

# Territoriality and Pairbonding of Gray Foxes in Mississippi

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*Abstract:* Spatial relationships of radio-monitored gray foxes (*Urocyon cinereoargenteus*) were examined over a 5-year period. Marginal overlap (<10%) of convex polygon home ranges of same sex adult foxes with adjacent home range boundaries provided evidence for territoriality. Extensive overlap was observed between juveniles and adults of opposite sex. Mean home range overlap of suspected mated pairs was  $61\% \pm 13\%$ , providing evidence of pair bonding between the sexes. Territory size (home range) may provide a useful measure of population density. Assuming 2 adult foxes inhabit the same range, adult gray fox population density in areas of suitable habitat in the lower Gulf Coastal Plain can be expected to range from 1 adult fox per 183–308 ha.

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A territory is defined as a “defended area” (Nobel 1939), “exclusive area” (Schoener 1968), or an area resulting from non-random spacing among individuals (Davies 1978). For canids, the term “territory” is often used synonymously with “home range.” Lord (1961) and Sargeant (1972) defined a territory as the area occupied by a family. Family areas were either spatially separate or contained regions of exclusive use. Spatial patterns resulting from territorial practices can have important management considerations.

Home range overlap is considered indirect evidence of established territorial boundaries. Progulske (1982) and Wooding (1984) report partial home range overlap among gray foxes whereas Yearsley and Samuel (1980) and Haroldson and

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Fritzell (1984) report extensive home range overlap. Extensive home range overlap may suggest a close association between members of a population. Conversely, little or no range overlap may indicate an avoidance or exclusion of some members.

Sharing of range by mates may explain the extensive overlap observed in some studies. Yet, reports of pair bonding in gray foxes are noticeably absent. Nicholson and Hill (1981), Progulske (1982), Haroldson and Fritzell (1984) report pairs of gray foxes sharing the same range.

To some extent, territoriality and pair bonding can influence population density (Krebs 1971), resource utilization (Maynard Smith 1974), and reproductive success (Howard 1920).

Most studies investigating gray fox movements and home range have been short-term (i.e., <2 years). The purpose of this study was to document intraspecific spatial relationships of gray foxes over a 5-year period. Knowledge of spatial relationships should provide indirect evidence whether territoriality and pair bonding exist for gray foxes.

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## Methods

The Copiah County Wildlife Management Area is located in southwestern Mississippi. Maintained by the MDWFP, the study area is comprised of approximately 2,600 ha of pine forest, mixed pine-hardwoods, bottomland hardwood stands, and fallow and agricultural fields. Upland forests are primarily loblolly pine (*Pinus taeda*) and shortleaf pine (*P. echinata*) mixed with hardwoods; oak (*Quercus* spp.), hickory (*Carya* spp.), and sweetgum (*Liquidambar styraciflua*) dominate the lowlands.

Topography is characterized by gently rolling hills with an average elevation of 180 m above mean sea level. Climate is characterized by warm summers and cool winters. Rainfall averages 140 cm annually. Mean annual temperature is 18° C with approximate 230–240 frost-free days.

Foxes were captured during the fall-early spring months (Sep–Mar) with 1.5 double coil spring leghold traps. Sex, age, and capture location were recorded for each fox. Relative age was determined at time of capture by examination of facial markings (Lord 1961). Foxes captured as juveniles were considered adults at 1 year of age.

Home range estimates were determined by monitoring radio-collared foxes, using portable H-type and permanent directional antennas. Observation stations were established to provide adequate coverage of the study and adjacent areas within the range of radio-collared foxes.

Telemetry readings taken on a radio-transmitter beacon placed at a known location were used to evaluate system accuracy. Beacon locations were kept secret from system operators. An error arc of  $\pm 8^\circ$  was determined from a pooled sample of readings ( $N = 160$ ) taken at 5 different observation stations.

Foxes were monitored throughout the study period. Monitoring was conducted in both diurnal and nocturnal periods. Most observations were taken between 1 hour before sunset to 1 hour after sunrise at 2 hour intervals. Daytime observations were taken randomly. Convex polygon home ranges (Mohr 1947) were generated for juvenile and adults by a modified form of the TELEM program (Koeln 1980).

