Seasonal Home Range Size and Movement Behavior of the Gray Fox on the Savannah River Site, South Carolina

David T. Sawyer,[1] *Department of Aquaculture, Fisheries and Wildlife, Clemson University, Clemson, SC 29634–0362*

T. T. Fendley, *Department of Aquaculture, Fisheries and Wildlife, Clemson University, Clemson, SC 29634–0362*

Abstract: Nineteen gray foxes (*Urocyon cinereoargenteus*) were equipped with radio-transmitter collars and located by triangulation on the Savannah River Site, Aiken, South Carolina, between 22 March 1985 and 24 May 1986. Telemetry locations (N = 3,008) were used to estimate seasonal home range sizes (N = 23) and calculate minimum total distances (MTD) moved (N = 192). Seasonal home range sizes were not different between sexes or seasons ($P > 0.05$). Average seasonal home range sizes were 173 ha for males, 139 ha for females, and 158 ha for both sexes combined. MTDs were not different between sexes ($P > 0.05$). Denning season MTDs ($\bar{x}$ = 3,459 m) were smaller than those of pup rearing ($\bar{x}$ = 5,360 m) and dispersal and mating ($\bar{x}$ = 5,742 m) seasons ($P < 0.05$).

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 44:379–389

Reviews of gray fox home range size and movement behavior have been provided by Trapp and Hallberg (1975), Fritzell and Haroldson (1982), Samuel and Nelson (1982), Hovis et al. (1984), and Fritzell (1987). These reviews depict the home range size of this species to be highly variable across geographic locations and provide limited information concerning sex and seasonal descriptions of home range size and movement behavior.

Temporal changes in use of home range area and travel distances probably reflect behaviors associated with seasonally occurring environmental and/or physiological conditions. These seasonal changes may affect reliability of data analyses that span seasonal boundaries (Hovis et al. 1984, Laundre and Keller 1984), and pooling data collected across several seasons eliminates sensitivity to changes in area use over time (Smith et al. 1981).

[1]David T. Sawyer, North Carolina Wildlife Resources Commission, Division of Wildlife Management, 851 Perrytown Rd., New Bern, NC 28562.

Laundre and Keller (1984), in a critical review of coyote (*Canis latrans*) home range size, suggested seasonal blocking of data collection using the 4-season scheme proposed by Smith et al. (1981). Smith et al. (1981) based their seasons (pair formation and breeding, gestation, pup rearing, and dispersal) on major phases of the coyote reproductive cycle. We believe a similar seasonal breakdown of gray fox telemetry data will provide the most reliable data analysis and most useful information.

Solar seasons do not take into account different environmental conditions that exist concurrently at different latitudes which can affect timing of physiological and behavioral phenomena (Laundre and Keller 1984). Therefore, obtaining measurements of home range size and movement behavior during seasons based on major phases of the gray fox's reproductive cycle would enable more reliable interstudy comparison of the species' spatial requirements. Seasonal estimates of home range and movement rates would be particularly useful when establishing indexing techniques such as scent station or predator call surveys. The objectives of this study were to estimate seasonal home range sizes and seasonal movement rates for male and female gray foxes on the Savannah River Site (SRS) and describe any sex and/or seasonal differences.

This is Technical Contribution No. 3115 of the South Carolina Agricultural Experiment Station, Clemson University. The study was conducted through the South Carolina Aquaculture, Fisheries and Wildlife Cooperative, a research and educational unit of Clemson University and the South Carolina Wildlife and Marine Resources Department. The study was partially supported by contract DE-AD09–76SR00819 between the University of Georgia and the U.S. Department of Energy. We thank O. E. Baker and M. W. Hall for technical assistance, H. S. Hill for statistical consultation, and the personnel at the University of Georgia's Savannah River Ecology Lab for their hospitality and assistance.

Methods

This study was conducted on a 110-km^2 portion of the 778-km^2 SRS located in Aiken, Allendale, and Barnwell counties of South Carolina. The SRS was closed to public access in 1952, and the U.S. Forest Service initiated a forest management program at that time. The study area, described by Buie (1980) and Griffith (1985), is located in the center of the SRS on the Aiken Plateau.

