1977

Population, Home Range, and Dispersal of Red Foxes in East-Central South Dakota

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POPULATION, HOME RANGE, AND DISPERSAL OF RED FOXES IN EAST-CENTRAL SOUTH DAKOTA

By

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Wildlife and Fisheries Science
(Wildlife Option)
South Dakota State University

1977

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RED FOXES IN EAST-CENTRAL SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Dr. V. Van Ballenberghe, under whose direction I began this investigation. I express sincere appreciation to my thesis advisor, Dr. P. A. Vohs, Jr., for his help and guidance throughout the remainder of the study and in preparation of the manuscript.

Thanks are extended to extension trappers L. Anderson, K. Johnson, and pilot A. V. Nelson for their help in conducting the aerial census of fox dens, and to J. Larson, R. Drier, F. Demary, and students who assisted in the collection of field data.

I thank personnel of the South Dakota Department of Game, Fish and Parks for their cooperation and for use of their equipment.

I am indebted to the many landowners in east-central South Dakota who reported active fox dens and who allowed access to their property. I also appreciate the efforts of many sportsmen who reported tagged foxes and supplied fox carcasses for the study.

Most of all, I wish to thank my wife, Gail, for her typing assistance, understanding, and continuous encouragement throughout the study.

Financial support for this project was provided by the South Dakota Department of Game, Fish and Parks, and the South Dakota State University Agricultural Experiment Station, Project 7216-654.

ABSTRACT

The population, dispersal movements and summer home range of red foxes (*Vulpes vulpes*) were studied in east-central South Dakota during 1974 and 1975. The spring population density of foxes on a 23,319 ha study area declined from 9.2 families/township in 1974 to 7.6 families/township in 1975.

Fifty-four percent of 130 foxes tagged in spring, 1974 and 1975 were recovered during the first year following tagging. Hunting and trapping accounted for 18.0 and 77.8 percent, respectively, of all reported fox mortality based on tag recoveries. Recoveries revealed that dispersing juvenile male foxes were more mobile than juvenile females; juvenile foxes traveled a mean distance of 39 km for males and 13 km for females. The longest distance traveled was 123 km by a juvenile male. Five female foxes tagged and recaptured as adults traveled less than 8 km. Fox recovery locations were randomly distributed with respect to direction of travel.

Results from successfully radio-tracking 1 adult fox during summer, 1974, and 4 adult foxes during summer, 1975, revealed that foxes used home ranges averaging approximately 648 ha in size. The smallest home range (236 ha) was used by a 1 1/2 year old barren female and the largest home range (916 ha) was used by an adult male of unknown age. Home ranges of adult foxes had well-defined boundaries, and overlap between contiguous home ranges was slight.

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INTRODUCTION

The purpose of this study was to obtain data on population density, dispersal movements, and home range size of the red fox (Vulpes vulpes) in eastern South Dakota. Specific objectives of the study were: (1) to estimate the population density and population trend of red foxes on a 23,319 ha study area in east-central South Dakota, (2) to estimate the level of human induced mortality of juvenile foxes during fall and winter, (3) to determine the distance and direction of fall and winter dispersal movements of juvenile foxes, and (4) to determine the size and spatial arrangements of red fox home ranges in the study area.

The role of the red fox as a predator of ring-necked pheasants (Phasianus colchicus) has generated interest in the species in South Dakota. Efforts to reduce predation by foxes on pheasants have constituted the major fox management strategy in the state. Bounties were paid for foxes from 1945 to 1972. An extension program designed to teach persons how to catch individual foxes and other mammalian predators that damage livestock has been active since 1972.

Intense public interest concerning fox-pheasant relationships in the mid 1960's prompted biologists of the Department of Game, Fish and Parks to study the relationship of red foxes to populations of ring-necked pheasants (Trautman and Fredrickson 1974). The study included food habits, reproductive characteristics, and population density of foxes.

The red fox is valued for its ecological role as a carnivore and the esthetic and recreational opportunities it provides in North

America (Scott 1955, Storm 1972). Sargeant (1972) stated that red foxes have considerable economic values and sporting qualities that rank them high as fur and game species.

The economic value of the red fox in South Dakota has increased in recent years from an average price of $7.67 per pelt in 1970-71 to $31.50 per pelt in 1973-74 (fur harvest records compiled by the South Dakota Department of Game, Fish and Parks); this increase was accompanied by an increase in harvest of foxes. Approximately 14,000 pelts were sold to South Dakota fur buyers during 1970-71 compared to 30,000 sold during 1973-74 (fur harvest records compiled by the South Dakota Department of Game, Fish and Parks). Allen et al. (1974) stated that the increased economic value and concurrent increase in hunting and trapping may result in marked increase in harvest levels of some local fox populations.

Data concerning aspects of life history and population dynamics of the red fox are needed in South Dakota. Information is also needed concerning the effects of heavy harvests on the fox population. These data are essential to the biological management of this valuable carnivore.

DESCRIPTION OF STUDY AREA

Studies of red fox population density, fall and winter dispersal, and mortality and summer home range were conducted during 1974 and 1975 in east-central South Dakota. Population density and home range were studied in a 23,319 ha study area which included Lake Sinai Township (T109N, R52W), sections 31 - 36 of Bangor Township (T110N, R52W), sections 31 - 34 of Volga Township (T110N, R51W), sections 1 - 12 of Nunda Township (T108N, R52W), sections 3 - 10 of Summit Township (T108N, R51W), and sections 3 - 10, 15 - 22, and 27 - 34 of Oslo Township (T109N, R51W) (Figure 1). Dispersal and mortality were studied in a larger area which included Brookings, Lake, Moody, Kingsbury, Clark, and Deuel counties in South Dakota as well as isolated, more distant areas where dispersing foxes were recaptured (Figure 1). The larger study area was required to obtain an adequate sample size of tagged animals.

Both study areas are located within the glaciated prairie of North America, commonly called the prairie pothole region (Smith et al. 1964). Within this region the study areas are situated on a major physiographic land division, the Coteau des Prairies (Westin et al. 1967). The Coteau des Prairies is an upland area which slopes gently to the south and west and is located between the Minnesota-Red River Lowland to the northeast and the James River Lowland to the west. Elevations range from 610 m in the north to 480 m in the south. Drainage flows southward via the Big Sioux River whose tributaries enter from the east (Flint 1955). Topography of the Coteau des Prairies is undulating. The land surface is poorly drained and pitted with many lakes and marshes of glacial origin.

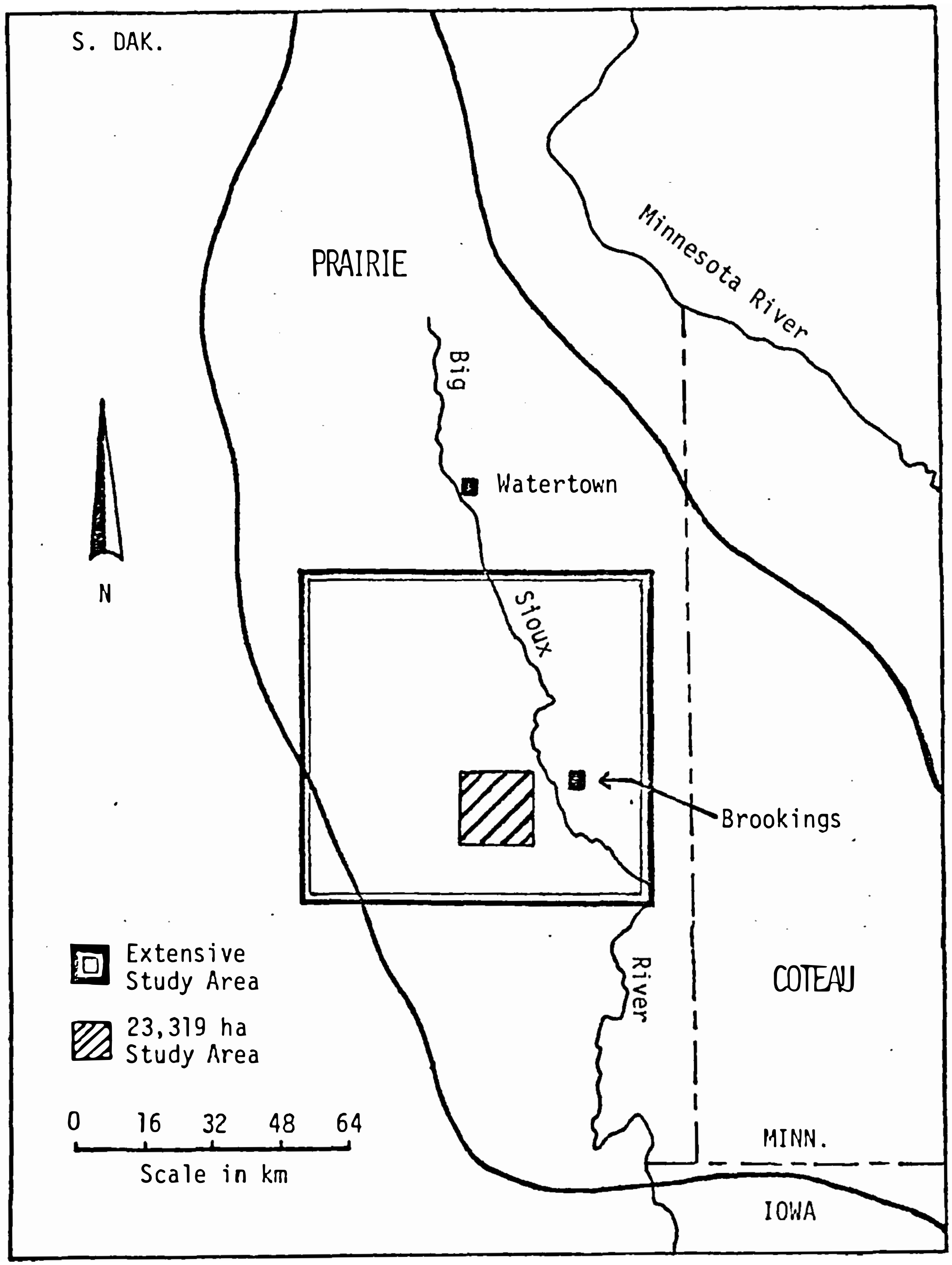

Figure 1. Location of study area.

The climate of east-central South Dakota is continental with cold winters and hot summers (Westin et al. 1967). July is the warmest month with mean daily high and low temperatures of 29.2 C and 14.7 C, respectively. January is the coldest month with mean daily high and low temperatures of -4.9 C and -16.8C. Annual precipitation approximates 51 cm and occurs as gentle rain, snow, or violent thunderstorms (Westin 1958). Accumulations of snow are rarely heavy; yet strong, prevailing winds often cause considerable drifting.

