasshopper mouse should be upgraded for inclusion on the Minnesota "Endangered" or "Threatened" Species List.

Objective 5: To make recommendations for future studies and management plans for the northern grasshopper mouse in Minnesota.

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MATERIALS AND METHODS

Preliminary Work

Prior to our 1990-1991 study, we completed an extensive literature review in order to learn more about the location, habitat, and ecology of small mammal species which are known to be located in Clay County, Minnesota. An extensive literature search was again completed in 1993 with an emphasis on the northern grasshopper mouse to determine the best locations for our study sites.

For the 1990-91 study we also sent a letter of inquiry and/or made a phone call to all museums/collections in Minnesota and North Dakota which were likely to have specimens of the target species from Clay or Lac Qui Parle Counties, MN. We also contacted The Field Museum of Natural History in Chicago, Illinois and the Museum of Natural History at the University of Kansas in Lawrence for information about possible specimens (Stockrahm 1991).

We visited the mammal museum at the University of North Dakota in order to view specimens of the target species. No specimens of northern grasshoper mice were from Clay or Lac Qui Parle counties.

We examined the "Minnesota Natural Heritage Program Element Occurrence Records" and compiled a list of the target species captured in Clay and Lac Qui Parle Counties in order to locate areas for possible study sites.

We consulted the "Checklist of Itasca State Park Mammals" (compiled by A. Sargent [sic] and W. H. Marshall) and found that no target species were held in the collection at the Biological Station in Itasca State Park.

Choosing Study Sites

The Minnesota Department of Natural Resources/Wildlife Section has compiled a list called the "Natural Communities in Clay and Lac Qui Parle Counties" which is entered in the Minnesota Natural Heritage Program Element Occurrence Records. This list was considered exhaustive by Rich Baker of the Minnesota Department of Natural Resources because the County Biological Survey had been completed in both counties. This list was examined in 1990 as a source of possible trapping sites. To identify possible study sites for the 1993 season, we located areas of suitable habitat (sandy/gravelly soils) by the following methods:

1) Examining "A Guide to Minnesota Prairies" (Wendt 1984), "Farm and Home Plat and Directory: Clay County, Minnesota" (1993, 1994), and other Clay County maps which showed habitat areas

2) Calling local gravel companies to inquire about inactive gravel quarry areas

3) Using previous study sites from our 1990-1991 study (Stockrahm 1991) with the Minnesota Department of Natural Resources. M. Goertel, field technician for that study, identified 3 sites in Clay County where northern grasshopper mice were located in the 1990-1991 studies. Field researchers for the 1993 study accompanied M. Goertel to these sites in order to view specific capture areas and the characteristic burrows of the northern grasshopper mouse. (We could only use 1 of these sites in our 1993 study due to access problems.)

4) Making observations of recommended study sites in order to locate soils, vegetation densities, burrows and tracks which are characteristic of the northern grasshopper mouse. Recommendations were made by landowners in Clay County, Dr. R. Pemble (Department Chair, Biology Department, Moorhead State University),

K. Chapman (Director of Science and Stewardship, Nature Conservancy, Minnesota Chapter), and B. Djupstrom (Supervisor of Scientific and Natural Areas Program, Minnesota Department of Natural Resources).

Habitat Information and Species Associations

Microhabitat was recorded for each small mammal capture location. General habitat characteristics were recorded for each study site and the surrounding areas (Appendix A). The main plant species at each study site were identified and recorded (Appendix B). This information *is* not comprehensive because most of the plant identification and collection were completed in August. It is possible that early-blooming species were not identified. Photographs were taken to assist in identification and to record habitat for the study sites.

Live-trapping

Trapping of 6 study sites in 1993 was conducted from 24 June to 20 August. The following information was collected for each animal captured: station number, habitat, presence/ absence of runway, species, sex, age, weight (Pesola field scale), tail length, and breeding condition (Appendix C). Each animal was toe-clipped for future individual identification and then released at the site of capture.

At each potential study site, a preliminary trap line of 25 Sherman live-traps was placed with each trap being 10 m apart. Traps were pre-baited with peanut butter and rolled oat mixture and/or canned dog food and locked open for 2 nights to increase trapping success. On the third and fourth evenings, the traps were baited and set. Trap checks were made at each sunrise following these trapping nights (Table 1). If a northern grasshopper mouse was captured, a 7 X 7 grid was set up around the area of capture, with the traps placed at 10-m intervals along each transect. These traps were also re-baited for 2 nights. On the third through sixth evening, the traps were baited and set. Trap checks were made at each sunrise following these trapping nights (Table 2). Slight variations in trapping schedule and grid configuration occurred due to weather and land restrictions (Appendix A).

After unsuccessful preliminary trappings at Sites 1 and 2, the peanut butter and rolled oats mixture used for bait was replaced by these of canned dog food. Northern grasshopper mice were captured when this bait was used. Concern developed over the effect of the dog food on the intestinal tract of the mice, so we began using the peanut butter mixture again for the food supply in the traps. Small amounts of dog food were then placed in traps to attract the target species.

Species Identification

Species of fauna and flora associated with our study sites were identified using the following field guides: mammals (Burt and Grossehheider 1980, Murie 1982, Whitaker 1980), amphibians (Behler and King 1979) , birds (Peterson and Peterson 1980, Bull and Farrand 1977),insects (Milne and Milne 1980), and plants (Staudinger 1967, Van Bruggen 1983). Plant names were taken from the Great Plains Flora Association (1986) (Appendix B). Photographs were taken to assist in identification of several species of animals, insects, and pants. Scientific names for all species identified are recorded in tables and appendices and not in the text of this report,.

Powdertracking

Some of the data used in this report were collected by D. E. Welberg Canfield and V. K. Goertel while conducting a small research project for a class instructed by D. M. Bruns Stockrahm. The research was designed to analyze fluorescent powdertracking, a relatively new technique first implemented by Lemen and Freeman (1985)1 for use with small mammals. This technique consists of applying fluorescent colored powder to a small mammal's pelage. The mammal is released; it then leaves behind a fluorescent trail which 'can be followed by an observer using an ultraviolet (UV) light., This technique allows the observer to follow the exact movement pattern of habitat use both vertically and horizontally (McShea and Gilles 1992).

To test the efficacy of this method in our study, Sites 1 (4 X 4 grid) and 2 (transect of 25 traps) were re-live-trapped during the nights of 24 September and 26 September 1993, respectively. Traps were set at sundown and checked every 30 minutes until a capture occurred. After data were collected, the first small mammals caught were gently placed into a plastic bag containing the selected fluorescent powder color (Radiant Color, 2800 Radiant Avenue, Richmond, California 94804). The powder was then carefully worked into the animal's pelage and the animal was released.

An hour after an animal's release, tracking of the animal began. The trail was followed by the researcher using a Versalume, PP-FFS, long and short-wave Adjusta-beam, Black light/UV light (Raytech Industries, P.O. Box 6, Stafford Springer, Connecticut 06076). Pink flagging and/or pink flags with sequence and animal number were used to mark the trail. The last flag was numbered and marked with the word "end". The trail was marked at every directional change and at occasional points when linear distances became greater than 3 m.

RESULTS

During the 1993 field season, 6 sites in Clay County were live-trapped (Table 3, Appendix D). Additional locations with promising habitat were unable to be trapped due to difficulties procuring permits, limited access to sites due to flood conditions, and/or time limitations (Appendix E).

Target Species

A total of 9 northern grasshopper mice (i.e., target species) were captured. These captures occurred only at Sites 1 (Fig. 1, Appendix D) and 4 (Fig. 2). During the July 1993 trapping at Site 1, the preliminary 25-trap transect resulted in only 1 capture of the target species. When the 49-trap grid (Grid A) was centered around this capture, we captured the original animal plus 4 additional conspecifics (Figs. 1, 3). In August, we returned to Site 1 and established a second 49-trap grid (Grid B) to gather additional data on the grasshopper mice population. Grid B slightly overlapped the edge of Grid A (Fig. 1). The August trapping resulted in captures of 3 previously-captured grasshopper mice ,'and 2 new ones (Fig. 4). Between the July and August trapping, the grasshopper mice distribution seemed to shift slightly towards the east. This shift happened at the same time that sand/gravel excavation activity increased in the area immediately northwest of our study site (Fig. 1).

Because we had captured the target species in our 1990-1991 studies on Site 4, we omitted the preliminary 25-trap transect. Instead, we immediately set up a 49-trap grid (Grid A) around the exact area where the previous captures had occurred (Fig. 2) When this resulted in no captures of the target species, we then placed a 25-tiap transect slightly to the west of Grid A and headed in a northwesterly direction. When 2 target species were captured along the transect, a second 49-trap grid (Grid B) was established (Fig. 2). On Grid B, between 15-19 August 1993, we repeatedly captured the same 2 animals (Fig. 5).

Habitat of capture sites

Site 1 was a gravel quarry and Site 4 was an area dominated by mesic blacksoil prairie (Wendt 1984). Much of the ground was exposed in areas of capture at each site. More than 20 and 30 floral species, representing 6 and 8 families, were identified at Sites 1 and 4, respectively (Appendix B). Although the vegetation at Sites 1 and 4 differed, more than 10 species were common to both plots (Table 4). Of these, the most abundant plants identified near capture locations were yellow and white sweet clover, thistles, golden rod, and common

witchgrass. These plant species are often associated with disturbed areas and sandy soils.

Burrow 1, use by northern grasshopper mice was observed by field worker on 2 separate occasions. One female at Site 4 was observed to esc pe down a burrow near the station where she was captured. This particular burrow was located next to fringed sage which was relatively abundant at Site 4 and in areas of Site 1. Another northern grasshopper mouse (adult male #110) was seen entering a burrow on 20 August 1994 after its capture. We released it at the site of capture and followed it for approximately 3 m to a group of burrows on the side of a hill. The immediate area was dominated by tall, sparse sweet clover and characterized by sandy soil. Incidently, male #110 was in a weakened condition when removed from the trap. It was taken into a vehicle and warmed up. While 'in the vehicle, it was observed killing and eating a grasshopper which had been captured by the researcher and presented to the mouse.

Times for best capture success

Studies have shown that the northern grasshopper mice have their peak activity during the new moon (Jahoda 1973) or at times of light rain (Jahoda 1970b) and their lowest activity during the full moon (Jahoda 1973) or heavy rains (Jahoda 1970b). During our study, we paid special attention to this and found that capture success seemed to be greatest near new moons, quarter moons, and on overcast nights. These data were inconclusive due to the fact that most nights were overcast.

Sex ratios

A total of 7 and 2 adult northern grasshopper mice were captured on Sites 1 and 4, respectively. At Site 1, 5 were males and 2 were females (Table 5). At Site 4, 1 was a male and 1 was a female (Table 6). A chi-square analysis of the sex ratios showed no significant difference from a 1:1 ratio at Site 1 (x^2 = 1.22, d.f. = 1, P > 0.10) or Site 4 (x - 0.00, d.f. = 1, P > 0.10) (Table 7), but sample sizes were small.

Recaptures

On Site 1, only 5 of the 7 northern grasshopper mice were captured more than once (Table 8). These 5 were captured a combined total of 26'times. At Site 4, the male and female were captured 6 and 5 times each, respectively.

Capture sequences and spacing

Capture sequence and locations of the northern grasshopper mice indicted that their ranges overlapped (Figs. 3, 4, 5). The sequences at Site 1 also indicated a general eastward shift in habit t use by male #77, male #82, and female #85 from 10 July to 20 A gust; This response coincided with the beginning of excavation directly west of the site. When captured during the same day, male #82 and female #85 were always within 32 m of each other, indicating that they might have been a mated pair. During any particular day, neither male #82 nor female #85 was ever captured closer than 30 m to male #77. Males seemed to be slightly wider ranging than females based on greatest distance between captures of the same animal (Table 9), but data were limited. Between 26 July and 20 August, male #82 was caught 8 times at 5 trap stations (Figs. 3, 4). He was caught once again on 24 September at a new trap station adjacent to one where he had previously been captured, for a total of 9 captures at 6 different stations. This animal moved the greatest linear distance between trap stations, i.e., 90.6 m (Table 9).

