Impact of Hunting Pressure on Adult Male White-tailed Deer Behavior

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Abstract: Hunting pressure can lead to drastic changes in white-tailed deer (*Odocoileus virginianus*) behavior, though previous studies have focused mainly on females and juvenile males. Adult male white-tailed deer have not been studied in the context of hunting pressure since the advent of GPS technology. During 2006–2007, we deployed GPS collars on nine adult (≥2.5 years old) male white-tailed deer to examine changes in home range (95% fixed kernel) and core area (50% fixed kernel) size, shifts in home range and core area, movement, activity, and vulnerability to harvest during Maryland's two-week firearms season at Chesapeake Farms. Home range and core area size did not change between pre-hunt and hunt periods, and although adult male white-tailed deer movement and activity decreased from pre-hunt to the hunt period, this was at least partially attributable to hunting season coinciding with the post-breeding period. Our results suggested that hunting pressure levels at Chesapeake Farms did not influence deer behavior to a point of decreasing harvest vulnerability. Limiting hunting pressure on a property may be an effective way to mitigate loss of harvest opportunities due to avoidance by white-tailed deer of hunted areas.

Key words: deer hunting, hunting pressure, Maryland, *Odocoileus virginianus*, white-tailed deer

The scientific literature is replete with research conducted on white-tailed deer (*Odocoileus virginianus*) fawns, juvenile males, and females. Less is known about adult male deer (Campbell et al. 2005) and although adult males have been studied with very high frequency (VHF) radiocollars (Van Etten et al. 1965, Kammermeyer and Marchinton 1976, Root et al. 1988, Sargent 1992), no prior research using GPS technology has been conducted solely on the interaction of hunting pressure and adult male white-tailed deer behavior—a dynamic of importance to managers developing harvest strategies for hunter opportunity and satisfaction. By combining GPS radiocollar and intensively-logged hunter-effort data, micro-temporal and micro-spatial aspects of white-tailed deer behavioral response to hunting pressure can be determined (Broseth and Pedersen 2000). Previous studies have encompassed a wide range of hunting pressure intensities from 4 hunters/km² (Pennsylvania; Diefenbach et al. 2005) to 77 hunters/km² (Pennsylvania; Murphy 1962), making comparisons among studies difficult. In addition to highly variable hunting pressure, hunting and breeding seasons coincide in many regions, making it difficult to differentiate male responses to hunting pressure versus breeding season-related behavioral fluctuations (Tomberlin 2007). Further, these potential interactions could be obscured because deer populations may not alter their behavior in response to hunting pressure below certain thresholds (Root et al. 1988).

Although white-tailed deer can temporarily shift home ranges to more secure cover or flee to refuges during periods of high disturbance (e.g., hunting season, cattle ranching, and agricultural practices), they typically exhibit high fidelity to established home ranges and deviations are only temporary (Marshall and Whittington 1968, Hood and Inglis 1974, Naugle et al. 1997, Brinkman et al. 2005, Rhoads 2006). Where security cover is more abundant, home range size may increase during hunting seasons (Pilcher and Wampler 1981, Root et al. 1988, Kilpatrick and Lima 1999); although home range size may remain stable before, during, and after hunting seasons (Vercauteren and Hygnstrom 1998). Core areas have been shown to remain geographically and geometrically stable (Root et al. 1988) or shift to more secure cover and increase in size during hunting season (Kilpatrick and Lima 1999).

Hunting pressure can influence deer movement and activity. During the breeding season, movement and activity naturally peak as males seek receptive mates and establish dominance hierarchies (Ozoga and Verme 1975, Ivey and Causey 1981). Conversely, if deer are disturbed and dense security cover is readily available, deer may decrease diurnal movement and activity during hunting season (Nixon et al. 1991, Vercauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). In more open and fragmented habitat, deer have been observed to increase diurnal movement by frequent flight responses to hunting-related disturbances, yet

remaining within their normal home range (Van Etten et al. 1965, Marshall and Whittington 1968, Dorrance et al. 1975, Root et al. 1988, Naugle et al. 1997).