Soils classified as the Chernozem group occur throughout the study area and were formed under native mid and tall grasses in a relatively cool, moist climate. Chernozem soils are high in organic matter and have a dark black surface horizon which grades into lighter material and into a final horizon of accumulated carbonate material (Westin et al. 1967).

Intensive farming and grazing have eliminated most of the native vegetation from the 23,319 ha study area. The present vegetation pattern includes extensive cropland and pastureland interspersed with lakes, pot-holes, shelterbelts, and farm woodlots. During 1973 and 1974, cultivated cropland comprised 44 percent of the land area in Lake Sinai Township, a representative portion of the 23,319 ha study area (Olson 1975). Marsh habitat occupied approximately 9 percent of the land area, and woodland habitat occupied approximately 2 percent of the land area (Olson 1975).

Corn, oats, wheat, flax, soybeans, and alfalfa comprised the major crops in the area, and beef cattle, dairy cattle, swine, and sheep were raised through a combination of supplemental feeding and pasturing. Access throughout the area was provided by a network of roads bordering most sections.

METHODS AND MATERIALS

Population Estimation

Spring population densities were estimated using an aerial census of active fox dens combined with an intensive survey of landowners. An autumn scent-post survey was conducted to determine fox population trend.

The aerial census involved a systematic search of the study area using the method described by Sargeant et al. (1975). The search was conducted between 15 May and 25 May in 1974 and 1975.

The search utilized a single-engine, high-wing aircraft. A pilot and two observers were present on each flight. At least one observer on each flight had previous experience in locating foxes and fox dens from the air. About 8.5 flight hours and 28.5 man-hours were required annually to search the study area. Parallel transects 0.32 km apart were flown in an east-west direction at elevations varying from 46 - 76 m above ground at speeds from 129 - 177 km per hour. Flights were not made when winds exceeded 32 km per hour or within 16 hours after a heavy rain. Land areas with dense cover, primarily the perimeters of semi-permanent wetlands, were circled during the search to avoid overlooking active dens. Potential den locations when sighted were recorded on county maps showing land ownership. Dens located from the air were visited by a ground crew following each aerial search.

All observations of adult and pup foxes, and/or active and recently active fox dens were used in determining the number of fox families occupying the study area. Individual observations were interpreted and identified as fox families according to the criteria described by Sargeant et al. (1975). A red fox family typically consists of an adult male and female and their pups from whelping to dispersal (Sargeant 1972).

Estimates of fox families based on data from the aerial survey were subject to several sources of error: (1) movement of families to a different den over 1.6 km from the original den, (2) overestimation of fox families living near study area boundaries, (3) individual dens located less than 1.6 km apart, and (4) the aerial observability of family indicators. Each error necessitated a method of adjustment.

Relocation of families to dens over 1.6 km apart would cause double counting of families and inflation of density estimates if uncorrected. An adjustment of 4.2 percent was applied to all families identified on the study area to compensate for this error (Sargeant et al. 1975).

Some fox families are identified by multiple sightings of dens and/or foxes (Sargeant et al. 1975). As a result, families stradling the study area boundaries are subject to possible double counting if searches of adjacent areas are conducted and the data for each area analyzed separately. A method described by Sargeant et al. (1975) was used to determine the extent of adjustment necessary to compensate for this source of error.

Occurrence of dens of two different fox families located less than 1.6 km apart would cause an underestimation of family density if unadjusted. Correction for this error was applied only when the situation was identified by information gained in radio-tracking.

The observability of family indicators (dens, pups, adults) from the air causes some fox families to be overlooked during an aerial survey (Sargeant et al. 1975). In the present study, the magnitude of this error and the adjustment necessary were estimated by conducting a survey of landowners in the study area following each aerial search to determine landowner knowledge of active fox dens. Dens reported by landowners were confirmed by a visit to the den site.

An estimate of the total number of fox families occupying the study area was determined by applying the four adjustment factors discussed above to family estimates obtained from the aerial survey. The adjusted total estimate of fox families was expanded to foxes per square mile using the methods of Scott and Selko (1939).

The scent-post survey was conducted in the study area during early September, 1974 and 1975, using the procedure described by Linhart and Knowlton (1975). Data from the survey were used to calculate an annual index of relative abundance for the red fox (Linhart and Knowlton 1975).

Tagging and Measurement of Fox Pups

Dens containing fox pups were located in spring 1974 and 1975 during the confined-use and dispersed-use period of denning (Sargeant 1972). Dens were found through reports from conservation officers, farmers, hunters, and trappers, by searches from the ground and air, and by requesting information concerning dens via the news media.

To capture fox pups, a minimum amount of noise was made while approaching a den site. A length of chicken wire set up around the den site and two persons equipped with dip nets facilitated the capture of pups once flushed from the den. Most foxes were flushed from dens by releasing water into the den entrance. Some foxes were chased from dens with the aid of a mechanical wire ferret (Storm and Dauphin 1965). Several dens were excavated to capture foxes not chased from dens by water or the ferret.

Once captured, monel metal tags (National Band and Tag Co., Newport Kentucky) were placed in each ear of each fox. Each tag was stamped with the appropriate identification to facilitate recovery.

Measurements of hind foot length were taken for each fox pup to determine approximate date of birth (Johnson et al. unpublished). Data concerning sex, weight, total length, tail length, and ear length were obtained for each pup. Information concerning the vegetative cover at each den location and the observed litter size of each family was recorded.

Tagged foxes were usually released at the location of initial capture. In three instances, however, landowners requested that fox pups be removed from the natal den and transplanted to a new area.

In this paper, dispersal is considered a movement of over 8 km (5 miles) airline distance between first and last capture location of foxes. This is based on evidence that home range sizes of nondispersing red foxes are less than 8 km in diameter (Murie 1936, Scott 1943, Storm 1965, Ables 1969, Sargeant 1972).

Determination of Home Range

Foxes were captured with Victor #1 1/2 double coil spring traps. Trapping was conducted during June and July. Dirt-hole sets and urinary post sets were used. Sets were placed on or near travel ways leading to and from active fox dens.

Twelve trapped foxes were fitted with radio transmitter collars. Each transmitter package consisted of a battery pack and miniature, pulsed-signal radio, potted in dental acrylic. Mercury batteries were used during 1974 and lithium batteries during 1975. Radio transmitters were built by Dav-tron Electronics Company (Minneapolis, Minnesota). Radio collars weighed approximately 140 gms and had a battery life of 3 to 6 months. Transmitters emitted pulsed signals in the 150 mHz range.

Directional antennas were used to home on the signal and to track foxes. Primary antennas used were portable three element and five element yagi antennas. Occasionally, a dual five element yagi antenna on a 9.18 m mast mounted in the bed of a pickup truck (Hallberg et al. 1974) was used to initially locate a fox. Receivers manufactured by Dav-tron Electronics Company (Minneapolis, Minnesota) were used with all antennas.

An attempt was made to locate each fox at approximately 2 - 3 hour nightly intervals on at least 5 nights per week. All foxes were not located every night because of the length of time required to locate specific foxes on many occasions.

Nearly all radio locations were obtained by triangulation. During 1975, the use of two receivers and antennas enabled researchers to obtain simultaneous bearings on foxes. This method provided the greatest possible accuracy and allowed the tracking of moving animals. Points of high elevation located throughout the study area and other known locations which could be readily plotted on maps were used in triangulation. On two occasions, a Cessna aircraft with a three-element yagi antenna fastened to each wing strut was used to locate foxes not found by other means.

Foxes were normally radio-tracked at distances less than 1.2 km. Tests showed that when a hand-held transmitter and receiver were both on level ground, the telemetrically determined transmitter locations averaged 76 m away from actual transmitter locations at a distance of 0.4 km. At 0.8 km, the error increased to an average 183 m between radio-determined and actual transmitter locations.

Home ranges for individual adult foxes were calculated with a compensating polar planimeter after boundaries plotted on a base map were delimited by the minimum area method (Mohr 1947). The geometric center of activity (Hayne 1949) and length-width ratio (index of linearity) were determined for each home range (Storm 1965). In this paper, the term home range coincides with the definition of Burt (1943).

Age Determination

Teeth from a sample of trapped foxes captured within 50 miles of Brookings, South Dakota, were collected during fall and winter 1974-75 and 1975-76. The maxilla from each fox was boiled in water to ease extraction of the canines and first premolars. Maxilla were segregated according to the general location where collected.

Radiographs of canine teeth were used to separate juveniles from adults based on relative widths of the root canal (Churcher 1960). First premolars from adult foxes were used to further differentiate some animals into year classes by the annular cementum technique similar to that described by Monson et al. (1973) with minor variations in the decalcification and staining procedure.

The juvenile age class (1 year old or less) referred to in this study includes the month of birth through 31 March of the following year.

RESULTS AND DISCUSSION

Spring Family Estimates

In 1974, an estimated 23 fox families or 9.2 families/township occupied the study area. Family density declined to 19 fox families or 7.6 families per township during 1975. Estimates of fox families in the study area and the effect of each known adjustment factor applied to aerial survey data are presented in Table 1.

Fox family density estimates based on aerial survey data were adjusted upward by 26.1 percent for 1974 and 26.3 percent for 1975. The error caused by observability of family indicators necessitated the largest adjustment factor as determined by interviews with landowners. Interviews with approximately 95 percent of all landowners on the study area revealed that 30.4 percent and 26.3 percent of all fox families identified on the study were overlooked during the aerial census during 1974 and 1975, respectively. Fifty percent of the dens that were overlooked were located in idle grassland surrounding wetlands. Careful searching of wetland perimeters during an aerial census is important to correct for this bias. The method of location for all fox families in the study area is presented in Appendix Tables 4 and 5.

Landowner interviews also revealed that landowners were aware of 87.5 percent and 84.3 percent of the total number of families identified during 1974 and 1975, respectively. Data from interviews served as a useful aid in determining the effectiveness of the aerial survey. This method was also used to test the effectiveness of the aerial census of red foxes in North Dakota (Sargeant et al. 1975).

Table 1. Effect of known adjustment factors on annual estimates of red fox families in east-central South Dakota during 1974 and 1975.

	1974	1975
Total fox families identified by air	17 families	14 families
Adjustment factors:		
Aerial observability of families[a]	+ 7.0	+ 5.0
Den moves of over 1.0 miles (1.6 km)[b]	- 1.0	- 0.8
Double count of edge families[c]	- 0.38	- 0.27
Individual fox families within one mile of each other[d]	-	+ 1.0
Total adjustment	+ 5.62 (6)	+ 4.93 (5)
Adjusted total fox families	23	19
Fox families/township	9.2	7.6
Percent total adjustment	26.1%	26.3%

[a]Natal dens overlooked by air and found by landowner interview and ground observation.

