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KIT FOX MOVEMENTS AND HOME RANGE USE IN WESTERN ARIZONA

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KIT FOX MOVEMENTS AND HOME RANGE USE IN
WESTERN ARIZONA

by
Bruce William Zoellick

A Thesis Submitted to the Faculty of the
SCHOOL OF RENEWABLE NATURAL RESOURCES
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE ECOLOGY
In the Graduate College
THE UNIVERSITY OF ARIZONA

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	v
LIST OF TABLES	vii
ABSTRACT	viii
INTRODUCTION	1
STUDY AREA	3
METHODS	4
Location Accuracy	4
Home Range Use	5
Movements and Activity	6
Home Range Size and Overlap	7
Seasons	7
RESULTS	9
Fox Density	9
Dens	9
Prey Distribution	11
Activity and Movements	13
Home Range Size and Spatial Organization	16
Home Range Use	20
DISCUSSION	31
Home Range Use	31
Activity and Movements	33
Home Range Size	34
Fox Density and Social Organization	37
APPENDIX A: ESTIMATION AND REDUCTION OF LOCATION ERROR IN RADIO-TRIANGULATION	40
APPENDIX B: HOME RANGE SIZE ESTIMATES CALCULATED WITH THE MINIMUM AREA METHOD	52
APPENDIX C: FIGURES OF FOX HOME RANGES DETERMINED WITH THE MINIMUM AREA METHOD	53
LITERATURE CITED	60

LIST OF FIGURES

Figure	Page
1. Distribution of kit fox dens in western Arizona compared to the values expected if the dens are distributed randomly relative to the distance to the nearest wash	10
2. Kit fox activity, measured in km traveled per hour, throughout the night during pup rearing (PR) and pair formation & breeding (PF & BR) seasons in western Arizona, 1983-84	14
3. Example of the ranging pattern of straight line movements typical of kit foxes in western Arizona	17
4. Spatial organization of home ranges of paired kit foxes in western Arizona, 1982-1984	21
5. Spatial organization of the pup rearing (March 16 through September 1983) and pair formation & breeding (October 1983 through January 1984) seasonal home ranges of 3 male kit foxes in western Arizona	22
6. Distribution of the distance traveled by fox F16 in different areas of her home range in western Arizona, December 1982 to August 1983	24
7. Distribution of the time spent by fox F16 in different areas of her home range in western Arizona, December 1982 to August 1983	26
8. Example of a system error adding to the movement error in radio-triangulation	41
9. Addition and subtraction of the system error with the movement error in radio-triangulation	42
10. The introduction of a second system error when using simultaneous triangulation bearings to estimate the location error in radio-triangulations	45
11. Addition and subtraction of the second system error with the location error when using simultaneous bearings to estimate the location error in radio-triangulations	46

12.	Pup rearing seasonal home range of the male kit fox F15, June to September 1983	53
13.	Pair formation & breeding seasonal home range of the male kit fox F15, October 1983 to January 1984	54
14.	The home range of the male kit fox F15 from June 1983 to January 1984	55
15.	The home range of the male kit fox F7 from September 1983 to March 1984	56
16.	The home range of the male kit fox F19 from February 1983 to January 1984	57
17.	The home range of the female kit fox F8 from October 1983 to January 1984	58
18.	The home range of the female kit fox F16 from December 1982 to August 1983	59

LIST OF TABLES

Table	Page
1. The distribution of the biomass of nocturnal rodents on the study area in western Arizona, April to September 1983	12
2. Nightly movements (km) of kit foxes in western Arizona, December 1982 to March 1984	15
3. Percent change in the size of kit fox home ranges in western Arizona with the addition of sequential full-night sample periods for 2 males and 1 female during pair formation & breeding season and 1 male during pup rearing season	18
4. Home range size estimates (km ²) of kit foxes in western Arizona, 1982-84, calculated with the grid method	19
5. Proportions of time spent by kit foxes in creosotebush flat and wash habitat classes in western Arizona, December 1982 to March 1984, in comparison to the availability of the classes .	25
6. Average travel speeds of kit foxes in creosotebush flat and wash habitat classes in western Arizona, December 1982 to March 1984	28
7. Habitat class use by individual kit foxes in western Arizona, December 1982 to March 1984, based on the number relocations in each class	29
8. Habitat class use by kit foxes in western Arizona, December 1982 to March 1984, based on the relocations of the 7 foxes in each habitat class	30
9. Home range size estimates (km ²) of kit foxes in western Arizona, 1982-84, calculated with the minimum area method . .	52

ABSTRACT

I examined kit fox (Vulpes macrotis) movements and home range use on a 51 km² study area of the Sonoran desert in western Arizona. I located 7 radio-collared foxes (3 females, 4 males) 2,596 times from December 1982 to March 1984. The foxes typically traveled in straight line movements to the edge of their home ranges and then back towards the interior. Male foxes traveled 8.6 to 26.3 km, and females 6.7 to 16.7 km in a night. Males traveled greater distances during the night during the breeding season ($P < 0.05$). Nightly movements of females were significantly smaller during gestation and early pup rearing ($P < 0.05$). Kit foxes preferentially denned, and spent significantly more time ($P < 0.01$) in creosotebush (Larrea divaricata) flats, but the distances traveled by the foxes in the creosotebush flats, and riparian wash areas supporting higher levels of prey biomass, did not differ from that expected by the availability of the areas ($P > 0.05$). Male and female foxes paired year around and maintained home ranges that overlapped very little with those of other pairs. Home ranges averaged 11.2 km² in size.

INTRODUCTION

Kit foxes inhabit desert and semi-arid regions of western North America (McGrew 1979). These flat, open habitats are often valued for agricultural and urban development. Because of their unwariness (Egoscue 1956), kit fox populations often decline substantially in areas inhabited by man. The long-eared kit fox (V.m. macrotis) was extirpated by man from southwest California by 1910 (Grinnell, Dixon, and Linsdale 1937). The San Joaquin kit fox (V.m. mutica) is on the list of endangered species (U. S. Department of the Interior 1976). Agricultural and industrial development of native habitats primarily caused the large decline in numbers of San Joaquin kit foxes (Laughrin 1970, Knapp 1978). Another subspecies (V.m. nevadensis) is listed as endangered by the state of Oregon (Olterman and Verts 1972). As the human population increases in the southwestern United States and more habitat is disturbed, kit fox numbers will continue to decline.

Details of kit fox movements are largely unknown (McGrew 1979). Knowledge of how foxes use resources available within their home ranges would be valuable in the conservation and management of kit foxes in areas where habitats are being disturbed. In this study, I examined movements and use of home range by the desert kit fox (V.m. arsipus) in relation to habitat characteristics and prey distributions. Specific objectives of the study were to determine the amount of time spent and distance traveled by kit foxes in creosotebush flat and riparian wash habitats compared to the availability of each within their home ranges;

to determine the distribution of prey and distinguish the activities of the foxes in the two habitats; to examine the size and spatial organization of home ranges of kit foxes; and to determine if movements of kit foxes and use of home range vary seasonally.

STUDY AREA

The study was conducted on 51 km² area of the Lower Colorado River Valley subdivision (Turner and Brown 1982) of the Sonoran Desert. The study area is located 7.5 km northwest of Tonopah, Arizona, on the the lower reaches of a flat, outwash plain sloping to the south from the Belmont and Big Horn Mountains. The elevation ranges from 425 to 365 m. The vegetation of the area is characterized by a creosotebush association (Brown, Lowe, and Pase 1979). Foothill paloverde (Cercidium microphyllum), blue paloverde (C. floridum), and ironwood trees (Olneya tesota) grow along washes, 10 to 50 m wide, that frequently incise the area. Shrubs commonly found along the washes include catclaw (Acacia greggii), wolfberry (Lycium spp.), whitethorn acacia (Acacia constricta), triangle-leaf bursage (Ambrosia deltoidea), and brittlebush (Encelia farinosa). The annual rainfall for the area averages 19.9 cm with most of it falling during the winter (December through February), and summer (July through September) rainy seasons. Mean daily temperatures during the summer average 31.1 C, and 11.3 C during the winter (Sellers and Hill 1974).

METHODS

I trapped 12 kit foxes in box traps baited with rabbit carcasses. The foxes captured were sexed, weighed, and fitted with radio-collars (Model L2B5, Telonics, Inc., Mesa, AZ). I located the foxes with a truck-mounted, paired yagi antenna, null tracking system.

One fox was located every 15 to 20 minutes during sample periods 4 to 8 hours long. I spaced the sample periods systematically throughout the nocturnal activity period of the foxes, so that each fox was monitored from sunset to sunrise once a month.

I estimated the minimum number of adult kit foxes present on the study area from trapping and radio-collaring of foxes combined with sightings of unmarked individuals outside of known ranges of radio-collared animals.

Location Accuracy

I triangulated the locations of the animals from fixed points along roads. With two null tracking systems, a second researcher and I simultaneously located kit foxes to estimate the location error present in the radio-triangulations (See Appendix A). The locations have a mean error of 94 m, and ninety-five percent of the locations are accurate within 236 m. Using a correction factor based on the speed and direction of travel of the fox just after triangulation (Appendix A), I reduced the mean location error on 87 percent (2265 of 2596) of the triangulations to 66 m. Ninety-five percent of the corrected

triangulations are accurate within 142 m. I included only the corrected triangulations in the home range use analyses because of the small size of the riparian wash areas. All locations were included in the movement and home range size analyses because the home range areas and nightly movements of the foxes were much larger than the location errors in the uncorrected triangulations. Thus, these analyses were probably not greatly affected by the inclusion of the triangulations with the larger location errors.

Home Range Use

I calculated the triangulation locations, and examined home range use of kit foxes with a telemetry program provided by J. W. Laundré. Home range use was examined with the grid method (Laundré and Keller 1981). I superposed a grid of 200 X 200 m wide cells on a 7.5 minute topographic map of the study area. The fox locations and grid lines were recorded as coordinates of the Universal Transverse Mercator Grid System.

The grid size was a compromise between an area small enough to include discrete areas of habitat and an area large enough to minimize the effects of triangulation errors. I assigned each grid cell within the home range of a fox to one of 6 habitat classes based upon the length of wash within the cell: creosotebush flat class (0 m of wash), >0-100 m of wash, >100-200 m, >200-300 m, and >300 m of wash habitat class. The range of wash habitat classes was established to aid in determining whether the foxes were selecting for creosotebush flat areas or avoiding more densely vegetated wash areas.

I tested whether the distances traveled and time spent by the foxes in the different habitat classes were proportional to the availability of the classes within their home ranges by the method of Neu, Byers, and Peek (1974), except I used the G-test of goodness-of-fit (Sokal and Rohlf 1981).

I assumed the triangulation error did not bias the placement of the fox locations within the grid cells of each habitat class. To test the validity of this assumption, I also examined fox home range use with a non-mapping technique (Marcum and Loftsgaarden 1980), in which I accounted for the triangulation error by placing error circles around the locations. The radii of the error circles were equal to 142 m (I estimated 95% of the corrected triangulations were accurate within 142 m). I assigned the fox locations, and random points to determine availability, to habitat classes based on the length of wash within the error circles. The location of fox dens relative to the distance to the nearest wash was also examined using the technique developed by Marcum and Loftsgaarden (1980).

Movements and Activity

I estimated the nightly movements of kit foxes by summing the distances between successive locations of a fox. Two sample periods were usually required to follow the movements of a fox from sunset to sunrise. Summations of distances between successive locations are representative of actual movements, since the triangulation errors from one location to the next are not accumulative (Appendix A). To measure kit fox activity throughout the night, I divided the distance moved by a

fox during each hour interval of a night, by the length of time the fox was monitored during the interval.

Home Range Size and Overlap

I calculated home range sizes with the grid method (Rongstad and Tester 1969, Voight and Tinline 1980, Laundré and Keller 1981) using grid cells 200 X 200 m wide. Home range sizes were estimated from the area of the grid cells entered by a fox during the time it was monitored. Cells not entered in the interior of a home range were also included in the size estimates, if they were enclosed by other cells entered by the fox.

I also calculated home range sizes with the minimum area method (Mohr 1947) using only convex polygons (Jennrich and Turner 1969). I estimated the size of the areas used nightly by kit foxes from the number of 200 X 200 m grid cells entered by the foxes during a night. Spatial overlap of the home range of one fox on another was calculated by the method of Macdonald, Ball, and Hough (1980).

Seasons

Following Smith, Cary, and Rongstad (1981) and Laundré and Keller (1984), I divided the year into three biological seasons based on the reproductive behavior of kit foxes: gestation (GE) from 1 February to 15 March, pup rearing (PR) from 16 March to 30 September, and pair formation & breeding (PF & BR) from 1 October to 31 January. I did not include a dispersal season because no juvenile foxes were radio-collared, and the adults did not disperse after PR season.

Home ranges sizes were estimated from the total number of samples obtained for each animal during a year. I also calculated seasonal home ranges if a fox was adequately sampled during that season as determined from area-observation curves (Odum and Kuenzler 1955).