Vulnerability to harvest (where hunting takes place from permanent hunting stands) is a direct function of the amount of diurnal movement, activity, and distances traveled by deer within hunting (non-refuge) areas (Roseberry and Klimstra 1974). Additional factors, including deer sex (Roseberry and Klimstra 1974), age (Maguire and Severinghaus 1954), population density (Holsworth 1973, Hansen et al. 1986), dispersal behavior (Rosenberry et al. 2001), habitat type and fragmentation (Murphy 1962, Van Etten et al. 1965), weather (Hansen et al. 1986), hunter density and hunting season length (Hansen et al. 1986), topography (Van Etten et al. 1965), and agricultural crop availability (Hansen et al. 1986, Vercauteren and Hygnstrom 1998) influence white-tailed deer vulnerability. A perceived decrease in vulnerability to harvest may actually be a decline in availability as deer move out of hunted areas and into refuges where hunting is either prohibited or hunter access is difficult and limited (e.g., swamps and large contiguous forests; Roseberry and Klimstra 1974, Larson et al. 1978, Naugle et al. 1997, Kilpatrick and Lima 1999). Even without refuges, white-tailed deer can reduce their risk of harvest by shifting their diurnal activities farther away from roads and hunting stand locations (Rost and Bailey 1979, Dorrance et al. 1975, Kilgo et al. 1998, Broseth and Pedersen 2000).

The objective of our study was to examine the influence of hunting pressure on adult male white-tailed deer using an assortment of spatial parameters designed to describe their behavioral response to disturbances caused by recreational hunting. We recognized that hunting pressure at our research site was far below the behavioral response threshold previously reported by Root et al. (1988; 0.45 hours/ha/day); however, the heightened accuracy and increased fix rates associated with GPS radiocollars provided us with an initial opportunity to re-examine this behavioral dynamic between adult male white-tailed deer and hunters. With the ability to examine movement data at a finer temporal and spatial scale, we hypothesized that deer behavior would not be altered in spatial proximity to hunting stands and that harvest vulnerability would consequently remain stable. In addition, because the hunting season coincided with the post-breeding season, we anticipated overall movement and activity rates would decline from the pre-hunt to hunt period.

Study Site

Chesapeake Farms is located on the Eastern Shore of the Chesapeake Bay in Kent County, Maryland, 10-km southwest of Chestertown (3910N 7610W). Owned by DuPont and operated by DuPont Crop Protection, Chesapeake Farms is a 1,300-ha wildlife management and agricultural research demonstration area. Approximately 50% of the study area was forested with non-alluvial swamps that consisted primarily of hardwood tree species with a moderately dense understory of small shrub species and vines. Cash crops composed 20% of the study area. Fallow fields and wildlife food plots composed 13% of the farm, and the remaining 17% was composed of non-forested wildlife cover and waterfowl impoundments (Shaw 2005).

Deer density and adult sex ratio (male:female) at Chesapeake Farms was most recently estimated (2007) to be 25 deer/km^2 and 1:1.5, respectively (M. Conner unpublished data). In addition to minimal harvest during the archery and muzzleloader seasons (~10 deer/year), the majority of deer harvest at Chesapeake Farms occurred during Maryland's two-week shotgun season from the first Saturday after Thanksgiving for two continuous weeks (no hunting allowed on second Sunday of season). Current harvest restrictions (in place since 1997) mandate that only males with at least ear-tip-wide outside antler widths (approximately 40 cm) be harvested. Because of harvest restrictions, the male age structure on Chesapeake Farms shifted from a population of mostly 1.5-year-old males to predominantly ≥2.5-year-old males during the late 1990s (Shaw 2005).

Methods

From June – August, 2006 – 2007, we captured 19 (2006 [$n = 10$] and 2007 [$n = 9$]) adult male (≥2.5 years old) white-tailed deer. We estimated deer age in the field by using antler and body characteristics (Richards and Brothers 2003). The animal capture and processing protocol was described in Karns et al. (2011), approved by the Institutional Animal Care and Use Committee at North Carolina State University (#05-024-0), and met guidelines of the American Society of Mammalogists (Sikes et al. 2011).

