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Home Range Characteristics of Corsac and Red Foxes in Mongolia

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Home range characteristics of corsac and red foxes in Mongolia

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Abstract

Red (*Vulpes vulpes*) and corsac foxes (*V. corsac*) live sympatrically throughout most of Mongolia, but few details of their home range characteristics exist. We captured and radio-tagged 13 red fox (♂ = 5, ♀ = 8) and 15 corsac foxes (♂ = 8, ♀ = 7) between 2004 and 2008. We tracked their movements to estimate home range sizes and examined the effects of four factors on home range size, including sex, age, season, and year. We determined mean home range size for 12 red and 10 corsac foxes that had sufficient data using fixed kernel methods. Mean home range size (90 % kernel) was 15.4 ± 2.2 SE km^2 for red foxes and 4.5 ± 0.8 SE km^2 for corsac foxes. Core areas within home ranges (50 % kernels) averaged 3.59 ± 0.68 km^2 for red foxes and 1.43 ± 0.32 km^2 for corsac foxes. Home ranges varied by sex, age, season, and year for both species and we found significant effects of sex among corsacs, with males occupying larger ranges than females; age among red foxes, with adults occupying larger ranges than yearlings; and year among red fox home ranges. We believe that resource availability probably influenced patterns of home range variability along with the significant variables we found. Our results provide among the first quantitative estimates of red and corsac fox home range size in Mongolia and a baseline for developing management and conservation actions.

Key words: Home range, Mongolia, Steppe, Territory, *Vulpes*

Introduction

Corsac and red foxes range widely across northern and central Asia (LARIVIÈRE & PASITSCHNIAK-ARTS 1996, CLARK et al. 2009). In Mongolia, both species occur sympatrically in many parts of the country and have been described as occurring in open expanses across steppe, semi-desert, and desert environments (OGNEV 1962, MALLON 1985, HEPTER & NAUMOV 1992, CLARK et al. 2006). However, corsac foxes appear to occupy primarily open grassland, shrubland steppe, and semi-deserts (MURDOCH et al. 2007). Red foxes, by comparison, reportedly range throughout the entire country, occupying all major vegetation zones from lowland desert regions to high alpine environments (MALLON 1985, CLARK et al. 2006). Although both species apparently remain relatively common, declines in recent years from over-hunting led to both species being listed as Near Threatened by the International Union for Conservation of Nature (IUCN) in Mongolia (CLARK et al. 2006, WINGARD & ZAHLER 2006).

Few studies have examined red fox space-use and ranging behavior in Mongolia and most information is based on opportunistic observations and reports. Elsewhere red foxes exhibit highly variable home range sizes (Cavallini 1996), and the availability of resources, such as food and habitat, affects home range size in the species (MACDONALD 1983). For example, in resource-rich areas such as urban and suburban environments, home ranges have been reported as small as 0.4 km^2 (Oxford, UK), whereas in resource-poor areas such as desert environments (e.g., Arctic and Arabian Desert), home ranges can exceed >40 km^2 (MACDONALD & REYNOLDS 2004). One red fox home range in the deserts of Oman reached 50 km^2 (LINDSAY & MACDONALD 1986). Overlapping home ranges also occur in some, but not all, urban and rural environments (HARRIS 1979, MEIA & WEBER 1996), and drifting territories have been reported (DONCASTER & MACDONALD 1991).

Home range sizes for corsac foxes are also highly variable, but few quantitative estimates of actual range sizes exist. Most estimates have been based on opportunistic observations, reports, and sightings. During favorable years in optimal habitats, corsac fox breeding pairs may use home ranges as small as 1 km^2 (POYARKOV & OVSYANIKOV 2004). However, low-quality habitat with low food abundance tends to result in larger home range sizes that may reach 35–40 km^2 (HEPTER & NAUMOV 1992). In the Celenograd area of the former Soviet Union, corsac foxes inhabited breeding territories estimated as 1.9–3.7 km^2 (POYARKOV & OVSYANIKOV 2004).

In this study, we aimed to estimate the home range characteristics of corsac and red foxes in a steppe region of Mongolia. Our objectives were to: 1) calculate and compare home range sizes for each species, and 2) examine the effects of four factors (sex, season, year, and age) on home range size. Our results provide among the first quantitative estimates of corsac and red fox home range sizes in Mongolia and northern Asia. They further provide a foundation for assessing the population dynamics and conservation status of both species.

