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Accuracy of Estimating Wolf Summer Territories by Daytime Locations

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ABSTRACT.—We used locations of 6 wolves (*Canis lupus*) in Minnesota from Global Positioning System (GPS) collars to compare day-versus-night locations to estimate territory size and location during summer. We employed both minimum convex polygon (MCP) and fixed kernel (FK) methods. We used two methods to partition GPS locations for day-versus-night home-range comparisons: (1) daytime = 0800–2000 h; nighttime = 2000–0800 h; and (2) sunup versus sundown. Regardless of location-partitioning method, mean area of daytime MCPs did not differ significantly from nighttime MCPs. Similarly, mean area of daytime FKs (95% probability contour) were not significantly different from nightime FKs. FK core use areas (50% probability contour) did not differ between daytime and nighttime nor between sunup and sundown locations. We conclude that in areas similar to our study area day-only locations are adequate for describing the location, extent and core use areas of summer wolf territories by both MCP and FK methods.

INTRODUCTION

Very high frequency (VHF) telemetry during daytime has been used to locate and observe wolves since the late 1960s (Mech, 1973). Telemetry projects typically locate wolves when conditions permit flying and observation of animals (Mech, 1973, 2009; Van Ballenberghe *et al.*, 1975; Fritts and Mech, 1981; Peterson *et al.*, 1984; Ballard *et al.*, 1987; Fuller, 1989; Wydeven *et al.*, 2009). These locations are used to estimate wolf-pack home ranges (usually MCPs or FKs) or territories. Because no study we are aware of has compared wolf spatial use during the day with that during the night using any method, wolf territories calculated using VHF locations might only be representative of wolf space use during daytime.

Global Positioning System (GPS) collars became available for wildlife research in the 1990s (Rodgers and Anson, 1994), and are now commonly used for wolf research. Because they can automatically collect large amounts of location data around the clock and in all weather conditions, they can provide an unbiased estimate of 24 h wolf-territory area and location, movement patterns (Merrill and Mech, 2003), predation behavior (Demma *et al.*, 2007), kill rates (Sand *et al.*, 2008; Webb *et al.*, 2008) and wolf home-range size (Mills *et al.*, 2006). However, we are unaware of any GPS-based comparisons between wolf home ranges determined at night versus day. Smith *et al.* (1981) calculated coyote (*Canis latrans*) minimum convex polygon (MCPs) from VHF locations collected during daylight, half-night

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and full-night tracking periods, and concluded that home range sizes determined from >3 nights of hourly locations were considerably larger than those determined from daylight locations.

Because a large body of extant wolf information exists that relied on daytime VHF locations, an assessment is needed to determine if wolf location data collected only during the day represent only the extent of daytime use or whether these data represent both day and night use. Thus we used GPS telemetry to determine how daytime wolf locations compare to those of nightime locations and thus to assess the suitability of using wolf locations obtained by the more conventional daytime methods to characterize a wolf territory. Studies comparing results between different home-range-estimation methods have been published elsewhere and were not the focus of this study.

STUDY AREA

We conducted our study during Jun. through Aug. of 2003–2004 in a 2100-km^2 area in the Superior National Forest (SNF) of northeastern Minnesota (48°N, 92°W). Nelson and Mech (1981) provided a detailed description of the study area. Wolves occurred throughout the study area at densities of 30–36/1000 km^2 during the study (Mech, 2009). White-tailed deer (*Odocoileus virginianus*) occurred at densities of 12–15/10 km^2 (M. H. Dexter, Minnesota Department of Natural Resources, unpublished report) and constituted the major prey of wolves in the area (Frenzel, 1974; Nelson and Mech, 1981, 1986), primarily fawns during summer (Van Ballenberghe *et al.*, 1975; Nelson and Mech, 1986; Kunkel and Mech, 1994).

METHODS

During May–Jul. 2003–2004 we live-trapped, immobilized, and examined six wolves from four packs using standard techniques (Demma *et al.*, 2007). We fitted wolves with store-on-board and remote-downloadable GPS radiocollars programmed to obtain locations at regular intervals [Advanced Telemetry Systems, Inc. (ATS), Isanti, MN; Televilt, Lindesberg, Sweden; and Vectronic Aerospace, Berlin, Germany]: the four Televilt collars at 10 min intervals and the single ATS and Vectronic collars at 15 min intervals, 24 h per day. (Mention of brand names does not constitute endorsement by the U.S. Government.) We did not test whether location accuracy differed between collar types. We expected locations of all collars to be within 5 m and 30 m of the true location 50% and 95% of the time, respectively (Moen *et al.*, 1997; Dussault *et al.*, 2001).