The PF & BR season was split into 2 separate seasons to analyze seasonal changes in movements, because it became obvious the males were behaving differently during the BR season. I grouped the movements of female foxes during GE and the first month of PR, to compare with their movements during the rest of the year because of small sample sizes.

RESULTS

I studied 7 foxes (3 females, 4 males) for periods of 5 to 12 months from December 1982 to March 1984, locating them 2596 times during 642 hrs of monitoring.

Fox Density

In the winters of 1982 and 1983, the study area had minimum densities of 1 fox per 4.3 km² and 1 fox per 4.6 km² respectively. Two to three additional animals could have been present each year, based on spaces within the study area not occupied by radio-collared foxes. This would give a likely maximum density of 1 fox per 3.6 km².

Dens

The foxes did not den randomly relative to the distance of the den to the nearest wash (G-test, $df = 2$, $P < 0.001$). Kit foxes preferentially denned away from washes in large creosotebush flats (Fig. 1).

Fox pairs denned in 10 to 15 different dens during the time I followed them. I found paired male and female foxes together in dens year around, but they most commonly denned together during PF & BR season. Dens within the home range of an individual or pair of foxes were used exclusively by those foxes, except during the BR season. Three of the 4 radio-collared males were found either with females, or located for extended periods of time at dens used by females of another pair during the BR season.

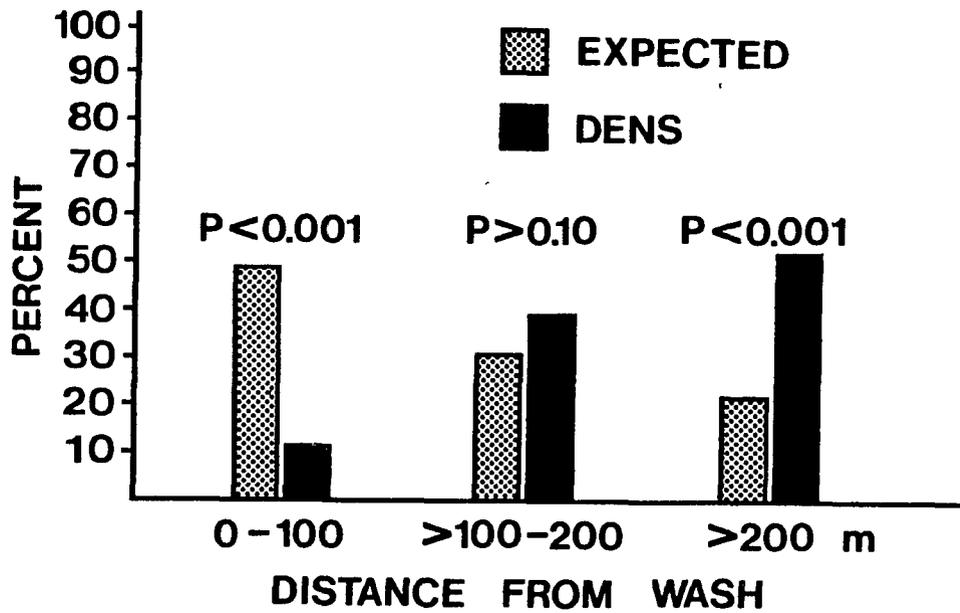


Figure 1. Distribution of kit fox dens in western Arizona compared to the values expected if the dens are distributed randomly relative to the distance to the nearest wash. Significance levels calculated following Neu et al. (1974).

Prey Distribution

Nocturnal rodents were livetrapped on the study area in the spring and fall from 1980 to 1984 by the Arizona Cooperative Wildlife Research Unit (Smith and Henry 1984). Indices of rodent biomass were calculated for zones 0 to 50 m out from washes in spring and fall 1983, based on the capture probabilities and average weights of the 3 commonest rodent species on the study area (Smith and Henry, unpubl. data). The biomass index for each zone was calculated with the following formula:

$$\text{Biomass index}_i = \sum_{j=1}^3 (p_{ij}) (m_j)$$

where p_{ij} , the capture probability of species j in zone i , is equal to the number of captures of species j in zone i divided by the total number of trap nights in zone i , and m_j is the average weight of species j .

Nocturnal rodent biomass was greatest in and near washes (Table 1). The biomass index dropped to 23.2 in the 11 - 20 m zone, and remained at about that level out to 41 to 50 m from washes. Additional trapping in the spring of 1984, of 540 trap nights in washes and 580 trap nights at distances 51 to 140 m from washes, again showed rodent biomass was highest in the washes and remained uniform across the creosotebush flats. The presence of white-throated wood rats (Neotoma albigula) accounted for the increase in biomass in and near washes. The uniform distribution of kangaroo rats (Dipodomys merriami) across the creosotebush flats caused the biomass index to remain even across the flats.

Table 1. Distribution of the biomass of nocturnal rodents on the study area in western Arizona, April to September 1983.

Zone ^a	Trap Nights	Biomass Index ^b
0 m	160	53.6
1 - 10	620	37.6
11 - 20	820	23.2
21 - 30	700	19.9
31 - 40	440	24.8
41 - 50	160	17.5

^aDistance in meters from the nearest wash.

^bBiomass index = the sum of the capture probabilities of the 3 commonest rodent species times their average weight.

Activity and Movements

The kit foxes became active around sunset, and usually returned to a den about a half hour before sunrise. During the day foxes remained inside dens. However, they occasionally would rest outside at dens, especially during sunny, warm days in the winter and early spring. The foxes did not increase their diurnal activity as nights became shorter in late spring and summer (corresponding to PR season).

The foxes were often inactive for 1 to 2 hours during a night. Their periods of inactivity were irregularly distributed throughout the night during PR season. Consequently, fox activity, measured in kilometers traveled per hour, varied little through the night (Fig. 2). Kit foxes during PF & BR, however, were the most active during the three hours after sunset (Fig. 2). The foxes decreased their activity during the middle of the night, and became more active again in the early morning.

Male kit foxes traveled 8.6 to 26.3 km in a night ($n = 31$). Female foxes moved 6.7 to 16.7 km in a night ($n = 16$) (Table 2).

The length of time kit foxes were active varied seasonally, because how long they were active was dependent on the length of the night. To analyze for seasonal changes in activity independent of night length, I standardized the nightly movements by dividing the distances moved by the length of time the fox was active.

Male kit foxes traveled significantly greater distances during BR than during PR and PF (Kruskal-Wallis test, $P < 0.05$). Movements of male foxes did not differ from PR to PF ($P > 0.05$). The male GE data were not included in the test. Female foxes traveled significantly

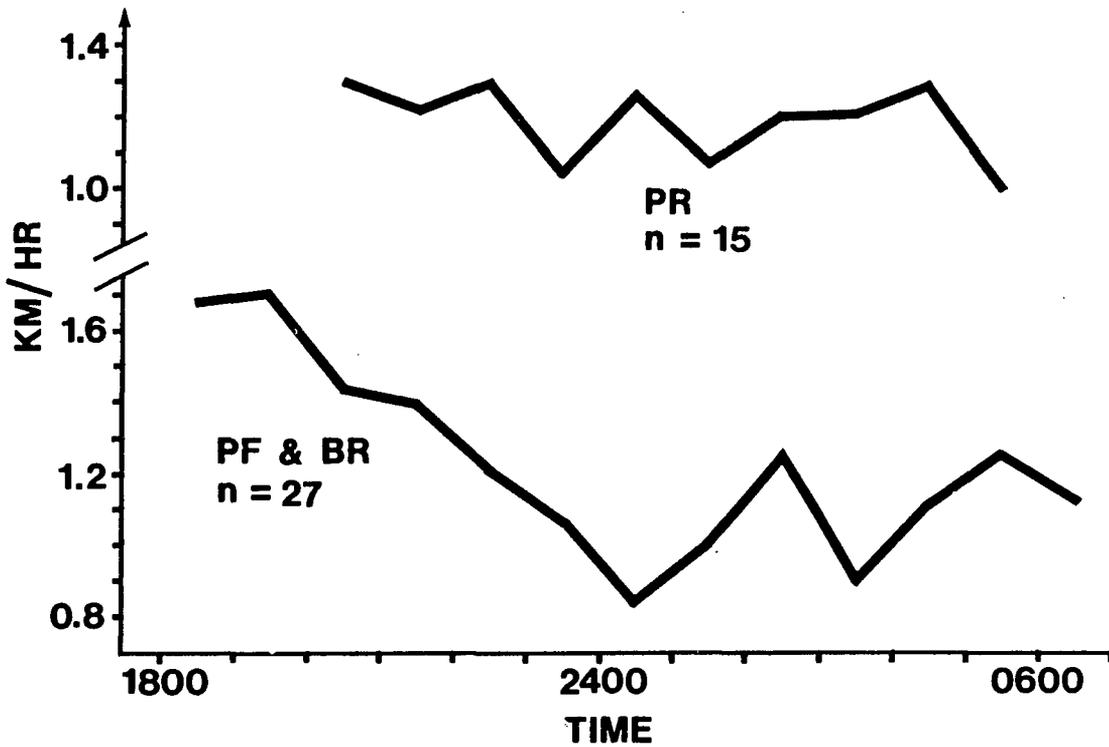


Figure 2. Kit fox activity, measured in km traveled per hour, throughout the night during pup rearing (PR) and pair formation & breeding (PF & BR) seasons in western Arizona, 1983-84. The lines connect hourly averages for 15 activity periods sampled during PR, and 27 activity periods during PF & BR.

Table 2. Nightly movements (km) of kit foxes in western Arizona, December 1982 to March 1984.

Sex	Gestation		Pup Rearing		Pair Formation		Breeding	
	\bar{X}	n ^a	\bar{X}	n	\bar{X}	n	\bar{X}	n
Males	13.5	2	11.3	12	13.6	8	18.9	9
Females	8.2 ^b	6			12.5 ^c	10		

^aNumber of observations.

^bAverage of movements during gestation and the first month of pup rearing.

^cAverage for pup rearing (the last 5 months), pair formation, and breeding seasons grouped together.

smaller distances during GE and early PR as compared to the rest of the year (t-test, unequal variances, $P < 0.05$). Differences between males and females were not examined because of the lack of adequate samples within seasons to compare.

The foxes typically traveled in straight line movements (Fig. 3), similar to the ranging behavior of coyotes (Laundré and Keller 1981). In these ranging movements, the foxes often traveled to the edge of their home ranges and then moved back towards the interior. Kit foxes traveled maximum distances of 3.0 to 4.8 km from dens.

Home Range Size and Spatial Organization

Area observation curves appeared to approach asymptotes by the fourth and fifth full-night samples taken within a season. Increases in home range size decreased to 1.5 and 5.5% by the addition of the fifth sample period for the grid method of calculating home range size in the PR and PF & BR seasons (Table 3). Increases in seasonal home range size dropped to less than 5% by the fifth full-night sample for the minimum area method.

Seasonal home ranges were calculated for animals monitored for at least 4 full-night sample periods during that season (Table 4). The seasonal ranges of 3 male foxes were significantly larger during PF & BR than during PR (paired t-test, 1 tail, $P = 0.023$). Fox F19 had the smallest home range of the 4 males, and was the only fox studied that was not paired with a female until the PF & BR season of 1983. Home ranges of females were not significantly smaller than those of the males (1 tail t-test, $df = 5$, $P = 0.098$) (Table 4). Home range sizes of males

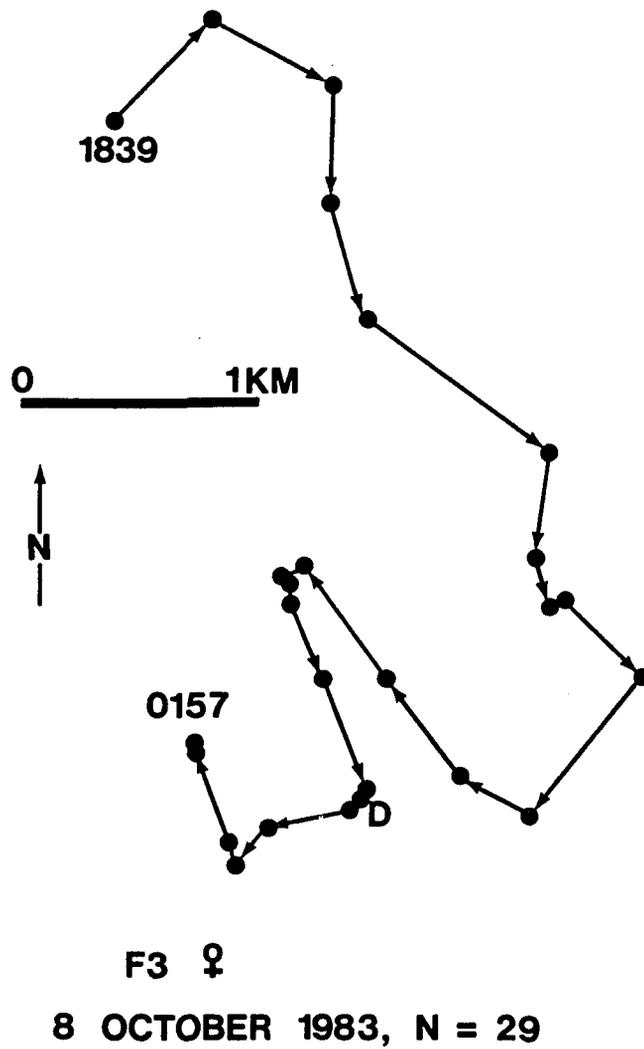


Figure 3. Example of the ranging pattern of straight line movements typical of kit foxes in western Arizona. The 29 locations plotted between 1839 and 0157 hrs are all 15 to 20 minutes apart. The "D" represents a fox den.