The majority (76%) of managed forest consisted of longleaf (*Pinus palustris*), slash (*P. elliottii*), and loblolly (*P. taeda*) pine plantations of varying ages and degrees of understory (Buie 1980). Other forest types in the study area consisted of mixed pine hardwood (1%), upland hardwood (2%), and bottomland hardwood (14%). Industrial areas (6%) and ponds and lakes (1%) also were present. A detailed description of SRS forest types and their components is given by Jones et al. (1981).

As a result of intensive forest management practices, there was a high degree of clearcut and pine stand interspersion. Clearcuts were restricted in size to 16 ha (Buie 1980). Old field habitat around industrial areas and within gas and power line corridors contributed to habitat interspersion. Numerous primary and secondary (gravel and dirt) roads facilitated fox trapping and radio telemetry. No gray fox hunting or trapping, except for research purposes, is permitted on the SRS.

Gray foxes were live captured and equipped with radio-transmitter collars. Directional bearings were obtained by triangulation from at least 2 reference points, geographic features clearly recognizable on SRS maps. Because of the large number of reference points available, most triangulation approximated 90° from the signal source at a distance of about 0.40 km. Radio equipped foxes were proximate in location and azimuths could usually be obtained for 2 to 3 foxes at a single reference point. Therefore, the time between first and second bearings for a particular fox was about 5 minutes. Average error polygon size was estimated to be 0.40 ha based on replicated azimuths obtained from transmitters at locations unknown to the observer. The tracking procedure consisted of obtaining locations every 2 hours during 24-hour tracking periods (diels) conducted 3 times each month.

Home range sizes were computed by Mohr's (1947) minimum area method using computer programs developed by Hill and Fendley (1982) and modified by Boyle (1986). Home range stabilization was determined by a modification of Odum and Kuenzler (1955). A <5% increase in estimated home range size was considered to indicate home range stabilization (Buie 1980). Analysis of gray fox movement behavior was based on computations of Minimum Total Distance (MTD) moved, calculated from diel locational data. MTD is the sum of the distances between sequential locations in a diel tracking period (Marchinton and Jeter 1966).

Major phases of the gray fox reproductive cycle consist of: breeding or mating (Jan–Feb, Sullivan 1956, Layne 1958, Wood 1958, Hall 1983), denning and whelping (Mar–May, Layne 1958, Wood 1958, Tullar and Berchielli 1982, Hall 1983, Nicholson et al. 1985), pup rearing after emergence from dens (Jun–Aug, Tullar and Berchielli 1982, Nicholson et al. 1985), and juvenile independence and dispersal (Sep–Feb, Sheldon 1953, Sullivan 1956, Tullar and Berchielli 1982, Hall 1983, Nicholson et al. 1985). Because timing of seasons may vary geographically, Laundre and Keller (1984) suggested investigators modify the end points and beginnings of seasons for their particular area. Since seasonal reproductive behaviors are difficult to observe and probably vary between individuals, we examined MTDs and home range cumulative area curves for increases or decreases in an effort to delineate the approximate onset and endings of seasons.

Comprehensive cumulative area curves were constructed for all foxes (using all available locational data) and compared for points of increase in home range area. Data contained in periods of stabilization were examined separately to determine points of decrease in home range area. In a similar manner, MTDs were examined for points of increase or decrease in travel distances. The latest date that the majority of MTD travel rates and home ranges were stable was considered to be the end of a season. Using these methods, the onset and cessation of gray fox reproductive seasons were established.

Once seasons were delineated, seasonal cumulative area curves were constructed (using locational data collected within season date brackets) for each fox and examined for home range stabilization. Only stabilized seasonal home range estimates were used in home range analysis. When a fox's home range began changing in area prior to the season's end, locational data collected after the last date that its home range was stable and prior to the season's end was not used in home range analysis. All MTDs were used in sex and seasonal analysis of movement behavior.