During the powdertracking study conducted on Sites 1 and 2 (September 1993), male #82 and female #85 were captured less than 23 m Apart at Site 1. (However, we only powdertracked non-grasshopper mice because we wanted to be sure this method was feasible before possibly endangering the more rare grasshopper mouse.) This verified that both were alive and were still occupying ~ the same general area. These later captures were at stations Adjacent to their July captures. Sand/gravel excavation appeared to be slowed or halted for the season in this area by September 1993.

Reproduction

All males fully or partially scrotal. All females appeared pregnant or perforate during 1 or more trap sessions. No juveniles were captured or sighted (Table 10).

Nontarget Species

Four, nontarget species were also captured: meadow and prairie voles, deer mice, and a white-footed mouse (Table 11). Deer mice and meadow voles were captured at both sites where the northern grasshopper mice were captured. Deer mice were captured in traps
both before and after northern grasshopper mice had been captured in the same traps.

Of the nontarget species, deer mice were most abundant/numerous, with captures at each site except Site 3 where no animals of any species were captured. A total of 31 adult males, 9 sub-adult males, 29 adult females and 3 sub-adult females were live-trapped (Table 12). No juveniles were captured. A chi-square analysis showed that sex ratio were significantly different from a 1:1 ratio only at Site 6 (x =

4.00, d.f. = 1, P < 0.05) (Table 7), but the Yates' corrected chi-square suggested that these differences were not significant. Several deer mice were successfully recaptured at these sites (Table 8*)*.

Meadow,voles, the next most abundant species, were trapped at Sites 1,2,4, and 6 (Tables *12, 13). A* total of 3 adult males, 1 juvenile male, 14 adult females and *6* sub-adult females were captured (Table 13). A chi-square analysis suggested that the se ratios were significantly different from a 1:1 ratio at Site 1 (x^2 = 6.*23*, d.f. -1, P < 0.05) (Table 7) and Site 4 (x = 5.00, d.f. = 1, P < *0.05)*. Recapture data (Table 8) for meadow voles revealed that 6 individuals at Site 1 were recaptured. Recapture rates at the other sites were poor.

Only 9 prairie voles were captured: 4 adult males and *5* adult females (Table 14). These captures all occurred at Site 1. A chi~square analysis suggested that th sex ratios were not significantly different from 1:1 ratio (x = 0.111, d.f. = 1, P >0.10)' (Table 7). Recapture data analysis revealed that 3 individuals were captured a combined total of *8* times (Table 8).

An adult male white-footed mouse was captured at Site 1 (Table *5)*. Several specimens of both deer mice and white-footed mice were examined at Moorhead State University Wildlife Museum before this identification was made. White-footed mice specimens appeared to have ai whiter belly and a more scaly-appearing tail than did the deer lice specimens, and our identification was based mainly on these 2 criteria. Positive identification is virtually impossible without examining the animal's skull because these species are difficult to distinguish from each other in the field. This problem was intensified by the fact that the capture took place at night during the powdertracking study.

Powdertracking

A total of *3* mice were powdertracked. At Site 1, 1 adult male white footed mouse was tracked for *56.35* m and 1 adult female deer mouse was tracked for 68.05 m. At Site 2, an adult male deer mouse was tracked for 120.08 m. No northern grasshopper mice were powder tracked because we wanted to be sure this technique was feasible for this species before trying it on them.

Using) a black light, the green fluorescent powder was more discernable than the orange powder. Initially, trails were 4 cm wide and gradually decreased to occasional specks less than 1 mm in diameter and approximately 1-100 cm apart. Trails were more prominent in grassy habitats than on gravel or sand substrates. Even though trails were more distinct in grasses, they were difficult to follow if a dense overlay of tall grasses was present.

Associated Faunal Species

A number of species of fauna were captured or sighted on/near our study sites. Tracks, scats, or other sign were also observed. Each observation was made at the study sites or in transit to/from the sites (Appendix F). Potential predators on the northern grasshopper mice in Clay County included foxes, coyotes, skunks, and hawks.

Several insect species were noted at each site (Appendix F). Most of those insects were noted at all of the study sites, with two exceptions. The wooly bear caterpillar was found only at Sites 1,2, and 4. The Nebraska cone-head was found only at Site 4.
Daddy-long-legs were frequently found in the traps at Site 1. An abundance of several species of crickets, grasshoppers, beetles and ants were noted in and around the traps at all sites.

General Observations

Although the habitat seemed suitable for several rodent species, no animals were captured at Site 3 during the summer of 1993.

A female northern grasshopper mouse (#96) at Site 1 was observed to have a seizure. She made a quick jerk and went limp immediately after being toe-clipped. When placed on the ground and subjected to tactile stimulation, she hopped up and ran away. This female was captured one time only.

One northern grasshopper mouse (male #8, Site 4) and one female prairie vole (Site 1) died during this study. The grasshopper mouse appeared to die of hypothermia, and several other animals were evidently stressed due to several cold, wet nights in late August. The 2 skins and skulls were preserved and are in the Moorhead State University Wildlife Museum, Moorhead, MN. The vole was positively identified as a prairie vole rather than a meadow vole by examination of the 3rd upper molar under a dissecting scope.

Discussion

All of our captures of northern grasshopper mice since 1990 have been in areas of sandy or gravelly soils with sparse vegetation. Northern grasshopper mice have been noted in areas of sandy soil in Kansas (Kaufman and Fleharty 1974, Kaufman et al. 1990), short-grass prairie in Colorado (Flake 1973), semi-stabilized sand dune in Utah (Egoscue 1960), desert grasslands in New Mexico (Rebar and Conley 1983), and sagebrush desert in Nevada (O'Farrell 1974). Because vegetation types and heights varied at the 2 sites where grasshopper mice were captured in 1993, our data indicate that vegetation type might not be as important as a sandy or gravely soil type.

Egoscue (1960) believed that northern grasshopper mice required soils which permitted frequent dust bathing to prevent their pelage from becoming oily or unkempt. He also mentioned that the grasshopper mice which he studied in Utah avoided marshy habitats, exceedingly rocky habitats, precipitous hillsides, shadscale (Atriplex confertifolia) flats with their accompanying alkaline soils, and pickleweed Allenrolfia occidentalis) hummocks (salt tolerant vegetation). Our data suggest that they avoided high moisture areas, although no true marshy areas were sampled in our study. Our data also suggested that they avoided extremely rocky areas which were present at Site 2. However, a male northern grasshopper mouse was captured on several occasions on or near a precipitous hillside at Site 1.

Cold, wet weather negatively influenced our 1993 trapping results. Although the habitat seemed suitable, no animals were captured at Site 3, possibly due to flooding rains during pre-baiting and trapping. Although no northern grasshopper mice were captured at Site 2, the habitat seemed to be excellent and burrows characteristic of grasshopper mice were located. We believed that a northern grasshopper mouse was seen running up a gravel slope at this site on 27 October 1993. Possible burrows were observed approximately 5 m from where this mouse was last seen. This site was also subjected to heavy (flooding) rains. The habitat looked suitable in late June. However, by early July, the area was very wet and not conducive to trapping. We recommend that Sites 2 and 3 be retrapped in future studies, hopefully during a drier year.

On Site 1, we captured a total of 5 males and 2 females on the 2 overlapping grids (Figs. 1, 3, 4). The locations and sequences of captures indicated that the animals might have shared common home ranges which appears to be contradictory to their reported aggressive and territorial behavior (Ruffer 1968). However, in our 1990-1991 studies, we also captured quite a few (6) grasshopper mice within a 50-m transect along 1 gravelly hill at our study site at Yellow Bank Hills (SNA) in Lac Qui Parle County (T118N, R46W, FJ S4) (Stockrahm 1991). In this earlier study, at least 2 of the males appeared to be young animals only reaching sexual maturity (base on scrotal condition). Possibly these were offspring which had not yet dispersed. We think that this might also be the case in our 1993 study, i.e., that the apparent overlap in home ranges corresponds to movements of undispersed family members.

Egoscue (1960) suggested that adult grasshopper mice live as bisexual pairs, but his data were inconclusive due to small sample size. On Site 1, we believe we had at least 1 mated pair. Male #82 and female #85 possibly shared a pair bond because they were often captured in close proximity to each other and they exhibited the same shift in space use. They also appeared to keep their distance from male #77, but more data would be required to determine the cause of this spacing pattern., On Site 4, the male and female also appeared to share a pair bond. The female appeared to be pregnant (based on vaginal condition and weight gain), and both animals were often caught in close proximity to each other. Both animals were caught at the identical

trap station on different days and appeared to be sharing the adjacent burrow system.

Sand/gravel excavation activities appeared to cause a shift in the distribution of the northern grasshopper mice to the east on Site 1 (Fig. 3, 4). Some of the overlapping space use was possibly due to migration coinciding with the sand/gravel excavation. An alternative explanation for the shift is conditioning to the traps (with enticing bait). During our study, a captured female northern grasshopper mouse (#96) made a quick jerk and went limp immediately after being toe-clipped. When placed on the ground and touched, she hopped up and r n away. This mouse was not captured again although the site was trapped for 5 more nights. This type of seizure was studied in southern grasshopper mice by McCarty and Southwick (1975). In this article they have a personal communication from A. E. Harriman who state that he observed spontaneous seizures in approximately 3% of trapped northern grasshopper mice.

A number of small mammal species were trapped in the same areas as were the northern grasshopper mice (Table 11). Northern grasshopper mice have been known to kill and eat other small rodents (Egoscue 1960). It was interesting to note that we captured deer mice in traps where northern grasshopper mice had recently been captured. Apparently, the scent of the grasshopper mice was not enough to prevent the deer mice from entering the traps.

Although we powdertracked species other than northern grasshopper mice, we think this technique has good potential to be used to study movements of the grasshopper mouse. The pigments in the fluorescent powder are reported by the manufacturer to be low in toxicity. Repeated exposures apparently have no ill effects on the animals (Lemen and Freeman 1985). Halfpenny (1992) found that the fluorescent powder may persist for at least 2 years in the environment, but he did not say whether or not trails were still trackable after exposure to the environment. Powdertracking has worked well to determine home ranges of prairie voles (Jike et al. 1988). Using this method, social interactions between nocturnal animals could be monitored (Kaufman 1989). Social interactions in deer mice (Kaufman 1989) and quantification of the foraging movements and monitoring of microhabitat use of white-footed mice have been studied using the powdertracking method (McShea and Gilles 1992).

The florescent green powder was easier to track with a UV/black-light when compared to the fluorescent orange powder. This could have been a result of the mouse's powdered pelage brushing against vegetation from all sides. on the gravelly and rocky terrain, where the mouse's body made little contact with the gravel substrate, the only powder visible was in the form of tiny fallen specks or markings on mouse-sized rocks. Also, small rocks would sometimes glow like the fluorescent powder. This made relocating a lost trail difficult.

Powder lost to surrounding vegetation caused the trail visibility to decrease as the length of the trail increased. Interesting circular areas of powder, approximately 8 cm in diameter, were occasionally found along each trail. These could have been attempts by the mouse to remove the powder indicating that the powder may have an effect on the mouse's behavior. Mikesic and Drickamer (1992) found that fluorescent powder affected the activity of wild house mice (Mus musculus) for 6 hours after application, but the effect was reduced after 24 hours.