[b]Subtract 4.2 percent of total families for which dens were identified.

[c]Subtract 3.8 percent of total families represented by data only in outer perimeter sections of study area.

[d]Fox family 19 (Appendix Figure 2) represents two individual fox families as determined by radio telemetry.

Sargeant et al. (1975) found that the total number of fox families identified during a spring aerial census of red foxes in North Dakota provided an accurate representation of fox family densities. The same technique with limited modification provided a useful estimate of fox family densities in east-central South Dakota.

My primary modification of the aerial census technique of Sargeant et al. (1975) was the use of one spring aerial search rather than two spring aerial searches per year. This modification resulted in the application of a large adjustment factor to compensate for observability of family indicators (number of fox families overlooked from the air) (Table 1).

The single aerial search used in this study accounted for an average 73.8 percent of the total number of families identified on the study area during 1974 and 1975. In North Dakota, results were similar; an average 72 percent of the total number of fox families identified per year were located by a single mid-May aerial search (Sargeant et al. 1975).

Data collected from visits to fox dens showed that dens were non-randomly distributed with respect to land use in the study area (Table 2). Pasture and idle farmland were the most preferred denning sites. These two land use types together accounted for 77.5 percent of the dens but comprised only 23.9 percent of the land area. Cropland occurred on 44.0 percent of the land area, yet contained only 7.5 percent of the dens. No natal dens were found in croplands during 1975. Two of three dens classified as located in cropland in 1974

Table 2. Distribution of 40 red fox dens in spring according to land use type on the study area, 1974 and 1975.

Land Use Type	Percent of Type Available[b]	Number of Dens for Combined Years
Cultivated cropland	44.0	3 (7.5)[a]
Pasture	17.0	18 (45.0)
Idle farmland	6.9	13 (32.5)
Hayland	10.1	6 (15.0)
Other	22.0	0 (0.0)

[a] Percentage in parenthesis.

[b] Data taken from T109N, R52W during 1973-74 (Olson 1975).

were located in fencelines between adjacent cropfields. The third den classified as located in cropland was situated in a very small island of grass in the center of a plowed field.

Dens situated within the four land use types were further classified according to their location in fencelines, gravel pits or on the edge of wetlands. Ten percent of all dens were situated in fencelines. Two and one half percent of all dens were located in gravel pits, and 20 percent of all dens were located on the grassy edge surrounding wetlands. Thirty-one percent of 19 dens located in the study area during 1974 were re-used by foxes during 1975.

Time of Conception

Approximate time of breeding for foxes during 1974 and 1975 based on hind foot measurements of fox pups (A. B. Sargeant, personal communication), occurred from the week of 9-16 January through the week of 15-21 February (Table 3). Most female foxes conceived during the last two weeks of January and first week of February.

Litter Size

Estimates of litter size based on the number of juveniles examined at 18 natal dens in late April and early May averaged five for both 1974 and 1975. This was a minimum estimate since few dens were excavated, and some juvenile foxes may have avoided capture by remaining underground in dry pockets during the flooding process. Drieslein (1967) reported that litter size of foxes in east-central South Dakota during 1965 averaged 4.6 based on fetal counts from

Table 3. Frequency of conception dates by weekly periods for 35 litters of red foxes in east-central South Dakota, 1974 and 1975.

Year	Number of Litters	Weekly Period					
		Jan. 9-16	Jan. 17-24	Jan. 25-31	Feb. 1-7	Feb. 8-14	Feb. 15-21
1974	15	-	7(45.7)[a]	6(40.0)	1(6.7)	1(6.7)	-
1975	20	1(5.0)	5(25.0)	7(35.0)	5(25.0)	1(5.0)	1(5.0)
Combined years	35	1(2.8)	12(34.3)	13(37.1)	6(17.1)	2(5.7)	1(2.8)

[a]Percentage in parenthesis.

female foxes. This figure was based on data collected prior to intensive efforts to reduce fox populations.

Density and Mortality

Fox populations pass from lowest annual density to highest density during spring. Knowledge of density in spring can be used to assess mortality during the previous year and predict densities of foxes in fall (A. B. Sargeant, personal communication). Spring estimates of fox families were expanded to estimate actual fox densities (Table 4) using a method similar to Scott and Selko (1939), and Drieslein (1967). Several assumptions were used to expand family density to fox density: (1) fox families were assumed to consist of two adults and 5.3 pups, (2) an even sex ratio of adult-sized fox was assumed at the start of the breeding season, and (3) five percent of the adult fox population was assumed to be nonbreeders. Based on examination of fox uteri during February in northern Illinois and northern Iowa, 95 percent of 188 females bred successfully and 5 percent were unsuccessful (Storm 1972). Assuming an even sex ratio, 5 percent of the males in the fox population would also be nonbreeding.

Estimates of family density as mentioned previously and expanded estimates of fox density for 1974 and 1975 indicated a decline in fox numbers from 1974 to 1975. An estimate of total annual fox reduction was calculated using the expanded fox density (Table 4). An estimated 76 percent decline occurred from the postnatal spring density of 170 foxes (1974) to a prenatal density of 40 foxes in the study area the

Table 4. Spring fox densities derived from family density estimates observed during spring denning period.

Year	Fox Families in Study Area		Foxes per Den		Fox pups and Breeding Adults[a]	Non-Breeders[b]	Foxes in Study Area	Foxes per Square Mile
1974	23	X	7.3	=	168	2	170	1.89
1975	19	X	7.3	=	139	2	141	1.56

[a]Assume an even sex ratio at start of breeding season (Sheldon 1950) from Storm thesis page 53.

[b]Assume 95% of adult females breeding.

following spring. Phillips et al. (1972) stated that when local fox populations are markedly reduced, vacant areas rapidly become repopulated by foxes moving in from surrounding areas. The decline in fox density observed in this study from May 1974 to May 1975 indicated that vacancies created by dead or dispersing animals were not completely filled in one year by foxes dispersing into the area. This suggests that population reduction may have been widespread rather than local in nature.

The decrease may have been caused by heavy exploitation of foxes through increased hunting and trapping pressure. Evidence of increased pressure came from records of annual sales of fox pelts to South Dakota fur buyers during recent years. In winter, 1970-71, approximately 14,000 fox pelts were sold to fur buyers throughout the state. This number increased to approximately 30,200 pelts sold to fur buyers in winter, 1973-74 (fur harvest records compiled by the South Dakota Department of Game, Fish and Parks). This increase was probably due to a gradual increase in the value of individual fox pelts during recent years. In winter 1970-71, the average price paid to sportsmen for a red fox pelt was $7.67 in South Dakota. This average increased to $21.50 in 1974-75 and $35.43 in 1975-76 (fur harvest records compiled by the South Dakota Department of Game, Fish and Parks).

Data concerning the nature and extent of the fox harvest was obtained by the reported mortality of 72 red foxes tagged and recovered during this study (Table 5). Five of these animals were recovered by the author. The importance of natural mortality factors, such as disease, parasites, and accidents not related to man were not determined. Tag recoveries reflected man-caused mortality.

Table 5. Recovery of tagged foxes by method of harvest, 1974-75 and 1975-76.

Time of Recovery	Number Recovered	Mortality Type			
		Hunting	Trapping	Road-kills	Other
Autumn-winter 1974-75	27	2 (7.4)[a]	23 (85.2)	1 (3.7)	1 (3.7)
Autumn-winter 1975-76	45	11 (24.4)[b]	33 (73.3)	1 (2.3)	--
Combined years	72[c]	13 (18.0)	46 (77.8)	2 (2.8)	1 (1.4)

[a] Percentage given in parenthesis.

[b] Two fox shot from airplane.

[c] Includes five recoveries trapped by author.

Recovery rates of tagged foxes in this study were higher than those reported in previous studies (Table 6). Approximately 62 percent of all foxes tagged as juveniles during 1974 were recovered during their first year of life. Two juvenile foxes tagged during 1974 were recovered as adults in winter, 1975-76. One of four adult foxes tagged during 1974 was recovered during the following hunting and trapping season. Approximately 51 percent of all foxes tagged as juveniles during 1975 were recovered during their first year of life. Four of seven adult foxes tagged during 1975 were recovered during the following hunting and trapping season.

Hunting and trapping accounted for approximately 96 percent of all reported fox mortality (Table 5). This mortality occurred from October through February. Trapping alone accounted for 78 percent. Hunting accounted for 18 percent. In contrast to these results, Phillips et al. (1972) reported that hunting accounted for 60 percent of reported mortality and trapping accounted for 22 percent of reported mortality in Iowa and Illinois.

The overall first year recovery rate of tagged foxes during 1974-75 was greater than that obtained during 1975-76 (59 percent versus 51 percent), but the difference was nonsignificant (x^2=0.55, $P > 0.05$). The change in the proportion of recoveries from trapping versus recoveries from hunting that occurred from 1974-75 to 1975-76 was nonsignificant (x^2=3.00, $P > 0.05$).

Table 6. Recovery rates of tagged red foxes as reported in various North American and European studies.

Location	Reference	Number of Foxes Tagged	Recovery Rate (Percent)
Iowa	Errington and Berry (1937)	236	7[a]
New York	Sheldon (1950)	120	33
Russia	Tchirkova (1955)	126	21
North Dakota	Donahoo (1962)	179	25
Sweden	Marcstrom (1968)	163	36
Denmark	Jensen (1973)	460	44
Iowa	Phillips (1972)	631	40[b]
Illinois	Phillips (1963-68) (1972)	295	39[b]
South Dakota	This study (1974-75)	130	55[c]

[a] Foxes tagged in this study were transported from natal dens to other release sites.

[b] Includes first, second and third year recoveries.

[c] Includes all recoveries to April 1976 and five recoveries trapped by author.

Some foxes harvested by man in this study were not reported. The extent of this loss could not be determined. Some recoveries were probably not reported due to a loss of both ear tags from captured animals. The probability of losing both ear tags was 1.0 percent based on 1975-76 recovery data. This was calculated using the formula described by Fairley (1969). Because of these losses, tag recovery rates presented in this study represent minimum estimates of man-caused mortality.

Scent Post Survey

Results obtained from a scent post survey conducted during 1974 and 1975 also indicated that red fox numbers declined from September 1974 to September 1975. The index of relative abundance (Linhart and Knowlton 1975) was 152 during 1974 compared to 112 during 1975.