Study area

We conducted the study in Ikh Nart Nature Reserve (hereafter Ikh Nart), a small protected area located in the south-eastern Mongolia (N 45.72°; E 108.65°). Established in 1996, Ikh Nart protects approximately 666 km^2 of rocky outcrops and open plains (MYAGMARSUREN 2000, READING et al. 2011). The reserve lies on the border of two major vegetation zones in Mongolia; the steppe and semi-desert zones (MURZAEV 1948). Gently rolling plains dominated by grasses, semi-shrubs, and shrubs characterize the steppe zone. The semi-desert zone is more rugged, consisting of rocky outcrops and steep drainages separated by shrublands and open, forb-dominated plains. The climate of the area is continental and highly variable. Winter months are often cold, dry, and windy with temperatures that reach below -40 ˚C. Summer months are hot and dry with temperatures often between 30 and 40 ˚C. Average temperature in the reserve is 5 ˚C and precipitation is rare and falls mainly as rain. Most precipitation occurs during July and August.

Ikh Nart harbors a large diversity of fauna that consists of mixed grassland and semi-desert species (MURDOCH et al. 2006, READING et al. 2011). Since 2004, on-going research projects have identified 38 mammal species, including carnivores such as corsac and red fox, Pallas' cat (*Otocolobus manul*), badger (*Meles leucurus*), wolf (*Canis lupus*), and lynx (*Lynx lynx*), and ungulates such as argali sheep (*Ovis ammon*), Asiatic ibex (*Capra sibirica*), Mongolian gazelle (*Procapra gutturosa*), and goitered gazelle (*Gazella subgutturosa*) along with >185 birds, 7 reptiles, and dozens of insect species (READING et al. 2011).

Methods

To estimate home range sizes and evaluate general ranging characteristics of foxes, we live-trapped and radio-tagged yearling and adult foxes from 2004 to 2008. We captured foxes using box traps (Model 208, Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) and padded soft-catch leg-hold traps (Victor Soft Catch 1.5, Woodstream Corporation, Lititz, Pennsylvania, USA). We baited traps with commercial hunting lures and modified leg-hold traps by increasing jaw offset to minimize the potential for injury. We set traps in the evening and checked them in early morning from June to September. We handled captured foxes in cloth bags without chemical restraint. We outfitted captured foxes with ear tags (Conservation tags, National Band and Tag Company, Newport, Kentucky, USA) and VHF radio-transmitters weighing 60 g for red foxes and 40 g for corsac foxes (model 1950 and 1930, Advanced Telemetry Systems, Isanti, Minnesota, USA), which comprised <5 % of body weight. All capture, handling, and radio-collaring protocols were reviewed and approved by the Denver Zoological Foundation.

We obtained locations on marked foxes using radio-telemetry. We used handheld and null-peak antennas to bi-angulate locations at distances from animals of typically 500 m. We maintained inter-bearing angles between 20˚ and 160˚ for estimating locations to minimize error (GESE et al. 1988). We attempted to collect a minimum of one daytime location and one nighttime location from every collared animal each week.

We calculated animal locations from bearings using the LOAS Program (v. 3.0.4., Ecological Software Solutions LLC, Hegymagas, Hungary). We used Arcview 3.2a Geographic Information Systems software (Environmental Systems Research Institute, Redlands, California, USA) with the Animal Movement extension (HOOGE & EICHENLAUB 1997) to estimate home ranges. We estimated home ranges as 90 % adaptive kernels and core areas within home ranges as 50 % fixed kernels and used least squares cross validation to select the smoothing parameter (Worton 1989). We conducted a repeated measures analysis of variance to determine the effects of four factors: sex, season, year, and age on fox home range size. We defined seasons on the basis of energetic demands related to reproduction. Seasons included: breeding, which included mating and gestation (December 15 to April 14), pup-rearing (15 April to 14 August), and the non-breeding dispersal period (August 15 to December 14).

We examined all variables for statistical test assumptions and transformed variables when necessary. We removed 1-2 outliers for some analyses, square root transformed 90 % kernel home ranges for both species, and natural log transformed 50 % kernel core areas for both species to meet statistical assumptions of normality. We used General Linear Models to control for the effects of multiple variables when comparing means. Unless otherwise noted, we report all means as ± 1 SE.

Results

We captured and radio-collared 15 corsac foxes (♂ = 8, ♀ = 7) and 13 red foxes (♂ = 5, ♀ = 8) between 2004 and 2008. We obtained 2,673 locations from red foxes from 2006 to 2008 and 1,983 locations from corsac foxes from 2004 to 2006 during the study (fig. 1).