Table 3. Percent change in home range size of kit foxes in western Arizona with the addition of sequential full-night sample periods for 2 males and 1 female during pair formation & breeding season and 1 male during pup rearing season.

N Samples	Grid Cell Method		Minimum Area Method	
	% Change	N ^a	% Change	N ^a
PF & BR Season				
2	61.3	3	60.8	3
3	47.5	3	45.3	3
4	18.5	3	6.9	3
5	5.5	3	3.3	3
PR Season				
2	63.8	1	36.5	1
3	34.6	1	13.7	1
4	12.0	1	8.2	1
5	1.5	1	0.0	1

^aNumber of animals used in calculating percentages.

Table 4. Home range size estimates (km²) of kit foxes in western Arizona, 1982-84, calculated with the grid method.

Fox	Pup Rearing ^a	Pair Formation & Breeding ^a	All Seasons ^b
Males			
F7		13.6	14.8 (7)
F10	8.3	10.1	12.0 (9)
F15	7.2	10.8	12.7 (8)
F19	4.9	7.1	9.8 (10)
\bar{X} =	6.8	10.4	12.3
Females			
F3		9.4	12.1 (10)
F8		10.0	10.0 (5)
F16			7.2 (9)
\bar{X} =		9.7	9.8

^aEstimated from at least 4 full-night sample periods of sequential locations.

^bNumber of months the animal was monitored during is given in parentheses.

and females averaged $11.2 \pm 0.94 \text{ km}^2$. The nightly ranges of the foxes averaged $2.5 \pm 0.10 \text{ km}^2$ ($n = 47$), or $22.2 \pm 0.95\%$ of the mean home range size for males and females.

The home ranges of paired males and females overlapped an average of 75.4%, with the home range of a female lying almost entirely within the range of the male fox it was paired with (Fig. 5). The home ranges of nonpaired animals overlapped significantly less (12.3%) than those of paired animals (t-test, $df = 30$, $P < 0.001$).

The home ranges of 3 female foxes monitored for 5 to 12 months, did not overlap at all. Overlap in home ranges of nonpaired foxes was greatest during the PF & BR season (Fig. 6). For 3 males for which seasonal home ranges were calculated, the average overlap of 22% during the PF & BR season was significantly larger than the mean overlap of 6% during the PR season (paired t-test, $df = 5$, $P < 0.001$).

The minimum area method calculations of home range size (Appendix B, Table 9) are presented for comparison with other studies, because the minimum area method is one of the commonest methods used to calculate home range size. This method included large areas of non-use within the home range estimates for male foxes, because of linear movements made by males to denning areas of other fox pairs during the BR season (Appendix C, Figs. 12-18).

Home Range Use

The foxes traveled similar distances (G-test of goodness-of-fit, $df = 24$, $P = 0.96$), and spent similar lengths of time (G-test, $df = 24$, $P = 0.27$) in the habitat classes within their home ranges.

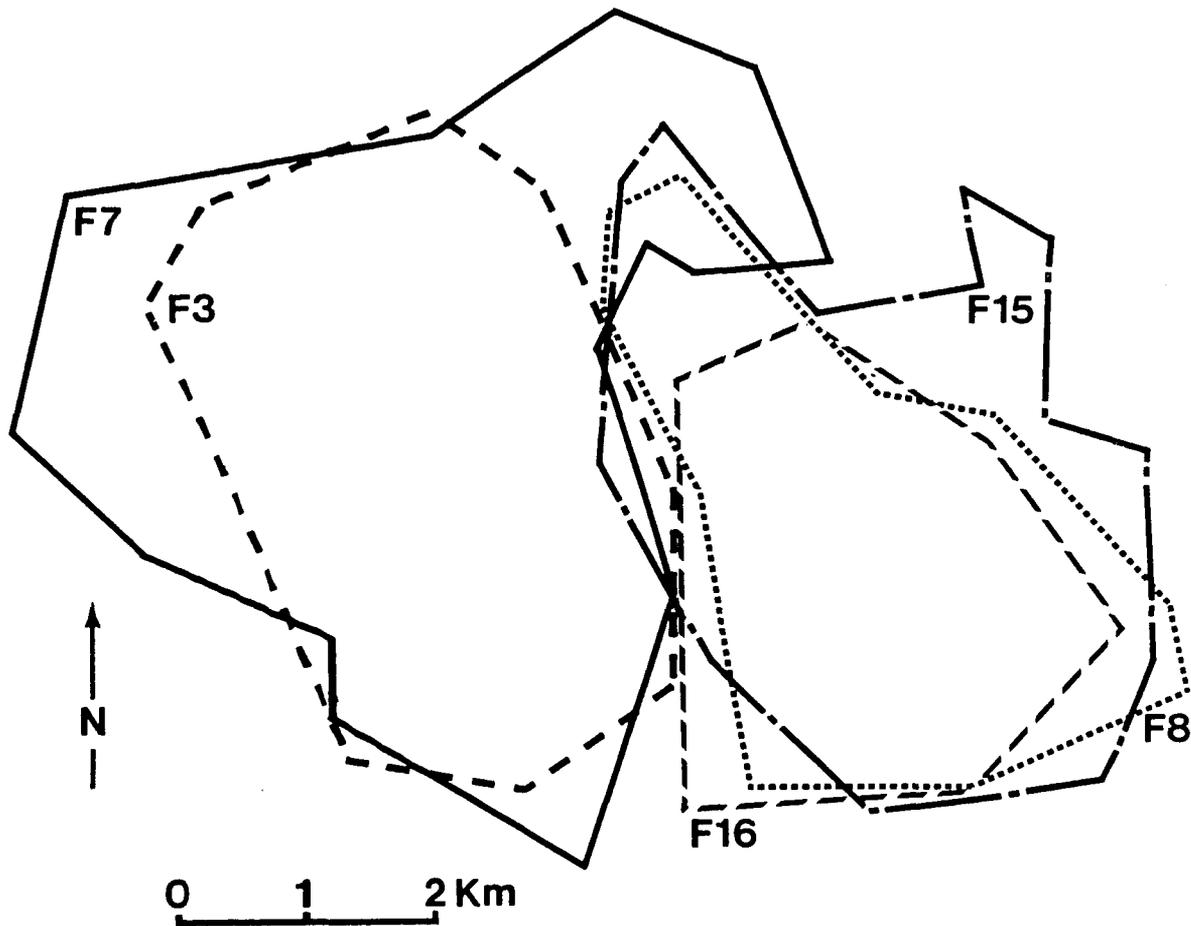


Figure 4. Spatial organization of home ranges of paired kit foxes in western Arizona, 1982-84. The female F3 and male F7 were paired during the entire study. The male fox F15 was paired with F16 from December 1982 until her death in August 1983. F15 and the female F8 were paired from October 1983 to January 1984. The home range boundaries are formed by lines drawn around the perimeter of the grid cells used by an animal.

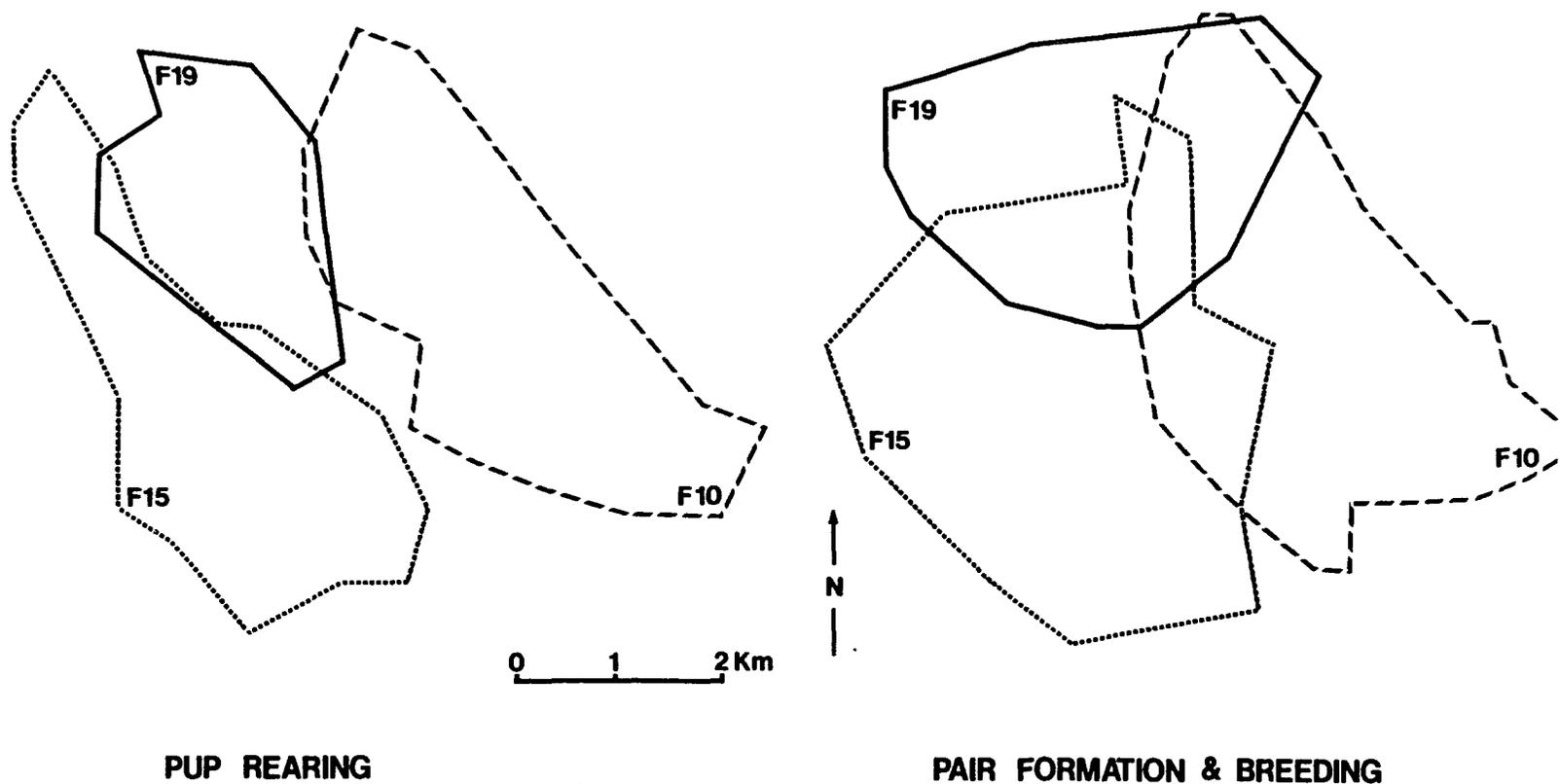


Figure 5. Spatial organization of the pup rearing (March 16 to September 1983) and pair formation & breeding (October 1983 through January 1984) seasonal home ranges of 3 male kit foxes in western Arizona. The home range boundaries are formed by lines drawn around the perimeter of the grid cells used by an animal.

Consequently, I summed the distances traveled and the time spent by the 7 foxes for each habitat class.

The distance traveled by all 7 foxes in the 5 creosotebush flat and wash habitat classes did not differ from that expected on the basis of their availability (G-test, $df = 4$, $P = 0.87$). The kit foxes also evenly distributed the distances they traveled throughout their home ranges (Fig. 8). Minor peaks in the distributions of the distances traveled were caused by the foxes returning to frequently used dens.

The null hypothesis that the amount of time kit foxes spend in each habitat class is proportional to its availability within their home ranges was rejected (G-test, $df = 4$, $P = 0.047$). The foxes spent significantly more time in the creosotebush flat habitat class than expected, and significantly less time in the >200-300 m of wash habitat class, with a trend towards less time spent in a class as the amount of wash increased (Table 5). Correspondingly, the time the foxes spent in different areas of their home ranges was very unevenly distributed (Fig. 9). They spent more time in creosotebush flats and near dens. The average speed kit foxes traveled at in each habitat class increased from 0.98 km/hr in the creosotebush flat areas to 1.33 km/hr in the >300 m of wash class (Table 6).

