COMPARISON OF SPATIAL AND TEMPORAL ACTIVITY OF RED FOXES AND GRAY FOXES IN NORTH-CENTRAL FLORIDA

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Abstract.—Two adult male red foxes (*Vulpes vulpes*) and five adult male gray foxes (*Urocyon cinereoargenteus*) were radio tracked in northwestern Putnam County, Florida, to obtain information on use of space and time by these morphologically similar canids. Mean home range size of red foxes was 961 ha (599 and 1323 ha; n = 2) compared to 550 ha (range 362-827 ha; n = 3) for gray foxes. The largest ranges of both species were primarily in high pine sandhill habitat. There was more overlap in home ranges between than within species. Both species were primarily nocturnal although red foxes tended to travel farther during nightly foraging activities. Gray foxes rested in dense cover during the daytime and foraged preferentially in open fields and mesic oak forests at night. Red foxes rested in more open habitats during the daytime and foraged preferentially in open fields and xeric oak forests at night. Coexistence of red foxes and gray foxes on the study area appeared to be facilitated by subtle differences in habitat use, dietary preferences, and low fox densities.

Until about 30 years ago red foxes (*Vulpes vulpes*) in Florida were confined to counties of the panhandle (Hall and Kelson 1959), and even in this area they did not appear to be abundant (Wood et al. 1958, Wood 1959), although Jennings et al. (1960) reported that red fox numbers were increasing in some western counties. The appearance of red foxes in north-central and central Florida in the 1960's and 1970's was apparently related to introductions by hunters (Lee and Bostelman 1969, Conti 1984). Subsequent expansion of red foxes into surrounding areas presumably has been facilitated by clearing and drainage (Lee and Bostelman 1969) since areas with an interspersion of pastures, fields, and woods appear to be their preferred habitat (Ables 1974). Whether the introduction of red foxes had an effect on the numerically abundant (Wood 1959) gray fox (*Urocyon cinereoargenteus*) is not known. Gray foxes are typically associated with dense woodlands and brushy areas (Trapp and Hallberg 1975), except in the extreme southeastern U.S. where they are more abundant in mixed woods and cultivated areas (Wood et al. 1958, Progulske 1982). Trapp and Hallberg (1975) suggested that this difference in habitat use by gray foxes in the southeast was related to the absence of red foxes, and hence competition. How these morphologically similar canids are currently coexisting in north-central Florida was the object of this study.

Florida Field Naturalist 17(1): 11-18, 1989.

Study Area and Methods

The study was conducted at the Katharine Ordway Preserve-Swisher Memorial Sanctuary in north-central Florida, Putnam County. Upland areas comprise about 64% of of this 3,750 ha tract and most uplands are dominated by high pine sandhills. Mesic hardwood forests fringe the dark water areas and with increasing elevation grade into xeric oak forests. The latter also occur around the clear water lakes and on old fields and pastures. Wetlands, mostly wet prairie, comprise the remaining 36% of this tract.

Five adult male gray foxes and two adult male red foxes were captured in live traps, radio-collared, and tracked for varying lengths of time. Foxes were classified as adult on the basis of size, weight, dental characteristics, and scrotal development.

The locations of tagged animals were determined by triangulation from know reference points using portable-receiving equipment. Home range size of individuals tracked for at least six months was determined by the minimum convex polygon method (Mohr 1947). Tagged animals were located during the day as well as at night to obtain information on rest site selection and foraging parameters. Each radio location was assigned to a habitat category based on the vegetation type within a 4-ha area (minimum area of resolution; Heezen and Tester 1967). If more than one habitat type was included in the 4 ha, each type was assigned a fractional value based on the actual coverage of the habitats in the quadrat. The proportion of different habitat types within the home ranges of red foxes and gray foxes were calculated from overlays on a habitat map. The distribution of the radio locations in the various habitats was assumed to reflect the proportionate use of those habitats. A Chi-square goodness-of-fit test was used to determine if red and gray foxes used the various habitats in proportion to their availability. Selection for or against particular habitat types was evaluated using Bonferroni confidence intervals (Byers et al. 1984).

Activity of animals was determined by recording changes in amplitude of signals from the transmitters; transmitters were not equipped with activity sensors (Garshelis et al. 1982). For analysis of travel patterns, only those nights with more than five locations on each animal were used. Estimates of the distance traveled per night were measured as the sum of the straight-line distances between consecutive locations.