For red foxes, female home ranges varied between 8.9–22.1 km^2 and male home ranges varied between 1.5–16.5 km^2 (fig. 2). Red fox core areas ranged between 1.7–6.9 km^2 for females and 0.4-3.9 km^2 for males. Mean home range and core area sizes for female red foxes (14.51 ± 2.45 km^2 and 3.92 ± 0.87 km^2, respectively) were larger than male foxes (11.89 ± 2.32 km^2 and 2.58 ± 0.55 km^2, respectively), but not significantly so (table 1; fig. 2). Similarly, male corsac foxes used smaller mean home ranges, 4.93 ± 0.77 km^2, than female foxes, 5.03 ± 1.78 km^2; also not significant (table 1; fig. 2). Corsac foxes used small core areas, with a mean area of 1.43 ± 0.32 km^2. Male corsac foxes used significantly smaller core activity areas (1.22 ± 0.55) than those of females (2.02 ± 0.87) (table 1, fig. 2).

Mean adult red fox home ranges covered 15.44 ± 2.16 km^2 (n = 43), significantly (table 1) larger than the mean yearling red fox home range size of 4.31 ± 1.04 km^2 (n = 7) (fig. 3). In contrast, mean home ranges for adult corsac foxes covered 4.52 ± 0.75 km^2 (n = 19), smaller than the mean yearling corsac fox home range size of 7.05 ± 1.91 km^2 (n = 4), but not significantly smaller (table 1, fig. 3). Core use areas displayed the same trend for both species (table 1, fig. 3).

We examined seasonality by comparing home range size during breeding, pup rearing, and dispersal seasons. Red foxes covered mean home ranges of 16.62 ± 4.59 km^2 during the breeding season, 13.33 ± 2.45 km^2 during the dispersal season, and 10.95 ± 2.34 km^2 during the pup rearing season (fig. 4). These differences were not significant (table 1). Corsac foxes used the largest home ranges during the dispersal season (5.91 ± 1.14 km^2), followed by the pup rearing season (4.40 ± 1.46 km^2), and then the breeding season (3.94 ± 0.39 km^2) (fig. 4), but these differences were not significant (table 1). We found similar trends for core use areas for both species (table 1, fig. 4).

We found significant affects from year for red foxes, but not for corsac foxes (table 1, fig. 5). For red foxes, home range and core use area increased significantly from 2006 (8.04 ± 1.92 km^2 and

