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Title: MOVEMENT PATTERNS AND RELATED BEHAVIOR OF THE RACCOON, PROCYON LOTOR, IN EAST-CENTRAL KANSAS

Abstract approved: Dwight L. Spencer

Two studies were conducted in east-central Kansas to describe various aspects of raccoon behavior and ecology. The first study dealt with movement patterns, social organization, denning behavior and mortality of raccoons on a privately-owned study area from August 1985 to May 1986 and September 1986 to May 1987. A cumulative total of 1987 relocations was obtained from 24 transmittered animals. Composite home ranges were estimated for 17 of them. Juvenile female home ranges were significantly smaller than other age groups ($P < 0.05$), while male home ranges were significantly larger than females ($P < 0.005$). Raccoons displayed annual and seasonal fidelity to portions of the study area. A total of 41 seasonal home ranges was estimated for 13 animals, with males and females responding differently to the seasons ($P < 0.05$).

High degrees of spatial overlap between adjacent home ranges were common among all sex and age groups monitored. Two adult males were closely associated with each other during the second year of the study.

Trees were the preferred den type, with 91% of all individual den sites being tree cavities. Some trees served as communal den sites with more than 1 transmittered raccoon using them at a given time.

The most common cause of mortality was apparently canine distemper. Losses were high in the first year, with 10 out of 20 transmittered raccoons found dead. The social tolerance exhibited by these raccoons may have contributed to the effect a highly communicable disease, such as canine distemper, had on the population.

Raccoons were also studied on a federal wildlife refuge from 1985 to 1987 to determine what effect, if any, prolonged flooding had on their movements and mortality. Extensive flooding occurred on the area during the fall of both years and most of the animals remained within the flooded area. Raccoons in flooded areas were seen on tree limbs and displayed movement from tree to tree, although no exposed land was available in their home range. Their inability to forage during the fall did not appear to affect their survival during the following winter.

MOVEMENT PATTERNS AND RELATED BEHAVIOR OF THE RACCOON, PROCYON LOTOR, IN EAST-CENTRAL KANSAS

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PREFACE

Two studies were conducted of Kansas raccoons from August 1985 to May 1986 and September 1986 to May 1987. Because objectives and physical properties of the 2 locations were different for each study, they are described in this thesis in two separate sections.

The first section deals with a study of movement patterns, denning behavior and mortality related to raccoon social organization on a privately-owned area. The second section deals with a study of movements and mortality related to prolonged flooding on a federal wildlife refuge. Both of these projects were part of an ongoing study being conducted by the Kansas Department of Wildlife and Parks.

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GENERAL INTRODUCTION

The raccoon (Procyon lotor) is a highly adaptable animal with a widespread distribution throughout the continental United States. Because of its opportunistic behavior, this species is successful in a wide range of habitats and adjusts its activities, such as food and den site selection, in response to the local environmental conditions.

Not surprisingly, previous telemetry studies of raccoons have revealed a wide variety of results concerning raccoon behavior and movement patterns. Although direct comparisons of home range estimates based on different methods of estimation or sampling are difficult (Jennrich and Turner 1969), estimates of raccoon home ranges have ranged from 5.1 ha in Ohio suburbs (Hoffmann and Gottschang 1977) to nearly 5000 ha in North Dakota (Fritzell 1978a). The size of the home range of a raccoon can be affected by the sex and age of the raccoon, population density, habitat quality, season and length of the study (Ellis 1964, Mech et al. 1966, Johnson 1970, Urban 1970, Roseberry 1977, Fritzell 1978a,b, Lehman 1977,1980, Sherfy and Chapman 1980, Glueck 1985).

The raccoons's secretive, nocturnal habits have limited investigations into their social organization, and this aspect of their behavior is still largely unknown. Fritzell (1978b) conducted an investigation concerning this problem and surmised latitudinal differences may affect raccoon social organization. He found key differences between his results and results from other studies conducted at lower latitudes.

Raccoons have also been found to utilize a wide variety of den sites, such as tree cavities, ground burrows, rock crevices, muskrat (*Ondatra zibethicus*) houses, abandoned buildings and storm sewers (Shirer and Fitch 1970, Giles 1954, Urban 1970), depending upon local availability and other factors (Berner and Gysel 1967).

Information concerning Kansas raccoons is limited. Stains (1956) conducted an extensive study, but the only reported telemetry investigation was a study comparing denning behavior of raccoons, opossums (*Didelphis virginiana*) and skunks (*Mephitis mephitis*) (Shirer and Fitch 1970).

The objectives of Section A of this study were to determine movement and denning patterns of raccoons living in east-central Kansas, and to describe the social organization of these animals.

Historically, few naturally-occurring impoundments of water occurred in the state of Kansas. Since the early 1900's, a number of multiple-use reservoirs have been constructed in various locales throughout the state, many times dramatically changing the surrounding terrain. In most cases, nearby drainages are often subjected to standing water for relatively long periods of time.

Although most natural drainages periodically experience flooding, in most circumstances this flooding consists of fast-moving water quickly rising and receding. In contrast, flooding caused by a nearby impoundment is characterized by stationary water remaining in the area for a longer period of time and slowly receding much later.

Many plants and animals associated with the riparian habitat of natural water courses have probably compensated for the former type of flooding described above, but the reservoirs present a more recent, different type of flooding than these organisms may have adapted to in the past.

A number of studies have noted the affinity raccoons display toward the riparian-type of habitat (Stains 1956, Johnson 1970, Lehman 1980). A strong affinity for wetlands could be detrimental to raccoons on floodplains which experience extreme flooding for relatively long periods of time. Because of some extensive flooding occurring on the Flint Hills National Wildlife Refuge during a study of raccoons on the area, an opportunity presented itself to observe how the animals reacted to being subjected to high levels of impounded water for a relatively long period of time.

Since raccoons represent an important renewable resource, it is important to determine what impact, if any, a large, man-made strucure such as John Redmond Reservoir has upon these animals. Therefore, a separate study is described in Section B.

SECTION A

Badger Creek study

1985-1987

DESCRIPTION OF BADGER CREEK STUDY AREA

The study area was located approximately 8 km east of Emporia, Lyon County, Kansas, on private land owned by area farmers. The majority of this area was in the flood plains of the Neosho and Cottonwood rivers, which join southeast of the study area. Most of the flat terrain was cropland with wheat, soybeans, corn and milo as the principal crops. Intermittent streams and the two rivers produce riparian habitat with cottonwood (*Populus deltoides*), elm (*Ulmus* spp.), willow (*Salix* spp.), sycamore (*Platanus occidentalis*) and maple (*Acer* spp.) as the dominant woody species. Remnants of the Osage Questa border the area on the north with grasses such as big and little bluestem (*Andropogon gerardii*, *A. scoparius*), indiangrass (*Sorghastrum nutans*), smooth brome (*Bromus inermis*) and switchgrass (*Panicum virgatum*) as the most conspicuous vegetation.

The study area is usually subjected to cold winters and warm summers, with mean daytime temperatures of 0 C and 25 C, respectively. The climate is continental, with temperate conditions. Precipitation is variable from season to season and year to year; the annual mean is 88 cm (range 64 - 114 cm). Annual snowfall averages 38 cm, with most occurring during the period November to April.

The bottomland soils are primarily composed of a

Chase-Osage association type, while the principal soil type of the surrounding hills is a Kenoma-Martin-Elmont association (Soil Conservation Service 1981).

Due to periodic flooding and poor drainage of the flood plains, some portions of the study area were temporarily inaccessible for research. Crops on some portions of the study area were not harvested, because of flooding, during the falls of both years.

The raccoon population was exposed to hunting, trapping and hounding during open seasons for both activities. Harvest on the area appeared to be low during the study.

METHODS

Live-trapping to obtain raccoons was conducted on the study area during 2 periods of each year of the study. Trapping occurred in the fall of 1985, spring and fall of 1986, and in the spring of 1987. Additional trapping was conducted by Kansas Department of Wildlife and Parks personnel before and after the study. Limited trapping was done in February 1986 to radio-collar additional raccoons following losses during the preceding fall. Because of the small number of trapnights involved, the February 1986 trapping data were included in spring 1986 trapping results.

Raccoons were caught with wire mesh, box live-traps placed in favorable areas to maximize capture success. Traps were checked each morning, and when a raccoon was captured, it was immobilized with an injection of ketamine hydrochloride. Each raccoon was measured, weighed, ear-tagged, and its physical condition was recorded; in some cases, adults were fitted with radio-collars. Specimens were also aged using the tooth wear technique (Grau et al. 1970). Some juveniles were surgically implanted with interperitoneal transmitters. Captured raccoons were then released at the capture site. Raccoons captured during flooding periods and during December 1986, were held overnight to ensure full recovery from drug-induced immobilization. One juvenile was inadvertently drowned in a trap because of overnight flooding. A variety of baits and lures were utilized to increase trapping success. Some raccoons were radio-collared by Kansas Wildlife and Parks personnel during spring and late summer, 1986.

The computer program CAPTURE (White et al. 1978) was used to estimate population densities based upon capture-recapture data. The model consistently selected by the program to be one of the best estimators for all trapping periods was used. The probability of the closure assumption being met was also calculated for each trapping period. Closure, in this case, refers to the assumption that a population at risk of capture remains constant in size and composition over the period of investigation (White et al. 1982).

Telemetry locations were determined by triangulation, using a receiver (Telonics, Mesa, Arizona) and a two-element, hand-held antenna, from designated sites along roads or by locating the animals while traversing the area on foot (usually to determine daytime resting sites or the animal's condition). Angles were plotted on topographic maps with Universal Transverse Mercator (UTM) coordinates and resulting locations were recorded on individual location sheets. Activity was also recorded for each location, with an animal considered active when its signal fluctuated while the antennae was held in a fixed position. Active animals tracked at night were usually triangulated in 5 to 7 minutes.

Core animals, located near the center of the study area, were usually tracked at night at 4 to 6 hour intervals. Ideally, all portions of a night were sampled at least twice a month for each individual. However, flooding during the fall in both years and mechanical failures late in the second year made this difficult. Peripheral raccoons, located on study area edges, were monitored when possible or when they moved into the study area. Attempts were made to obtain a minimum of 3-5 daytime locations per week for all transmittered animals; however, some raccoons were inaccessible for extended periods of time due to flooding and poor road conditions. During such times, no locations were recorded for these animals. During periods of favorable weather, more locations were obtained.

Although many investigators have used Burt's (1943) commonly accepted definition of home range, or include their own definition, in studies of animal movements, actual definition of a "home range" is dependent upon the method of analysis of animal locations they have recorded. A "home range" in this study merely refers to that area estimated to reflect an animal's movements through a period in time.

In this study, all locations obtained for a raccoon were used in estimating its area of movement, with one exception. Adult male 1755 moved almost 1 km from his previously known area of movement and was found dead soon afterward. It was apparent he probably died from canine distemper and based upon observations of another transmittered raccoon that became infected with the disease, this movement was not included for the estimation of his home range area.

The two models of home range estimation used in this study were the minimum area method (described by Mohr 1947) for descriptions of spatial overlap between adjacent raccoons, and a bivariate ellipse model (Jennrich and Turner 1969) for statistical comparisons between groups.

Since the bivariate ellipse was employed for comparisons among groups and individuals because of its greater statistical stability, efforts were made to minimize possible biases inherent in this model. The area-observation curve (Odum and Kuenzler 1955) was plotted to determine the minimum number of relocations necessary to accurately estimate an individual raccoon's home range.

Because the bivariate ellipse is also sensitive to dependent data, a test of independence between successive observations (Swihart and Slade 1985a) was employed to eliminate this bias. For those home range estimates in which successive relocations were autocorrelated, subsets of relocations representing little or no movement were discarded and the areas recalculated.

Additionally, all successive relocations separated by a time interval of less than 24 hours were removed from home range data sets and those home ranges again recalculated (Swihart and Slade 1985b).

Raccoon home ranges were also calculated using the harmonic mean model (Dixon and Chapman 1980) and are presented in the Appendix. The harmonic mean estimates were included because of the increasing popularity of this technique and the possible desire for future reference. Gustafson and Fox (1983) found that the size of the grid used in the calculations affects the estimated area, therefore, grid size as well as the contour percentages were held constant throughout the calculations, with grid size being 12 and contour percentage 95.

This study consisted of two separate annual periods; August 1985 to May 1986 and September 1986 to May 1987. Composite home ranges (Andelt 1985) were estimated for raccoons and were calculated using all locations obtained for a raccoon during one annual monitoring period. Only raccoons with a minimum of 28 locations spanning at least 3 months of the period were used in the sample; an exception was 1 juvenile female. In addition, each animal monitoring period was divided into seasonal intervals (Fall, September - November; winter, December - January; breeding, February - March; spring, April)(Stains 1956), and seasonal home ranges were calculated using locations obtained for raccoons during these intervals. A minimum number of locations was obtained initially in

August 1985; they were included with the fall sample for the first year. Locations were obtained for 2 days early in May for both years, and they were used in the April samples.

Changes in home range locations (commonly called 'shifts') and possible dispersals for individuals were studied by determining the convex polygon for a time interval and then calculating the percentage of locations obtained during a later time interval falling within the polygon. An arithmetic center (activity center of Hayne 1949) was also computed for both time intervals and the distance between them used as another measure of interpreting spatial shifts in activity area.

Spatial overlap of adjacent raccoon home ranges refers to the portion of a raccoon's minimum area home range which was also included in the minimum area home range of another raccoon. It was expressed as a percentage for both raccoons (Slate 1985). This is a common method used to describe spatial overlap between raccoons, however, it does not always accurately reflect a shared utilization of space. Therefore, overlap area measurements are presented along with an estimate of the utilization of the common area by both raccoons. The estimate of use of the common area was calculated by determining the percentage of relocations of raccoon A found within raccoon B's home range polygon, and vice versa.

Temporal overlap was expressed for raccoons with a high degree of spatial overlap by calculating an index of association. The index was determined for a pair of adjacent raccoons as follows:

$$\text{index of association for simultaneous locations} = \frac{\text{cumulative distance between raccoon A and raccoon B}}{\text{cumulative distance between successive locations for either raccoon A or B}}$$

The assumption was that 2 raccoons that are associated should have a smaller cumulative distance between them than the cumulative distance they travel. The index is subjective, but is a method by which to interpret observed data. There is a bias toward overestimating the index when dependent locations are used in the measurement. This bias was minimized by deleting successive identical locations (if $X_1Y_1 - X_2Y_2 = 0$ for both raccoon A and B, then location X_2Y_2 for both raccoons was deleted). The index is a measurement that is useful only for comparative purposes. Percentages of simultaneous locations separated by a specified distance (200, 100 and 50 meters) were also used to describe possible associations for overlapping raccoons.

Raccoons were occasionally approached on foot during the day to determine den sites. The term 'den site' used in this study refers to a structure or immediate area being utilized by a raccoon for diurnal rest. It may or may not fit the traditional concept of a den. The term is used here because of its history of use in other studies. A 'reused den site' pertains to a den site, already recorded having been used by a raccoon at a previous time, being used again either by the same or a different animal.

Raccoon carcass necropsies were performed by Wildlife and Parks personnel to determine possible causes of mortality. Carcasses found in relatively good condition were analyzed by the Southeastern Cooperative Wildlife Disease Study, Dept. of Veterinary Parasitology, College of Veterinary Medicine, University of Georgia, Athens, and the Veterinary Diagnostic Laboratory, College of Veterinary Medicine, Kansas State University, Manhattan.

The General Linear Model Procedure routine from SAS (SAS Institute Inc., Cary, N.C. 27511) was used for analysis of variance (ANOVA) between groups. Duncan's multiple range test was used when there was a difference ($P < 0.05$) between more than 2 groups. Any differences between observed and expected use of overlap zones between adjacent raccoon home ranges were determined by Chi-square analysis. Student's t-test was used to analyze differences, if any, between male and female diurnal activity. Means are presented with ± one standard error.

RESULTS

Trapping.

A total of 2031 trapnights was accumulated from the 4 trapping periods (Table 1). The fall 1985 trapping period represented the most extensive trapping effort (N = 892), while the last trapping period (spring 1987) had the fewest trapnights (N = 135). Population estimates were not calculated for the spring 1985 trapping period because of the limited number of trapnights and low catch results. Tests for the closure assumption for the first 3 trapping periods indicated that the assumption was not met for the spring 1986 trapping period.

There was a decline in the estimated population number during the 3 trapping periods and a corresponding decline in population density. During the fall 1985 period, when the population number was at its highest level during the study, juveniles composed 53% of the sample (N = 16). One year later, the population had decreased, but juveniles were still 57% of the sample, although the actual number of juveniles captured decreased 50% (N = 8).

Population numbers decreased from the spring 1986 trapping period to the fall 1986 trapping period, although the juvenile population, young produced in 1986, was available for capture during the fall period. Therefore, there may have been some losses continuing through the

Table 1. Trapping effort on Badger Creek study area and population estimates (N) using the jackknife estimator (Mh model) from the CAPTURE program, and associated values from the closure test from the same program.

		No. of Raccoons Captured						
Trapping Period	Number of Trapnights	Number of Individuals	Total Captures	M(h) Value	N	95% CI	Closure	Density (Raccoon/ha)
Fall 1985 (8/27 - 10/10)	892	29	34	0.86	88	55 to 121	P<0.81	1/2.3
Spring 1986 (2/25 - 2/27; 3/25 - 5/9; 6/3 - 6/21)	403	15	18	1.00	66	30 to 102	P<0.03	1/3.9
Fall 1986 (8/28 - 9/16; 12/5 - 12/24)	601	21	29	0.88	40	26 to 55	P<0.06	1/6.5
Spring 1987 (3/11 - 4/25)	135	8	9					

summer.

Telemetry.

Telemetry was conducted from 15 August 1985 to 5 May 1986 and again from 20 September 1986 to 3 May 1987. Twenty animals were equipped with transmitters during the first period (3 of these were transmittered in a preliminary trapping period earlier that spring). Four juvenile females and 1 juvenile male were implanted with inter-peritoneal transmitters and all others were radio-collared. This included 7 adult and 2 yearling females, and 4 adult and 1 yearling male. Of the 18 original animals transmittered during the fall 1985 trapping period , 9 were lost by the end of October, 1985, and 5 more were lost by January 1986 (Table 2). As a result of this high loss early in the study, additional trapping was necessary during February 1986, and 2 more raccoons were radio-collared. Composite home ranges were calculated for 12 of the transmittered animals.

Additional raccoons were transmittered by Kansas Wildlife and Parks personnel during the summer of 1986. Four of these were used for the second year of this study. The remaining sample included 5 animals monitored the first year.

The animals monitored during the second year were 3 adult and 2 yearling females, and 2 adult and 2 yearling males. Composite home ranges were calculated for all 9 animals.

able 2. Monitoring periods for each animal transmittered on Badger Creek study area, 1985-87.

accoon	Age Class	Sex	Capture Date	Date of Final Location	Number of Relocations	Fate
724	I	F	6-4-85	5-1-87	201	active
58	III	F	7-3-85	1-15-86	45	CD
26	II	F	7-11-85	1-8-86	52	UD
1678	II	M	7-11-85	1-16-86	27	CD
292	II	F	8-28-85	5-5-86	172	UD
1755	II	M	8-30-85	10-30-85	19	CD
234	J	F	9-5-85	11-1-85	14	CD
143	J	F	9-6-85	12-3-85	28	U
055a	J	M	9-6-85	10-7-85	4	UD
176	III	F	9-6-85	1-23-86	63	CD
1070	II	F	9-7-85	5-3-87	238	active
265	I	F	9-11-85	9-27-85	4	U
257	II	M	9-12-85	10-7-85	4	U
996	IV	F	9-16-85	5-5-86	156	UD
1785	I	M	9-17-85	11-5-85	11	H
1738	IV	M	9-18-85	5-3-87	199	active
055b	J	F	10-8-85	11-2-85	6	SR
025	J	F	10-9-85	11-4-85	3	SR
757	J	F	2-26-86	2-11-87	165	U
202	III	F	2-26-86	5-3-87	191	active
1255	I	F	5-6-86	5-3-87	66	active
227	I	M	8-31-86	4-25-87	140	UD
252	I	M	9-2-86	5-3-87	119	active
327	II	M	9-4-86	4-25-87	153	UD

U = fate unknown
UD = cause of death unknown
SR = study related mortality
H = harvested by hunters
CD = canine distemper (diagnosed or strongly suspected)

A cumulative total of 1987 radio locations was obtained from all transmittered animals during the 2 year study. The mean number of locations obtained for each raccoon was 83 (range 3-238).

Home Range.

The area-observation curve was plotted for all animals with a minimum of 30 locations. The average asymptotic value was 21 locations, therefore animals with less than that number were not used. One exception was juvenile female 234 because it was found that juveniles have smaller home ranges, and in this case the 14 relocations obtained for this animal were probably representative of that animal's movements.

Of 21 composite home range estimations, only 1, 234, was determined to meet the assumption of independence between successive relocations (alpha = 0.25). For animals tracked throughout a monitoring year, relocations obtained during the winter interval were removed and the test for independence for each animal recalculated because some of the animals displayed limited movement during that season. No composite home ranges met the assumption of independence after recalculation. All relocations obtained less than 24 hours from the previous relocation were removed from each animal's data set in addition to the winter season data. Tests for independence were recalculated and all remained positively autocorrelated.

Composite home ranges for the raccoons are shown in Table 3. Correlation between sample size (number of locations obtained for each raccoon) and the estimated area for each raccoon was lowest for the bivariate ellipse, with r = 0.38, and -0.09 for the minimum area and bivariate ellipse models, respectively. Estimates from the bivariate ellipse were used for comparative purposes.

Estimated composite home range areas calculated for juvenile females were significantly smaller than yearling or adult estimates (df = 16, $P < 0.05$). This was the only significant difference among age classes. With yearlings and adults combined, male estimates were larger than females ($F = 11.04$, df = 1, 17, $P = 0.0017$). The largest home ranges in the study were recorded for yearling males.

Five animals tracked during both monitoring periods remained in the same general areas in both years, as indicated by the high percentages of annual home range overlap in Table 4.

<u>Seasonality of Movement Patterns</u>.

Forty-one seasonal home ranges were calculated for 15 raccoons during the 2 years. Correlation coefficients for seasonal home range estimates in relation to number of relocations were 0.26 and -0.03 for the minimum area and bivariate ellipse models, respectively. Bivariate ellipse estimates were used for statistical comparisons.

Of 41 seasonal home ranges estimated, only 1 was

Table 3. Composite home range estimations (hectare) for raccoons on the Badger Creek study area, 1985-87.

				COMPOSITE HOME RANGES			
		Number of Locations		Minimum Area		Bivariate Ellipse	
Raccoons	N	$\bar{X}$	Range	$\bar{X}$	SE	$\bar{X}$	SE
Adult Females	9	102.1	45-172	107.4	17.9	136.6	16.1
Yearling Females	3	110.7	66-148	75.2	24.9	87.2	30.8
Juvenile Females	3	29.7	14-47	25.5	2.5	56.0	5.6
Adult Males	4	95.0	28-162	155.6	29.5	215.4	42.6
Yearling Males	2	129.5	119-140	308.6	93.0	273.2	3.8

Table 4. Annual home range fidelity for Badger Creek raccoons, 1985-86 and 1986-87.

			Number of Locations				
Raccoon	Sex	Age Class	1985-86	1986-87	E1	E2	Distance between arithmetic centers (m)
202	F	III	51	140	88	41	389
1070	F	II	106	131	83	68	547
724	F	I	148	53	85	83	130
757	F	J	47	118	79	80	198
1738	M	IV	37	162	89	70	294

E1 = % of radio-locations obtained during the 1985-86 monitoring period located within the convex polygon plotted for than animal from radio-locations obtained during the 1986-87 monitoring period.

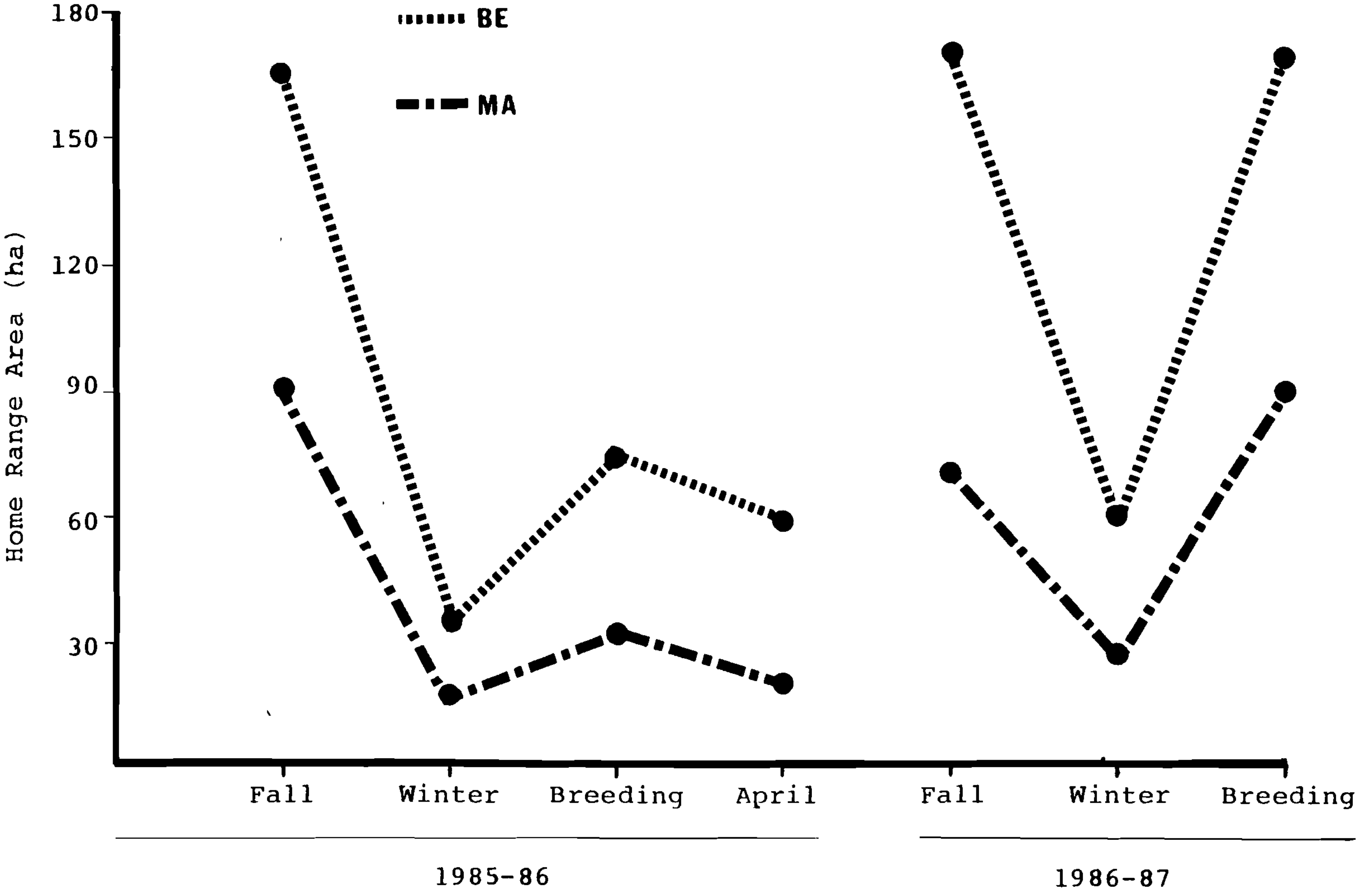
E2 = % of radio-locations obtained during the 1986-87 monitoring period located within the convex polygon plotted for than animal from radio-locations obtained during the 1985-86 monitoring period.

determined to meet the assumption of independence between successive observations. No attempt was made to remove data to approach independence because this method was unsuccessful for composite home range estimates.

All monitored raccoons exhibited seasonal variation in movement patterns. Seasonal home range estimates did not differ significantly between yearlings and adults (F = 0.77, df = 1, 40, P = 0.3872) but males and females responded differently to the seasons (F = 6.51, df = 1, 40, P = 0.0167). Seasonal fluctuation of home range size for females is shown in Figure 1. The females displayed a distinct decline in home range area during the winter interval (December - January) for both years. Adult females 1070, 176 and 292 decreased their home range areas by 71%, 82% and 78%, respectively, during the first year, and 1070 decreased her area by 94% during the second year.

