Movements of White-tailed Deer in Shenandoah National Park, Virginia

John J. Scanlon,[1] *Virginia Cooperative Wildlife Research Unit, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061*

Michael R. Vaughan, *Virginia Cooperative Fish and Wildlife Research Unit, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061*

Abstract: Seasonal movements and total range areas were smaller ($P < 0.01$) for radio-collared female white-tailed deer (*Odocoileus virginianus*) live-captured along the Skyline Drive corridor of Shenandoah National Park, Virginia (roadside areas of mowed grass and abutting mixed oak-hardwood forest) than for radio-collared females captured in more remote backcountry areas of the Park (mixed oak-hardwood forest >1 km from Skyline Drive). Mean total range areas were 444 ha (SE = 181 ha, $N = 3$) for females captured on the Drive, and 879 ha (SE = 443 ha, $N = 4$) for females captured in the backcountry. Mean total range areas were smaller ($P < 0.05$) for radio-collared males captured in the backcountry areas, $x = 1{,}586$ ha (SE = 797 ha, $N = 3$) than for radio-collared males captured on Skyline Drive, $x = 1{,}846$ ha (SE = 49 ha, $N = 2$). However, there was no difference ($P > 0.5$) in their mean seasonal ranges. Females moved along Skyline Drive throughout the year to utilize mowed grass forage, but males were located along the Drive primarily when does were in estrus.

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White-tailed deer are a valued resource for the 2 million annual visitors to Shenandoah National Park (SNP), Virginia. Both human and deer activity are concentrated along Skyline Drive, a paved road extending the length (170 km) of the 8,364-ha Park. Deer are locally concentrated along the mowed grass corridor and mixed oak-hardwood forest associated with Skyline Drive (Scanlon and Vaughan 1983*a*), causing concern among SNP officials about habitat degradation and deer-car collisions. The objective of this study was to quantify seasonal and annual move-

[1]Present address: Massachusetts Division of Fisheries and Wildlife, Field Headquarters, Westboro, MA 01581

ments of deer along Skyline Drive and in more remote "backcountry" areas of the Park (>1 km from the Drive).

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Methods

Two study areas (about 65 km^2 each) were established: 1 in the north end of the Park at Piney River and the second in the south end of the Park at Loft Mountain. A campground was near Skyline Drive in each study area, and a 5–15-m width of mowed grass was common along the 8–9 km of Skyline Drive. The remainder of the study areas was completely forested, with the exception of a few old home sites in backcountry areas that had been abandoned in the 1930s. The forest is predominately mixed oak-hardwood: red, black, and white oak (*Quercus rubra. O. velutina.* and *O. alba*), hickory (*Carya* spp.), yellow poplar (*Liriodendron tulipifera*), and scattered pines (*Pinus* spp.) in the overstory, with shrubs such as redflag (*Symphocarpus orbiculatus*), mountain laurel (*Kalmia latifolia*), spice bush (*Lindera benzoin*), witch hazel (*Hamamelis virginiana*), and blueberry (*Vaccinium* spp.) in the understory.

This study covered a 15-month period (Oct 1981–Jan 1983) when free-ranging white-tailed deer were live-captured with powdered succinylcholine chloride (Day et al. 1980) fired from a Palmer dart rifle (Liscinsky et al. 1969). Numbered ear tags and 1-piece doe collars or 2-piece expandable buck collars were placed on captured deer. Expandable collars were fashioned after a design by Hamilton (1962) and used a thin flexible spring sheathed in lubricated plastic tubing to connect the 2 halves of the collar.

Sixteen (7 from Skyline Drive and 9 from the backcountry) of 60 live-captured deer received radio-collars (Telonics Inc., Mesa, Ariz.), and 44 (40 from Skyline Drive and 4 from the backcountry) deer received color-collars. Observations of marked deer were collected from field workers, Park employees, and Park visitors.

Radio signals were received with a standard 2-element hand-held antenna. To minimize the error polygon associated with triangulation, locations were calculated only when the angular difference between 2 or 3 fixes taken was between 40–140 degrees. In addition, 2 or 3 fixes used for locations were taken within 15 minutes, except during 2 winter ice storms when up to 90 minutes were required to complete triangulations. Locations were made over relatively short distances (0.1-3.5 km) and allowed accurate approaches for visual observations of deer anywhere in the Park.

Locations were usually obtained over 3 consecutive days in 1 study area, fol-

lowed by 3 consecutive days in the second study area (3 days on and 3 days off in each area). Generally, 3–4 locations were obtained per animal per day; 1 location at dawn, 1 or 2 during late morning and/or mid-afternoon, and 1 at dusk.

Locations, movements, and range areas were calculated from telemetry data with the computer program "TELEM" (Koeln 1980), which provided convex polygon (Mohr 1947) and non-circular calculations (Jennrich and Turner 1969) of range areas. While convex polygon data are presented for comparisons among individual deer, area estimates might best be considered as indices of home range rather than specific areas with finite boundaries (Smith 1983).

