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ORIGINAL ARTICLE

Preliminary Data Used to Assess the Accuracy of Estimating Female White-Tailed Deer Diel Birthing-Season Home Ranges Using Only Daytime Locations

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Very high frequency.

Abstract

Because many white-tailed deer (*Odocoileus virginianus*) home-range and habitat-use studies rely only on daytime radio-tracking data, we were interested in whether diurnal data sufficiently represented diel home ranges. We analyzed home-range and core-use size and overlap of 8 adult-female Global-Positioning-System-collared deer during May and June 2001 and 2002 in the Superior National Forest, Minnesota, USA. We used 2 traditional means of analysis: minimum-convex polygons (MCP) and fixed kernels (95% FK, home range and 50% FK, core use) and two methods to partition day and night location data: (1) daytime = 0800-2000 h versus nighttime = 2000-0800 h and (2) sunup versus sundown. We found no statistical difference in size of home-range and core-use areas across day and night comparisons; however, in terms of spatial overlap, approximately 30% of night-range areas on average were not accounted for using daytime locations, with even greater differences between core-use areas (on average approximately 50%). We conclude that diurnal data do not adequately describe diel adult-female-deer, May-June home-ranges due to differences in spatial overlap (location). We suggest research to determine (1) if our findings hold in other circumstances (e.g., exclusive of the parturition period, other age classes, etc.), (2) if our conclusions generalize under other conditions (e.g., across deer range, varying seasons, etc.), (3) if habitat-use conclusions are affected by the incomplete overlap between diurnal and diel data, (4) how many nocturnal locations must be included to generate sufficient overlap, and (5) the influence of using other kernel sizes (e.g., 75%, 90%).

Introduction

VHF (very high frequency) radio locations have been used since the 1960's to investigate animal movements and related ecology [1-2]. Traditionally, due largely to logistics (e.g. aerial telemetry), such data were primarily restricted to diurnal or crepuscular periods and often used to assess home ranges [3-4]. Many white-tailed deer (*Odocoileus virginianus*) home-range and habitat-use studies have traditionally comprised only daytime or crepuscular locations (e.g. [5-7]). Depending on how well diurnal data represent diel home ranges, certain subjects such as behavior, habitat use, habitat selection, etc. may not be definitively addressed using diurnal-only data. Thus we were interested in the degree to which diurnal data accurately represented diel home ranges.

Whereas this subject has been assessed for wolves (*Canis lupus*, [8]), it has yet to be examined in white-tailed deer during May-June (e.g., this period encompasses the typical birthing season in our study area, [9]). One study investigated whether year-around diurnal data were appropriate to estimate diel habitat-use patterns in white-tailed deer but did not address home-range comparisons [10]. Another compared global positioning system (GPS) and VHF diurnal and nocturnal home ranges of white-tailed deer during winter [11]. That study determined that whereas diurnal and nocturnal winter home ranges were similar, their "differences may have important implications for studies focused on deer use of space, habitat, and resources at a finer scale" [11, page 779]. We assessed: (1) whether May-June diurnal deer data adequately represented corresponding nocturnal data and (2) whether different partitioning methods of day and night affected this comparison.

Methods

Study area

Our study area was comprised of 2,060-km^2 in the Superior National Forest, Minnesota, USA during May-June 2001 and 2002. (See [9] for detailed description). During 2002, prefawning deer densities throughout our study area were 4-14/10 km^2 (M. H. Dexter, Minnesota Department of Natural Resources, unpublished report). The primary predator of deer there is the wolf [9,12-13], and mean wolf density was approximately 25/1000 km^2 during our study [14].

Methods

During March 2001 and April 2002, we live-trapped, anesthetized, examined and fitted with GPS radiocollars [Advanced Telemetry Systems, Inc. (ATS), Isanti, MN] female deer [15]. We programmed GPS collars to acquire locations every 15 or 30 min, 24 h/day during May-June although some collars had varying schedules. We expected locations to be within 5 m and 30 m of the true location 50% and 95% of the time, respectively [16-17].