The kit foxes were relocated in the different habitat classes in dissimilar proportions (G-test, $df = 24$, $P < 0.001$), thus I examined each fox separately. Each fox was relocated in the habitat classes in proportions significantly different from that expected from the availability of the classes within their home ranges (G-tests, $df = 4$, $P < 0.05$). Four of the 7 foxes were relocated in the creosotebush flat

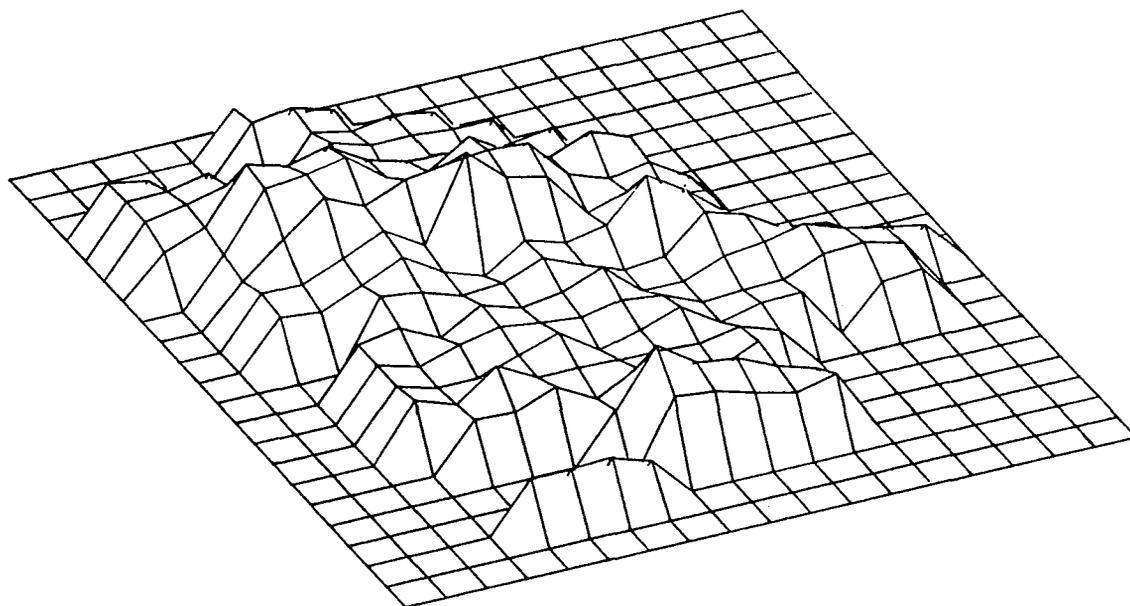


Figure 6. Distribution of the distance traveled by fox F16 in different areas of her home range in western Arizona, December 1982 to August 1983. Each grid cell represents a 200 X 200 m square area of her home range.

Table 5. Proportions of time spent by kit foxes in creosotebush flat and wash habitat classes in western Arizona, December 1982 to March 1984, in comparison to the availability of the classes. The significance of the differences were calculated following Neu et al. (1974).

Habitat Class	Proportion Available	Proportion of time spent	Difference ^a	P-value
Creosotebush Flat	0.438	0.509	0.071	P < 0.01
>0-100 m wash	0.142	0.141	-0.001	P > 0.10
>100-200 m	0.115	0.109	-0.006	P > 0.10
>200-300 m	0.228	0.182	-0.047	P < 0.05
>300 m	0.077	0.059	-0.018	P > 0.10

^aCalculated for each habitat class by subtracting the proportion available from the proportion of time spent in that class.

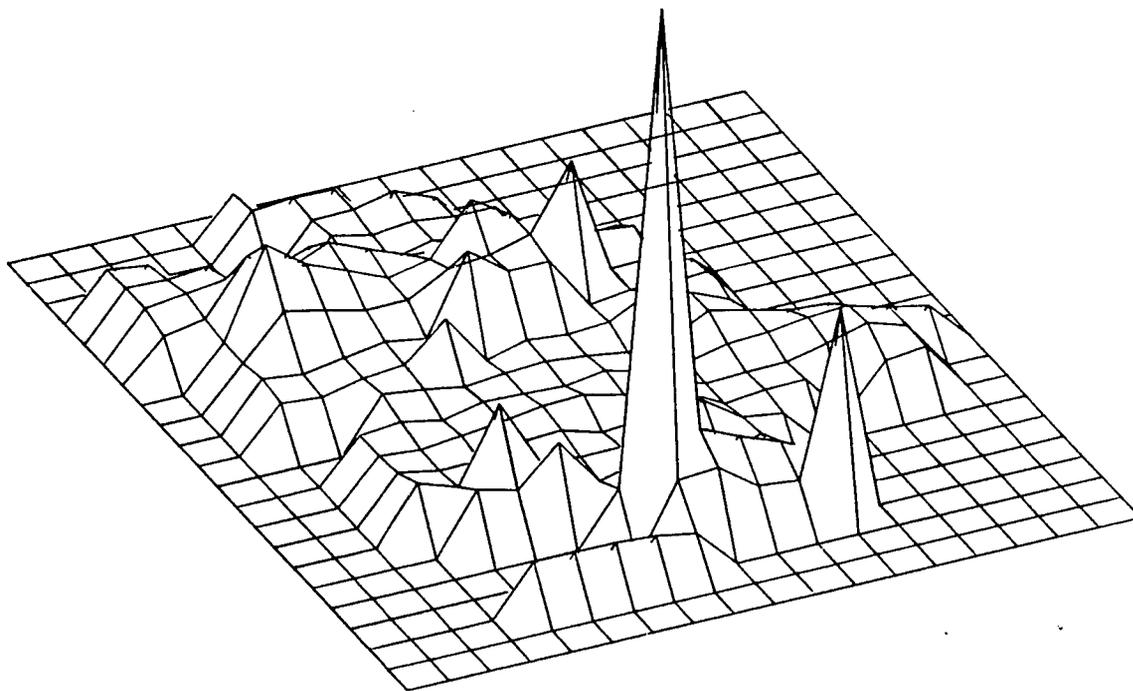


Figure 7. Distribution of the time spent by fox F16 in different areas of her home range in western Arizona, December 1982 to August 1983. Each grid cell represents a 200 X 200 m square area of her home range.

habitat class significantly more than expected, and 6 of the 7 animals were relocated in the > 300 m of wash class significantly less than expected (Table 7). No kit foxes were relocated in the creosotebush flat habitat class less than expected, nor was a fox relocated in the >300 m of wash class more than expected. The animals did not use the >0-100 to >200-300 m of wash classes in a consistent manner.

To directly compare the relocation analysis to the time and distance analyses, I summed the relocations of the 7 foxes for each habitat class. The animals were not relocated in each habitat class proportional to the availability of the classes (G-test, $df = 4$, $P < 0.001$). The kit foxes were relocated in the creosotebush flat habitat class significantly more than expected, and significantly less than expected in the >300 m of wash class (Table 8). When the >200-300 m, and >300 m habitat classes were merged in the relocation and time spent analyses, the foxes were relocated in and spent significantly less time than expected in the resulting >200 m of wash class ($P < 0.01$).

Kit foxes often returned to and remained at dens for 1 to 2 hours during a night. The foxes were still relocated in the creosotebush flat habitat class significantly more than expected ($P < 0.05$), after taking the relocations at dens out of the analysis.

Table 6. Average travel speeds of kit foxes in creosotebush flat and wash habitat classes in western Arizona, December 1982 to March 1984.

Habitat Class	Average Travel Speed ^a km/hr
Creosotebush Flat	0.98
>0-100 m of wash	1.08
>100-200 m	1.07
>200-300 m	1.25
>300 m	1.33

^aCalculated by dividing the amount of distance traveled in each habitat class by the amount of time spent in that class.

Table 7. Habitat class use by individual kit foxes in western Arizona, December 1982 to March 1984, based on the number of relocations in each class (+ = relocated in that class more than expected, - = relocated in that class less than expected). The significance levels were calculated following Neu et al. (1974).

Habitat Class	Females			Males			
	F3	F8	F16	F7	F10	F15	F19
Creosotebush Flat	++	+	++			++	
>0-100 m wash		-			-		
>100-200 m			--				+
>200-300 m			--		+		
>300 m	--		--	-	-	-	-

-,+ = P < 0.05
 --,++ = P < 0.01

Table 8. Habitat class use by kit foxes in western Arizona, December 1982 to March 1984, based on the relocations of the 7 foxes in each habitat class. The significance of the differences were calculated following Neu et al. (1974).

Habitat Class	Proportion Available	Proportion of relocations	Difference ^a	P-value
Creosotebush Flat	0.359	0.454	0.095	P < 0.01
>0-100 m wash	0.076	0.065	-0.011	P > 0.10
>100-200 m	0.096	0.103	0.007	P > 0.10
>200-300 m	0.289	0.278	-0.011	P > 0.10
>300 m	0.180	0.102	-0.078	P < 0.01

^aCalculated for each habitat class by subtracting the proportion available from the proportion of relocations in that class.

DISCUSSION

In both the relocation analysis and the grid cell analysis based on time, the foxes spent significantly more time than expected in the creosotebush flat habitat class. The differences between the analyses in the >200-300 and >300 m of wash habitat classes are probably caused by some triangulation error entering the grid cell analysis. When the 2 wash classes were merged, both methods showed the foxes spent significantly less time in the areas with the greatest amounts of wash. Thus, the triangulation error present in the locations did not greatly bias the results of the grid cell analyses.

Home Range Use

The average speed the foxes traveled in each habitat class increased with the amount of wash in the class. That kit foxes prefer to rest in creosotebush flat areas explains the differences in the travel speeds, and the different lengths of time spent and distances traveled by kit foxes in the creosotebush flat and wash habitat classes. If the foxes were avoiding the wash areas then the distances traveled, in addition to the lengths of time spent, in the habitat classes with the largest amounts of wash should have been significantly less than expected by the availability of those classes.

Kit foxes also dened preferentially in large creosotebush flats. The foxes often returned to dens during the night to rest, thus many grid cells containing dens had low average travel speeds and high

percent time values. However, when relocations at dens were taken out of the habitat class analysis, the animals still spent significantly more time than expected in the creosotebush flat areas. Thus, the foxes spend significantly more time in the creosotebush habitat class, because they prefer both to rest and den there. Kit foxes possibly prefer these open areas for resting and denning, because they are better able to detect predators such as coyotes (Canis latrans) there. Egoscue (1962) also reported kit foxes denning invariably on flat terrain where vegetation was sparse.

Nocturnal rodent biomass on the study area was highest in and near washes. Although I did not census cottontail rabbits (Sylvilagus auduboni), they were clearly more common in and near washes, which skewed the distribution of prey biomass even more towards the wash areas. Kit foxes are carnivorous with nocturnal rodents and lagomorphs comprising the majority of the diet (Egoscue 1962, Laughrin 1970, Morrell 1972, Smith 1978, Fisher 1981). The higher prey biomass in wash areas increases the benefit of kit foxes to hunt there, and may be why the foxes did not avoid the more densely vegetated wash areas despite their preference for resting and denning in the open creosotebush flats.

The foxes may not respond to the higher prey biomass in the washes by traveling greater distances through the wash areas because of diet preferences. Also, the increased vegetative complexity of the wash areas may reduce the foraging efficiency of the kit foxes, and consequently the amount of prey biomass actually available to the foxes in the wash areas.

The study area is predominantly creosotebush flats. The openness of habitat and even distribution of prey across the creosotebush flats, combined with the linear distribution of local areas of increased prey biomass (riparian washes), all probably contributed to kit foxes traveling through their home ranges in straight line movements. The foxes seldom foraged in back and forth movements within localized areas as coyotes (Laundré and Keller 1981), and red foxes (Vulpes vulpes) (Sargeant, Forbes, and Warner 1965, Siniff and Jessen 1969) often do, nor did they remain in areas of locally high use as observed in red foxes (Storm 1965, Ables 1969). Instead the kit foxes typically ranged out to the edge of their home ranges and back to the center in linear movements. Consequently, the distances traveled by the animals were uniformly distributed throughout their home ranges. The foxes also entered a large proportion of their home ranges each night, in their ranging movements.

Activity and Movements

The regular periods of inactivity of kit foxes during the middle of the nights during PF & BR are probably rest periods to divide up the long nights (averaging 13 hrs in length). Nights during PR averaged just 10 hours in length. The periods of inactivity during PR may be rest periods triggered by prey captures, as the periods of inactivity were irregularly distributed throughout the night. Golightly (1981) found a similar winter season (corresponding to PF & BR) pattern of activity.

Egoscue (1956) reported females spent most of their time in dens during early PR. Females in this study traveled significantly smaller distances during GE and early PR, and it was also the only time during the year that they were located in dens during the night for extended periods of time.

Male foxes traveled longer distances and farther out from the center of their home ranges during BR season to visit other females, causing the significant increase in activity of males during BR as compared to PR and PF seasons. Home ranges of males were also significantly larger during PF & BR as compared to PR, because of movements to visit females. Data of Daneke, Sunquist, and Berwick (1984) and Golightly (1981) also suggest seasonal changes in male activity.

Home Range Size

Calculations of home range size with the grid method are influenced by the size of the grid cell chosen (Macdonald et al. 1980, Laundré and Keller 1981). In this study, the selection of relatively small grid cells (4 ha in area) undoubtedly prevented the overestimation of home range size, but resulted in some cells in the interior of seasonal and multiple-season home ranges not being entered during the time the animal was monitored.