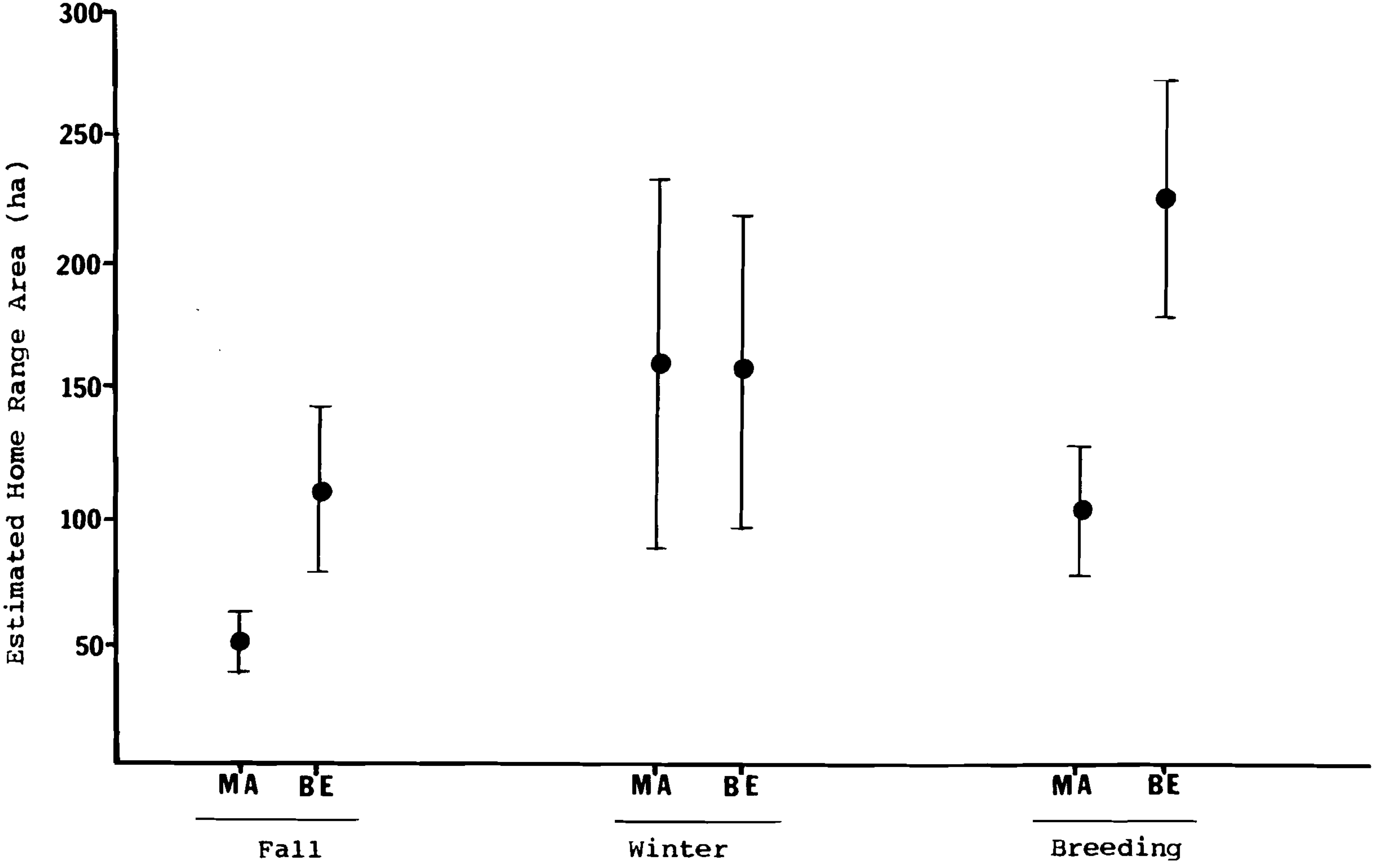
Seasonal changes in home range area for males could be determined only for the 1986-87 monitoring period (Fig. 2). Male home ranges were different from females during the winter and breeding intervals (Winter: F = 4.95, df = 1, 11, P = 0.0503; Breeding: F = 8.23, df = 1, 10, P = 0.0185). In contrast to females, home range fluctuations from season to season among males exhibited considerable variation. Adult male 327 displayed a consistent increase in home range area during the year, whereas 1738 decreased his area slightly during the winter

Figure 1. Bivariate ellipse (BE) and minimum area (MA) seasonal home range estimates for adult female raccoons on Badger Creek study area 1985-87.



BE
MA
180
150
120
90
60
30
Home Range Area (ha)
Fall
Winter
Breeding
April
Fall
Winter
Breeding
1985-86
1986-87

Figure 2. Estimated average seasonal home ranges for male raccoons on Badger Creek study area 1986-87. Vertical lines represent ± one standard error. Home range models are minimum area (MA) and bivariate ellipse (BE).



Estimated Home Range Area (ha)
300
250
200
150
100
50
MA
BE
Fall
MA
BE
Winter
MA
BE
Breeding

interval and then increased during the breeding interval.

Yearling males were much more variable than adults in their movement patterns. Number 227 exhibited a marked increase in area during the winter interval and maintained that behavior throughout the breeding interval; he traveled considerable distances (over 2 km) out of his former area of movement only to return to the general area at a later time. In contrast, 252 displayed a sharp decline in home range area during the winter interval and then increased his area of movement during the succeeding interval.

Raccoons commonly exhibited small shifts of area between seasonal home ranges during this study (Table 5). In general, however, the raccoons were consistent in the location of their areas of movement. A high percentage of the radio locations obtained for adults and yearlings during the April interval were found in their respective minimum area polygons calculated for the fall interval.

There was a difference between males and females in response to season, with more variation and lower percentages occurring for females in the breeding interval, and lower percentages for males during the winter interval. The lower percentage of female locations during the breeding interval falling within the winter home ranges was due to 3 of the females (2 individual raccoons; 1 was tracked both years, therefore N=3) in the sample decreasing their winter home ranges dramatically

Table 5. Seasonal spatial stability of home ranges expressed as percentage of radio locations found within the preceding season interval's minimum area home range polygon (Mohr 1947) and the seasonal distance between arithmetic centers (Hayne 1949) for raccoons located on the Badger Creek study area, 1985-87.

			Number of locations/individual		Percentage of locations occurring within the previous season's home range		Distance* between arithmetic centers	
Sex	Season	Number of Individuals	$\bar{X}$	± SE	$\bar{X}$	± SE	$\bar{X}$	± SE
Females	Winter	6	48.8	5.14	88.8	6.82	233.5	76.0
	Breeding	6	34.8	2.82	59.2	8.33	249.0	48.21
	April	6	20.4	0.61	82.0	3.45	174.3	39.83
Males	Winter	4	61.5	5.90	59.8	5.60	503.2	131.02
	Breeding	4	35.8	3.60	72.2	8.05	198.0	99.03

Winter = December - January

Breeding = February - March
* = distance in meters

(described in the preceding section). Therefore, breeding season percentage may be deceiving, implying that raccoons may have been utilizing different areas, but this is not true. Adult female 292 exhibited seasonal fidelity to a particular area (Fig. 3). Percentage of breeding season locations found within the fall home ranges for the sample, excluding the 3 animals mentioned above (insufficient data were obtained for 1070a during the fall interval for seasonal home range estimation), was 77.8. Therefore, females were still found inhabiting the same general area during the breeding season interval as earlier in the year.

The relative consistency among seasonal average distances between arithmetic centers supports the conclusion of female raccoon fidelity to familiar areas from season to season (Table 5).

Males also exhibited seasonal home range fidelity but were not as predictable as females (Table 5). The lower percentage of male locations obtained during the winter interval occurring within the fall home ranges and difference between arithmetic centers is partly attributable to a small number of individuals monitored and 1 yearling possibly dispersing from his previous location. Yearling male 252 apparently shifted his home range to the east of his original area (Fig. 4). Only 22% of his locations obtained during the Feb.-Mar. interval (N=27) were found in the fall polygon. In addition, area

Figure 3. Seasonal home range overlap for adult female 292 during the 1985-86 monitoring period on the Badger Creek study area (Fall = FL, Winter = WR, Breeding = BG, April = AL).

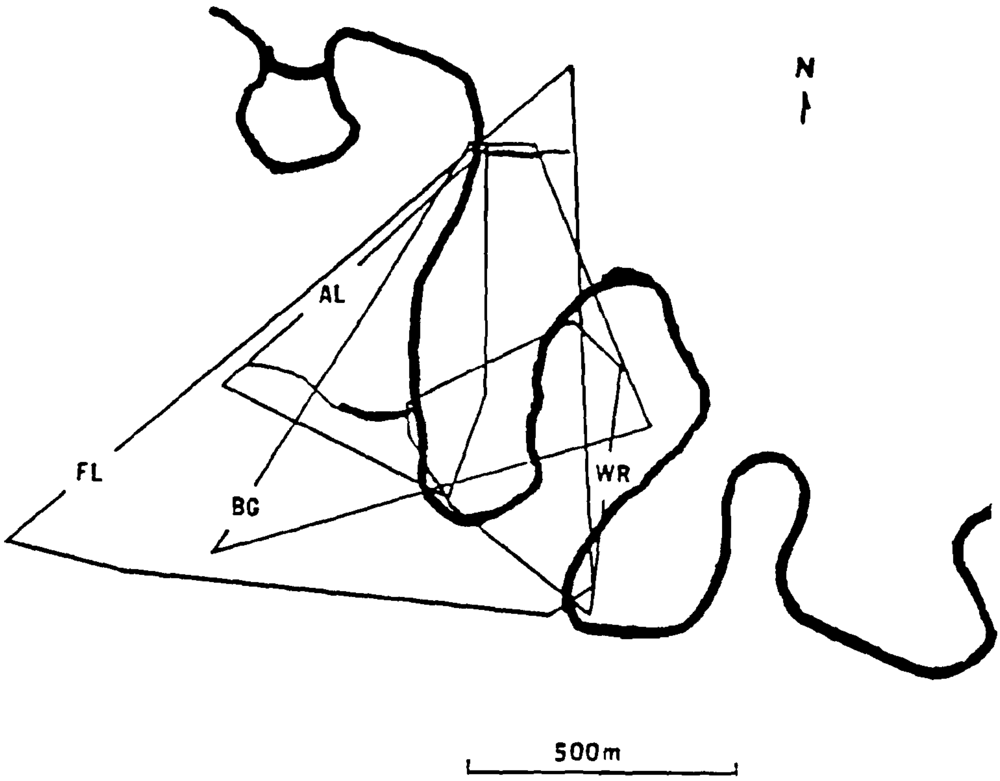
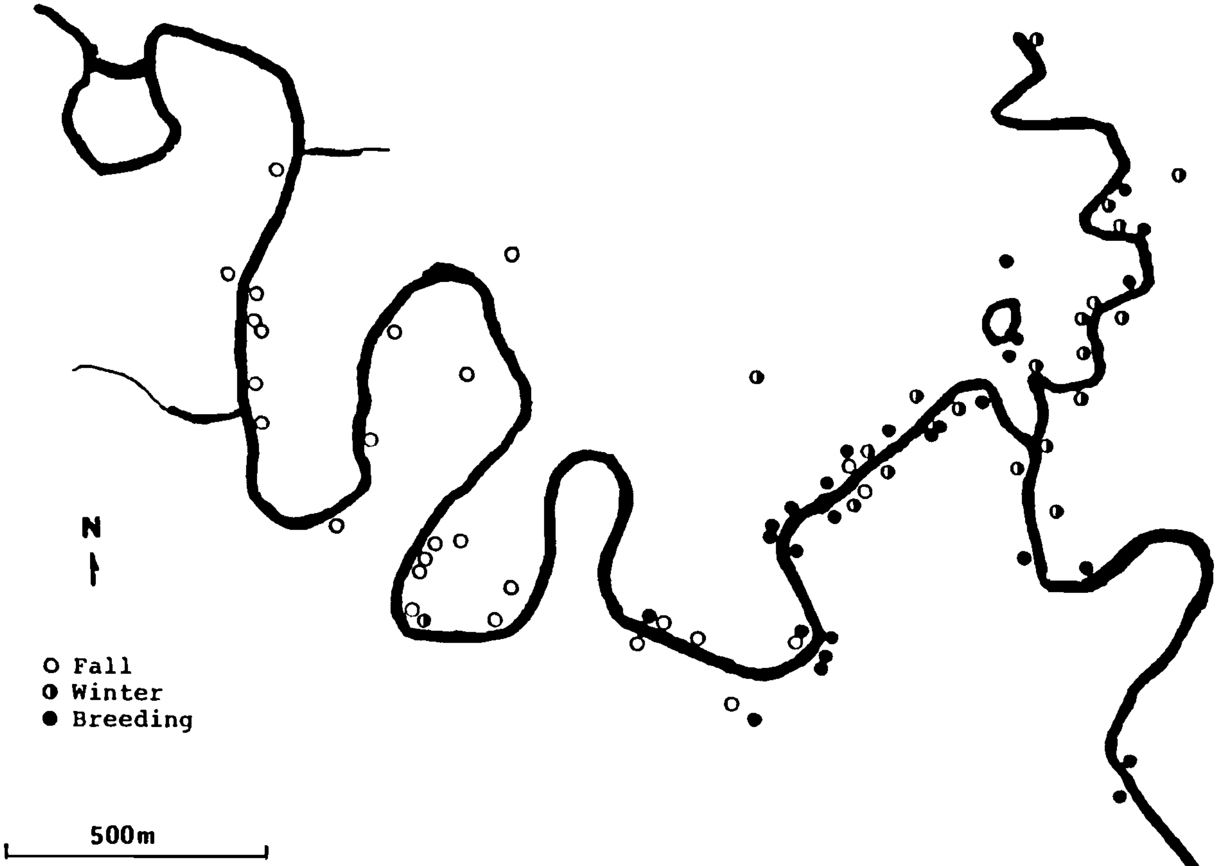

N
AL
FL
BG
WR
500m

Figure 4. Seasonal home range overlap for yearling male 252 during the 1986-87 monitoring period. Each symbol may represent more than one relocation.


N
○ Fall
◐ Winter
● Breeding
500m

of overlap between interval polygons gradually decreased; the winter polygon overlapped 28% of the fall polygon, and the Feb.-Mar. polygon only overlapped 8% of the fall polygon.

Average percentage for male locations obtained during the winter interval found within the fall home ranges was larger, and average distance between arithmetic centers was considerably smaller, when they were calculated without 252 in the sample (64.7% and 381.7m SE=± 119.3m, respectively).

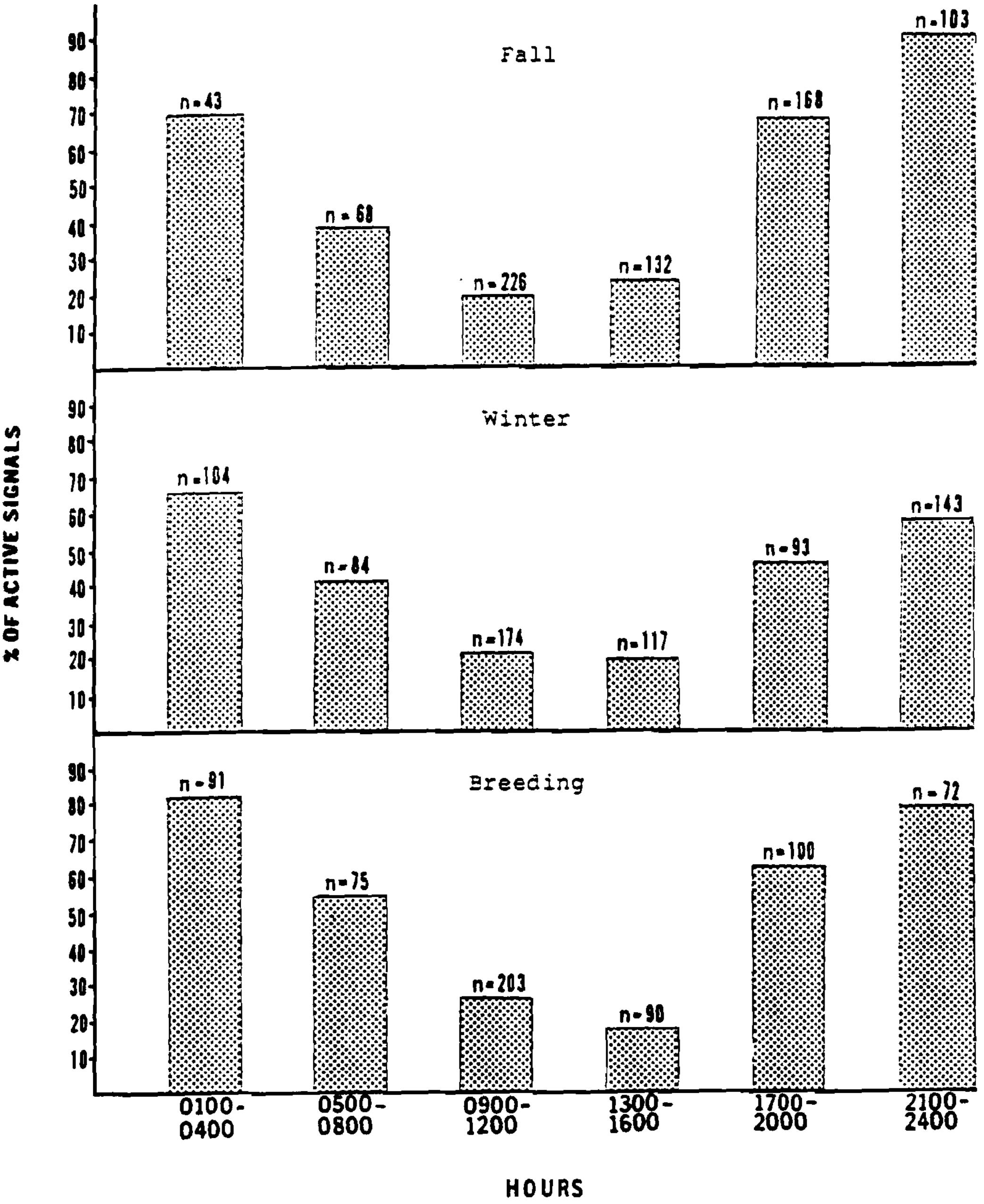
<u>Activity</u>.

Raccoons became active between 1800 and 1900 hours (Fig. 5). They were usually active during all times of the night except during the winter interval. Raccoons remained inactive from 9 January to 23 January, 1987, when there was a combination of snow cover and temperatures consistently below freezing.

There was more variation in the time that raccoons ceased activity than the time they initiated activity. In general, activity declined during the 0600 and 0700 hours.

Raccoons were not tracked during diurnal hours; however, a limited amount of information was acquired from radio locations during the morning and again that afternoon as nighttime tracking began. Any differences between the 2 locations would represent minimum distance traveled during the day. For N=56, the average distance

Figure 5. Seasonal activity patterns of raccoons on Badger Creek study area expressed as percentage of locations at which animals were active as opposed to sleeping or resting. April locations were pooled with the breeding interval because of small sample sizes.


% OF ACTIVE SIGNALS
Fall
n=43
n=68
n=226
n=132
n=168
n=103
Winter
n=104
n=84
n=174
n=117
n=93
n=143
Breeding
n=91
n=75
n=203
n=90
n=100
n=72
10
20
30
40
50
60
70
80
90
0100-0400
0500-0800
0900-1200
1300-1600
1700-2000
2100-2400
HOURS

between the 2 diurnal locations was 139.5 meters, range was 0 to 552 m. There was no significant difference between males and females ($P > 0.05$).

Social Organization.

There was a high degree of spatial overlap among raccoons and their use of overlap areas.

Females - Home range overlap between adjacent females and their respective use of those overlap zones is shown in Table 6. The high loss rate of transmittered animals made it difficult to observe the relationship between adjacent raccoons for an extended period. During the fall 1985 interval, there was overlap among several females (Fig. 6), but only 2 adult females, 292 and 996, were monitored throughout the first year. They exhibited a high degree of spatial overlap for most of the period (Table 6).

Only 3 adjacent adult females were monitored during the second year; all 3 were also tracked for at least portions of the first year. They had little or no overlap in the first year, but exhibited some overlap and shared use of space in the succeeding year (Table 6).

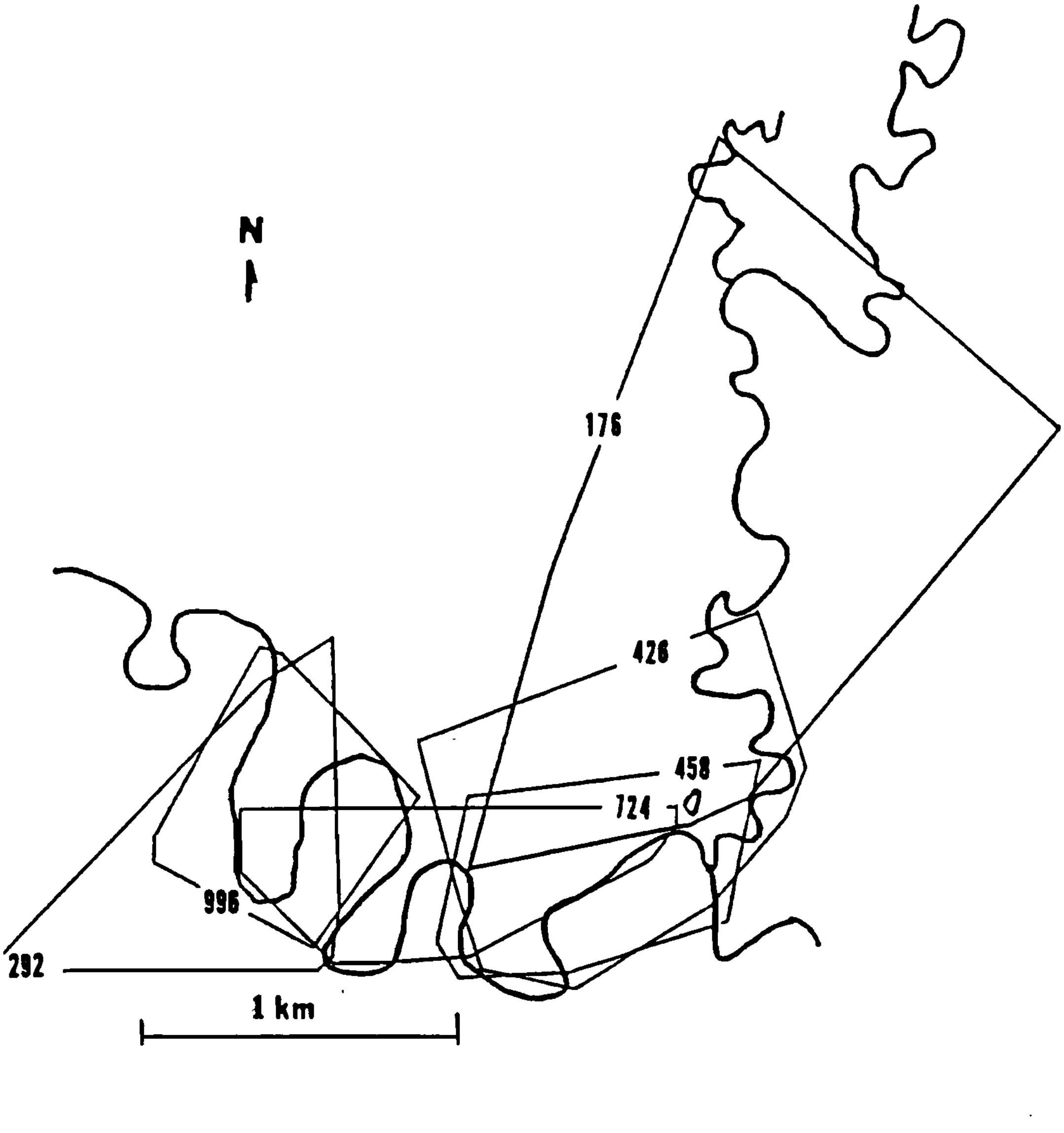
Yearling home ranges were overlapped considerably by adult females (only 3 yearlings were monitored). During the fall interval in the first year, 1 yearling (724) was overlapped by 4 adult females (Fig. 6). This same animal, having graduated to the adult rank in the second monitoring period, in turn overlapped another

Table 6. Female raccoon home range overlap expressed as the percentage of relocations found within the overlap zone between two adjacent raccoons (P), and the percentage of the home range composed of the overlap zone (O). The number of relocations obtained for each animal is represented by N.

	Raccoon Number		Fall						Winter						Breeding					
			A			B			A			B			A			B		
Year	A	B	N	P	O	N	P	O	N	P	O	N	P	O	N	P	O	N	P	O
1985-86	292	996	71	82	66	56	74	78	53	8	11	53	17	8	26	73	37	** 26	85	92
	458	426	35	89	95	34	65	53												
1986-87	202	1070	47	89	71	** 37	42	43	48	19	11	** 54	33	61	37	65	49	35	34	44
	724	1070	19	42	82	** 37	30	34	13	0	0	54	0	0	17	35	67	** 35	14	21
	202	724	47	42	47	** 19	37	70	48	8	12	13	46	30	37	38	30	17	53	85
	202	1255	47	53	70	29	48	36	48	56	44	21	62	55	37	5	7	11	73	68
	724	757	19	53	24	** 44	66	35	13	15	1	68	48	1						

**= $P < 0.05$ for the dyad

Figure 6. Female raccoon home range overlap during the fall season interval on the Badger Creek study area, 1985.


N
176
426
458
724
996
292
1 km

yearling, 757. These 2 animals were found in the same den tree simultaneously on 16 October 1986 and 5 November 1986. Although their area of overlap was not particularly large relative to their respective home range areas, they were found within this shared area many times (Table 6). Raccoon 757 was not an offspring of 724.

The average percentage of relocations found within the overlap zones for each animal was 47. The number of relocations found within the overlap zone was significantly different than expected on 7 occasions ($P < .05$). This analysis did not reveal any general trends for female raccoons with respect to the observations within the overlap zones being higher or lower than expected. However, there were some consistencies within individual dyads, with 724 and 1070 consistently found within their overlap zone less than expected while the opposite was true for 724 and 757.

Males - Percentages of home range overlap and use of the overlap zones for adjacent male raccoons are shown in Table 7. Chi-square analysis revealed differences in observed and expected use of overlap zones on only 5 occasions. On each of those occasions, both members of the dyad were found in the overlap zone more often than expected. Unlike females, there did appear to be a general trend for relocation percentages within the overlap zone to be higher than the relative percentage of home range composed of the overlap zone for both animals

Table 7. Male raccoon home range overlap expressed as the percentage of relocations found within the overlap zone between two adjacent raccoons (P), and the percentage of the home range composed of the overlap zone (O). The number of relocations obtained for each animal is represented by N.

			Fall						Winter						Breeding					
	Raccoon Number		A			B			A			B			A			B		
Year	A	B	N	P	O	N	P	O	N	P	O	N	P	O	N	P	O	N	P	O
1985-86	1755	1678	14	86	88	28	75	88												
	1738	1678	37	94	97	28	69	53												
1986-87	1738	227	42	81	72	41	83	79	68	60	51	65	14	10	43	61	59	33	50	32
	1738	252	42	98	99	38	55	50	68	0	1	44	0	1	43	0	0	27	0	0
	1738	327	42	88	88	40	88	95	68	100	100	69	62	56	43	93	92 **	40	82	46
	227	252	41	90	85 **	38	63	37	65	23	14 **	44	86	75	33	37	14 **	27	59	31
	227	327	41	78	88	40	88	83	65	58	16 **	69	77	46	33	83	73	40	78	67
	252	327	38	63	42	40	95	99	44	2	8	69	4	4	27	0	0	40	0	0

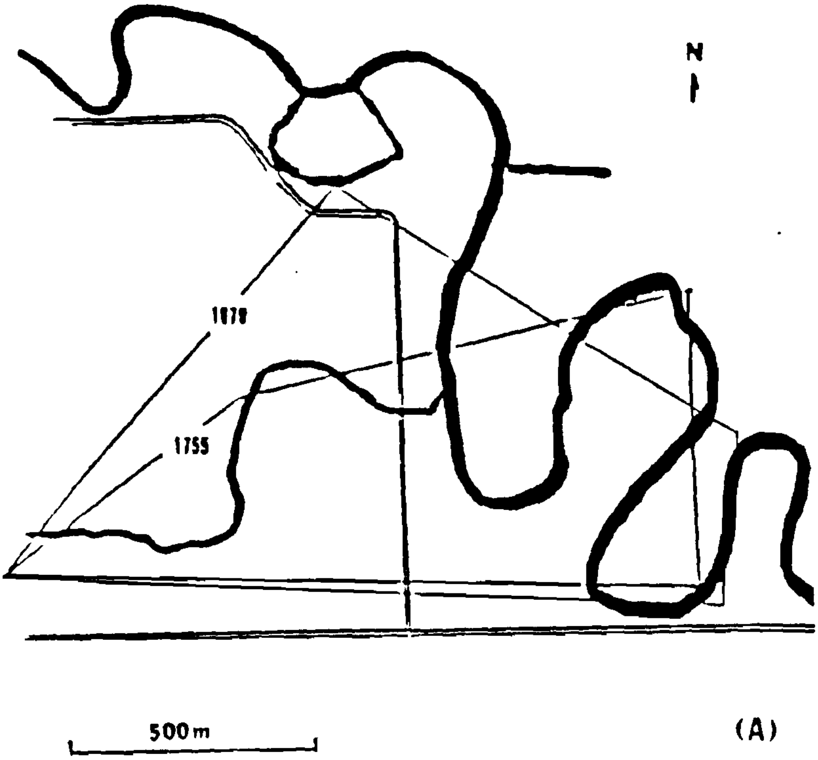
**= $P < 0.05$ for the dyad

of the dyad.