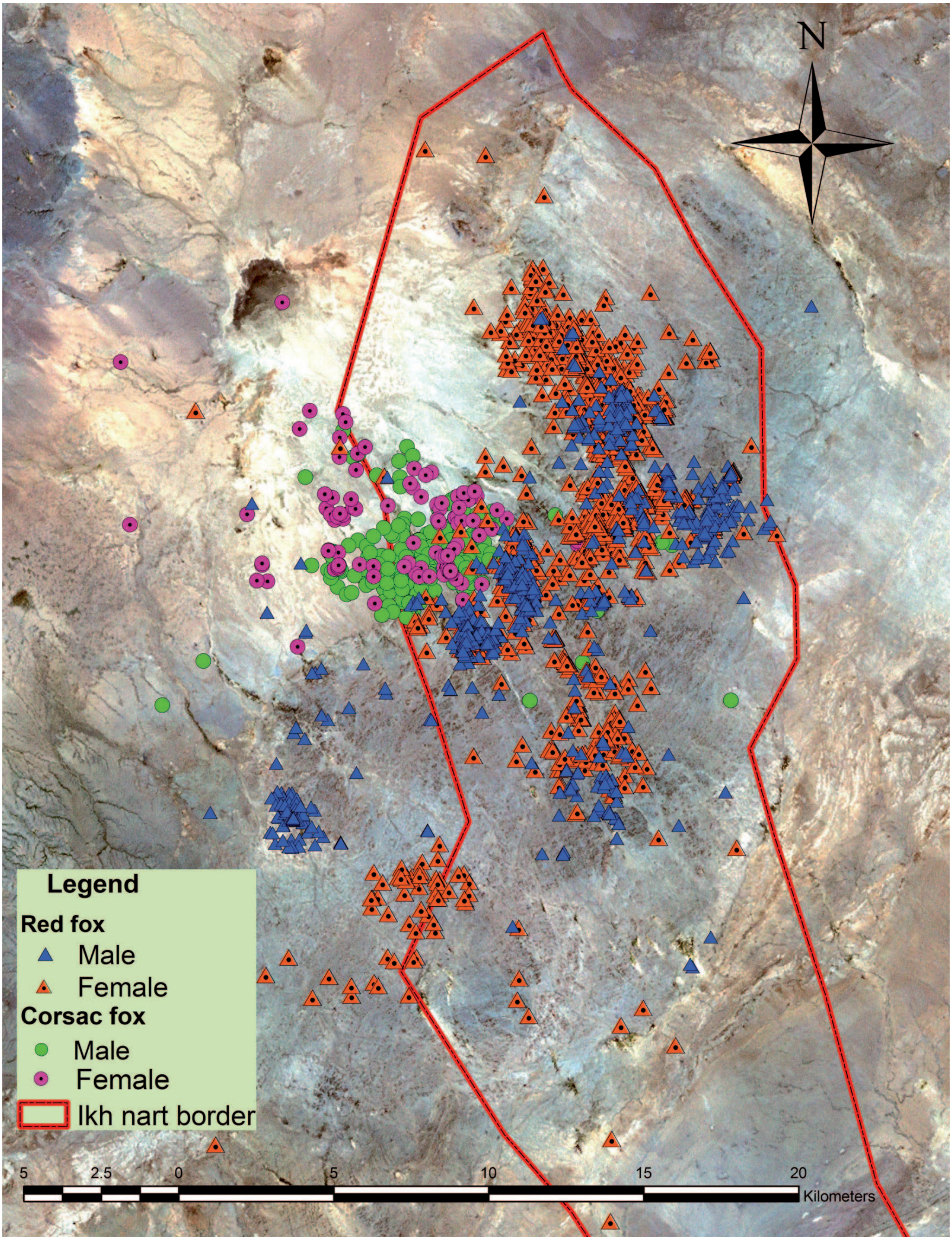

Fig. 1: Locations of radio-collared red foxes (*Vulpes vulpes*; *n* = 12) and corsac foxes (*V. corsac*; *n* = 10) collected in Ikh Nart Nature Reserve, Mongolia from 2004 to 2006 for corsac foxes and 2006 to 2008 for red foxes. Locations overlaid on a composite satellite image of the reserve.

Table 1: Effects of sex, season, year, and age on red fox (*Vulpes vulpes*; *n* = 12) and corsac fox (*V. corsac*; *n* = 10) home range sizes in Ikh Nart Nature Reserve, Mongolia from 2006 to 2008 using General Linear Models. Analyses conducted on square root transformed 90 % kernel data and log transformed 50 % kernel data. We removed 2 outliers for the 90 % kernel red fox data, 1 outlier for the 50 % kernel red fox data, and 1 outlier for the 50 % corsac fox data. Home ranges estimated as 90 % fixed kernels and core areas represented as 50 % fixed kernels

Variable	df	Mean Squares	F-Ratio	P
Red fox **90 % Kernel: *n* = 48; adj. R^2 = 0.425**				
Sex	1	0.27	0.27	0.61
Season	2	1.71	1.73	0.19
Age	1	13.55	13.76	**< 0.01**
Year	2	7.77	7.90	**< 0.01**
Telemetry locations	1	12.43	12.63	**< 0.01**
Error	40	0.98		
50 % Kernel: *n* = 49; adj. R^2 = 0.467				
Sex	1	0.29	0.57	0.46
Season	2	1.18	2.27	0.12
Age	1	10.14	19.46	**< 0.001**
Year	2	4.11	7.89	**< 0.01**
Telemetry locations	1	4.72	9.05	**< 0.01**
Error	41	0.52		
Corsac fox **90 % Kernel, *n* = 23, adj R^2 = 0.445**				
Sex	1	1.60	3.20	0.09
Season	2	1.29	2.58	0.11
Year	2	1.66	3.32	0.06
Age	1	0.17	2.82	0.11
Telemetry locations	1	1.41	0.33	0.58
Error	15	0.95		
50 % Kernel, *n* = 22, adj R^2 = 0.457				
Sex	1	7.38	7.72	**0.02**
Season	2	1.64	1.72	0.22
Year	2	1.71	1.79	0.20
Age	1	0.01	0.02	0.90
Telemetry locations	1	4.16	4.35	0.06
Error	14	0.51		

