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POPULATION ECOLOGY OF FRANKLIN'S GROUND SQUIRREL IN EAST-CENTRAL ILLINOIS

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Abstract

Franklin's ground squirrel (*Spermophilus franklinii*) is declining in the eastern portion of its range, but many aspects of the ecology and behavior of the species in this region are not well known. During spring 2002, we live-trapped a small, apparently isolated, population of Franklin's ground squirrels in a 12-ha tallgrass prairie restoration located south of Urbana, Champaign County, Illinois. During the period following emergence from hibernation males used larger areas than females, and areas used by males overlapped to a high degree. Burrow systems were located most often in areas of cool season grasses with well-drained and moderately well-drained soils. Burrow systems also were often associated with trees, trash heaps, and buildings which may offer some degree of protection from predators, conspecifics, and weather. Fourteen juvenile Franklin's ground squirrels (7 males and 7 females) were radio-tracked throughout dispersal to determine how far dispersers traveled, the timing of dispersal, if dispersal distance differed between sexes, and if the agricultural matrix surrounding the study site was a barrier to the process. Males dispersed farther than females, but individuals of both sexes moved $\geq$ 1 km away from the study site. The farthest movement recorded was by a male who traveled 3.6 km. Dispersal was age-dependent for both sexes, occurring at 7-9 weeks of age. Agricultural fields did not seem to hinder movement, probably because dispersal occurred before row crops were harvested. Open areas such as roadways, however, may be barriers to some individuals.

Key Words

burrow location, census, dispersal, Franklin's ground squirrel, grassland, habitat use, home range, soil drainage

Introduction

Franklin's ground squirrel (*Spermophilus franklinii)* is declining throughout much of the Midwestern United States (Van Petten and Schramm 1972, Lewis and Rongstad 1992, Johnson and Choromanski-Norris 1992, Pergams and Nyberg 2001, Martin et al. 2003). It is listed as "endangered" in Indiana (Indiana Department of Natural Resources 1993), as a "species of special concern" in Wisconsin (Wisconsin Department of Natural Resources 1993), and as "rare" in Iowa (Bowles et al.1998). The decline of this grassland species parallels the loss of its favored habitat to agricultural practices and human encroachment (Van Petten and Schramm 1972, Lewis and Rongstad 1992). Conservation actions focused on *S. franklinii* would benefit other grassland dependent species as well, but the ecology of Franklin's ground squirrel needs to be better understood before effective and efficient management actions can be taken (Martin et al. 2003).

It is often difficult to locate populations of *S. franklinii* to assess the relative regional abundance of the species; however, once populations are found, they are very trappable and readily studied (Sowls 1948). Franklin's ground squirrels prefer the thick vegetation of tallgrass and mid-grass prairies and are rarely seen in open areas (Haberman and Fleharty 1972, Hall 1981, Ellis 1982, Jones et al. 1983, Hoffmeister 1989, Benjamin 1991, Kurta 1995). Locating the species is further complicated by its

patchy distribution throughout much of its range in the Midwest. Habitat descriptions for *S. franklinii* in the literature are generally broad. A more specific examination of habitat used by Franklin's ground squirrel, including preferred vegetation types and cover requirements, would help focus survey efforts and provide clear management goals.

The presence of well-drained soils is an important factor in the suitability of an area for burrowing mammals, such as Franklin's ground squirrel. Haberman and Fleharty (1972) noted that *S. franklinii* in Nebraska occupied an area that had silty, well-drained soils. Benjamin (1991) determined that soil characteristics affected the location of burrows in Indiana as well. Micro-topographic features also may provide drier locations for burrows. Other studies have found that *S. franklinii* often excavate burrows in the mounded substrate of raised railroad beds (Ellis 1982, Benjamin 1991, Johnson and Choromanski-Norris 1992, Martin et al. 2003).

Large, cover-providing objects such as shrubs or buildings may benefit ground squirrels by offering protection from predators, weather, and conspecifics. Wistrand (1974), Murray and Vestal (1979), Kaufman and Kaufman (1989), and Koprowski (1989) all showed a relationship between the placement of *S. tridecemlineatus* burrows and tombstones, large rocks, and trees. Similar forms of cover also were a determining factor of beechey ground squirrel (*Spermophilus beecheyi*) burrow locations (Fitch 1948, Owings and Borchert 1975). Kennicott (1857), Sowls (1948), Ellis (1982), Jones et al. (1983), Erlien and Tester (1984) and Choromanski-Norris, et al. (1989) all noted that individual trees, tree lines, and shrubs were present in areas occupied by Franklin's ground squirrels, but did not describe them as sources of cover.

Murie (1973) hypothesized that the social organization and behavior of Franklin's ground squirrels differ from that of other ground squirrel species. Haggerty (1968), Murie (1973), Ellis (1982), and Martin et al. (2003) found the sex ratio of adult populations to be near 1:1, but other ground squirrel species tend to have more females than males (Evans and Holdenried 1943, McCarley 1966, Mayer 1953, Sheppard 1972). The sex ratio of *S. franklinii* may be a consequence of similar dispersal rates of male and female juveniles (Martin et al. 2003). If this is true, then the persistence of individual populations may be more dependent on a regional metapopulation structure than if juvenile females were strongly philopatric.

The remnants of Midwestern grassland habitat occur in a highly fragmented state within an agriculturally dominated matrix. To persist in this landscape, grassland-dependent species must be able to utilize relatively small, sometimes isolated, patches of habitat and have the ability to move through the matrix to other patches. No studies have examined the dispersal abilities of juvenile Franklin's ground squirrels or the possible dependence of local colonies on a regional metapopulation. It is not clear how far individuals are able to disperse or if the structure of matrix habitat is a limiting factor of dispersal.

In this study, we examined the placement of Franklin's ground squirrel burrows of a single population in the context of vegetation type and structure, soil drainage characteristics, and the presence of large cover-providing objects. We also conducted a live-trapping census of the population during April and May. Capture locations were used to estimate the area and type of habitat used by adults during this period. Fourteen juvenile Franklin's ground squirrels were radio-collared and tracked throughout the

dispersal process to examine the demography of dispersers, the timing of dispersal, how far animals will travel, and if the agricultural matrix is a barrier to the process.

Study Site

The Barnhart Grove Prairie is a 12-ha tallgrass prairie restoration located 3 km south of Urbana, Illinois that is maintained by the Barnhart Grove Prairie Restoration Project, a not-for-profit corporation, in conjunction with the Champaign County Soil and Water Conservation District and the Illinois Department of Natural Resources. The Barnhart Prairie is known to harbor a population of Franklin's ground squirrels (Martin et al., 2003). Four distinct areas of established tallgrass prairie occurred on the study site: the North Prairie (NP = 2.95 ha), the West Prairie Circle (WPC = 0.91 ha), the South Prairie Circle (SPC = 0.82 ha), and the Southeast Prairie (SEP = 1.14 ha), all of which were seeded with warm season prairie grasses and forbs between 1987 and 1990. These areas were bordered by grassy fields associated with a farm homestead, which were dominated primarily by brome grass (*Bromus* spp.). We refer to the three largest areas of non-prairie fields as Driveway (D), a 400-m long, 15-m wide strip of unmowed grass along the gravel road leading to the homestead; House (H), the 1.53-ha grassy area that surrounded the house and outbuildings; and South Brome (Sbr), a 1.83-ha area of unmowed grass around WPC, SPC and SEP. We defined the study site as all non-agricultural areas of the Barnhart Prairie (NP, WPC, SPC, SEP, D, H, and Sbr).