To minimize any potential movement bias resulting from wolf capture and immobilization, we excluded GPS locations collected during the first 5 d post-capture. We plotted all GPS data in ArcMap and used Hawth's Analysis Tools (2007) to calculate summer home ranges.

We estimated summer ranges for each wolf by using both the MCP (Mohr, 1947) and FK (Seaman and Powell, 1996) methods. We chose the MCP method because it is frequently used in determining home-range areas as a basis for estimating wolf population density; and the FK method because it is another commonly-used estimator which provides a utilization distribution (rather than a simple home range outline) and centers of activity (core use areas). We calculated MCPs and FKs using 100% of locations (but *see* next paragraph for data exclusions), and we considered these locations representative of minimum summer home ranges of our GPS-collared wolves. For the FK method, we used the 50% and 95% probability contours to estimate core use areas and territory location respectively.

We compared day and night home ranges calculated by both MCP and FK methods for each wolf using two techniques to partition day and night GPS locations for calculating territories: (1) daytime vs. nighttime: daytime locations = 0800–2000 h; nighttime locations

= 2000–0800 h; and (2) sunup vs. sundown: sunup locations were between sunrise and sunset times (National Oceanic and Atmospheric Administration sunrise/sunset calculator: http://www.srrb.noaa.gov/index.html) as determined at the geographic center of each wolf's GPS locations on the median day of their study period (sunrise range: 0511–0607; sunset range: 2009–2106); sundown locations were between sunset and sunrise. For each comparison we randomly selected from the larger data set the equivalent number of locations comprising the smaller data set. This removed any potential bias in pair-wise comparisons of MCP and FK area calculations resulting from differences in sample size. We used a paired *t*-test to assess for area differences, and determined proportion of overlap between day and night MCPs and FKs for both methods.

We compared MCPs and FKs of daytime vs. sunup locations for each wolf to determine the extent of overlap between day home ranges of both daytime-determination techniques.

RESULTS

During summers 2003–2004 we captured and fitted six wolves (2M, 4F) with GPS radiocollars from four wolf-pack territories. Wolf ages were 1–8 y old and included one breeding male and two breeding females (Table 1). Mean number of locations was 968 (SE = 242.6) for daytime-nighttime comparisons and 912 (SE = 160.0) for sunup-sundown comparisons. There was no significant relationship between number of locations and area for either partitioning technique using either the MCP or FK method.

Mean area of day MCPs did not differ from night MCPs ($t_5 = 0.63$, $P = 0.56$). Mean overlap between day and night MCPs was 79% (range = 0.65–0.92; SE = 0.03; Fig. 1). Area of sunup MCPs did not differ from sundown MCPs ($t_5 = 1.87$, $P = 0.12$). Mean overlap between sunup and sundown MCPs was 74% (range = 0.52–0.86; SE = 0.05; Fig. 1).

Mean area of daytime FKs (95% probability contour) did not differ from nighttime FKs ($t_5 = 0.26$, $P = 0.81$). Mean overlap between daytime and nighttime FKs was 78% (range = 0.67–0.93; Fig. 2). Area of sunup FKs did not differ significantly from sundown FKs ($t_5 = 1.17$, $P = 0.30$). Mean overlap between sunup and sundown FKs was 80% (range = 0.72–0.91; SE = 0.03; Fig. 2).

FK core use areas (50% probability contour) did not differ between daytime and nighttime ($t_5 = 0.30$, $P = 0.78$) or sunup and sundown ($t_5 = 0.57$, $P = 0.59$) locations (Fig. 2). Mean core use area overlap of breeding wolves was greater than that of nonbreeders for both daytime-nighttime ($t_4 = 3.36$, $P = 0.03$) and sunup-sundown ($t_4 = 4.40$, $P = 0.01$) comparisons. Although our sample was small, the difference is plausible because summer use of homesites by breeding wolves is more extensive than that of nonbreeders (Demma and Mech, 2008).