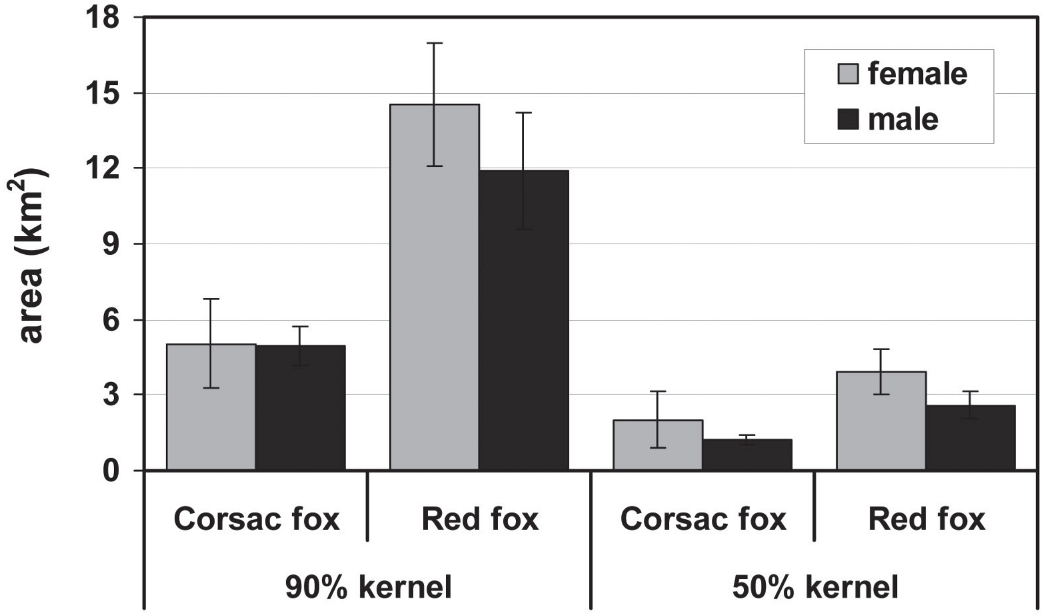

Fig. 2: Comparison of male and female red fox (*Vulpes vulpes*) and corsac fox (*V. corsac*) mean (± SE) 90 % and 50 % kernel home range sizes in Ikh Nart Nature Reserve, Mongolia from 2004 to 2006 for corsac foxes and 2006 to 2008 for red foxes.

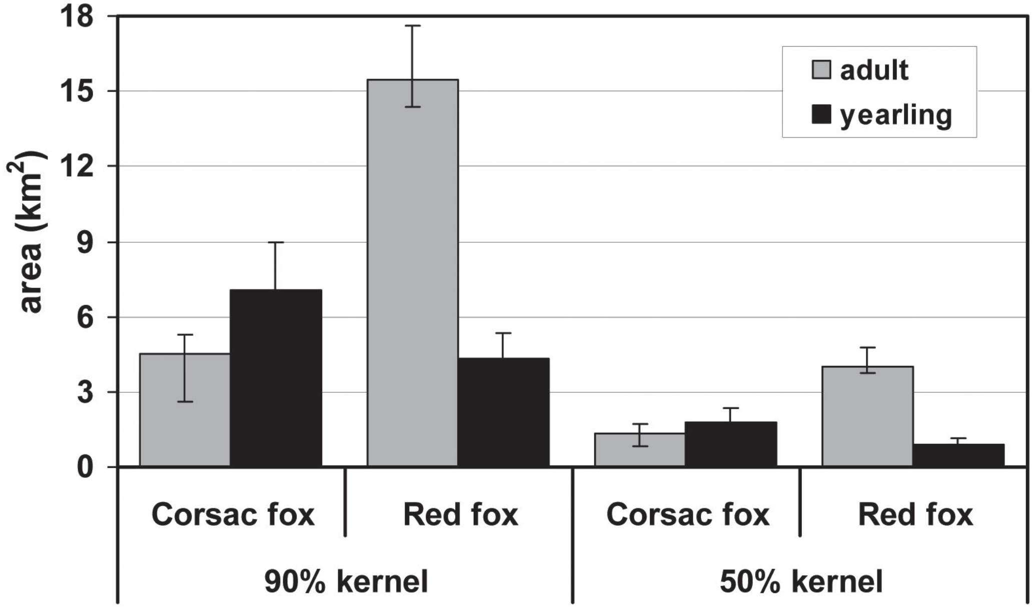

Fig. 3: Comparison of adult and yearling red fox (*Vulpes vulpes*) and corsac fox (*V. corsac*) mean (± SE) 90 % and 50 % kernel home range sizes in Ikh Nart Nature Reserve, Mongolia from 2004 to 2006 for corsac foxes and 2006 to 2008 for red foxes.