Cells not entered within a home range can be the result of sampling strategy, or biologically relevant factors (Macdonald et al. 1980). Because of the homogeneity of the study area, the cells not entered in the interior of the home ranges were probably an artifact of

the sampling strategy. The area-observation curve analysis also indicated this. The majority of cells added to the seasonal home range of a fox by the addition of the fourth and fifth full-night sample periods were in the interior of the home range already delineated by previous samples. Thus, I included all interior cells in the estimates of home range size.

I concluded that at least 4 full-night samples of sequential locations are required to adequately measure the size of seasonal home ranges of kit foxes during PR and PF & BR. Estimates of the size of the home ranges used by kit foxes throughout the year to meet their maintenance, growth, and reproductive needs are undoubtedly affected by the seasons during which the animals are monitored. PF & BR seasonal home ranges were calculated for 6 of the 7 foxes in this study. Male foxes significantly increased the size of their seasonal ranges during PF & BR. For one female that was monitored during 10 months of the year, her PF & BR seasonal range was almost as large as her annual home range. Thus, most foxes were monitored over several seasons, and intensively during PF & BR when seasonal home ranges were the largest. Consequently, the calculations of annual home range are probably good estimates of the size of the areas used by the foxes during a year.

The assumption that home ranges are shaped as convex polygons was not always met in the minimum area method calculations of home range. Therefore, the grid method calculations best represent the kit fox home ranges and are the estimates used throughout the rest of the discussion.

Home range sizes from this study are 2 to 4 times larger than previous estimates of 2.6 to 5.1 km² for kit foxes in California and Arizona (Morrell 1972, Knapp 1978, Golightly 1981). Seasonal home range size estimates from this study are 2.5 to 5 times larger than summer and winter estimates (roughly corresponding to PR and PF & BR) from a study done in western Utah (Daneke et al. 1984).

Increases in home range size with increasing metabolic needs, and thus increasing body weight have been well documented in mammals (McNab 1963, Harstad and Bunnell 1979, Mace, Harvey, and Clutton-Brock 1982, Gittleman and Harvey 1982), although a large amount of variation is present in this relationship. Gittleman and Harvey (1982) found a significant amount of the variation in the relationship of home range size to metabolic need in carnivores was explained by diet. Animals which are exclusively carnivorous have much larger home ranges, presumably because they are feeding higher on the trophic structure and thus have less food per unit area.

The home range size - metabolic need relationship predicts kit foxes should use large home ranges relative to their body size and metabolic needs as a consequence of their carnivorous diet. Following Gittleman and Harvey (1982), and using an average body weight of 1.75 kg, and a group size of 2, I calculated the standardized metabolic needs of kit foxes to equal 3.04. The ratio of kit fox home range size (using a mean of 11.2 km² for kit foxes in this study) to metabolic needs is 3.68. I calculated ratios of 0.47 for the red fox, 0.41 for the gray fox (Urocyon cinereoargenteus), 0.13 for the bat-eared fox

(Otocyon megalotis), and 0.20 for the crab-eating fox (Cerdocyon thous) from data in Gittleman and Harvey (1982).

The ratio calculated for the kit fox from my data is much larger, as predicted, than those of the gray, bat-eared, and crab-eating foxes which are either omnivores or insectivores. The diet of the red fox, however, is about 65% carnivorous (Gittleman and Harvey 1982). Yet, the kit fox ratio of home range size to metabolic need is much larger than the red fox ratio. The large difference in the kit fox and red fox ratios is probably a function of the high productivity of the habitats in which the red fox has been studied, in addition to diet differences.

The ratio of kit fox home range size to metabolic need is very similar to the ratios of 2 other North American canids which are highly carnivorous, the coyote with a ratio of 3.40 and the wolf (Canis lupus) with a ratio of 4.04 calculated from data from Gittleman and Harvey (1982). Thus, the home range size estimates from this study agree well with predictions made from the home range size - metabolic needs relationship and are probably indicative of the size of home ranges used by kit foxes across their geographic range. This is further supported by the large home ranges (6.7 to 28.8 km²) of swift foxes (Vulpes velox) (Hines 1980), which are very similar in their ecology and appearance to kit foxes except they inhabit grassland habitats (Kilgore 1969).

Fox Density and Social Organization

Habitat productivity, and the dispersion of resources within habitats can cause large intraspecific variation in home range or territory size, and also social behavior (Kruuk and Parish 1982,

Hersteinsson and Macdonald 1982, Macdonald 1983). Kit foxes in this study remained paired year around and maintained territories which overlapped very little with those of other pairs. Female foxes occupied exclusive home ranges from other females, and most of the overlap between males, and males with females other than they were paired with occurred during the PF & BR season. Home range overlap increased during PF & BR, because of the movements of males to denning areas of other fox pairs during BR season. I observed male foxes with, and in dens of females of other pairs during BR season, but I did not actually observe a male mate with another female other than the one he was paired with. Morrell (1972) reported males mating with more than one female during the breeding season.

The density estimates of 1 kit fox per 3.6 to 4.6 km² for this study are intermediate between density estimates of 1 fox/5.1 km² for western Utah (Egoscue 1956, 1962), and estimates of 1 fox per 1.3 to 2.6 km² across the San Joaquin Valley, California (Grinnell et al. 1937, Laughrin 1970, Swick 1973, Morrell 1975). The estimates, however, are considerably lower than the density of 1 fox/0.4 km² for a local, relatively undisturbed area of the San Joaquin Valley (Morrell 1972, T. O'Farrell, pers. communication).

The social system of kit foxes may be as flexible as that of red foxes and arctic foxes (Alopex lagopus) (Hersteinsson and Macdonald 1982). Polygamous groups of kit foxes have been observed in the Sonoran (Golightly 1981) and Great Basin deserts (Egoscue 1962, 1975). Further research is needed to determine to what degree home range (territory) size, or group size changes relative to increased habitat productivity.

Macdonald (1981) hypothesized that heterogeneous distributions of rich patches of food favor the formation of larger social groups in red foxes. The territorial kit fox pairs observed in this study may reflect the uniform distribution of prey over much of the study area.

APPENDIX A

ESTIMATION AND REDUCTION OF LOCATION ERROR IN RADIO-TRIANGULATION

Two sources contribute to the location error in radio-triangulations when one person triangulates the position of an animal: the error in the radio-tracking system (E_s), and the error due to the movement of the animal during the time interval between the 2 triangulation bearings (E_m) (Fig. 8). An error polygon is formed around the triangulated position of an animal by the system error in the triangulation bearings (Heezen and Tester 1967). The true intersection of the triangulation bearings can be anywhere within the system error polygon. The error in the tracking system and the error due to the movement of an animal are independent. Thus, the system error can either add to or subtract from the movement error such that $E_1 = E_m \pm E_s$, where E_1 is the location error, E_m is the movement error, and E_s is the system error (Fig. 9).

Ideally, to measure the effects of the system and movement errors on location accuracy the initial location of an animal should be determined visually without error. A bearing is taken when the animal is at the initial location. A second bearing, completing the triangulation, is then taken after a time interval equal to the normal time delay involved in triangulation. The measured distance between the initial true location and the triangulated location then equals the location error (Fig. 9). A researcher can then estimate the mean and

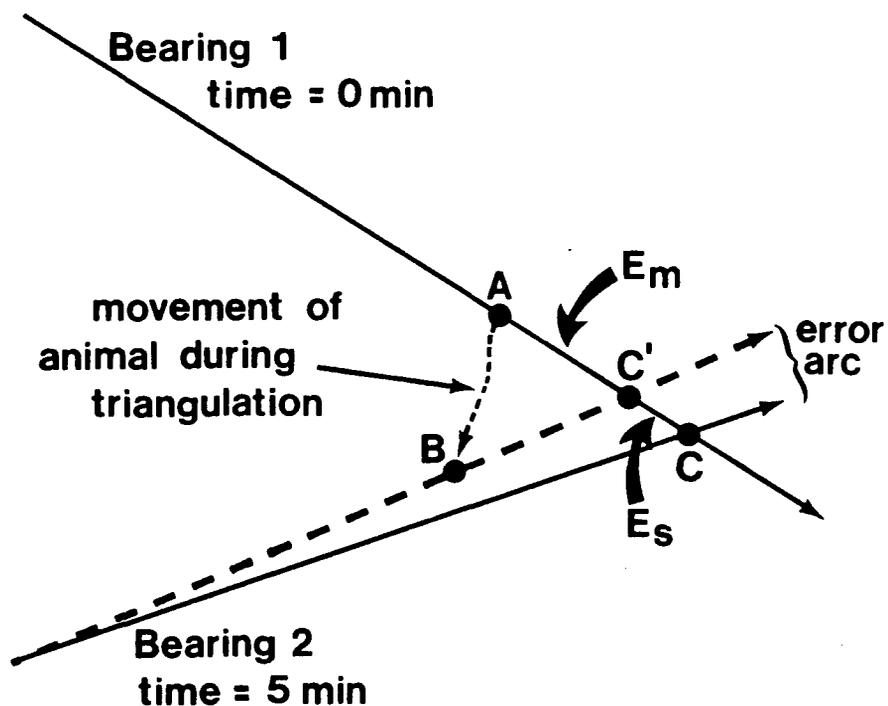


Figure 8. Example of a system error adding to the movement error in radio-triangulation. The distance from the true initial location of the animal (A) to the true intersection of the 2 triangulation bearings (C') equals the movement error (E_m) caused by the movement of the animal to point B during the time delay. The system error (E_s) shifts the intersection of the bearings from C' to C, and adds to E_m to produce a larger location error (the distance from A to C). In this simplified example bearing 1 is assumed to be a true bearing.

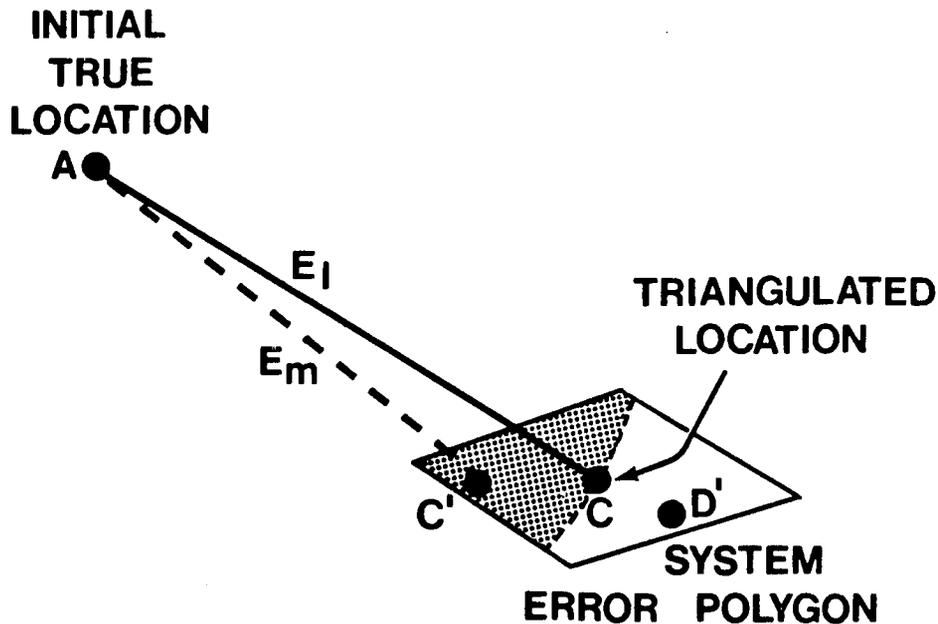


Figure 9. Addition and subtraction of the system error with the movement error in radio-triangulation. The true intersection of the triangulation bearings after the time delay can be anywhere within the system error polygon. The dashed line in the system error polygon is equidistant from the initial true location (A), at a distance equal to the location error (E_1). If the true intersection is within the shaded portion of the error polygon (point C'), then the system error adds to the movement error (E_m , the distance from A to C') to produce a larger location error (E_1 , the distance from A to C). If the true intersection is in the unshaded portion of the polygon (point D'), then the system error subtracts from the movement error (the distance from A to D') to produce a smaller location error (E_1).

variance of the location errors in radio-triangulations from a sample of system and movement error combinations.

Kit foxes are difficult to locate visually without causing the foxes to alter their behavior. Therefore, I developed a technique to estimate the location error in the fox radio-triangulations using simultaneous triangulation bearings. I also developed a method to reduce the size of the location errors by correcting for the movement of the foxes during the triangulations.

Methods

I estimated the system error in the tracking system from 40 repeated measurements of the angle between 2 reference radio-transmitters. I triangulated the location of the foxes from known points along roads. Each of the 2 bearings used to triangulate the location of an animal was oriented by measuring the angle between the bearing to the fox and a reference bearing to a radio-transmitter at a known location. Consequently, bias in the triangulation bearings was eliminated by measuring the difference between the bearings to the fox and the reference transmitter.

To estimate the location error in the radio-triangulations, a second researcher and I took simultaneous bearings from different locations to estimate the initial position of a fox. Then, 4 to 5 minutes later another bearing was taken to triangulate the position of the fox, simulating the normal triangulation procedure. The measured distance between the initial triangulation, and the location

triangulated 4 to 5 minutes later estimates the location error due to the system and movement errors.