In the past, H had been mowed regularly but in 2002 the homestead was unoccupied for the first half of the summer and the yard was allowed to grow naturally until the end of July, at which time it was mowed again. During summer 2002, an

additional 8-ha strip of land was seeded with warm season grasses and forbs along the western edge of the homestead. Agricultural fields planted with either corn (*Zea mays*) or soybeans (*Gycine max*) surrounded the entire site. A map of the Barnhart Grove Prairie was digitized from Illinois Digital Orthophoto Quadrangles (Illinois Department of Natural Resources Geospatial Data Clearinghouse 1998/1999) using ArcView 3.2a (Environmental Research Systems Institute 2000) (Fig. 1).

The Barnhart Grove Prairie was situated atop Yankee Ridge, a moraine of the Wisconsin glaciation. Soil types present on the property were identified using Soil View 2.0 (U.S. Department of Agriculture, Natural Resources Conservation Service and the Illinois Cooperative Soil Survey 2001). Well-drained and moderately well-drained soils characteristic of moraines covered most of the property (Wyanet silt loam, Catlin silt loam, Dana silt loam, and Blackberry silt loam) (Fig. 2).

Methods

Location of burrow systems

From late January through early April 2002, we searched the Barnhart Prairie intensively for Franklin's ground squirrel burrows. Burrow entrances, measuring roughly 8 cm in diameter (Haberman and Fleharty 1972), could easily be seen during this time of year due to the paucity of vegetation that normally conceals them during the growing season. In areas where thick plant matter still covered the ground, burrow openings were located by feeling for them with our feet while walking transects. H had been mowed at the end of the previous year and NP was burned in early April 2002, which greatly facilitated the search for burrows in these two areas.

The locations of all burrow openings were recorded using a GeoExplorer3 GPS unit (Trimble Navigation Limited). These points were differentially corrected to within one meter using data from the University of Illinois GPS community base station and were mapped using ArcView 3.2a (Fig. 2). Burrow entrances clustered within 5-10 meters of each other were assumed to constitute burrow systems. All burrow systems were examined on 20 May and again on 24 June for signs of ground squirrel activity such as unobstructed entrances, nearby runways, fresh dirt piles, and the presence of food waste such as seed husks.

We grouped the "well-drained" and "moderately well-drained" soil types present on the site into the single category "drained" and defined all other soil types as "non-drained". We then categorized placement of burrow systems in relation to four habitat types: drained prairie, non-drained prairie, drained cool season grass and non-drained cool season grass. To examine selectivity in the location of burrow systems, we used a chi square test to compare the number of burrow systems in each habitat type to the expected number of burrow systems based on the relative area of each habitat.

A second chi square test was used to examine selectivity of burrow system placement in relation to large, cover-providing objects. We counted the number of burrow systems within a 5-m buffer around all trees, trash heaps, and buildings on the site and compared this number to the expected value based on the total buffered area.

Live-trapping of resident adults

Beginning 5 April 2002, 10 single-door, collapsible Tomahawk live traps (Tomahawk Live Trap Co., Tomahawk, WI), 48 x 16.5 x 16.5 cm in size, were placed

near burrows in D, H, SPC, and Sbr to determine if Franklin's ground squirrels had emerged from hibernation. The traps were baited with peanut butter and sunflower seeds. They were opened around 0800 h, examined at 1200 h, and examined again and then closed at approximately 1700 h.

On 9 April, following the first capture of a Franklin's ground squirrel, we placed 38 traps in the south half of the study site. We set traps near ground squirrel burrows to increase the likelihood of capture. Every Franklin's ground squirrel captured was uniquely marked using human hair dye (Lady Clairol Blue-Black No. 124), and sex, reproductive condition, general physical condition, and weight (to the nearest 5 grams using a Pesola spring scale) were recorded. Some traps were moved to new burrows following the repeated capture of an individual.

Traps were opened 3-4 days per week for two weeks following the schedule previously outlined. On 22 April all traps were moved to the north half of the property. The traps were rotated between the south half and the north half of the study site every two weeks through the end of May at which time no new individuals were being caught. The distance between the two points of capture farthest from each other was calculated for each squirrel as an indicator of the size of the area used by each animal. The difference between the averages of these distances for males and females was compared using a t-test. Minimum convex polygon home ranges also were constructed for each individual based on re-capture locations.

Monitoring juvenile dispersal

We define dispersal as a broad range of one-way movements by an animal away from a home site (Stenseth and Lidicker 1992). Dispersal of juvenile Franklin's ground squirrels therefore occurs when their areas of use permanently shift away from their natal burrow sites.

Traps were placed near the burrows of pregnant females beginning 6 June. When juveniles were captured or seen near a burrow, additional traps were placed in the vicinity. Sex and weight were recorded for all juveniles captured and a small patch of fur was clipped from the rump of each individual to identify previously captured animals.

Model M1540 radio transmitters (Advanced Telemetry Systems, Inc.) were attached to fourteen juvenile ground squirrels (7 males and 7 females). We initially intended to collar one male and one female from each litter. However, soon after weaning, juveniles appeared to use multiple, shared burrow systems, making the identification of littermates difficult. We attempted to minimize any confounding effects of relatedness or location of origin on the likelihood of dispersal by selecting individuals from burrow systems distributed throughout the study site.

The transmitters were mounted on plastic cable ties that were sized to the neck circumference of adult Franklin's ground squirrels. The collars were fit to the neck circumference of the juveniles using foam padding, which allowed for expansion of the collars as the animals grew. The collars each weighed 4 g and were attached to squirrels weighing ≥170 g; therefore the collars never exceeded 3% of the mass of each animal. Extrapolating from the growth curve of Franklin's ground squirrels described by Sowls (1948), at this time the squirrels were between 7-9 weeks old.

Radio-collared squirrels were located 3-5 days per week using an ATS radio receiver and both a hand-held three-element Yagi antenna and a vehicle-mounted Yagi antenna system until either the animals began hibernation or their signals were lost. Once a signal was detected, the location of the squirrel was pinpointed by walking to the animal using the hand-held antenna. Locations were determined in the morning between 0700-0800 h, prior to the animals emerging from their burrows for the day, and again between 1200-1700 h while they were active above ground. Animals making long distance movements were located more often if possible. All locations were recorded using a Garmin eTrex Vista GPS unit (Garmin International, Inc.) with an accuracy of five meters. Radio-tracking was conducted 17 July-2 September, after which all fourteen juveniles had disappeared or begun hibernation.

Parturition took place over a 3-4 week period based on the continuing appearance of new individuals weighing <170 g throughout the last three weeks of July. Even though initial collaring dates varied among individuals (17 July-6 August), we assumed that since the animals all weighed the same when they were collared, they also were approximately the same age and therefore their movement patterns were comparable.

The period in which each animal was monitored was divided into 5-day blocks. Within each of these blocks the arithmetic mean for all location points was calculated to determine the center of activity during that period. The distances between the centers of activity for each consecutive block were used to examine movement patterns. Total distances of dispersal were calculated as the difference between the first and last centers of activity.

Results

Location of burrows

We located 215 individual burrow entrances that constituted 82 burrow systems (Fig. 2). As of 20 May, 26 of these burrow systems were active, all but two of which were located in the non-prairie grass areas. By 24 June, the number of burrow systems being used increased to 42, including twelve in the prairie plots (Table 1). With the exception of those in H, burrow systems usually had 2-5 entrances. Systems located in H had 5-8 openings, and these openings were spaced farther apart than those in other parts of the property (Table 1, Fig. 2).