For most wolves MCP area differences relative to partitioning methods were minor and showed consistent, albeit insignificant, patterns (*i.e.*, daytime and sunup MCPs > nighttime and sundown MCPs respectively). Two wolves had disparate day and night characteristics relative to partitioning method. Daytime MCP areas for wolves 893 and 897 were < nighttime, while sunup areas > sundown. Both wolves had 1–2 occasions where they traveled near the edge of their summer territories just after sunrise or just prior to sunset, the timing of which put the locations in different day/night categories depending on partitioning method. Some locations from those travel bouts were used to determine MCP boundaries hence resulting in the contrasting day/night patterns between partitioning methods. Because FK area boundaries are determined by utilization distributions and do not rely only on the peripheral locations of point clusters (as with the MCP method), FK areas of the previously discussed wolves were consistent between partitioning techniques.

TABLE 1.—Comparisons of areas (km^2) of minimum convex polygons (MCP) and fixed kernel (FK) of daytime and nighttime locations of wolves by GPS collars during summer, Superior National Forest, Minnesota

MCP				Daytime vs. Nighttime					Sunup vs. Sundown				
Wolf no.	Sex	Age	Dates of GPS collar activity	No. locations	Daytime area	Nighttime area	Percent daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Percent sunup to sundown area	Overlap
881a	M	8	6/21/2004–8/07/2004	1334	185.1	183.4	101%	0.83	948	186	183.8	101%	0.86
883	F	1	6/03/2003–7/05/2003	371	187.4	186.6	100%	0.85	679	188.8	195.3	97%	0.86
893a	F	2	6/11/2003–7/11/2003	909	79.5	94.2	84%	0.65	814	79.3	68.3	116%	0.52
897	F	2	6/26/2003–7/09/2003	323	76.8	83.1	92%	0.76	428	94.4	63.5	149%	0.66
899a	F	2	6/27/2004–9/03/2004	1893	244.2	175.1	139%	0.71	1589	232.9	167.5	139%	0.70
901	M	2	6/16/2003–7/17/2003	977	231.6	234.9	99%	0.92	1014	235.4	220.5	107%	0.85
			mean	968	167.4	159.6	103%	0.79	912	169.5	149.8	118%	0.74
			SE	242.6	29.8	24.0	7.8%	0.04	160.0	27.6	27.4	8.7%	0.06

FK (95% probability contour)				Daytime vs. Nighttime					Sunup vs. Sundown				
Wolf no.	Sex	Age	Dates of GPS collar activity	No. locations	Daytime area	Nighttime area	Percent daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Percent sunup to sundown area	Overlap
881a	M	8	6/21/2004–8/07/2004	1334	219.6	212.9	103%	0.93	948	218.42	214.4	102%	0.91
883	F	1	6/03/2003–7/05/2003	371	256.42	265.2	97%	0.74	679	263.9	264.5	100%	0.80
893a	F	2	6/11/2003–7/11/2003	909	98.8	104.3	95%	0.77	814	98.4	99.9	98%	0.72
897	F	2	6/26/2003–7/09/2003	323	118.3	140.5	84%	0.67	428	132	138.4	95%	0.79
899a	F	2	6/27/2004–9/03/2004	1893	195.5	178.7	109%	0.80	1589	188.8	176.6	107%	0.81
901	M	2	6/16/2003–7/17/2003	977	272.3	248.4	110%	0.77	1014	269.5	243.6	111%	0.77
			mean	968	193.5	191.7	100%	0.78	912	195.2	189.6	102%	0.80
			SE	242.6	29.1	25.5	0.0%	0.04	160.0	28.4	25.8	0.0%	0.03

TABLE 1.—Continued

FK (50% probability contour)				Daytime vs. Nighttime					Sunup vs. Sundown				
Wolf no.	Sex	Age	Dates of GPS collar activity	No. locations	Daytime area	Nighttime area	Percent daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Percent sunup to sundown area	Overlap
881a	M	8	6/21/2004–8/07/2004	1334	44.53	44.8	99%	0.75	948	44	46.8	94%	0.76
883	F	1	6/03/2003–7/05/2003	371	70.35	75.2	94%	0.36	679	76.9	73.1	105%	0.50
893a	F	2	6/11/2003–7/11/2003	909	18.4	17.8	103%	0.87	814	18.4	17.3	106%	0.84
897	F	2	6/26/2003–7/09/2003	323	20.7	30.8	67%	0.65	428	22.8	31.9	71%	0.64
899a	F	2	6/27/2004–9/03/2004	1893	25.9	25.2	103%	0.91	1589	24.4	25.4	96%	0.93
901	M	2	6/16/2003–7/17/2003	977	73.99	52.2	142%	0.54	1014	73.1	49.6	147%	0.54
			mean	968	42.3	41.0	101%	0.68	912	43.3	40.7	103%	0.70
			SE	242.6	10.2	8.6	0.1%	0.09	160.0	10.7	8.2	0.1%	0.07