To reduce the movement error in the radio-triangulations, I examined the rate at which the second triangulation bearing changed during and just after triangulation. The change in the bearing caused by the movement of the fox after triangulation could always be determined by taking an additional bearing 2 to 4 minutes after the triangulation was completed. The change in the second bearing caused by the movement of a fox during triangulation was unknown, except when the fox was initially located with 2 simultaneous bearings. Thus, from data from 40 simultaneous locations, I developed an equation to predict and correct for the rate of bearing change during triangulation from the rate of change after triangulation. I then evaluated the effectiveness of the equation with another sample of 26 simultaneous locations.

Results and Discussion

Using the simultaneous location method, I estimated the radio-triangulations had a mean location error of 94 ± 7.24 m ($n = 91$). Also from the distribution of 91 location errors, I estimated that 95% of the triangulations had location errors of 236 m or less.

The measurement of location errors with simultaneous bearings is complicated by the introduction of a second system error by estimating the initial position of an animal with simultaneous triangulation bearings (Fig. 10). However, the 2 system errors appear to add to and subtract from the movement error in proportions similar to the single system error with the movement error (Figs. 9 and 11). Consequently,

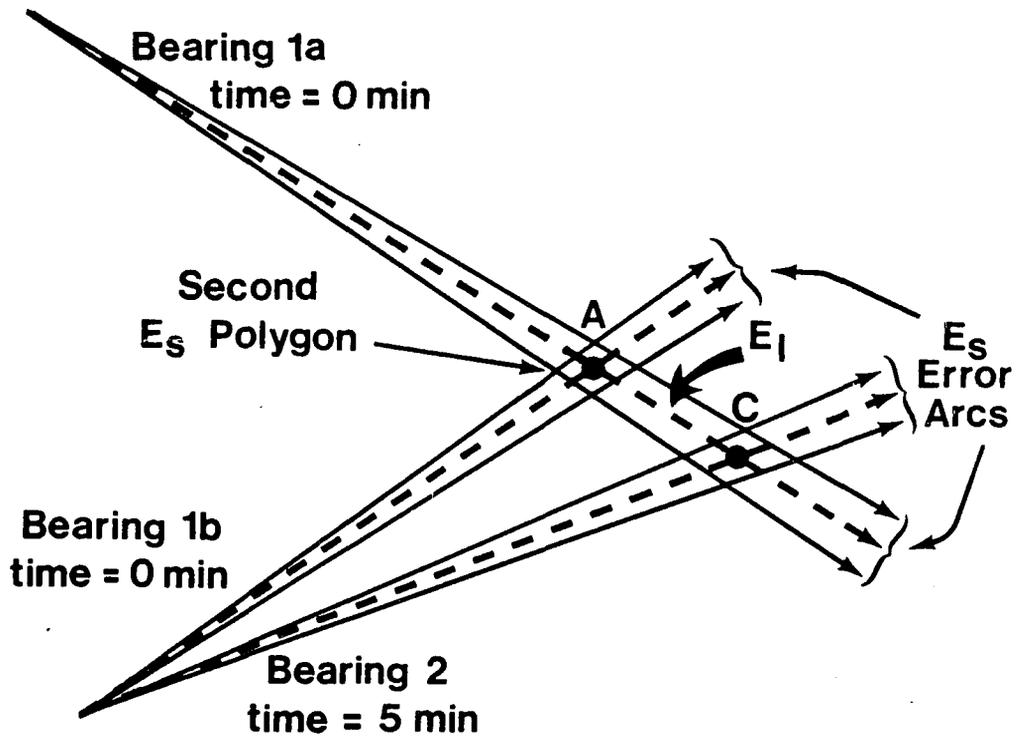


Figure 10. The introduction of a second system error when using simultaneous triangulation bearings to estimate the location error in radio-triangulation. The second system error (E_s) polygon is introduced by estimating the initial location of the animal (A) with simultaneous bearings 1a and 1b. The second system error can either add to or subtract from the location error (E_1), which is equal to the distance from the true initial location (somewhere within the second E_s polygon) to the time delayed triangulation (C).

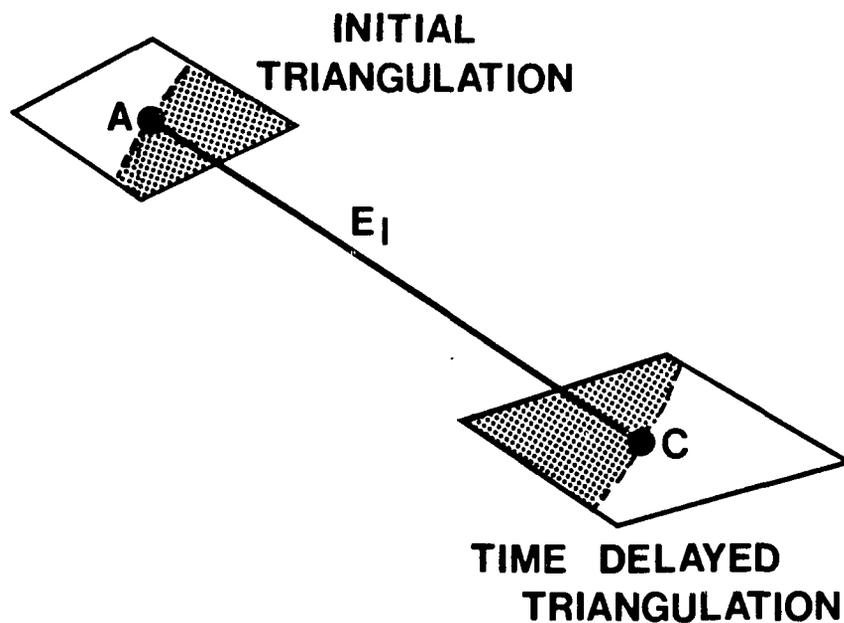


Figure 11. Addition and subtraction of a second system error with the location error, when using simultaneous bearings to estimate the location error in the radio-triangulations. The dashed line in the system error polygon of the initial triangulation is equidistant from the time delayed triangulation (C), at a distance equal to the location error estimate (E_1 , the distance from A to C). The second system error, added by estimating the initial position with triangulation, adds to the location error estimate (E_1) if the true initial location is within the shaded portion of the error polygon. If the true location is in the unshaded portion of the error polygon, then the second system error subtracts from the location error estimate.

the estimate of the mean location error is probably not significantly changed.

The addition of the second system error increases the variance of the location error estimates. For a given error polygon with a maximum width of $2x$, the two system errors can together add and subtract maximums of $-2x$ and $+2x$ from the movement error compared to $-1x$ and $+1x$ for a single system error with the movement error.

However, the increased variance caused by the second system error probably does not greatly change the size of the largest location error estimates because of the small size of the system errors relative to the movement errors. The null tracking system had a mean system error of $0.7^\circ \pm 0.069^\circ$ ($n = 40$), and a maximum system error of 1.5° . The foxes were located at distances of 1.2 km or less with the 2 triangulation bearings generally intersecting at an angle of 60° . Thus, the average system error of a triangulation made at a distance of 1.2 km is equal to 36 m, and the maximum system error is 78 m. Because the average distance the foxes were located at was about 0.6 km, the overall mean system error in the radio-triangulations is probably 18 m.

The simultaneous location data also indicated that location errors from one triangulation to the next are not accumulative. In one sample session 4 hours and 40 minutes long, we located a fox 17 times with simultaneous bearings. The distance between the triangulations including the location errors differed only 1.9% from the distance of 5.1 km traveled by the fox (calculated from the simultaneous triangulations which contained only system errors).

Reduction of Location Error

For the first group of 40 simultaneous locations, the direction of change in the bearing after triangulation reliably predicted the direction of change during triangulation when the fox was moving rapidly. For the 22 rates of change in the bearing after triangulation that were $>1.5^{\circ}/\text{min}$, the foxes reversed their direction of travel only one time. For rates of change $\leq 1.5^{\circ}/\text{min}$, the foxes reversed their direction 6 of 18 times. Thus, I developed a correction factor to apply to triangulations when the rate of change in the bearing after triangulation was $>1.5^{\circ}/\text{min}$. Triangulations with rates of change $\leq 1.5^{\circ}/\text{min}$ were not included because of the unreliability of the slower rates to predict the direction of travel of the fox during triangulation.

A simple linear regression best predicted the rate of change in the bearing during triangulation from the rate after triangulation. The equation relating the rate during triangulation (Y) to the rate after triangulation (X) is $Y = 1.391 + 0.324(X)$ ($r^2 = 0.15$, $P = 0.076$, $n = 22$).

One pair of rates had a Y value greater than 2 standard deviations from the regression line. Because I did not want one pair of rates to have a significantly larger effect on the regression equation than others, I removed this pair from the regression, and recalculated the relationship. The revised equation is $Y = 1.002 + 0.387(X)$ ($r^2 = 0.24$, $P = 0.024$, $n = 21$). Although the regression equation explains only a small proportion of the variation in the rate of bearing change during triangulation, the direction of change in the bearing

after triangulation does reliably predict which direction to correct for the movement of the fox. Thus, the average location error of the triangulations was significantly reduced (paired t-test, $df = 38$, $P < 0.005$), by estimating and correcting for the movement of a fox during triangulation with the equation relating the change in the bearing during triangulation to the change after triangulation. The mean of the location errors equaled 60 m after correction compared to a mean of 90 m before the errors were corrected. I could not calculate the location error of one of the triangulations because the bearings did not continue to intersect after the movement of the fox during the time delay.

I evaluated the correction factor with a second set of simultaneous triangulation locations to determine whether it was applicable to the entire population of radio-triangulations. Of a sample of 26 simultaneous triangulations, 14 had rates of change in the second bearing after triangulation $>1.5^\circ/\text{min}$. The foxes did not reverse their direction of travel for any of these rates. The correction factor (applied only to the 14 triangulations with rates $>1.5^\circ$) significantly reduced the size of the mean location error for the second group of triangulations (paired t-test, $df = 25$, $P < 0.005$). The mean of the location errors after correction equaled 75 m compared to 120 m before the errors were corrected.

I also calculated the regression equation relating the rate of change in the bearing during triangulation to the rate of change after triangulation for the 14 rates $>1.5^\circ/\text{min}$. The equation for the second group of triangulations is $Y = 2.184 + 0.298(X)$ ($r^2 = 0.38$, $P = 0.019$,

n = 14). I was not able to test if the slopes of the equations from the 2 groups of triangulations are equal, because the 2 groups had unequal mean square errors ($P < 0.01$) (Neter and Wasserman 1974). However, the 95% confidence intervals for the two slopes are very similar. The confidence intervals for the slopes of the first and second equations are ($0.06 < b_1 < 0.72$) and ($0.10 < b_2 < 0.49$). The similarity of the slopes, and the effectiveness of the regression equation (derived from the first group of triangulations) in correcting the movement errors present in the second group of triangulations, indicates the correction factor is representative of the entire population of radio-triangulations.

I applied the correction factor to 87% (2265 of 2596) of the fox radio-triangulations. From the location errors present in 65 triangulations after the correction factor was applied (determined from the simultaneous triangulations). I estimated the corrected radio-triangulations had a mean location error of 66 ± 5.75 m, and that 95% of the corrected triangulations had location errors of 142 m or less.

Conclusions

The application of the correction factor reduced a significant amount of the movement error present in the radio-triangulations. The mean location error of the corrected triangulations (66 m) is significantly smaller than the mean location error of the uncorrected triangulations (94 m) (t-test, unequal variances, $P < 0.05$). Most importantly, the correction factor greatly reduced the size of the largest errors caused by rapid movements of the foxes during

triangulation. Ninety-five percent of the corrected triangulations had errors less than or equal to 142 m compared to 236 m for the uncorrected location errors.

The correction factor did not completely eliminate the movement errors, because of the large variation in the speeds of travel of the foxes from the interval during triangulation to the interval after triangulation. Also, the movement errors produced when the foxes were moving slowly could not be corrected because the direction of travel of the foxes after triangulation did not reliably predict the direction of travel during triangulation for rates of bearing change $\leq 1.5^\circ/\text{min}$.

APPENDIX B

HOME RANGE SIZE ESTIMATES CALCULATED WITH THE MINIMUM AREA METHOD

Table 9. Home range size estimates (km²) of kit foxes in western Arizona, 1982-84, calculated with the minimum area method.