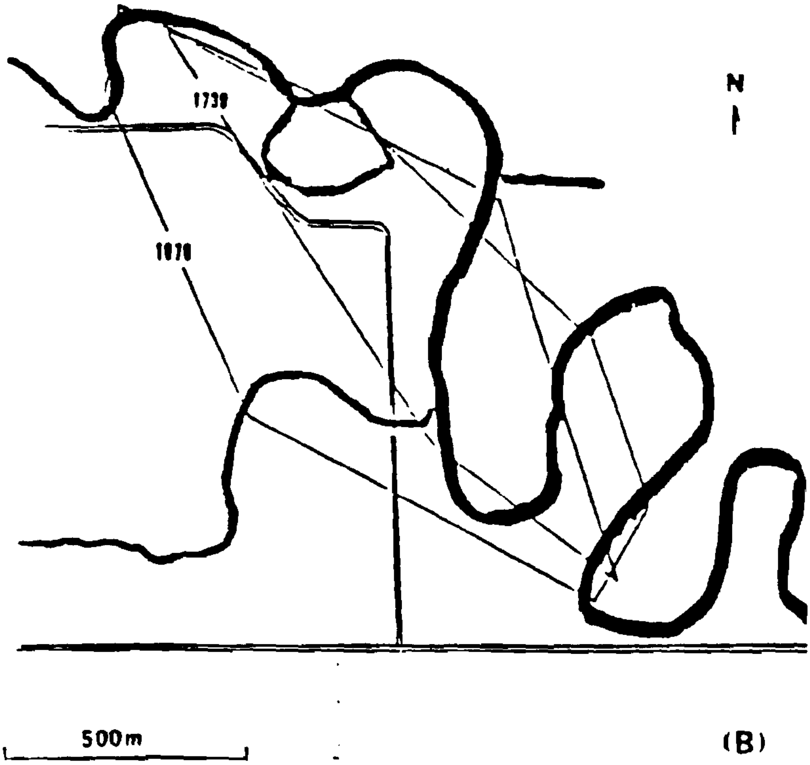
During the 1985-86 monitoring period, limited data were obtained for 3 adult males (Table 7). Adult males 1678 and 1755 displayed a high degree of spatial overlap during the early portion of the fall interval (Fig. 7a). Adult male 1755 traveled nearly one km from his previous area of movement on October 25 and was found dead on October 29. After the death of 1755, 1678 appeared to change his movement patterns and overlapped 97% of 1738's home range (Fig. 7b). Location of his home range polygon changed slightly, but only 40% of the locations recorded for this animal during November were found within the home range polygon calculated for the period when animal 1755 was alive. On two occasions 1678 and 1738 were found using the same den tree simultaneously; 1678 subsequently died at the end of December, probably due to the same mortality factor that caused 1755's demise, although the carcass was too decomposed for verification of the cause of death. The remaining male's transmitter ceased functioning in December.

Unfortunately, little is known of 1738's movement patterns before 1755's death and, consequently, the relationship between the 3 animals is largely speculative. Five of 6 locations obtained for 1738 during the time 1755 was alive were located within both 1755 and 1678's home ranges. On 1 of these occasions, all 3

Figure 7. Spatial home range overlap for adult males 1755 and 1678 during October 1985 (A), and spatial overlap for 1678 and adult male 1738 during November and December 1985, immediately after 1755's death (B).



(A)



(B)

animals' daytime resting sites were triangulated to <50m apart.

Adult male 1738 was re-collared and 3 other males were radio-collared during the summer of 1986 by state personnel and were monitored throughout the 1986-87 monitoring period. All 4 males shared the same portion of the study area with each other as evidenced by large percentages of overlap areas and the respective number of locations found for each animal within those areas during the fall interval. This situation changed during the winter interval, with yearling male 252 displaying little overlap with either of the adult males. This decrease in shared area coincided with the shift in home range described earlier for this animal.

Yearling male 227 also decreased his spatial overlap with the others during the same time period, although he did not shift his home range area, but dramatically expanded his home range area (Appendix II). Because of this expansion in area of movement patterns, he overlapped all the other males, but had a relatively low percentage of radio locations within those zones of overlap.

During the breeding interval, 252 continued to maintain an area east of the adult males while 227 decreased his movements to an area consistent with the others. Yearling 227 resumed utilization of shared space with the 2 adult males characteristic of the fall interval.

The 2 adult males, 327 and 1738, maintained a high degree of spatial overlap and usage of overlap zones throughout the monitoring year (Table 7).

Supplemental information from trapping data collected during the monitoring periods suggest further overlap may have occurred with tagged males (Appendix III). Telemetry locations of radio-collared males with insufficient data to estimate home ranges are also represented.

Male-Female overlap for the first year between males and females could only be determined for the fall interval. All 3 males overlapped the same females, which could be expected since the males occupied the same general portion of the study area. They overlapped extensively 2 adult females and 1 juvenile female, and overlapped portions of a yearling and another juvenile female (Table 8).

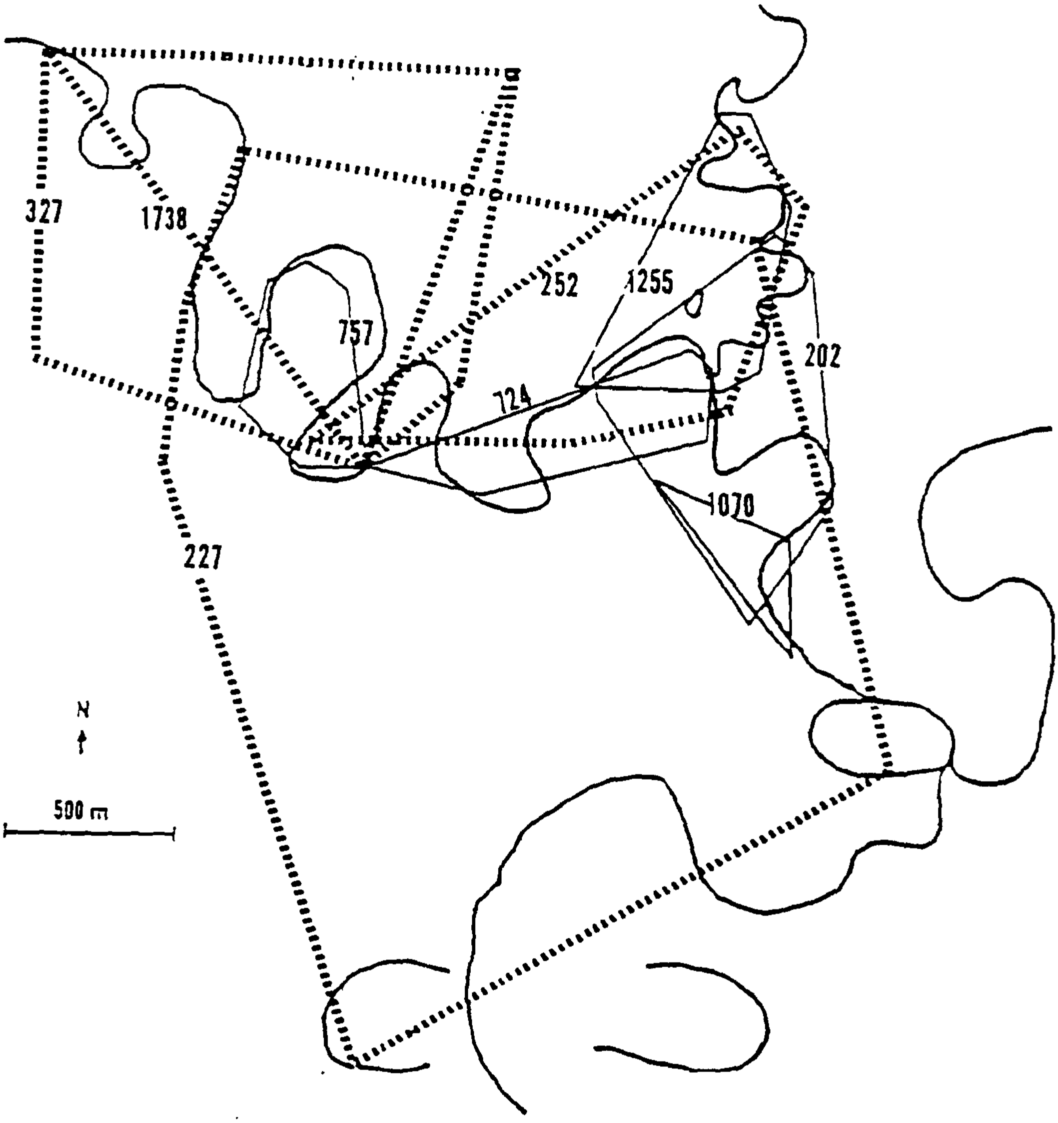
Home range overlap between males and females during the 1986-87 period was common (Fig. 8), although the number of radio-collared animals for this period was small. Each female during this period shared a common area with at least 1 male.

Spatial overlap between adjacent raccoons was affected by temporary food sources. The carcass of a hog was deposited by receding flood waters in a small drainage near the Neosho River on 5 March 1987. During the period ble 8. Percentage of female relocations within a male's minimum area (Mohr, 1947), indicating intersexual raccoon home range overlap, during the fall 1985 monitoring interval.

Adult Males	Adult Females				
	292	328	234	724	143
55*	97	86	17	37	56
78	96	64	64	33	52
38	81	80	79	27	56

- contains only those female locations up to the date of 1755's death.

Figure 8. Spatial home range overlap for male and female raccoons during the winter interval 1987 on the Badger Creek study area. Male home ranges are represented by dotted lines.



327
1738
757
252
1255
724
202
1070
227
N
500 m

between 5 and 14 of March, 5 radio-collared raccoons were located consistently near the area containing the hog (Fig. 9a,b). On 7 March, daytime locations for all 5 animals were within a 300m radius of the carcass. Male 252 was visually sighted in a tree within 20m of the carcass on 5 March and was captured in a trap less than 10m from the carcass on 11 March. Female 202 was captured less than 10m from the carcass on 14 March.

Although 2 of the raccoons moved a considerable distance from their normal daytime resting areas to utilize this food source, none of the radio locations obtained during that time represented home range extensions.

Temporal Overlap.

Temporal overlap could only be estimated for raccoon pairs that were monitored simultaneously. Simultaneous locations were obtained for 4 raccoon dyads that exhibited a high degree of spatial overlap; 2 adult males, 2 pairs of adult females, and 1 pair of adult and yearling males (Table 9).

Adult females 292 and 996 were monitored throughout the 1985-86 period and did not appear to be associated together, as evidenced by the index of affiliations consistently over 1.0 and the small percentage of paired locations less than 50m apart.

Simultaneous locations for adult females 1070 and 202 obtained during the second year are shown in Table 9.

Figure 9. Evidence for raccoon utilizaton of a temporary food source during early spring. Telemetry locations for raccoons obtained during 2 February to 26 February 1987 (A) and telemetry locations for raccoons during 5 March to 15 March 1987, while a hog carcass was deposited on the area (B).

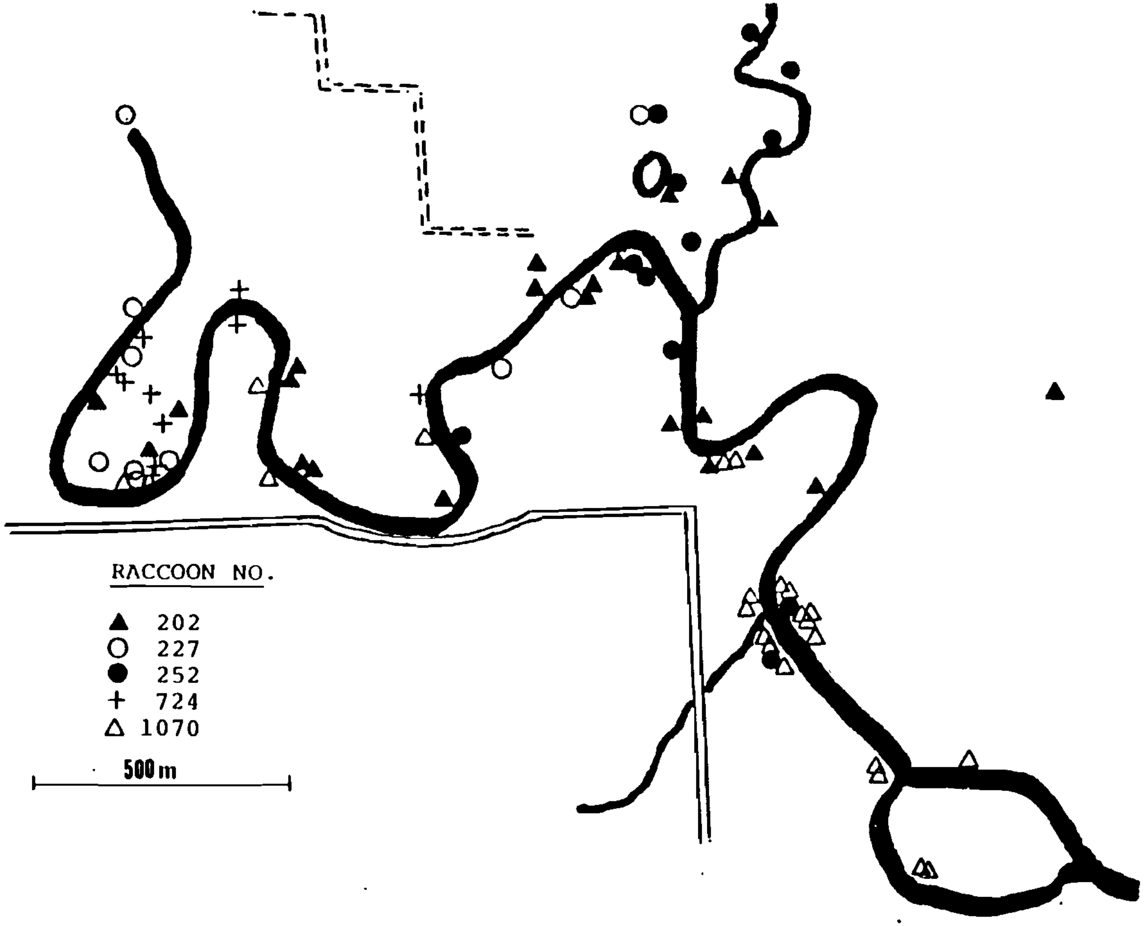


Figure 9 (a).

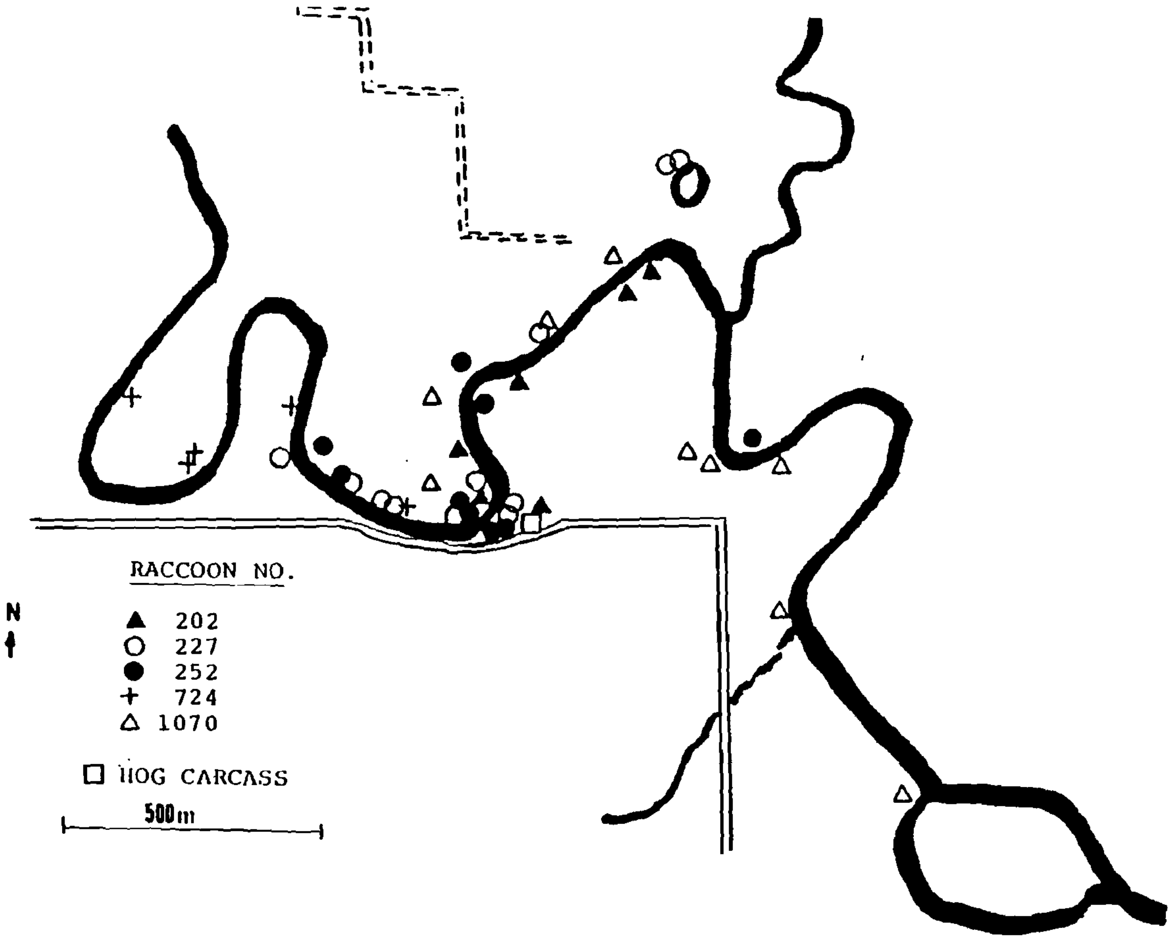


Figure 9 (b).

Table 9. Intrasexual temporal overlap of raccoons with extensively overlapping home ranges on the Badger Creek Study Area, 1985-87.

			Index of Association						Distance between Simultaneous Locations(m)					
Raccoon dyad			Fall		Winter		Breeding		d $\leq$ 200m		d $\leq$ 100m		d $\leq$ 50m	
A	B	N	A	B	A	B	A	B	n	%	n	%	n	%
M1738	M327	120	0.67	0.90	1.88	1.16	0.90	0.79	77	64	50	42	44	37
M327	M227	118	0.72	1.01	1.76	1.34	0.98	1.30	39	33	31	26	21	18
F202	F1070	100	1.54	1.21	2.08	7.60	2.26	1.65	17	17	7	7	4	4
F292	F996	136	1.39	2.10	2.79	2.40	1.24	1.24	46	34	13	10	7	5

Fall = October-November
Winter = December-January
Breeding = February-March
N = Total number of simultaneous radio-locations
M = Male
F = Female

Their location results are similar to the other adult female pair.

Males showed a greater affinity for each other than females did for each other. Adult male 327 and yearling male 227 were found together occasionally, but there is no evidence they ever traveled together. The closest association recorded occurred between adult males 1738 and 327. Although they were never observed traveling together, some evidence suggests the possibility. Within each season interval, this pair had time intervals during which they were consistently found close together.

Some characteristic periods of apparent association between these 2 animals are shown in Table 10, along with one period of definite non-association in February for comparison. The periodic intervals of association between these 2 raccoons occurred throughout the 1986-87 monitoring year. Two things should be noted in Table 10; for raccoons closely associated with each other, both t and I.A. should be nearly equal when comparisons are made between animals.

There were other occasions that suggested these 2 males were traveling together. Some of the more extreme distances recorded between successive daytime locations where 1738 and 327 were located together (<25m) are: 700m between 29 and 30 December 1986, 650m between 30 and 31 December 1986, 1.2km between 23 and 24 February 1987, and 1.1km between 6 and 7 March 1987. An example is shown in

Table 10. Degree of association between the as the Index of Association (I.A.), and the total distance, in meters, between relocations for each raccoon (t).

	pairs of simultaneous locations	Male Raccoons			
		1738		327	
Monitoring Period	(N)	I.A.	t	I.A.	t
October 15 to October 31, 1986	11	0.52	3157	0.52	3116
November 24 to November 26, 1986	7	0.14	1031	0.13	1085
December 10 to December 15, 1986	7	0.08	1958	0.07	2246
December 28, 1986 to January 5, 1987	10	0.09	3330	0.08	3580
January 30 to February 3, 1987	7	0.17	2456	0.16	2627
February 4 to February 21, 1987	13	2.45	4179	1.43	7183
February 23 to March 11, 1987	12	0.19	5402	0.19	5497
March 20 to April 7, 1987	6	0.10	2114	0.09	2292

Figure 10. They were never found more than 50m apart during 5 partial nights of simultaneous (t < 5 min.) tracking (17 November 1986, 24 November 1986, 10 December 1986, 31 December 1986, 30 March 1987).

Associations between males and females appeared to be occasional and sporadic during the second year (Table 11). Female 757 was found sharing a den tree with males on a number of occasions (3 different males on 7 occasions), but was never found traveling with any of them. It appeared that most of these incidents were coincidental due to certain trees being more heavily utilized than others, rather than the raccoons traveling together. An example of this occurred on 24 November 1986 when 757, 227, 327 and 1738 were all found in one cottonwood being used as a daytime denning site. That night, all 4 animals were monitored simultaneously for 4 hours, during which time 757 traveled in a different direction from the others. Raccoons 1738 and 327 traveled together during the tracking period, while 227 moved separately from the others. On 25 November 1986, 757, 327 and 1738 were found sharing the same tree as the previous day.

Yearling male 252, after his possible dispersal, was occasionally located by triangulation near (<50m) females throughout the remainder of the year. Most of these locations consisted of daytime fixes, and nighttime tracking showed that he was not moving with the female he

Figure 10. Daytime radio-locations for adult males 1738 and 327 suggesting they were traveling together. Each circle represents simultaneous locations less than 50 meters apart.

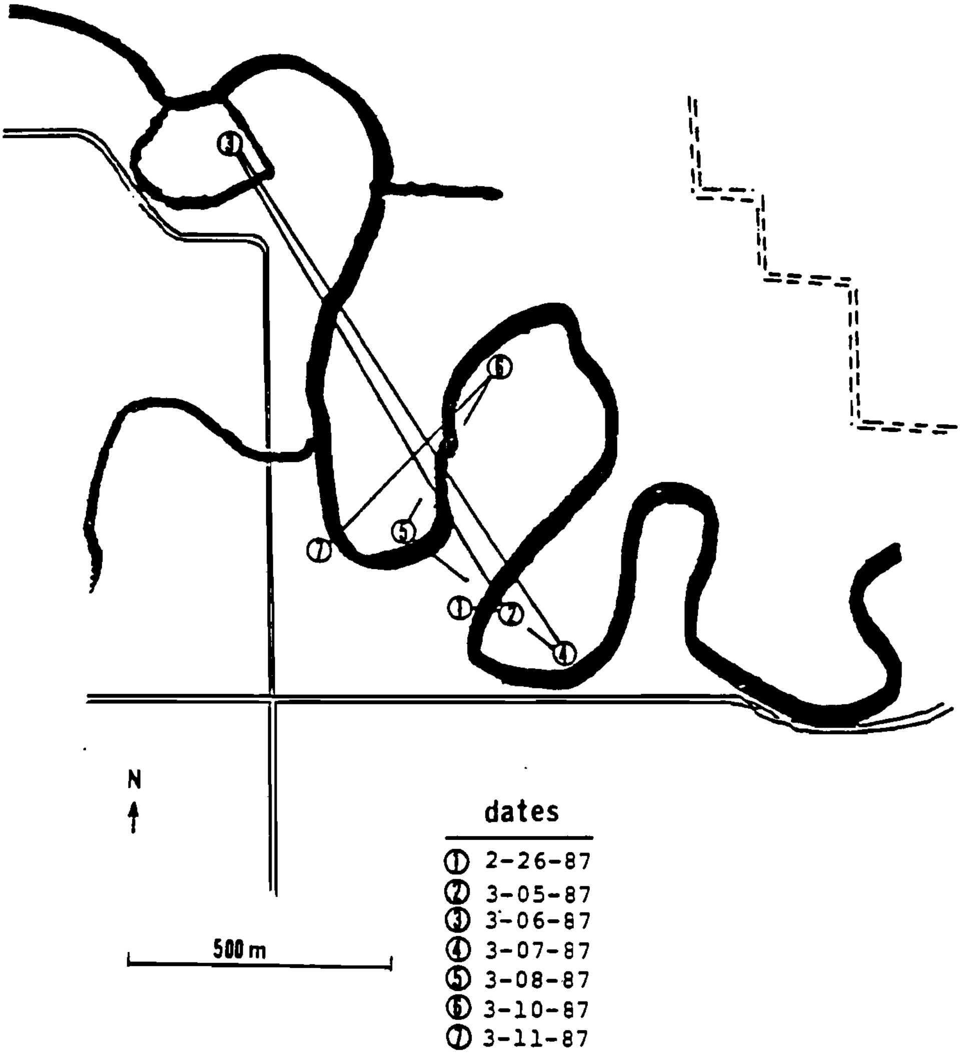

③
⑥
⑤
⑦
①
②
④
N
500 m
dates
① 2-26-87
② 3-05-87
③ 3-06-87
④ 3-07-87
⑤ 3-08-87
⑥ 3-10-87
⑦ 3-11-87

Table 11. Intersexual temporal overlap of raccoons with extensively overlapping home ranges on the Badger Creek Study Area, 1985-87.

			Index of Association						Distance between Simultaneous Locations(m)					
Raccoon dyad			Fall		Winter		Breeding		$d \leq 200m$		$d \leq 100m$		$d \leq 50m$	
A	B	N	A	B	A	B	A	B	n	%	n	%	n	%
M252	F202	60	2.12	1.31	1.50	1.55	1.22	1.03	16	27	9	15	6	10
M327	F757	80	1.03	1.30	1.23	4.12	-	-	34	42	25	31	25	31
M227	F757	78	1.18	1.91	1.01	3.94	-	-	29	37	19	24	14	18
M252	F1070	18	-	-	-	-	1.55	2.54	3	17	2	11	2	11

Fall = October-November
Winter = December-January
Breeding = February-March
N = Total number of simultaneous radio-locations
M = Male
F = Female

was associated with earlier that day. An exception to this occurred on 20 January 1987 when he was found sharing a den tree with yearling female 1255. Snow had fallen within the past 12 hours and the only tracks evident within 100m of the tree were 2 sets of raccoon tracks. Both sets led away from the tree along a stream bank for approximately 50m. They circled around and come back to the tree. Both sets were never more than 10m apart and many times were less than 1 meter apart. Successive radio locations on 23, 27, and 28 of January indicated they were still together. On 30 January they were not together and were never located together again for the remainder of the year.

Dispersal.

Juveniles were associated with their mothers during late August and early September. On 27 August 1985, I observed adult female 458 accompanied by 4 juveniles. During the same evening, a Kansas Wildlife and Parks aide observed an unmarked female with 2 juveniles traveling on the ground (pers. commun. Doug Neufeld). On 9 September 1985, adult female 176 was captured simultaneously in the same trap with juvenile 056b and another juvenile was found in a tree directly above the 2 in the trap.

Three transmittered juvenile females with enough data acquired for home range estimates displayed no dispersal-type movements, although none were monitored throughout a monitoring year.

Capture-recapture information from trapping efforts revealed little additional information. Of 24 juveniles, 18 females and 6 males, captured during the fall trapping periods in both years, only 1 male and 2 females were recaptured during a later trapping period. Each of these animals was recaptured near its original capture location. Four of these juveniles were known to have died during the initial trapping period.

Two out of 4 yearling males captured during a fall trapping period were recaptured on the area during a later trapping period, while a third was known to have been harvested on the area. The behavior of yearling males 227 and 252, described earlier, suggested that they may have experienced pressure to shift their movement patterns before the breeding season.

Two radio-collared yearling females displayed no dispersal-type movements while they were being monitored.

Denning Behavior.

A total of 53 individual den sites were recorded 143 times during the study (Table 12). Tree cavities accounted for 91% of the individual den sites and 95% of the reused dens. Trees were used consistently throughout both monitoring periods. The high incidence of reused resting sites in relation to the number of individual sites reveals the heavy use received by some tree cavities.

Table 12. Den types recorded for raccoons on Badger Creek study area, 1985-87.

	Individual	Reused
Maple (*Acer* spp.)	25	46
Cottonwood (*P. deltoides*)	17	76
Willow (*Salix* spp.)	1	6
Hollow log	2	3
Ground den	3	4
Sycamore (*P. occidentalis*)	2	4
Honey locust (*G. triacanthos*)	1	1
White oak (*Q. alba*)	1	2
Box elder (*A. negundo*)	1	1
TOTAL	53	143

Raccoons were only occasionally approached while I was on foot. Therefore, these results are probably conservative and some tree cavities may have received more use than recorded here. Additional telemetry evidence strongly supports this.

At least 5 different trees were used in both years, usually by different raccoons. One cottonwood was used by 9 different transmittered individuals, 4 of whom used it repeatedly (Table 13). Out of the 19 individual den trees recognized during the 1986-87 season, 11 were found to be used at least once by more than one radio-collared raccoon.

Mortality.

Of the 20 animals transmittered in fall 1985, 10 were found dead during the first year (Table 2). Fates of 2 are unknown because their signal was lost, and the fate of another was undetermined because her transmitter was located at the bottom of the Neosho river. Two additional radio-collared raccoons were found dead during the summer of 1986. A summary of the mortality that occurred during the period appears in Fig. 11.

In addition to the radio-collared raccoon mortality occurring during the first year, 1 ear-tagged raccoon was apparently hit by a train, and 2 unmarked raccoons apparently died of canine distemper.