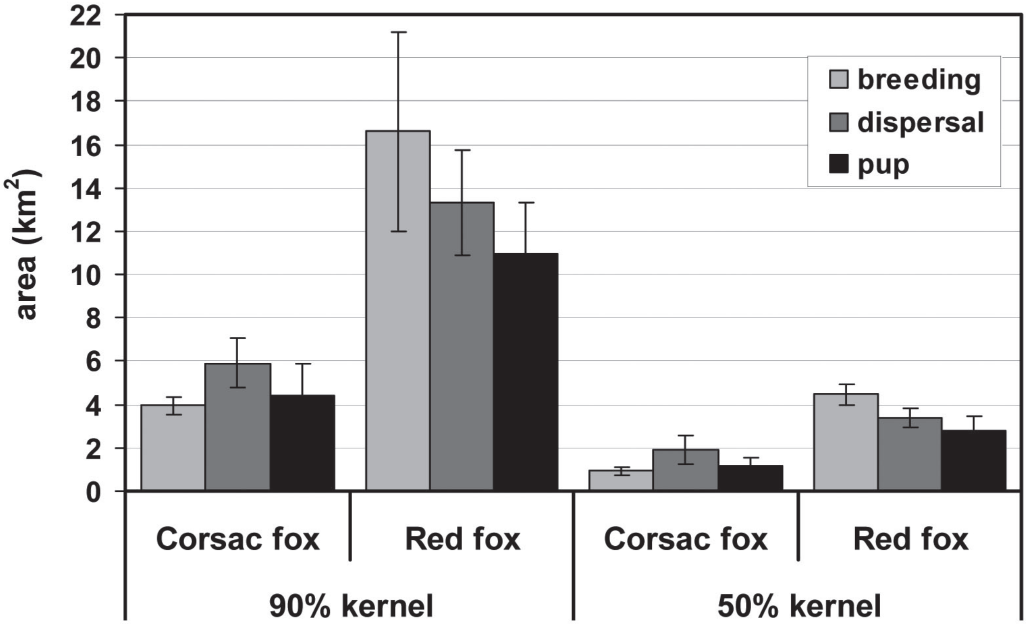

Fig. 4: Comparison of A) corsac fox (*V. corsac*) and B) red fox (*Vulpes vulpes*) mean (± SE) 90 % and 50 % kernel home range sizes by season in Ikh Nart Nature Reserve, Mongolia from 2004 to 2006 for corsac foxes and 2006 to 2008 for red foxes. Seasons defined by the energetic demands of foxes related to reproduction: breeding, which included mating and gestation (December 15 to April 14), early pup-rearing (15 April to 14 August), and the non-breeding dispersal period (August 15 to December 14).

1.80 ± 0.48 km^2, respectively) to 2007 (13.90 ± 2.15 km^2 and 3.67 ± 0.45 km^2, respectively) to 2008 (19.23 ± 5.75 km^2 and 5.11 ± 0.73 km^2, respectively). Corsac foxes used their largest home ranges and core areas in 2006 (7.70 ± 3.20 km^2 and 2.10 ± 0.70 km^2, respectively) and their smallest home ranges and core areas in 2005 (4.09 ± 0.82 km^2 and 1.50 ± 0.46 km^2, respectively), with their home ranges and core areas in 2004 falling between 6.22 ± 1.14 km^2 and 1.05 ± 0.36 km^2, respectively.

The number of telemetry locations used to calculate the 90 % kernel home ranges and 50 % kernel core areas significantly influenced area for red foxes (fig. 6), but not corsac foxes (table 1). As the number of telemetry locations increased, the size of both the home range and core area for red foxes decreased.

Corsac foxes and red foxes also exhibited similar activity patterns, with both species primarily active at night. However, we noted fine-scale differences in nocturnal movements. Both species occurred in all major habitats, but we detected differences in habitat selection at multiple spatial scales. Corsac foxes selected mainly 'steppe' habitats in open plains. These habitats included dense shrubland, semi-shrubland, and tall grassland. Red foxes selected more rugged, semi-desert habitats such as rocky outcrops and open shrubland (fig. 1).

Discussion

Corsac and red foxes range widely across Mongolia and occupy most major biomes in the country (MALLON 1985, CLARK et al. 2006). Both species represent among the most widespread and perhaps most common carnivores in Mongolia. However, populations are thought to be declining