Using GLM procedures of SAS Version 5 (SAS 1985), a split plot analysis of variance procedure was used to test gray fox home range size and MTDs for differences between sexes, seasons, and sex by season interactions. If an analysis of variance comparison resulted in a significant difference, means were separated using a Least Significant Difference (LSD) test.

Results and Discussion

Home Range

Nineteen gray foxes were equipped with radio-transmitter collars and located by triangulation (N = 3,008) between 22 March 1985 and 24 May 1986. Sufficient locational data were recorded to construct stabilized cumulative area curves for 14 of 19 radio tracked gray foxes. Examination of cumulative area curves and MTD rates enabled the delineation of 3 gray fox seasons: denning (1 Mar–23 May), pup rearing (24 May–31 Aug), and dispersal and mating (1 Sep–28 Feb).

Twenty-three seasonal home ranges were estimated for the 14 individual animals with stabilized cumulative area curves (Tables 1, 2). The average number of observations required to delineate a stabilized seasonal home range was 71 (N = 7) in the pup rearing season, 72 (N = 9) in the dispersal and mating season, and 64 (N

Table 1. Seasonal and comprehensive stabilized home range estimates (ha) for 8 male gray foxes radio-tracked on the Savannah River Site, South Carolina, 1985–86.

	Seasonal home range size				
I.D. no.	Pup rearing	Dispersal -mating	Denning	Seasonal average	Comprehensive home range
437	127 (84)[a]	339 (180)	128 (86)	198 (350)	354 (392)[b]
456	93 (106)	134 (168)	69 (99)	99 (373)	153 (396)
563[c]	3,369 (128)			3,369 (128)	3,439 (153)
686		497 (94)		497 (94)	572 (127)
734	201 (117)			201 (117)	225 (181)
883		99 (79)	65 (74)	82 (153)	118 (167)
940			86 (99)	86 (99)	102 (185)
982		238 (106)		238 (106)	238 (108)
Mean	140 (102)	261 (125)	87 (90)		252 (222)

[a] Number of radio locations are in parentheses.
[b] Observations not used in seasonal home range estimates were used to calculate comprehensive home range (see methods).
[c] Fox 563 was not included in statistical comparisons or pup rearing season and comprehensive home range averages because of atypically large estimates.

Table 2. Seasonal and comprehensive stabilized home range estimates (ha) for 6 female gray foxes radio-tracked on the Savannah River Site, South Carolina, 1985–86.

I.D. no.	Seasonal home range size: Pup rearing	Dispersal -mating	Denning	Seasonal average	Comprehensive home range
653	63 (77)[a]		98 (99)	81 (176)	276 (189)[b]
694	82 (105)	118 (185)		100 (290)	122 (333)
711	73 (95)			73 (95)	86 (121)
863		298 (107)		298 (107)	324 (121)
902		156 (68)	98 (86)	127 (154)	209 (168)
919		346 (85)	59 (100)	203 (185)	357 (185)
Mean	73 (92)	230 (111)	85 (95)		229 (186)

[a] Number of radio locations are in parentheses.
[b] Observations not used in seasonal home range estimates were used to calculate comprehensive home range (see methods).

= 7) in the denning season. Comparisons of gray fox home range size indicated no differences between sexes ($F = 1.07$, df = 1, $P > 0.05$) or seasons ($F = 3.58$, df = 2, $P > 0.05$), nor any significant sex-by-season interaction ($F = 0.09$, df = 2, $P > 0.05$). The yearly average of seasonal home ranges was 173 ha for males, 139 ha for females, and 158 ha for males and females combined.

Male and female gray fox home range sizes also were similar ($P > 0.05$) in Florida (Progulske 1982), in Louisiana (Foote 1984) and on the SRS (Jeselnik 1981). Jeselnik (1981), who delineated 3 seasons (mating, Dec–mid-Mar; denning, Mar – Jul; and post denning, Aug–Nov) based on reproductive behaviors described by Wood (1958), also reported no seasonal home range differences for SRS foxes. Trapp (1978) reported gray fox home range size as an average of seasonal estimates, but did not test for differences in home range size. Although no study has shown significant differences between male and female home ranges, the majority have reported larger average home range estimates for males (Follman 1973, Hallberg 1974, Yearsley and Samuel 1980, Nicholson and Hill 1981, Progulske 1982, Foote 1984, and Wooding 1984).