Age Ratios

An age ratio of 3.1 juveniles per adult was observed in a sample of 233 red foxes collected from trappers in eastern South Dakota during winter 1974-75 (Appendix Table 6). An age ratio of 5.3 juveniles per adult was observed in a sample of 171 foxes collected during winter 1975-76. The difference between years was significant (x^2=4.51, $P < 0.05$). Phillips (1970) stated that a "normal" fall age ratio of red foxes was approximately 2.6 based on a sample of foxes collected from northeastern Iowa in 1966 and 1967. This "normal" ratio agrees closely with the age ratio one might expect in the spring following the birth of pups. The 1974-75 age ratio of 3.1 obtained in this study was not significantly different (x^2=0.69, $P > 0.05$) from that described by Phillips; however, the 1975-76 age ratio of 5.3 was significantly different (x^2=4.51, $P < 0.05$) from Phillips "normal". The ratio for combined years of 4.02 was also significantly different (x^2=4.02, $P < 0.05$) from the age ratio provided by Phillips.

Certain factors should be considered when using age ratios in any study. An observed difference in age ratios between years or areas may reflect differences in productivity, differences in juvenile or adult mortality, differences in trapping methods, or the effect of long-term intensive trapping on an area (Phillips 1970).

Since litter size of foxes in this study appeared to change little between years, the significant difference in age ratios probably did not reflect a change in recruitment. As trapping methods probably were similar during both years, the observed difference in age ratios from 1974-75 to 1975-76 probably did not reflect a change in trapping methods.

Significant difference between the age ratios observed in the present study and the "normal" (Phillips 1970) are most likely a reflection of the intensiveness of trapping and hunting pressure being exerted on fox populations in east-central South Dakota.

When intensive fox hunting and trapping ceases in late winter, few resident pairs may remain in an area. This may have been the situation following the fox hunting and trapping season of 1974-75. This scarcity of adult resident foxes and a resultant movement of many juvenile foxes dispersing into or through the area during the following trapping season may have caused the unusually large percentage of juveniles as reflected in the 1975-76 sample of harvested foxes.

Movements of Ear-tagged Foxes

A total of 130 red foxes (119 juveniles and 11 adults) were captured, ear-tagged, and released during spring and summer, 1974 and 1975. Thirteen of these were transplanted from the natal area. Tag returns obtained from 59 foxes during winter 1974-75 and 1975-76 provided data for determining fox movements during fall and winter.

The exact timing of initial dispersal was not determined. One juvenile male remained in its natal area at least through 9 September 1975 as determined by radio-tracking. Another radio-marked juvenile male remained in its natal range at least through 20 August 1974. Initial tag recoveries were obtained with the beginning of the trapping season in October. The first recovery occurred on 16 October 1974 from a juvenile male that had dispersed 39 km from its location of initial capture. On 21 October 1974, a juvenile female fox was recaptured 31 km from its location of initial capture. On 23 October 1975, a juvenile female was recaptured 56 km from its location of initial capture. Based on these findings, dispersal probably began during early October and was well underway by mid-October for red foxes in east-central South Dakota. Storm (1972) stated that few red foxes in Iowa and none of 35 foxes in Minnesota carrying functional radios left their natal range before October.

Thirty-two of 59 juvenile foxes recovered during their first year of life dispersed. Twenty-four of 33 tagged juvenile males were captured more than 8 km from the point of initial release. Eight of 26 tagged juvenile females traveled more than 8 km from the point of release. Juvenile males showed a greater tendency to disperse than juvenile females. Jensen (1973), Storm (1972), and Phillips et al. (1972) similarly found that juvenile males traveled greater distances than juvenile females.

None of the five adult females tagged and recaptured in this study traveled more than 8 km from point of initial capture. Storm (1972) reported that the tendency to disperse was less pronounced in adult red foxes than juveniles. Jensen (1973) reported that only one of 15 tagged adult foxes traveled more than 8 km from the location of initial capture.

Fixes from 39 litters were tagged in this study. One or more recoveries were obtained for 30 of these litters. Dispersal by one or more individuals occurred in 21 of the litters tagged. Storm (1972) similarly found that dispersal by at least one individual occurred in the majority of litters tagged in Illinois and Iowa.

More than twice as many juvenile females as juvenile males were recaptured from October through February less than 16.1 km from the original capture site, and more males than females traveled greater distances during their first year (Figure 2). The recovery distances for all juvenile males ranged from 0.0 to 123.9 km with a mean distance of 39.4 km (Table 7). The range for females was 0.0 to 56.3 km

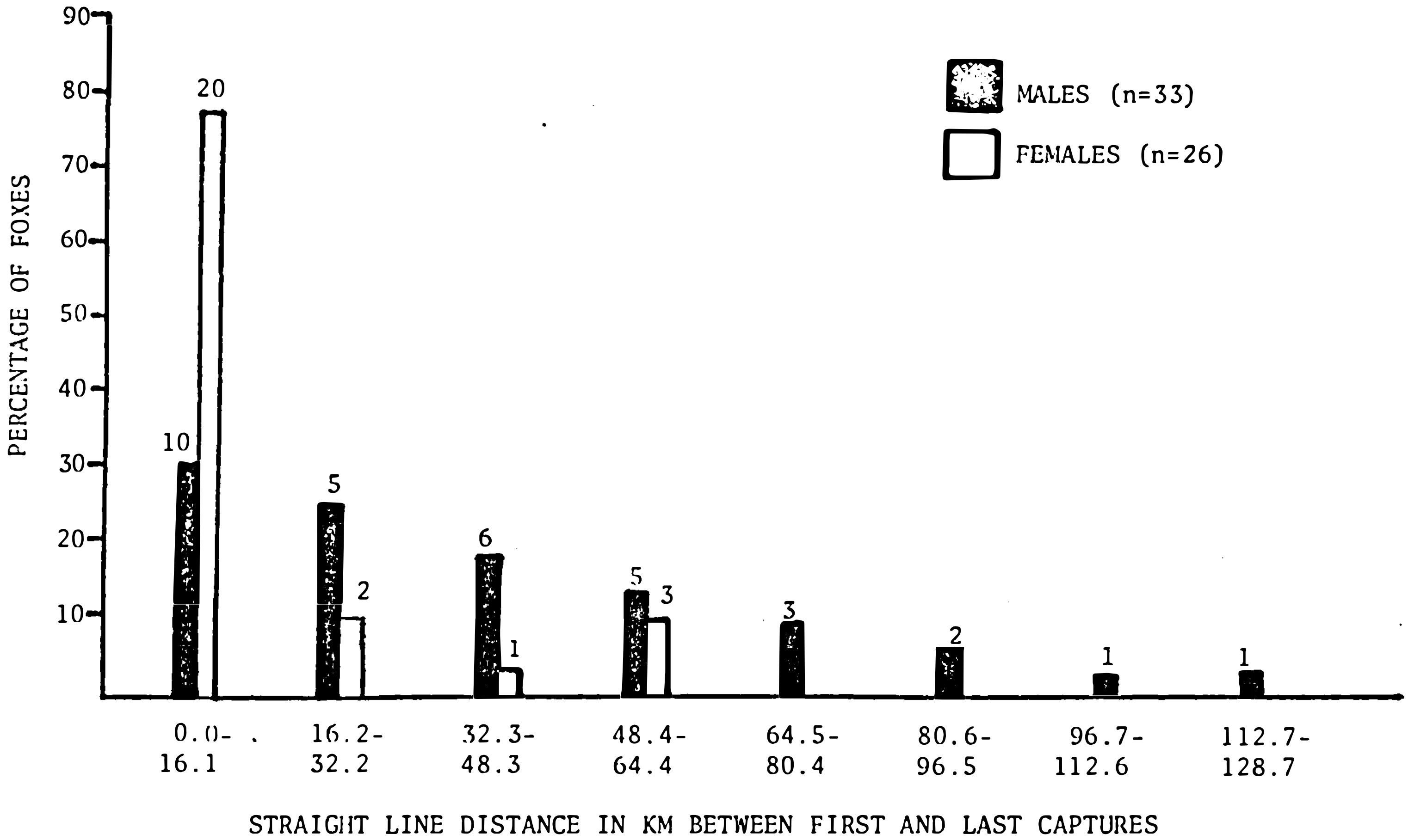

Figure 2. Straight-line distance between the first and last captures for male and female red foxes marked as juveniles, 1974 and 1975.

Table 7. Distance in km between first and last captures of red foxes tagged as juveniles in 1974 and 1975 and recovered during their first year of life.

Month Recaptured	Males: Number of Animals	Males: Distance Mean	Males: Distance Range	Females: Number of Animals	Females: Distance Mean	Females: Distance Range
October	10	20.9	0.0-62.8	8	17.5	0.0-56.3
November	17	42.2	1.9-99.8	15	9.6	0.0-53.9
December	3	65.5	57.9-80.4	3	21.2	4.8-53.1
January	2	62.8	---	0	---	---
February	1	53.1				
Total	33			26		
Mean		39.4			13.4	
Range			0.0-123.9			0.0-56.3

with a mean distance of 13.4 km (Table 7). The maximum distance traveled by a juvenile male was 123.9 km. The maximum distance traveled by a juvenile female was 56.3 km. Phillips et al. (1972), Jensen (1973), and Storm (1972) also observed that juvenile males generally traveled greater distances than did juvenile females.

Although sample sizes were small, the mean recovery distance by month for juvenile males showed an increase each month from October through December (Table 7). Storm (1972) observed this trend and believed that the smaller travel distances observed earlier reflected the possibility that some males were killed before or during dispersal. Storm (1972) reported that data for foxes recovered during January and February probably provided the most accurate records of dispersal since these animals probably survived the dispersal period and were settled in a new area. Unfortunately, the small number of tag returns recovered during these months, in this study, precluded comparison.

In contrast to juvenile males, the mean distance traveled by juvenile females did not increase greatly from October through December (Table 7). Storm (1972) observed that the distance traveled by juvenile females did not increase during the period October through December indicating that dispersal by females occurred at a more uniform rate and for fewer animals than for males.

Data for studying direction of dispersal were provided by recovery locations of 34 foxes which traveled more than 8 km from the point of release. These data indicate that locations of recovered animals were randomly distributed with respect to direction of travel (Table 8).

Table 8. Distribution of tag recoveries by direction for foxes that traveled more than 8 km from their natal ranges.

Test Comparison	Number of Animals NW	NE	SE	SW	Chi-Square Value
All directions	9	9	13	3	6.11
	North			South	
North versus south	18			16	.118
	East			West	
East versus west	22			12	2.94

Phillips et al. (1972) observed a greater proportion of fox recoveries north of release sites than in other directions. They felt this trend may have reflected the increased vulnerability of foxes to hunting pressure in areas north of fox release points since snow was more frequent in regions north of their study areas.

