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Radiotelemetry was used during 1983 and 1984 to collect information on short-term areas of activity for black-footed ferrets (*Mustela nigripes*) near Meeteetse, Wyoming. This population ultimately provided ferrets for the captive-breeding program that bred and released offspring into the wild since 1991. We fitted 5 adult ferrets and 13 juveniles with radiotransmitters and followed their movements during late summer and fall. Adult males had 7-day areas of activity that were >6 times as large as those of adult females. Activity areas of adult males varied little in coverage or location on a weekly basis, but females sequentially shifted their areas. Unlike juvenile females, juvenile males tended to leave their natal colonies.

Key words: center of activity, dispersal, movement, *Mustela nigripes*, radiotelemetry

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Black-footed ferrets (*Mustela nigripes*; hereafter, ferret) were formerly widespread in central North America. Their populations decreased throughout the last century to near extinction by the late 1970s as a result of extermination of prairie dogs (their main prey) and the spread of disease (Biggins and Godbey 1995; Biggins et al. 1998). In 1973 the ferret was the least known endangered mammal in the United States because of its nocturnal, semifossorial habits and the few known populations (Erickson 1973). In 1981 a small population was discovered in a complex of white-tailed prairie dog (*Cynomys leucurus*) colonies near Meeteetse, Wyoming. During 1983 and 1984 we used radiotelemetry to collect information on areas of activity for ferrets in this population. Our overall objective was to develop data on ferret activity and spatial use among sex and age groups. The Meeteetse population of ferrets was decimated by canine distemper (*Morbillivirus*) and plague (*Yersinia pestis*) in 1985 (Forrest et al. 1988), and 18 individuals were brought into captivity, forming the foundation for a captive-breeding program. We present data on sequential areas of activity (using minimum convex polygons) during 1983–1984 for Meeteetse ferrets monitored intensively for short periods of time between August and December. We compare the sizes of activity areas and shifts in centers of activity for male and female and adult and juvenile ferrets.

Materials and Methods

The ferret population we studied occupied the western Big Horn Basin in northwestern Wyoming near the town of Meeteetse (44°09′N, 109°08′W—Biggins et al. 2011). The small population of ferrets occupied a 29-km^2 complex of 33 white-tailed prairie dog colonies ranging in size from 0.5 ha to 13 km^2 (Forrest et al. 1985). Animals were monitored on the East Core, West Core, and Pump Station prairie dog colonies, some of the largest prairie dog colonies in the area (Forrest et al. 1985).

During 1983 and 1984 we captured ferrets using tube traps inserted into burrows where ferrets had been observed during searches with spotlights (Campbell et al. 1985). We anesthetized ferrets with ketamine hydrochloride (Thorne et al. 1985) under veterinary supervision following protocols of the United States Fish and Wildlife Service. We radiocollared ferrets with 2-stage, 3-volt transmitters (Wildlife Materials, Inc., Murphysboro, Illinois) with whip antennas and flexible, lightweight vinyl collars (Biggins et al. 2006a). Transmitter weight was 13 g, and battery life was about 1.5 months. We monitored ferrets using tracking stations on hills (travel trailers and trucks) equipped with 11-element, dual-beam yagi antennas. We tested the telemetry system for accuracy (Biggins et al 2006a). We also used handheld, 3-element yagi antennas and receivers to find burrows occupied by ferrets, shed collars, and predator-killed or injured ferrets.

During 1983 we trapped and radiocollared ferrets in August and monitored them through December. We took bearings at intervals of 3–8 min nightly for each ferret. Because battery life for the transmitters was only 1.5 months, we retrapped radiocollared ferrets during late September and again in early November for collar replacement. We removed all transmitters during December because of mud accumulation on the collars (Biggins et al. 2006a) and because decreased ferret activity prevented us from regularly monitoring the health of each ferret. During 1984 we began radiotracking in mid-August and continued through mid-October, when we again removed collars to prevent mud accumulation. We monitored ferrets on a 24-h basis, taking bearings no more frequently than every one-half hour during the day but at night every 15 min if few animals were above ground. Research was done humanely and in accordance with guidelines of the American Society of Mammalogists that were published later (Gannon et al. 2007).