Range areas were calculated for each radio-collared deer from all available data (total range areas) and for consecutive activity periods (Hayne 1949) of 45 days each. These encompassed late-winter (1 Jan–15 Feb), early spring (16 Feb–31 Mar), spring (1 Apr–14 May), fawning (15 May–1 July), summer (2 July–15 Aug), late-summer (16 Aug–1 Oct), breeding (2 Oct–16 Nov), and mid-winter (17 Nov–31 Dec). Total range areas were calculated only for deer that had been tracked through at least 1 breeding or mid-winter period and had a minimum of 25 radio-locations. Range areas for 45-day activity periods were calculated for deer that had a minimum of 10 radio-locations during that period.

For statistical analysis, sex and capture location (Skyline Drive or backcountry) were treated separately. Mean total range areas and means of range areas for 45-day activity periods were compared with a *t*-test for the difference between 2 means (Sokal and Rohlf 1969:220–223).

Results

Each radio-collared adult female ($N = 3$) captured along Skyline Drive displayed localized movements in the immediate vicinity of the Drive throughout most of the year (Table 1). These does moved into the backcountry only during severe winter storms, or during spring. These occasional movements were brief, and does always returned to the same localized area along the Drive in 24-72 hours. Even though these occasional, disparate movements enlarged the range areas for does captured along the Drive, total range areas were still smaller ($P < 0.05$) for these does than for females captured in the backcountry. Females captured on Skyline Drive had smaller ($P < 0.01$) mean range areas across all activity periods than females captured in the backcountry.

Two of 3 radio-collared does captured in the backcountry were never located near Skyline Drive. The third radio-collared doe moved from the backcountry to Skyline Drive on 1 occasion (in late winter) during the first 6 months after capture (5 Nov 1981), but on 21 May 1982 she moved 3 km to an area directly adjacent to the Drive where she gave birth to a single fawn. The doe and fawn remained near Skyline Drive throughout the fawning, summer, and late-summer periods, then returned to the original capture area in the backcountry during the breeding period. Between 2 October and 20 November 1982 the doe and fawn moved between the

Table 1. Mean activity period and total range areas (ha) for white-tailed deer along Skyline Drive (SD) and in the backcountry (BC) of Shenandoah National Park, Virginia, 1981–1983.

	Range Areas (ha)											
	Females						Males					
	SD			BC			SD			BC		
Activity Period	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N
Mid-winter	99		1	447	303	2	747		1	269	126	2
Late-winter	185		1	250	11	2	81		1	523	425	2
Early-spring	70	38	2	118	27	2	176		1	82		1
Spring	325		1	492	264	2	108	40	2	113		1
Fawning	65	25	2	116	35	3	284	204	2	73	31	2
Summer	92	65	2	168	51	4	389	284	2	605	344	3
Late-summer	125	38	2	251	74	4	164	75	2	635	216	3
Breeding and mid-winter	130	17	2	341	213	4	914	465	3	410	230	2
Mean of activity periods	136	30	8	273	51	8	358	101	8	339	83	8
Total range	444	181	3	879	443	4	1864	49	2	1586	797	3

fawning and capture area 3 times, then settled in the capture area where they remained for the duration of the study.

All radio-collared does were observed with 1 or 2 fawns in 1982, and all does reduced their range areas during fawning, then subsequently increased their range areas through the summer and late-summer periods (Table 1). This trend was consistent regardless of capture site.

All color-collared females ($N = 23$) captured along Skyline Drive were resighted ($x = 19.8$ sightings, SE = 2.8, $N = 467$), and sightings of most females occurred over a relatively short segment of the Drive ($x = 7.5$ km, SE = 2.5, $N = 23$). Only 4 of 23 color-collared females were sighted over segments of the Drive longer than 8 km (segments of 11–42 km).

One of 3 color-collared backcountry does was captured during a winter cold snap (−18° to −7° C) in January 1982, and was subsequently sighted 21 times along a 15-km section of the Drive (Apr to Dec 1982). A second color-collared doe was sighted only once after capture (Dec 1981), when she was observed (May 1982) in the backcountry within 1 km of the capture site. The third color-collared doe was never sighted after capture (Jan 1981).

Male white-tailed deer generally ranged widely regardless of capture site. Total range areas were larger ($P < 0.05$) for males captured along the Drive than for those captured in the backcountry. Movements for males captured along the Drive were greatest during the breeding and mid-winter periods, when they repeatedly moved 2–3 km between the Drive and the backcountry. Of 3 radio-collared males (2 adults and 1 yearling) captured in the backcountry, 1 adult roamed widely during the rut while the second adult and the yearling established restricted breeding territories. Only the yearling was ever located along the Drive.

While males captured in the backcountry moved about less during the breeding

and mid-winter periods than males captured along the Drive, this difference was not consistent over the remaining activity periods, and the means of range areas for all 45-day activity periods were not different ($P > 0.5$) between males captured in the backcountry and along Skyline Drive.