Radio Telemetry Studies

During 1974, five radio collars were placed on red foxes, but due to equipment malfunction, useful movement data were obtained from only three animals: a juvenile male (1), an adult male (2), and an adult female (3). I judge that home range size was adequately measured only for adult male 2 due to intermittant tracking attempts and too few radio fixes for the other two study animals. During summer 1975, five adult foxes and two juvenile foxes were radio-collared. Transmitters on one juvenile male (4) and on four adult (females 5, 6, 7, and 8) functioned throughout the summer. Sargeant (1972) reported that the home range size of any adult family member during a 2 week period in summer portrayed the entire family home range. On this basis, I judge home range size was adequately measured for adults 5, 6, 7 and 8. These foxes plus adult no. 2 tracked during 1974, provided the primary data on summer movements and home range presented. None of the radio-tagged foxes appeared to experience debilitating trap injuries that may have affected their movement patterns.

Age, sex, reproductive status, and other data relative to the radio-tagged foxes are presented in Tables 9 and 10. Foxes radio-

Table 9. Data relative to radio-marked foxes in the study area, summer 1974.

	Animal		
	Juvenile Male (1)	Adult Male (2)	Adult Female (3)
Date collared	6/19/74	7/14/74	6/15/74
Location of release	Brookings Co., T109N, R52W, Sec. 31, NE 1/4	Brookings Co., T109N, R51W, Sec. 15, SE 1/4	Brookings Co., T109N, R52W, Sec. 34, NE 1/4
Date of recapture	11/5/74		12/11/74
Distance and direction traveled between release and recapture location	25.8 km SE of initial capture location		1.0 km NW of initial capture location
Tracking dates	6/25/74 - 8/20/74	7/17/74 - 8/20/74	7/19/74 - 9/2/74
Number of radio foxes	26	39	30

Table 10. Data relative to radio-marked foxes in the study area, summer 1975.

	Animal				
	Juvenile Male (4)	Adult Female (5)	Adult Female (6)	Adult Female (7)	Adult Female (8)
Date collared	6/25/75	7/1/75	7/4/75	6/30/75	6/24/75
Location of release	Lake Co., T108N, R51W, Sec. 8, SE 1/4	Brookings Co., T109N, R51W, Sec. 34, NE 1/4	Brookings Co., T109N, R51W, Sec. 28, NW 1/4	Lake Co., T108N, T51W, Sec. 2, SW 1/4	Brookings Co., T109N, R51W, Sec. 32, SE 1/4
Date recaptured	11/10/75	11/16/75	11/13/75	8/6/75	12/8/75
Distance and direction traveled between release and recapture location	24.14 km SE	0.98 km NW	1.22 km SE	2.26 km NW	7.13 km NE
Tracking dates	7/9/75 - 9/9/75	7/9/75 - 9/4/75	7/9/75 - 9/4/75	7/9/75 - 7/13/75 and 8/5/75 - 9/6/75	7/9/75 - 9/9/75
Number of radio fixes	60	102	91	71	108
Reproductive status during spring 1975		breeding female 7 pups	breeding female 8 pups	breeding female pups unknown	nonbreeding female
Age class[a]	juvenile	2 1/2	2 1/2	adult, age unknown	1 1/2

[a]Age determined by annular cementum technique (Monson et al. 1973).

tracked during 1974 were followed intermittently over a period extending from 19 July to 20 August. Ninety-five radio fixes were recorded. Foxes radio-tracked during 1975 were followed daily over the period from 9 July to 4 September, and 432 radio fixes were recorded.

The mean home range size for 5 adult foxes successfully tracked in this study was 648 ha (1600 acres) with a mean length:width ratio (Stumpf and Mohr 1962) of 1.52. Movements of adult male 2 encompassed an area of 916 ha (2264 acres) with a length:width ratio of 1.28 (Table 11). Movement of females 5, 6, 7, and 8, encompassed areas ranging from 236 ha (583 acres) to 874 ha (2158 acres) with length: width ratios ranging from 1.25 to 2.25 (Table 11). The mean home range size of adult foxes radio-tracked during 1975 was 581 ha (1436 acres). Sargeant (1972) summarized his home range findings, reviewed the results of other home range studies, and concluded that red fox families in the midwest tended to occupy home ranges 259 ha to 777 ha in size.

Adult female 8 occupied a home range markedly smaller in size compared to the other adult foxes. The reason for the smaller home range was unknown. This female was without pups and was later determined to be 1 1/2 years old at time of capture. Females 5 and 6 each whelped a litter of pups, and each was observed to be 2 1/2 years old at time of capture. Adult female 7 also whelped a litter of pups, but her age was unknown.

Table 11. Home-range parameters of radio-marked foxes in the study area, summer 1974 and 1975.

Animal	Home Range Area (ha)	Maximum Length (km)	Maximum Width (km)	Index of Linearity
Juvenile male* no. 1	86	1.41	0.97	1.45
Adult male no. 2	916	4.04	3.15	1.28
Adult female* no. 3	280	2.31	2.06	1.12
Juvenile male no. 4	206	2.18	1.23	1.77
Adult female no. 5	874	4.11	2.98	1.38
Adult female no. 6	629	3.58	2.87	1.25
Adult female no. 7	587	3.66	2.58	1.42
Adult female no. 8	236	2.68	1.19	2.25

* Due to intermittant tracking attempts and to few radio fixes, home range size of these animals not used in computation of mean home range size.

Juvenile male 4 occupied a smaller home range than did adult foxes (Table 11). Storm (1972) radio-tracked an adult male and juveniles in the same family group and observed the adult male traveling over a larger area than the juveniles.

The shape of fox home ranges for adults and juveniles as determined by length:width ratios was somewhat linear. These findings were similar to those of Storm (1965) and Follman (1973). Follman (1973) suggested that the occurrence of a linear shape indicates the importance of this pattern to red foxes and possibly is caused by behavioral interaction between foxes.

Sargeant (1972) indicated that red foxes have an innate minimum and maximum spatial requirement, and that within these spatial limits, home range size is a reflection of population density. The low to medium fox population density (7 to 9 families per township) observed in this study probably accounted for the larger than average size of individual fox home ranges.

Sargeant (1972) stated that red fox families are territorial and occupy well-defined, non-overlapping, contiguous areas with boundaries that are maintained through nonaggressive behavioral mechanisms. In the present study adult females 5, 6, 7, and 8, occupied well-defined, adjacent, non-overlapping home ranges during summer, 1975 (Figure 3). The four contiguous home ranges encompassed almost all available land area except for open water and wet, marshy habitat. Portions of home range boundaries appeared many times to conform to physical boundaries such as roads, shelterbelts, or marsh shorelines.

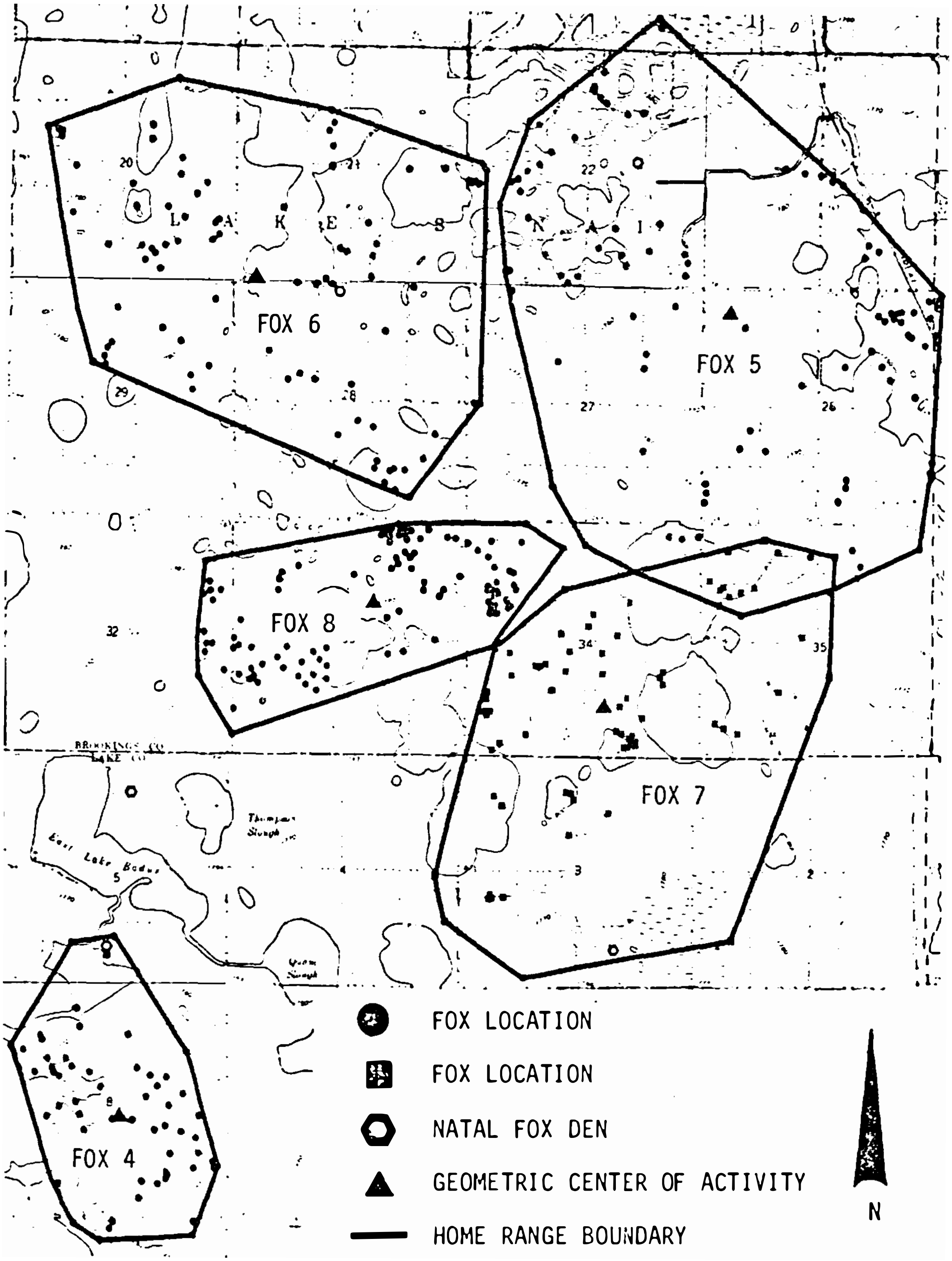

Figure 3. Home ranges of five red foxes in east-central South Dakota, summer 1975.