Although not statistically different, the average home range size for males in this study was larger than for females in each season and progressively increased from the denning season through the pup rearing season and the dispersal and mating season (Tables 1, 2). Mean seasonal home range sizes for females did not follow this trend, as the smallest average home range estimate was calculated for the pup rearing season, and the largest for the dispersal and mating season (Table 2). When both sexes were combined, the trend in mean seasonal home range size followed that of the males, which had the larger sample size of the 2 sexes. Jeselnik (1981) described variations in average male and female seasonal home range sizes to follow the same trends, but found the sexes combined followed the trend of the females, which had the larger denning season sample size.

Larger dispersal and mating season home ranges are probably the result of increased movements due to mating activities, absence of pup rearing responsibilities, and/or a decreasing abundance of prey. All radio-tracked female foxes of this study were suspected to have had pups during both the denning and pup rearing seasons and 2 males were suspected to be mates of denning and pup rearing females. Smaller denning and pup rearing season ranges were probably the result of decreased movement associated with denning activities, low pup mobility, and/or an increasing supply of food. Follman (1973) attributed an increase in gray fox territories (here interpreted as home range) in February to increased activity brought on by breeding, and small territories of females during April to be a result of whelping. Nicholson and Hill (1981) reported that general increases in home range size occurred for most foxes in late fall and winter and that the smallest nightly ranges for adult females generally occurred in April. These descriptions support the trends in seasonal home range reported here and by Jeselnik (1981).

Seasonal changes in area of use were predominantly a result of expansions or contractions of the home range boundary rather than shifts of home range location. Only 2 foxes (males 563 and female 653) of the 14 with valid seasonal home range estimates made noticeable shifts in home range location. Jeselnik (1981) described the seasonal shifts in home range location of SRS gray foxes to be small in relation to the total range area involved and found extensive overlap to exist between all seasonal home ranges of the same fox. Only slight shifts in monthly home ranges were described by Haroldson and Fritzell (1984) for gray foxes in Missouri.

A statistical comparison of comprehensive home range sizes was not conducted in this study because of the variability in length of time and time of year that individual foxes were radio-tracked. Comprehensive home ranges were calculated (using all available data of each fox having a stable home range within at least 1 season) to provide information for those wishing to compare our home range estimates with those of studies that did not estimate seasonal home range sizes (Tables 1, 2). Due to the possibility of home range expansions, contractions, or shifts caused by behavioral changes occurring during parts of the year that individual foxes were not radio tracked, it is uncertain that a reliable mean comprehensive home range size was obtained in this or other studies. Additionally, comparison of comprehensive home range size within studies is biased if comparisons are made between animals that are not radio-tracked during the same periods of the year (Hovis et al. 1984). For example, Fuller (1978) who had no concurrently radio-tracked foxes, attributed differences in female gray fox home range size to differences in habitat quality within their home ranges. Comprehensive estimates do, however, describe the largest area of use for each individual and are therefore valuable in documenting total area requirements over time.

Movement Behavior

Statistical analysis revealed no difference in daily movement due to sex (F = 0.10, df = 1, $P > 0.05$) or the interaction of sex and season (F = 2.18, df = 2, $P > 0.05$), but a difference due to season (F = 20.41, df = 2, $P < 0.01$). No significant differences were found between daily movements of males and females by Progulske (1982), annual movements of males and females by Follman (1973), or males and females tracked during the non-breeding season of Foote (1984).

The significant difference between seasons in this study was due to the smaller movements of foxes during the denning season (Table 3). Mean MTD rates of the pup rearing and dispersal and mating seasons were not significantly different from each other. Progulske (1982) reported seasonal MTD rates to be the smallest in the denning and whelping season and the largest during the breeding season. Foote (1984) found no significant difference between female travel distances during the breeding and non-breeding season, but did report significantly greater movements for males during the breeding season. In this study, significantly larger pup rearing and dispersal and mating season MTD rates for both sexes were probably a result of 1 or more of the following possibilities: fewer pup rearing responsibilities and/or increased pup mobility, increased movements associated with mating activities (Progulske 1982), and increased movements as a result of decreasing prey abundance (Progulske 1982).