One of the transmittered raccoons was observed while apparently infected with canine distemper. Adult

13. Raccoon den use of one particular cottonwood located on Badger Creek study area, fall 1985 to spring 1987.

Date	Raccoon(s) Located in Tree	Age and Sex of Raccoons
-03-85	1678	AM
-23-86	292	AF
-20-86	227, 252	YM, YM
-05-86	1738, 757, 723	AM, YF, AF
-10-86	1738, 327, 757	AM, AM, YF
-11-86	327, 757	AM, YF
1-24-86	227, 1738, 327, 757	YM, AM, AM, YF
1-25-86	1738, 327, 757	AM, AM, YF
2-18-86	757	YF
2-22-86	1738	AM
1/27/87	327, 757	AM, YF
2/11/87	227, 10	YM, YM

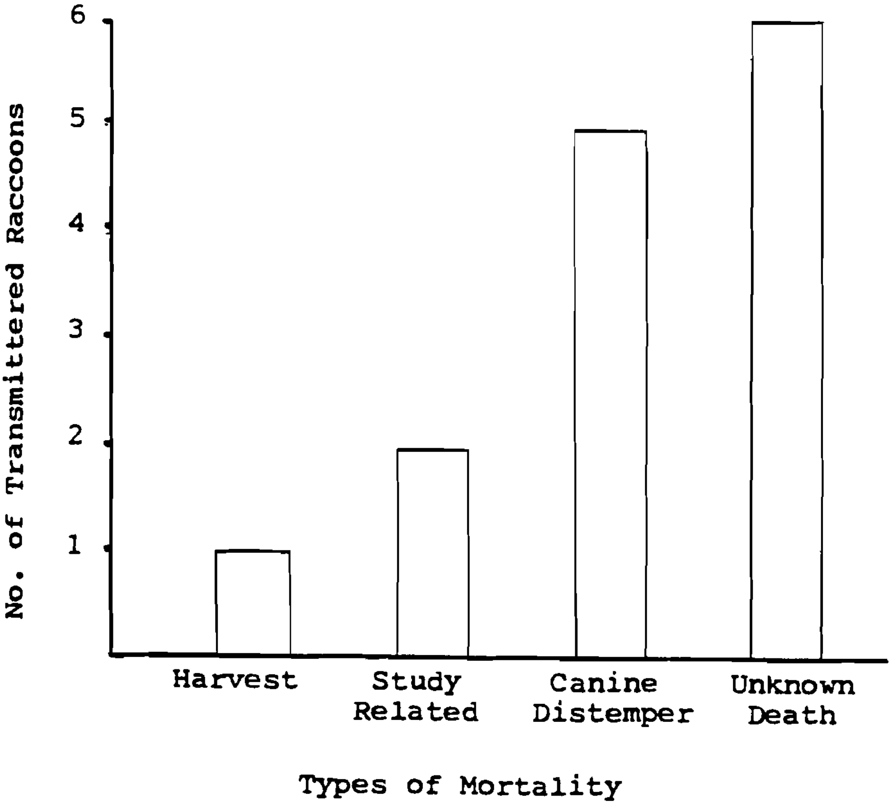
= adult male

= adult female

= yearling male

= yearling female

Figure 11. Classification of causes of mortality for transmittered raccoons found dead during a two-year study, 1985-87, on the Badger Creek study area.


6
5
4
3
2
1
No. of Transmittered Raccoons
Harvest
Study Related
Canine Distemper
Unknown Death
Types of Mortality

female 458 was discovered under some exposed tree roots in a river bank on 21 December 1985. She was easily seen and appeared reluctant to move to cover. This seemed strange since the temperature that day was low and the other raccoons, approached on foot, were denned up. On 24 December 1985, she was seen again wandering about during the day and when I approached her she made no attempt to flee. I was able to touch her and she did not respond. Her signal was not detected again until 13 January 1986; her carcass was pulled out of the river ice on 15 January 1986. Although hypothermia/drowning was diagnosed as the immediate cause of death, the animal was classified as a canine distemper victim because her abnormal behavior probably contributed to drowning.

All animals suspected of having succumbed to canine distemper displayed the same signs when found in the field. They were in relatively good morphological condition, and were found in the open on the ground. All appeared to be traveling when they "dropped in their tracks." Upon necropsy, they exhibited a gastro-intestinal enteritis. Disease may have been a factor in some disappearances of radio-collared animals that were never relocated.

Both 'unknown' deaths during the first year consisted of badly decomposed carcasses. Only 2 radio-collared animals were found dead during the second year, and both occurred near the end of the monitoring year. They were adult male 327 and yearling 227. Causes of death could not be determined.

A raccoon's fate classified as 'unknown' was probably killed illegally. Female 757's radio-collar was found in the river on 11 February 1987 with the nut unscrewed. She was never recaptured during later trapping efforts.

One juvenile, not being monitored, and 2 ear-tagged raccoons were harvested from the study area during the 1986-87 hunting season (pers. commun. Lloyd Fox). Another transmittered raccoon not monitored during the study was removed illegally on 12 April 1987 (pers. commun. Lloyd Fox).

DISCUSSION

Home Ranges.

A basic assumption in all telemetry investigations is that the transmitter does not affect the animal's behavior or movement. Radio-collars are generally assumed to not inhibit a raccoon in either of these respects (Urban 1970). An adult female was radio-collared by Kansas Wildlife and Parks personnel during the spring of 1985 and her signal was subsequently lost soon after. She was recaptured on 26 February 1986 and re-transmittered. It was discovered at the time that the original transmitter had malfunctioned due to a battery leak and the acid was causing a physiological response of the animal. The throat had a large, open wound surrounding the transmitter and mucous covered the ventral side of the animal. Her pelt was thin and yellow and her behavior in the trap was extremely subdued. Obviously the lithium chloride was affecting her physically and, as a result, may have affected her behavior. Since the transmitter was not operating during the 1985 period, this possible bias was not represented. She was monitored for the remainder of the spring and for the entire 1986-87 period and she was recaptured on 14 March 1987 in good physical condition. Her throat had healed completly.

The assumption that an animal's position in its home range at a given point in time is not a function of its position at a previous period in time may not be realistic for raccoons. Laundre and Keller (1984) felt that because of the coyote's typical movement patterns and behavior, it was highly debatable if any pair of successive relocations of an individual meets the criteria of independence. Evidence from this study suggests a similar type of behavior for raccoons.

Swihart and Slade's (1985a) test for independence of successive animal locations is necessary for large data sets accumulated over short periods of time, whereas, during this study, data were collected more or less uniformly throughout relatively long monitoring periods. They recognized that there were at least 3 instances that the null hypothesis of independence could be rejected, although the time interval between locations was acceptable. One of these was characteristic of raccoon behavior observed in this study. They stated that "rejection of the independence hypothesis might arise in individuals that travel along well-defined paths in a temporally predictable manner." Therefore, the possibility of an accumulation of dependent fixes affecting these results is probably negligible, but the independence test may be useful for describing raccoon behavior.

There was considerable individual variation in composite home range size within sex and age groups, with the exception of juvenile females. Johnson (1970) considered questionable estimations of area of raccoon movements through long periods of time. He described raccoon movements as consisting of small, shifting centers of activity within a much larger area of general familiarity, and this greater area of familiarity was not as useful when applied to raccoons as measurements of raccoon movements over short periods. The seasonality of movements found for the raccoons in this study reaffirms his description of their movements and certainly, to thoroughly understand raccoon behavior, their movements must be studied at short intervals. However, their movements over a long period of time are also an important parameter in describing raccoon behavior. The composite home range estimates in this study could be considered as the "much larger area of general familiarity" reported by Johnson. However, this space may represent the area required by a raccoon in this particular type of environment to survive a range of seasons through a large portion of the calendar year. Of 5 animals monitored during both monitoring periods, all maintained the same general area from year to year. This sample included 2 adult, 1 yearling and 1 juvenile female, and 1 adult male (ages represent the estimated age of the animal during the first year).

The individual variation reported for composite home ranges could probably be attributed to differences in sample size and season of monitoring among the study animals. however, the evidence presented by raccoons monitored continuously throughout a monitoring year suggested that these factors are not the only explanation for the differences. Some factors attributed to variations in raccoon home ranges are sex and age, time of year, condition of habitat, population density, and family group relations (Ellis 1964, Mech et al. 1966, Johnson 1970, Urban 1970, Fritzell 1978a,b, Lehman 1977, 1980, Sherfy and Chapman 1980, Glueck 1985).

Yearling males averaged the largest home ranges. This differed from other investigators who found adult males had the largest home ranges (Urban 1970, Lehman 1977, Fritzell 1978a,b, Sherfy and Chapman 1980, Allsbrooks 1981, Greenwood 1981). These discrepancies can probably be attributed to a small sample size of adult males in this study. Only 2 adult males were tracked during the breeding season. Slate (1985) attributed the higher estimates for adult females over males in his study to limited data on males during the breeding season. Johnson (1970) and Fritzell (1978a) found adult males expanded their movements during the breeding season. However, Urban (1970) found an old male had a smaller home range than younger adult males.

Seasonality of Home Range Area.

Seasonal variation in the size and location of home range was exhibited by virtually all raccoons for which movement was calculated. This was consistent with other investigations (Ellis 1964, Johnson 1970, Urban 1970, Fritzell 1978a,b, Allsbrooks 1981). Slate (1985) found a lack of seasonality in distance traveled but believed it to be unique to suburban raccoons.

The large decrease in movement for females during the winter interval was similar to what Allsbrooks (1981) and Glueck (1985) reported in their studies, but Stuewer (1943) and Johnson (1970) found raccoon movements increased during winter. The decrease of female home range size from fall to winter months was probably a response to decreasing temperatures (Twichell and Dill 1949, Sharp and Sharp 1956, Mech et al. 1966, Allsbrooks 1981). The field crop and fur harvest seasons coincided with this decrease in size. However, the population was probably only mildly harassed by hunters during this time. Only 1 transmittered raccoon was harvested during the 1985-86 fur harvest season, and 3 were taken during the 1986-87 season (pers. commun. Lloyd Fox). Glueck (1985) determined that raccoon home ranges in Iowa decreased from fall to winter because of prevailing weather conditions rather than from human disturbance or changes in cover or food availability due to grain harvest. It is interesting that while adult and yearling males home range area estimates varied, nearly all increased during the winter interval whereas adult female home range areas decreased. This suggests that movements associated with the male's breeding season may have begun early, or that there may be a preliminary phase associated with the traditional concept of the breeding season and its associated behavior for males. As mentioned earlier, some investigators have evidence that adult male raccoons increased their movement patterns during the breeding season (Johnson 1970, Fritzell 1978a, Greenwood 1981, Slate 1985).

In addition to the seasonal fluctuation in home range area, some raccoons may also have made small shifts in the location of their movements from season to season. This may have been due, in part, to the obvious interrelationship between these 2 parameters, although other studies have also described seasonal movement pattern shifts, probably due to changes in local food availability (Ellis 1964, Johnson 1970, Allsbrooks 1981), except for suburban raccoons (Slate 1985).

Social Organization.

Johnson (1970) stated that there is some kind of social organization among raccoons. Observers of raccoons at feeding stations have consistently reported some form of social hierarchy (Sharp and Sharp 1956, Tevis 1947), or at least mutual avoidance behavior (Slate 1985).

Many investigations, attempting to deal with the problem of social organization have been limited, and some results have been contradictory. Although Mech and Turkowski (1966) found a considerable overlap of adult female daily resting sites, they believed the raccoons maintained a "minimum distance." Similarly, Fritzell (1978b) also found 2 parous female's home ranges overlapping broadly, but noted no encounters between adult females and any other yearling or adult raccoons. In contrast, Twichell and Dill (1949) found many raccoons resting together and they believed the individuals belonged to different family groups.

Johnson (1970) did not find direct evidence of raccoons defending fixed territories, but he added "other forms of territorial defense, not so well understood, may exist." He then provided some supporting evidence for Tevis' "feeding territory." In the same study, he also presented limited evidence from trapping data that suggested "some degree of tolerance among familiar males during the breeding season." Slate (1985) found no territoriality for suburban New Jersey raccoons, although he stated "adult raccoons tended to avoid any prolonged contact with other adults." He believed avoidance behavior replaced aggressive interactions as a function of food and space partitioning for suburban, high density populations.

Fritzell (1978b), in contrast to all previous investigations, presented strong evidence for territorialism among adult males. He believed possible latitudinal differences in social behavior accounted for his contrasting results. Lehman (1984) also found adult males in Indiana excluding each other from their respective home ranges.

In this study, there was some degree of overlap between home ranges among all sex and age groups monitored. Overlaps occurred both spatially and temporally, suggesting that these raccoons were socially tolerant of each other during most of the monitoring periods. Although female raccoons exhibited degrees of spatial overlap and use of those overlap zones, analysis revealed that, in most cases, adjacent females' movements were unrelated to each other.

Slate (1985) also noted apparent indiscriminant, broad overlap among urban raccoon populations, and observed the raccoons in areas of intense overlap. He found a focal point within the overlap areas consisted of feeding sites and noted some type of mutual avoidance behavior among adults at these sites. Another type of focal point overlap for raccoons in this study was associated with den sites. Certain den trees were shared by a number of transmittered raccoons during the second monitoring period. All "core" study animals monitored during the second year were found sharing a den tree at least once with another transmittered raccoon. This is supported by data showing radio-collared raccoons in den trees with unmarked raccoons.

The relationship between raccoons 327 and 1738 in 1986-87 was interesting, considering the evidence linking

1738 to at least 1, and maybe 2, adult males in the previous year. Both animals overlapped each other spatially and temporally during the second year of the study. It is also interesting that the 2 radio-collared male raccoons found sharing den trees with 1738 during the second year were found dead near the end of the study. Both males associated with 1738 in the first year also died under similar circumstances.

Associations between the adult males described in this study indicated that more work is needed to understand what function, if any, is responsible for this behavior. Possible explanations are difficult because there are no references to this situation in the literature.

One possible advantage of this type of behavior would be at feeding sites similar to those described by Tevis (1947), Sharp and Sharp (1956), and Slate (1985). Sharp and Sharp (1956) found that 75 to 80 % of the raccoon population fed in packs or pairs at a Nebraska feeding site. These groups, upon approaching the feeding site, would displace any solitary, adult raccoons already present. It was evident that some form of social hierarchy existed in their population, and possibly adult or yearling animals attained their status in this hierarchy partly through pack associations.

When a raccoon is utilizing food sources available to a number of other raccoons, it might be mutually advantageous to that raccoon and another to form a temporary bond during the time the feeding site is being used. This might help explain why 1738 and 327 were found together for a sequence of days throughout the second monitoring year and then were not found together for intermittent periods of time of variable length. However, this is largely conjecture and no other evidence was obtained to substantiate or dispute such a hypothesis.

Comparisons between this study and Fritzell's (1978b) must be made with caution because each study represents observations made at different times of year. The use of communal feeding sites is probably more common during the winter and early spring than in the summer months. This, in turn, may be partly responsible for differences in the behavior described in these 2 studies.

Dispersal.

Dispersal of young raccoons in eastern Kansas is not well understood, either because of limited data or variability in behavior of the animal. Stains (1956) reported that the number of cohesive family groups in Kansas declined after October, and no contradictory evidence was found in this study.

Although Johnson (1970) found no tagged juveniles outside his study area, he concluded that some probably left the area as shown by the low recapture rates after December and January. His results were similar to the trapping results in this study. However, the strong possibility of the high mortality rate affecting these results precludes any assumptions that may be drawn concerning dispersal among juvenile raccoons in Kansas. Juvenile raccoons are especially susceptible to canine distemper (Johnson 1970).

Slate (1985) reported juveniles remaining on a suburban tract throughout his study, which concluded in the spring (May). Urban (1970) presented evidence of fall dispersal of juvenile males on a marsh in Ohio. In studies of raccoons in North Dakota, Fritzell (1977,1978b) reported dispersal of young, male raccoons during the spring and early summer of their first year. He found sibling bonds dissolving after their first winter (Fritzell 1977).

Telemetry data accumulated for juvenile and yearling females failed to detect any dispersal-type movements. Unfortunately, little telemetry data were obtained from juvenile males, but extensive data were accumulated for 2 yearling males during the second year. Both of these animals began the year sharing the same portion of the study area with at least 2 adult males. As the winter months approached, both animals changed either the location of their movements or their movement patterns. Although neither animal moved off the study area, yearling male 252 moved to another portion of the study area and maintained little or no spatial overlap with the 2 adult males occupying his previous area.

Yearling male 227 displayed several long distance travels and changed his movement patterns without abandoning his fall home range.

Danielson and Swihart (1987) found that introduced, similar-sized rodent species avoided areas occupied by residents temporally, but not always spatially. When introduced in an area occupied by a resident, these new animals did not exhibit the movement patterns characteristic of an established home range. Additional intraspecific pressure from other local males may have been reduced by mortality, thus enabling 227 to continue using the same general area during the pre-breeding and breeding season by changing his normal utilization of space.

Evidence from these data suggests yearling males may disperse from areas inhabited by adult males or avoid contact with these males.

Denning Behavior.

Studies concerning den types used by raccoons have been extensive and results have been somewhat variable. Tree cavities have been the most common den type reported, but other types are utilized including rock crevices, animal burrows, abandoned buildings, storm sewers, muskrat houses and snow cavities (Holman et al. 1983, Lynch 1974, Urban 1970, Slate 1980). Shirer and Fitch (1970) studied the denning behavior of raccoons near Lawrence, Kansas, and found they used a variety of den types, with the most common being in rock outcrops. Their study animals displayed such variation in den type selection that they concluded the "raccoons seemed to have individual differences in their preference for different types of shelters."

Animals in this study heavily utilized tree dens, with ground den use occurring as isolated incidents. There did not appear to be the "individual preference" described by Shirer and Fitch (1970) in raccoon den selection during this study. All were found to use trees predominantly, and many den trees were used by more than one raccoon.

Various factors may influence the den selection by raccoons. Those that have been recognized by investigators include availability of den type (Stuewer 1943, Dorney 1954, Hoffmann and Gottschang 1977), prevailing weather conditions (Berner and Gysel 1967, Holman et al. 1983), reproductive condition of females (Ellis 1964), degree of harassment from raccoon hunters (Giles 1942) and the microclimate of the den (Berner and Gysel 1967). Availability of other den types, may account for some of the differences between the denning behavior shown by these raccoons and those of other investigators. The floodplain's flat terrain did not provide the rock outcrops or crevices described by Giles (1942) and Shirer and Fitch (1970).

Some studies have found raccoons selected ground dens during winter as a response to decreasing temperatures (Berner and Gysel 1967, Holman et al. 1983). Because of the few hills and flat topography in the floodplain, the number of ground dens present on the study area may have been limited and, if present, vulnerable to flooding or poor drainage. This may help explian why no difference in den type use occurred among study area raccoons.

Shirer and Fitch (1970) found some dens were used by more than 1 raccoon, and even by other species, which led them to comment on the apparent tolerance raccoons expressed toward each other. Tolerance sometimes extended to simultaneous sharing of the same den. Although they did not record raccoons sharing den occupancy with another raccoon (except for 3 juvenile littermates), their comments apply to the situation discovered during this study. They described certain well-situated dens as being communal property of the population. One such tree fitting that description during this study is presented in Table 11. All transmittered animals regularly monitored during the 1986-87 season were found sharing a den tree with at least 1 other transmittered raccoon. This was probably not in response to a lack of available dens. The high degree of communal denning among the different age and sex groups demonstrated during the 1986-87 period has not been reported by others.

Tree den use was probably higher than that represented here. As an example, I observed 3 raccoons apparently resting on a large cottonwood tree branch commonly used by adult males 1738 and 1678. As I approached, they scrambled across the limb and disappeared in the tree. It was determined that the only transmittered animal located in the tree at that time was 1738. Spotlighting the tree that evening revealed at least 4 raccoons in the tree. This incident is also an example of the difficulties involved when trying to accurately identify the 'den site' or 'daily resting site' currently being used by a raccoon. The tree cavity was recorded as 1738's den site on this particular occasion even though a group of raccoons was seen outside on a limb. One may assume that those raccoons would not have been resting on the limb of that particular tree if the sanctity offered by the nearby cavity was not there. This is another reason the term 'den site' was used to describe this set of data instead of 'daily resting site', which has been used occasionally by other investigators (Mech et al. 1966, Holman et al. 1983).

Mortality.

Raccoon populations are subject to a variety of mortality factors. Legal fur harvest and motor vehicles have been determined to be principle causes of mortality for populations in Wisconsin, North Dakota and Iowa (Root 1981, Fritzell and Greenwood 1984, Glueck 1985). Dogs were considered a primary factor in limiting raccoon populations in eastern Tennessee (Warr 1979). Starvation and extreme parasitic infection were the principal causes of mortality among raccoons in Minnesota (Mech et al. 1968).

A distemper-like disease has been discovered in Kansas raccoon populations on a number of occasions. Menges and Stains (1955) and Stains (1956) described an epizootic in Kansas raccoons that was apparently canine distemper. Johnson (1970) presented a summary of canine distemper occurring in various raccoon populations and he noted that it most commonly occurred in dense raccoon populations. Lehman (1977) and Roseberry (1977) found that canine distemper was a major cause of mortality for raccoons in Indiana and Oklahoma, respectively. Roseberry (1977) found the distemper at high population levels. Mech et al. (1968) noted occurrences of canine distemper within a raccoon population in Minnesota. What effect disease-related mortality had on populations in Wisconsin was undetermined, but may have been substantial (Root 1981).

The social tolerance raccoons expressed toward each other may have been instrumental in compounding the effect of canine distemper on the population. Communal denning and the utilization of certain food sources by the community probably facilitated the spread of the highly communicable disease. One particular male, 1738, was found sharing a den with a number of animals during the course of this study. Nine raccoons were found dead, in or near his composite home range, from canine distemper or what was supected to be canine distemper. This high mortality, in turn, may have affected a component of raccoon social organization: the dispersal of young raccoons, particularly the males.

SUMMARY

1. Raccoons were studied from 1985 to 1987 on a privately-owned area to describe their movement patterns, social organization and related behavior.

2. Data were obtained through live-trapping and radio-tracking methods. A total of 2031 trapnights and 1987 radio-locations were recorded during the study.

3. Raccoon densities varied little during the study; ranging from 1 raccoon per 6.5 ha to a 1 raccoon per 2.3 ha.

4. Raccoons were socially tolerant of each other, commonly sharing den trees and, on at least one occasion, sharing the same food source. In most cases, they exhibited large degrees of spatial, and at times, temporal overlap.

5. A canine distemper epizootic was a dominating factor in the first year of the study. Mortality declined among the transmittered animals during the second year, but some still occurred.

6. Trees were the preferred raccoon den site during the study with no seasonal change in use. Some raccoons appeared to prefer individual trees for den sites, although all had a number of different den sites.

7. Kansas raccoons 'den up' or markedly restrict their movements during extreme winter conditions, particularly when low temperatures are combined with snow

cover.

8. There were differences between the sexes in seasonal movement patterns with females exhibiting a marked decline in home range area during the winter.

9. Adults used the same area from year to year.

10. Yearling males may disperse from their natal areas, although to what extent the high mortality among the population in the first year affected this is unknown.

SECTION B

Flint Hills National Wildlife Refuge study

1985-1987

DESCRIPTION OF THE STUDY AREA

The study area was located on a portion of the Flint Hills National Wildlife Refuge approximately 33 km southeast of Emporia, Kansas. The refuge lies in the flood pool of nearby John Redmond Reservoir and is susceptible to periodic flooding during periods of excessive rainfall. Up to 90% of the refuge's 7493 ha may be inundated at times. Parts of the refuge were leased for farming and the principal crops were soybeans and milo. Crop harvest was restricted on the study area due to flooding just prior to the harvest seasons.

In addition to small portions leased as cropland, the area also consists of old fields undergoing secondary succession to grassland, and all are criss-crossed by creeks and the Neosho River. The drainages, along with a number of oxbows, provide the refuge with considerable riparian habitat of which cottonwood, willow, elm (*Ulmus* spp.), sycamore, and silver and red maple are the dominant woody species. Vegetation of old field areas consist primarily of switchgrass, prairie cordgrass (*Spartina pectinata*) and, in some areas, smartweed (*Polygonum* spp.).

The climate is essentially the same as that described for Badger Creek study area in Section A.

Floods commonly occur during the spring and fall each year, and often are slow in receding. Water may remain on the refuge for weeks at a time. Furbearers are legally protected year-round on the study area portion of the refuge.

METHODS

Trapping was conducted during the fall and spring of each year. The purposes and methods of trapping and radio-collaring of raccoons were identical to those described in Section A, with the exception of a few animals being kept overnight during the fall 1985, trapping interval while transmitters were made for them. Unfortunately, a yearling male was captured on 20 September 1985 and subsequently escaped in Emporia while a transmitter was being prepared. This animal is included in catch numbers but not in density estimates for that trapping period.

Telemetry relocations were obtained in the same manner as described in Section A. Composite and seasonal home ranges were estimated using the minimum area method, also described in the preceding section. Seasonal home ranges were calculated for animals with an acceptable number of relocations.

Restricted access to the study area made consistent sampling throughout the monitoring periods impractical. Periodically, the study area was not accessible due to flooding, and portions of the refuge were closed during the waterfowl hunting season thereby prohibiting telemetry tracking of animals located in those areas. The number of relocations used for seasonal home ranges was relatively consistent, and comparisons between the estimates probably accurately reflect trends in seasonal raccoon movement patterns.

The same statistical analysis procedures employed in Section A were also used in this study. Means are presented with ± one Standard Error. Comparisons between age groups and seasons were made using ANOVA.

RESULTS

Trapping.

Trapping effort for the 4 trapping periods combined totalled 1103 trapnights (Table 14). The total number of individual raccoons captured during the 2 years was 59.

The population estimate and associated tests were not calculated for the spring 1987 trapping period because of limited trapnights and too few captured raccoons. The assumption of closure was acceptable for the fall 1985 and spring 1986 trapping periods as indicated by the large closure test value in the CAPTURE program (Table 14).

Density estimates for the area increased from a low of 1 raccoon per 28.1 ha during the fall 1985 period to 1 raccoon per 2.3 ha for the following fall. Although the same number of juveniles (N = 5) were caught in both fall periods, they only made up 23% of the sample during the fall 1986 period while they represented 46% of the sample during the fall 1985 period.

Flooding.

Extensive flooding occurred during the month of October in both years. Water levels reached 6m above conservation pool (pers. comm. Dave Wiseman) over the study area after 14.5 cm of rain fell in 5 consecutive days (October 8-12, 1985). Water remained impounded at

Table 14. Trapping effort on FHNWR study area and population estimates (N) using the jackknife estimator (Mh model) from the CAPTURE program, and associated values from the closure test from the same program.

		No. of Raccoons Captured						
Trapping Period	Number of Trapnights	Number of Individuals	Total Captures	M(h) Value	N	95% CI	Closure	Density (Raccoon/ha)
Fall 1985 (8/2 - 9/23)	326	11	12	0.93	15	2 to 28	P<0.79	1/28.1
Spring 1986 (4/23 - 4/28)	222	20	35	0.93	28	20 to 36	P<0.95	1/10.6
Fall 1986 (9/11 - 9/17; 11/7 - 11/26)	438	22	30	0.92	92	52 to 131	P<0.02	1/2.3
Spring 1987 (3/20 - 4/13)	117	6	8					

flood level well into December.

A similar condition occurred almost 1 year later, except the water receded approximately 4 weeks after the initial rains.

The area was also subjected to flooding in the springs of 1986 and 1987, although water levels were not as high or as long in duration as the fall floods.

Home range.

Four raccoons were radio-collared during the spring 1985 trapping season and 4 more were radio-collared in the fall 1985 trapping season. An adequate number of relocations was obtained for composite home range estimates for only 2 of the raccoons (342, 522a). Four of the 6 other raccoons were lost to transmitter malfunctions, another slipped a collar, and 1 transmitter was located in a tree that represented either a slipped collar or a dead animal (Table 15).

Spring trapping in 1986 resulted in 9 more animals being transmittered, including 2 that had been radio-collared the previous spring and whose transmitters malfunctioned soon after their initial release (Table 15). Composite home ranges were determined for all transmittered animals and seasonal home ranges were calculated for 6. Three more animals were radio-collared in fall, 1986, but only 1 of them was consistently relocated during the second year of the study.

Composite home ranges were calculated for 12

Table 15. Monitoring periods for each animal transmittered on Flint Hills National Wildlife Refuge study area, 1985-87.

Raccoon	Age Class	Sex	Capture Date	Date of Final Location	Number of Relocations	Fate
604	IV	F	4-24-85	-	-	U
655	IV	F	4-26-85	-	-	U
660	IV	F	5-7-85	-	-	U
1078	II	M	8-22-85	10-22-85	3	U
326	I	F	8-22-85	9-7-85	2	slipped collar
342	J	F	9-17-85	4-7-86	22	CD
522	III	F	9-18-85	4-13-87	68	active
1516	III	M	9-20-85	10-22-85	3	U
807	III	F	4-24-86	4-30-87	104	active
496	IV	F	4-23-86	4-13-86	81	active
791	IV	F	4-25-86	4-29-87	118	UD
404	I	F	4-24-86	4-30-87	120	active
474	II	F	4-25-86	12-18-86	25	U
104	I	F	4-26-86	4-30-87	65	active
952	V	F	4-27-86	4-30-87	38	active
936	V	F	4-27-86	4-30-87	91	active
155	I	F	9-13-86	3-2-87	21	U
875	I	F	9-16-86	4-30-87	91	active

U = fate unknown
UD = cause of death unknown
CD = canine distemper (diagnosed or strongly suspected)

female raccoons (Table 16). Correlation between number of locations and estimated home range area was r = 0.37. Data on nighttime movements were not available for 2 raccoon composite home ranges calculated for the first year (342 and 522a), and few data were available for 3 composite home ranges in the second year (474, 522b, and 952). Home ranges were significantly larger for adult females than yearling females (F = 5.99, df = 1,10, P = 0.0369). The lone juvenile female represented the smallest home range estimate (raccoon 342 = 18.9 ha).