Fluorescent powdertracking in conjuction with live-trapping can be advantageous over live-trapping alone. In fluorescent powdertracking, exact movements are able to be traced. By using fluorescent powdertracking, locations of burrows or nestings sites can be found. Live-trapping is static and only allows the observer to compare areas of capture to areas of non-capture. Bait used in the live-traps may affect the foraging activity of the rodent.

Powdertracking also has some advantages over radio-telemetry tracking. The required equipment needed is less expensive and easier to obtain. The method takes little effort to learn and execute. Perhaps the greatest advantage is the fact that tracking the animals' powdertrail does not have to be simultaneous with the animals' movements. Tracking can take place at a later time.

Disadvantages of fluorescent powdertracking over radiotracking are present as well. Because of the small number of available colors and the similarities between some colors, the number of mice which can be tracked at a particular time is limited. Persistence of the color in the environment (Halfpenny 1992) might eliminate the chance to powdertrack in the same area for over two years. The powder can also be passed to other animals through social interactions (Kaufman 1989).

In our study, general disadvantages of fluorescent powdertracking were also found. Tracking had to take place at night when it was dark so that the black light could be used effectively. When tracking during a full moon or near artificial light, tracking was more difficult. The fluorescent powder might make the powdered animals more visible to predators, but as of 1988 no studies had been done to assess mortalities associated with powdertracking (Mulls an 1988).

Concluding Remarks and Recommendations

A thorough literature search indicated that northern grasshopper mice were relatively rare in Minnesota. Contact with all of the major museums in Minnesota area indicate that few specimens of this species exist. Our research since 1989 has indicated that grasshopper mice are rare in western Minnesota. Because of the low number of captures, we recommend that the northern grasshopper mouse be considered for the status of "special concern species" in Minnesota. It was especially interesting to note that we caught equal numbers of prairie voles and northern grasshopper mice in this study, yet the prairie vole already has the status of "special concern species" in Minnesota while the northern grasshopper mouse does not have this designation.

All captures of the northern grasshopper mouse were in areas of sandy or gravelly soils, often in areas of old or current gravel excavation. It is possible that sandy and gravelly soils are a major factor limiting the distribution of the this species. Literature indicates that this species uses these types of soils to "dustbathe". At this time, it is possible that the loss of this type of habitat is the biggest threat to the survival of this species. For these reasons, habitats of this type should be investigated further.

Prairie voles were caught in an area of current excavation at Site 1. Further studies should be done on this site if habitat remains in the next few years. We have recently received $3000 in funding from he Minnesota Department of Natural Resources to continue our studies of the northern grasshopper mouse. We plan to include studies of prairie voles in these continuing studies.

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Table 11. Schedule of prebaiting, setting, and checking traps for the preliminary trapping sessions of the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

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 future trapping or they were removed from the site.

Table. Schedule of prebaiting, setting, and checking traps for the intensive trapping sessions of the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

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

[a] Intensive trapping on Grid 8 at Site 1 was only conducted for 3 consecutive nights due to stormy weather and stress exhibited by several animals on the morning of Day 6.

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

Table 3. List of locations trapped during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

SITE NUMBER	STUDY SITE	T	R	S
1	Ames Sand & Gravel, Inc.	141N	46W	NE 1/4 of 36
2	Bicentennial Prairie	141N	45W	SW 1/4 of 5
3	Brad Bjerken (B-B Ranch)	141N	45W	19
4	Bluestem Prairie	139N	46W	W 1/2 of 23
5	Keith Hansen	139N	45W	NW 1/4 of 29
6	Moorhead State University Regional Science Center	139N	46W	SW 1/4 of 12

Table 4. Plant species found on both Site 1 and Site 4 where northern grasshopper mice were captured during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

FAMILY SCIENTIFIC NAME	COMMON NAME	OTHER SITES WHERE THESE PLANTS OCCURRED
ASTERACEAE		
Artemisia fringida	fringed sage[a]	3
Cirsium spp.	thistle[a]	2
Liatris sp.	blazing star	2
Solidago spp.	goldenrod[a]	5
FABACEAE		
Dalea purpurea	purple prairie clover	2
Melilotus alba	white sweet clover[a]	2,5
Melilotus officinalis	yellow sweet clovers	2,5
POACEAE		
Agropyron sp.	wheatgrass[a]	2
Bromus inermis	smooth brome[a]	5
Panicum capillare	common witchgrass[a]	
Stipa comata	needle-and-thread[a]	3

[a] These species were noted in close proximity to traps were northern grasshopper mice were captured.

Table 5. Age and sex structure of all species captured at Site 1, Ames Sand & Gravel, Inc., T141N, R46W, NE 1/4 of S36, during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

	MALE	FEMALE	TOTAL
DEER MICE			
Peromyscus maniculatus			
Adult	16	16	32
Sub-adult	7	1	8
Total	23	17	40
MEADOW VOLES			
Microtus pennsylvanicus			
Adult	2	7	9
Sub-adult	0	4	4
Total	2	11	13
PRAIRIE VOLES			
Microtus ochrogaster			
Adult	4	5	9
NORTHERN GRASSHOPPER MICE			
Onychomys leucogaster			
Adult	5	2	7
WHITE-FOOTED MOUSE			
Peromyscus leucopus			
Adult	1[a]		1

[a] Several specimens of both deer mice and white-footed mice were examined at Moorhead State University Wildlife Museum before this identification was made. White-footed mice specimens appeared to have a whiter belly and a more scaly-appearing tail than did the deer mice specimens, and our identification was based mainly on these 2 criteria.

Table 6. Age and sex structure of all species captured at Site 4, Bluestem Prairie, T139N, R46W, S23, during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota.

	MALE	FEMALE	TOTAL
DEER MICE			
Peromyscus maniculatus			
Adult	5	5	10
MEAD VOLES			
Microtus ochrogaster			
Adult	0	5	5
NORTHERN GRASSHOPPER MICE			
Onychomys leucogaster			
Adult	1	1	2

Table 7. Chi-square analysis of sex ratios for the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. The degree of freedom = 1.

SPECIES[a]	SITE	MALES	FEMALES	CHI-SQUARE VALUE	P VALUE
NGM	l[b]	5	2	1.218	>0.10
NGM	4[b]	1	1	0.000	>0.10
DM	1	23	17	0.900	>0.10
DM	2	5	6	0.090	>0.10
DM	4	5	5	0.000	>0.10
DM	5[b]	3	4	0.142	>0.10
DM	6[b]	4	0	4.000	<0.05[c]
MV	1	2	11	6.230	<0.05
MV	2[b]	1	1	0.000	>0.10
MV	4[b]	0	5	5.000	<0.05[c]
MV	6[b]	1	3	1.000	>0.10
PV	l[b]	4	5	0.111	>0.10

[a] NGM = northern grasshopper mice (Onychomys leucocaster), DM = deer mice (PeromrLscus maniculatus), MV = meadow voles (Microtus pennsvlvanicus), PV = prairie voles (Microtus ochrogaster).

[b] The expected frequencies are too low for an accurate chi-square test.

[c] Yates' corrected chi-square suggests that theses differences are not significant (P>0.10).

Table 8. Recapture data for each study site from the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. C/A is number of captures per total number of animals of a species captured. C/R is the number of captures per number of animals of that species which were recaptured. NGM = northern grasshopper mice, PV = prairie voles, MV = meadow vole, DM = deer mice.[a]

SITE	NGM		PV		MV		DM	
	C/A	C/R	C/A	C/R	C/A	C/R	C/A	C/R
1	28/7	26/5	14/9	8/3	22/13	15/6	84/40	62/18
2	0	0	0	0	2/2	0	14/11	6/3
4	11/2	11/2	0	0	7/5	3/1	25/10	22/07
5	0	0	0	0	0	0	8/7	2/1
6	0	0	0	0	4/4	0	6/4	4/2

[a] On the last trapping session at Site 1, 1 white-footed mouse was captured. Several specimens of both deer mice and white-footed mice were examined at Moorhead State University Wildlife Museum before this identification was made. White-footed mice specimens appeared to have a whiter belly and more scaly-appearing tail than did the deer mice specimens, and our identification was based mainly on these 2 criteria.

Table 9. The greatest linear distance between captures for each individual northern grasshopper mouse during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Animals # 96 and 110 were not recaptured after their initial capture. M = male, F = female.

ANIMAL NUMBER	SEX	TOTAL NUMBER OF CAPTURES	GREATEST DISTANCE BETWEEN CAPTURES (m)
8	M	6	64.0
11	F	5	51.0
77	M	7	78.1
82	M	9	90.6
85	F	5	63.2
94	M	2	20.0
96	F	1	____
103	M	2	20.0
110	M	1	____

Table 10. Age and sex structure of northern grasshopper mice captured at all sites during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. A = adult, SA = sub-adult, J = juvenile, M = male, F = female.

SITE	MALES A/SA/J	FEMALES A/SA/J	TOTAL A/SA/J	TOTAL M/F	TOTAL ALL
1	5/0/0	2/0/0	7/0/0	5/2	7
2	0	0	0	0	0
3	0	0	0	0	0
4	1/0/0	1/0/0	2/0/0	1/1	2
5	0	0	0	0	0
6	0	0	0	0	0
TOTAL	6/0/0	3/0/0	9/0/0	6/3	9

Table 1. Summary of nontarget species live-trapped during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. M = male, F = female.

SPECIES	STUDY SITE NUMBER 1 M/F	2 M/F	3 M/F	4 M/F	5 M/F	6 M/F	TOTAL M/F
DEER MICE							
Peromyscus maniculatus	23/17	5/6	0/0	5/5	3/4	4/0	40/32
MEADOW VOLES							
Microtus pennsylvanicus	2/11	1/1	0/0	0/5	0/0	1/3	4/20
PRAIRIE VOLES							
Microtus ochrogaster	4/5	0/0	0/0	0/0	0/0	0/0	4/5
WHITE-FOOTED MICE							
Peromyscus leucopus	1[a]/0	0/0	0/0	0/0	0/0	0/0	1/0

[a] Several specimens of both deer mice and white-footed mice were examined at Moorhead State University Wildlife Museum before this identification was made. White-footed mice specimens appeared to have a whiter belly and more scaly-appearing tail than did the deer mice specimens, and our identification was based mainly on these 2 criteria.

Table 12. Age and sex structure of deer mice (Peromyscus maniculatus) captured at all sites during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. A = adult, SA = sub-adult, J = juvenile, M = male, F = female.

	MALES	FEMALES	TOTALS		
SITE	A/SA/J	A/SA/J	A/SA/J	M/F	ALL
1	16/7/0	16/1/0	32/8/0	23/17	40
2	4/1/0	5/1/0	9/2/0	5/6	11
3	0	0	0	0	0
4	5/0/0	5/0/0	10/0/0	5/5	10
5	3/0/0	3/1/0	6/1/0	3/4	7
6	3/1/0	0/0/0	3/1/0	4/0	4
TOTAL	31/9/0	29/3/0	60/12/0	40/32	72

Table 13. Age and sex structure of meadow voles (Microtus pennsylvanicus) captured at all sites during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. A = adult, SA = sub-adult, J = juvenile, M = male, F = female.

SITE	MALES	FEMALES	TOTALS		
	A/SA/J	A/SA/J	A/SA/J	M/F	ALL
1	2/0/0	7/4/0	9/4/0	2/11	13
2	0/0/1	1/0/0	1/0/1	1/1	2
3	0	0	0	0	0
4	0	5/0/0	5/0/0	0/5	5
5	0	0	0	0	0
6	1/0/0	1/2/0	2/2/0	1/3	4
TOTALS	3/0/1	14/6/0	17/6/1	4/20	24

Table 14. Age and sex structure of prairie voles (Microtus ochrogaster) captured at all sites during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. A = adult, SA = sub-adult, J = juvenile, M = male, F = female.