We programmed 3300L Lotek GPS collars to collect hourly fixes throughout September – March and 20-minute fixes from 5 November – 9 December during 2006 and 2007 (collars actually recorded locations at five-minute intervals during 2007, but we reduced data to 20-minute intervals for consistency). Collars were equipped with a mortality sensor that triggered after eight hours inactivity and emitted a double-pulse VHF signal. We monitored deer twice weekly to ensure collars were properly functioning and deer were alive. Also, collars were equipped with a dual-axis activity sensor that recorded the number of times (0 to 255) the horizontal and vertical orientation of the head or neck of the deer changed during each five-minute interval; 0 indicated no activity and 255 indicated maximum activity (Coulombe et al. 2006). We censored data with a pre-determined set of quality control metrics and omitted

all three-dimensional (3D) fixes with PDOP >10, two-dimensional (2D) fixes with PDOP >5, all fixes with altitudes outside the range of –100 m to 100 m, malfunctioned fixes as indicated by VHF pulse rates or absent VHF signal from analyses, and all fixes <7 days post-capture (to reduce possible bias of capture-related stress; D'Eon and Delparte 2005, Tomberlin 2007).

Based on parturition and fawn capture data collected during a previous study and a 200-day gestation period for white-tailed deer, pre-hunt period (which coincides with breeding season) was defined as 5 November–24 November 2006 and 5 November–23 November 2007 (Verme 1965, Verme 1969, Tomberlin 2007). The hunt period (Maryland's annual two-week shotgun season) was 25 November–9 December in 2006 and 24 November–8 December in 2007. To compare different periods of the day, we defined dawn as 30 minutes preceding sunrise to 90 minutes after sunrise; dusk as 90 minutes preceding sunset to 30 minutes after sunset; day as the period between dawn and dusk; and night as the period between dusk and dawn. Thirty minutes before sunrise and 30 minutes after sunset were important because these times correspond with the beginning and end of legal hunting hours.

We imported GPS fixes for each deer into ArcMap 9.2 (Environmental Systems Research Institute, Inc., Redlands, California) for analyses. We projected all data in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983 Zone 18 North (m). We used hourly fixes from the duration of GPS collar deployment to generate fixed-kernel home ranges (95%) and core areas (50%) using a smoothing parameter (200) based on close examination of a wide range of possible values and comparing corresponding polygons to true distribution of GPS fixes and geographical boundaries (i.e., Chesapeake Bay shoreline; Laver 2005). We calculated each deer's pre-hunt and hunt home ranges and core areas. Also, we calculated intensity of use (measures the degree to which an animal's core area is concentrated within its home range; Lent and Fike 2003) for overall, pre-hunt, and hunt periods by using core area:home range ratio.

We calculated movement within the pre-hunt and hunt periods as the straight-line distances between consecutive 20-minute fixes. Where gaps existed in the dataset due to data censoring, the movement on either side of the missed location was omitted from analysis. We compared movement during dawn, day, dusk, and night for each study period. Also, we examined micro-scale movements (20-minute fix interval) of adult male deer in relation to known hunter locations during 2006 and 2007 firearms season. For each hunter, hunting stand, time dropped off, and time picked up were recorded by hunting guides at Chesapeake Farms.

Because horizontal (x-axis) activity sensors are overly sensitive and tend to misclassify bedded animals as active (Beier and McCullough 1988, Coulombe et al. 2006), we chose to use data from the vertical (y-axis) sensor only. For analysis, we used the vertical activity value collected during the five minutes prior to each 20-minute fix. We compared activity for dawn, day, dusk, and night between the pre-hunt and hunt periods.

To estimate vulnerability of deer to harvest during the shotgun season, we buffered each permanent hunting stand to 100 m (approximate maximum effective range of scoped slug shotguns) and intersected all fixes during the pre-hunt and hunt periods with the 100-m hunting stand buffer to calculate vulnerability. Hunting stands were distributed across the entire property. We did not require hunting stands to be occupied by a hunter for this analysis, although all stands were used periodically throughout the firearms season; however, only fixes within Chesapeake Farms boundaries were analyzed because we had no knowledge of hunting stand locations off the property. Any deer with a fix inside the hunting stand buffers during legal shooting hours was considered vulnerable to harvest for that single GPS fix. We defined vulnerability as the ratio of vulnerable locations to total locations and compared dawn, day, and dusk vulnerability values between pre-hunt and hunt periods.