A total of 18 seasonal home ranges was calculated for 8 animals (Table 17). Correlation between number of locations and estimated home range area was r = -0.56.

Adult female seasonal home ranges were larger (F = 4.77, df = 1,17, P = 0.0495) than yearling females. There was no significant difference among the seasons (F = 1.81, df = 2,17, P = 0.2063) in home range area. Four of 5 animals having their home ranges calculated for both fall and winter intervals exhibited a decline in area during the winter interval. Three exhibited area declines of more than 70% (404 = 78%, 807 = 74%, and 791 = 80%).

Data for raccoon movements during the fall 1985 flood were minimal. During the period from 8 October to 12 October 1985, 14.5 cm of rainfall resulted in water levels on the refuge reaching 6 m above normal. The area remained under water until December. Three transmittered animals were approached by boat on 22 October 1985. All

Table 16. Composite home ranges (in hectares) estimated for raccoons on the FHNWR study area, 1985-87.

Raccoon Number	Age Class	N	MA
342	J	21	18.9
404	I	108	73.1
474	II	25	178.9
496	IV	80	312.9
522a	III	28	134.2
522b	IV	40	272.8
791	IV	118	323.4
807	III	104	205.5
936	V	90	350.4
952	V	38	228.5
104	I	63	147.5
875	I	91	175.0

N = number of radio-locations

MA = minimum area

Table 17. Seasonal home range estimates (in ha) for female raccoons on FHNWR study area.

	Fall		Winter		Breeding	
Raccoon	N	MA	N	MA	N	MA
Yearlings						
104			31	25.9		
404	26	53.0	44	11.6	32	25.1
875	28	81.9	30	64.2	28	82.4
$\bar{X}$		67.5		33.9		53.8
Adults						
807	21	124.8	43	33.1	22	71.4
791	28	220.5	44	42.9	30	32.4
936	25	240.1	23	273.4	29	172.9
522b	19	149.9				
496					32	24.9
$\bar{X}$		145.0		75.2		69.2

N = number of relocations

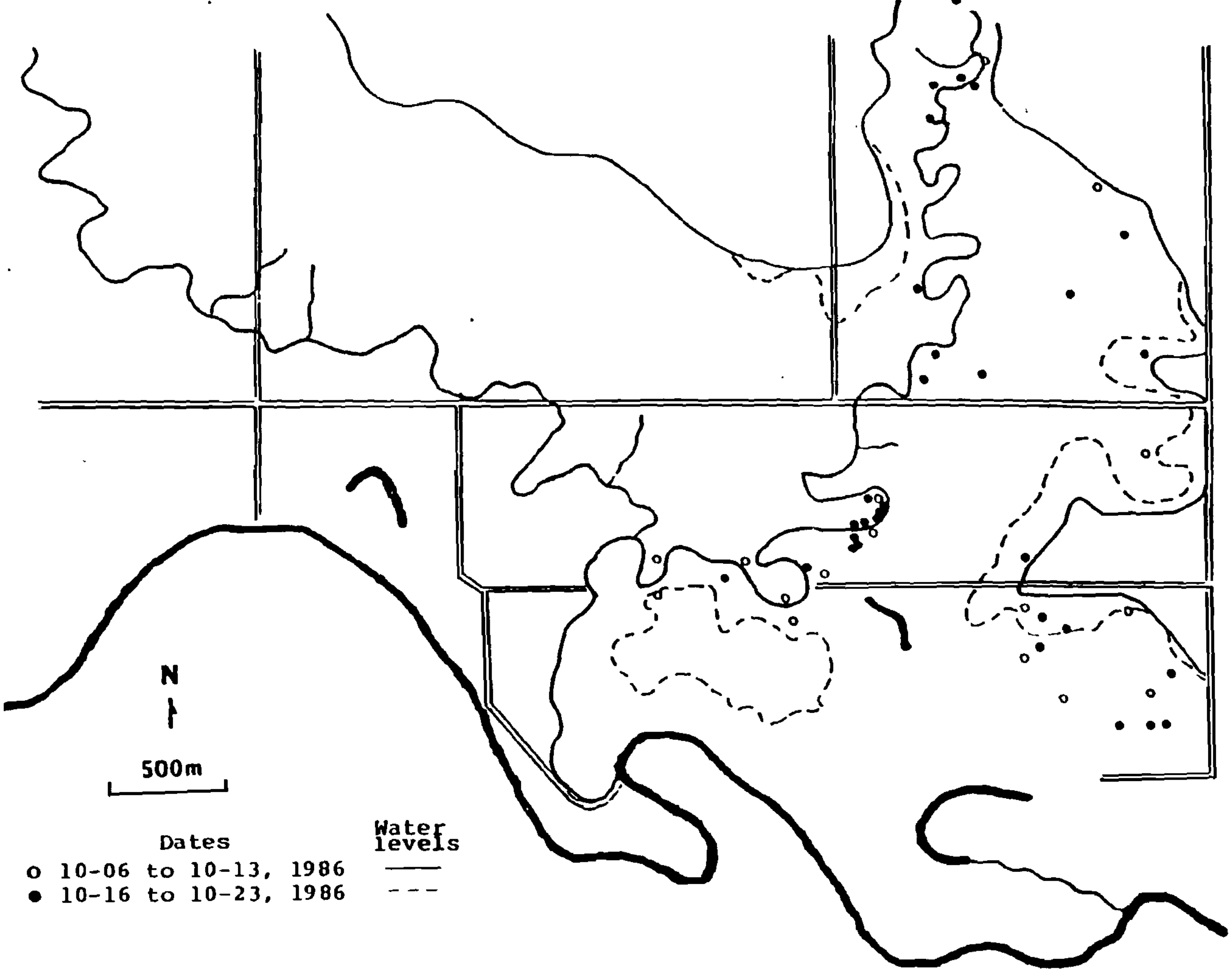
MA = minimum area

3 were located within the flooded area and were visually sighted in trees (pers. commun. Lloyd Fox). The transmitter on 1 of these animals, adult male 1078, was malfunctioning and her signal was only periodically received for a short time afterwards. Subsequent relocations obtained for the other animals (342 and 522a) indicated that they had not moved out of their home ranges during the flood.

More information was obtained for raccoons during the fall 1986 flood. It was possible to compare relocations obtained for raccoons during the flood and relocations obtained before and after the flood. Preliminary information was obtained concerning the raccoons' movements during the spring and summer preceding the fall 1986 flood. Unfortunately, no telemetry data were recorded on the study area before the flood. Of 7 raccoons located during the initial flood stages, 6 were still located within the area of movement determined for them when tracked during the previous spring and summer.

The majority of radio locations for the raccoons was located within the flooded region, although sampling was not equal among individual raccoons (Fig. 12). From the initial stages of rising water on 30 September to 23 October, when waters first began receding, a minimum of 38 relocations was determined to be within the flood area, while 16 were near the shoreline or on land. The number of radio-locations located within the flooded region was

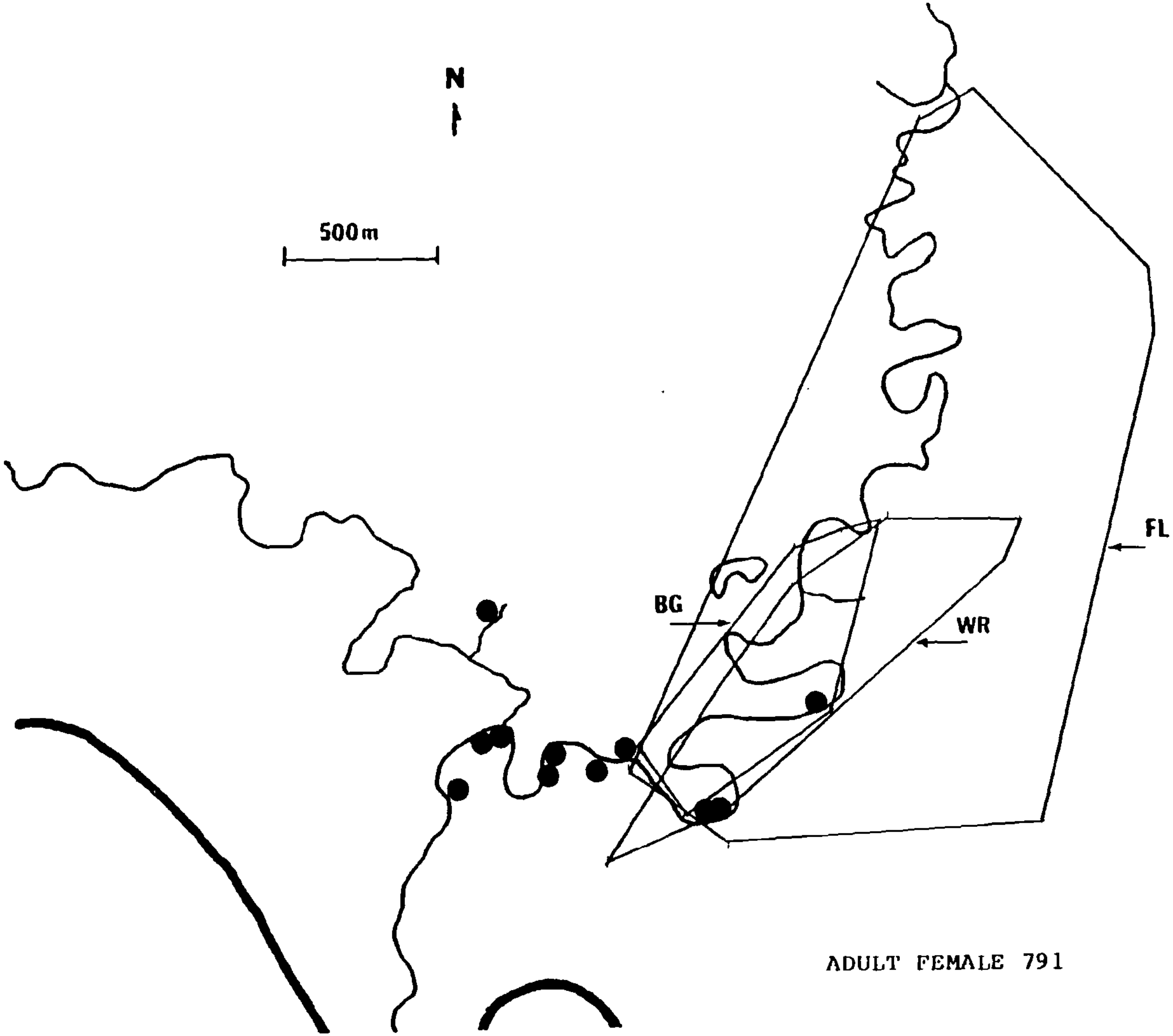
Figure 12. Water levels (lines) and associated radio-locations (dots) for raccoons during a flood on the FHNWR study area, 1986.


N
500m
Dates
Water levels
○ 10-06 to 10-13, 1986
● 10-16 to 10-23, 1986

conservative, while the number of locations near or on the land was probably relatively accurate due to logistical differences. Direction of radio signals for 3 raccoons obtained during the flood indicated they were located in the southern portion of the study area, but this area was located farthest from the nearest point of land and triangulation was not possible.

When fall home ranges were compared to the other seasons, only raccoon 791 expanded its fall home range during the flood to include the upland hills to the north of the study area. Raccoon 791 was triangulated within flood waters on 6 October, approximately 1 week after water had risen above the creek banks. This was verified when 791 was visually sighted clinging to the side of a dead snag in water over 3 m deep on 8 October 1986. This observation was near earlier relocations obtained for 791 during the previous spring and summer, and it was 1.2 km from the nearest point of exposed land. On 10 October, 791 was located 1.6 km northeast of the previous location, at the edge of the exposed hills to the north. This northward movement continued when 791 was visually sighted in a tree at the edge of a creek 3 days later (13 October), approximately 740 m north of the previous location. This animal eventually moved back to its original home range area when the flood waters receded. She was not found in the northern, upland areas during the remainder of the monitoring period (Fig. 13).

Figure 13. Seasonal home ranges for adult female 791, showing the extensive movements she displayed during a flood in the fall, 1986. Dots represent locations obtained for this animal during the previous spring (fall = FL, winter = WR, breeding = BG).



ADULT FEMALE 791

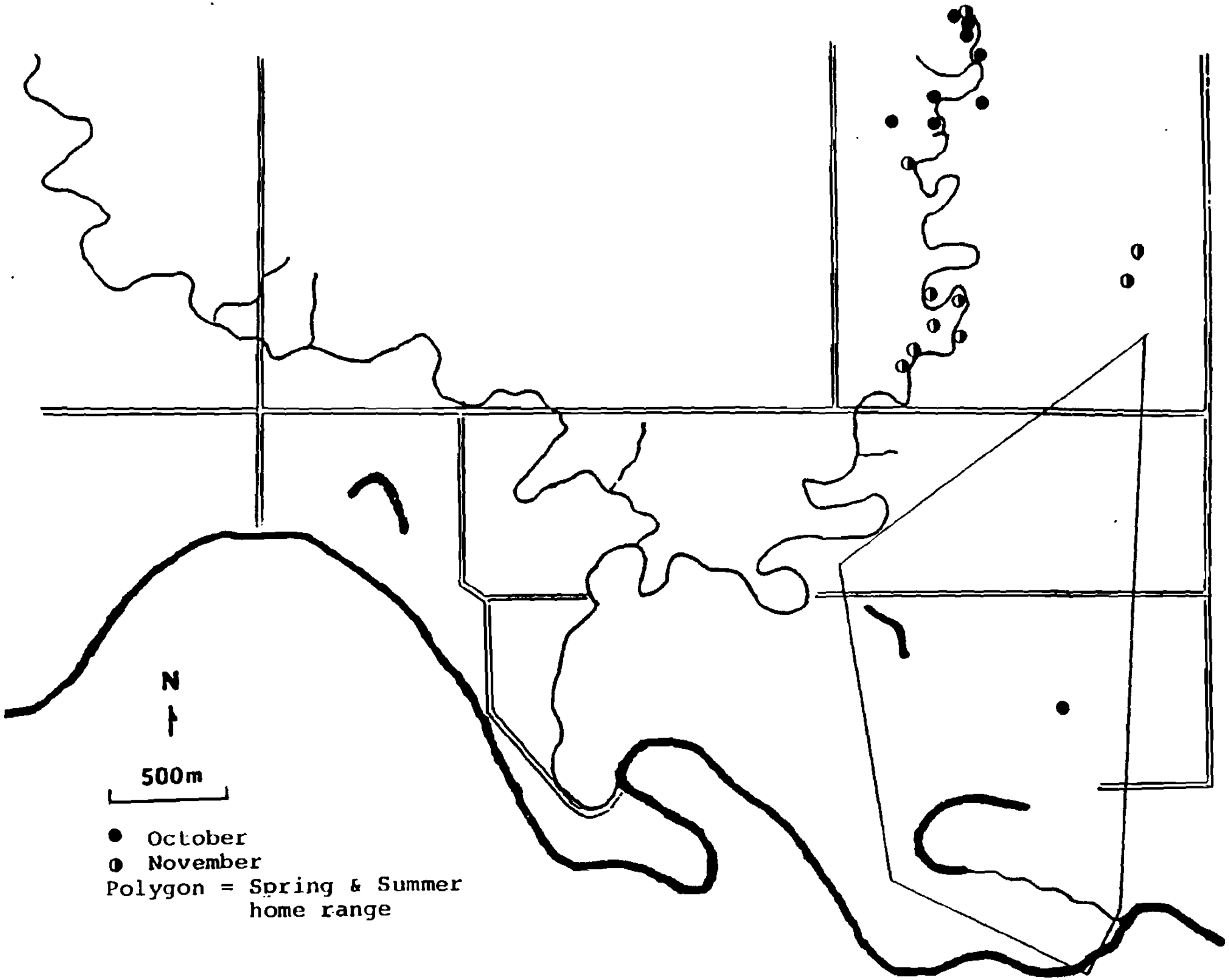
In a similar fashion, raccoon 522 moved a considerable distance, apparently to avoid flood waters, after spending an initial period within the flooded region (Fig. 14). Raccoon 522 used much of the same portion of the study area in both years, except during the flood in the second year. During early stages of the flood, signal directions indicated that 522 was in the southern portion of the study area but triangulation was possible only on 13 October 1986.

The next radio fix (16 October) for 522 was located 2.8 km to the north in upland terrain, an area relatively unaffected by flooding. Subsequent fixes indicated that she remained in this area until 17 November 1986. Her next location, located in the southern portion of the study area, was recorded on 4 December 1986.

In contrast to movements described for previous raccoons, the majority remained within their home ranges even though the areas were completely covered by water. Because of the water height, many potential den trees were unusable as sanctuaries during the flood. This was verified by 6 sightings of radio-collared raccoons located on tree limbs, or clinging to a snag, in areas of extreme flooding.

Although the total home range areas of raccoons 404 and 875 were subjected to varying depths of water, there was some movement by these animals during the flood. An example of this was displayed by 875 who was

Figure 14. Radio-locations obtained for raccoon 522b before, during, and after a flood on the FHNWR study area, 1986.


N
500m
● October
◐ November
Polygon = Spring & Summer home range

visually sighted in a small elm tree in water 3 m deep, on 8 October, and was seen 260 m away on 10 October in the hollow of a snag in approximately 0.3 m deep water. Subsequent triangulated fixes indicated that 875 was still mobile and on 17 October 875 was located in a sycamore tree 970 m from the last visual sighting. Water depth surrounding the tree was over 1 m.

<u>Mortality</u>.

Only one transmittered animal was found dead during the 2 year study. Number 791 was found on a creek bank and had apparently been dead for 2 or more days. The cause of death could not be determined, although necropsy revealed an aborted fetus (Pers. commun. Lloyd Fox).

Juvenile female 342 was found in what appeared to be an advanced stage of canine distemper, and was collected for diagnosis. Analysis by the Southeastern Cooperative Disease Study, University of Georgia, confirmed the animal was infected with canine distemper.

Two animals were lost while in traps. One was shot while in the trap (Pers. commun. Lloyd Fox), and an adult female died in a trap while she was being held overnight for processing. The only other raccoon found dead during the study was apparently a roadkill.

DISCUSSION

Trapping effort data collected during the fall 1985 trapping period may have been inadequate to estimate the population. Population size increased from the fall 1985 period to the spring 1986 period although trapping effort decreased during the spring.

The closure test calculated an appropriate value for only the fall 1986 trapping period. However, it is believed that the assumption of a closed population was acceptable for all trapping periods for which it was calculated because 95% confidence intervals were relatively small (White et al. 1978). Estimates for this study were comparable to those of other studies; however, density estimates for this study may have been too high since none of the various modifications proposed to improve density estimates (Dice 1938, Wilson and Anderson 1985) was employed. Raccoon densities extremes have been reported for populations in Minnesota (Mech et al. 1968, 70.3 ha per raccoon) and Missouri (Twichell and Dill 1949, 0.4 ha per raccoon).

The rapid increase in raccoon numbers on the area recorded for 1985-86 and 1986-87 continued during 1987-88 (Unpubl. data, Lloyd Fox). The estimated number of raccoons on the area during fall 1985 was 15 (2-28, 28.1 ha per raccoon), 92 raccoons (52-131, 2.3 ha per raccoon) for 1986, and 143 raccoons (96-191, 1.5 ha per raccoon) for 1987. The increase in population density may have been a response to a recent distemper-like epizootic reported for raccoons near the study area (Section A). The population may have been at low density due to disease when this study was initiated in the spring of 1985. Preliminary trapping results (Unpubl. data, Lloyd Fox) taken during the 1985 spring revealed a population of 27 and density of 12.7 ha per raccoon, which was larger than the fall 1985 estimate, but smaller than the subsequent estimates for 1986 and 1987.

Males were not represented in home range calculations, but estimates for females were interesting. Because of the lack of nighttime relocations, composite home range estimates for this study are probably underestimated. Lehman (1984) found that raccoon home ranges estimated using diurnal locations were significantly smaller than home ranges estimated using nocturnal locations. Although the estimates in this study are probably affected by this bias, they were still larger than composite home range estimates for the raccoons in Section A. This was surprising since both populations were situated in similar habitat with a distance of approximately 25 km separating them.

The prolonged flooding experienced by animals in this study was not a direct cause of the difference between the two studies.. Only one raccoon extended its movements beyond its normal range as a result of flooding during the study.

The importance wetland habitat plays in the ecology of raccoon populations has been described in several studies concerned with raccoon habitat utilization (Stains 1956, Johnson 1970, Urban 1970, Sonenshine and Winslow 1972, Hoffmann and Gottschang 1977, Fritzell 1978b). Most raccoon activity on an Indiana site occurred within a floodplain (Lehman, 1980).

Flooding on the Flint Hills National Wildlife Refuge plays an important part in the ecosystem of the refuge. In 2 years of study on the area, however, extreme flooding characterized by water levels as high as 6m above conservation pool, covered the area for months in the fall of both years. Most of the study area was inundated with water during these periods.

Limited evidence obtained during the fall of 1985 suggested that raccoons subjected to flooding for extended periods of time remained within the floodplain. Subsequent investigations during a similar situation the second year supported this conclusion. It was apparent that trees utilized by raccoons during peak flooding were not den trees, and provided little sanctuary from the elements. Surprisingly, there was movement from one location to another by raccoons remaining within the flooded region. This may have been in response to being approached by me in a canoe while they were in a vulnerable position. An attempt was made to minimize any distress the animals might have experienced due to my presence. Some of the animals were never visually sighted but merely circled by me until a location could be determined.

Studies concerned with raccoon weight fluctuations have reported heaviest weights occurring in the fall and that fall weight gain may be important in surviving extreme winter conditions (Mech et al. 1968, Johnson 1970, Moore and Kennedy 1985). Malnutrition affected raccoon survival in Wisconsin (Root, 1981) and Minnesota (Mech et al. 1968). The opportunity for raccoons present on the study area to maximize their body condition for the oncoming winter must have been limited when their home ranges were under water for critical periods during the fall. The energy requirements for movements recorded for the raccoons during high water levels would also inhibit weight gains necessary during this period. Even the extensive movements undertaken by some animals to avoid the flooding would have been energy-demanding.

The ability of a raccoon to withstand periods of extreme winter conditions by remaining inactive (discussed in Section A) may be limited if the animal did not have sufficient energy reserves preceding such an event. Raccoons in this study were subjected to such a condition during January, 1987, and they remained inactive during that period, much like raccoons subjected to the same conditions in another study (Section A). Mortality attributed to malnourishment or exposure to adverse conditions was not discovered for any of the transmittered animals. Therefore, transmittered animals exposed to flooding during a critical period in the fall survived while restricting their movements during the winter. The limited agricultural crop harvest in both years due to the timing of the floods may have provided more food than usual during the winter months, although raccoons are not noted to heavily utilize milo and soybeans.

Less extreme flooding in spring rather than fall occurred during both years of the study, but little information was obtained about effects such flooding may have had on reproduction. The increase in population numbers during the study suggests that reproduction was not appreciably affected, although the increase could have been produced by immigration from adjacent areas.

SUMMARY

1. A study was conducted from 1985 to 1987 on the Flint Hills National Wildlife Refuge to describe how flooding affected raccoon movement patterns and mortality. The area is subjected to severe flooding; at times 90% of the refuge's 7493 ha can be covered by water.

2. There was an increase in population density occurring during the study. Raccoon density began at an estimate of 28.1 ha per raccoon during the initial trapping period, and subsequent increases resulted in a density of 2.3 ha per raccoon for the fall 1986 trapping period.

3. Adult female composite and seasonal home ranges were larger than yearling female home ranges.

4. Extreme flooding during the fall did not appear to affect raccoon behavior or survival during the following winter.

5. Raccoon response to severe increases in water levels on the area in the fall of 1986 was variable, although most of the animals remained within the flooded region for the duration of the flood.

6. Apparently, there was some movement exhibited by those raccoons remaining within flooded areas, even though their home ranges contained no exposed land.

GENERAL CONCLUSION

Supplemental data acquired during the study in Section B, when compared to Section A, provide general characteristics that can be applied to raccoon populations in eastern Kansas:

1. Sizes in raccoon home ranges varied widely from one local area to the other.

2. Raccoons utilized tree dens predominately during the winter on both areas, although there was some individual variation. Some trees appeared to serve as communal den sites, and were used by a number of transmittered raccoons.

3. Broad spatial overlap among female raccoon home ranges was common during both studies. Unfortunately no data were obtained for males on the FHNWR study area.

4. Most female raccoons restricted their movements during the winter, particularly during periods of snow cover combined with low temperatures.

5. Adults use the same general areas from year to year.

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APPENDICES

pendix I . Composite home range estimates for raccoons on Badger Creek study area 1985-87. All means are presented with ± standard error.

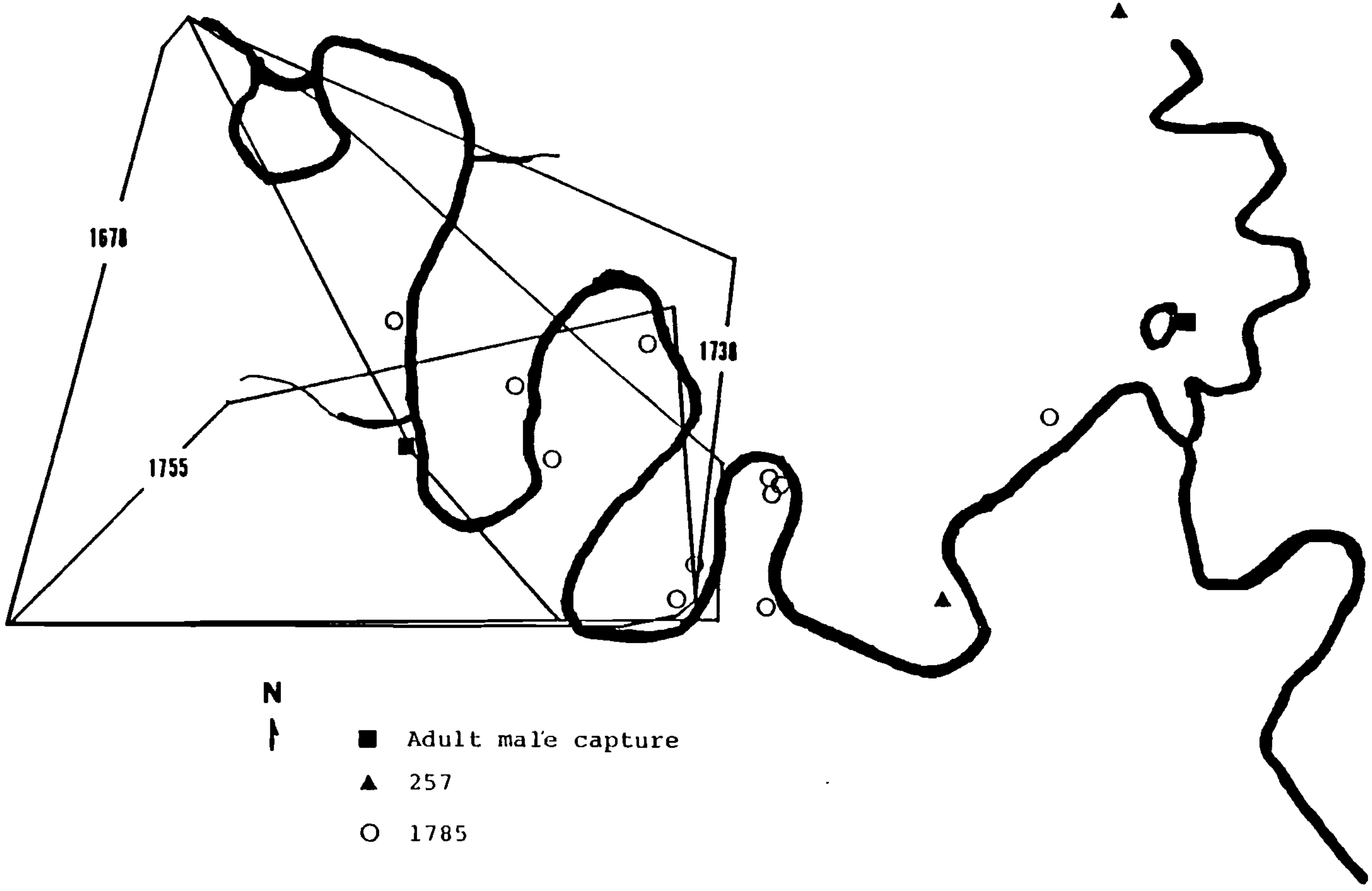
ccoon	N	CP	BE	HM
458	45	76.6	136.4	88.6
426	52	100.2	196.5	129.4
724b	53	58.6	127.8	78.9
1070b	131	204.1	158.2	162.8
202b	140	118.2	165.4	112.6
292	172	68.5	85.0	91.1
996	156	57.2	51.7	52.4
176	63	185.8	194.0	171.4
1070a	107	97.8	114.2	109.5
$\bar{X}$	102.1 ± 16.6	107.4 ± 17.9	136.6 ± 16.1	110.7 ± 12.9
757b	118	26.4	32.3	22.4
724a	148	91.4	90.6	162.7
1255	66	107.9	138.8	138.0
$\bar{X}$	110.7 ± 13.8	75.2 ± 24.9	87.2 ± 30.8	107.7 ± 43.2
234	14	23.6	67.0	
143	28	22.5	51.8	
757a	47	30.4	49.2	
$\bar{X}$	29.7 ± 9.6	25.5 ± 2.5	56.0 ± 5.6	
1738a	37	123.5	236.1	86.6
1738b	162	130.8	122.6	152.3
1678	28	124.1	321.4	75.7
327	153	244.0	181.4	179.6
$\bar{X}$	95.0 ± 36.2	155.6 ± 29.5	215.4 ± 42.3	123.6 ± 25.2
227	140	401.6	277.0	219.0
252	119	215.6	269.5	230.0
$\bar{X}$	129.5 ± 10.5	308.6 ± 93.0	273.2 ± 3.8	224.5 ± 5.5

Appendix II . Seasonal home range estimations (ha) for raccoons located on the Badger Creek study area 1985-87. Minimum area (MA), bivariate ellipse (BE), and harmonic mean (HM) models were used.

