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MOVEMENT AND SPATIAL ORGANIZATION OF RACCOONS IN NORTH-CENTRAL FLORIDA

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Abstract.—Raccoons (*Procyon lotor*) were live-trapped in north-central Florida in November 1991, and February, May and August 1992. Twenty adults were radio-collared and followed throughout the winter and spring. Adult raccoon home ranges overlapped with those of up to 31 other raccoons. Home-range overlap was high both between and within sexes. Contact between raccoons was observed throughout the winter and spring and there was no winter denning. Males moved faster and farther than females, had larger home ranges, and their home ranges overlapped with larger numbers of other raccoons and larger proportions of each other raccoon's home range.

Raccoons are the most widely distributed species of the New World family Procyonidae. Their range extends from central Canada, throughout the U.S. except for the northern Rocky Mountains and the Great Basin, south to the tropics of Central America (Kaufmann 1982). Raccoons are highly adaptable (Mugaas et al. 1993) and their social organization, movement patterns and reproductive behaviors vary with climate, habitat type, and level of human activity (Kaufmann 1982). We describe movements and spatial organization of raccoons during the winter and spring in northern Florida, an area with a mild winter where raccoons have an extended breeding season.

Movements and home-range sizes of raccoons vary with age, sex, habitat, season, food availability, and probably other factors. Home ranges of males are generally larger than those of females, which are even more restricted when they have young (see review in Sanderson 1987). In the northern parts of their distribution raccoons make less extensive movements during the winter than during other seasons (Sanderson 1987). In all studies from Tennessee northward, periods of inactivity or reduced activity have been noted during very cold weather and when snow covers the ground. The lengths of these periods vary, but in very cold climates denning may last up to four months (Kaufmann 1982, Mugaas and Seidensticker 1993).

Previous research indicates that the most common social grouping among raccoons is a mother and her young of the year and that associations between adult males and females for activities other than breeding are rare (Kaufmann 1982). However, communal winter denning is known from several locations (Twichell and Dill 1949, Whitney and Underwood 1952, Mech and Turkowski 1966, Rabinowitz 1981). Groups of

siblings or females and their offspring often den together, and occasionally groups including one or more adult males have been found in the same winter den (Twichell and Dill 1949, Mech and Turkowski 1966). Animals of both sexes and all ages will also congregate at a concentrated food source (Sharp and Sharp 1956, Seidensticker et al. 1988).

In captivity, raccoons that were originally captured from the same area showed a higher frequency of dominant-subordinate interactions and fewer aggressive encounters than did animals captured farther apart, indicating a rudimentary social structure among neighboring raccoons and some degree of "neighbor recognition" (Barash 1974). Home ranges of adult females overlap extensively (Stuewer 1943, Johnson 1970, Urban 1970, Worley 1980, Allsbrooks and Kennedy 1987, Seidensticker et al. 1988), as do those of adult males (Stuewer 1943, Urban 1970, Lotze 1979, Worley 1980, Seidensticker et al. 1988), although Fritzell (1978) found little overlap in the ranges of adult males in the harsh environment of the prairies of North Dakota. Thus, adult male and female ranges overlap to a large degree, and males may mate with several females in a year. However, the extent of home-range overlap among a large number of individuals within a relatively small area has not been reported in the literature.

Study Area and Methods

The study was conducted at the Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary (the Ordway Preserve), a 3,750-ha mosaic of sandhill uplands, hardwood hammocks, old fields, and wetlands in Putnam County, north central Florida. Currently, the only human activities on the preserve are research and educational excursions from the University of Florida. The study area encompassed 1,257 ha in the western part of the preserve and on adjacent private lands (Figure 1). Private lands were rural residential areas, with widely-spaced houses interspersed in hardwood hammock around lakes, slash pine plantations, and a small town, Melrose, Florida.

Climate in the area is humid and subtropical (Chen and Gerber 1990). Mean annual rainfall over the last 30 years was 135 cm (National Oceanic and Atmospheric Administration 1960-1990). About 60% of the annual precipitation falls between May and September, but there is considerable yearly variation in both the timing and extent of the rains (Ryser 1991). Winter temperatures can fluctuate greatly, and freezing temperatures occur on at least a few days and nights each year (Ryser 1991).