Because we posed similar questions for deer as Demma and Mech did for wolves [8] we generally followed the methods used by those researchers. We plotted all data in ESRI® ArcMap™ 10.0 (2010) and used Geospatial Modeling Environment version

0.5.5 Beta (2011) to generate home ranges and calculate centroids, polygon area and overlapping polygon area. We excluded locations if a deer had not yet completed her spring migration, or if the deer was dispersing or moving to a novel home range as determined by examination of the plotted locations.

Because we were interested in whether methods traditionally used by researchers to estimate home ranges based on diurnal data were comparable to results based on nocturnal data, we used 2 traditionally applied [3] home-range-estimation methods (minimum convex polygon; MCP [18] and fixed kernel; FK [19]) to estimate May-June deer home ranges. May-June data were the only locations available to us for these tests. To generate our kernel-density estimates we used fixed smoothing with least-squares cross validation and home and core-range areas delineated at 95% (95% FK) and 50% (50% FK) probability contours, respectively. We generated day and night home ranges based on: (1) daytime (2000-0800h) vs. nighttime (0800-2000h) and (2) sunup vs. sundown (National Oceanic and Atmospheric Administration solar calculator: http://www.esrl.noaa.gov/gmd/grad/solcalc/) [8]. To remove potential bias in pairwise comparisons of day-night home ranges, we generated equal sample sizes of day and night data by randomly excluding data from the larger sample in each comparison [8]. We assessed proportion of overlap between day and night MCPs and FKs and used 2-tailed, paired t-tests in Excel (version 14.0.7106.5003, Microsoft® Office Professional Plus 2010) to examine area differences [8]. We similarly assessed partitioning method by evaluating overlap and area differences between daytime and sunup MCPs and FKs [8].

Results

During March 2001 and April 2002, we fitted 8 female deer aged 1 to 13-years old with GPS radiocollars, and we analyzed GPS locations during May-June of each deer's capture year (Table 1). [Note deer ages increase by 1 yr in May/June (Table 1) relative to their spring capture ages.] We excluded the first 2 of 416 locations for Deer 8000 and the first of 1,616 locations for Deer 8044 during that period because these locations indicated the deer were still migrating to their May-June ranges. We also excluded the last 118 of 674 locations for Deer 8014 because these locations indicated the deer dispersed from its May-June home range. These exclusions were done before the random data exclusions. After all exclusions, the mean number of locations available was 456.4 (SE = 119.3) for daytime vs. nighttime comparisons and 452.8 (SE = 115.0) for sunup vs. sundown comparisons (Table 1).

Mean areas of daytime MCPs and nighttime MCPs were not significantly different nor were mean areas of sunup and sundown MCPs (Table 1; $t_7 = -1.50$, P = 0.18 and $t_7 = 1.23$, P = 0.26, respectively). Overlap averaged 72% (SE = 0.04, range = 0.50-0.81) for daytime vs. nighttime MCPs and averaged 70% (SE = 0.03, range = 0.53-0.85) for sunup vs. sundown MCPs (Table 1).

Mean areas of daytime 95% FKs and mean nighttime areas were not significantly different nor were mean areas of sunup and sundown 95% FKs (Table 1; $t_7 = -0.73$, P = 0.49 and $t_7 = 0.70$, P = 0.51, respectively). Overlap averaged 68% (SE = 0.04, range = 0.49-0.83) for daytime vs. nighttime 95% FKs and averaged 66% (SE = 0.04, range = 0.49-0.82) for sunup vs. sundown 95% FKs (Table 1).

Table 1: Comparisons of areas (ha) of minimum convex polygons (MCP) and fixed kernels (FK) of day and night locations of female deer by Global-Positioning-System (GPS) collars during May-June 2001 and 2002, Superior National Forest, northeastern Minnesota, USA. The number of locations refers to those available to select from when generating each polygon.