[a] Breeder

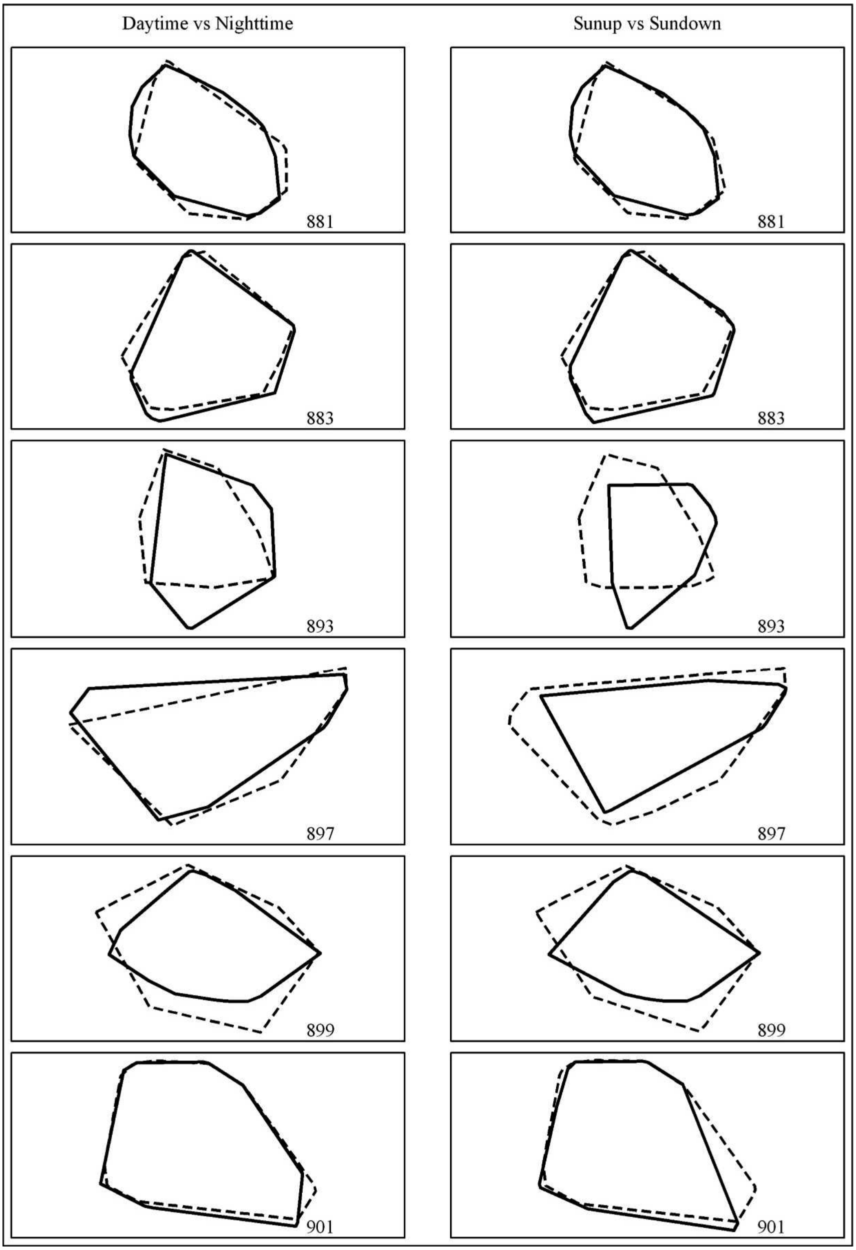

FIG. 1.—Day (dashed) and night (solid) minimum convex polygons (MCPs) of Global Positioning System (GPS) wolf locations partitioned using two different techniques in the Superior National Forest of northeastern Minnesota, USA, during 2003–2004