Results

Red Fox 1 (RF1) used an area of about 600 ha during the six months (February-July 1985; 68 locations) he was tracked. From early April until he was found dead in mid-July, RF1 centered his movements on a den with four young. The den was located in an open field just outside the preserve, and he and his mate regularly brought domestic ducks and chickens to the den. About five months after RF1's death another adult male red fox (RF2) was captured within the former range of RF1. The home range of RF2 was more than double (1,323 ha) that of RF1, and 95% of RF1's former range was included within the range of RF2. The much larger home range of RF2 compared to RF1 may reflect the fact that RF2 was tracked over a longer period (December 1985 to May 1987; 104 locations) and thus his range is a composite of several seasons. No other red foxes were seen on the preserve from 1985 to 1987 and, based on the assumption that red foxes are monogamous (Ables 1974), the density of adult foxes was estimated at 0.15/km^2.

Mean home range of the three adult gray fox monitored long enough to provide information on home range size was 550 ha, about half that of the two red foxes ($\bar{x} = 961$ ha). Gray Fox 7 (GF7) used an area of 827 ha during the 10 months (January-October 1986; 94 locations) he was tracked. Gray Fox 8 (GF8) was tracked from January 1986 to January 1987 (91 locations) and his range was 460 ha. The other male (GF9) used an area of 362 ha from January to July 1986 (73 locations). Based on the spatial distribution of assumed pairs of gray foxes (Fritzell and Haroldson 1982), the density of adult foxes on the preserve was estimated at 0.4/ km^2.

The largest fox ranges in this study were primarily in high pine sandhill habitat. This fairly homogeneous habitat constituted 75% or more of the ranges of RF1, RF2, and GF7. The intermediate-sized range of GF8 included about 58% high pine sandhill; the smallest range (GF9) contained less than 30% of this habitat. The range of GF9 also had a greater interspersion of habitat types than those of other foxes on the preserve.

There was more overlap in home ranges between than within species. The home ranges of GF7 and GF8, and those of GF8 and GF9, did not

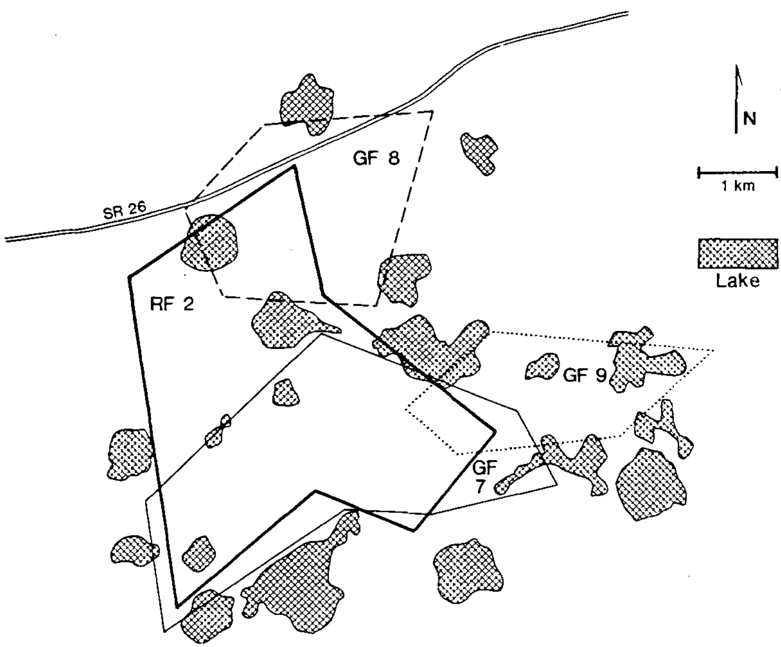

Figure 1. Home ranges of Ordway foxes in 1986-87, including RF2 (thick, solid line), GF7 (thin, solid line), GF8 (dashed line), GF9 (dotted line).

Table 1. Habitat use by red foxes, Ordway Preserve, 1985-1987.