	MALES	FEMALES	TOTALS		
SITE	A/SA/J	A/SA/J	A/SA/J	M/F	ALL
1	4/0/0	5/0/0	9/0/0	4/5	9
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
TOTAL	4/0/0	5/0/0	9/0/0	4/5	9

Fig. 1. Map of Site 1 (T141N, R46W, NE 1/4 of S36) of the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Small dots indicate trap stations. A portion of the preliminary (L-shaped) 25-trap transect is represented by the line of 16 dots extending northeast of Grid A. This area was dominated by grasses, but the rest of the preliminary transect and both grids were characterized by exposed ground, yellow and white sweet clover, and several species of thistles. Further details on ground cover and trapping procedures are described in Appendix A.

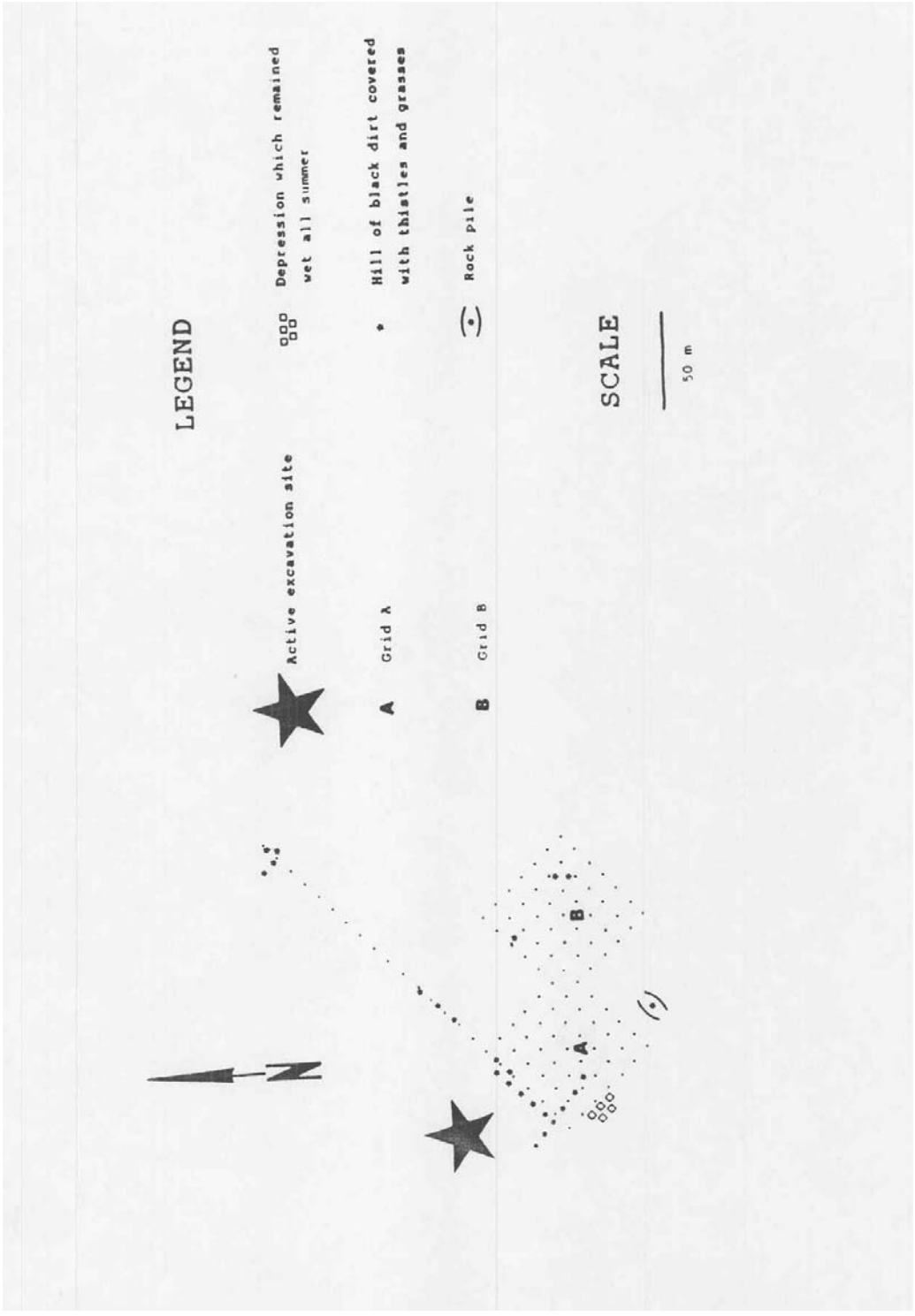

LEGEND
Active excavation site
Depression which remained wet all summer
A Grid A
Hill of black dirt covered with thistles and grasses
B Grid B
Rock pile
SCALE
50 m
N
A
B

Fig. 2. Map of Site 4 (T139N, R46W, W 1/2 of S23) of the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Small dots indicate trap stations. Further details on ground cover and trapping procedures are described in Appendix A.

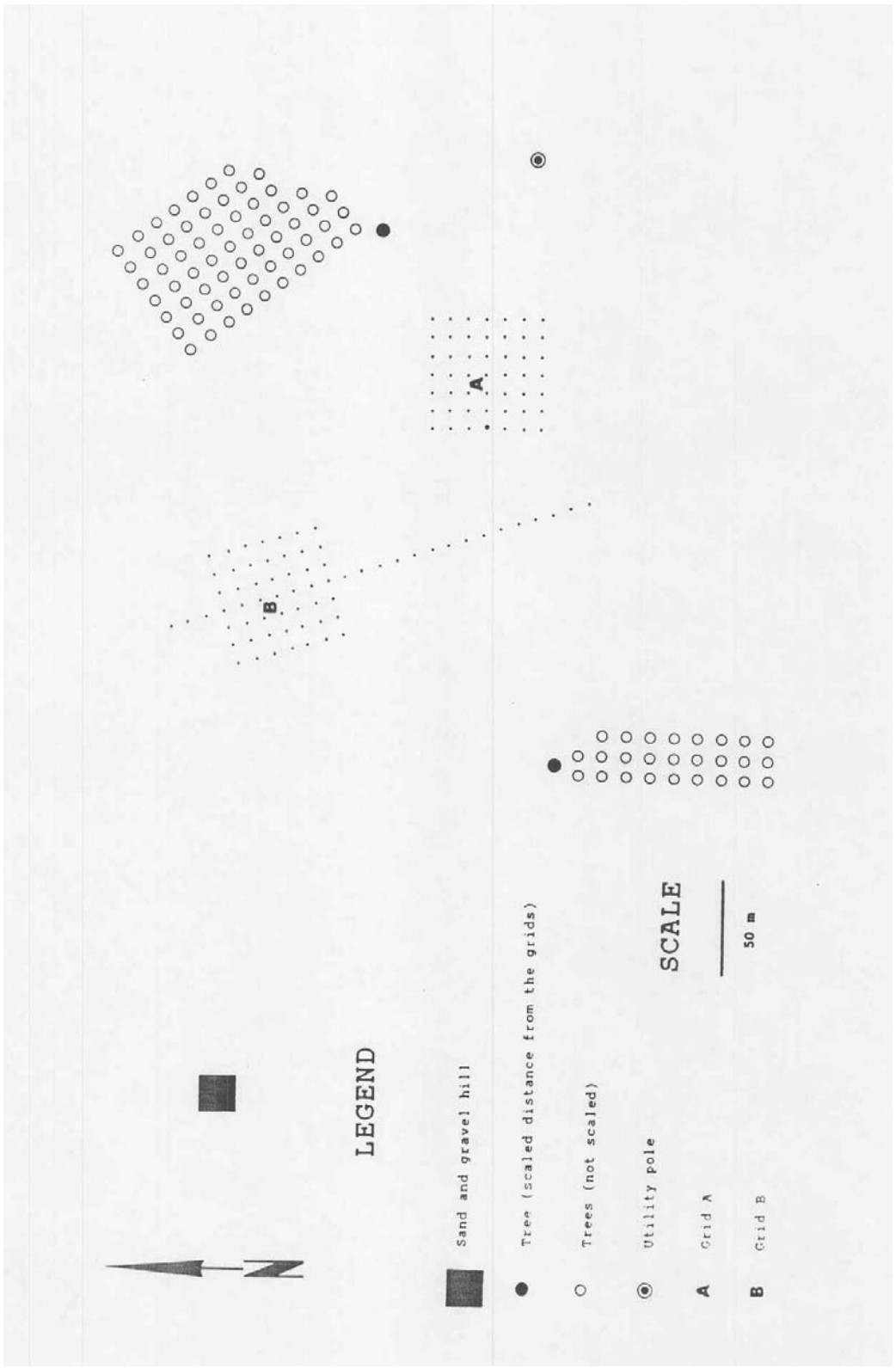

N
LEGEND
Sand and gravel hill
Tree (scaled distance from the grids)
Trees (not scaled)
Utility pole
A Grid A
B Grid B
SCALE
50 m
A
B

Fig. 3. Location of northern grasshopper mice captures on Grid A of Site 1 (Fig. 1) during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. A portion of Grid B was included on this map to make it easier for the reader to understand the northern grasshopper mouse movements discussed in this report. Small dots indicate trap stations. Letters denote dates of capture: a = 10 July, b = 24 July, c = 26 July, d = 27 July, e = 28 July.

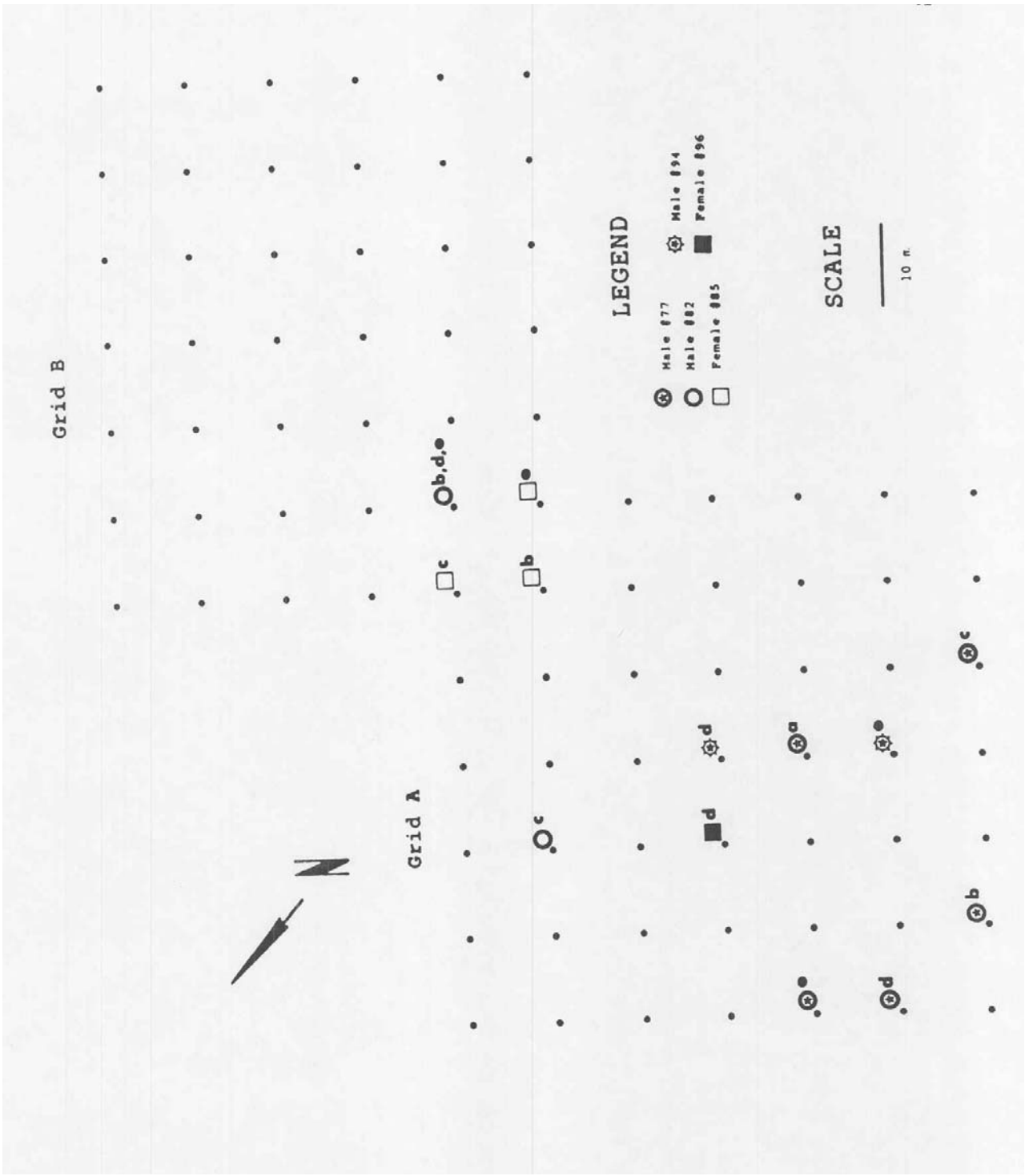

Grid B
Grid A
N
LEGEND
Male #77
Male #82
Female #85
Male #94
Female #96
SCALE
10 m