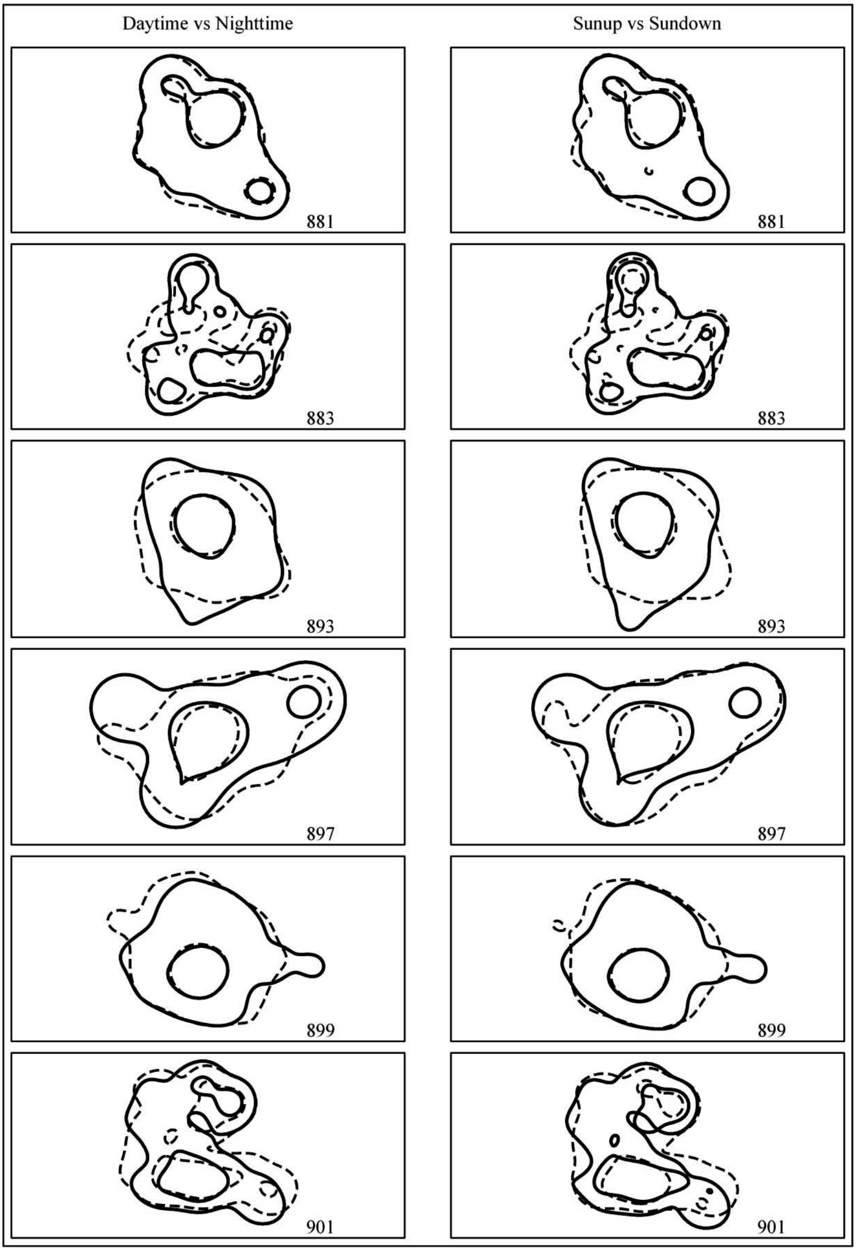

FIG. 2.—Day (dashed) and night (solid) fixed kernels (50% and 95% probability contours) of Global Positioning System (GPS) wolf locations partitioned using two different techniques in the Superior National Forest of northeastern Minnesota, USA, during 2003–2004