Comparisons between pre-hunt and hunt metrics were evaluated using a student's paired t-test. Within pre-hunt or hunt study period, we used ANOVA to compare metrics between dawn, day, dusk, and night. All statistical analyses were performed in Program R (R Development Core Team 2009) and α was considered significant at <0.05.

Results

Nineteen collars (10 in 2006, 9 in 2007) were deployed, and we documented no capture myopathy. All collars were eventually retrieved, but only four collars in 2006 and five in 2007 collected data throughout the pre-hunt and hunt periods. We censored the other 10 collars because of disease-related mortality (Karns et al. 2009) or mechanical failure. We cleansed 11% of fixes from the overall data set based on PDOP, altitude thresholds, and malfunctioned fixes.

Mean overall home range (95%) size was 386 ± 129 (mean ± standard error) ha and core area (50%) size was 81 ± 27 ha. Between the pre-hunt (home range 306 ± 51 ha; core area 71 ± 12 ha) and hunt periods (home range 261 ± 44 ha; core area 59 ± 10 ha), we detected no difference in mean home range (95%) size (*paired* $t_{(8)} = 1.91$, $P = 0.090$) or mean core area (50%) size (*paired* $t_{(8)} = 1.54$, $P = 0.160$). Mean number of hourly fixes for overall study period was 4,214 ± 172. Also, we used a mean number of 420 ± 5 and 328 ± 3 fixes for pre-hunt and hunt periods, respectively. Overall intensity value was 0.22 ± 0.07, and we detected no difference between

the pre-hunt (0.24 ± 0.08) and hunt (0.23 ± 0.08) period (*paired $t_{(8)} = 0.42$, $P = 0.690$*).

Based on movement paths between 20-minute fixes, overall pre-hunt movement (120 ± 10 m) was greater than the hunt period (89 ± 7 m; *paired $t_{(8)} = 6.73$, $P < 0.010$*). We used a mean number of 1257 ± 29 and 971 ± 32, 20-minute fixes for each deer during pre-hunt and hunt periods, respectively. Movement decreased in dawn, day, dusk, and night periods from the pre-hunt to hunt period (Figure 1). Within the hunt period, movement was higher during the dusk and night hours than dawn and day, and movement during day hours decreased from the dawn period ($F_{(2,33)} = 21.89$, $P < 0.010$). Additionally, we documented 23 instances (during the 126 deer days during Maryland's firearms season) where the distance between a male white-tailed deer and a known hunter location was ≤ 100 m. In nine of those instances, the deer changed direction of movement and/or exhibited flight behavior when disturbed by hunters. When pronounced flight response occurred ($n = 7$), average distance traveled was 257 m (maximum = 550 m).

We detected a decrease in overall activity (pre-hunt 32 ± 4 to hunt 22 ± 3; *paired $t_{(8)} = 4.97$, $P < 0.010$*) and in dawn, day, dusk, and night activity from the pre-hunt to hunt period (Figure 2).

Overall vulnerability was similar between pre-hunt (0.08 ± 0.02) and hunt (0.09 ± 0.03) study periods (*paired $t_{(8)} = 0.32$, $P = 0.760$*). Similarly, we observed no difference in vulnerability during dawn, day, dusk, or night hours. Within the actual hunt period, deer were equally vulnerable to harvest irrespective of day period.

Figure 1. Movement (meters) between pre-hunt and hunt study periods during dawn, day, dusk, and night for adult male white-tailed deer at Chesapeake Farms, Maryland, 2006–2007 (error bars represent 1 standard error).

Figure 2. Activity between pre-hunt and hunt study periods during dawn, day, dusk, and night for adult male white-tailed deer at Chesapeake Farms, Maryland, 2006–2007 (error bars represent 1 standard error).