Smaller female denning season MTD rates were probably the result of whelping and denning activities. Decreased movement and smallest nightly ranges of females during the months of March and April were observed by Follman (1973) and Nicholson and Hill (1981). Smaller MTD rates for males during the denning season also are suspected to be the result of denning behavior. As observed by Nicholson et al. (1985), males demonstrated diurnal affinities to den sites. Two observations made during this study provide evidence that male gray foxes do spend some time in the vicinity of the den site. On 15 May 1985 a den site was located by searching the diurnal resting area of a radio-collared male gray fox, and on 23 May 1986 2 gray foxes suspected to be a mated pair were seen with 3 pups resting in the center of an overgrown secondary road. Little is known of the contribution of male gray foxes in pup rearing, although male red foxes have been reported to assist the female (Ables 1975).

Comprehensive MTD rates for males averaged 5,303 m, females averaged 4,545 m, and sexes combined averaged 4,987 m (Table 3). Other researchers using similar methods of data collection have reported considerably smaller MTD rates

Table 3. Average minimum total distance moved by sex and season for 19 gray foxes radio-tracked on the Savannah River Site, South Carolina, 1985–86.

	Mean distance moved (m)			
Sex	Pup rearing	Dispersal -mating	Denning	Comprehensive
Males	5,887 (28)[a]	5,695 (56)	3,935 (28)	5,303 (112)
Females	4,493 (17)	5,819 (35)	2,984 (28)	4,545 (80)
Combined[b]	5,360 (45)[1]	5,742 (91)[1]	3,459 (56)[2]	4,987 (192)

[a] Number of diel periods are in parentheses.
[b] Combined sexes with the same number are not significantly different ($P > 0.05$).

for gray foxes than those reported here. Progulske (1982) listed average daily movements in northeastern Florida to be 3,505 m (N = 25) for males, 2,890 m (N = 25) for females, and 3,179 m (N = 50) for sexes combined. Foote (1984) reported average MTD rates for males to be 4,233 m (N = 30) and for females to be 3,735 m (N = 20) in southeast Louisiana. Both Progulske (1982) and Foote (1984) reported substantially larger average home range estimates than those of our study. Although possibly coincidental, the MTDs of our study and those reported by Progulske (1982) and Foote (1984) progressively increased with study area latitude.

Implications

As observed by Foote (1984) gray foxes are capable of crossing their estimated home ranges daily. By comparing average seasonal MTDs (Table 3) with an estimate of their respective approximate home range diameters (most home ranges were not perfectly square or round but slightly elongated), it is obvious that foxes could traverse their home ranges in less than half the diel period. Foote (1984), also confirmed that the actual distances traveled between locations were much greater than 2-hour sampling intervals could detect. Decreasing the time interval between successive locations would better describe gray fox movements, although small time intervals could affect estimates of home range due to the possibility of autocorrelation (Swihart and Slade 1985).

Using average seasonal home range sizes and MTD travel rates of combined sexes, an index of home range utilization [index = $\bar{x}$ MTD rate (km) / $\bar{x}$ home range size (km^2)] can be calculated. Indices of home range utilization were 4.02 for the denning season, 5.01 for the pup rearing season, and 2.32 for the dispersal and mating season. Based on these indices, the probability of a particular fox locating a scent station established within its home range would be greatest during the pup rearing season. However, the probability of establishing 1 or more scent stations within the area of use of a particular fox would be greatest during the dispersal and mating season, when home ranges are largest. Because dispersal and mating season travel rates are sufficient for SRS gray foxes to thoroughly traverse their home ranges, we believe that an individual is more likely to respond to randomly established surveys during this season. Higher rates also could be expected during this season because it contains the largest mobile population size. Additionally, increased social interaction resulting from dispersing juveniles and selection of mates could enhance visitation to certain attractants. Conner et al. (1983) reported highest gray fox visitation to scent stations in a Florida study occurred from October through December.