Raccoons were trapped in November 1991, and February, May, and August 1992 for four to five nights per trapping session. Raccoons captured for the first time were anesthetized by intramuscular injection with ketamine hydrochloride (Ketaset, Bristol Laboratories, Syracuse, NY) at a dosage of 10 mg/kg estimated body mass (Bigler and Hoff 1974) and were measured, weighed, and ear-tagged. Recaptured animals were identified, weighed, and released. In November and February all animals classified as adults (n = 29), based on large size, permanent dentition, and testicular or mammary development, were fitted with radiocollars (Advanced Telemetry Systems, Bethel, MN) with a battery life of approximately six months. Radiocollars were 1% of the mean body mass of males and 2% of the mean body mass of females. These collars were removed from recaptured animals in May and August.

From November 1991 to May 1992, radiocollared animals were located by triangulation (Kenward 1987) with portable telemetry equipment from known locations along

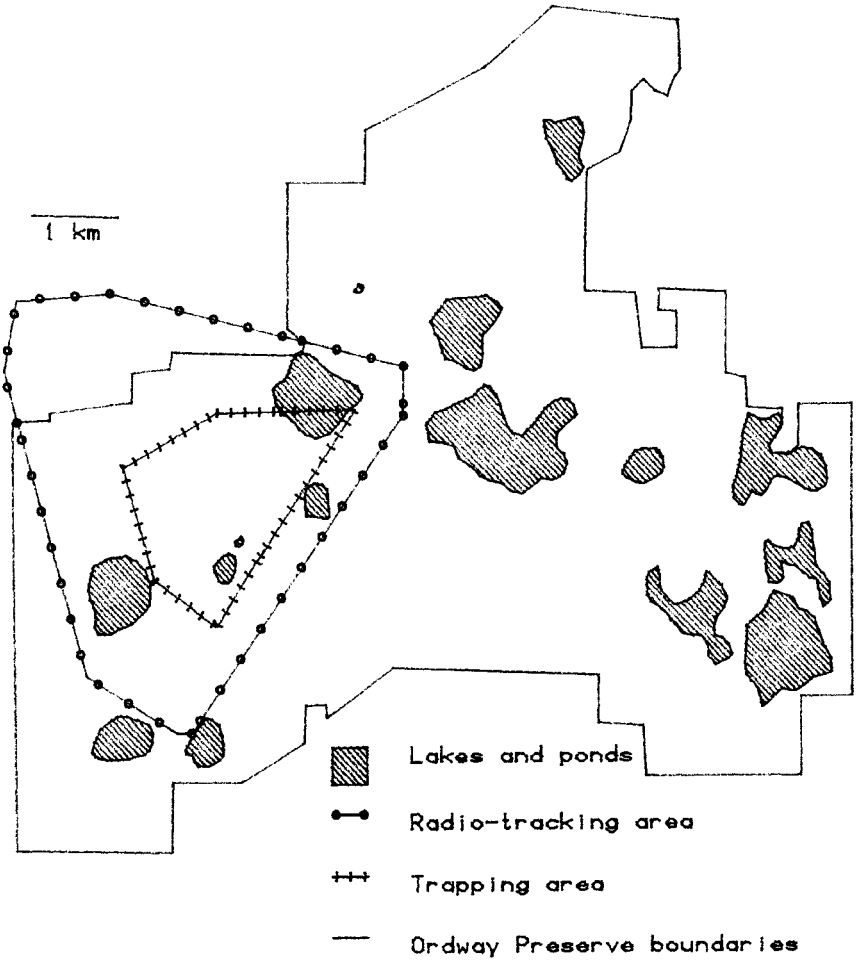

Figure 1. Study area on the Ordway Preserve and neighboring private lands.

roads, or by following the signal to the animal. Triangulation error was estimated by taking readings on transmitters in known places from locations normally used for radiotracking. Mean triangulation error (Heezen and Tester 1967) for bearings taken from 200 to 600 m away was 58.8 m, with a 95% confidence interval of 34.0 to 83.6 m. When animals were on the preserve most readings were taken from a distance of 200 to 600 m, but when they were off the preserve the distances were sometimes greater.

Raccoons were located in the daytime one or more times a week. At night, when raccoons were active, one to four individuals were radio-located every two hours throughout the night. Each raccoon was followed all night at least once every two months. Approximately 40% of locations on each animal was collected at night and 60% was daytime locations. Data collected on radio-tagged animals for which there were fewer than 50 locations were used in descriptions of home-range overlap and descriptions of social interactions, but not for home-range analysis.