Home ranges were plotted in a time series to visually compare temporal integrity and spatial patterns among foxes. The first time period began with onset of the study and terminated with the death of the first fox. To allow adequate time for surviving foxes to adjust spatially to the death of a fox, each succeeding time period began with the termination of the previous one and continued until the death of a fox at least 4 months later. Radio-locations taken prior to the start of each time period were excluded from home range calculations. Thus, each time period represented fox activity only during that time period. Time periods were not based on seasonal or biological criteria (i.e., breeding seasons or whelping periods) so that territoriality could be evaluated under all possible influences.

Percentage overlap was calculated for all overlapping home ranges of foxes for each time period. Home range overlap was further delineated by sex and age of fox. All possible combinations of overlap (adult, juvenile, male, and female) were examined.

Responses of adjacent radio-collared foxes to areas vacated by deceased radio-collared foxes were examined by comparing distance between home range centers calculated before and after death. Home range center was considered the position calculated by arithmetic mean  $x$  and  $y$  coordinates. Shifts in home range centers were tested by Wilcoxon's matched-pairs test. A significant reduction in distance between home range centers could be expected if territorial boundaries were relaxed due to the death of a neighboring fox.

Home range expansion also was tested because an adjacent fox could be expected to increase its range to occupy the vacated area. A Wilcoxon's matched-pairs test was used to compare home range size before and after the death of an adjacent conspecific. Standardized home range estimates for each surviving fox (before and after) were determined by selecting equal observations (before and after) to the time period with the lowest sample size.

## Results

From January 1981 to December 1985, 25 gray foxes (13 females, 12 males) were monitored for range and movements (Table 1). Nine time periods were generated to examine spatial tendencies. Home range overlap (Table 2) was not observed for any female foxes during the first year. Juveniles from January to May

**Table 1.** Home range estimates of gray foxes monitored on the Copiah County Wildlife Management Area, Mississippi, 1981–1985.

Period monitored	ID	Capture date	Sex	Age	Home range (ha)	<i>N</i>
1 Jan 81–31 Apr 81	088	10 Jan 81	♀	juv.	321	16
	093	31 Jan 81	♀	juv.	212	14
	099	07 Feb 81	♀	adult	80	6
	092	10 Mar 81	♀	adult	64	6
1 May 81–31 Dec 81	088	10 Jan 81	♀	adult	64	17
	092	10 Mar 81	♀	adult	283	51
	098	13 Mar 81	♀	adult	9	5
1 Jan 82–31 May 82	199	02 Jan 82	♂	juv.	716	123
	393	25 Jan 82	♂	adult	43	11
	089	30 Jan 82	♀	juv.	245	80
	096	03 Mar 82	♀	adult	366	115
	193	08 Mar 82	♂	adult	404	113
	092	10 Mar 81	♀	adult	76	18
	098	31 Mar 81	♀	adult	115	33
1 Jun 82–31 Dec 82	089	30 Jan 82	♀	adult	206	13
	193	08 Mar 82	♂	adult	99	7
	090	17 Oct 82	♀	juv.	721	11
	292	30 Oct 82	♀	juv.	341	5
	196	13 Dec 82	♂	juv.	241	8
1 Jan 83–31 May 83	089	30 Jan 82	♀	adult	281	56
	193	08 Mar 82	♂	adult	128	39
	090	17 Oct 82	♀	juv.	302	26
	292	30 Oct 82	♀	juv.	391	46
	196	13 Dec 82	♂	juv.	322	51
	194	16 Dec 82	♂	juv.	314	56
	188	15 Mar 83	♂	adult	233	40
1 Jun 83–31 Dec 83	091	13 Feb 83	♀	juv.	578	54
	193	08 Mar 82	♂	adult	246	20
	292	30 Oct 82	♀	adult	498	116
	091	13 Feb 83	♀	adult	414	112
	188	15 Mar 83	♂	adult	326	149
	197	18 Sep 83	♂	juv.	1,191	129
	132	11 Oct 83	♂	juv.	1,043	63
	031	24 Oct 83	♀	juv.	958	73
	133	26 Oct 83	♂	adult	455	65
1 Jan 84–30 Apr 84	134	06 Dec 83	♂	juv.	342	27
	292	30 Oct 82	♀	adult	173	25
	188	15 Mar 83	♂	adult	188	26
	197	18 Sep 83	♂	juv.	248	36
	031	24 Oct 83	♀	juv.	266	35
	133	26 Oct 83	♂	adult	486	35
1 May 84–30 Nov 84	134	06 Dec 83	♂	juv.	259	35
	292	30 Oct 82	♀	adult	723	35
	194	16 Dec 82	♂	adult	148	23
	197	18 Sep 83	♂	adult	336	84
	388	11 Sep 84	♂	juv.	598	68
	232	11 Sep 84	♀	juv.	353	67
033	20 Sep 84	♀	juv.	692	48	