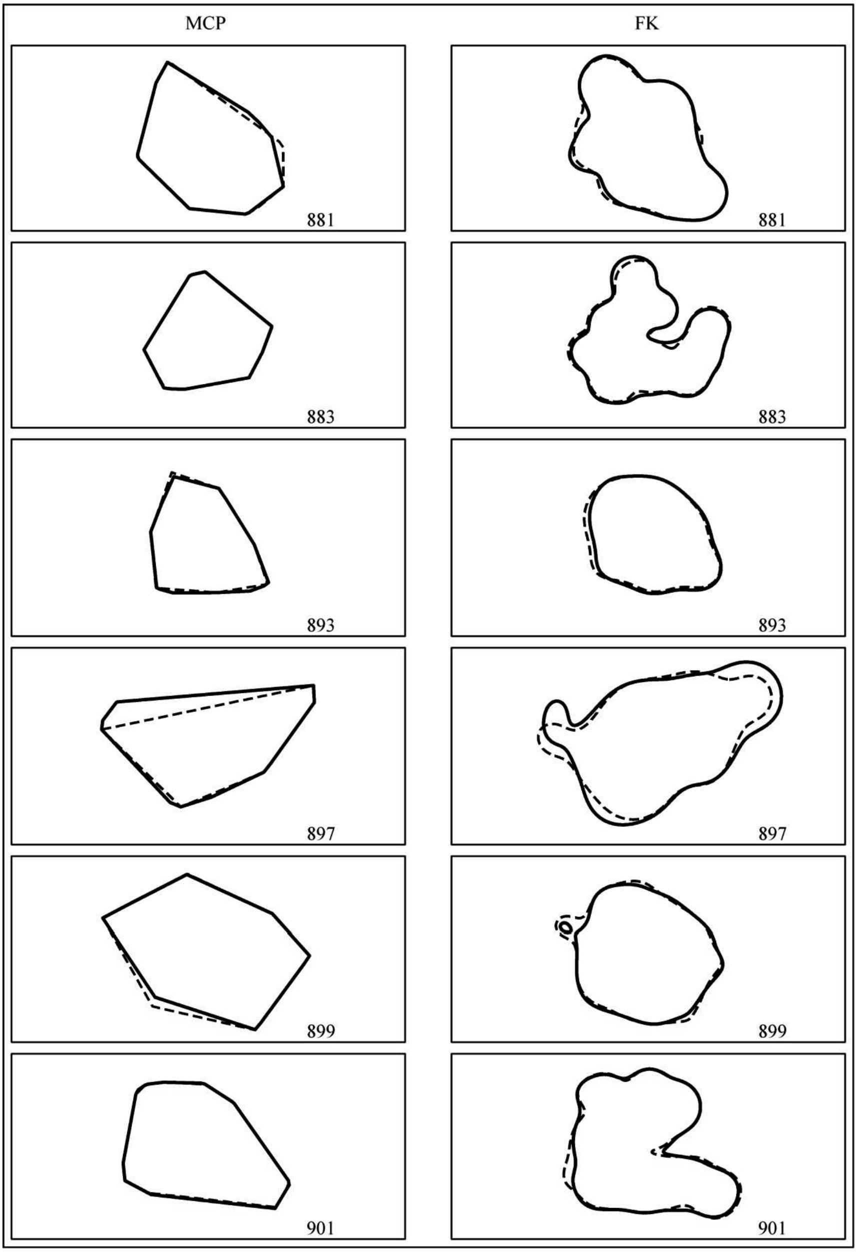

FIG. 3.—Daytime (dashed) and sunup (solid) minimum convex polygons (MCPs) and 95% probability contour fixed kernels (FKs) of wolf Global Positioning System (GPS) collar locations during summers 2003–2004 in the Superior National Forest in northeastern Minnesota (daytime locations: 0800–2000; sunup locations were those between sunrise and sunset at the geographic center of each wolf's GPS locations on the median day of their study period)

Mean overlap of daytime vs. sunup home ranges was 95% (range 81–100, SE = 2.8) for MCPs, and 92% (range 84–95, SE = 1.7) for FKs (Fig. 3).

DISCUSSION

The day and night territories of our wolves were comparable in size and location for both the MCP and FK home range estimation methods. Regardless of which technique we used to partition day and night locations, our findings suggest that using only day locations is a reasonable method to estimate location and area of summer wolf home ranges by both the MCP and FK methods in areas similar to our study area.

Individual wolf movements at the periphery of summer territories during early morning or late in the day can potentially result in differences between day and night MCP characteristics relative to technique used to partition locations. The FK method (95% probability contour) for determining territory boundaries was more consistent between data partitioning methods. Regardless, both methods produced similar day home ranges in terms of location and area.

Even with the advent of GPS collars, VHF telemetry continues to be a valuable tool to reliably locate and observe wolves. Further, there is a large body of extant wolf research which relied on VHF telemetry collected during daylight hours. Comparisons between GPS and VHF telemetry studies are inevitable. We propose that summer wolf territory area and location estimated by using only day VHF locations are accurate in study areas similar to ours as long as a sufficient sample of locations is collected throughout the duration for which the estimate applies. Because wolves are widely distributed and daily light regimens vary with latitude, we suggest that studies similar to ours be conducted elsewhere to determine the degree to which our results can be generalized. We conducted our study during summer when dens and rendezvous sites are generally the focal point of wolf movements. Future studies including fall, winter and spring wolf locations would elucidate whether day locations are adequate to estimate areas of year-round territories.

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