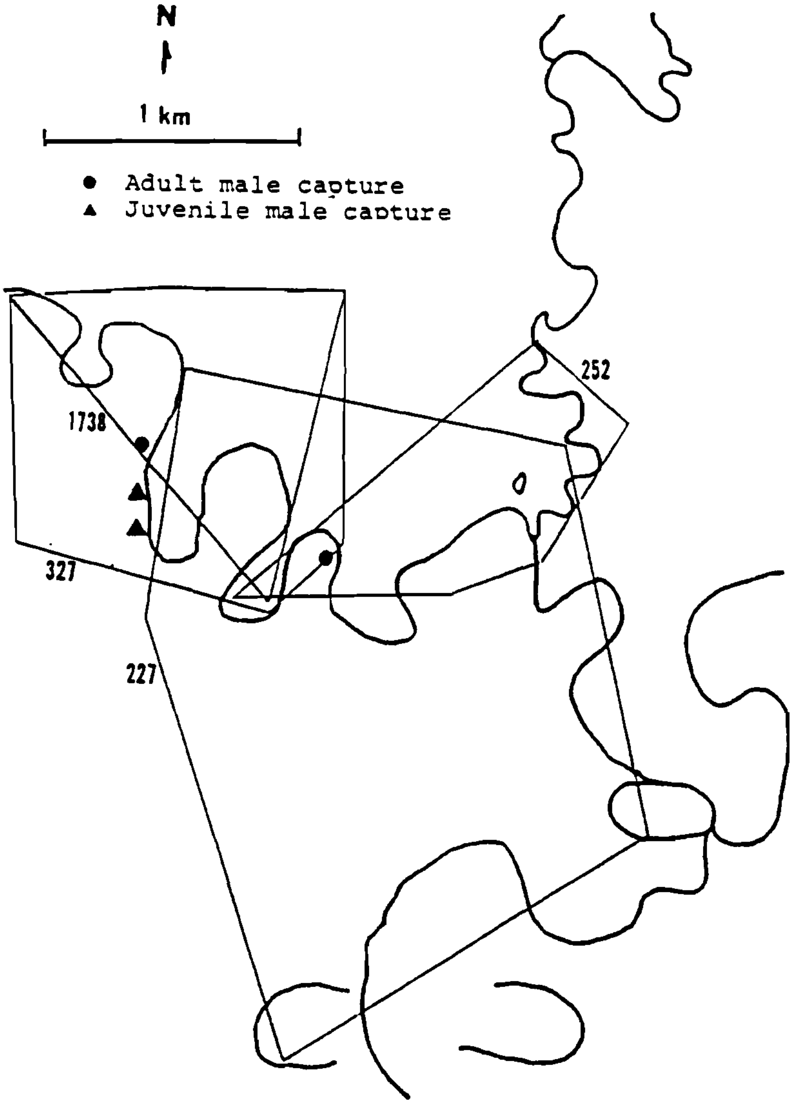
	Fall			Winter			Breeding			April		
Raccoon	MA	BE	HM	MA	BE	HM	MA	BE	HM	MA	BE	HM
Females												
202a							28.4	46.6	53.7	19.0	56.7	-
1070a				10.1	23.3	28.8	52.0	130.3	70.7	42.6	122.7	73.2
292	63.1	84.6	85.3	12.5	20.0	14.8	33.5	90.6	43.8	19.4	48.6	36.5
996	53.4	78.3	83.1	17.1	28.2	21.5	12.5	27.2	20.8	3.2	7.4	5.1
458	52.9	100.5	77.5									
426	95.1	184.9	-									
724a	49.6	83.4	E	56.5	149.1	105.1	12.2	35.3	E	16.8	38.0	-
176	185.8	370.9	264.9	36.1	63.7	-						
202b	53.5	107.1	81.6	46.9	110.2	61.6	72.6	163.1	111.4			
757b	24.9	40.6	31.3	12.9	27.0	18.7						
1070b	87.6	235.2	112.1	7.8	9.4	10.7	109.0	178.0	158.2			
Males												
1738b	42.0	93.7	63.3	72.8	70.3	134.4	70.2	129.6	86.1			
227	37.2	72.8	57.1	383.8	328.9	E	130.5	329.3	151.8			
252	88.8	211.2	115.3	71.9	79.2	81.9	64.0	177.5	103.6			
327	37.6	76.3	73.6	131.0	162.2	153.0	160.8	269.6	225.8			

E = harmonic mean estimations were not possible due to program error;
- = harmonic mean estimations were not attempted due to small sample size.

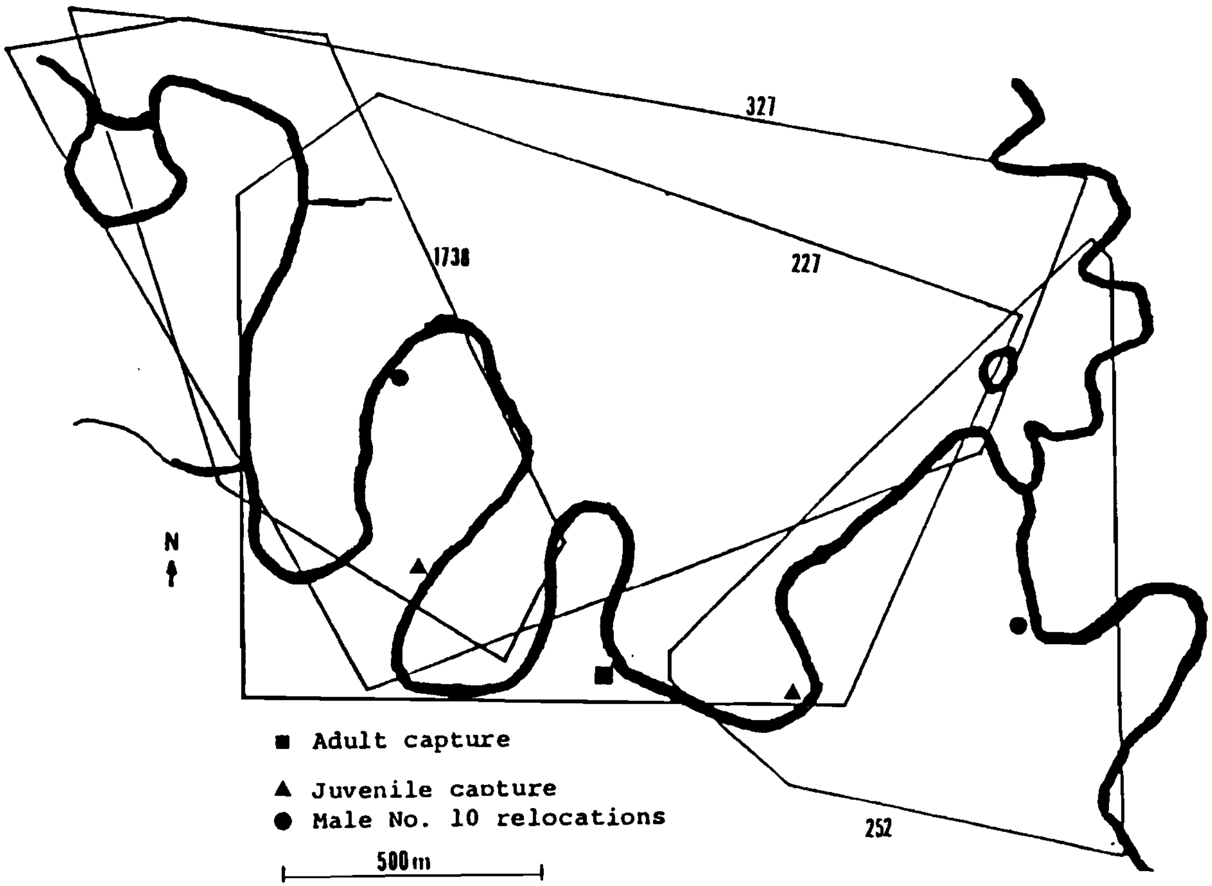
Appendix III (a-c). Examples of overlap as evidenced by 1) capture locations for untransmittered males, 2) home ranges for radio-collared males, and 3) radio-locations for transmittered males with insufficient data for home range estimation.



Appendix III (a) Fall, 1985

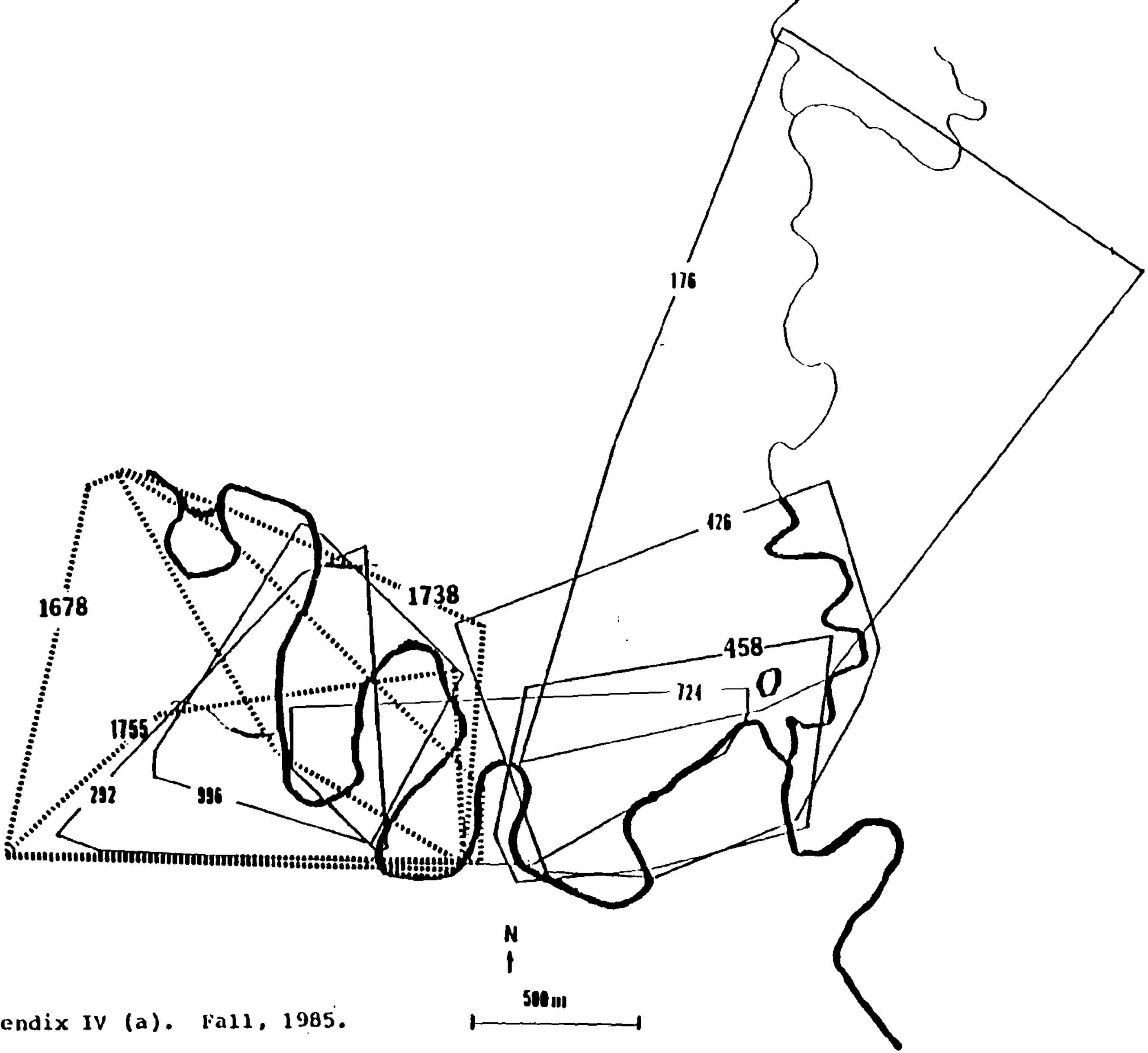


Appendix III (b). Winter, 1986-87.

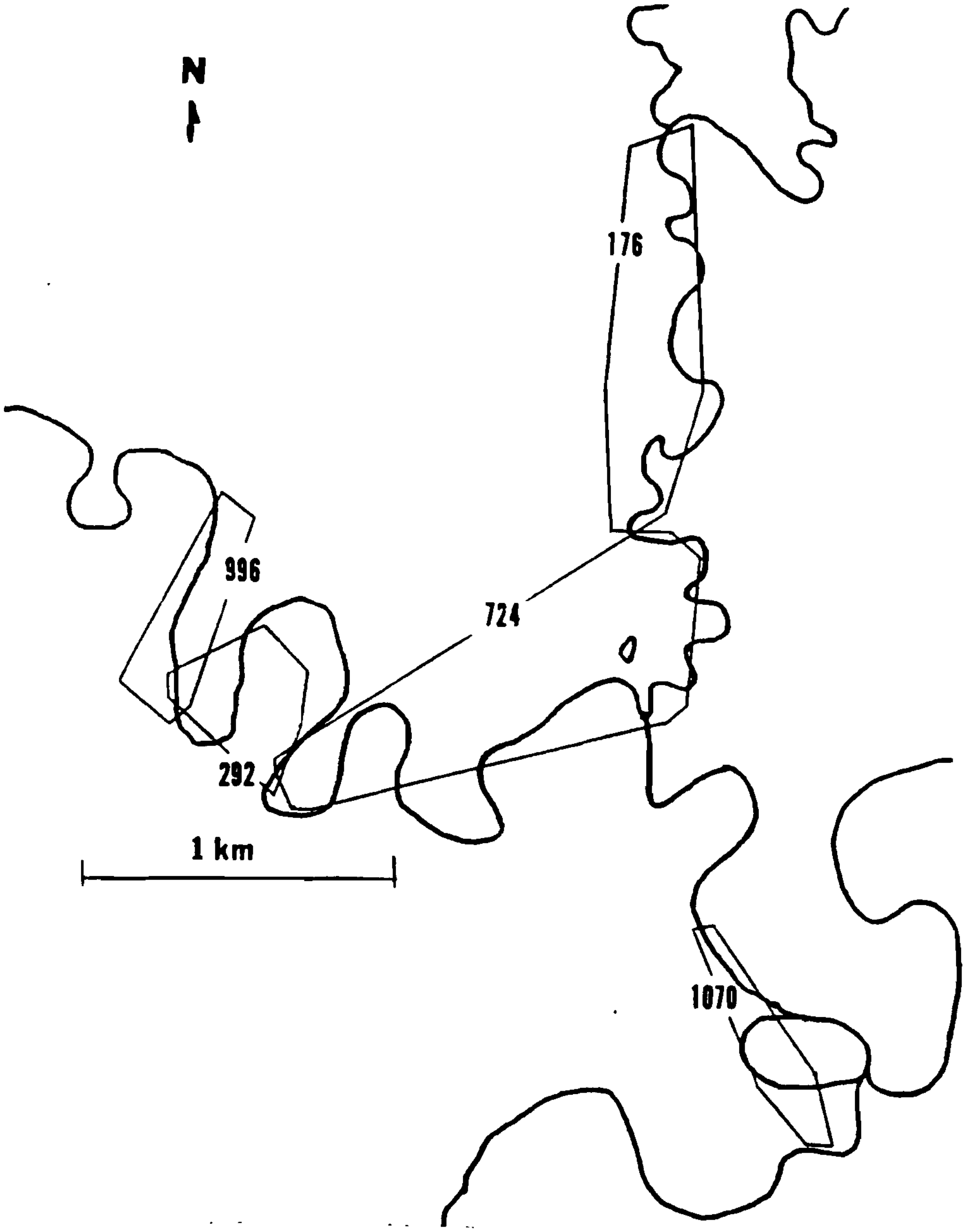


Appendix III (c). Breeding, 1987.

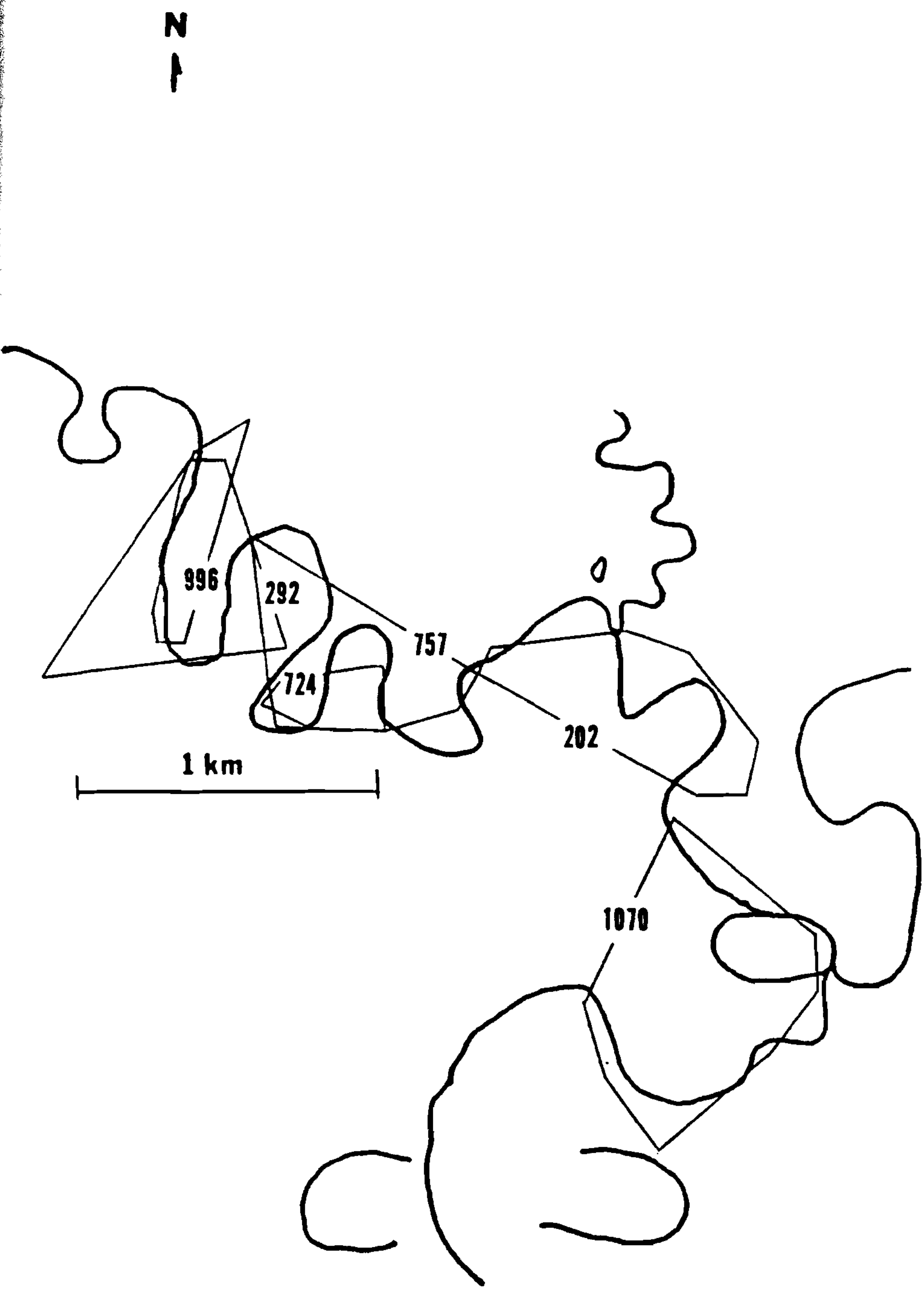
Appendix IV (a-g). Seasonal home ranges for raccoons located on the Badger Creek study area from 1985 to 1987. Males are represented with dotted lines.



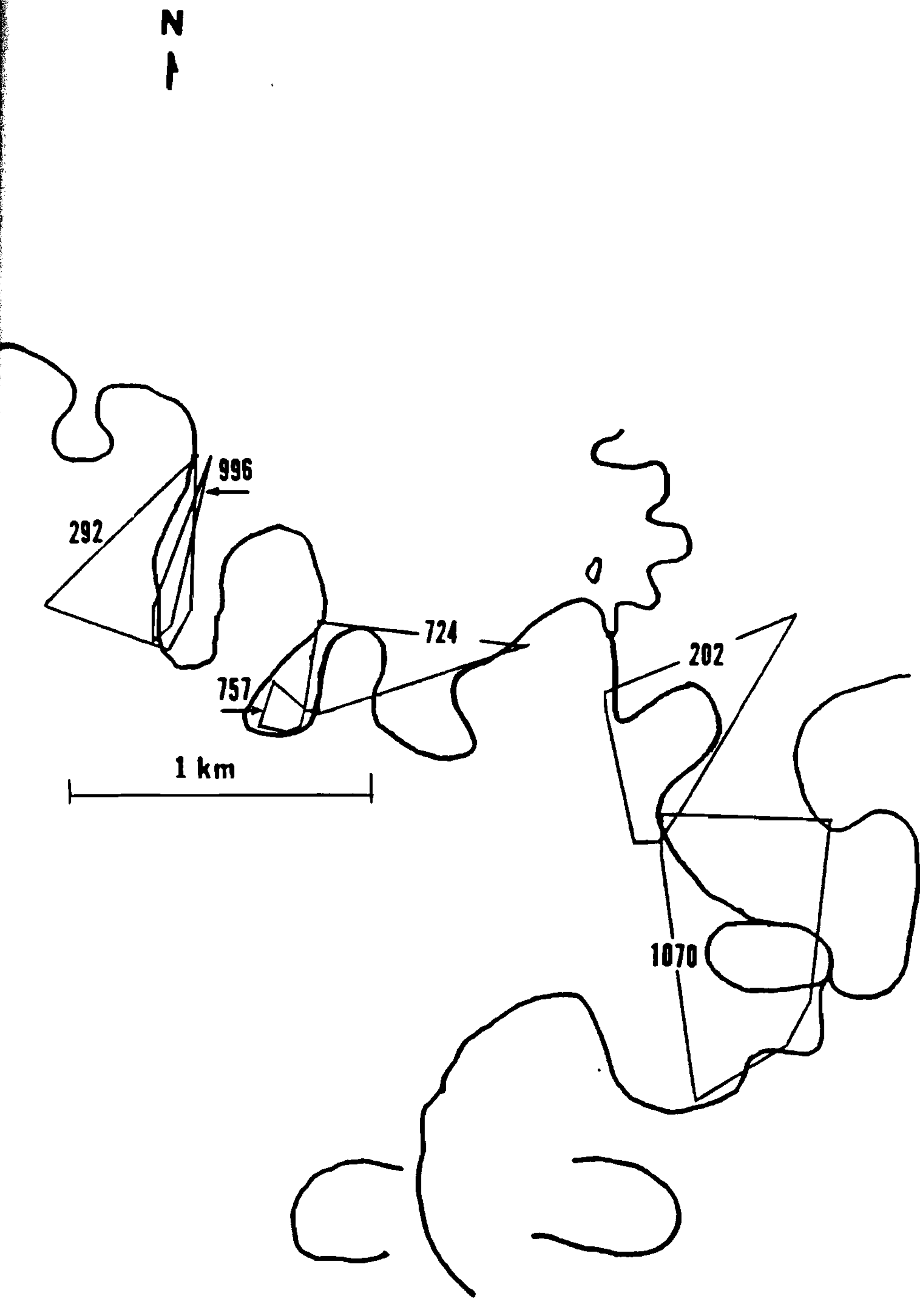
Appendix IV (a). Fall, 1985.



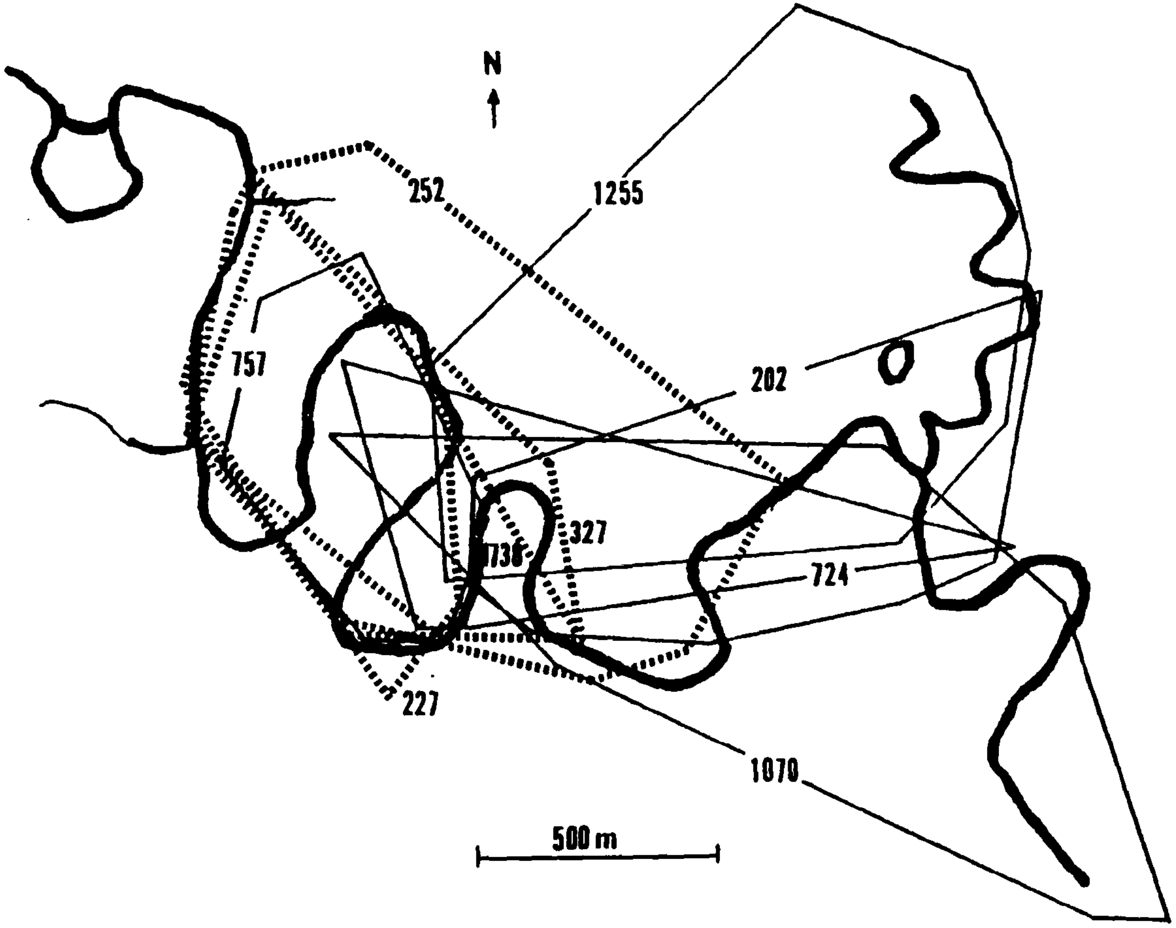
Appendix IV (b). Winter, 1985-86.