A map of the area was created by digitizing roads and habitat contours from 1":200' aerial photos (Florida Department of Transportation 1989) using the ERDAS (Version 7.5, ERDAS, Inc., Atlanta, GA) geographic information system. The digitized maps were converted into the ARC/INFO (Version 3.4D, Environmental Systems Research Institute, Redlands, CA) geographic information system format for editing and manipulation. Home ranges were calculated for the 20 animals that were located >50 times using the program HOME RANGE (Ackerman et al. 1990). Corrected minimum convex polygons (MCPcorr) (Ryser 1991), which were minimum convex polygons (MCPs) (Mohr 1947) with lake areas subtracted, were used for comparisons of home-range sizes between the sexes and for calculation of home-range overlap

Mean home-range sizes of males and females were compared with the Mann-Whitney test (Mann and Whitney 1947). Proportions of home ranges overlapped by radiocollared raccoons was measured with ARC/INFO. For each animal with >50 locations we determined the total number of raccoons of both sexes whose ranges overlapped that individual's range. This total included radiocollared animals with >50 locations and uncollared animals captured during the study period. Mann-Whitney tests (Mann and Whitney 1947) were used to compare range overlap by sex in terms of number of ranges overlapped and mean proportions of each individual's range that were overlapped by other raccoons. Proportions of home ranges that individuals shared with male and female raccoons were compared with the Wilcoxon matched pairs test. Statistical analyses were performed using the program Statistica 5.1 for windows (StatSoft 1996).

Distances between consecutive locations were measured for each animal using ARC/INFO. Lakes were skirted in the measurements, but otherwise the shortest straight-line distance was taken. Nightly movements were the sum of straight-line distances between consecutive locations. Mean hourly movements (based on readings taken two hours apart), mean nightly movements, and mean distance between consecutive daytime rest sites were calculated for each animal, averaged for both sexes, and comparisons between the sexes were made with Mann-Whitney tests.

RESULTS

Mean home-range size of males was almost four times that of females ($U = 0$, $P = 0.0002$). Males tended to move faster and farther each night than females. Mean hourly movement of males was two times faster than that of females ($U = 9$, $P = 0.0026$). Mean nightly movement of males was also over two times farther than that of females ($U = 3$, $P = 0.0005$). Mean distance between consecutive rest sites for males was three times that of females ($U = 9$, $P = 0.0026$) (Table 1).

Home-range overlap was extensive between and within sexes. Each raccoon's range overlapped with the ranges of four to 31 other raccoons. Overall, male ranges overlapped with ranges of more raccoons than did female ranges ($U = 14.5$, $P = 0.01$). Male ranges overlapped with more female ranges than female ranges did with each other ($U = 6.5$, $P = 0.001$), but there was no difference between the sexes in the number of male ranges they overlapped with ($U = 38$, $P = 0.43$) (Table 2).

Home-range overlap varied from less than 1% to 100% (Table 3). Females shared larger mean proportions of their home ranges with other raccoons (of either sex) than did males ($U = 6$, $P = 0.001$). For both sexes, a greater mean proportion of home ranges was shared with

Table 1. Movement parameters and home-range size of radio-collared raccoons, Ordway Preserve, Florida, November 1991-May 1992.

	HM[1]	NM[2]	CRS[3]	MCPcorr[4]
MALES (n = 8)				
Mean	229.6	2,586	710.6	259.9
SE	32.5	298	162.7	43.1
Minimum	116.4	1,700	242.1	137.0
Maximum	370.4	4,280	1,569.7	435.0
FEMALES (n = 12)				
Mean	115.1	1,283	271.2	66.4
SE	12.2	121	27.1	8.8
Minimum	62.9	720	183.6	29.0
Maximum	214.9	2,200	498.2	118.0
OVERALL				
Mean	160.9	1,805	446.5	143.4
SE	19.3	199	81.3	27.9

[1]HM = mean hourly movement in meters.
[2]NM = mean nightly movement in meters.
[3]CRS = mean distance (meters) between consecutive rest sites.
[4]MCPcorr = minimum convex polygon with lake area subtracted (ha).

males than with females (U = 3, P = 0.0001) (Table 3). Figure 2 illustrates the distribution and overlap of home ranges of the radio-tagged raccoons with >50 locations.

Radiocollared raccoons were usually located alone, but they were found with other raccoons at 15 rest sites (9.6% of total number) and females were captured with young 11 times (Table 4), in sandhill, swamp, and hardwood hammocks. On another 11 occasions, animals were located in rest sites within 100 m of each other. One time, three females (#21, #28, and #29) and a male (#12) were found resting within 150 m of each other in the swamp, although their actual rest sites were not seen. When they became active at dusk they did not travel together.