Based on the average dispersal and mating season home range size and the standard scent station survey procedure (stations established on transects 0.32 km apart), an individual fox's home range may contain from 1 to 8 stations depending on the orientation of a linear home range. The combination of many stations within the home range and large travel rates may result in visitation to several stations by an individual fox during the 1 night scent station survey period. Therefore, to reduce the probability of multiple visitations by an individual fox, our home range and movement estimates indicate that the distance between scent stations used for surveying gray foxes should be increased.

Gray fox home range sizes are possibly affected by population density (Trapp and Hallberg 1975, Jeselnik 1981, Nicholson and Hill 1981). As a result of visitation probabilities changing with different home range sizes, an increase in fox density could occur without resulting in an increase in scent station visitation rate. Additional studies are needed to evaluate the relationships between survey methodologies and gray fox home range size, travel rates, and population density.

Seasonal computations of home range as used in this and other studies (Trapp 1978, Jeselnik 1981) and possibly monthly computations of home range (Follman 1973, Haroldson and Fritzell 1984) should give more reliable home range estimates because information is used to delineate a home range only for the period during which it is collected. Seasonal estimates of home range are more informative than monthly or comprehensive estimates because they are associated with various temporal behaviors controlled by environmental and/or physiological conditions. In addition, locational data gathered from an individual, which are likely to be insufficient to produce a reliable comprehensive (cumulative or composite) home range estimate, may be more than ample to produce a reliable (i.e. stabilized) home range estimate during 1 or more biological seasons. In our study the pattern of change in home range size and diel movement behavior was used to delineate the onset and cessation of reproductive seasons. Seasons based on reproductive behaviors rather than calendar periods allow intrastudy and interstudy comparisons of home range size, movement behavior, and, if plant communities are similar, comparisons of habitat use.

Literature Cited

Ables, E. D. 1975. Ecology of the red fox in North America. Pages 216–236. *in* M. S. Fox, ed. The wild canids; their systematics, behavioral ecology and evolution. Van Nostrand-Reinhold Co., New York.

Boyle, K. A. 1986. A comparison of methods of home range analysis. M. S. Thesis, Clemson Univ., Clemson, S.C. 67 pp.

Buie, D. E. 1980. Seasonal home range and movement patterns of the bobcat on the Savannah River Plant. M. S. Thesis, Clemson Univ., Clemson, S.C. 68pp.

Conner, M. C., R. F. Labisky, and D. R. Progulske, Jr. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes, and opossums. Wildl. Soc. Bul. 11:146–152.

Follman, E. H. 1973. Comparative ecology and behavior of red and gray foxes. Ph.D. Diss., South. Ill. Univ., Carbondale. 152pp.

Foote, A. L. 1984. Home range, movements, and habitat utilization of gray foxes in eastern Louisiana. M. S. Thesis, La. State Univ., Baton Rouge. 91pp.

Fritzell, E. K. 1987. gray fox and island gray fox. Pages 408 – 420 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. eds. Wild furbearer management and conservation in North America. Ontario Trappers Assoc., Ontario, Can.

——— and K. J. Haroldson. 1982. *Urocyon cinereoargenteus* Ecol. Mammal. Species Rev. 189. 8pp.

Fuller, T. K. 1978. Variable home-range sizes of female gray foxes. J. Mammal. 59:446–449.

Griffith, M. A. 1985. Seasonal home range sizes, movement patterns and dispersal behavior of the bobcat on the Savannah River Plant. M. S. Thesis, Clemson Univ., Clemson, S.C. 78pp.

Hall, M. W. 1983. Artificial dens and feeders in the stocking and management of gray fox for sport hunting. M. S. Thesis, Univ. Ga., Athens, 113pp.

Hallberg, D. L. 1974. A contribution toward the better understanding of the gray fox (*Urocyon cinereoargenteus*) temporal and spatial natural history. M. S. Thesis, Calif. State Univ., Sacramento. 285pp.

