

Spatial Interactions of Yarded White-tailed Deer, *Odocoileus virginianus*

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We examined the spatial interactions of nine female White-tailed Deer (*Odocoileus virginianus*) in two deeryards (winter aggregations) in northeastern Minnesota during February-April 1999. Global positioning system (GPS) collars yielded seven pair-wise comparisons of deer that were located at the same time (≤ 1 minute apart) and that used overlapping areas. Deer traveled separately and did not associate with one another. Within overlapping areas, comparisons of distances between deer and distances between random locations indicated deer moved without regard to each other. Similarly, comparisons of observed and expected probabilities of deer using areas overlapping those of other deer also evinced that deer moved independently.

Key Words: White-tailed Deer, *Odocoileus virginianus*, GPS tracking, movements, space use, home-range overlap, radio-tracking, spatial interaction, Minnesota.

Every autumn, northern White-tailed Deer (*Odocoileus virginianus*) migrate from individual summer home ranges and aggregate in winter deeryards dominated by coniferous forests which have reduced snow depths compared to adjacent deciduous forests (Severinghaus and Cheatum 1956). The trail systems produced by many deer enhance access to forage and is advantageous in escape from predators (Messier and Barrette 1985; Nelson and Mech 1981). All sub-units of deer society, single deer, females with fawns, matriarchal groups, male groups, and mixed groups (Hawkins and Klimstra 1970), occupy deeryards. Except for a deer's group members and perhaps deer that overlapped with them on their summer range, yarded deer encounter unfamiliar deer originating from different summer ranges (Nelson and Mech 1987).

Initially, deeryards appear as places where large numbers of deer intermingle. However, winter home-range sizes of yarded deer are generally < 200 ha (Lesage et al. 2000), whereas deeryards can be 1-3 orders of magnitude larger (Nelson and Mech 1987; Van Deelen et al. 1998; Whitelaw et al. 1998; Lesage et al. 2000; Sabine et al. 2002). Thus, it is clear that individual deer do not move throughout their entire deeryard, but occupy smaller home ranges adjacent to or overlapping a subset of all the deer using a deeryard.

Interactions among yarded deer with overlapping home ranges have not been examined, because the dense vegetation in deeryards prohibits direct observation. At openings within deeryards where supplemental feed was provided, deer have been seen aggressively displacing other deer attempting to feed at the same site (Kabat et al. 1953; Ozoga 1972). However, it is unknown whether conflicts influenced space use when deer returned to dense cover.

Radio-tracking allows the study of deer spatial dynamics without having to observe deer directly. For pairs of deer using overlapping areas, and located simultaneously, movements, distances between locations (Doncaster 1990) and simultaneous use of overlaps quantify spatial interactions (Minta 1992; Powell et al. 1997; Powell 2000). Such results can then provide evidence of attraction, avoidance, or no interaction among deer.

Only one radio-tracking study located yarded deer simultaneously, but it employed a fixed-base automatic tracking system, and only measured home-range size and timing of migration (Rongstad and Tester 1969). The spatial interactions of the yarded deer were not examined.

The recent development of global positioning system (GPS) radio-telemetry and the ability to program location rates removed the heretofore logistical constraints of simultaneous radio-tracking large far-ranging animals (Rodgers et al. 1996). Accordingly, we employed GPS telemetry to locate deer simultaneously in order to examine the spatial interactions of yarded deer using areas overlapping those of other deer.

Materials and Methods

We conducted this study in the Garden Lake and Isabella deeryards in northwestern Lake County, Minnesota (48°N, 91°W) near the northern edge of deer range (Nelson and Mech 1981, 1987). Each deeryard encompassed approximately 30 km² with minimums of 6-17 deer/km² at Isabella (Nelson and Mech 1986a) and > 17 -34 deer/km² at Garden Lake (M. Nelson, unpublished). Most (83%) deer annually migrate a mean of 12 km \pm 1.2 SE, (Isabella) and 25 km \pm 1.8 SE (Garden Lake) between summer and winter home ranges (Nelson and Mech 1987). Topography is flat, glaciated