Females were observed with small young in July, August, October, November, and December and with males from November through March. Two different pairs of adult males were found together in the same tree, but adult females were never found together. One pair of males (#16 and #24) located sleeping in the same tree one day also foraged together during the night for three to four hours, and these two animals were found in rest sites within 100 m of each other at another time. Their home ranges overlapped approximately 57% (Table 3). The other pair of males found in a tree together (#1 and #17) had ranges that overlapped more than 75% (Table 3). Female ranges were overlapped from 73-100% (Table 3) by the ranges of the males they were found with. A male (#33)

Table 2. Number of home ranges with which ranges of adult raccoons located ≥50 times overlapped, Ordway Preserve, 1991-1992.

MALES				FEMALES			
ID[1]	Males	Females	Total	ID[1]	Males	Females	Total
1	10	12	22	2	5	7	12
8	10	9	19	3	6	4	10
12	7	8	15	4	3	1	4
16	14	17	31	5	7	5	12
17	7	10	17	9	9	7	16
18	6	7	13	13	6	3	9
24	7	15	22	19	7	5	12
33	5	8	12	21	12	9	21
				25	3	4	7
				26	7	4	11
				28	8	6	14
				29	11	8	19
Mean	8.25	10.75	18.88		7.00	5.25	12.25
SD	2.92	3.62	6.17		2.76	2.26	4.79

[1]ID = individual raccoon identification number.

and female (#13), located at rest sites within 100 m of each other one day, were resting in the same tree the next day. This female had been with male #17 two days earlier, and was palpably pregnant when she was captured six weeks later. Male #33's range encompassed 84% of male #17's range, and male #17's range encompassed 49% of male #33's (Table 3).

Raccoons monitored in the same vicinity during a night typically moved independently, although they sometimes used the same area during the course of the night. Movements of raccoons were not linear, and animals changed directions and back-tracked frequently. Female #20 was observed foraging for about 30 minutes after she left her rest site on 6 January 1992. She walked at a fairly steady pace with nose to the ground, pausing frequently and occasionally scratching and digging. She travelled about 75 m in half an hour.

Because individuals varied greatly in their movements, and sample sizes were small for each individual, no attempt was made to correlate the amount of movement with ambient temperature. However, on no occasion was a raccoon found not to move at all during the night, even when temperatures were below 0°C.

DISCUSSION

Adult raccoons at the Ordway shared their ranges to varying degrees with up to 31 other adults of both sexes. It is probable that not all raccoons in the area were detected, especially on the edges of the study

Table 3. Mean proportions of home ranges of radio-collared raccoons shared by other raccoons located ≥50 times, Ordway Preserve, 1991-1992.

MALES				FEMALES			
ID[1]	Males	Females	Combined	ID[1]	Males	Females	Combined
1	0.20	0.15	0.18	2	0.81	0.48	0.63
8	0.43	0.29	0.35	3	0.48	0.20	0.38
12	0.51	0.31	0.40	4	0.99	0	0.99
16	0.25	0.13	0.18	5	0.32	0.20	0.26
17	0.43	0.15	0.26	9	0.53	0.12	0.47
18	0.41	0.18	0.27	13	0.71	0.56	0.68
24	0.22	0.05	0.10	19	0.92	0.58	0.75
33	0.48	0.12	0.27	21	0.40	0.47	0.42
				25	1.00	0.16	0.58
				26	0.59	0.40	0.51
				28	0.50	0.32	0.45
				29	0.42	0.37	0.40
Mean	0.37	0.17	0.25		0.64	0.32	0.54
SD	0.12	0.09	0.10		0.24	0.16	0.20

[1]ID = individual raccoon identification number.

area. Also, home-range sizes used to measure overlap are most likely underestimates of annual home ranges because they were based only on winter and spring data and because the minimum convex polygon method is dependent on sample size and underestimates home-range size (White and Garrott 1990). Thus, the true amount of overlap in the area is probably even greater than that detected in this study. This extent of home-range overlap has not been previously reported, but there are few published studies with a large number of radiocollared raccoons followed simultaneously in a small area.

As in other studies (Fritzell 1978, Lotze 1979, Taylor 1979, Worley 1980, Rabinowitz 1981, Allsbrooks and Kennedy 1987), males occupied larger ranges which overlapped more extensively and with more individuals than females, and they traveled faster and farther than did females. It is hypothesized that home-range size is related to body size (McNab 1963), spatial and temporal dispersion of resources (Macdonald 1983), and habitat quality (Ellis 1964). Ellis (1964) concluded that raccoons have smaller home ranges and move less in areas of high quality habitat. The data on home-range size and movement parameters in this study are not consistent and suggest that they may be influenced independently by different factors, or in different ways by the same factors.