The number of burrow systems in the four habitat types (drained prairie, non-drained prairie, drained cool season grass, non-drained cool season grass) were not based on the area of available habitat ($\chi^2 = 26.42$, df = 3, $P < 0.05$). There were fewer burrow systems than expected in non-drained prairie and more burrows than expected in drained grass (Table 2). Placement of burrow systems also was not random in relation to large cover objects ($\chi^2 = 41.8$, df = 1, $P < 0.05$). More than one-third (25/82) of the burrow systems were located within 5 m of trees, trash heaps, and buildings, whereas this habitat was only 9.5 % of the study area (Table 3).

Live-trapping of resident adults

The first Franklin's ground squirrel (Male 1) was captured in H on 9 April. This individual was re-captured six times in April, but no other animals were seen until 23 April at which time the first female and 3 additional males were captured. In total, 19

squirrels (9 males and 10 females) were trapped on the study area. All males were scrotal and five had wounds on their rumps, presumably the result of disputes with other males.

All individuals, with the exception of Male 7 and Female 2, were captured ≥3 times (range 1-11, mean ± SD = 4.3 ± 2.3). Males and females were captured in most of the available prairie and grass habitats. During April and May the average distance between the farthest points of capture for males was 344 ± 106 m, whereas for females it was only 71 ± 83 m (t = -6.14, df = 16, $P < 0.0001$) (Table 4). Only one female appeared to use an area similar in size to that of the males. There was also a high degree of overlap in the areas used by males (Fig. 3).

Monitoring juvenile dispersal

We were able to follow seven of the 14 radio-collared animals until hibernation (3 males, 4 females). The distances between the first and last centers of activity for the males were 3632 m, 1221 m, and 117 m. The distances for the females were 450 m, 196 m, 67 m, and 66 m. The first two of the males dispersed away from the study site to other small grassland patches in which we subsequently discovered other colonies of Franklin's ground squirrels. All four of the females dispersed to other areas within the study site. The third male eventually settled back on the study site after spending two days ranging at times up to 1.25 km away. Similarly, one of the females spent a day ranging 1.5 km from the study site before returning. Both of these individuals were located near the edge of nearby roadways several times during the course of their long-distance movements but were never known to cross any roads during their exploration. Their movement was limited to the agricultural fields surrounding the study site.

Four individuals (2 males, 2 females) were last located during or soon after making long-distance exploratory movements away from their original centers of activity. The distances of these movements were 614 m and 2275 m for the males, and 256 m and 1482 m for the females. All of these distances were traveled in ≤5-6 hours. Presumably all four of these individuals were attempting long distance dispersal movements when they disappeared.

Three individuals (2 males, 1 female) were lost very early during tracking. We assumed that these losses were attributable to predation or transmitter failure since they occurred well before any of the animals had begun to exhibit exploratory movement behavior. It is notable that one of these males was an albino.

The timing of dispersal appeared to be age-dependent. When the shifts between consecutive centers of activity were averaged for all males and females within the 5-day tracking blocks, peaks occurred for both sexes in block 4 regardless of the actual dates of the movements (Fig. 4). Extrapolating from the growth curve described by Sowls (1948), the animals were 9-11 weeks old when this peak in dispersal activity occurred.

Discussion

Our finding of 2-3 entrances per Franklin's ground squirrel burrow system is consistent with the observations of Haberman and Fleharty (1972). The variation in burrow configurations in H compared to those in other areas of the study site may be the result of them originally being dug by thirteen-lined ground squirrels. Rongstad (1965) described *S. tridecemlineatus* burrows as including hiding tunnels with additional

entrances. This species has frequently been observed in the mowed areas of the site in past years.

The pattern of burrow system placement and use that we observed reflects Franklin's ground squirrel's preference for thickly vegetated habitat. The overwhelming majority of burrows used during the early part of the summer were located in D, Sbr, and in a clump of grass in the northwest corner of H that had not been mowed during the previous fall. Cool season grasses, primarily *Bromus* spp., were the predominant ground cover in these areas. By the time that the squirrels emerged from hibernation, these grasses provided ample cover and a plentiful source of food and nesting material.

Cool season grasses appear to be an important element of Franklin's ground squirrel habitat in that they provide the cover that the species prefers during the early part of the summer. Haberman and Fleharty (1972), Iverson and Turner (1972), and Ellis (1982) also found an association between *S. franklinii* and habitat with a cool season grass component. As Benjamin (1991) noted, Franklin's ground squirrel is not strictly dependent on native prairie systems. Management efforts aimed at conserving or restoring tallgrass prairie habitat alone may not be the best strategy for conserving Franklin's ground squirrel.

The North Prairie was burned in the spring of 2002. Several burrows were located in this plot, but ground squirrels did not use them until the grasses and forbs grew and vegetative cover was restored. Chromanski-Norris et al. (1989) also found that Franklin's ground squirrels avoided previously-used habitat for a period of time after it was burned. This suggests that burning should be avoided in critical Franklin's ground squirrel habitat during periods when the species is active. Similarly, burrows in the

portions of H that had been mowed during the previous fall were not used until the grass grew. The structural component of Franklin's ground squirrel habitat may be relatively simple to maintain and expand. Allowing grasses to grow unfettered, especially adjacent to areas already harboring populations of *S. franklinii*, would provide potential sources of cover.

Soil drainage characteristics have had an influence on the placement of ground squirrel burrows in the Barnhart Prairie (Fig. 2, Table 2). Twice as many burrow systems were located in drained cool season grass than expected based on the available area of this habitat. This density was much higher than that in the non-drained cool season grass or drained prairie areas implying that cover or drainage alone do not maximize the suitability of an area for *S. franklinii*. Few burrow systems were located in non-drained prairie areas. Although Franklin's ground squirrels located burrows in areas with moderate drainage characteristics and seasonally marginal cover, well-drained areas with permanent cover may serve as refuges if the suitability of marginal habitat declines.

In addition to soil characteristics, micro-topographic features seemed to play a role in the placement of burrows in the study site. Many burrow entrances were positioned on the tops of small mounds and none were located in depressions large enough to collect water. Restoring topographic relief to grassland habitat may benefit Franklin's ground squirrels.

Trees and shrubs may provide a means of escape when Franklin's ground squirrels are threatened. Both Kennicott (1857) and Sowls (1948) witnessed *S. franklinii* climbing into trelliswork and small trees when being pursued by humans or other squirrels. Twice during this study Martin witnessed a male run directly to the nearest

tree, a white mulberry (*Morus alba*), after it was released from a trap and climb to a height of about 1.5 m where it froze and flattened itself against a limb. Its gray mottled fur provided excellent camouflage against the tree bark.

Large cover-providing objects can be grouped into two categories. Horizontal cover (rocks, buildings, tree trunks, etc.) provides protection from conspecifics, terrestrial predators, and, to some extent, weather. Vertical cover (shrubs and tree canopies) shelters individuals from weather and may interfere with aerial predation. Due to small sample size we grouped all cover objects together and considered only their general protective value. Many more burrows throughout the Barnhart property were within 5 m of cover objects (trees, trash heaps, and buildings) than would be expected in a random distribution (Table 3). Cover-providing objects may improve the attractiveness of an area to Franklin's ground squirrel.