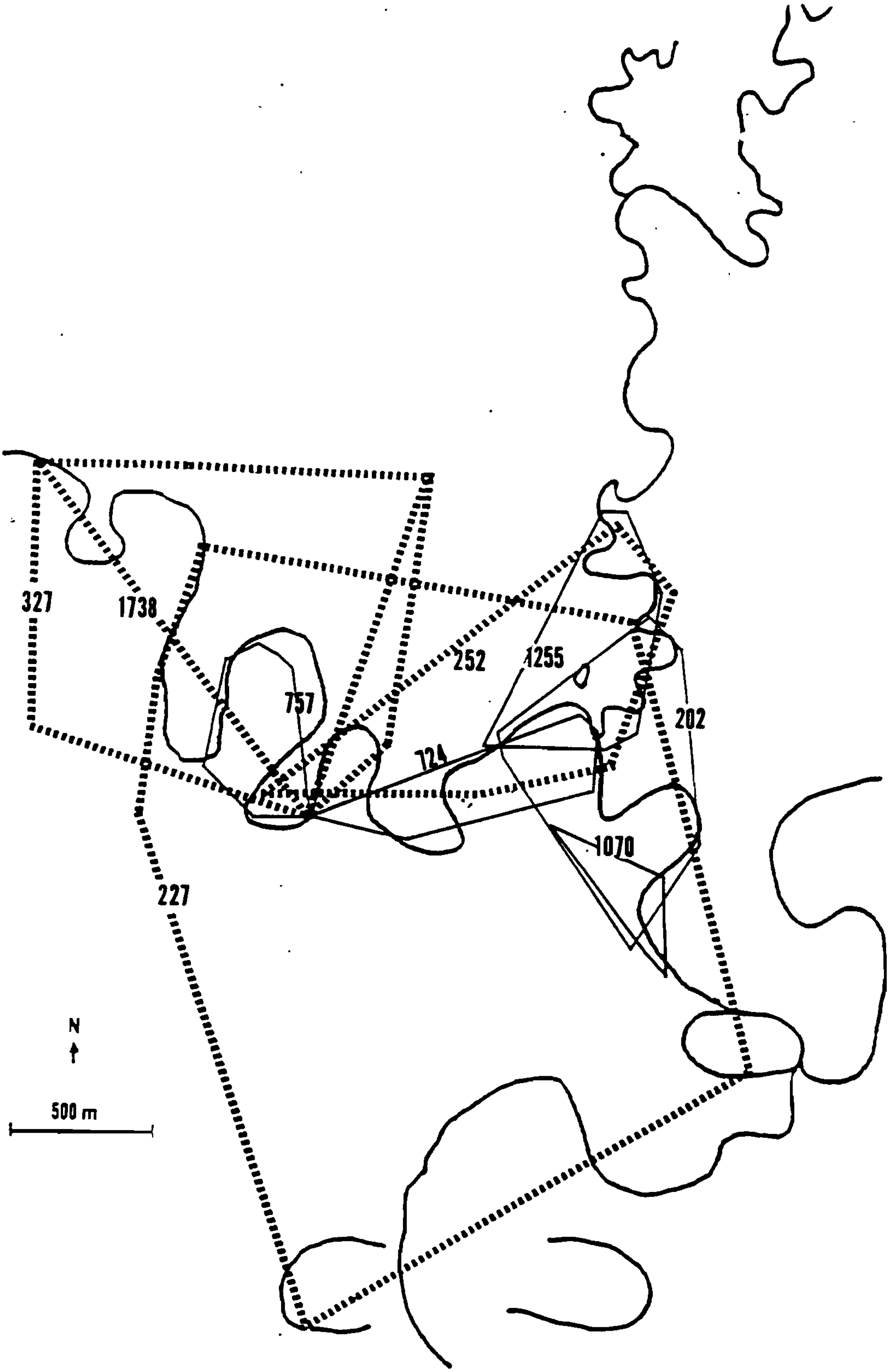
Appendix IV (c). Breeding, 1986.



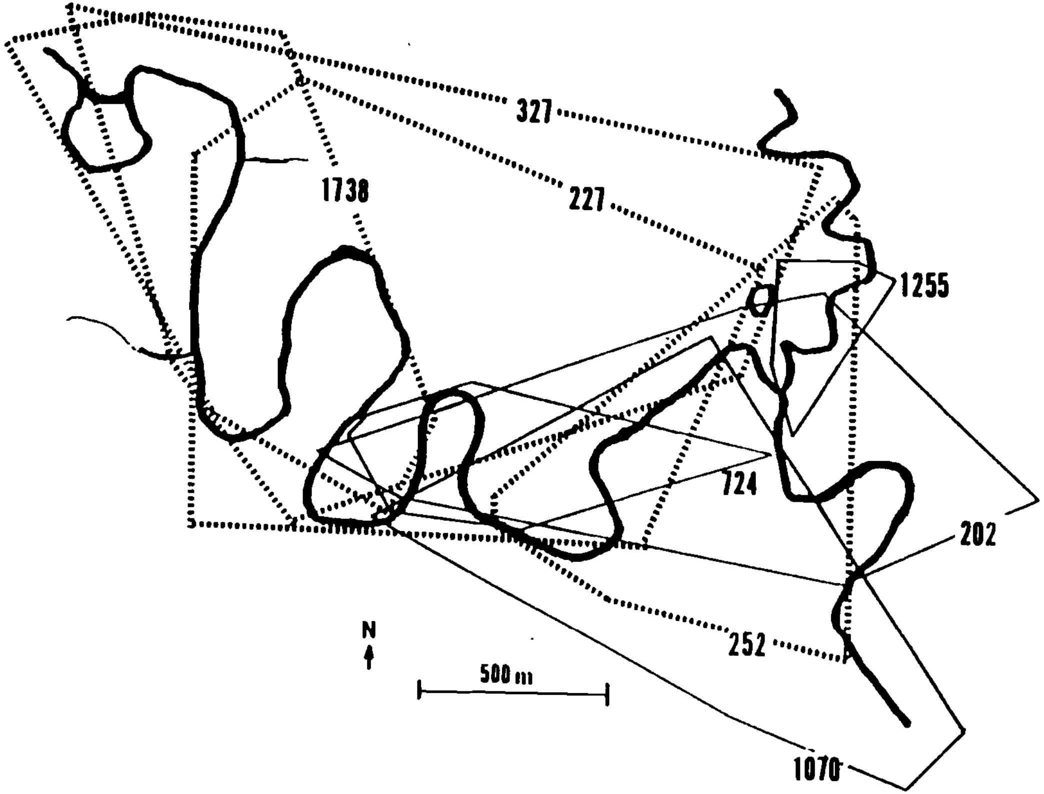
Appendix IV (d). April, 1986



Appendix IV (e). Fall, 1986.

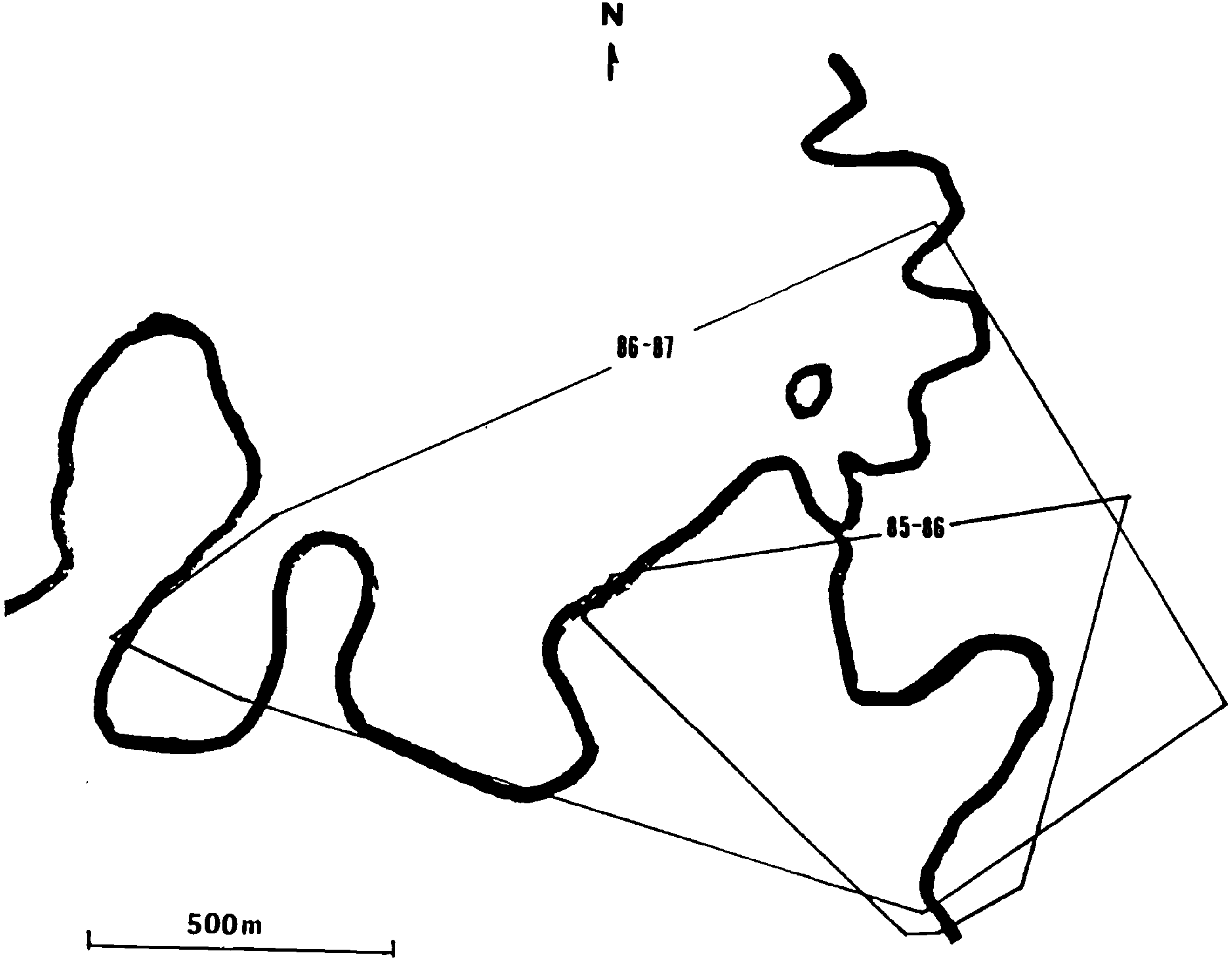


Appendix IV (f). Winter, 1986-87.

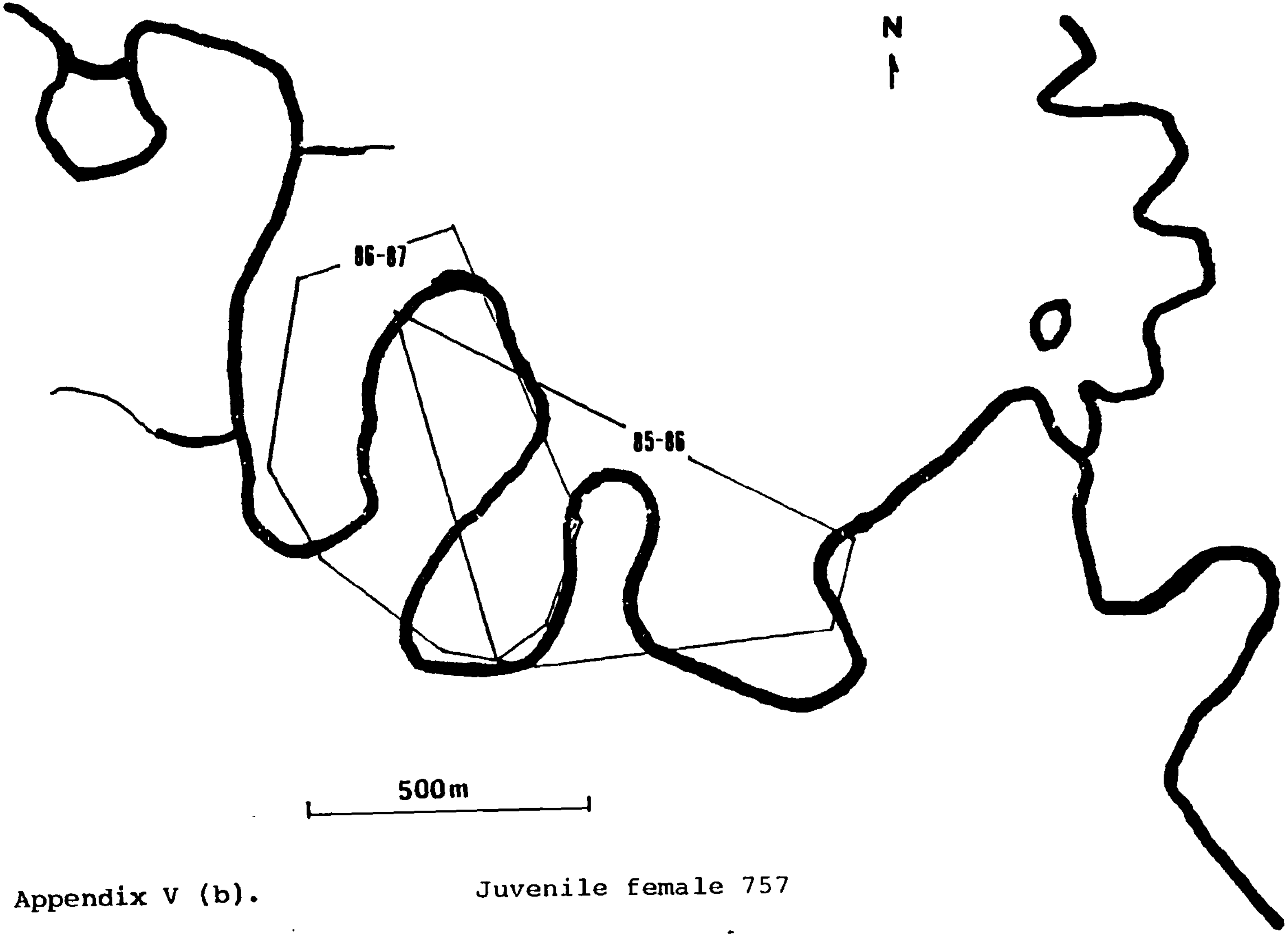


Appendix IV (g). Breeding, 1987.

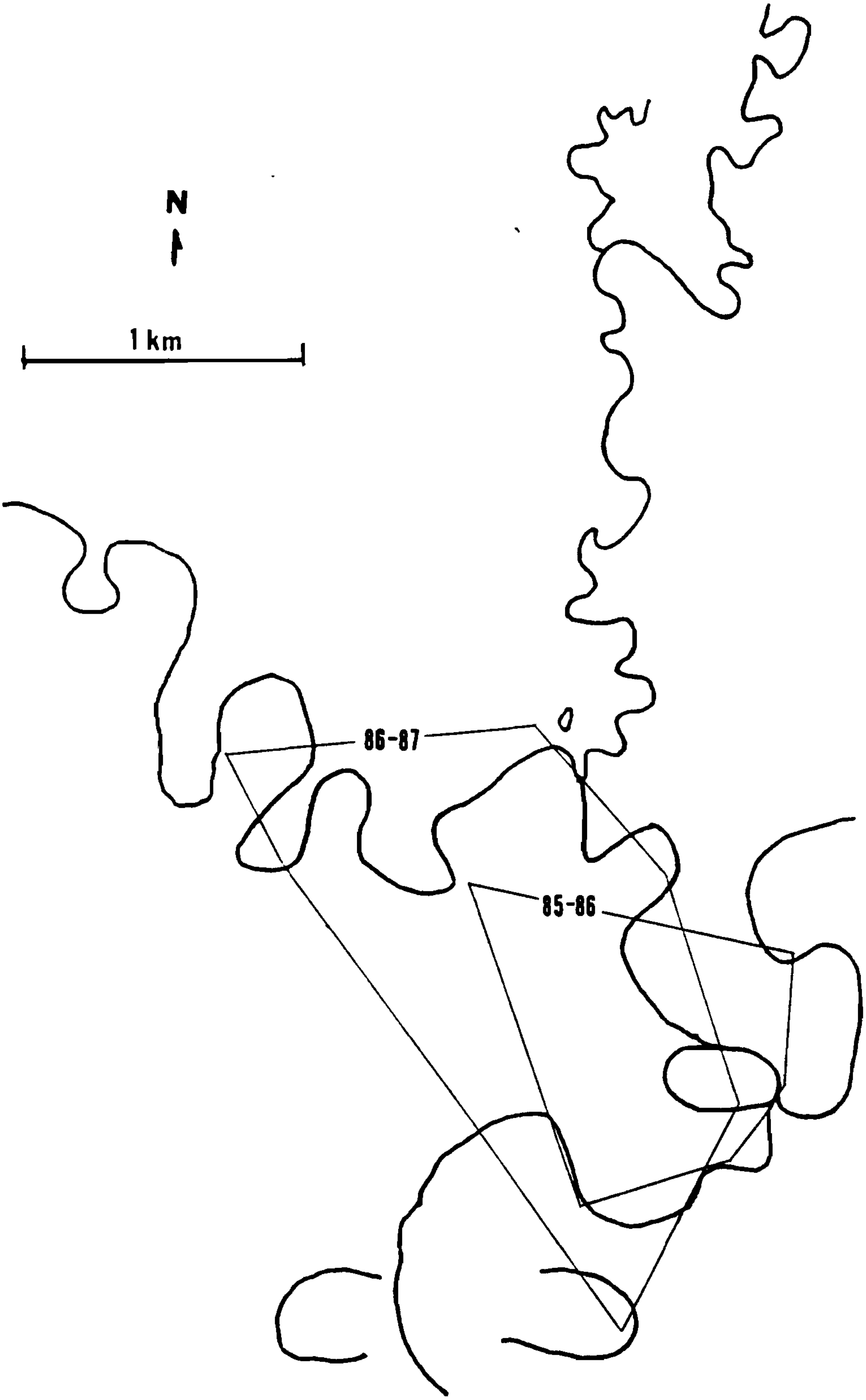
Appendix V (a-e). Annual overlap of composite home ranges for those raccoons monitored in both years, 1985-86 and 1986-87, on the Badger Creek study area.



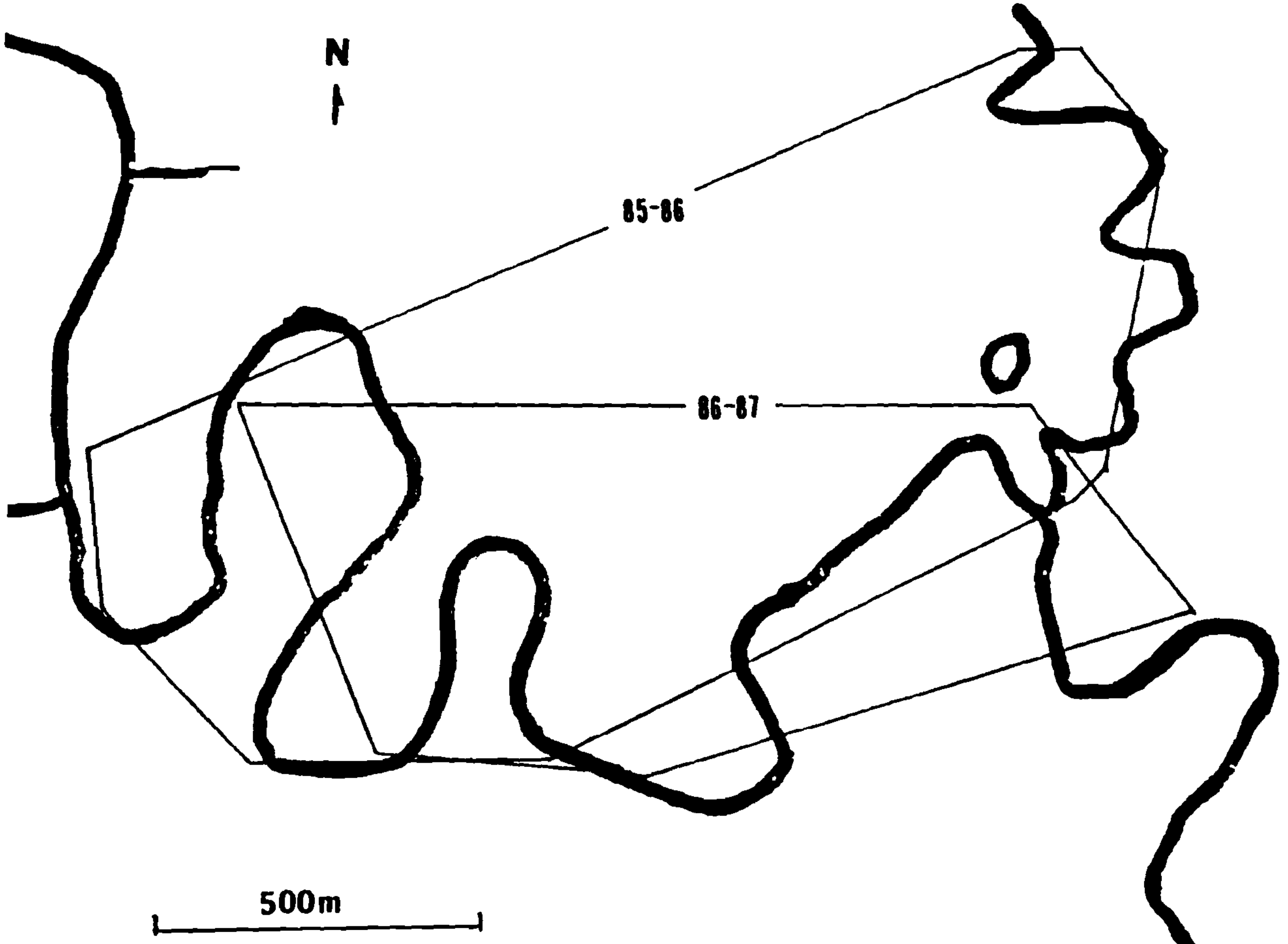
Appendix V (a). Adult female 202



Appendix V (b). Juvenile female 757

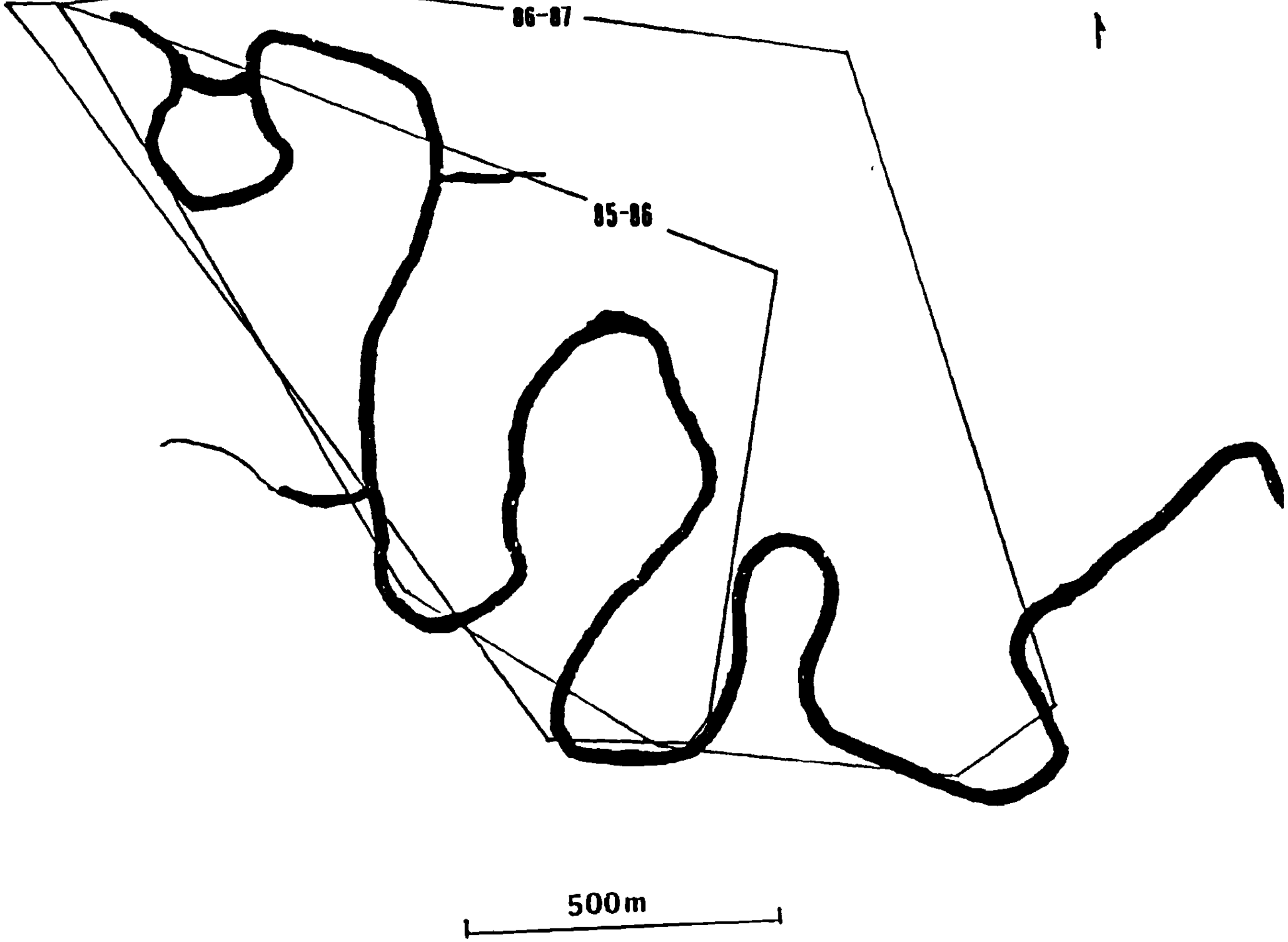


Appendix V (c). Adult female 1070



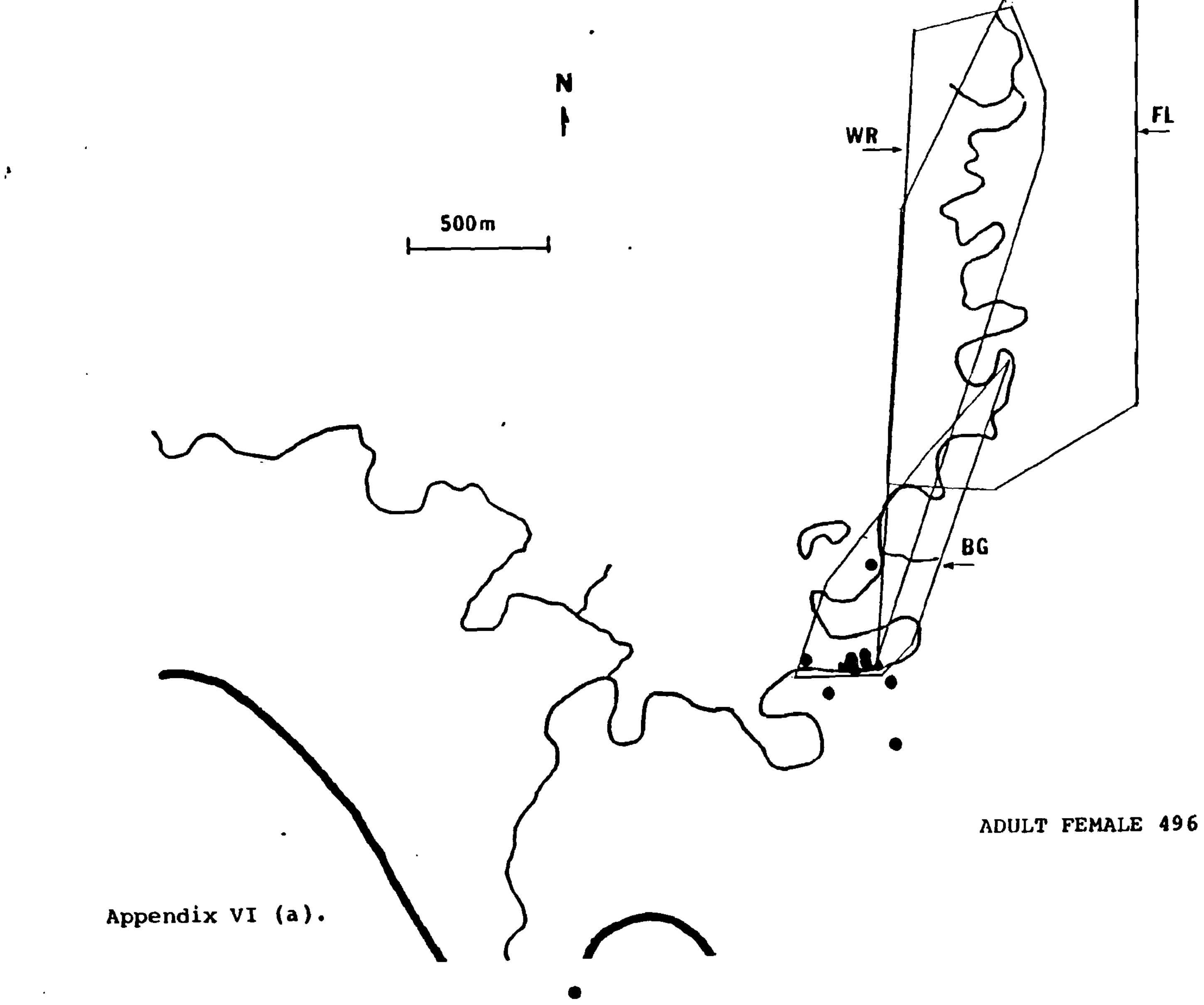
Yearling female 724

Appendix V (d).