*(continued on next page)*

**Table 1.** (continued)

Period monitored	ID	Capture date	Sex	Age	Home range (ha)	N
1 Dec 84–31 Mar 85	232	11 Sep 84	♀	juv.	552	50
	388	11 Sep 84	♂	juv.	1,667	66
	197	18 Sep 84	♂	adult	230	74
	033	20 Sep 84	♀	juv.	1,594	66
	394	07 Dec 84	♂	adult	356	66

appeared to isolate themselves from members of the same sex, apparently establishing their home range after dispersal from their natal area. Adults also isolated themselves unless they shared area with a mate. Some marginal overlap (<10%) was observed among adult males. Overlap was highest between male-female foxes regardless of age class.

A Wilcoxon's matched-pairs test failed to confirm a significant change in home range size after the death of any fox ( $T = 7$ ,  $P = 0.14$ ,  $N = 7$ ). Most surviving foxes actually decreased their home range size (Table 3). Because of a limited sample, comparisons between sex and age were not examined. Home range size of adjacent foxes changed little ( $\bar{x} = -6.5\%$ ,  $SE = 22\%$ ,  $N = 7$ ). The largest increase in home range size was 21%.

Adjacent surviving foxes did not shift their home range center toward areas vacated by the death of a fox ( $T = 12$ ,  $P = 0.03$ ,  $N = 11$ ). In fact, distances between home range centers increased ( $\bar{x} = 33$  m,  $SE = 43$  m).

Home ranges for males and females thought to be mated pairs because they were frequently located in close association with each other, overlapped considerably ( $\bar{x} = 61\%$ ,  $SE = 12\%$ ,  $N = 10$ ) whereas home ranges of foxes not thought to be mated pairs overlapped a lesser extent ( $\bar{x} = 22\%$ ,  $SE = 5\%$ ,  $N = 11$ ).

**Table 2.** Average home range overlap (%) of radio-collared gray foxes on the Copiah County Wildlife Management Area, Mississippi. Sample sizes are shown in parenthesis.

Combination	Mated pairs		Adjacent non-mated pairs					
			♂/♂		♂/♀		♀/♀	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Juv.-juv.	64.2 (5)	12.2	32.2 (1)	0.0	17.9 (4)	19.8	1.9 (3)	0.8
Juv.-adult	57.3 (3)	13.9	32.9 (6)	19.8	27.2 (10)	24.1	19.2 (3)	22.8
Adult-adult	57.6 (2)	17.3	9.2 (1)	0.0	4.6 (3)	0.5		
All	60.8 (10)	13.4	29.8 (8)	18.7	21.0 (17)	22.2	10.5 (6)	17.8

**Table 3.** Spatial response of adjacent surviving gray foxes to home range centers of deceased foxes on the Copiah County Wildlife Management Area, Mississippi, 1981–1985.

Deceased fox	Adjacent survivor	% change in home range size	Shift in home range center (m)
91	31	-44	11.5
	134	-25	48.6
	197	-23	-135.9
132	292	21	148.0
194	188	-19	177.7
	292	21	-12.5
196	197	-23	313.1
31	197	-8	75.9
133	292	18	-4.1
134	197	-8	78.3
188	292	18	63.6
Composite Mean $\pm$ SE		-6.5 $\pm$ 22.3	32.8 $\pm$ 43.3

## Discussion

Spatial response of surviving radio-collared foxes to areas recently vacated by the death of a fox was subtle. Surviving foxes did not expand nor shift their home range towards the vacated areas.

Two explanations could account for the lack of spatial response by surviving foxes. First, the vacated area could already be occupied by another fox of the same sex. However, trapping efforts were intensive each year of the study, and based on capture/effort data, it is believed that a high percentage of foxes living on the area were monitored. Second, the area was not saturated with foxes and all resource needs were met without adjusting home range. An adult mortality rate of 66%–70% (Tucker and Jacobson 1986) and a documented outbreak of distemper in 1984 kept the population below capacity. In this case, there would be no need for a fox to expand its range unless limited by food or cover. Further, in 7 out of 11 cases, home range size decreased.