Fig. 4. Location of northern grasshopper mice captures on a portion of Grid B of Site 1 (Fig. 1) during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Grid A was included on this map to make it easier for, the reader to understand the northern grasshopper mouse movements discussed in this report. Small dots indicate trap stations. Letters denote dates of capture: a = 18 August, b = 19 August, c = 20 August.

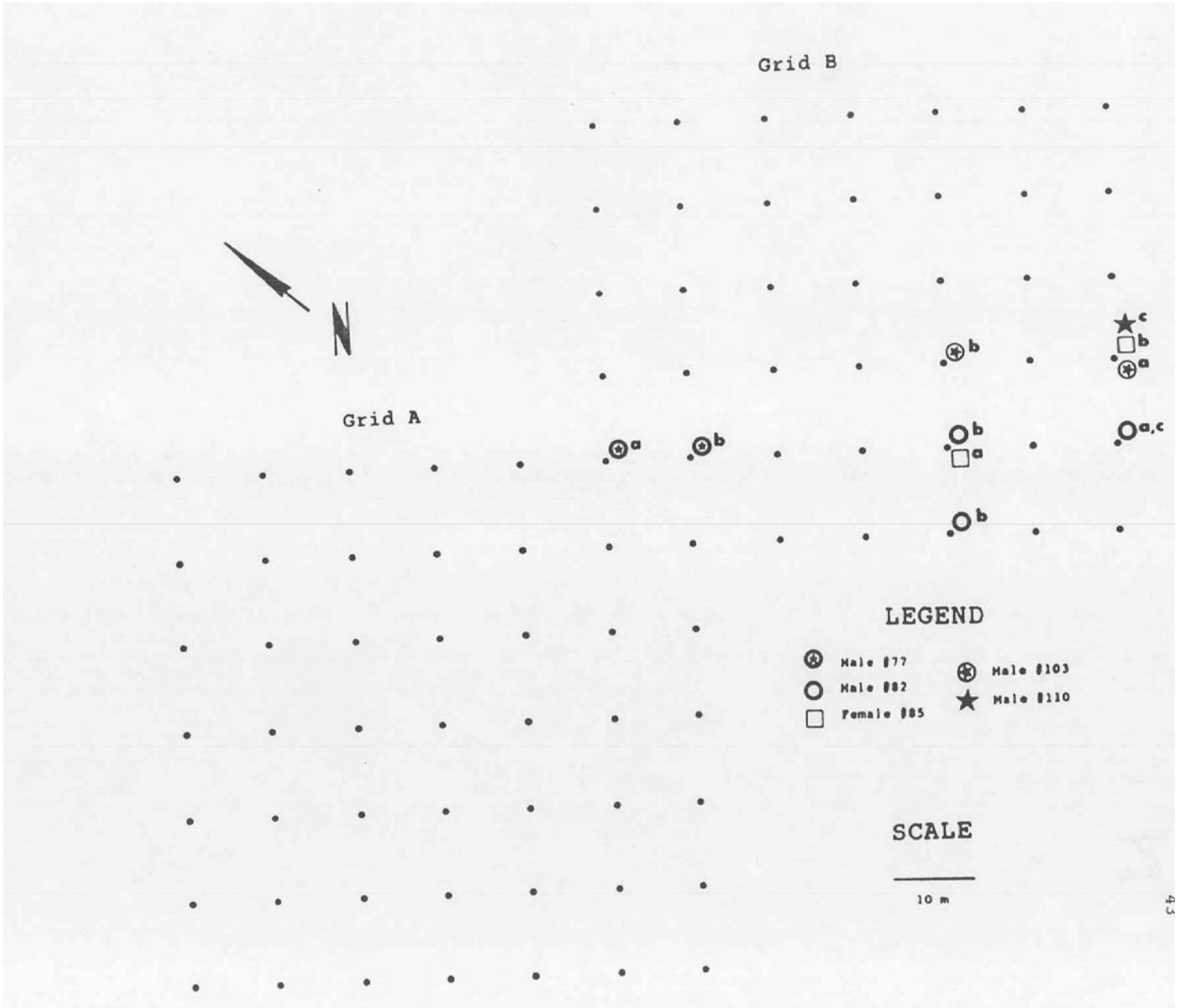
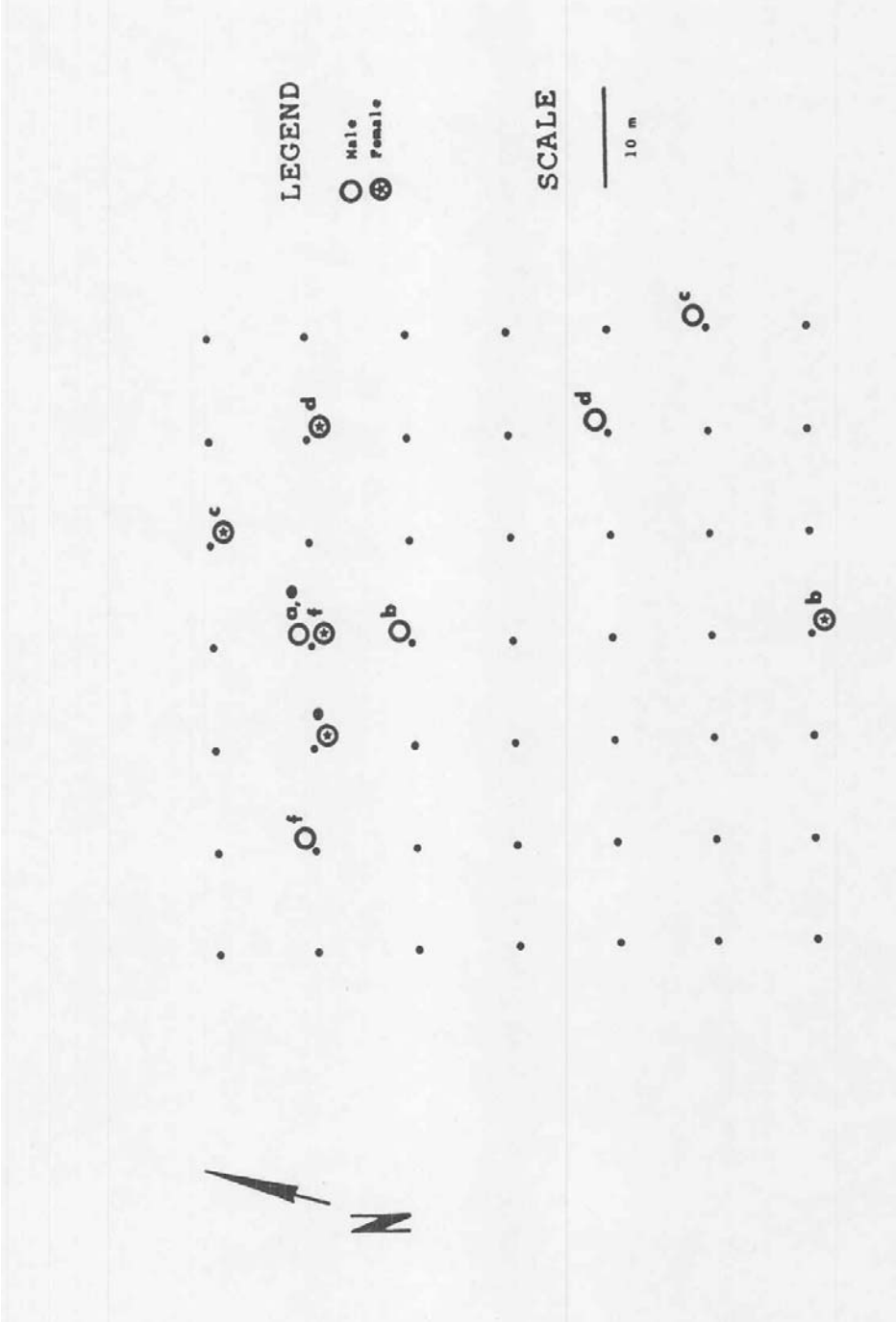

Grid B
Grid A
N
LEGEND
Male #77
Male #82
Female #85
Male #103
Male #110
SCALE
10 m

Fig. 5. Location of northern grasshopper mice captures on Grid B of Site 4 (Fig. 2) during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Small dots indicate trap stations. Letters denote dates of capture: a = 7 August, b = 8 August, c = 15 August, d = 17 August, e = 18 August, f = 19 August.


LEGEND
Male
Female
SCALE
10 m
N

APPENDIX A: HABITAT AND TRAP CONFIGURATION DESCRIPTIONS

APPENDIX A: Habitat and trap configuration descriptions of the study sites for the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Scientific names for plants are listed in Appendix B. General maps for all sites are included in Appendix D.

Site 1: Ames Sand & Gravel, Inc.; T141N, R46W, NE 1/4 of S36; Clay County, MN

This hilly area was characterized by sandy and gravelly soils, with several large areas of exposed gravel. Many of the hills were formed by previous sand, soil, and gravel excavation. Towards the end of the 1993 field season, the area directly northwest of our trapping site was being excavated. The habitat suitable for northern grasshopper mice at this site was limited to small scattered islands of habitat. The vegetation at this site included fringed sage, blazing star, prairie coneflower, goldenrod, goat's beard, lead plant, purple prairie clover, yellow and white sweet clover, blue-eyed grass, wheatgrass, little bluestem, smooth brome, common witchgrass, yellow foxtail, needle-and-thread, prairie wild rose, common mullein and several species of thistles (Appendix B). Due to the high level of precipitation received during the summer of 1993, a small depression at the southwest edge of our trap grid was moist for a large part of the summer (Fig. 1). To the north/northwest of this wet area was a hill of black soil. The vegetation cover on this hill was dominated by several species of thistles. The area surrounding Site 1 was used for agriculture, grazing, and gravel, sand, and soil excavation.

Because no obvious landmarks existed in the area of our initial 25-trap line, we ran it 225 degrees from a hill in the SW 1/4 of the NE 1/4 of S36 (Fig. 1). Traps were set up in an "L" shape, with the first 21 traps running 225 degrees from the black dirt hill mentioned above. Because we ran into a precipitous, thistle-covered hillside, the last 4 traps were placed in a line running from Trap 21 at 135 degrees. The first 7 X 7 grid (Grid A) was placed so that the 24th trap station (capture location of target species) of the original 25-trap line became the grid's approximate center. The grid edges ran at 315 degrees and 45 degrees (Fig. 1). The second 7 X 7 grid (Grid B) was placed so that the eastern corner of Grid A was the western corner of Grid B. These grid edges also ran at 315 degrees and 45 degrees (Fig. 1). The vegetation on the first 110 m of the 25-trap line was characterized by grasses. The rest of the transect and the 2, 7 X 7 grids were dominated by yellow and white sweet clover and several species of thistles.