One area of home range overlap was observed between females 5 and 7. The apparent overlap was perhaps caused by minor changes in the boundaries of home ranges during the radio-tracking period since radio fixes for female 5, located in the area of overlap, were recorded during July and early August, while fixes for female 7 located in the area of overlap were recorded during late August and early September.

Few data concerning habitat use and nightly activity were gathered since individual foxes were located one to three times per night at widely spaced intervals. On several occasions, however, individual foxes were radio-tracked throughout the night and early morning hours. On these occasions individual foxes were observed to travel over a large portion of their home range during a single night.

Individual foxes appeared to regularly use a particular area each day as a bedding area. Known resting areas in this study were located in cornfields, shelterbelts, and dry cattail marshes. Similarly, Storm (1965) found that red foxes in Illinois regularly returned to a familiar rest area for daytime resting but seldom re-used a particular bedding place.

Storm (1972) observed that at the age of 12 to 15 weeks juveniles begin to separate from their littermates and parents, and become spatially distributed throughout the family home range. Juvenile male 4 belonged to a litter of eight pups. This fox was trapped on the night of 25 June 1975 and was captured with a littermate. The capture location was approximately 1.3 km southeast of the den site. On the same night, four additional littermates were trapped; two were captured together approximately 0.3 km south-southwest of the den site and two were captured together approximately 0.1 km east of the den site. One fox from each captured pair possessed ear tags at the time of capture and this was presumed to indicate that all belonged to the same litter.

CONCLUSIONS

The late-May aerial census of fox dens and the resulting estimate of family density provided a suitable method for monitoring fox populations in eastern South Dakota. The method is useful primarily in areas with little tree cover.

Conclusions concerning the impact of two years of high fur prices on the fox population were based primarily on the results of monitoring the population density and home range size of foxes on a 23,319 ha study area and on estimates of human-caused fox mortality based on recoveries of tagged foxes.

Family estimates indicated a decline in the fox population from a medium density in spring 1974 to a medium-low density in spring 1975. The decline may have been caused by intensive human pressure in the form of hunting and trapping. Evidence for this conclusion is based primarily on high first year recovery rates (54 percent) of tagged foxes. These recovery rates include five foxes recovered by the author. Recovery rates were higher in the present study than in previous studies (Table 6). Recovery rates represented a minimum estimate of human-caused mortality during September through February since some tag loss did occur and some recovered animals were probably not reported.

Mortality of foxes outside the September through February period was unknown. A crude estimate of the total annual mortality of foxes from 1974 to 1975 was 76 percent based on pre and post natal population estimates.

Approximately 73 percent of the marked and recovered juvenile male foxes dispersed during the first year. Dispersal was less pronounced among female foxes; 31 percent dispersed. The mean distance traveled by all juvenile foxes recovered during their first year was approximately 28 km. Males generally traveled greater distances than females. These dispersal rates and the distances traveled, especially by juvenile foxes, insure a high rate of interchange between local fox populations and provide a rapid means of filling vacant spaces created by foxes harvested or dispersing from an area. The high mobility of the red fox must be considered when weighing the positive and negative aspects of implementing a fox reduction program.

Summer home range size and spatial arrangement were studied on an area within the glaciated prairie pothole region. Adult foxes occupied home ranges averaging 648 ha (1600 acres). Individual home ranges appeared to have well-defined boundaries. Overlap between contiguous home ranges was slight.

The red fox is an economically valuable mammalian species in South Dakota as evidenced by the volume of pelts sold each year and the high price paid per individual fox pelt. Further evidence of this value is provided by data from this study which showed that man, through hunting and trapping, accounted for approximately 96 percent of the mortality of foxes as reported by tag recoveries. The fox offers recreational opportunities to trappers and hunters from October through February

This includes a long period when the majority of game seasons are closed. The overall value of this mammal to sportsman may increase in years to come if the numbers of other game animals decline (Storm 1972). Future management decisions concerning red foxes should be based not only on depredations of foxes upon wild fowl and domestic livestock but also on the significance of the fox as a valuable furbearer and game species.

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Appendix Table 1. Hectares and percentage (in parentheses) of land use types on sample plots, 1973-74 (Olson 1975).

Land use type	Number of hectares 1973	1974	Average
Residual Cover	88.66 (24.4)	74.70 (20.5)	81.68 (22.4)
Marsh	35.50 (9.8)	32.38 (8.9)	33.94 (9.3)
Idle farmland	31.33 (8.6)	19.37 (5.3)	25.35 (6.9)
Shelterbelt	9.09 (2.5)	9.03 (2.5)	9.06 (2.5)
Fencerow	6.44 (1.8)	7.05 (1.9)	6.75 (1.9)
Roadside	6.30 (1.7)	6.87 (1.9)	6.58 (1.8)
Crops	156.04 (42.9)	164.40 (45.1)	160.22 (44.0)
Corn	81.16 (22.3)	80.36 (22.0)	80.76 (22.2)
Oats	41.98 (11.5)	40.68 (11.2)	41.33 (11.3)
Flax	14.06 (3.9)	24.23 (6.6)	19.14 (5.3)
Wheat	11.97 (3.3)	18.74 (5.2)	15.36 (4.2)
Barley	3.89 (1.1)	0.39 (0.1)	2.14 (0.6)
Stubble	2.22 (0.6)	0.00	1.11 (0.3)
Sorghum	0.76 (0.2)	0.00	0.38 (0.1)
Hayfields	38.68 (10.6)	34.73 (9.5)	36.71 (10.1)
Alfalfa	35.73 (9.8)	29.83 (8.2)	32.78 (9.0)
Tame hay	2.93 (0.8)	4.85 (1.3)	3.89 (1.1)
Clover	0.02	0.06	0.04
Miscellaneous	80.48 (22.1)	90.78 (24.9)	85.64 (23.5)
Pasture	58.95 (16.2)	64.86 (17.8)	61.91 (17.0)
Lake Sinai	14.68 (4.0)	14.73 (4.0)	14.70 (4.0)
Roads	3.55 (1.0)	3.58 (1.0)	3.57 (0.9)
Fallow	1.61 (0.4)	4.11 (1.1)	2.86 (0.8)
Residential	0.88 (0.2)	0.44 (0.1)	0.67 (0.2)
Farmyard	0.62 (0.2)	2.22 (0.6)	1.42 (0.4)
Creeks	0.19 (0.1)	0.17 (0.1)	0.18 (0.1)
Feedlots	0.00	0.67 (0.2)	0.33 (0.1)
Total	363.86	364.62	364.25

Appendix Table 1. Hectares and percentage (in parentheses) of land use types on sample plots, 1973-74 (Olson 1975).

	Number of hectares		
Land use type	1973	1974	Average
Residual Cover	88.66 (24.4)	74.70 (20.5)	81.68 (22.4)
Marsh	35.50 (9.8)	32.38 (8.9)	33.94 (9.3)
Idle farmland	31.33 (8.6)	19.37 (5.3)	25.35 (6.9)
Shelterbelt	9.09 (2.5)	9.03 (2.5)	9.06 (2.5)
Fencerow	6.44 (1.8)	7.05 (1.9)	6.75 (1.9)
Roadside	6.30 (1.7)	6.87 (1.9)	6.58 (1.8)
Crops	156.04 (42.9)	164.40 (45.1)	160.22 (44.0)
Corn	81.16 (22.3)	80.36 (22.0)	80.76 (22.2)
Oats	41.98 (11.5)	40.68 (11.2)	41.33 (11.3)
Flax	14.06 (3.9)	24.23 (6.6)	19.14 (5.3)
Wheat	11.97 (3.3)	18.74 (5.2)	15.36 (4.2)
Barley	3.89 (1.1)	0.39 (0.1)	2.14 (0.6)
Stubble	2.22 (0.6)	0.00	1.11 (0.3)
Sorghum	0.76 (0.2)	0.00	0.38 (0.1)
Hayfields	38.68 (10.6)	34.73 (9.5)	36.71 (10.1)
Alfalfa	35.73 (9.8)	29.83 (8.2)	32.78 (9.0)
Tame hay	2.93 (0.8)	4.85 (1.3)	3.89 (1.1)
Clover	0.02	0.06	0.04
Miscellaneous	80.48 (22.1)	90.78 (24.9)	85.64 (23.5)
Pasture	58.95 (16.2)	64.86 (17.8)	61.91 (17.0)
Lake Sinai	14.68 (4.0)	14.73 (4.0)	14.70 (4.0)
Roads	3.55 (1.0)	3.58 (1.0)	3.57 (0.9)
Fallow	1.61 (0.4)	4.11 (1.1)	2.86 (0.8)
Residential	0.88 (0.2)	0.44 (0.1)	0.67 (0.2)
Farmyard	0.62 (0.2)	2.22 (0.6)	1.42 (0.4)
Creeks	0.19 (0.1)	0.17 (0.1)	0.18 (0.1)
Feedlots	0.00	0.67 (0.2)	0.33 (0.1)
Total	363.86	364.62	364.25

Appendix Table 2. Body dimensions and tagging data collected from fox pups during 1974.

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
1	5/4/74	001	T111N	F	1640	112	592	203	60	1.6		11/74
		002	R50W									
		003	Section 29	F	1600	114	592	206	62	4.8	NW	11/74
		004										
		005		M	1640	114	622	187	65	39.4	NW	10/74
		006										
		007		F	1680	114	611	202	63	1.6		11/74
		008										
2	5/9/74	009	T110N	M	1360	117	---	190	60	2.4		10/74
		010	R48W									
		011		F	1360	114	---	203	60	5.6	W	10/74
		012										
3 (T)	5/16/74	013	T110N	M	1820	106	606	202	65			
		014	R50W									
		015	Section 29	M	1820	121	613	192	66	124.7	SE	1/75
		016										
		017	released	M	1860	117	638	194	66	80.5	SE	12/74
		018										
		019	T109N	M	2040	117	607	190	64	62.8	SE	10/74
		020	R50W									
		021	Section 3	M	1910	111	616	190	64	no travel		10/74
		022										
4	5/16/74	026	T109N	F	1820	126	711	241	68	no travel		10/74
		027	R50W									
		028	Section 3									

Appendix Table 2. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
10	5/21/74	029	T108N	F	---	127	737	254	73	38.6	SE	12/75
		031	R52W									
		032	Section 8									
		033		M	---	116	673	216	70	88.6	NW	11/74
		034										
		035										
11	5/22/74	042	T109N	M	---	133	787	248	78	3.2		11/74
		043	R51W									
			Section 5									
12	5/21/74	036	T109N	F	---	122	673	248	73			
		037	R51W									
		038	Section 4	M	---	133	718	264	71	no travel		10/74
		039										
13	5/22/74	040	T108N	M	2840	132	781	270	83			
		041	R52W									
			Section 8									
14	5/23/74	044	T108N	M	2960	130	724	235	71	1.6		11/74
		045	R51W									
		046	Section 3	F	2950	119	673	206	70			
		047										
		049		F	2950	130	689	202	68	19.3	SE	12/75
		050										
15	5/25/74	051	T109N	F	3040	133	708	222	76			
		052	R52W									
			Section 20									