We used program TRITEL to calculate rectangular coordinates from azimuth data and estimate areas of error quadrangles associated with each telemetric fix (Biggins et al. 2006a). Accuracy of stations used in this study (Biggins et al. 2006a) was $\pm$ 0.66° to $\pm$ 1.54° (90% confidence). We used the minimum convex polygon method (Mohr 1947) to estimate activity areas for each 7-day period, including all telemetric locations (100% polygons calculated with program CALHOME—Kie et al. 1996). We excluded dispersal movements and up to 3 excursions before estimating activity areas. We defined an excursion as a movement involving $\geq$1 telemetric locations of >250 m beyond the perimeter of the area of activity, as measured from the most distant point of the excursion to the nearest point on the boundary of the activity area, followed by a return to the area of activity, with <18 h total elapsed time from departure to return. We defined dispersal as a move of >500 m outside the defined area of activity, with no return to that area of activity. We eliminated telemetric locations that were associated with excursions or dispersal, rather than eliminating outliers, by specifying minimum convex polygons of <100% because the intensive tracking data allowed us to document the detailed temporally sequential movements that were extraordinary. Although the purposes of moves we define as excursions remains unknown, we believe exclusion of these movements is more biologically justifiable than using the minimum convex polygon procedure of removing a fixed percentage of individual points that in our data would have been associated arbitrarily with multiple movements and nights. Centers of activity for each 7-day activity area were calculated as means of x- and y-coordinates for all telemetric locations within the area defined (Hayne 1949). We calculated a shift in center of activity as the distance separating consecutive weekly centers of activity for an animal; thus, shifts numbered 1 fewer than centers of activity for each animal, and shifts could not be calculated for animals with a single center of activity.

The 7-day (weekly) periods of activity began when radiotracking of a ferret commenced. If breaks in tracking occurred, a new period began when tracking was resumed. Data for incomplete 7-day periods were discarded. The data set consisted of 61 weekly periods for the 18 ferrets. We used the median of multiple weekly activity areas for each ferret as the single observation for each individual to represent the typical size of its weekly activity area. We similarly used the median for each individual to represent the typical distance separating its consecutive weekly activity centers. We analyzed these representative sizes of weekly activity areas and the representative weekly shifts in activity centers for all animals using a 2-factor factorial analysis of variance, with age and sex as the main effects. We examined residual plots to verify the normality assumption and used Brown and Forsythe's variation of Levene's test to test for homogeneity of variances (Brown and Forsythe 1974). We applied a priori linear contrasts to the age*sex interaction to examine comparisons of particular interest, which included comparing adult females to adult males and comparing juvenile females to juvenile males. We used PROC GLM version 9.0 (2003; SAS Institute Inc., Cary, North Carolina) for analyses.

Results

During 1983, 8 ferrets (Table 1), including 3 adults (2 females and 1 male) and 5 young (4 females and 1 male), were radiomonitored. Three of the juvenile females were from a litter of one of the radiocollared adult females. During 1984, 10 ferrets (1 adult female, 1 adult male, 2 juvenile females, and 6 juvenile males) were radiomonitored. Triangulation from fixed tracking sites provided 5,724 telemetry locations on these ferrets. We removed an average of 4.9% of the telemetric locations for each ferret-period due to excursions and dispersals; 26 of 61 animal-periods had no excursions or dispersals as defined.

The interaction between age and sex was significant ($F_{1,14}$ = 16.76, $P \leq 0.01$). Adult females had substantially smaller weekly activity areas (17.2 ha) than did adult males (117.4 ha; linear contrast: $F_{1,14} = 29.11$, $P < 0.01$), but activity areas of juvenile females did not differ significantly from those of juvenile males (16.8 ha and 28.0 ha, respectively; linear contrast: $F_{1,14} = 0.97$, $P = 0.34$).

As with activity areas, weekly shifts in centers of activity resulted in significant age*sex interactions ($F_{1,9} = 11.70$, $P <$ 0.01). Although adult females exhibited much smaller weekly activity areas than did males, they showed much greater weekly shifts of activity centers than did adult males (377.8 m compared to 141.6 m, respectively; linear contrast: $F_{1,9}$ = 5.11, $P = 0.05$). Male activity areas were spatially stable (Fig. 1) but overall areas of activity for adult females consisted of largely separate 7-day activity areas that were used sequentially (Fig. 2). Although weekly activity areas did not differ between juvenile sex classes, a difference in weekly

Table 1.—Median weekly area of activity (Area), median weekly shift in center of activity (COA), number of radiotelemetry fixes, and number of weekly observation periods for observation periods for adult (A), juvenile (J), female (F), and male (M) ferrets radiotracked at Meeteetse, Wyoming, during 1983 and 1984.