Discussion

We observed a decrease in adult male white-tailed deer movement and activity during the hunting season; however, this was not surprising because the hunting season corresponded with the post-breeding period when males, physically stressed from the rigors of breeding season, reduce movement and activity after the majority of females have been fertilized (Tomberlin 2007). However, in high density populations with unbalanced sex ratios, a pronounced secondary rut (as unbred females enter their second estrus cycle) could extend elevated levels of movement and activity and further disguise influences of hunting pressure on white-tailed deer behavior (Knox et al. 1988). At Chesapeake Farms, the balanced sex ratio resulted in no perceptible secondary breeding season, and adult male white-tailed deer did not exhibit a secondary peak in movement, activity, or home range size. We do acknowledge that our limited sample size and timing of the hunting season relative to the breeding season limits our ability to make firm conclusions about some observed movements; however, the close temporal proximity and/or overlap of hunting seasons with the white-tailed deer breeding season i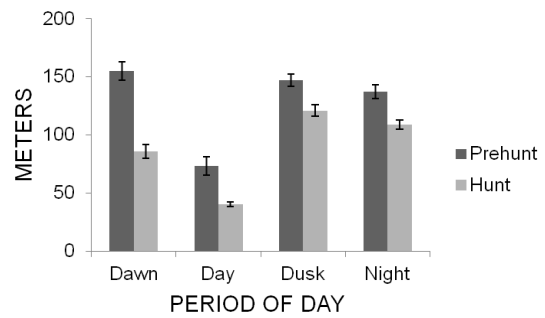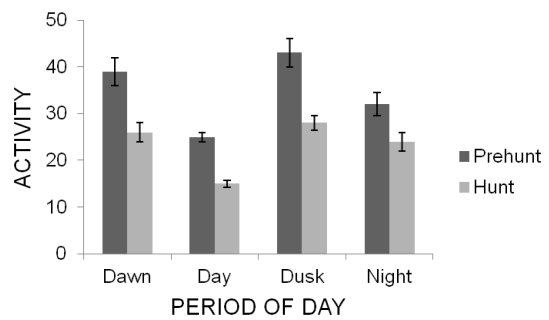s a ubiquitous issue across the species' North American range. Ideally, future studies examining the impact of hunting pressure on game species behavior should employ a non-hunted control group for more robust comparison.

Though white-tailed deer exhibited less movement during the hunt period, adult males occupied the same spatial extent as home range and core area size did not decrease. Movements within a 24-hour cycle mirrored the crepuscular nature of white-tailed deer, but within the hunt period, dusk and night movements were higher than movements during dawn hours. One likely explanation is that deer returned from the fields (primary feeding areas) to bedding areas earlier in the morning due to repeated disturbance from interior property roads used to transport hunters to and from stands as roads were mostly located in and around fields; movement to feeding areas during dusk hours was more temporally consistent and was not reduced. Interestingly, higher movement rates during crepuscular hours did not result in higher vulnerability rates as compared to the day hours during the hunt period. Instead, we would have surmised that vulnerability would be lower during day hours when male deer utilized interior forest habitats simply be-

cause many hunting stand locations were located in close proximity to roads and/or open fields. Based on overall vulnerability values between study periods, adult male white-tailed deer did not appear to purposefully avoid hunting stand locations during the hunting season. On a related note, high fix rates enabled us to examine adult male flight responses to disturbances during hunting season. Of the 23 deer/hunter interactions, the nine documented flight responses were temporary and no change in daily habits or shifts in home ranges or core areas were observed. In fact, adult males were commonly flushed from fields near dusk or bedding areas during mid-afternoon only to resume activities in the same location later. Documented disturbances did not push deer out of their home range (Naugle et al. 1997, Vercauteren and Hygnstrom 1998); thus, excursions (≥1-km movements outside home range) by adult males during the fall and winter (Karns et al. 2011) were not related to hunting activities.

Although adult male movement and activity decreased from pre-hunt to the hunt period, this was likely attributable to hunting season coinciding with the post-breeding period. Because deer did not exhibit any notable avoidance of hunted areas or perceptibly change daily habits in response to being hunted, results indicated the current levels of hunting pressure on Chesapeake Farms were not sufficient to induce considerable change in adult male white-tailed deer behavior. Managers wanting to maximize harvest opportunities for hunters should maintain low to moderate levels of hunting pressure intensity to prevent white-tailed deer from adapting their behavior, and it appears that limited direct disturbances to white-tailed deer do not cause major behavioral shifts or changes.

Acknowledgments

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