The Franklin's ground squirrels on the study site used a broader range of habitats than those selected for burrows and were routinely recaptured in several different habitat types. Areas used by individuals probably shift throughout the summer as some food sources are depleted and others become abundant. The size and type of areas used by *S. franklinii* also may change throughout the summer for social reasons. The April emergence dates that we observed concur with annual emergence dates found in other studies (Sowls 1948, Haberman and Fleharty 1972, Iverson and Turner 1972, Choromanski-Norris et al. 1986, Choromanski-Norris et al. 1989). Males appear above ground before females at which time they establish dominance relationships (Kivett et al. 1976). Mating commences as soon as the females emerge. We conducted our census during this period. Males were routinely re-captured at distances farther from their

previous capture sites than were females. Since our traps were set near burrows, males likely ranged more widely to visit a greater number of burrow systems while searching for mating opportunities. Females on the other hand seemed to use much smaller areas around single, or only a few, burrow systems (Fig. 3, Table 4). Females eventually use larger areas as they build up fat reserves for the winter, but this does not occur until after the young of the year have been weaned (Iverson and Turner 1972, Ellis 1982, Choromanski-Norris et al. 1986, Choromanski-Norris et al. 1989, Martin personal observation).

Juvenile females appeared more philopatric than juvenile males, although the number of radio-collared juveniles tracked until hibernation was small (4 of 4 philopatric females versus 1 of 3 males). However, individuals of both sexes traveled distances >1 km during dispersal or when making exploratory movements. It is not known whether dispersal distances of up to roughly 4 km, such as we observed, are typical of Franklin's ground squirrel or rather reflect the patchy, fragmented distribution of available habitat surrounding our study site. If the ability to traverse distances of 1-4 km is characteristic of *S. franklinii*, then conservation strategies that maintain suitable habitat in clustered patches may present a viable alternative to large contiguous systems.

Roadways, apparently due to their open aspect, appeared to be a barrier for some of the juveniles that we observed making long-distance movements. The crop fields surrounding the Barnhart Prairie had not yet been harvested during the dispersal period and were regularly traversed by dispersers and individuals undertaking exploratory movements. Thus, row-crops may not pose a barrier to dispersal as long as ground cover is maintained throughout July and August. Adult males begin hibernating mid-July –

August (Murie 1973, Choromanski-Norris et al. 1986, Iverson and Turner 1972, Krohne and Schramm 1994) before most juveniles have dispersed. This may result in the need for additional dispersal movements by yearlings soon after spring emergence due to territorial disputes. The lack of cover in agricultural fields during this time of year may be an impediment to movement.

Two of the males that dispersed away from our study site eventually settled into other colonies. Conspecific attraction and the presence of a regional population may be important for successful dispersal by Franklin's ground squirrel. Mortality during dispersal may increase if nearby colonies do not exist, even if patches of suitable habitat do, because dispersers may continue to move in search of conspecifics. Further research on the dispersal behavior of Franklin's ground squirrel will be critical to assess whether isolated populations can persist, or whether management should be focused on a regional scale by maintaining metapopulations.

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Table 1. Location, configuration, and activity of Franklin's ground squirrel burrow systems in the Barnhart Grove Prairie.

AREA[1]	BURROW SYSTEMS	AVGERAGE OPENINGS PER SYSTEM	ACTIVE SYSTEMS AS OF 5/20	ACTIVE SYSTEMS AS OF 6/24
NP	17	2.5	0	8
WPC	2	2.5	0	0
SPC	9	1.9	2	3
SEP	3	2.0	0	1
D	10	2.6	8	10
H	12	4.3	5	7
Sbr	29	2.3	11	13
TOTAL	**82**	**2.6**	**26**	**42**

[1] NP = North Prairie, WPC = West Prairie Circle, SPC = South Prairie Circle, SEP = Southeast Prairie, D = Driveway, H = House, Sbr = South Brome

Table 2. Use-availability analysis of Franklin's ground squirrel burrow system placement in four habitat groupings in the Barnhart Grove Prairie.

HABITAT	AREA (m^2)	BURROW SYSTEMS observed (expected)
Drained Prairie	35,105	25 (26.69)
Non-drained Prairie	23,131	7 (19.56)
Drained Grass	26,946	42 (22.79)
Non-drained Grass	11,779	9 (9.96)

Table 3. Use-availability analysis of Franklin's ground squirrel burrow system placement in relation to 5-m buffers around cover-providing objects (trees, trash heaps, and buildings).

PROXIMITY TO COVER	**AREA** (m^2)	**BURROW SYSTEMS** observed (expected)
Within 5 m of cover object	9,217	25 (7.79)
More than 5 m from cover object	87,744	57 (74.20)

Table 4. Capture, recapture data for adult Franklin's ground squirrels trapped in the Barnhart Grove Prairie from 9 April-23 May 2002.

I.D.	**Number of captures**	**Distance between farthest points of capture** (m)
Male 1	11	329
Male 2	7	347
Male 3	3	241
Male 4	6	325
Male 5	4	309
Male 6	3	322
Male 7	1	n/a
Male 8	6	594
Male 9	4	285
		Avg = 344 ± 106
Female 1	3	113
Female 2	2	26
Female 3	3	3
Female 4	4	14
Female 5	3	87
Female 6	7	282
Female 7	5	64
Female 8	4	73
Female 9	3	2
Female 10	3	46
		Avg = 71 ± 83

Figure Legend

Fig. 1. – The Barnhart Grove Prairie. The inset illustrates the location of the study site in relation to Champaign-Urbana, Illinois.

Fig. 2. – Burrow locations and drained soils on the Barnhart Grove Prairie. Differences in the number and spacing of burrow entrances in H (**1**) from those in the rest of the site, including Sbr (**2**), are probably due to the burrows in H being dug by thirteen-lined ground squirrels, whereas the rest were dug by Franklin's ground squirrels.

Fig. 3. – Minimum convex polygon home ranges for adult male and female Franklin's ground squirrels based on capture, re-capture locations collected 9 April-23 May 2002.

Fig. 4. – Shifts in centers of activity for male and female Franklin's ground squirrels during radio-tracking. Fourteen squirrels were initially collared (7 males, 7 females) but animals were lost throughout the tracking period. All squirrels were 7-9 weeks old at the beginning of block 1.

Fig. 1.