Canadian Shield dominated by lakes and rivers (Heinzelman 1996). Forests are mixtures of aspen (*Populus tremuloides*), Jack Pine (*Pinus banksiana*), and spruce (*Picea* spp.) (Heinzelman 1996). Temperatures remain $< 0^{\circ}\text{C}$ November-March, and weekly snow depths average 30 cm and 50-64 cm during 48% and 52% of winters respectively (Nelson and Mech 2006). Hunting and Wolf (*Canis lupus*) predation are the primary causes of deer mortality (Nelson and Mech 1986b). Supplemental feed provided by recreational feeding is available to deer in both deeryards.

We captured adult female deer in Clover traps (Nelson and Mech 1981), extracted an incisor (Nelson 2001) for aging, and fitted them with Advanced Telemetry System (ATS, Isanti, Minnesota) releasable GPS radiocollars (Merrill et al. 1998) programmed to obtain 1 location per hour. Positional accuracy was < 50 m for 50% and < 100 m for 85% of locations, respectively (Bowman et al. 2000). We remotely released the collars from deer and downloaded locations to a computer for spatial analysis.

We restricted our analyses and comparisons to pairs of deer that used overlapping areas. From pairs of locations with the same date and hour, we derived 95% fixed-kernel areas (Worton 1989, 1995) for each deer, calculated with least-squares cross-validation using the Animal Movement (Hooge et al. 1999) and Spatial Analyst extensions in the software ArcView GIS (version 3.3, Environmental Systems Research Institute, Inc., Redlands, California).

We used three approaches to examine the spatial interactions between these pairs. First we looked for evidence of deer traveling together to determine if they were associated. We considered paired locations < 100 m apart during several hours of movement to be evidence of travel together and some type of association.

Secondly, we assumed that the most likely evidence of deer interaction would be found in the areas deer shared at the same time. Auditory, olfactory, and visual contact could all potentially play a role in deer interactions and manifest their influence in the distance between deer. If two deer interacted by being attracted to, or avoiding each other, then distances between them at the same time should be smaller or larger respectively, than distances between random pairs of locations recorded at different times. Therefore, we computed distances between locations recorded ≤ 1 minute apart inside areas of overlap and used the method described by Chamberlain and Leopold (2000) to compare the distribution of distances among three classes (< 0 -100), < 100 -200), and > 200 m) with the distribution expected if deer traveled independently. We used R software (R Development Core Team 2005) to implement our analysis.

For the third and final test for spatial interaction, we used proportions of locations spent individually and simultaneously within overlap areas shared by pairs

of deer to estimate probabilities of individual and joint use. When individuals use overlap areas independently, probabilities of joint use should equal products of probabilities of individual use (Powell et al. 1997). We used chi-squared goodness-of-fit tests to compare observed numbers of instances of joint use with numbers expected if deer used overlap areas independently. Because successive locations of individual deer probably were not independent, our test results likely underestimated Type I error rates (probabilities of detecting association or avoidance when deer used overlap areas independently).

Results

We captured and attached GPS collars to nine adult female deer during 2 February – 9 April 1999 (Table 1). This allowed seven pair-wise comparisons (median = 14 days) of deer radio-tracked at the same date and time and with overlapping home ranges (Table 1). The GPS collars successfully acquired 69-99% (median = 89) of all potential locations during the tracking periods we compared. Simultaneous locations yielded 90-99% (median = 94.2) of the locations available for such comparisons.

Deer were located < 100 m apart $< 15\%$ of the time during 1940 pairs of locations from all deer. In examining locations chronologically, we found no evidence of pairs of deer being located and traveling together.

Five pairs of deer had 33, 40, 50, 79, and 88 locations (≤ 1 minute apart) within overlapping areas. We found no evidence that deer were located close together (within < 100 or 100 - 200 m) or far apart (> 200 m) more frequently than expected if they used overlapping areas independently ($\chi^2_2 = 0.6$ - 4.5 , $P = 0.10$ - 0.73). Small sample sizes for two pairs of deer precluded interpretation of their results.