		Proportions of locations			Selection[2]		
Habitat[1]	Proportion available	Total (n=172)	Daytime (n=66)	Night time (n=106)	Total	Daytime	Night time
HPS	0.745	0.442	0.591	0.349	–	0	–
XOF	0.089	0.279	0.167	0.349	+	0	+
OFP	0.085	0.250	0.242	0.255	+	+	+
MHF	0.061	0.023	0.0	0.038	–	–[3]	0
WP	0.020	0.006	0.0	0.009	0	–[3]	0

[1]Habitats are high pine sandhill (HSP), xeric oak forest (XOF), old fields or pastures (OFP), mesic hardwood forest (MHF), and wet prairie (WP).

[2]Selection indicates whether the expected use fell within (0), below (–), or above (+) the confidence interval (alpha = 0.10) of the observed use derived from the Bonferroni z statistic (Byers et al. 1984).

[3]Confidence interval could not be calculated but avoidance indicated.

overlap (Fig. 1). Only about 72 ha (20%) of GF9's range overlapped with GF7. However, the range of GF7 was almost completely (85%) overlapped by RF2, while about one-third of GF8's range was also included in RF2's range. No evidence of interspecific avoidance was noted between individuals with overlapping ranges, although this behavior could easily have gone undetected with the low intensity of monitoring employed in this study.

Both red foxes and gray foxes were primarily nocturnal, although some movement occurred in early morning or late afternoon. There were no significant differences (Chi-square test, $P > 0.05$) in their activity patterns. For red foxes, 95% of night time records (n=82) and 25% of daytime records (n=100) were active, compared to 92% (n=271) and 29% (n=194), respectively, for gray foxes. The mean distance traveled per night for red foxes was 4.7 km (range 3.0-5.7 km, n=6) compared to 3.9 km (range 2.6-4.5 km, n=6) for gray foxes; the difference in mean distance traveled per night was not significant (*t*-test, $P > 0.05$).

Red foxes and gray foxes did not utilize habitats in proportion to their availability (Tables 1 and 2). Both species used high pine sandhill less than expected, although red foxes frequently rested there during the daytime. Old fields and pastures were used more than expected by red foxes as daytime rest sites, but most of this use was associated with a den with small young. About 81% of daytime locations of red fox were in high pine sandhill, old fields and pastures, or habitats that tend to have open understories. Gray foxes showed a preference for xeric oak and mesic hardwood forests as daytime retreats, or habitats with dense understories. No gray fox was located during the daytime in an old field.

Table 2. Habitat use by gray foxes, Ordway Preserve, 1983-1987.

		Proportions of locations			Selection[2]		
Habitat[1]	Proportion available	Total (n=352)	Daytime (n=110)	Night time (n=242)	Total	Daytime	Night time
HPS	0.648	0.349	0.345	0.351	–	–	–
XOF	0.162	0.304	0.482	0.223	+	+	0
OFP	0.070	0.136	0.0	0.198	+	–[3]	+
MHF	0.036	0.165	0.173	0.161	+	+	+
WP	0.084	0.045	0.0	0.066	–	–[3]	0

[1]Habitats are high pine sandhill (HSP), xeric oak forest (XOF), old fields or pastures (OFP), mesic hardwood forest (MHF), and wet prairie (WP).
[2]Selection indicates whether the expected use fell within (0), below (–), or above (+) the confidence interval (alpha = 0.10) of the observed use derived from the Bonferroni z statistic (Byers et al. 1984).
[3]Confidence interval could not be calculated but avoidance indicated.

pasture, or wet prairie. A few daytime rest sites of gray foxes were in trees; three different individuals were located nine times resting 2-3 m above ground in live oak (*Quercus virginiana*) trees. At night, both species preferentially used old fields and pastures. Gray foxes also showed a night time preference for mesic hardwood forests, whereas xeric oak forests also were preferred by red foxes. Wet prairies either were avoided or seldom used by both species.

DISCUSSION

The mean home range size of adult male gray foxes in this study ($\bar{x}=550$ ha) is similar to that reported from Alabama (Nicholson 1982) and Missouri (Haroldson 1982), but range sizes of adult males from other states are substantially smaller (see Hovis et al. 1984). Elsewhere in Florida, an adult male gray fox tracked at Archbold Biological Station, Highlands County, had a range of 269 ha (Wassmer 1984). At the Welaka Reserve in southern Putnam County, the home ranges of two adult males measured 286 and 917 ha (Progulske 1982).