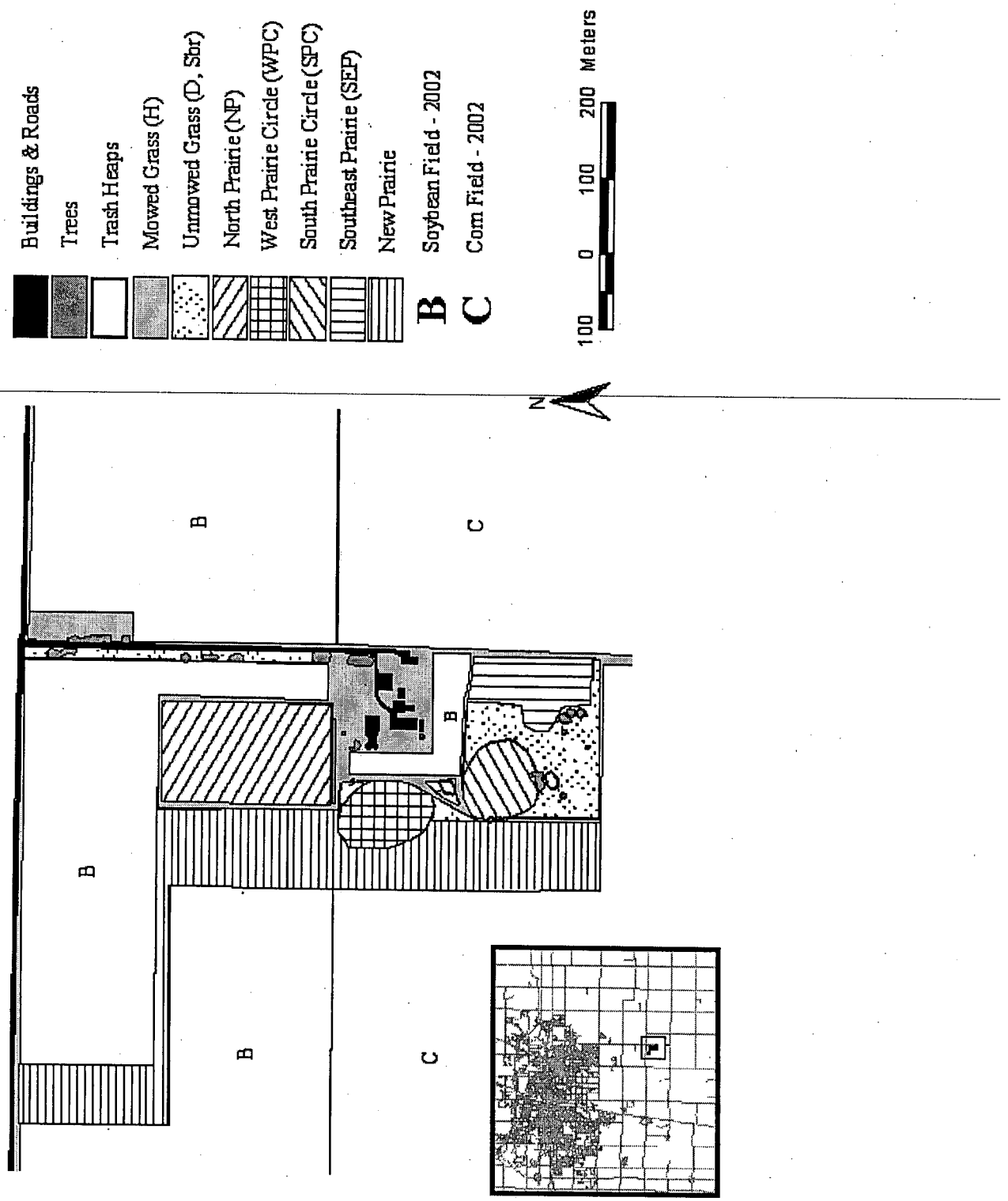

Buildings & Roads
Trees
Trash Heaps
Mowed Grass (H)
Unmowed Grass (D, Sbr)
North Prairie (NP)
West Prairie Circle (WPC)
South Prairie Circle (SPC)
Southeast Prairie (SEP)
New Prairie
B Soybean Field - 2002
C Corn Field - 2002
100 0 100 200 Meters
N
B
C
B
B
B
C

Fig. 2.

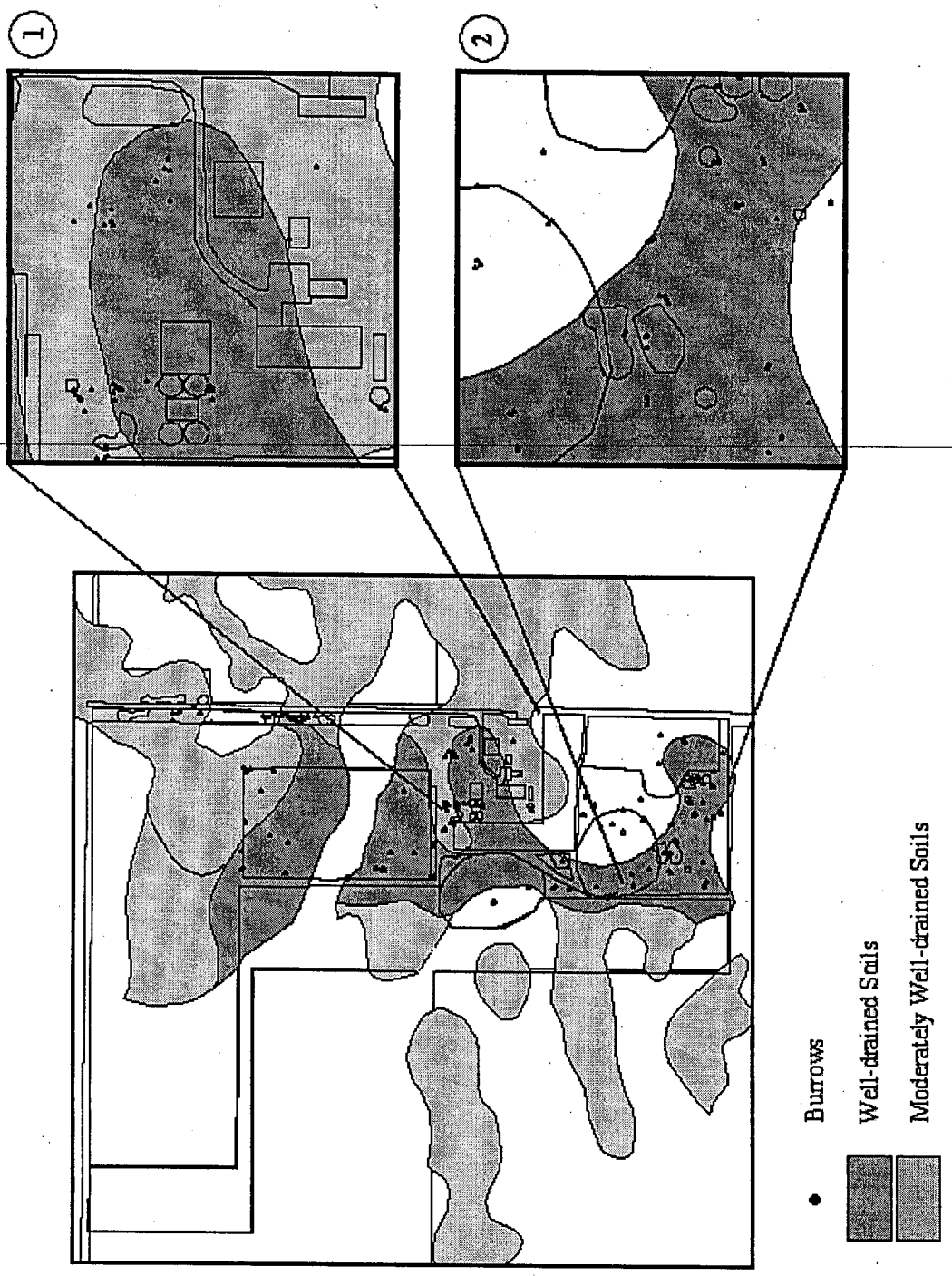

1
2
Burrows
Well-drained Soils
Moderately Well-drained Soils

Fig. 3.