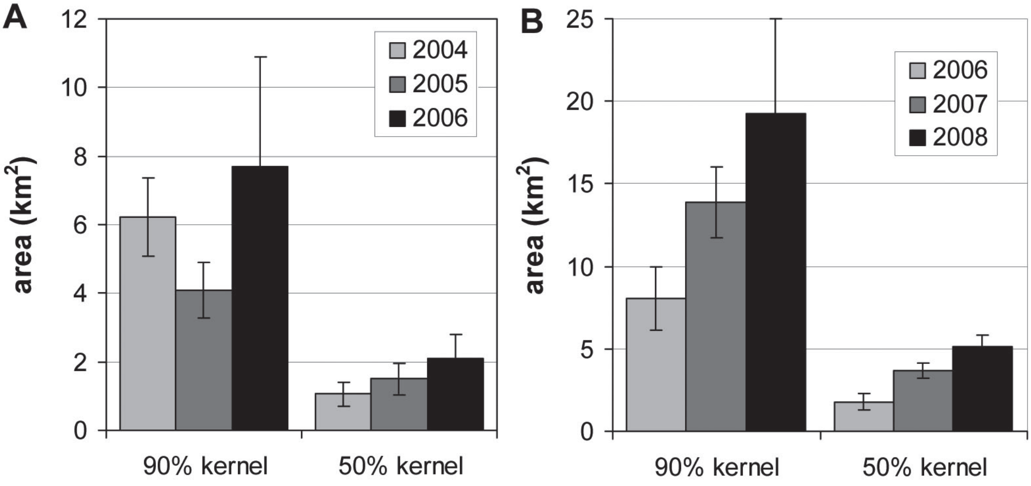

Fig. 5: Comparison of A) red fox (*Vulpes vulpes*) and B) corsac fox (*V. corsac*) mean (± SE) 90 % and 50 % kernel home range sizes by year in Ikh Nart Nature Reserve, Mongolia from 2004 to 2006 for corsac foxes and 2006 to 2008 for red foxes.

due to over-hunting and the need exists for management strategies to better protect both species, especially in protected areas such as Ikh Nart (CLARK et al. 2006, WINGARD & ZAHLER 2006). Little information exists on the ecology and ranging behavior of both species in Mongolia, which limits management, and most published information has been based on opportunistic observations and reports. Our study aimed to quantify the basic home range characteristics of corsac and red foxes. The results provide a baseline measure of the ranging behavior of both species and will provide a foundation for their conservation in Ikh Nart and elsewhere in Mongolia.

Red foxes occupied relatively large home ranges. The average home range size for our study population compared well with home range estimates for foxes at similar latitudes. For example, red foxes occupied home ranges that averaged 14.7 km^2 in Maine, USA (HARRISON et al. 1989). Home ranges elsewhere tend to be smaller (CAVALLINI 1996). Corsac foxes occupied smaller home ranges than red foxes, which probably reflects their smaller size (MURDOCH et al. 2009). Average corsac fox home ranges compared well with home ranges of other similar arid-adapted foxes, such as swift foxes (*Vulpes velox*) and kit foxes (*V. macrotis*) (LIST & CYPHER 2004, MOEHRENSCHLAGER & SOVADA 2004).

Home ranges exhibited variation by sex and age, and temporally, by season and year and we detected some significant influences on home range size. We expected these factors to affect both fox species in a similar manner, given their close taxonomic relationship and general ecology (Hepter and Naumov 1992). However, we found factors with a significant effect only influenced home ranges of one species and not the other. This may be due to our relatively small sample size, behavioral or ecological differences between species, or other confounding variables that we did not consider.

Regarding sex, we found that both red and corsac fox females occupied larger home ranges than males, but that only corsac females core ranges were significantly larger than those of males. In contrast to our study, males commonly use larger ranges than females among carnivores and may reflect several factors for red and corsac foxes. Females have different energetic demands, especially during pup-rearing that may increase range size (LARIVIÈRE & PASITSCHNIAK-ARTS 1996, CLARK et al. 2009). Yet, males may seek extra-pair matings with neighboring females or engage in more territorial behavior than females, which could extend the size of their ranges (IOSSA et al. 2008).