Fox	Pup Rearing ^a	Pair Formation & Breeding ^a	All Seasons ^b
Males			
F7		19.7	23.5 (7)
F10	9.2	10.8	14.2 (9)
F15	9.1	14.4	18.2 (8)
F19	4.4	6.6	11.3 (10)
\bar{X} =	7.3	12.9	16.8
Females			
F3		9.6	11.9 (10)
F8		11.8	11.8 (5)
F16			8.4 (9)
\bar{X} =		10.2	10.7

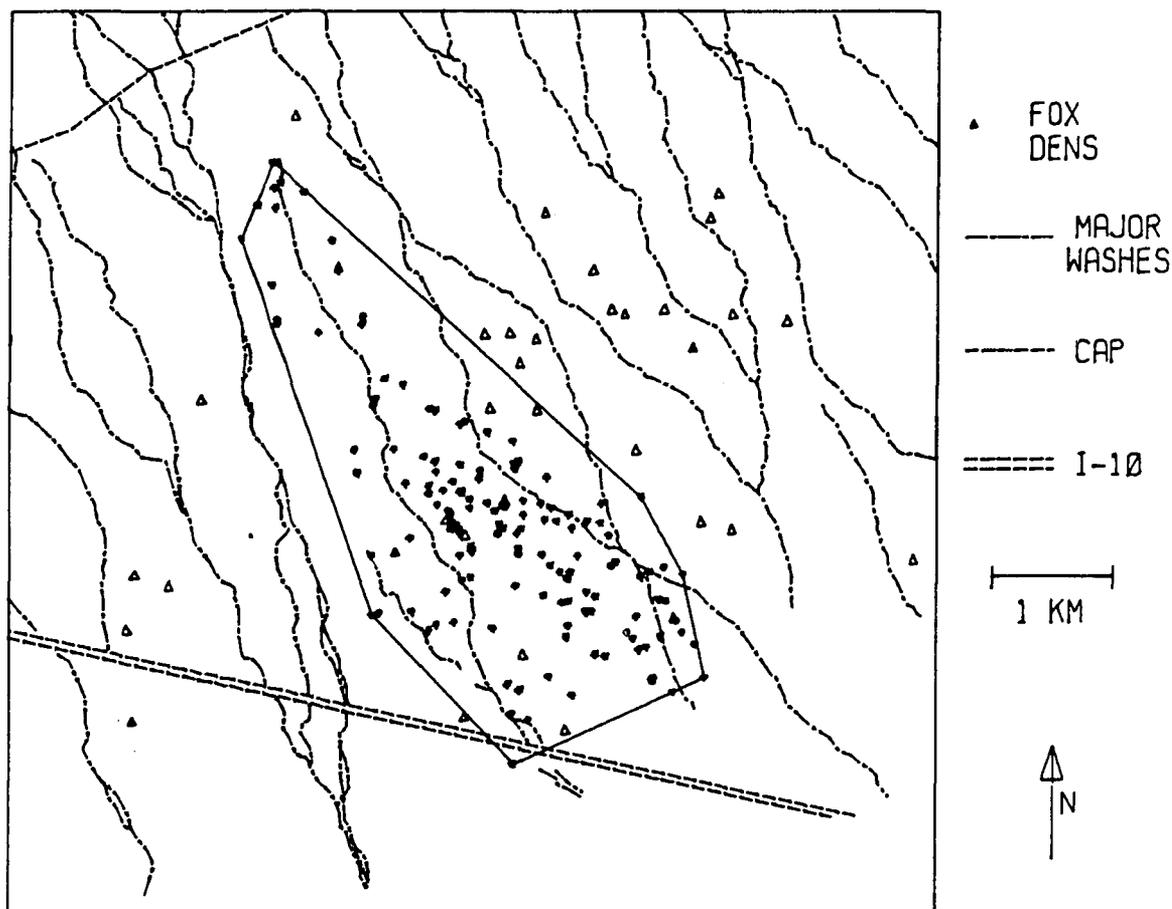
^aEstimated from at least 4 full-night sample periods of sequential locations.

^bNumber of months the fox was monitored during is given in parentheses.

APPENDIX C

FIGURES OF FOX HOME RANGES DETERMINED WITH THE MINIMUM AREA METHOD

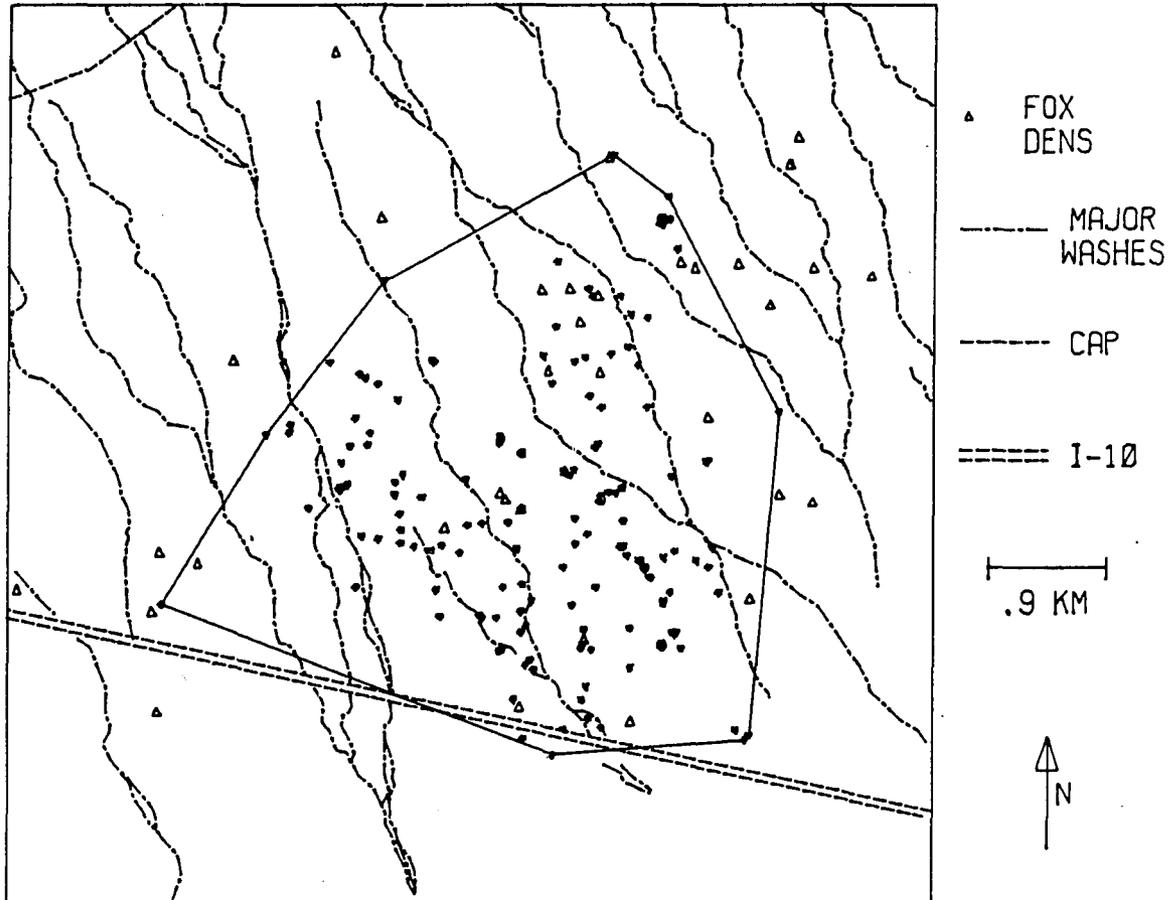
TONOPAH DESERT, ARIZONA
FOX NO. 15 DATE 6/1/83 TO 9/30/83



HOME RANGE SIZE = 9.12 KM²
ANIMAL LOCATIONS PLOTTED = 158

Figure 12. Pup rearing seasonal home range of the male kit fox F15, June 1983 to September 1983.

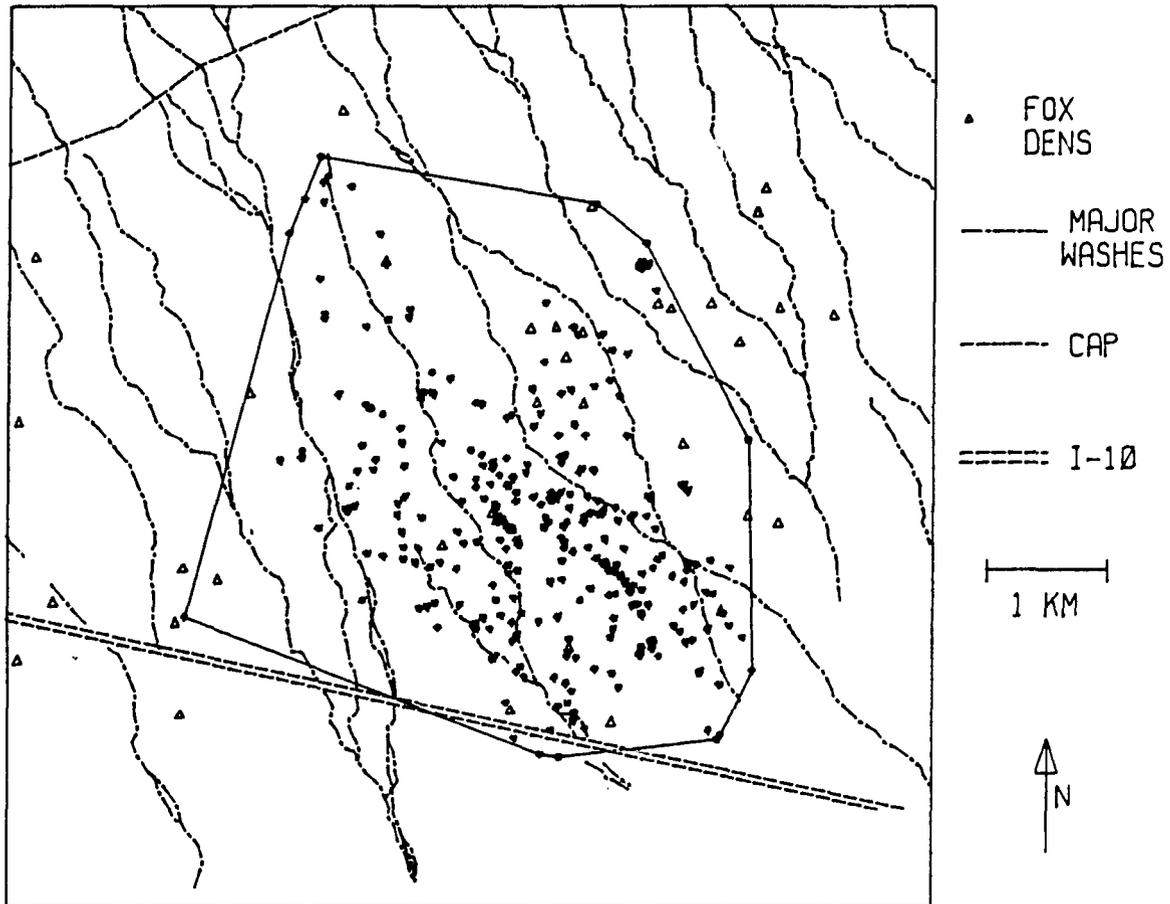
TONOPAH DESERT, ARIZONA
FOX NO. 15 DATE 10/1/83 TO 1/31/84



HOME RANGE SIZE = 14.42 KM²
ANIMAL LOCATIONS PLOTTED = 175

Figure 13. Pair formation & breeding seasonal home range of the male kit fox F15, October 1983 to January 1984.

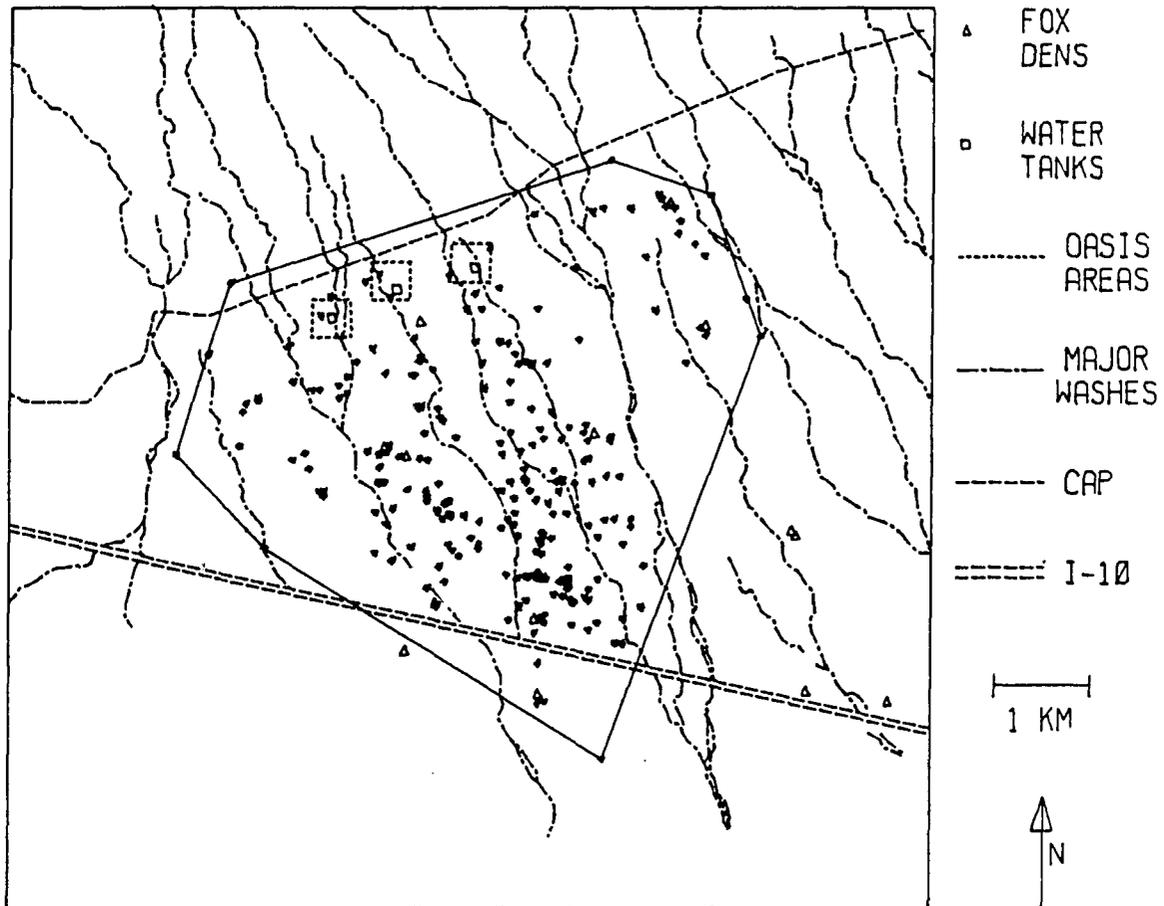
TONOPAH DESERT, ARIZONA
FOX NO. 15 DATE 6/1/83 TO 1/31/84



HOME RANGE SIZE = 18.15 KM²
ANIMAL LOCATIONS PLOTTED = 333

Figure 14. The home range of the male kit fox F15 from June 1983 to January 1984.