Site 2: Bicentennial Prairie (SNA); T141N, R45W, SW 1/4 of S5; Clay County, MN

This site had scattered hills which were mainly due to past sand and gravel excavation. The soil was sandy with areas of exposed gravel. Due to heavy rains, parts of this site and the surrounding area were periodically very moist over the summer. The vegetation consisted mainly of grasses, including wheatgrass, big and little bluestem, sideoats grama, blue grama, bluegrass, needle-and-thread, sand dropseed, and porcupine-grass. Many forbes were also present. These included: wormwood, several species of thistle, purple coneflower, fleabane, blaring star, prairie coneflower, harebell, palespike lobelia, lead plant, ground-plum, purple prairie clover, white and yellow sweet clover, breadroot scurf-pea, wild onion, northern bedstraw, and ground cherry (Appendix H). The area directly north of this site was used for sand/gravel excavation by a private landowner and the area directly west was Clay County land used for sand/gravel excavation.

The 25-trap line began at 13.5 m, 115 degrees from the NW corner of the SW 1/4 of section 5 and ran 170 degrees south. The topography of the first 140 m of the transect was flat and contained all the plant species listed above. The next 70 m were along the top edge of a black dirt hill dominated by tall grasses. The last 30 m were characterized by exposed gravelly soil and sparse yellow and white sweet clover.

Site 3: Brad Bjerken (B-B Ranch); T141N, R45W, S19; Clay County, MN

This gently rolling area was characterized by sandy soil. The area was used for grazing, making the vegetation difficult to identify. Species identified included fringed sage, prairie coneflower, needle-and-thread, and the prairie wild rose. The area around this site was used for agriculture and gracing.

The 25-trap line ran at 80 degrees and began 15 m from a pole denoting a Viking Gas high pressure gas line. This pole was located directly west of a section line road which separates Keene Township (T141N, R45W) Section 19 and Flowing Township (T141N, R46W) Section 24 and was approximately 400 m north of the border between Keene Township Sections 19 and 30.

Site 4: Bluestem Prairie (SNA and TNC); T139N, R46W, W 1/2 of S23; Clay County, MN

This site was slightly more elevated than the surrounding area. Two, 7 X 7 trap grids and 1 preliminary 25-trap line were set up at this site (Fig. 2). Several species of plants were located on both grids. These included common witchgrass, bluegrass, fringed sage, needle-and-thread, prairie wild rose, spiderwort, prairie sand reed, wheatgrass, several species of aster and sedges, blue grams, Junegrass, pubescent wheatgrass and smooth brome (Appendix B). Blazing star, curly-top gumweed, crested wheatgrass, slender wheatgrass, Kentucky bluegrass, barnyard grass, and milkweed were

unique to Grid A, while white and yellow sweet clover, goldenrod, western wheatgrass, wild aster, sideoats grama, big bluestem, wormwood, hoary vervain, and purple prairie clover were unique to Grid B. Thistles were much more prevalent on Grid B than on Grid A. The area surrounding this site was used for agriculture and grazing.

Trap 1 of the first 7 X 7 grid (Grid A) was placed 87.7 m, 268.5 degrees from a utility pole just inside the entrance to Bluestem Prairie (Appendix D). The grid edges ran at 0 degrees and 270 degrees. A patch of trees and an old house were located NE of Grid A. The 25-trap line was placed to the west of this original 7 X 7 grid and ran at 345 degrees. The southeast corner of the second 7 X 7 grid (Grid B) was 85 m, 320 degrees from the NW corner of Grid A, with its edges running at 255 and 345 degrees. A sand and gravel hill was located 227 m, 272.5 degrees from the NW corner of Grid B.

Site 5: Keith Hansen; T139, R45W, NW 1/4 of S29; Clay County, MN

This site was an abandoned gravel quarry which consisted of a deep center pit of exposed gravel surrounded by elevated areas of sandy to gravelly soil, with sparse to dense vegetation and areas of exposed gravel. The vegetation at this site included milkweed, wild aster, curly-top gumweed, brown-eye susan, goldenrod, goat's beard, white and yellow sweet clover, death camass, slender wheatgrass, intermediate wheatgrass, smooth brome, barnyard grass, bluegrass, sand dropseed, and curly dock (Appendix B). Elm, cottonwood, and young willow were also noted. The latter 2 species were both found in low lying areas, but because of the porous nature of the soil, there was no standing water. The area surrounding this site was used for agriculture.

Because of this terrain, the 25-trap line was separated into 2, "L"-shaped trap lines. Line 1 consisted of trap stations 1-12, and Line 2 consisted of trap stations 13-25. Trap Station 1 of Line 1 was located in a clump of trees where boulders had been dumped west of the central pit area. This line ran at 100 degrees for 70 m and then at 10 degrees for 40 m. Line 2 began in a southwest area of the central pit 166 degrees from Trap Station 8 (corner of Line 1) and ran at 190 degrees for 70 m and then at 100 degrees for 50 m.

Site 6: Moorhead State Regional Science Center; T139N, R46W, SW 1/4 of S12; Clay County, MN

This gently rolling area, characterized by sandy soils, was previously a plowed field and is now dominated by brome. The 25-trap line ran east to west up a small hill, across the top, and down the other side. The area surrounding this site was Regional Science Center and Buffalo River State Park land.

APPENDIX B: PLANT SPECIES LIST

Appendix B: Plant species list for sites studied during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. This list is not comprehensive. Common and scientific names were taken from The Great Plains Flora Association (1986). Numbers refer to the study site number in which that species was noted (Table 3). Asterisk (*) denotes plants found at capture sites of northern grasshopper mice.

FAMILY SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER
ASCLEPIADACEAE		
Asclepias sp. L.	milkweed	4,5
ASTERACEAE		
Artemisia fringida Willd.	fringed sage*	1,3,4
Artemisia absinthium L.	wormwood	2,4
Aster spp. L.	wild aster*	4,5
Cirsium spp. P. Mill	thistle*	1,2,4
Cirsium arvense (L.) Scop.	Canadian thistle	2,4
Cirsium vulgare (Savi) Ten.	bull thistle	1
Echinacea sp. Moench	purple coneflower	2
Erigeron sp. L.	fleabane	2
Grindelia squarrosa (Pursh) Dun.	curly-top gumweed	4,5
Liatris sp. Schreb	blazing star	1,2,4
Ratibida sp Raf.	prairie coneflower	1,2,3
Rudbeckia triloba L.	brown-eye Susan	5
Solidago spp. L.	goldenrod*	1,4,5
Tragpogon dubius Scop.	goat's beard	1,5

FAMILY SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER
CAMPANULACEAE		
Campanula rotundifolia L.	harebell	2
Lobelia spicata Lam.	palespike lobelia	2
COMMELINACEAE		
Tradescantia sp. L.	spiderwort*	4
CYPERACEAE		
Carex spp. L.	sedge*	4
FABACEAE		
Amorpha canescens Pursh	lead plant	1,2
Astragalus crassicarpus Nutt.	ground-plum	2
Dalea purpurea Vent.	purple prairie clover	1,2,4
Melilotus alba Medic.	white sweet clover*	1,2,4,5
Melilotus officinalis (L.) Pall.	yellow sweet clover*	1,2,4,5
Psoralea esculenta Pursh	breadroot scurf-pea	2
IRIDACEAE		
Sisyrinchium angustifolium P. Mill	blue-eyed grass	1
LILIACEAE		
Allium drummondii Regel	wild onion	2
Zigadenus sp. Michx.	death camass	5
POACEAE		
Aoropyron sp. Gaertn.	wheatgrass*	1,2,4
Aaropyron caninum (L .) Beauv. ma ius (Vasey) C. L. Hitchc.	slender wheatgrass	4,5

FAMILY SCIENTIFIC NAME NUMBER	COMMON NAME	STUDY SITE
Agropyron cristatum (L.) Gaertn.	crested wheatgrass	4
Agropyron intermedium (Host) Beauv.	intermediate wheatgrass	5
Acropyron smithii Rydb.	western wheatgrass*	4
Andropogon gerardii Vitman	big bluestem*	2,4
Androvocon scoparius Michx.	little bluestem	1,2
Bouteloua curtipendula (Michx.) Torr.	sideoats grama*	2,4
Bouteloua stracilis (H. B. K.) Lag. ex Griffiths	blue grama*	2,4
Bromus inermis Leyss. inermis	smooth brome*	1,4,5
Bromus spp. L.	brome	6
Buchloe dactvloides (Mutt.) Engelm.	buffalo grass*[a]	4
Calamovilfa longifolia (Hook.) Scribn.	prairie sandreed*	4
Echinochloa crusgalli (L.) Beauv.	barnyard grass	4,5
Koeleria pyramidata (Lam.) Beauv.	Junegrass	4
Panicum capillare L.	common witchgrass*	1,4
Poa sp. L.	bluegrass*	2,4,5
Poa Pratensis L.	Kentucky bluegrass	4

FAMILY SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER
Setaria alauca (L.) Beauv.	yellow foxtail*	1
Sporobolus cryptandrus (Torr.) A. Gray	sand dropseed	2,5
Stipa comata Trin. & Rupr.	needle-and-thread*	1,2,3,4
Stipa spartea Trin.	porcupine-grass	2
POLYGONACEAE		
Rumex crispus L.	curly dock	5
ROSACEAE		
Rosa arkansana Porter	prairie wild rose	1,3,4
RUBIACEAE		
Galium boreale L.	northern bedstraw	2
SALICACEAE		
Populus sp. L.	cottonwood	5
Salix sp. L.	willow	5
SCROPHULARIACEAE		
Verbascum thapsus L.	common mullein*	1
SOLANACEAE		
Phvsalis sp.	ground cherry	2
ULMACEAE		
Ulmus sp. L.	elm	5

FAMILY SCIENTIFIC NAME	COMMON NAME	STUDY SITE NUMBER
VERBENACEAE		
Verbena stricta Vent.	hoary vervain*	4

[a] Unverified field identification.