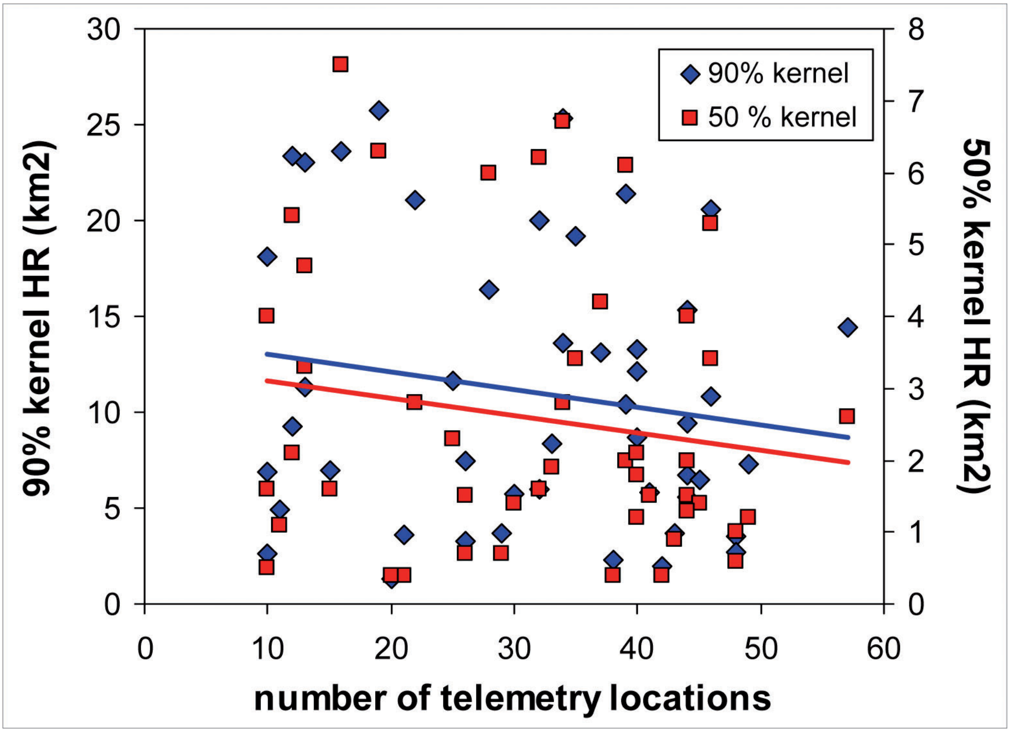

Fig. 6: Correlation between number of telemetry locations and both 90 % kernel home range sizes and 50 % kernel core use areas for red foxes (*Vulpes vulpes*) in Ikh Nart Nature Reserve, Mongolia from 2006 to 2008; 90 % kernel home range = 13.92 – 0.092 (telemetry days); 50 % kernel core area = 3.36 – 0.024 (telemetry days).

Body mass dimorphism may also explain differences, especially among red foxes, which generally exhibit slight size dimorphism (larger males than females) (IOSSA et al. 2008). However, previous studies in Ikh Nart suggested little dimorphism among either corsac or red foxes (MURDOCH et al. 2009).

Regarding age, we found that only red fox adults had significantly larger ranges than yearlings. We did not detect significant differences in range size between adults and yearlings among corsacs, although yearlings generally used larger ranges than adults. This may have resulted from our small sample size for yearlings, but may also relate to efforts among yearlings to find and establish their own home ranges or perhaps disruptions in social structure due to intensive hunting and trapping by local herders (see below) (MURDOCH et al. 2010b).

Regarding temporal effects, we found relatively stable home ranges of both species across seasons, but significantly different range sizes by year for red foxes. Yearly changes probably reflect broad-scale fluctuations in resource availability due to changes in precipitation. Precipitation is variable and occurs rarely in the Gobi Steppe ecosystem (READING et al. 2006, READING et al. 2011), which influences the abundance of prey species such as small mammal and insect species (MURDOCH et al. 2010a). We found that home ranges generally expanded during years with less rainfall.

Although we did not assess habitat use among foxes, foxes clearly exhibited distinct patterns of selection with corsacs favoring open steppe areas, including grasslands and shrublands, and red foxes favoring more rugged, rocky terrain. We believe that home range size largely reflects the distribution of habitats and resources within them. The Resource Dispersion Hypothesis (RDH) provides a framework for interpreting variation in home range size (MACDONALD 1983). The RDH predicts that territory size is a function of the dispersion of food resource patches across a landscape, and that the fruitfulness of those patches influences group size (JOHNSON et al. 2002). Corsac and red foxes consume mainly small mammals and insects (MURDOCH et al. 2010a) that occur in relatively discrete patches in Ikh Nart, and we recommend that future studies examine how the dispersion of these patches affects range size.

Another important factor that probably shapes the ranging behavior of both species is hunting and trapping. Corsac and red foxes possess valuable furs and local people intensively hunt both species in many regions of Mongolia, including Ikh Nart (WINGARD & ZAHLER 2006, MURDOCH et al. 2010b). Harvesting usually occurs in early winter, and remains largely unregulated. A reduction in population densities due to over-harvesting probably reduces intra and interspecific competition, and allows individual foxes to occupy larger home ranges. Little information exists on the effects of harvesting on the behavior, ecology, or population dynamics of either species.

Our study certainly had limitations, but demonstrated the feasibility of safely and effectively capturing, radio-collaring, and tracking the movements of corsac and red foxes in the Mongolian landscape. Our study represents the first effort to radio-collar corsac foxes and first to radio-collar red foxes in Mongolia. We recommend that future research explore the spatial dynamics of each species and how various landscape factors influence patterns of distribution. Occupancy modeling based on non-invasive surveys (MACKENZIE et al. 2002) represents an approach that could be used to understand these patterns.

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