MCP			Daytime vs. Nighttime					Sunup vs. Sundown				
Deer no.	Age (Yr)	Dates of GPS collar locations used	No. locations	Daytime area	Nighttime area	Ratio daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Ratio sunup to sundown area	Overlap
8000	2	5/7/2001-6/30/2001	153	76.1	84.4	0.90	0.81	187	78.1	82.0	0.95	0.85
8002	2	5/15/2001-6/28/2001	625	114.8	135.7	0.85	0.70	518	136.9	92.5	1.48	0.64
8004	14	5/4/2001-6/30/2001	408	143.6	177.9	0.81	0.65	406	159.2	164.4	0.97	0.68
8012	3	5/1/2001-6/27/2001	49	387.8	411.5	0.94	0.81	68	393.7	415.8	0.95	0.81
8014	2	5/3/2001-6/7/2001	247	122.4	96.7	1.27	0.75	259	124.4	92.6	1.34	0.71
8044	6	5/13/2002-6/30/2002	572	81.4	81.6	1.00	0.50	748	99.5	64.6	1.54	0.53
8050	2	5/1/2002-6/30/2002	469	76.1	86.7	0.88	0.72	364	74.6	81.5	0.92	0.67
8058	2	5/7/2002-6/28/2002	1128	92.0	96.8	0.95	0.81	1072	90.5	79.8	1.13	0.71
		Mean	456.4	136.8	146.4	0.95	0.72	452.8	144.6	134.2	1.16	0.70
		SE	119.3	36.9	39.6	0.05	0.04	115.0	37.1	41.6	0.09	0.03

FK (95% probability contour)			Daytime vs. Nighttime					Sunup vs. Sundown				
Deer no.	Age (Yr)	Dates of GPS collar locations used	No. locations	Daytime area	Nighttime area	Ratio daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Ratio sunup to sundown area	Overlap
8000	2	5/7/2001-6/30/2001	153	80.0	117.8	0.68	0.63	187	87.9	111.9	0.79	0.49
8002	2	5/15/2001-6/28/2001	625	67.5	68.2	0.99	0.63	518	73.1	56.2	1.30	0.60
8004	14	5/4/2001-6/30/2001	408	132.0	156.9	0.84	0.74	406	123.8	155.8	0.79	0.76
8012	3	5/1/2001-6/27/2001	49	729.8	726.5	1.00	0.66	68	716.2	659.0	1.09	0.65
8014	2	5/3/2001-6/7/2001	247	119.0	127.2	0.94	0.83	259	123.9	126.1	0.98	0.82
8044	6	5/13/2002-6/30/2002	572	64.6	44.8	1.44	0.49	748	60.9	40.8	1.49	0.49
8050	2	5/1/2002-6/30/2002	469	73.7	70.2	1.05	0.71	364	75.7	68.9	1.10	0.74
8058	2	5/7/2002-6/28/2002	1128	74.1	67.4	1.10	0.75	1072	73.8	62.1	1.19	0.72
		Mean	456.4	167.6	172.4	1.01	0.68	452.8	166.9	160.1	1.09	0.66
		SE	119.3	80.8	80.3	0.08	0.04	115.0	78.9	72.6	0.09	0.04

FK (50% probability contour)			Daytime vs. Nighttime					Sunup vs. Sundown				
Deer no.	Age (Yr)	Dates of GPS collar locations used	No. locations	Daytime area	Nighttime area	Ratio daytime to nighttime area	Overlap	No. locations	Sunup area	Sundown area	Ratio sunup to sundown area	Overlap
8000	2	5/7/2001-6/30/2001	153	15.9	29.8	0.53	0.35	187	18.7	28.6	0.66	0.34
8002	2	5/15/2001-6/28/2001	625	13.7	12.7	1.08	0.68	518	12.9	12.3	1.05	0.69
8004	14	5/4/2001-6/30/2001	408	18.5	21.3	0.87	0.67	406	16.8	22.5	0.74	0.68
8012	3	5/1/2001-6/27/2001	49	161.2	135.1	1.19	0.52	68	157.8	118.8	1.33	0.39
8014	2	5/3/2001-6/7/2001	247	30.2	33.4	0.91	0.63	259	30.7	31.6	0.97	0.66
8044	6	5/13/2002-6/30/2002	572	17.9	5.9	3.03	0.33	748	14.9	5.2	2.87	0.35
8050	2	5/1/2002-6/30/2002	469	19.3	20.8	0.93	0.28	364	19.5	20.9	0.93	0.28
8058	2	5/7/2002-6/28/2002	1128	19.8	15.2	1.30	0.67	1072	18.8	15.1	1.24	0.59
		Mean	456.4	37.1	34.3	1.23	0.52	452.8	36.3	31.9	1.22	0.50
		SE	119.3	17.8	14.7	0.27	0.06	115.0	17.5	12.8	0.25	0.06