APPENDIX C: FIELD FORM

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SMALL MAMMAL TRAPPING FIELD FORM

Page____of____

Date__________ Weather________________________
Observers______________________________________
Study Plot Number________ Round Number__________
Study Plot Location______________________________
County_________________ T______ R______ S______

Donna Bruns Stockrahm
Moorhead State University
Biology Department
Moorhead, MN 56563
(218) 236-2576

Station	Quad	Trap Size	Habitat	Runway	Species	Animal Number	Sex	Age	Weight (g)	Tail (mm)	Breeding Condition

APPENDIX D: STUDY SITE MAPS

STUDY SITE 1 DESIGNATED AS: ●

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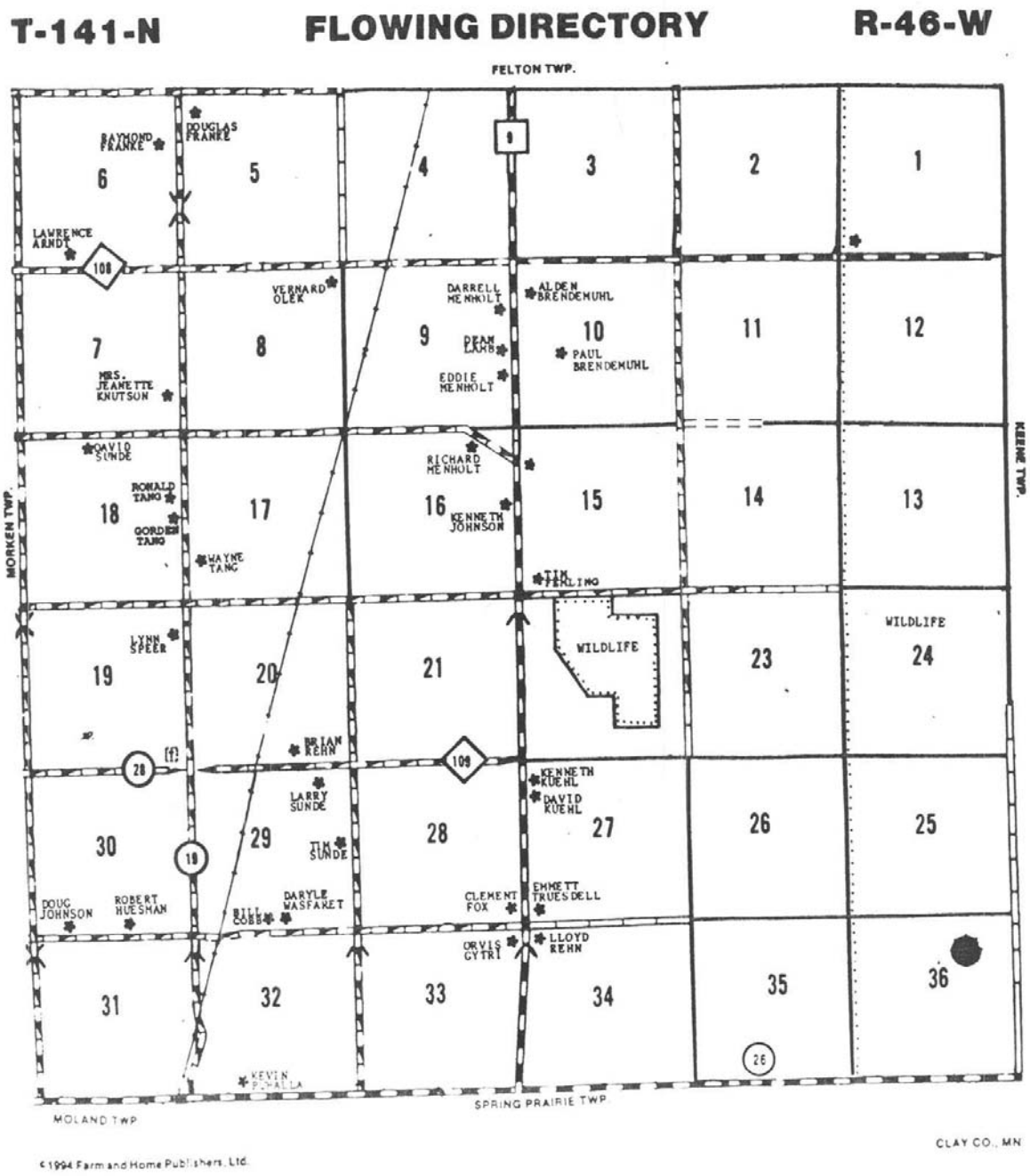
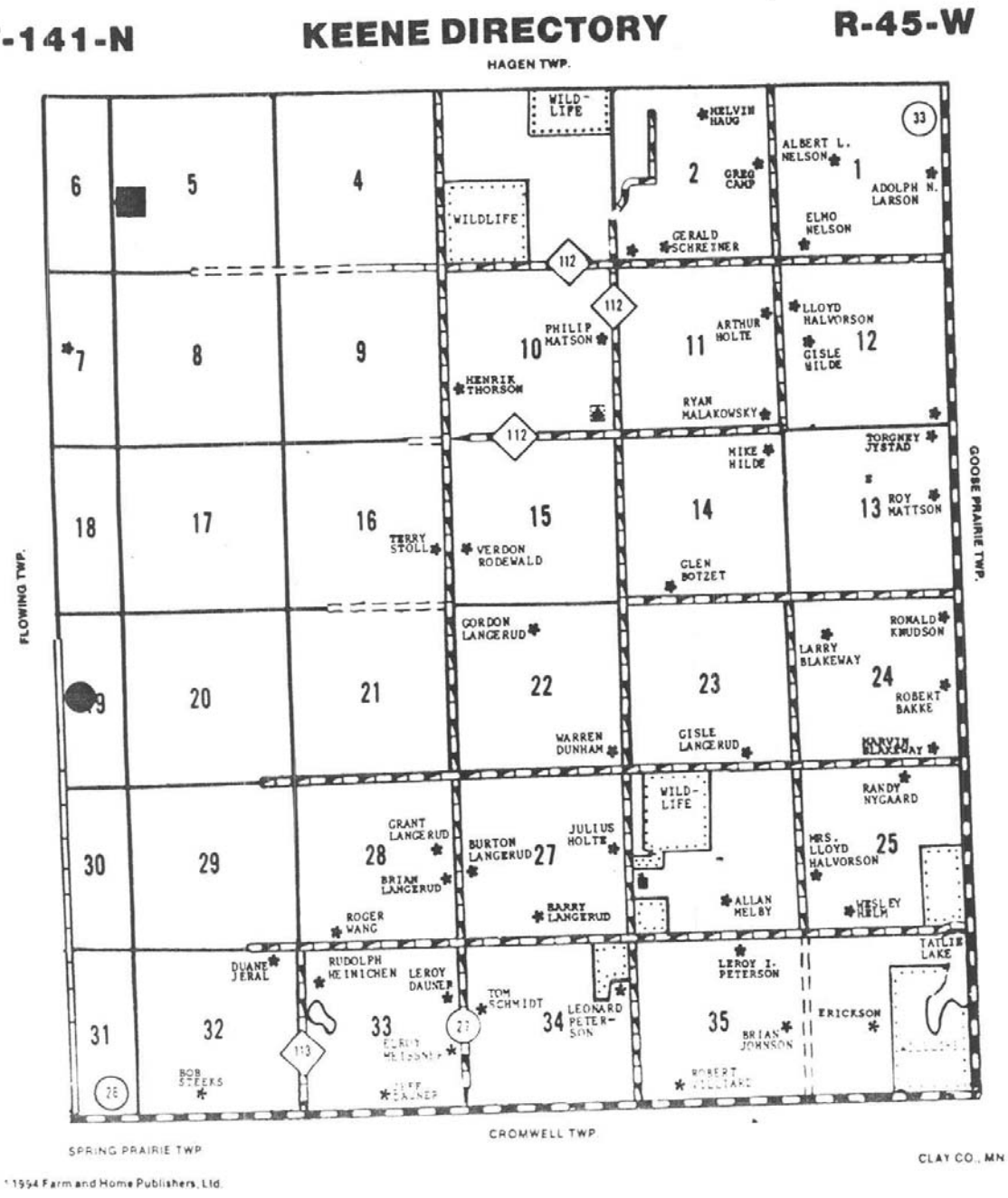


STUDY SITE 2 DESIGNATED AS: ■

STUDY SITE 3 DESIGNATED AS: ●

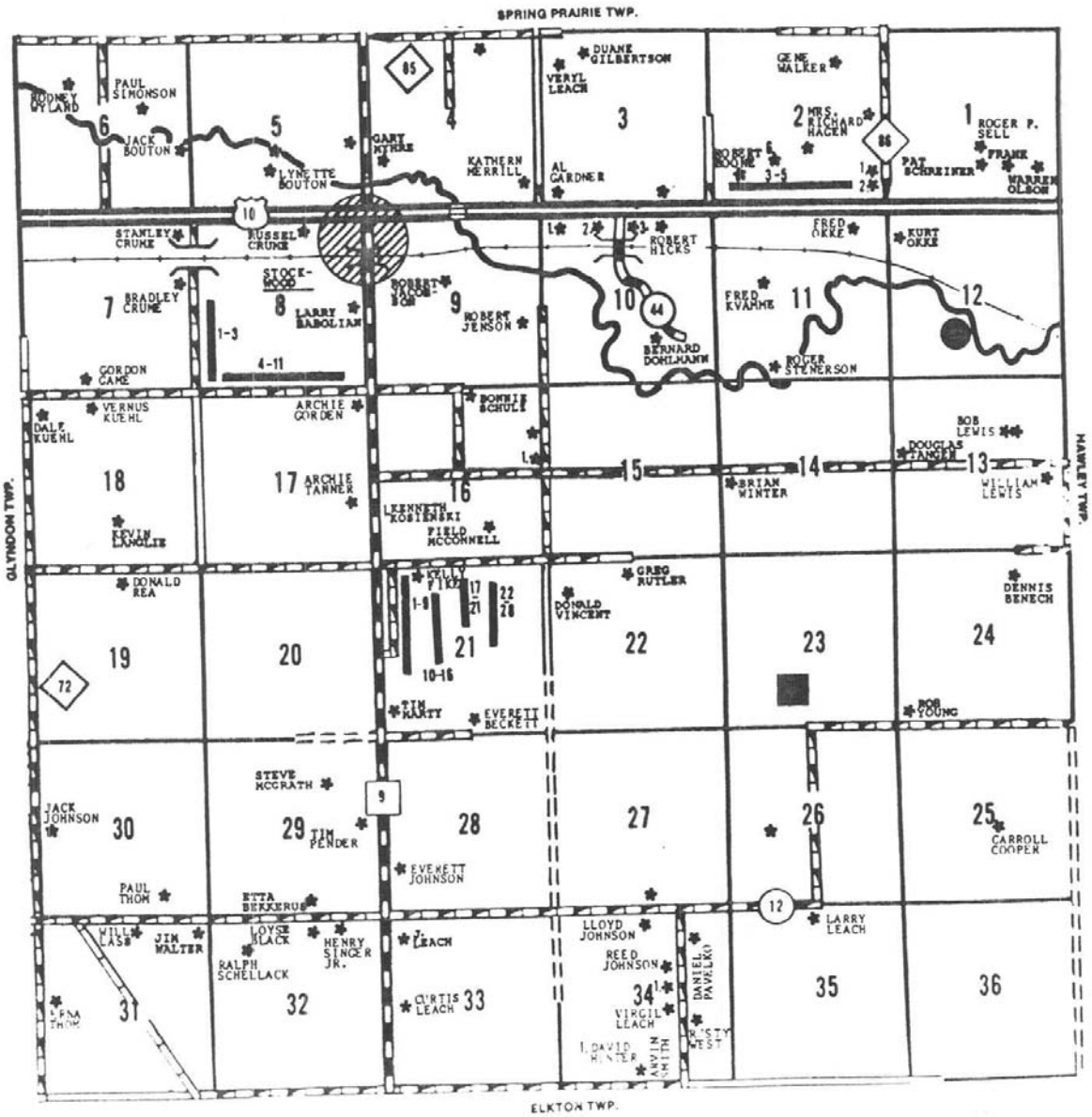


61

STUDY SITE 4 DESIGNATED AS: ■

STUDY SITE 6 DESIGNATED AS: ●

T-139-N **RIVERTON DIRECTORY** **R-46-W**



See Pages 20-21 For Additional Names.