Ferret	Age	Sex	Area (ha)	COA shift (m)	Fixes	No. weeks
03-83	A	F	36.79		93	1
08-83	A	F	4.84	232.33	238	2
05-84	A	F	9.84	523.20	86	2
02-83	A	M	136.90	161.75	1,845	10
01-84	A	M	97.87	121.41	626	7
04-83	J	F	35.25		86	1
05-83	J	F	11.13	153.93	408	4
06-83	J	F	14.81	124.65	350	4
10-83	J	F	14.42	155.23	945	9
06-84	J	F	11.54	337.44	125	3
09-84	J	F	13.91	77.78	197	4
01-83	J	M	7.51		47	1
03-84	J	M	11.34	311.82	275	4
11-84	J	M	18.31	427.72	94	2
52-84	J	M	11.58	425.73	77	2
53-84	J	M	36.30		41	1
54-84	J	M	29.23	290.43	78	2
55-84	J	M	81.82	1578.81	113	2

shifts in activity centers was found between juvenile females and juvenile males (169.8 m compared to 606.9 m, respectively; linear contrast: $F_{1,9} = 7.67$, $P = 0.02$). As opposed to adults, juvenile males showed much greater shifts in centers of activity than did juvenile females, a phenomenon consistent with the dispersal of males. At least 4 of the 7 males dispersed 1–7 km to other colonies during the period we monitored them, compared to no dispersal for the 7 juvenile females.

Discussion

Our data are the 1st to quantify differences between adult male and female ferrets with regard to sizes of short-term (7-d) activity areas and associated shifts of centers of activity. The disparity between minimum convex polygon–based areas used by males and females on a weekly basis greatly exceeds minimum convex polygon–based comparisons between sexes for longer periods (Biggins et al. 1985; Livieri 2007). This phenomenon seems at least partly due to the differences in shifts of short-term centers of activity by females.

Differences were shown in the age*sex interaction for weekly shifts in activity centers, with adult females exhibiting much greater weekly shifts of activity centers than males. Adult males had the most stable activity areas of the sex and age cohorts of ferrets, with areas of activity varying little in size or location during late summer and fall. Although medians for shifts in consecutive 7-day centers of activity for adult females were more than double those for adult males, those distances used in the statistical modeling understate the differences relative to sizes of activity areas. If we assumed activity areas to be circular, adult females shifted their centers of activity by 81% of the median diameters of their activity areas, compared to a shift by adult males that averaged only 12% of the diameters of their areas. Examination of our intensive radiotracking data suggests that the large overall activity areas for adult females likely are composed of smaller areas that are used sequentially. These sequential shifts have