The large home ranges of gray foxes, at least on the Ordway Preserve, are probably related to low biomass of available small mammal prey. Excluding the fossorial pocket gopher (*Geomys pinetis*), the only small terrestrial mammal in the sandhill habitat is the Florida mouse (*Peromyscus floridanus*) and it occurs at low densities of 0.1 to 3.1/ha (J. F. Eisenberg, unpubl. data). Species richness of small mammals increases in the more mesic areas (Brand 1987), but even in these habitats prey densities are relatively low (*P. gossypinus*, 4 to 20/ha; *Sigmodon hispidus*, 2 to 8/ha; *Neotoma floridana*, 1.2 to 3/ha; J. F. Eisenberg, unpubl. data). Rabbits (*Sylvilagus*) and small mammals are important winter food items of gray foxes whereas more invertebrates and plant food are consumed in the summer (Wood et al. 1958). Both the cottontail (*S. floridanus*) and marsh rabbit (*S. palustris*) are known to occur on the preserve but neither appears to be common (pers. obs.).

The mean home range size of the two male red foxes in this study ($\bar{x} = 960$ ha) is similar to range sizes of red foxes in farmland in central and eastern North America (Schofield 1960, Storm 1965, Sargeant 1972, Yearsley and Samuel 1980). As red foxes are primarily predators of small mammals whereas gray foxes tend to be more omnivorous (Nelson 1933, Scott 1955, Hockman and Chapman 1983), red fox ranges on the Ordway would be expected to be larger than those of gray foxes. In the only other study that compared red and gray foxes in the same area, Follmann (1973) found that male red foxes had larger territories than male gray foxes in southern Illinois. In this study, mean home range size of male red foxes was almost twice as large as that of male gray foxes.

Variation in home range size of gray foxes have been attributed to several factors (see Fritzell and Haroldson 1982) but habitat differences, which affect prey dispersion and abundance, and in turn, fox density (Trani 1980, Wood et al. 1958), are probably the most important variable. A similar hypothesis has been presented by Macdonald (1981) to account for variation in home range sizes of red foxes. Support for the hypothesis is provided by the observation that home ranges of gray foxes and red foxes are larger in homogeneous habitats (Sargeant 1972, Macdonald 1981, Haroldson 1982, Progulske 1982) than in interspersed or more heterogeneous habitats (Trapp 1973, Hallberg 1974, Fuller 1978, Yearsley and Samuel 1980, Macdonald 1981). Similarly, the largest ranges of individual gray foxes in this study were those that contained more homogeneous habitats.

Both species of fox in this study were principally nocturnal and crepuscular; some early morning or late afternoon movement was recorded for both species, but it was not known if foxes were foraging or simply changing rest sites. Studies of red foxes and gray foxes in other areas also indicate that they are primarily active at night and sedentary during the daytime (see Ables 1974, Trapp and Hallberg 1975). Follmann (1973) also reported that red foxes traveled significantly farther than gray foxes during their daily movements. Results from this study support his findings.

The habitat use patterns of gray fox in this study are similar to those reported for southern Georgia and Florida (Wood et al. 1958, Progulske 1982, Wassmer 1984) in that foxes rested in dense cover during the daytime and foraged in open areas at night.

Coexistence of the two species of fox on the Ordway is apparently facilitated by subtle differences in habitat use and its relationship to dietary preferences. Follmann (1973) reached a similar conclusion in his study in southern Illinois, although there the densities of red foxes and gray foxes were about equal. On the Ordway, gray foxes are about three times more numerous than red foxes but neither exists at high densities. At the Welaka Reserve, Progulske (1982) estimated gray fox density at 1.0/km^2, about twice the density recorded at Ordway. Estimates of gray fox densities from other areas vary from 1.2 to 2.1 per km^2 (see Fritzell and Haroldson 1982). Red fox densities in favorable habitats may reach 1-2 adults/km^2 (Ables 1974). On the Ordway, the generally unproductive nature of the dominant habitat, the homogeneous high pine sandhill, limits fox densities and under these conditions the potential for competition appears to be minimized.

ACKNOWLEDGMENTS

This study was supported by funds from the Ordway Chair of Ecosystem Conservation at the University of Florida. Field work and data collection were contributed by P. Crawshaw, M. Okoniewski, L. Caine, M. DuPraw, J. Ryser, D. Daneke, D. Wright, K. Meyer, D. Pearson, M. Ludlow, and D. Franz. Their efforts are greatly appreciated. The editorial comments on the paper from J. F. Eisenberg and F. C. Sunquist were greatly appreciated.

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