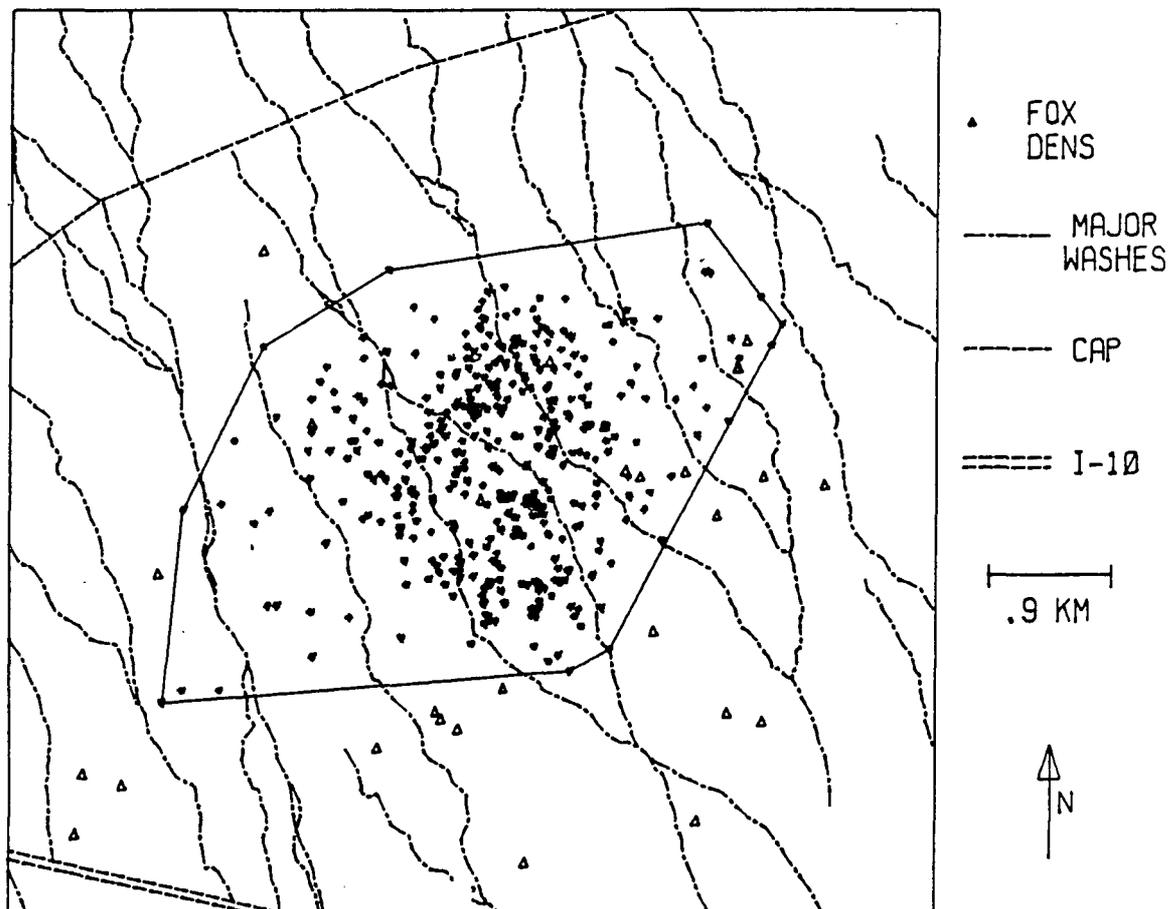
TONOPAH DESERT, ARIZONA
 FOX NO. 7 DATE 9/1/83 TO 3/31/84



HOME RANGE SIZE = 23.50 KM²
 ANIMAL LOCATIONS PLOTTED = 290

Figure 15. The home range of the male kit fox F7 from September 1983 to March 1984.

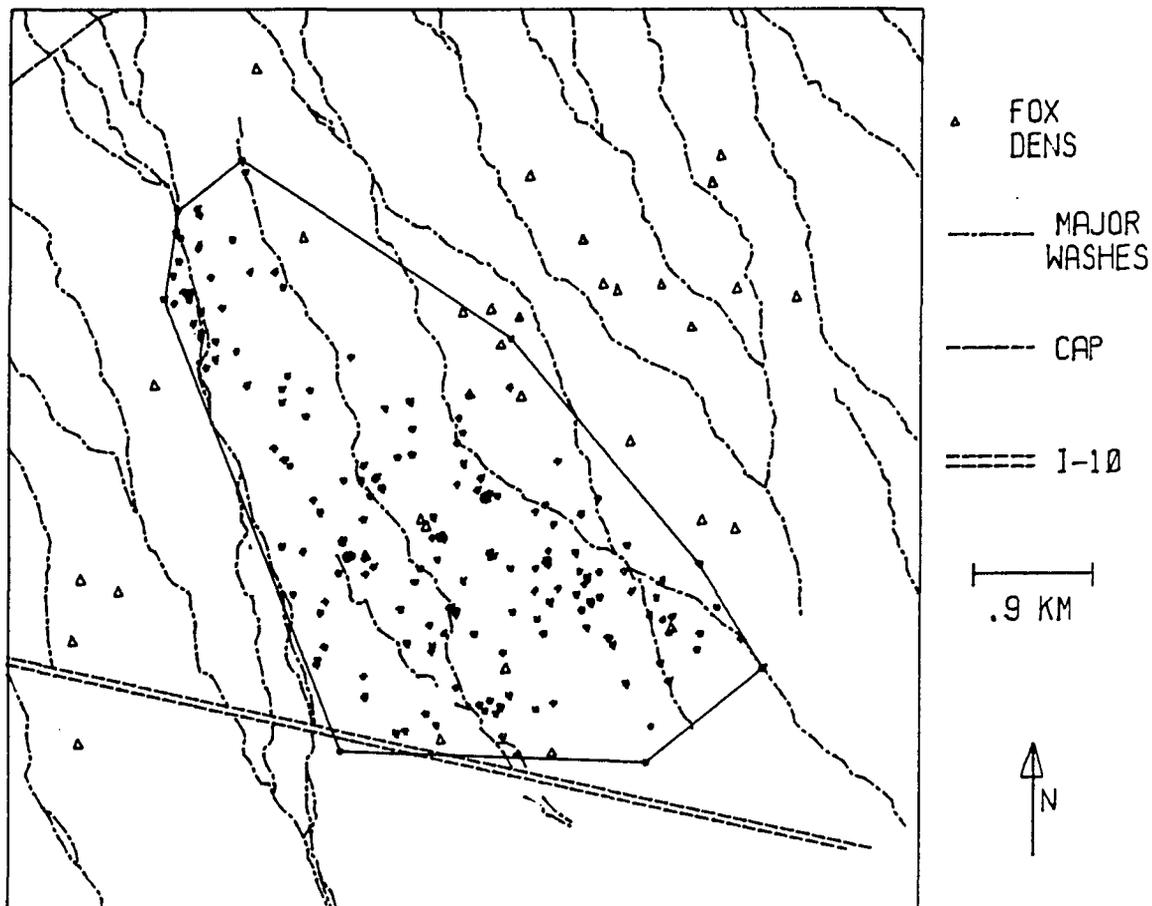
TONOPAH DESERT, ARIZONA
FOX NO. 19 DATE 2/1/83 TO 1/31/84



HOME RANGE SIZE = 11.34 KM²
ANIMAL LOCATIONS PLOTTED = 426

Figure 16. The home range of the male kit fox F19 from February 1983 to January 1984.

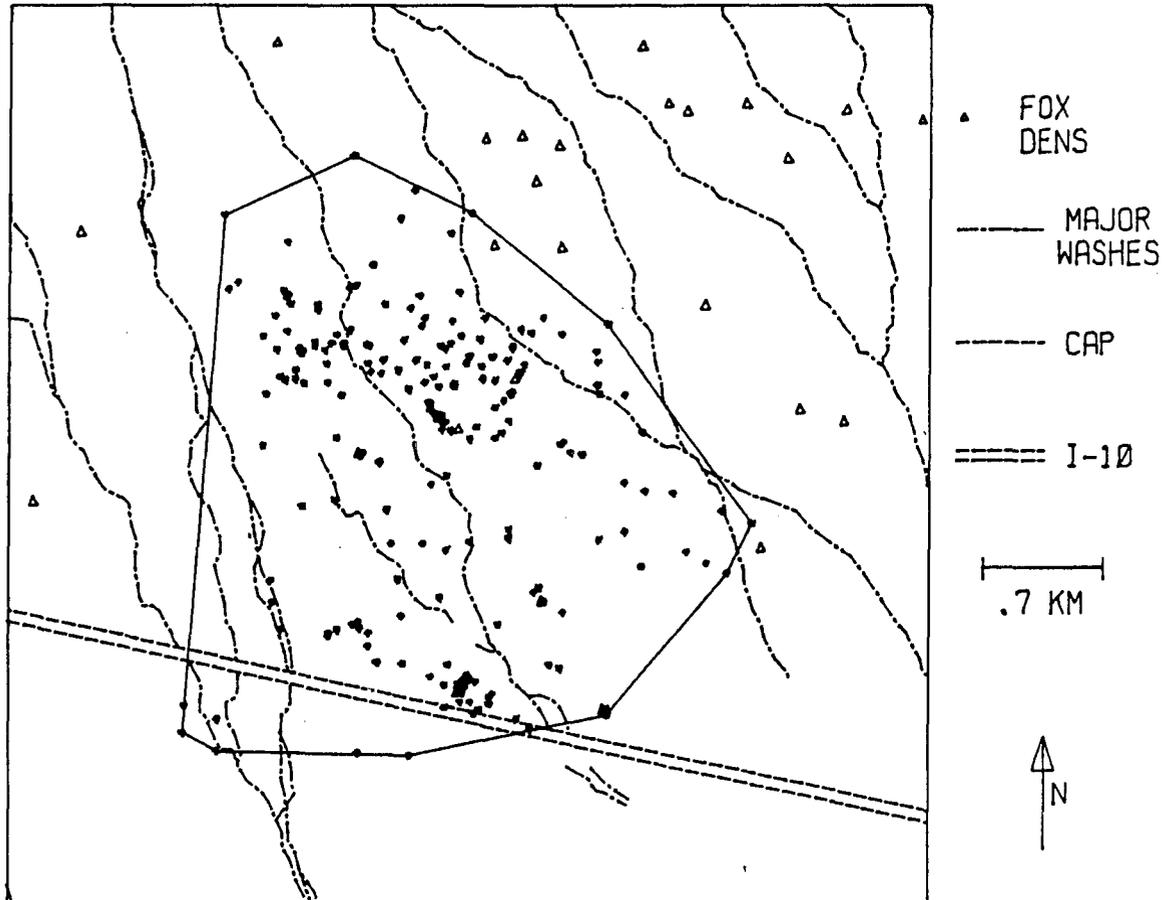
TONOPAH DESERT, ARIZONA
FOX NO. 8 DATE 10/1/83 TO 1/31/83



HOME RANGE SIZE = 11.78 KM²
ANIMAL LOCATIONS PLOTTED = 227

Figure 17. The home range of the female kit fox F8 from October 1983 to January 1984.

TONOPAH DESERT, ARIZONA
 FOX NO. 16 DATE 12/1/82 TO 8/31/83



HOME RANGE SIZE = 8.41 KM²
 ANIMAL LOCATIONS PLOTTED = 266

Figure 18. The home range of the female kit fox F16 from December 1982 to August 1983.

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