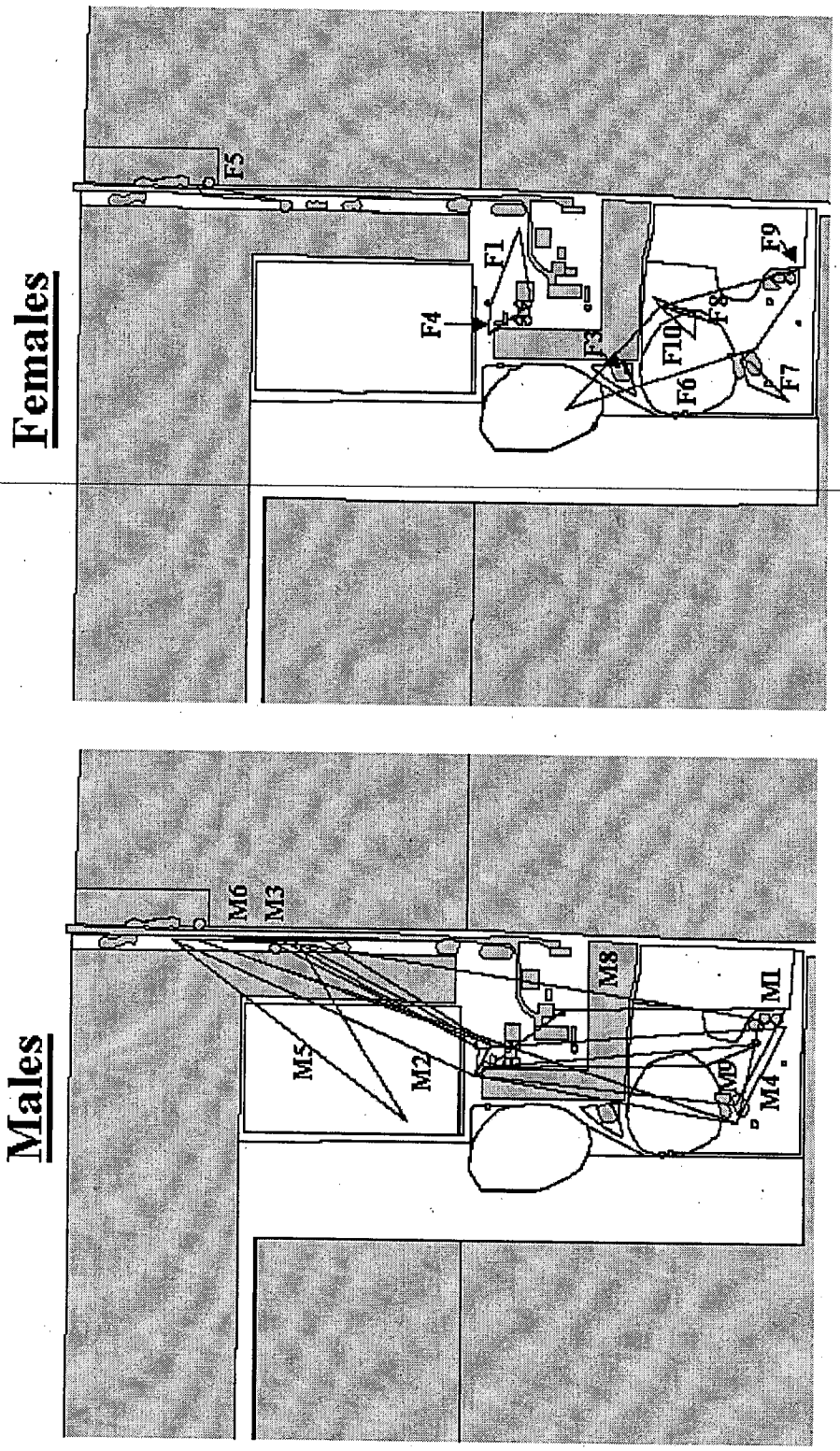
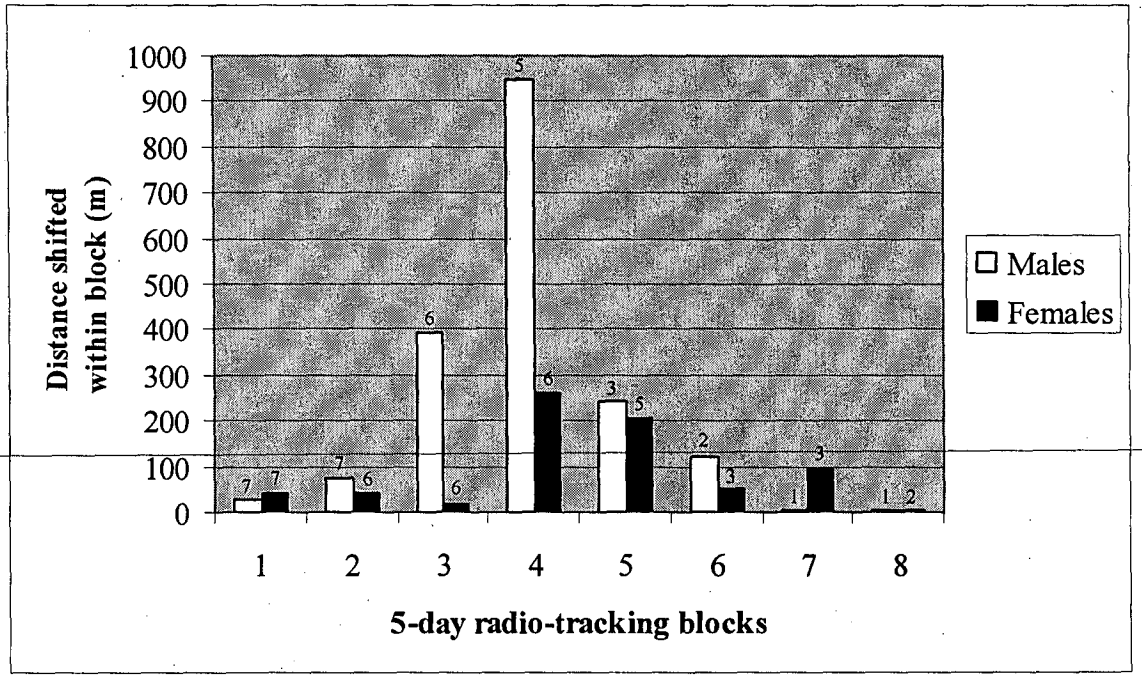


Fig. 4.

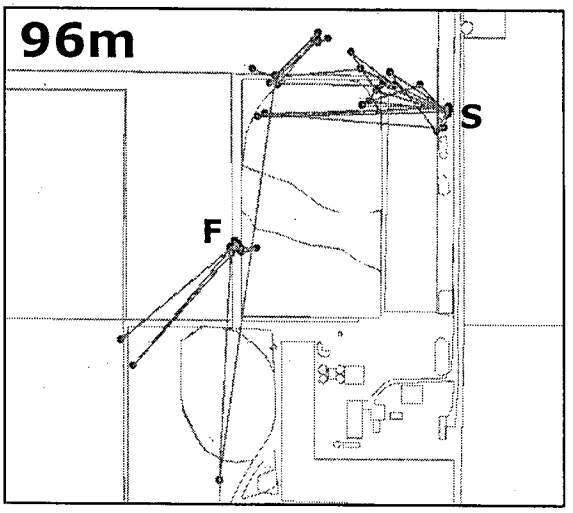

Distance shifted within block (m)
1000
900
800
700
600
500
400
300
200
100
0
7
7
7
6
6
5
6
3
5
2
3
1
3
1
2
1
2
3
4
5
6
7
8
5-day radio-tracking blocks
Males
Females

Supplemental Material

The following seven figures show the movements of juvenile animals that were radio-tracked through the entire dispersal process until hibernation. S = starting natal burrow, F = finishing hibernation burrow. Each point represents an individual tracking location and the lines connect consecutive points. The distance in the upper left corner of each figure is the distance between the first and last centers of activity, which is a measure of the total distance of dispersal.