Haroldson, K. J. and E. K. Fritzell. 1984. Home ranges, activity, and habitat use by gray foxes in an oak-hickory forest. J. Wildl. Manage. 48:222–227.

Hill, H. S. and T. T. Fendley. 1982. Animal movement and home range determination package. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:656–663.

Hovis, J. A., R. F. Labisky, and S. R. Humphrey. 1984. Biology of the gray fox, with implications for its management in Florida. Univ. Fla. School For. Resour. and Conserv. Wildl. Policy Pap. 1. 29pp.

Jeselnik, D. L. 1981. Comparative analysis of movement, behavior, and habitat utilization of free-ranging gray foxes. M. S. Thesis, Univ. Ga., Athens, 104pp.

Jones, S. M., D. H. Van Lear, and S. K. Cox. 1981. Major forest community types of the Savannah River Plant: A field guide. Savannah River Plant, Nat. Environ. Res. Park Prog., USDE SRO-NERP–9. 64pp.

Laundre, J. W. and B. L. Keller. 1984. Home-range size of coyotes: a critical review. J. Wildl. Manage. 48:127–139.

Layne, J. N. 1958. Reproductive characteristics of the gray fox in Southern Illinois. J. Wildl. Manage. 22:157–163.

Marchinton, R. L. and L. K. Jeter. 1966. Telemetric study of deer movement-ecology in the southeast. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 20:206–214.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223–249.

Nicholson, W. S. and E. P. Hill. 1981. An ecological study of the gray fox in eastcentral Alabama. Coop. Wildl. Proj. Final Rep., Proj. W–44–5. 47pp.

———. E. P. Hill, and D. Briggs. 1985. Denning, pup-rearing, and dispersal in the gray fox in East-Central Alabama. J. Wildl. Manage. 49:33–37.

Odum, E. P. and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72:128–137.

Progulske, R. P., Jr. 1982. Spatial distribution of bobcats and gray foxes in eastern Florida. M. S. Thesis, Univ. Fla., Gainesville, 62pp.

Samuel, D. E. and B. B. Nelson. 1982. Foxes. Pages 475–490 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America. The Johns Hopkins Univ. Press, Baltimore, Md.

SAS Institute, Inc. 1985. SAS User's Guide: Basics, Version 5 Ed. Cary, N.C. SAS Inst., Inc. 1290pp.

Sheldon, W. G. 1953. Returns on banded red and gray foxes in New York State. J. Mammal. 34:125–126.

Smith, G. J., J. R. Cary and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildl. Soc. Bul. 9:88 – 93.

Sullivan, E. G. 1956. Gray fox reproduction, denning, range, and weights in Alabama. J. Mammal. 37:346–351.

Swihart, R. K. and N. A. Slade. 1985. Influence of sampling interval on estimates of home-range size. J. Wildl. Manage. 49:1019–1025.

Trapp, G. R. 1978. Comparative behavioral ecology of the ringtail (*Bassariscus astutus*) and the gray fox (*Urocyon cinereoargenteus*) in Southwestern Utah. Carnivore 1:3–32.

——— and D. L. Hallberg. 1975. Ecology of the gray fox (*Urocyon cinereoargenteus*): a review. Pages 164–178 *in* M. S. Fox, ed. The wild canids: their systematics, behavioral ecology and evolution. Van Nostrand-Reinhold Co., New York.

Tullar, B. F., Jr., and L. T. Berchielli, Jr. 1982. Comparison of red foxes and gray foxes in central New York with respect to certain features of behavior, movement, and mortality. N.Y. Fish and Game J. 29:127–133.

Wood, J. E. 1958. Age structure and productivity of a gray fox population. J. Mammal. 39:74–86.

Wooding, J. B. 1984. Coyote food habits and the spatial relationship of coyotes and foxes in Mississippi and Alabama. M. S. Thesis, Miss. State Univ., Mississippi State. 43pp.

Yearsley, E. F. and D. E. Samuel. 1980. Use of reclaimed surface mines by foxes in West Virginia. J. Wildl. Manage. 44:729–734.