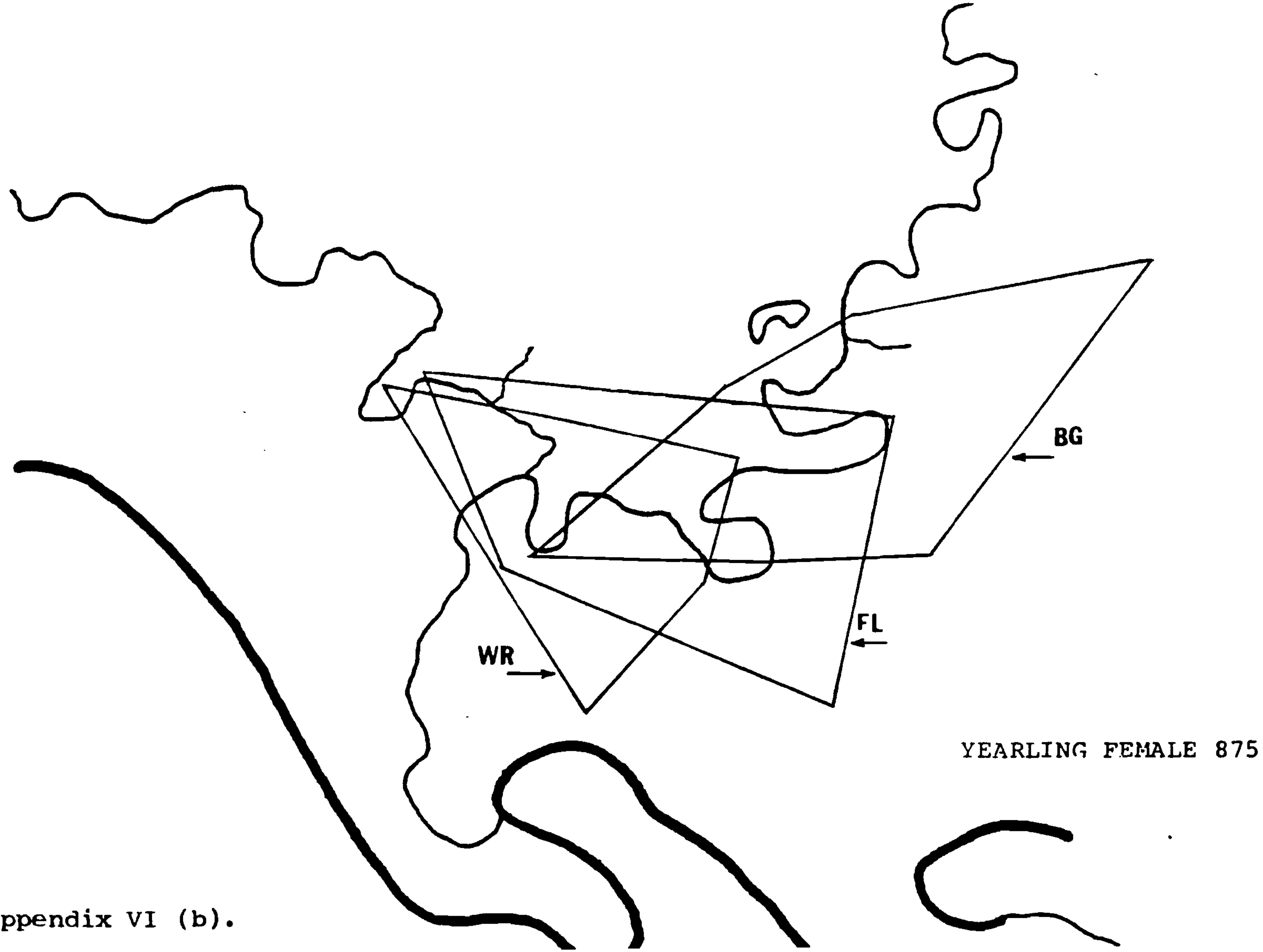
Appendix V (e). Adult male 1738

Appendix VI (a-e). Seasonal home ranges for raccoons located on the FHNWR, 1986-87. Dots represent relocations obtained during spring 1986 (fall = FL, winter = WR, and breeding = BG).

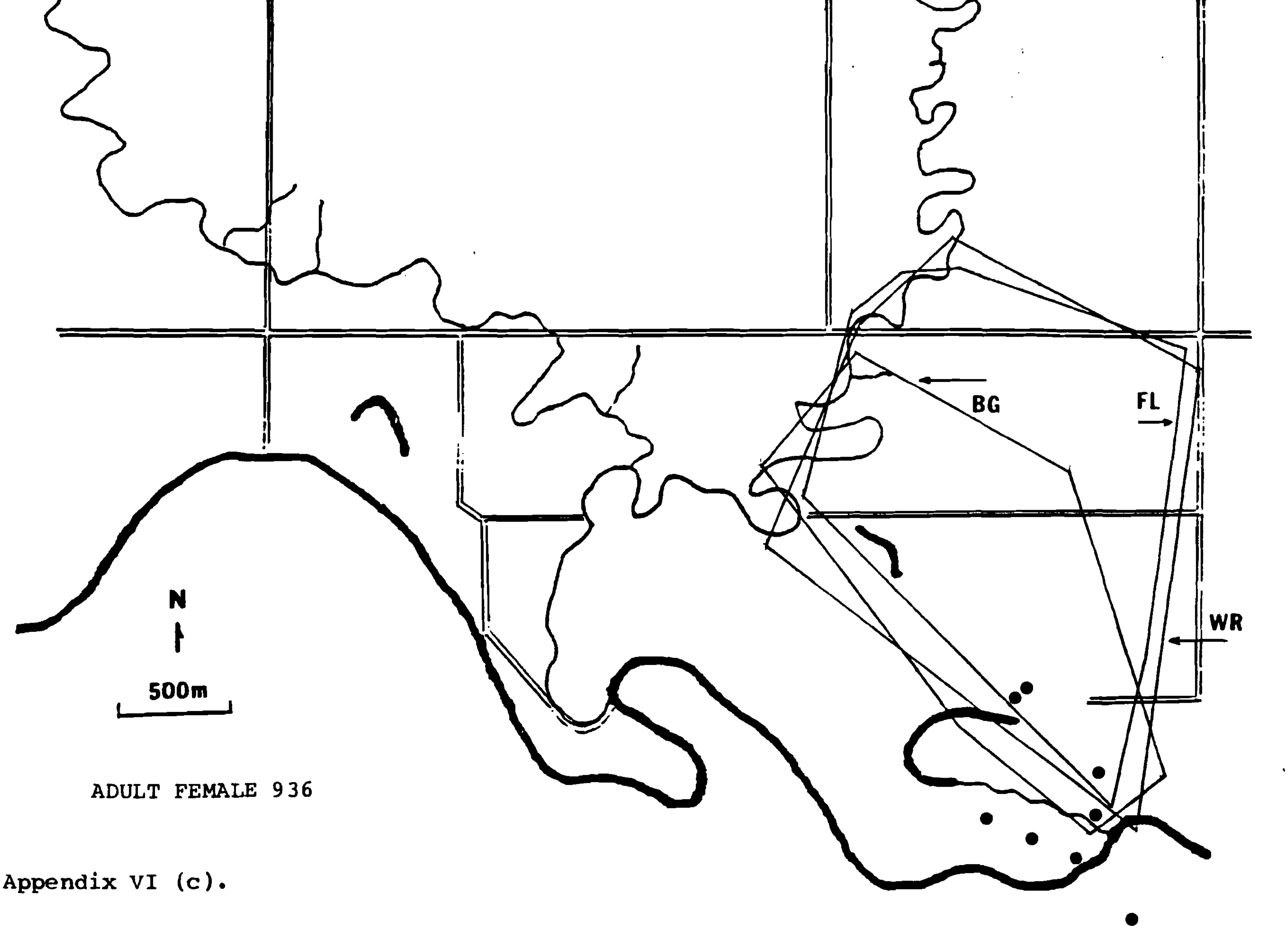


ADULT FEMALE 496

Appendix VI (a).

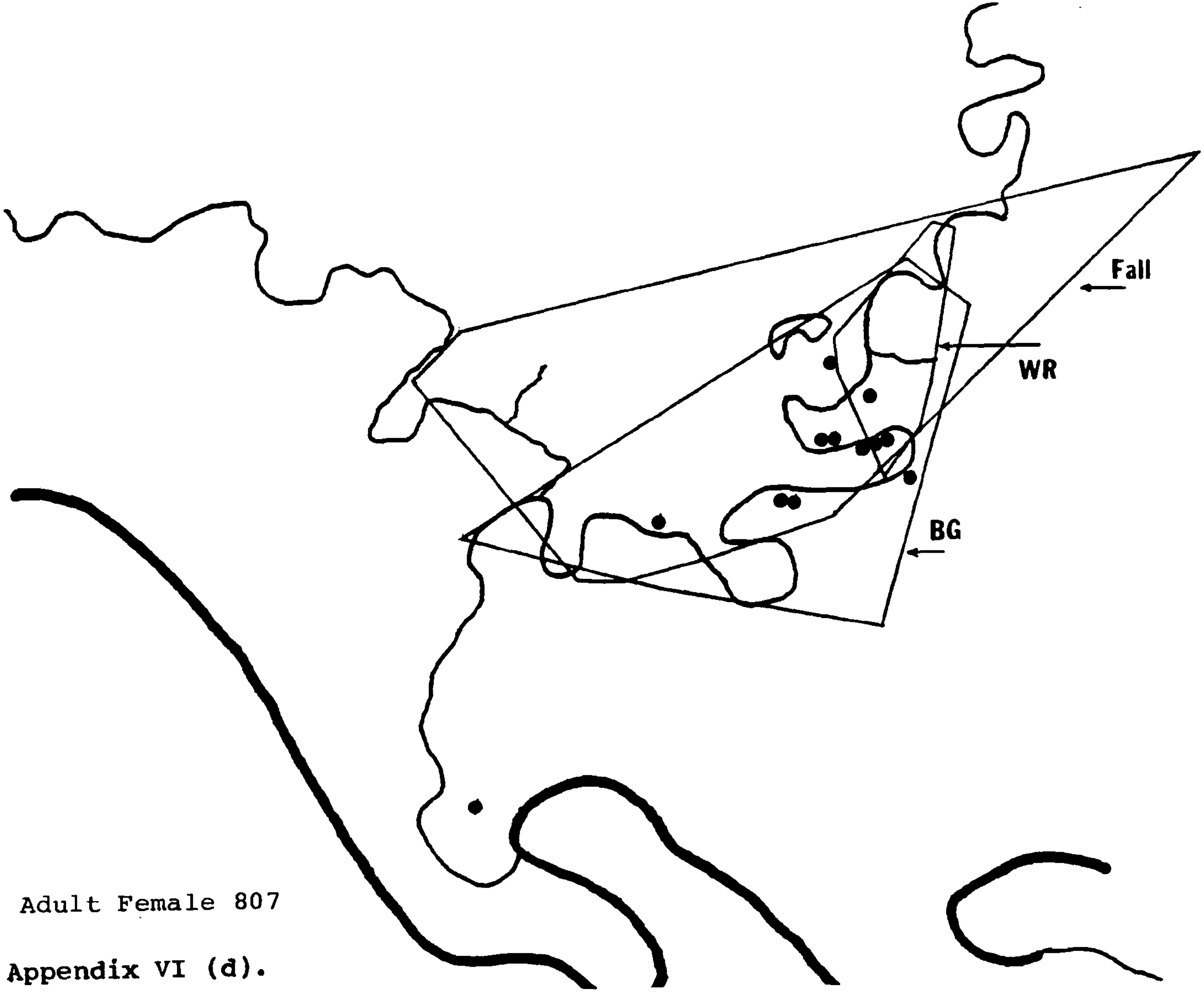


Appendix VI (b).



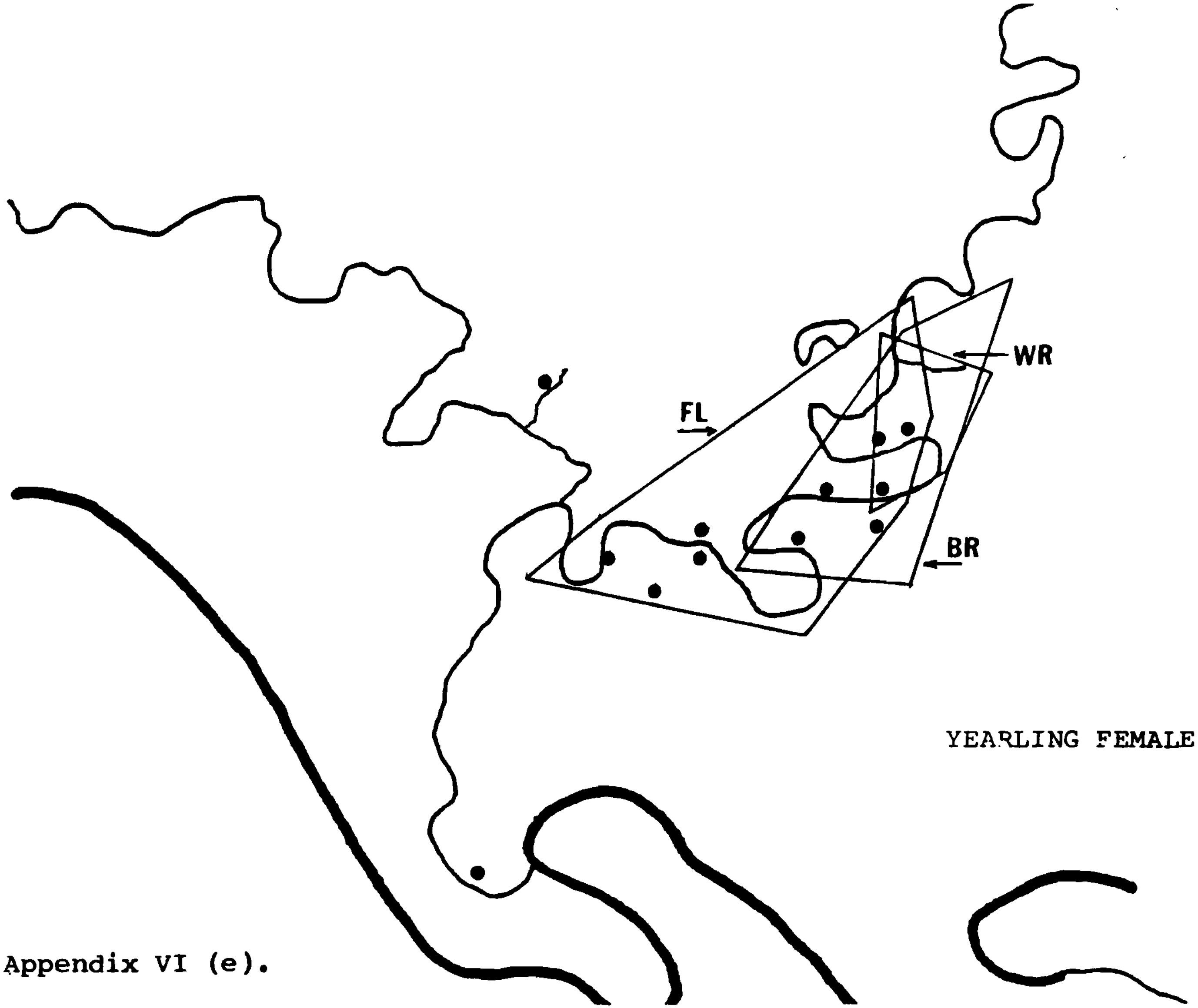
ADULT FEMALE 936

Appendix VI (c).



Adult Female 807

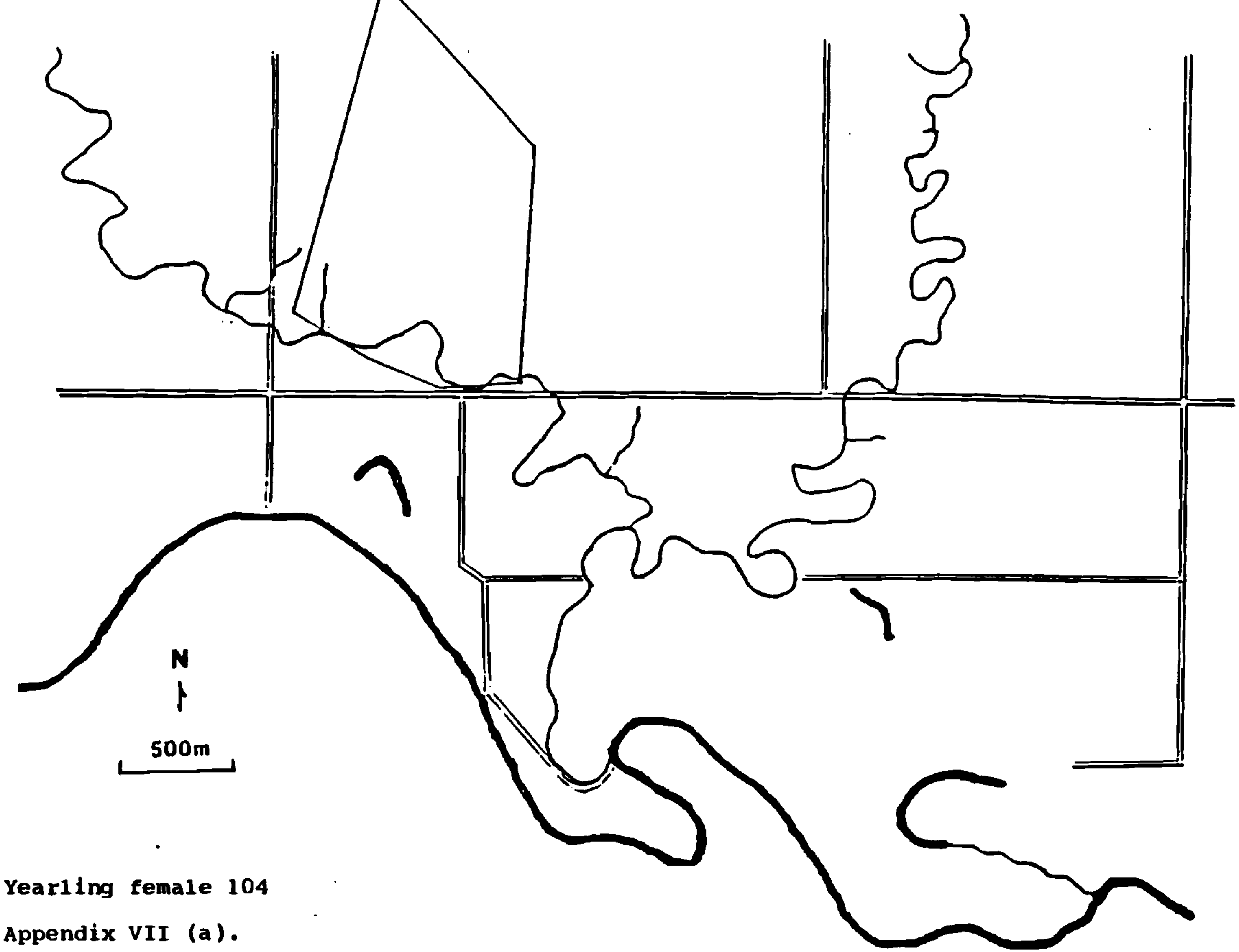
Appendix VI (d).



YEARLING FEMALE 404

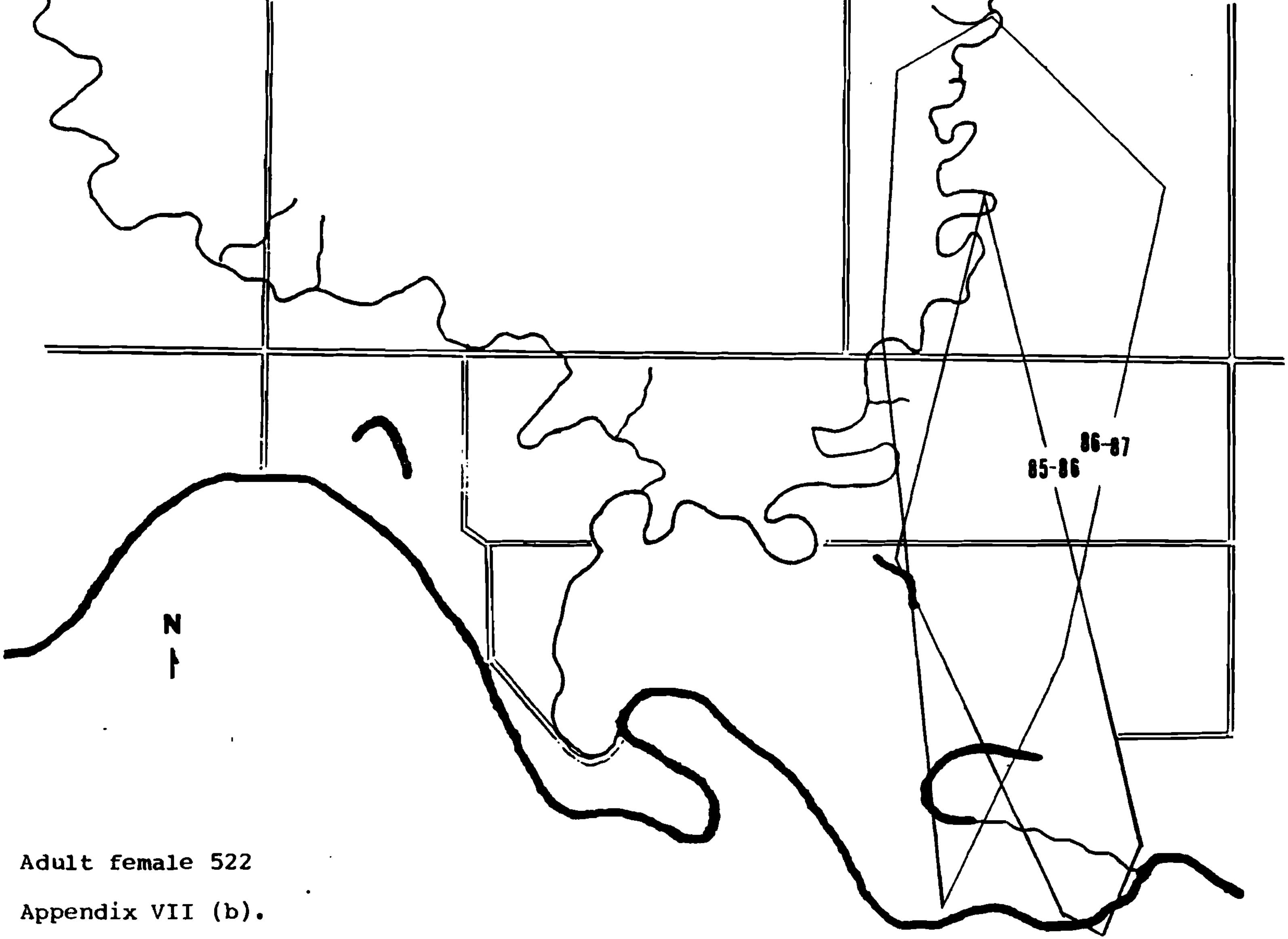
Appendix VI (e).

Appendix VII (a-d). Composite home ranges for those raccoons with insufficient data for seasonal home range estimations on the FHNWR study area.



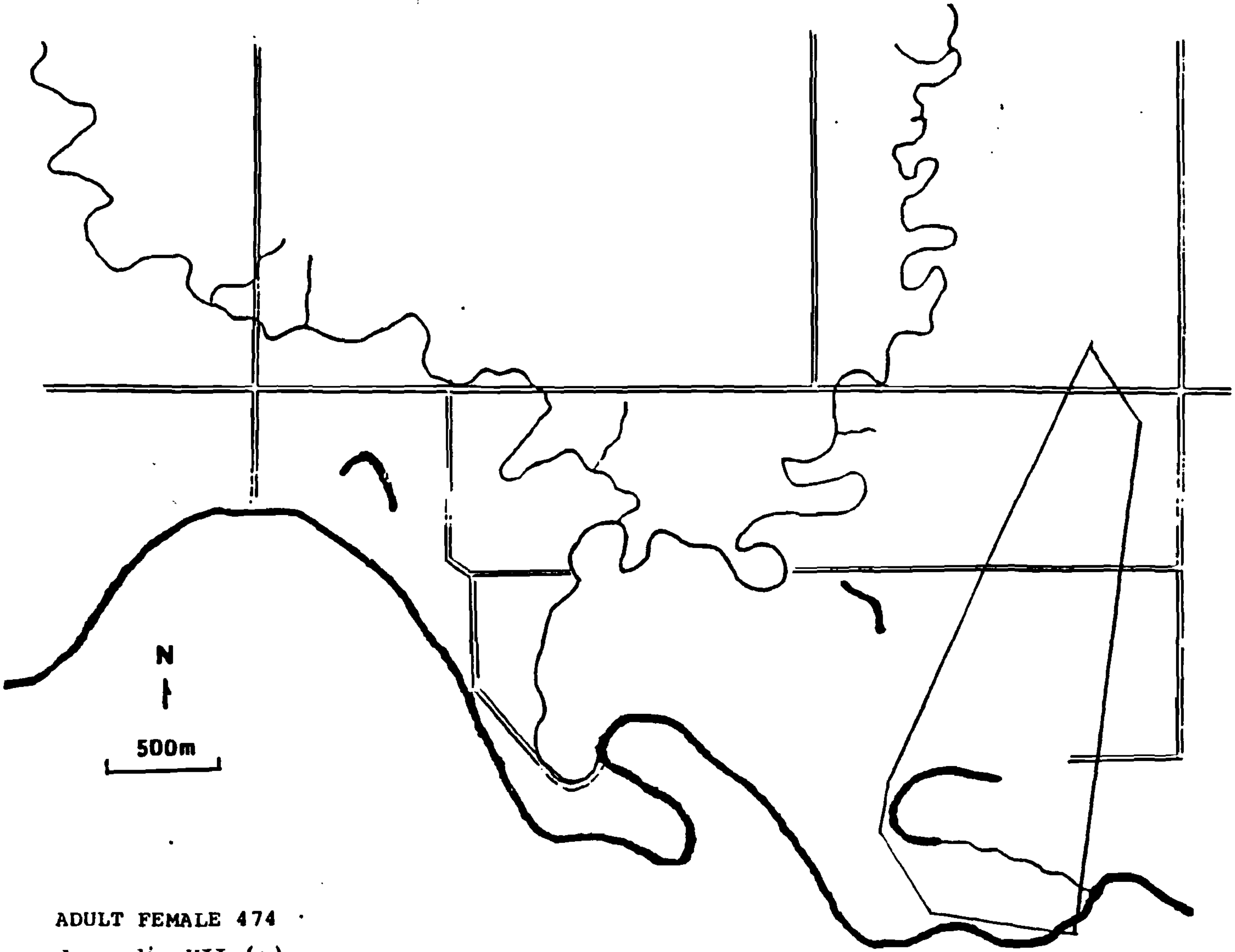
Yearling female 104

Appendix VII (a).



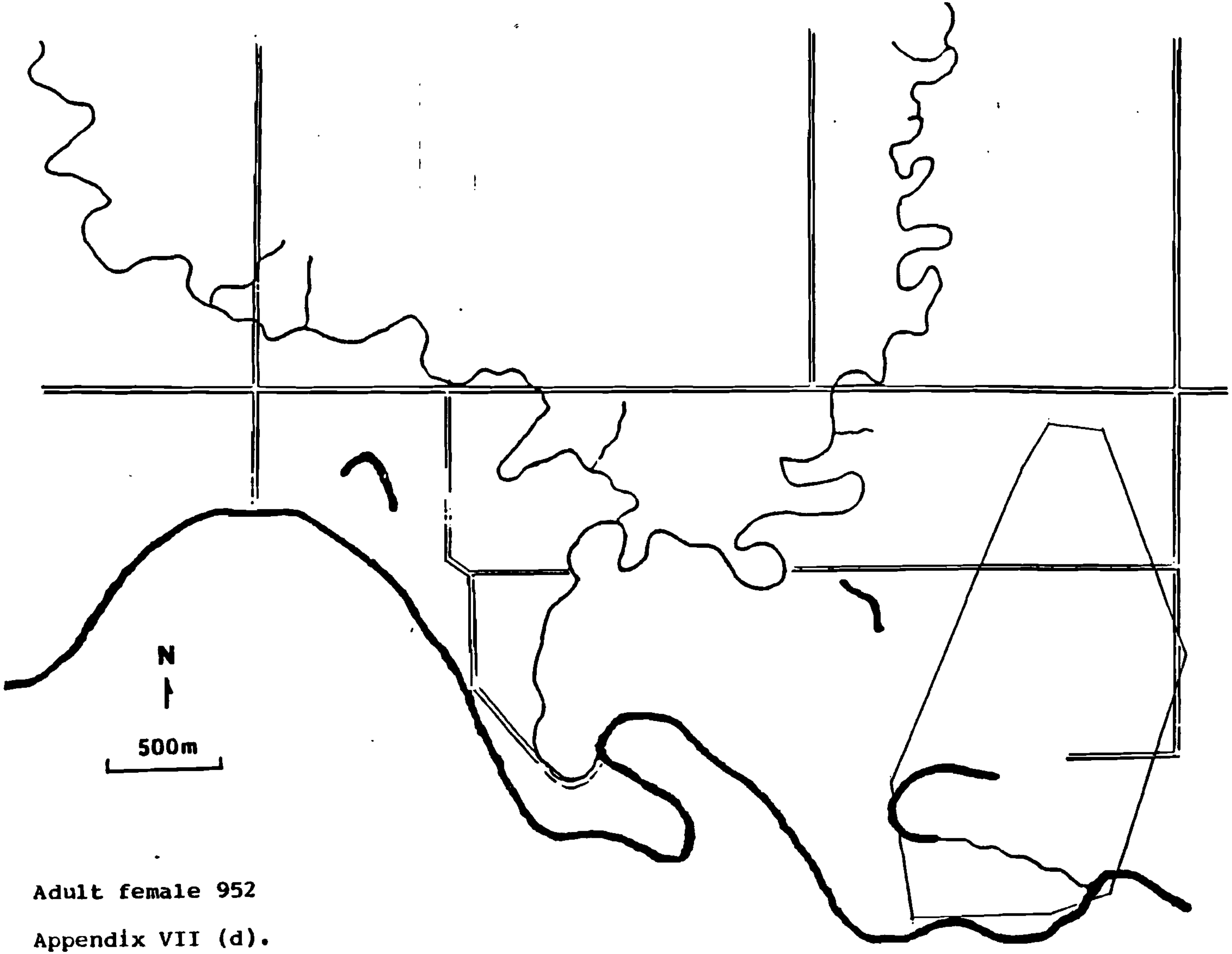
Adult female 522

Appendix VII (b).



ADULT FEMALE 474

Appendix VII (c).



Adult female 952

Appendix VII (d).

Signature of Graduate Student

Signature of Major Advisor

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