One potential bias in estimating degree of overlap observed among fox home ranges is the method used to delineate home range perimeter. The convex polygon method can easily include areas not utilized by the fox and magnify the degree of overlap.

Marginal home range overlap (narrow overlap near the home range boundary) between adults of the same sex suggests that gray foxes practice territorial tendencies. Trapp (1973), Follman (1973), Progulske (1982), and Wooding (1984) found similar spatial patterns among gray foxes. In contrast, Hovis et al. (1984) in a review paper, reported that the frequent overlap of home ranges, e.g., Yearsley and Samuel (1980) and Haroldson and Fritzell (1984), suggested a low degree of territoriality among gray foxes. Yearsley and Samuel (1980) reported range overlap for

gray foxes using land bridges as travel corridors. These land bridges were considered important in facilitating intraspecific contacts. Haroldson and Fritzell (1984) reported considerable home range overlap of gray foxes, but they were spaced farther apart than expected by random occupation of habitat. Further, neither kinship of neighboring foxes nor influence of sympatric predators was determined by either Haroldson and Fritzell (1984) or Yearsley and Samuel (1980).

Although foxes did not adjust their home range with respect to the death of an adjacent fox, exclusion of same-sex adults provided exclusive areas for the family unit. Under these guidelines we believe that territoriality is practiced among gray foxes (Lord 1961, Sargeant 1972).

Adults tolerated the presence of juveniles within their home range prior to their dispersal. Nicholson and Hill (1981) report a strong bond between adult females and their young before dispersal. In this study, several radio-collared juveniles dispersed during September-May to new areas. The close association between adults and juveniles supports the concept of a family unit described by Lord (1961). This may explain why juvenile and adult home ranges frequently overlapped.

The sharing of home range areas by some males and females, especially during the spring months (Mar-May), suggests that pair bonding exists between the sexes. Progulské (1982) also observed mated pairs with a high degree of overlap (60%–64%), whereas non-mated pairs overlapped considerably less (6%–35%). Nicholson (1982) and Haroldson and Fritzell (1984) also report fox pairs maintaining the same range during the entire study. This study provides additional evidence of pair bonding as supported by the close association between several radio-collared fox pairs. Sometimes the range of 1 fox encompassed the entire range of the other fox and they were frequently located together. Pair bonding was further supported by observation of a radio-collared fox pair in association with a litter of pups tagged at the female's den site. Both male and female foxes remained close to the den site until radio-collar failure prevented further monitoring of the male.

Generally, mated pairs consisted of a juvenile-adult combination. These foxes were considered mated pairs because they were frequently located close together after the dispersal period, October to January (Sheldon 1950, Nicholson and Hill 1981). A high adult mortality rate (Tucker and Jacobson 1986) reduced the availability of adults as mates. This may explain the preponderance of juvenile-adult pair bonding observed in this study.

## Management Implications

Future management strategies for gray foxes should consider territorial and pairbonding activities. The establishment of territories demonstrated by foxes in this study may be a useful measure of population density. Territory size (home range) can therefore be used to estimate the maximum population level that may be expected in an area. Annual adult home range size of foxes in this study ranged from 366 to 616 ha. If we assume 2 adult foxes inhabit the same range and

account for boundary overlap, the adult fox population density in a given area of suitable fox habitat in the lower Gulf Coastal Plain can be expected to range from 1 adult fox per 183–308 ha. According to these calculations, the fox population density on the Covich County WMA would be expected to range from 9 to 15 adult foxes (0.32–0.55 foxes per km<sup>2</sup>). Over a 5-year period, a juvenile-adult ratio of 0.9:1 was determined from trapping efforts (Tucker and Jacobson 1986). If the population level was expanded to include 1 juvenile fox per adult fox, a population density of 0.69 to 1.15 foxes per km<sup>2</sup> could be expected. This compares favorably with the density of 1.0 to 1.5 foxes per km<sup>2</sup> found by Lord (1961) and Progulské (1982) in Florida using age-ratio reduction and mark-recapture techniques, respectively.

Home range estimates observed in this study were similar to those reported in Missouri (Haroldson and Fritzell 1984) and Florida (Progulské 1982). Geographic locations with smaller territories reported for foxes may expect higher fox population densities. Future studies should investigate factors influencing territory size.

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