Fig. 26.

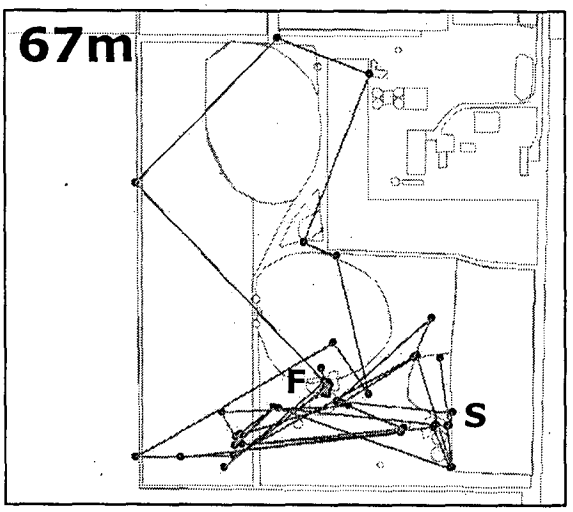
Drive Female



During the period following collaring, the movements of Drive Female were limited to the area immediately around her natal burrow. Over time she gradually began using portions of NP, as well as the soybean field immediately north of NP, until she eventually undertook a relatively long-distance dispersal movement to her hibernation burrow.

Fig. 27.

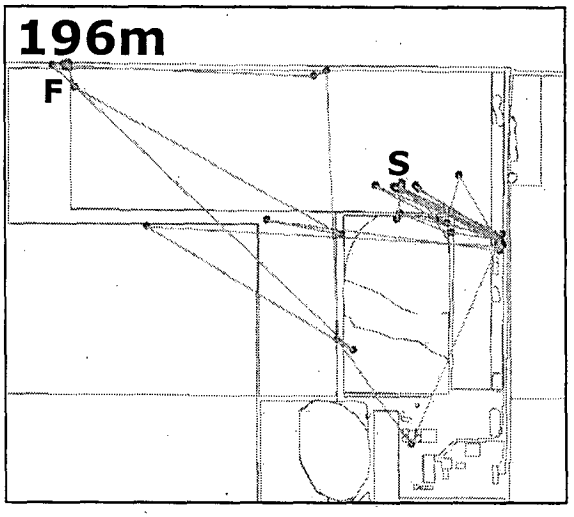
Southeast Female



Southeast Female showed a pattern similar to Drive Female of expanding her area of use away from her natal burrow which peaked in a long distance exploratory movement that ended in a permanent shift in area of occupancy.

Fig. 28.

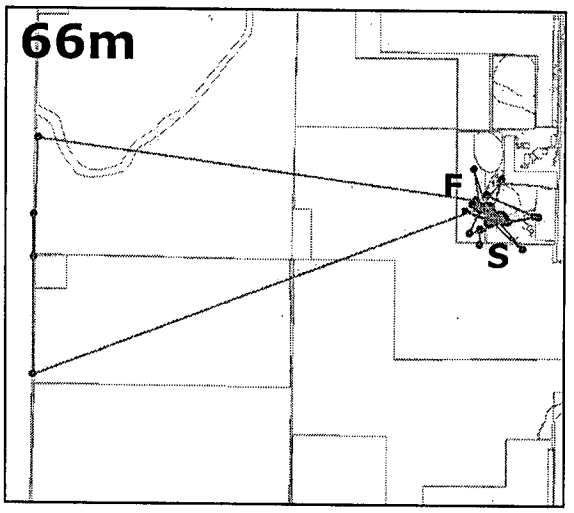
North Female



North Female followed the same "expanding area of use" movement pattern as the previous two females.

Fig. 29.

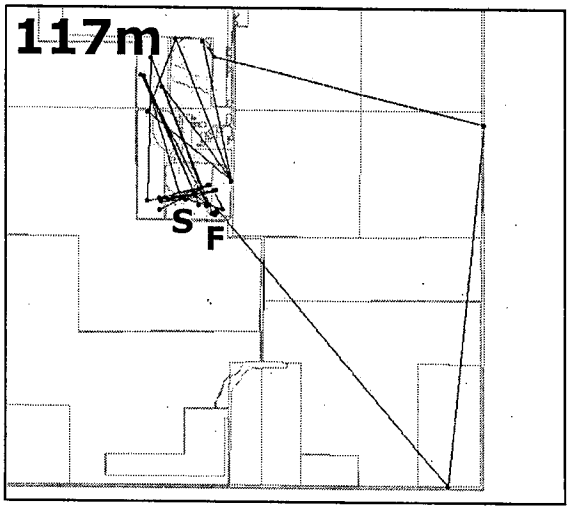
South Female



The movements of South Female were not limited to the Barnhart Prairie. She underwent a long-distance exploratory movement 1.5 km westward through both soybean and corn fields in the time span of 5-6 hrs. She spent the night along the nearest roadway to the west, but was never known to cross the road. The next morning she returned to the study site. The straight line distance of this movement was roughly 3.5 km.

Fig. 30.

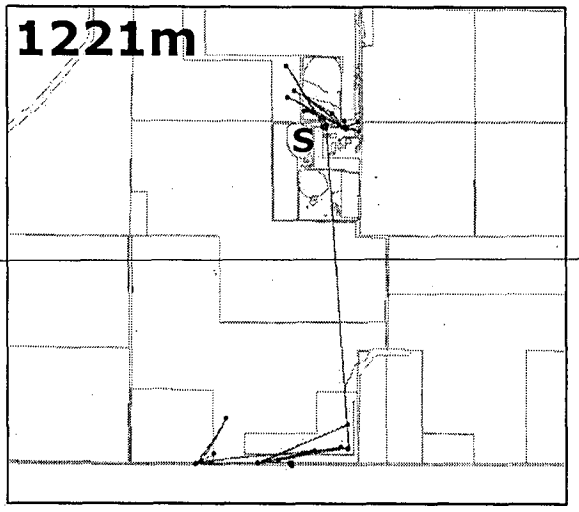
South Male



The movements of South Male were similar to those of South Female. He underwent a long distance exploration of 3 km away from the study site before returning and hibernating relatively close to his natal burrow.

Fig. 31.

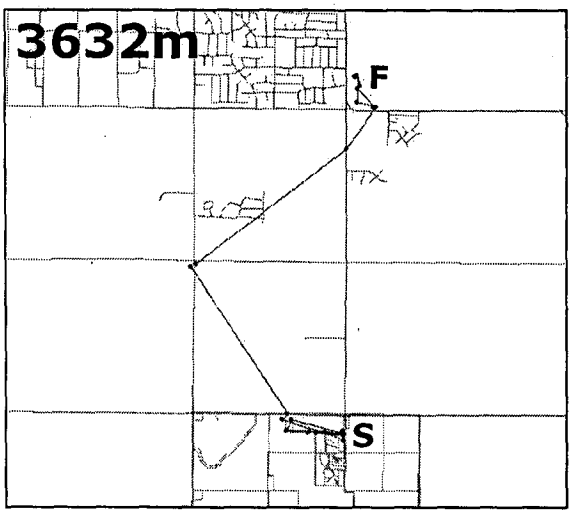
House Male



House Male successfully dispersed off of the study site to another patch of restored tallgrass prairie. Trapping in this patch revealed that it was occupied by another population of Franklin's ground squirrels.