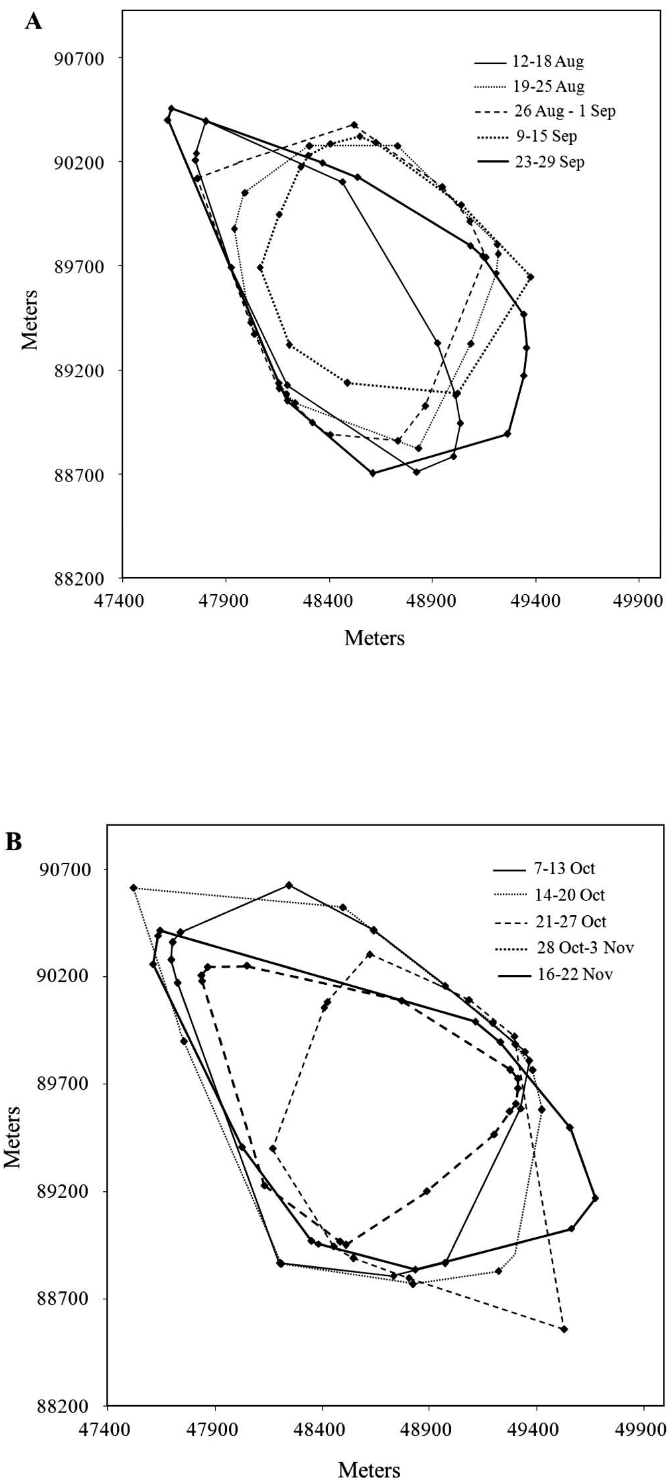

Fig. 1.—Seven-day activity areas of radiotagged adult male black-footed ferret 02-83 during A) 12 August–29 September and B) 7 October–22 November 1983. Locations are shown using the Universal Transverse Mercator Zone 12 North.

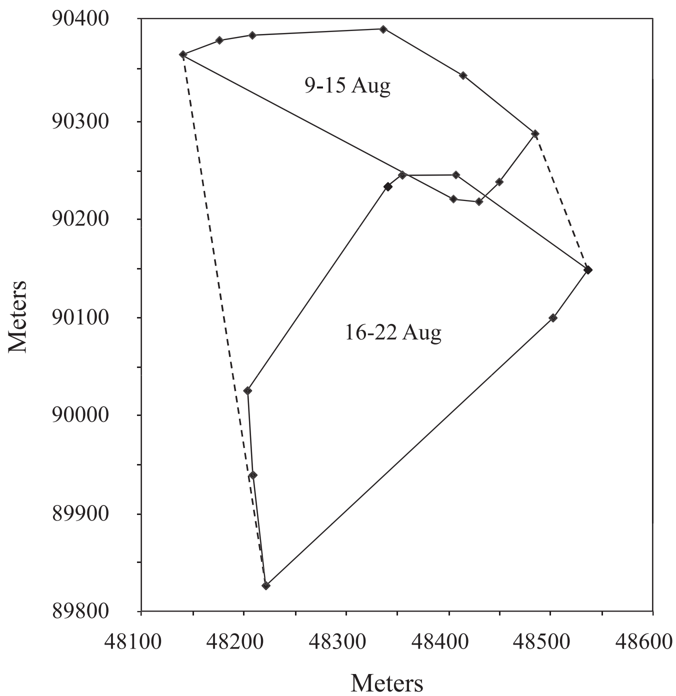

Fig. 2.—Activity area of radiotagged adult female black-footed ferret 08-83 during 9–22 August 1983. This 2-week, 13.63-ha area of activity is composed of 2 smaller activity areas from 9 to 15 August (2.97 ha) and 16 to 22 August (6.70 ha) that were used sequentially. Locations are shown using the Universal Transverse Mercator Zone 12 North.

been noted anecdotally by the authors and others for female ferrets with litters but largely are undocumented in the literature. Paunovich and Forrest (1987) reported that during August 1985 an adult female ferret at the Meeteetse site moved her litter 18 times, but spatially explicit details were not provided. Shifts by females could be in response to patchiness of habitat combined with depletion of available prairie dog prey due to predation by the ferrets or due to abandonment by prairie dogs of the areas of high ferret activity, phenomena mentioned for reestablished ferret populations by Biggins et al. (2006b) and Jachowski et al. (2008).

The greater shifts in weekly activity areas shown by juvenile males compared to juvenile females likely reflects dispersal movements we documented near the end of the periods of radiotracking as young ferrets made a transition to independence. Females tended to remain near their natal areas while males dispersed, perhaps due to interactions with the adult males that were resident.

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