All pair-wise comparisons of overlap between deer indicated deer occupied overlapping areas at the same time during 1.8-27.0% (median = 16.8) of locations, and used their overlaps as expected if they moved independently of each other ($\chi^2_2 = 0.01$ - 1.5 , $P = 0.22$ – 0.91).

Discussion

None of our deer were family members or members of the same social group as evidenced by them traveling separately. Our analyses of distances between simultaneously located pairs of these deer in their overlap areas, and probabilities of using overlapping areas, suggested they moved independently of each other. It is unknown if our overlapping pairs of deer had conflicts at recreational feeding sites they shared. However, if there were such interactions there as well as elsewhere, their effects did not manifest themselves in the distances between deer and their use of overlapping area. Contrary to this, Gavin et al. (1984) speculated that agonism possibly acted as a spacing mechanism among Columbian White-tailed Deer (*O. v. leucurus*),

TABLE 1. Deer ages, tracking periods, simultaneous (same hour and day) locations estimating 95% fixed-kernal areas, and area overlap for seven comparisons of nine yarded female deer in northeastern Minnesota 2 February to 9 April 1999.

Deeryard	Comparison deer number	Age yrs	Tracking periods	Snow depth (cm) start	Snow depth (cm) end	Days	Locations	95% Kernal Area (ha)	Overlap Area (ha)
Isabella	7862	2	2-17 February	46	53	15.2	274	99	20
	7864	12						20	
	7864		11 February-15 March	46	69	31.8	496	16	12
	7872	3						49	
Garden Lake	7862		11-17 February	46	53	6.2	109	28	7
	7872							35	
	7840	5	1-9 April	15	10	8.6	164	28	8
Deeryard	7924	10						22	
	7908	10	18-31 March	43	20	13	249	52	19
	7924							48	
	7920	8	17-31 March	43	20	13.7	263	89	38
	7922	4						64	
	7920		19 March- 8 April	43	10	19.8	385	31	15
Median	7928	1						70	
		5				13.7	263	42	15
		1				6.2	109	16	7
		12				31.8	496	99	38

similar to home range defense exhibited by Black-tailed Deer (*O. hemionus columbianus*, Miller 1974) and parturition territoriality by maternal White-tailed Deer (Ozoga et al. 1982). However, Nixon et al. (1991) found no evidence for defense of space by wintering deer in Illinois. They observed spatial tolerance among socially separate White-tailed Deer bedding within 100 m of each other after prior aggressive interactions. Similarly, 30 beds of yarded deer in northern Wisconsin were observed close to each other near a supplemental feeding site where deer competed aggressively for food (Kabat et al. 1953). We also observed large numbers of yarded deer bedding 10-50 m from each other on lakes adjacent to recreational feeding sites. This was a unique situation due to extremely deep snow (95 cm) in the woods, but nonetheless consistent with our results indicating that yarded deer tolerated unrelated deer nearby. Conceivably our deer with overlapping areas might have aggressively competed for naturally occurring food similar to competition for supplemental food. However, our observations of deer using baited capture sites in previous studies indicated deer were displaced only short distances (5-10 m) by dominant deer. Thus the spatial effect of feeding competition is likely limited to the specific site and time.

Hirth (1977) observed high social tolerance and grouping behavior throughout the year by Texas deer living in an open grass-shrub environment. Maternal females there increased their agonistic behavior and isolated their young fawns but rejoined their social groups and other deer daily after tending their fawns. Thus, females displayed social intolerance in one context while simultaneously being social in another. This is analogous to that of yarded deer tolerating the presence of other deer while being agonistic when directly competing for food. Both examples reflect a deep-seated propensity for social grouping, which likely evolved as a defense against predation (Hirth 1977; Nelson and Mech 1981; Messier and Barrette 1985; Geist 1998). Deer close to other deer benefit from the vigilance of other deer, share the risk of being detected or killed, and when forced to flee predators, their multiple escape paths and motion may confuse predators.

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