Fig. 32.

Drive Male

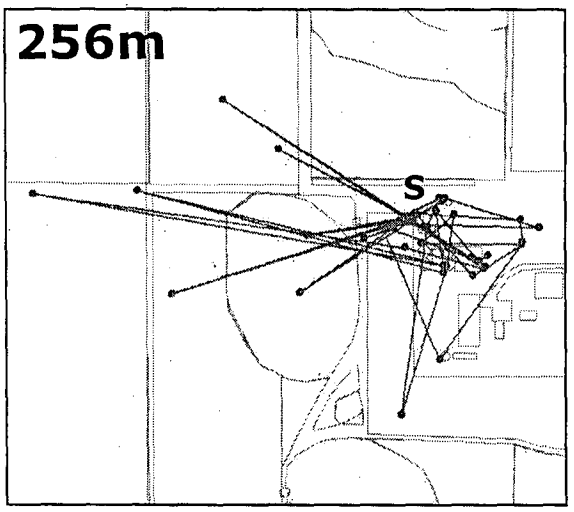


Drive Male dispersed the farthest of any individual that I radio-tracked. He traveled a straight line distance of 5 km over two days crossing several roads and traveling through corn and soybean fields. He finally settled in a patch of weedy grass that harbored another Franklin's ground squirrel population.

The following four figures show the movements of four individuals that were lost during the course of, or soon after, making long distance exploratory movements. I assumed that these individuals were in the process of dispersing when they were last located. The distance in the upper left corner of each figure is the distance between the natal borrow and the farthest location point recorded.

Fig. 33.

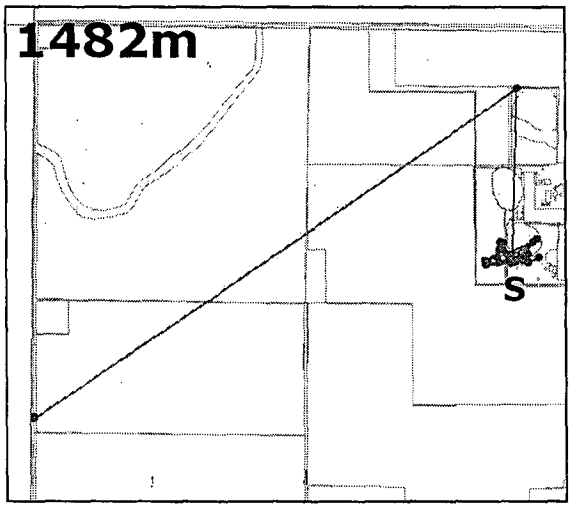
House Female



House Female disappeared after making what appeared to be numerous exploratory movements to the west of her natal burrow.

Fig. 34.

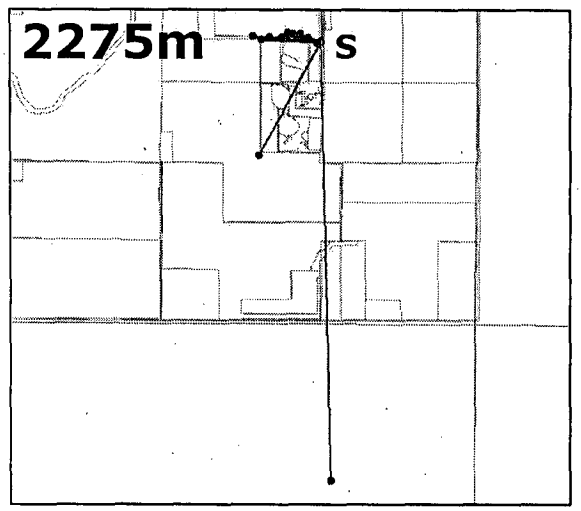
Southwest Female



Southwest Female was last located 1.5 km west of the study site.

Fig. 35.

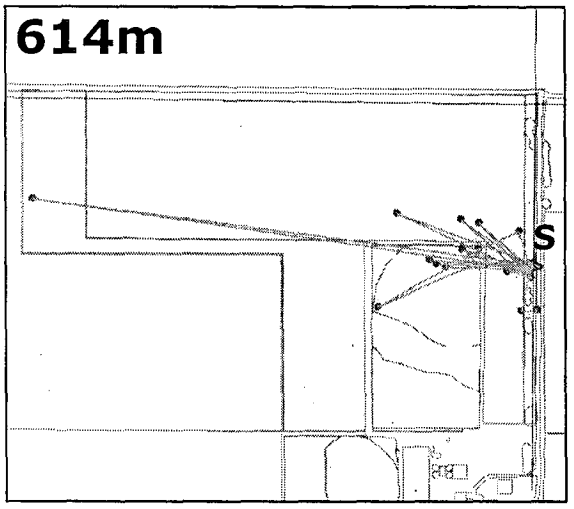
South Drive Male



South Drive Male was last located traveling southward through a corn field over 2 km south of the study site.

Fig. 36.

Central Drive Male



Central Drive Male disappeared soon after making a long exploratory movement to the west of his natal burrow.

Live-trapping Survey of Barnhart Prairie Study Site, 2003.

Because we are interested in conducting future research on Franklin's ground squirrels, we wanted to ascertain whether the number of squirrels at Barnhart Prairie in 2002 was typical. On four days in late April and early May 2003, we returned to the area studied in 2002 and searched for burrows of Franklin's ground squirrel. We found or relocated 34 presumptive burrows and marked these with flags.

Heske and Martin had other commitments for 2003, so live-trapping was conducted in June 2003 by Anne Bartlett, Center for Wildlife Ecology, Illinois Natural History Survey. Bartlett followed trapping protocols used in 2002. She set 20 Tomahawk live traps near presumed burrows in the North Prairie and along the Driveway on June 14, 15, and 16. Traps were placed in the field the day before trapping began to accustom squirrels to their presence and facilitate setting traps quickly in the morning. Traps were baited with sunflower seeds and set before 0800 each day, then checked between 1000 and 1200, and checked again between 1400 and 1500. Traps were closed but left in place after the afternoon check, until removed on the final day of trapping. Trapping was conducted in the South Prairie and around the House on June 23-27 (five nights). Twenty traps were located near presumed burrows in these areas on the day before the trapping began, and daily protocols were the same as for the earlier trapping. All Franklin's ground squirrels captured were weighed, their sex was determined, and individuals captured for the first time were marked by clipping a small patch of fur on their rump. Animals were released at the capture site immediately after handling.

Results

A total of 13 individual Franklin's ground squirrels were captured. Captures included 8 adult females and 5 adult males. Although the trapping effort in 2003 was not as intensive as that in 2002, the number of squirrels captured in 2003 compared favorably to the 19 adults (10 females, 9 males) captured in 2002.

Implications

The similar number of squirrels captured in 2002 and 2003 suggests that this population typically consists of only about 20 or fewer adult squirrels. This number is too small to constitute a viable population if the Barnhart Prairie colony was indeed isolated from other colonies of Franklin's ground squirrels. Our telemetry data revealed that other small colonies may be within dispersal range of the Barnhart Prairie colony. Thus, we may have uncovered a true metapopulation, a group of spatially distinct colonies linked by dispersal. This possibility is exciting, as few studies have been conducted on the dynamics of metapopulations of vertebrates. We hope to develop future studies on the dispersal dynamics of Franklin's ground squirrel, and the demographic and genetic consequences of metapopulation structure for this species.