The two raccoons (Male #16, MCPcorr = 435 ha; Male #24, MCPcorr = 429 ha) with the largest home ranges at the Ordway were those whose ranges included the highest proportions of sandhill, the least-

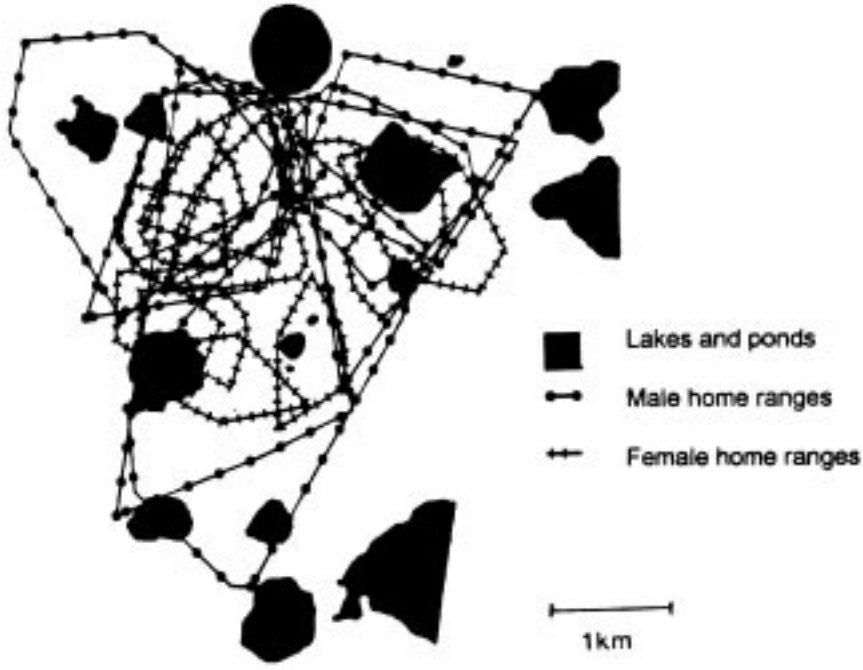

Figure 2. Raccoon home-range overlap at the Ordway Preserve, November 1991-May 1992.

preferred habitat type (Walker 1995). These raccoons also moved the farthest during the night and had the fastest rate of movement. In contrast, the raccoon whose home range included the highest proportion of swamp, the most-preferred habitat type (Walker 1995), had the smallest home range (Female #9, MCPcorr = 29 ha) but her rate of movement and the distance she traveled at night were not significantly different from other female raccoons at the Ordway.

The home-range size and movement parameters of Ordway raccoons are similar to those obtained in a study of raccoons in xeric scrub habitat in south-central Florida (Worley 1980). Male home-range size and movement parameters and female movement parameters were not significantly different from those in this study, but female home-range sizes were larger than at the Ordway (t = -4.1, P = 0.0008). The habitat in south-central Florida is more xeric and lacks the wetland areas that Ordway raccoons preferred (Walker 1995).

Raccoons at the Ordway usually foraged and rested alone. Extensive home-range overlap could be facilitated by temporal and spatial avoidance of other raccoons, although we cannot conclude that from our data. Black bears in North Carolina whose ranges overlapped did

Table 4. Raccoons found together, Ordway Preserve, Florida, November 1991-May 1992.

	Numbers of occurrence	Months of occurrence
Female with young	17	July, August, October, November, December
Female with male	6	November, February, March
Female with female	0	
Male with male	2	March, April
Female and unknown adult	1	January
Total	26	

not exhibit mutual avoidance among neighbors (Horner and Powell 1990). Contact between raccoons at the Ordway was infrequently noted, but it was observed in a variety of forms, and was surely an under-representation of social behavior because of the limitations of using radio-telemetry to study a nocturnally-active species.

Ordway raccoons did not den to avoid harsh weather, and some degree of contact between individuals was observed throughout the winter. This year-round contact between adult raccoons may be what allows the persistence of enzootic rabies (Smith et al. 1990) in raccoons in Florida. In a study in the mountains of Virginia, a rabies epizootic died out over the winter because the incubation period of the virus was not long enough to bridge the raccoons' noninteractive period during the fall and winter (Seidensticker et al. 1988).

It is evident from this and previous studies that raccoons, that appear to have a basic social structure amenable to group formation, may share living space with large numbers of other raccoons. It is certainly an oversimplification to label raccoons a solitary species, although they are not group-living. They have a high level of social tolerance, but as a small-bodied, nocturnal omnivore the benefits they could accrue from group-living may be outweighed by the advantages of solitary living (Linn 1984).

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