CLAY CO., MN

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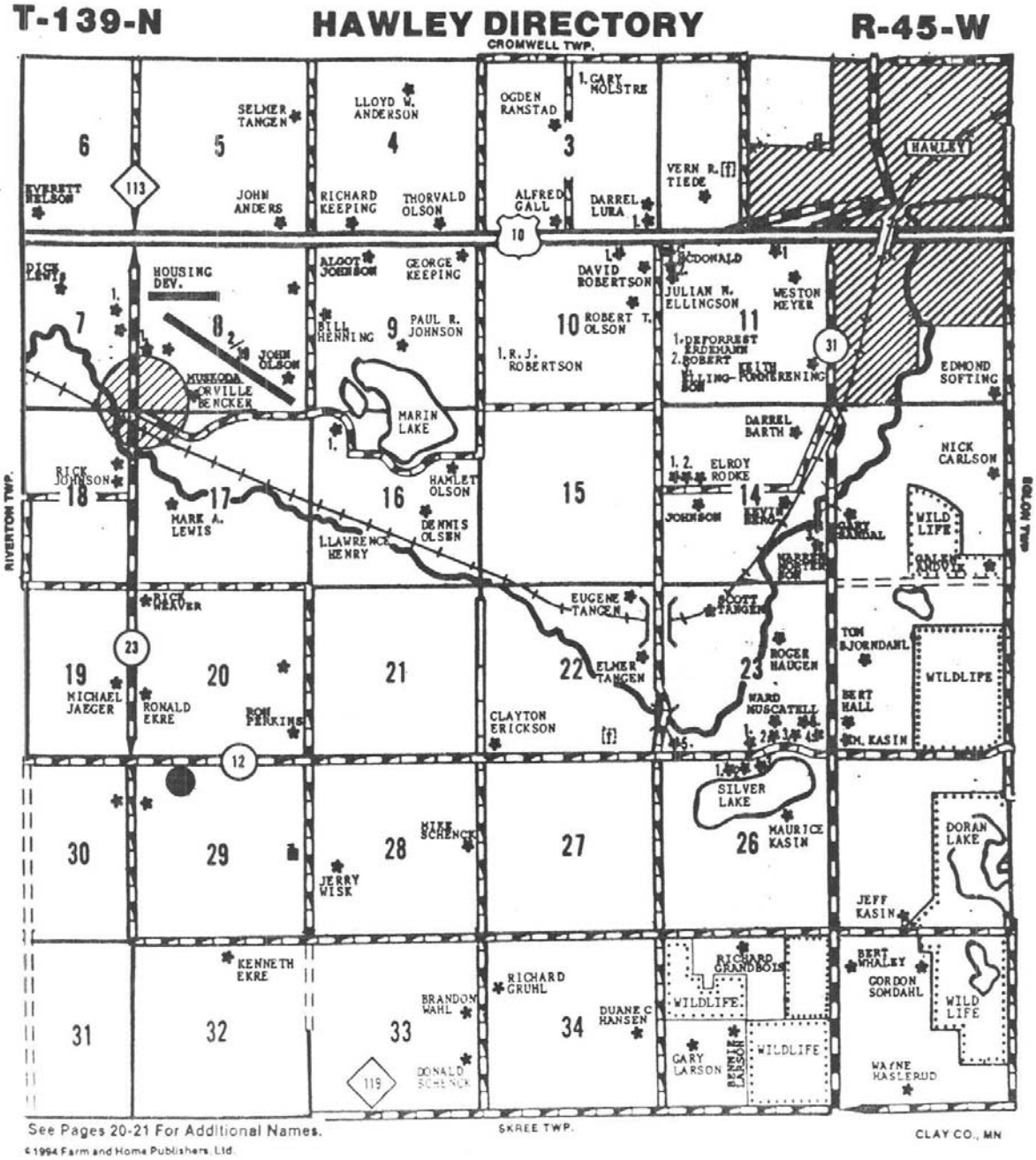
STUDY SITE 5 DESIGNATED AS: ●



APPENDIX E: POTENTIAL STUDY SITES

Appendix E. List of potential study sites in Clay County, Minnesota for future studies on northern grasshopper mice. Most of these sites have not been checked by the researchers for signs of this species.

TITLE/OWNER	T.	R.	S.
Koat Bros., Inc.	138N	46W	9,10,22,27
Manston, Harlan	138N	46W	27
Lunder, Floyd	139N	44W	7
Oliver, Dean A.	139N	44W	5,6
Burlington Northern	139N	45W	17
Dittmer, Edwrd	139N	45W	7
Ekre, Ronald K.	139N	45W	20
Johnson, Rick	139N	45W	18
Lewis, Robert	139N	45W	17
Buffalo River State Park	139N	46W	11,14
Kost Bros., Inc.	139N	46W	3
The Nature Conservancy	139N	46W	22
Allen, Francis	139N	47W	32
Benedict Farms	139N	47W	32
Connelly, Ruth	139N	47W	32
Fitzgerald, Ronald	139N	47W	32
Glyndon Co. Farms	139N	47W	17
Zimmerman, Ronald	139N	47W	32
Henning, Catherine	140N	45W	32
Krabbenhoft, Paul	140N	45W	31
Lewis, Robert	140N	45W	32
Loock, Vernon	140N	45W	31
Minnesota State Land	140N	45W	32
Slager, Jerome	140N	45W	30
Sliper, John	140N	45W	30
Spiesz, O. W.	140N	45W	30
Ames Sand & Gravel, Inc.	140N	46W	2
Kost Bros., Inc.	140N	46W	13,23
Peters, George	140N	46W	12
Schultz, Rick	141N	44W	8
B-B Ranch, Inc.	141N	45W	7,8
Clay County Land	141N	45W	6
RDO Farms, Inc.	141N	45W	29,30
Reyelts, William	141N	45W	29

TITLE/OWNER	T.	R.	S.
RDO Farms, Inc.	141N	46W	25
Williams, Fred, Jr.	141N	46W	25
Braseth, Steven W.	142N	44W	4
Opsahl, Jeffery	142N	44W	4
Clay County Land	142N	45W	31
Hanson, Lester	142N	45W	33
Kost Bros., Inc.	142N	45W	32
Mjolsness, Daniel 8.	142N	45W	33

APPENDIX F: FAUNAL SPECIES LIST

Appendix F. Faunal species which were captured or sighted on/near the study sites during the 1993 northern grasshopper mouse study conducted in Clay County, Minnesota. Signs (e.g., tracks, feces, and burrows) were also noted. Numbers refer to study site numbers where species and/or sign were observed (Table 3). "x" denotes animals sighted while traveling to or from the study sites.

CLASS FAMILY SPECIES	CAPTURED	OBSERVED	SIGN
MAMMALIA			
CANIDAE			
Canis latrans coyote		1[a]	1[b]
Urocyon cinereoargenteus gray fox		x[c]	
Vulpes fulva red fox		x[d]	
fox sp.		x[e]	
CERVIDAE			
Alces alces moose		2,x[f]	
Odocoileus virginianus white-tailed deer		1,2,4	1,5
CRICETIDAE			
Microtus ochrogaster prairie vole	1		
Microtus pennsylvanicus meadow vole	1,2,4,6		
Onychomys leucogaster northern grasshopper mouse	1,4	2[g]	
Peromyscus leucopus white-footed mouse	1[b]		
Peromyscus maniculatus deer mouse	1,2,4,5,6		1[i]

SPECIES	CAPTURED	OBSERVED	SIGN
CLASS			
FAMILY			
GEOMYIDAE			
Geomys bursarius or Thomomys talpoides pocket gopher			1,2,4[j]
LEPORIDAE			
Lepus townsendii white-tailed jack rabbit		1	1[k]
MUSTELIDAE			
Mephitis mephitis striped skunk		3[l]	1[n]
Taxidea taxus badger			4[n]
SCIURIDAE			
Marmots monax woodchuck			5°
AVES			
ACCIPITRIDAE			
Circus cyaneus northern harrier		1,2,3	
Buteo swainsoni Swainson's hawk		x[p]	
Buteo jamaicensis red-tailed hawk		4,5[q]	
ALAUDIDAE			
Eremophila alpestris, horned lark		1	
FRINGILLIDAE			
Junco hyemalis "slate-colored" junco		5	

CLASS FAMILY SPECIES	CAPTURED	OBSERVED	SIGN
PARULIDAE			
Dendroica Petechia yellow warbler		2	
PHASIANIDAE			
Phasianus colchicus ring-necked pheasant		x[r]	
SCOLOPACIDAE		3	
Limosa fedoa marbled godwit			
TURDIDAE			
Sialia sialis eastern bluebird		4	
AMPHIBIA			
BUFONIDAE			
Bufo cognatus great plains toad		5	
Bufo woodhousei woodhouse's toad		1	
RANIDAE			
Rana sylvatica wood frog		5	
ARACHNIDA		[s]	
PHALANGIDA (ORDER) daddy-long-legs			
INSECTA			
APIDAE			
Apis mellifera honey bee			

CLASS FAMILY SPECIES	CAPTURED	OBSERVED	SIGN
ARCTIIDEA *Isia isabella* woolly bear caterpillar			
CARABIDAE *Pterostichus* spp. common black ground beetles			
CULICIDAE mosquitoes			
FORMICIDAE ants			
PENTATOMIDAE *Acrosternum hilare* green stink bug			
RHOPALIDAE *Leptocoris trivittatus* eastern boxelder bug			
Nicrophorus marginatus margined burying beetle			
SILPHIDAE *Silpha lapponica* northern carrion beetle			
SIPHONAPTERA (ORDER) spp. fleas			

CLASS

FAMILY

SPECIES	CAPTURED	OBSERVED	SIGN
TETTIGONIIDAE			
Neoconocephalus nebrascensis Nebraska cone-head		[u]	

[a] Observation reported by hunters to have taken place on the evening of 9 November 1993.

[b] Observed canid tracks, possibly coyote, on several occasions, including tracks observed in fresh snow on 10 November 1993.

[c] Observed 1 on Highway 9, approximately 4 mi north of Highway 10, and another on County Road 23, 1 mi north of Site 5.

[d] Observed in a field beside County Road 12, 1 mi southwest of Site 4.

[e] Observed at a distance crossing County Road 12, approximately 1 mi east of Site 4.

[f] Observed a cow and yearling calf (estimated age) on Highway 9, approximately 7.5 mi north of Highway 10.

[g] Observed probable northern grasshopper mouse running in a gravel pit. Positive identification was not made. However, habitat was similar to that of Site 1, an area of northern grasshopper mouse capture: characteristic burrows were also sighted.

[h] Examined several specimens of both deer mice and white-footed mice at Moorhead State University Wildlife Museum before identification of white-footed mouse. White-footed mice specimens appeared to have a whiter belly and a more scaly-appearing tail than did the deer mice specimens. Our identification was based mainly on these 2 criteria.

[i] Observed several tracks.

[j] Observed several mounds at Sites 1, 2, and 4. The mounds were frequently located in a line and the sizes and shapes of the mounds were more characteristic of the plains pocket gopher (Geomys bursarius) (Whitaker 1980).

[k] Observed several tracks.

[l] Found dead approximately 0.5 mi south of Site 3.

[m] Detected scent on 2 nights and observed tracks on several mornings.

[n] Observed signs of excavation on several occasions. Dirt often disturbed, but frequent rains destroyed tracks. Found fecal material, possibly from a badger, on dirt mounds. A possible badger den was also observed approximately 1.25 mi northeast of Site 3. Dirt was often disturbed at the entrance, but frequent rains destroyed tracks.

[o] Found skull.

[p] Sighted on County Road 12 near Site 4.

[q] Observed 2 at a distance. Positive identifications not made.

[r] Found dead on Highway 9, 2.3 mi north of Highway 10.

[s] Observed several species of arachnids and insects at each site. We did not identify all of the arthropod species because it was beyond the scope of this study. Members of the Order Orthoptera (grasshoppers and crickets) are of special interest because the northern grasshopper mouse's diet includes many species of this order.

[t] Observed only at Sites 1, 2 and 4.

[u] Observed at Site 4 only.

Note: We sighted additional tracks and feathers which were not positively identified. Some examples follow. Toad, bird, and small mammal tracks were noted in the mud at Site 1. A partially eaten game bird was found near the sand and gravel hill at Site 4. Tracks of a large deer or small moose and predator were noted at Site 5.