The yearling male from the backcountry was observed with an adult female and a fawn when he was captured on 23 June 1982. His movements were confined to the backcountry capture area through mid-July, and he was observed with the doe and fawn during this period. Beginning in mid-July, he moved repeatedly between the capture area and other backcountry areas on both sides of Skyline Drive, rejoining the doe and fawn when in the capture area. During the breeding period he moved to and remained in an area directly adjacent to the Drive where he was observed making scrapes and rubs. The doe and fawn were not observed in the breeding territory.

Twelve of 17 color-collared males captured along Skyline Drive were resighted ($x = 5.9$, SE = 1.6, $N = 78$), and even though weeks or months elapsed between sightings, all 12 males were consistently resighted along a relatively short section of Skyline Drive ($x = 2.0$ km, SE = 0.5, $N = 12$). Likewise, when the 3 radio-collared males captured along the Drive were subsequently located on the Drive, the locations were all within a 2-km section of road which included the capture site. A single color-collared male was captured in the backcountry (Jan 1982) and was resighted only once (Mar 1982), within 1 km of the capture site.

Discussion

Mowed grass on the roadside was the primary forage for deer along Skyline Drive during most if not all the year (Scanlon and Vaughan 1983*a*), and the presence of this forage likely resulted in the localized movements observed for many female deer in SNP. Localized movements were occasionally interrupted by temporary forays into the backcountry during severe winter weather and in spring, and it is possible that the color-collared female captured in the backcountry and subsequently sighted 21 times along Skyline Drive was on a temporary movement when she was captured during a winter cold snap. Occasional trips outside of local activity centers have been noted for many normally sedentary does (Inglis et al. 1979).

While many females concentrated their movements near Skyline Drive, some of these does did move long distances along the Drive (up to 42 km). Such movements were in marked contrast to males, whose locations were always confined to a 2–3-km section of the Drive. However, males moved repeatedly between the Drive and the backcountry throughout much of the year, and such repeated movements were not observed for females.

Shifts in range area we noted for one pregnant doe are not unusual (Sparrowe and Springer 1970, Bartush and Lewis 1978, Nelson and Mech 1981), but it seems worthwhile to note that after the shift to Skyline Drive occurred, this doe remained along the Drive for more than 130 consecutive days (21 May–2 Oct 1982) and was never recorded in observations of marked deer. The particular area of the Drive she

used was not characterized by mowed grass (rock ledge occurred there), but native grasses and forbs were abundant under the forest canopy within 50–100 m of the road, and the doe was observed feeding here on a number of occasions. She used habitat directly adjacent to the Drive without becoming habituated to it.

Sparrowe and Springer (1970) found that home range patterns included 1 or more sub-areas of habitat which filled a deer's needs for a given time; when requirements changed, or when resources were depleted, the deer moved to another subarea. Dahlberg and Guettinger (1956) proposed that deer remain in a particular area until habitat conditions deteriorate, or until disturbance occurs. Inglis et al. (1979) found range areas to be dynamic, their locations altered with the passage of time. However, for many female deer associated with Skyline Drive, a relatively small, fixed area of mowed grass and abutting oak-hardwood forest continually supplies adequate food and cover. Habitat conditions do not deteriorate to any great extent even during years of acorn failure because grass along the roadside is constantly available, except during winter storms, and movements of deer associated with the Drive are correspondingly small. Young does sometimes inherit parts of their mother's home range (Nelson and Mech 1981) and it seems likely that localized movements of female deer along Skyline Drive will be a continuing characteristic of SNP deer.

The larger total range areas for males captured along the Drive versus the backcountry may be an artifact of small sample size, but the point remains that all males ranged widely and did not appear to become habituated to the Drive. Males occur most frequently in social groups along Skyline Drive during the breeding and midwinter periods (Scanlon and Vaughan 1983b), and the presence of does in estrus rather than grass forage likely attracts the males. While female deer in SNP are attracted to Skyline Drive by the grass forage, males are attracted to the Drive primarily during the rut.

Management Implications

Movements of deer observed in this study can be visualized as a continuum that is weighted primarily toward constant use of the skyline Drive corridor (by adult females and their young), secondarily toward combined use of areas in the backcountry and along the Drive (primarily by males, but also by some females during fawning) and lastly toward exclusive use of backcountry areas (by both sexes).

To discourage the localized range areas observed for many females in SNP, mowed grass along Skyline Drive could be replaced over a period of years with rock terrace and native shrubs of low forage value. Removing the mowed grass would likely result in expanded ranges for deer to fulfill requirements for food, and at the same time would preserve the open vistas along the roadside enjoyed by Park visitors. The opportunity for visitors to view deer could be maintained by widening existing trails near Skyline Drive to encourage growth of native herbaceous vegetation which deer would likely use as forage.

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