Mean areas of daytime 50% FKs (core-use area) and sunup 50% FKs were not significantly different from nighttime and sundown areas (Table 1; $t_7 = 0.66$, $P = 0.53$ and $t_7 = 0.81$, $P = 0.44$, respectively). Overlap averaged 52% (SE = 0.06, range = 0.28-0.68) for daytime vs. nighttime 50% FKs and averaged 50% (SE = 0.06, range = 0.28-0.69) for sunup vs. sundown 50% FKs (Table 1).

Mean overlap for daytime vs. sunup MCPs was 92% (SE = 0.03, range = 0.82-0.99), 90% (SE = 0.01, range = 0.86-0.95) for 95% FKs and 86% (SE = 0.01, range = 0.80-0.91) for 50% FKs.

Discussion

Because our preliminary data are biased toward females (8 of 8), 2-yr olds (5 of 8) and the birthing season (which can alter and restrict home-range use [20-22]), our conclusions should not be extended to other age classes and genders.

While we found no significant differences in home-range and core-use area sizes between day and night for both partitioning techniques, overlap measures indicated approximately 30% of night ranges on average were not accounted for using day locations, with even greater differences between core use areas. In some cases ~70% of the core-use area did not overlap. We conclude that diurnal data do not adequately describe diel adult female deer May-June home-ranges (due to differences in spatial overlap) using the MCP or 95% FK methods, and stress that core-use estimation (50% FK) especially may miss potentially important nocturnal locations. Indeed, for biological questions, management or conservation purposes, the absolute size of a home range may be less important than its location and shape. Our May-June findings echo the conclusions of Kochanny et al. [11] that although adult female deer diurnal and nocturnal winter home ranges were similar, important differences existed on a finer scale. We suggest additional research to determine if our findings hold under other circumstances (e.g., exclusive of the parturition period, other age classes), to determine if our conclusions generalize across deer range, seasons and varying factors that determine home-range size and location [23] and to determine how the degree of non-overlap between diurnal and diel ranges translates into biologically meaningful metrics such as varying habitat use (see [24] as it relates to roe deer, *Capreolus capreolus*).

Both partitioning techniques (daytime vs. nighttime or sunup vs. sundown) revealed similar day results as evidenced by relatively high overlap values for each of the home-range and core-use estimation methods. Thus, we conclude that either partitioning technique is valid in areas similar to our study area during May-June. Partitioning technique may be more relevant during winter when temperature fluctuations due to sunup would be more significant. However, this remains to be tested.

Although it was beyond the scope of this study to detail the strengths and weaknesses of traditional home range estimation methods, important critiques of the methods exist (e.g., overestimation of home range, sensitivity to small samples, etc.) and the method selected can alter results considerably [25]. While our study instead focused on the application of these traditional methods, we nevertheless recommend additional research investigating alternate kernel sizes (e.g., 75%, 90%), determining how many nocturnal locations are required to generate adequately shaped (i.e., sufficient overlap) 24-hr home ranges, and assessing how white-tailed deer behavior, habitat use and selection can be influenced by location sampling regimes [25].

Because much traditional research derived from VHF diurnal data exists on female-deer home ranges, our findings suggest that, in areas similar to our study area during

May and June, diurnal home ranges and location data for adult does are not sufficient for management decisions requiring diel ranges except for coarse-location needs. Although GPS-collaring systems are relatively more expensive, usually of shorter duration and often deployed on fewer animals, we recommend these for studies of diel deer behavior, habitat use and selection if diel VHF telemetry locations are not feasible.

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