Appendix Table 2. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
16	5/26/74	054	T110N	F	1910	117	692	197	70	4.4	NW	11/74
(T)		055	R51W									
		056	Section 26	F	1820	114	654	200	70	16.1	NW	11/74
		057										
		058	released	F	1750	113	686	203	70			
		059										
		060	T109N	M	2140	124	737	213	71	48.3	NE	11/74
		061	R52W									
		062	Section 21	M	1910	121	714	200	73			
		063										
17	5/29/74	064	T109N	M	2360	127	698	254	71	41.9	NE	/74
		065	R52W									
		066	Section 27	M	1960	110	667	217	65			
		067										
18	5/29/74	068	T108N	F	2140	133	752	243	73	2.4		10/74
		069	R52W									
		070	Section 8	M	2270	140	787	256	78	1.6		10/74
		071										
		072		F	2180	133	743	257	76	41.0	SE	11/74
		073										
19	6/19/74	106	T109N	M	3090	154	---	286	81	25.8	SE	11/74
		107	R52W									
			Section 31									

Appendix Table 2. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
20	6/19/74	101	Kingsbury	M	3090	152	952	359	90	one re-		
		102	County									
		103		F	2820	152	917	324	84	captured		
21	5/31/74	089	T109N	M	3090	152	816	279	83			
		090	R52W									
		083	Section 35	M	2730	151	838	273	86			
		084										
		093		F	----	140	---	---	--			
		094										
22	5/30/74	079	T109N	M	2140	135	730	235	73	20.9	NW	11/74
		080	R52W									
		087	Section 21	F	1730	124	692	226	71			
		088										
		081	Kingsbury	F	2460	135	822	257	79			
		082	County									
(T)		085	released	F	2320	135	781	260	79	31.4	SE	10/74
		086	same as									
			above									

Appendix Table 3. Body dimensions and tagging data collected from fox pups during 1975.

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
1	2/6/75	126/127	T109N R48W Section 15	M	1677	109	635	190	64			
		129/130		M	1509	108	610	201	66	4.8	N	10/75
		131/132		M	1509	108	635	183	64			
2	5/11/75	152/153	T109N R50W Section 3	F	1591	116	645	187	67			
		149/155		M	1677	117	603	190	68			
		156/157		M	1618	116	622	190	67			
		158/159		F	1536	113	648	197	64	no travel		10/75
		160/161		M	1732	119	667	190	64			
3	5/14/75	133/134	T108N R50W Section 22	F	1277	103	581	171	60	14.8	SE	11/75
		136/138		M	1645	105	600	168	64	49.4	SE	10/75
		139/162		F	1391	100	606	162	56	--	--	11/75
		164/165		F	1164	95	540	159	59	56.3	NE	10/75
		166/167		M	1418	102	578	165	59	48.3	NE	10/75
		168/169		M	1564	109	603	184	60	20.9	SW	11/75

Appendix Table 3. Continued

Den	Date tagged	Tag no.	Location of capture of release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
		176 177		F	1418	106	590	152	57			
		174 178		M	1591	113	597	178	64			
		175 179		F	1250	102	578	178	64	24.1	NE	11/75
		180 181		M	1309	103	578	171	60			
		182 194		M	1336	106	590	184	64			
4	5/15/75	197 198	T109N R50W Section 5	F	1677	116	660	216	66			
5	5/16/75	192 193	T110N R51W Section 24	F	adult							
		141 143		M	1645	109	651	194	64	53.1	NE	2/76
		146 147		F	1704	111	645	197	64	--	--	4/76
		195 199		F	1764	119	648	216	66			
		142 144		F	1904	116	645	210	66	5.6	SE	12/75
		172 173		M	1732	111	578	178	66	0.2	SW	10/75
		170 171		F	1477	102	565	165	60	2.4	SE	11/75
		184 185		F	1477	105	616	184	64	4.8	SE	12/75
		186 187		F	1477	102	572	165	60			

Appendix Table 3. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
6	5/19/75	190 191	T113N R50W	F	1590	121	---	190	66	--	--	12/75
		189 188	Section 6	M	2218	124	---	203	68			
		201 202		M	2045	124	--	216	76	33.0	SW	11/75
7	5/19/75	203 204	T111N	M	936	84	---	140	49.2			
8	5/20/75	207 208	T109N R48W	M	2700	140	---	248	76			
		211 212		M	2473	138	---	254	82			
9	5/21/75	213 214	T109N R51W	F	adult					1.2	NW	12/75
		215 216		M	2554	127	444	241	76	10.4	E	11/75
10	5/21/75	217 218	T114N R56W	M	2100	130	676	216	76			
		219 220	Section 3	M	1991	127	679	216	73	73.2	SW	11/75
		221 222		M	2045	133	718	229	76			
		223 224		M	2045	132	686	216	76			
		225 226		M	1873	130	667	216	76			
		227 228 229		F	1764	122	673	203	70	4.0	NW	11/75

Appendix Table 3. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
12	5/22/75	230 231	T107N R49W	M	2218	121	660	203	73			
		232 233	Section 31	F	1873	121	651	206	73			
		234 235		F	1704	111	625	194	68			
		236 237		F	2159	117	644	206	70	6.8	NW	10/75
		238		F	1704	114	540	187	70			
13	5/25/75	240 245	T109N R51W	F	2159	127	730	229	73	no travel		11/75
		244 249	Section 18	F	2159	127	692	219	79			
14	5/26/75	243 246	T109N R52W	M	1991	128	679	210	79	57.9	NW	12/75
		247 248	Section 36	M	1873	128	692	229	76	47.5	NE	11/75
		274 275		M	1873	128	660	216	79	no travel		1/76
		272 273		M	----	130	692	222	76			
15	5/27/75	276 277	T108N R53W	F	1645	117	635	184	70	53.1	NW	12/75
16	5/27/75	278 279	Lake County Bddus Twnship	M	2045	127	678	216	76			
		280 281	Section 27	M	2104	124	698	229	76			
17	5/28/75	298 299	T108N R52W Section 21	F	2213	127	730	229	73	6.4	NE	11/75

Appendix Table 3. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
18	5/30/75	282	T108N	M	2727	140	768	267	81			
		283	R50W									
		284	Section 3	M	2727	138	756	260	79	20.5	NW	11/75
		285										
		286		M	2386	137	737	254	82			
		287										
19	5/30/75	288	Lake County	M	2159	135	705	248	79	93.3	NE	11/75
		289	Summit Twp									
		291	Section 11	M	2045	133	718	235	73			
		293										
20	5/31/75	270	T108N	M	----	---	---	---	--	21.7	SE	11/75
		271	R52W									
	6/3/75	266	Section 5	F								
		267										
		268		M								
		269										
	6/2/75	294								--	--	11/75
	6/24/75	322		F	----	---	---	---	--	53.9	NW	11/75
		323										
		324		M						99.8	E	11/75
		325										
		320		F								
		321										
20a	6/5/75	301	T115N	F	2327	133	686	267	76	6.4	SE	11/75
		302										
21	6/4/75	296	T112N	M	2554	149	816	295	86	59.5	SE	12/75
		297	R54W									
			Section 11									

Appendix Table 3. Continued

Den	Date tagged	Tag no.	Location of capture and release	Sex	Weight (gm)	Hind foot length (mm)	Total length (mm)	Tail length (mm)	Ear length (mm)	Dispersal distance (km)	Dispersal direction	Date of recapture
22	6/4/75	253 254	T113N R54W	F	2500	141	813	292	82			
		255 256	Section 21	F	2500	137	756	267	79			
		258 259		M	2954	152	781	286	86	67.6	NW	11/75

Appendix Table 4. Data concerning fox families located in study area, 1974.

Family	Den location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
1	Brookings Co., T110N, R52W, Sec. 35	yes	air	adult fox	pasture-cropland (fenceline)
2	Brookings Co., T109N, R52W, Sec. 1	yes	air	den-fox pups	idle grassland-cropland (fenceline)
3	Brookings Co., T109N, R52W, Sec. 10	no	air	den-no fox	idle grassland
4	Brookings Co., T109N, R52W, Sec. 22	yes	air	den-no fox, adult fox nearby	pasture
5	Brookings Co., T109N, R52W, Sec. 8	no	air	adult fox	---
6	Brookings Co., T109N, R52W, Sec. 20	yes	air	den-fox pups	idle grassland

Appendix Table 4. Continued

Family	Den location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
7	Brookings Co., T109N, R52W, Sec. 21	yes	ground	active den	idle grassland (slough)
8	Brookings Co., T109N, R52W, Sec. 26	yes	ground	active den	---
9	Brookings Co., T109N, R52W, Sec. 31	no	ground	active den	alfalfa
10	Brookings Co., T109N, R52W, Sec. 34	yes	air	den-fox pups	cropland (fenceline)
11	Brookings Co., T109N, R52W, Sec. 35	yes	air	den-fox pups	pasture
12	Brookings Co., T109N, R51W, Sec. 5	yes	air	den-fox pups	pasture

Appendix Table 4. Continued

Family	Den location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
13	Brookings Co., T109N, R51W, Sec. 3	yes	ground	active den	---
14	Lake Co., T108N, R52W, Sec. 6	no	ground	active den	idle grassland
15	Brookings Co., T109N, R51W, Sec. 16	yes	air	den-fox pups	pasture
16	Brookings Co., T109N, R51W, Sec. 15	yes	air	den-fox pups	alfalfa
17	Brookings Co., T109N, R51W, Sec. 18	yes	ground	active den	pasture (gravel pit)
18	Brookings Co., T109N, R51W, Sec. 32	yes	ground	active den	pasture

Appendix Table 4. Continued

Family	Den location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
19	Brookings Co., T109N, R51W, Sec. 34	yes	air	den-adult fox and fox pups	cropland
20	Lake Co. T108N, R51W, Sec. 3	yes	air	den-fox pups	pasture
21	Lake Co. T108N, R51W, Sec. 5	no	air	den-fox pups	idle grassland (slough)
22	Lake Co., T108N, R52W, Sec. 11	yes	air	den-no fox	idle grassland (slough)
23	Lake Co., T108N, R52W, Sec. 8	yes	air	den-fox pups	cropland (fenceline)
24	Lake Co., T108N, R52W, Sec. 5	yes	air	den-fox pups	alfalfa

Appendix Table 5. Data concerning fox families located in study area, 1975.

Family	Den Location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
1	Brookings Co., T110N, R52W, Sec. 33	yes	air	den-no fox	idle grassland (slough)
2	Brookings Co., T109N, R52W, Sec. 5	yes	ground	active den	pasture
3	Brookings Co., T109N, R52W, Sec. 1	yes	air	den-adult fox	idle grassland
4	Brookings Co., T109N, R52W, Sec. 18	no	air	den-no fox	idle grassland (slough)
5	Brookings Co., T109N, R52W, Sec. 13	yes	ground	active den	pasture
6	Brookings Co., T109N, R52W, Sec. 22	yes	air	den-fox pups	pasture

Appendix Table 5. Continued

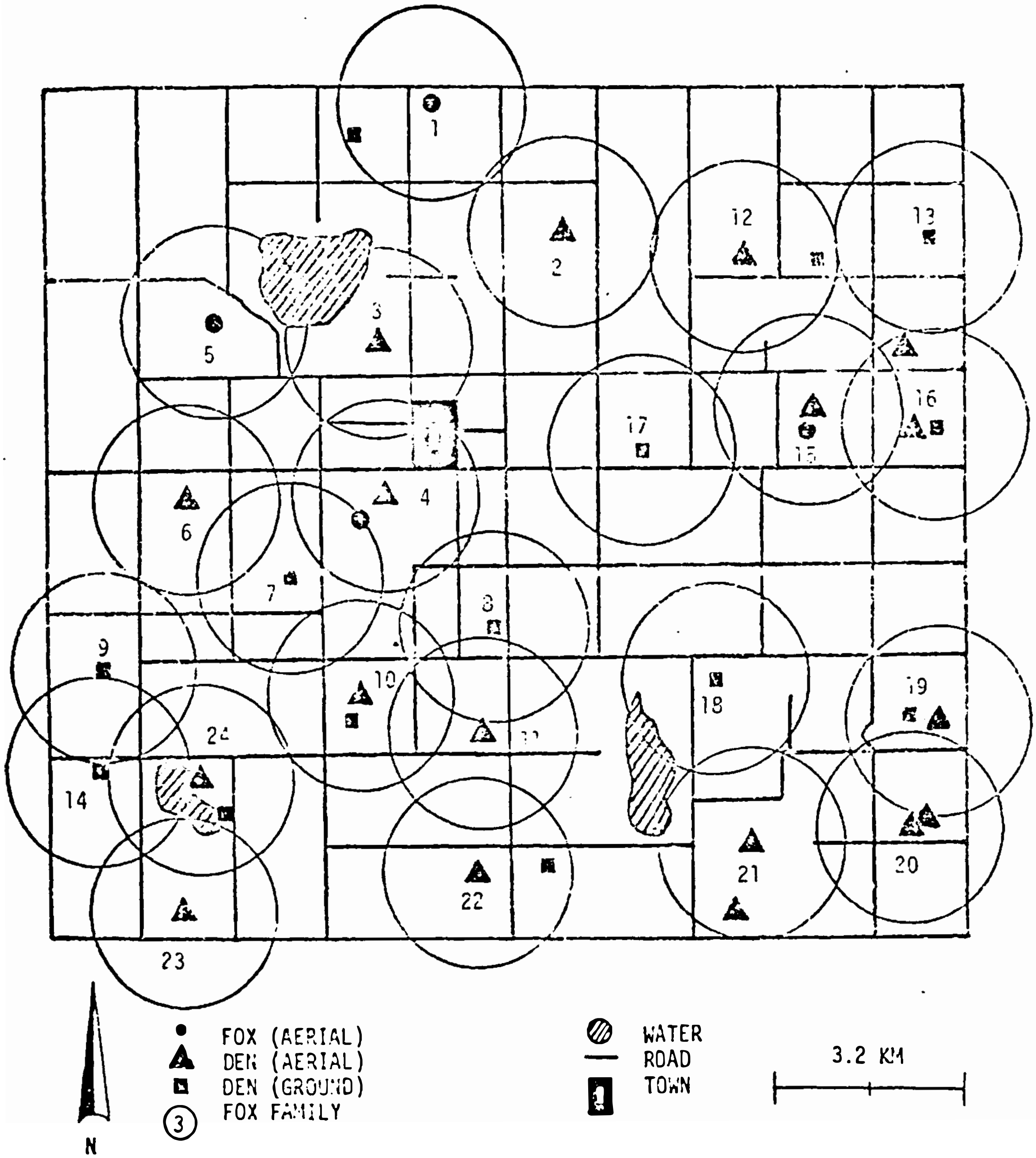
Family	Den Location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
7	Brookings Co., T109N, R52W, Sec. 28	yes	air	den-fox pups	idle grassland (slough)
8	Brookings Co., T109N, R52W, Sec. 31	yes	air	den-no fox	idle grassland (slough)
9	Brookings Co., T109N, R52W, Sec. 35	yes	ground	active den	---
10	Brookings Co., T109N, R52W, Sec. 36	yes	air	den-fox pups	pasture
11	Brookings Co., T109N, R51W, Sec. 4	yes	air	den-no fox	pasture
12	Brookings Co., T109N, R51W, Sec. 18	yes	air	den-no fox	pasture

Appendix Table 5. Continued

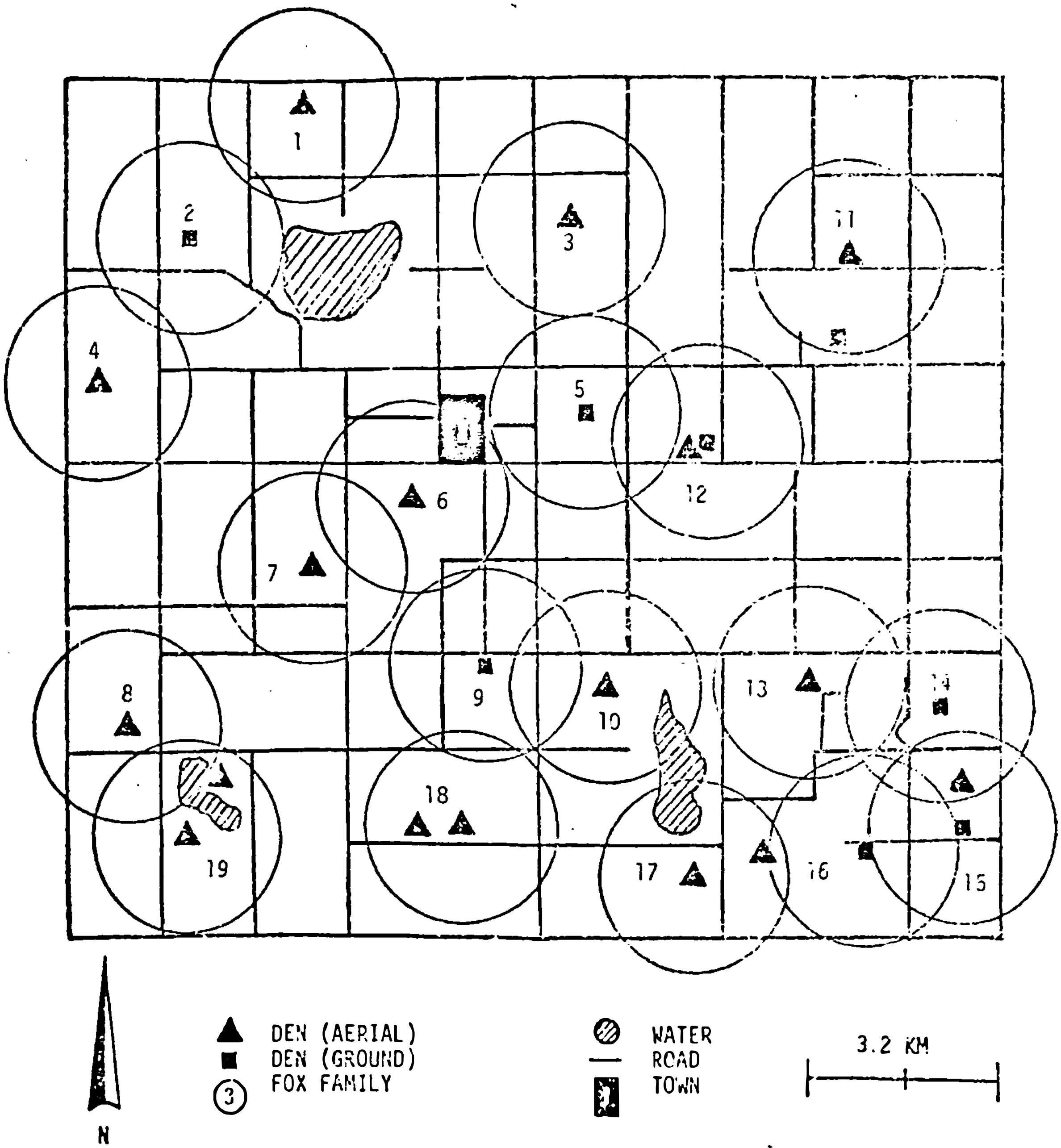
Family	Den Location	Landowner knowledge of fox family	Method of location	Family indicator	Cover type around den
13	Brookings Co., T109N, R51W, Sec. 32	no	air	den-fox pups	pasture
14	Brookings Co., T109N, R51W, Sec. 34	yes	ground	active den	pasture
15	Lake Co., T108N, R51W, Sec. 3	yes	air	den-fox pups	alfalfa
16	Lake Co., T108N, R51W, Sec. 9	yes	ground	active den	pasture
17	Lake Co., T108N, R51W Sec. 7	no	air	den-no fox	idle grassland
18	Lake Co., T108N, R52W, Sec. 3	yes	air	den-no fox	alfalfa
19	Lake Co., T108N, R52W, Sec. 5	yes	air	den-fox pups	pasture (slough)

Appendix Table 6. Age data for foxes trapped during fall and winter, 1974-75 and 1975-76.

Year	Contributor	Sample Size	Adult	Juvenile	Ratio (adult:juvenile)
1974-75	T. Rose	36	8	28	1:3.5
	E. Overend	41	10	31	1:3.1
	J. Sweeting	49	15	34	1:2.3
	J. Martin	24	6	18	1:3.0
	C. Jensen	83	18	65	1:3.6
Total		233	57	176	1:3.1
1975-76	J. Sweeting	48	11	37	1:3.4
	J. Martin	36	7	29	1:4.1
	C. Jensen	87	9	78	1:8.6
Total		171	27	144	1:5.3



Appendix Figure 1. Delineation of individual fox families observed from air and ground in the study area, during 1974.



Appendix Figure 2. Delineation of individual fox families observed from air and ground in the study area, during 1975.