Effect of Roads and Traffic on Deer Movements in a Georgia Park

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Abstract: Effects of traffic volume on white-tailed deer (*Odocoileus virginianus*) movement patterns and behavior have not been well documented. During summer 2004, we monitored survival and home ranges of 34 radiocollared deer (6 males and 28 females) in a heavily visited state park in Georgia to determine effect of road distribution on home range use. We also monitored hourly movements for eight females in relation to daily patterns of vehicle volume within the park. Although deer behavior was altered by frequent exposure to traffic and roadside feeding of deer by park visitors, no deer were killed by vehicles during the study. Deer did not selectively use habitats within their home ranges based on proximity of nearest roads. We found no differences ($P > 0.05$) in deer distances from nearest roads during any 24-hr period. Mean rate of travel for the eight females increased ($P < 0.001$) when mean traffic volume within the park increased (1400–2000 hours) and decreased when traffic volume decreased (2000–0200 and 0200–0800 hours), suggesting park vehicles had a disruptive effect on deer movements.

Key words: diel, deer movements, deer-vehicle collisions, Georgia, *Odocoileus virginianus*, state park, vehicular traffic, wildlife damage management

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Movements and activity patterns of white-tailed deer in relatively unfragmented habitats have been studied extensively (Marchinton and Hirth 1984). However, less is understood about behavior of deer in suburban habitats and parks (Swihart et al. 1995). When considering frequency of deer-human interactions in parks, movement and activity patterns of park deer likely differ from those of their more rural counterparts (Beier and McCullough 1990, Swihart et al. 1995). Extensive road networks, high traffic volume, and recreational activities of visitors adversely affect deer movement and habitat use (Taylor and Knight 2003, Alexander et al. 2005). For example, high traffic volume and greater visitor activity during the day may force deer to use important feeding habitats only at night (Frost et al. 1997, Taylor and Knight 2003). Although most parks discourage supplemental feeding of deer by visitors, deer behavior is altered where it is praciced (Kilpatrick and Stober 2002).

To our knowledge, only one other study examined deer movements in relation to park roads (Scanlon and Vaughan 1985), and none have intensively monitored effects of vehicle volume on temporal movements of deer. Our objectives were to monitor deer survival and movements during summer (season of highest park visitation) on a heavily visited Georgia park, with special focus on home range size, spatial arrangement of home ranges, and temporal responses of deer to traffic volume.

Methods

Red Top Mountain State Park (RTMSP) lay within a 578-ha peninsula on Lake Allatoona in north-central Georgia (34º9'N 84º43'W). About 85% of the land within the park was forested with mixed pine (*Pinus* spp.)-hardwood, upland hardwood, and pine-dominated forests. Other habitats on the park include lawns, grassy roadsides, and mowed wildlife openings. Terrain was transitional from the Piedmont to the Ridge and Valley Region with moderately sloping foothills and areas with little or no slope. Commercial silviculture was not practiced on RTMSP, except sanitation cuts were conducted when insects killed stands of trees. In 2002, about 40.5 ha of a pine-dominated stand were managed by prescribed fire; otherwise use of prescribed fire within the park was infrequent. Because of its proximity to Atlanta (56 km), RTMSP was the most heavily visited park in Georgia (>1.2 million visitors annually, Killmaster 2005). Constructed features of the park included 4 km of roads, 19 km of hiking trails, a lodge and restaurant, campground, marina, group shelters, and picnic areas. Although discouraged by park officials, park visitors have been providing deer with supplemental foods for more than a decade (Killmaster 2005). During three years (2001–2003) before our study, about 40 deer were killed each year by vehicles traveling the park's roads (Killmaster 2005).

Deer population density on RTMSP in January 2004 was estimated at 36 deer/km^2, based on mark-resight surveys using infrared cameras (Jacobson et al. 1997, Killmaster 2005). During February-March 2004, sharpshooters from the U.S. Department of Agriculture's Wildlife Services reduced the population to about 10 deer/km^2 by shooting any deer not wearing a radiocollar (as described below). This herd reduction occurred after we had radiocollared our study deer and ≥3 months before we began collecting data on deer movements.

As part of a larger deer ecology project on RTMSP (Killmaster 2005), during January 2004, we captured 41 deer (>1 year old; 33 females, 8 males) by shooting them with radiotelemetry darts (Pneu-Dart, Williamsport, Pennsylvania) that contained xylazine hydrochloride (2.5 mg/kg estimated body weight) and ketamine hydrochloride (3 mg/kg estimated body weight). We followed capture and handling techniques approved by the University of Georgia Institutional Animal Care and Use Committee (IACUC #A2003–10132–0). We darted deer from a vehicle along roads or at off-road locations baited with whole, shelled corn. We fitted each captured deer with a radiocollar equipped with an eight-hour mortality sensor (Advanced Telemetry Systems, Inc., Isanti, Minnesota). We attached white or yellow, numbered ear tags (National Band and Tag Co., Newport, Kentucky) to the exterior surfaces of radiocollars to allow visual identification of each deer. Before releasing deer at their capture sites, we administered yohimbine hydrochloride (0.35 mg/kg estimated body weight) intravenously to reverse effects of xylazine hydrochloride (Mech et al. 1985).

We placed electronic traffic counters (Diamond Traffic, Oakridge, Oregon) across three primary roads within RTMSP to monitor traffic volume (i.e., vehicles/hr) and temporal patterns of traffic flow. Traffic counters recorded number of vehicles traveling on one side of each road. However, all roads ended at a cul-de-sac (i.e., no two-way flow of traffic). Data loggers (Sensource, Youngstown, Ohio) recorded dates and times when vehicles crossed traffic counters.

To monitor movements and activity patterns of deer, we established 160 geo-referenced radiotelemetry stations at easily accessible points along roads and trails. We assigned each station an identifying number, permanently marked it with a metal tag, and recorded its geographical coordinates (±5 m) with a handheld Geographical Positioning System (Geoexplorer III, Trimble Navigations Ltd., Sunnyvale, California). We calculated telemetry locations of deer by sequential triangulation of bearings from three or more geo-referenced stations, recorded within a 20-minute period (Mech 1983). Standard error of telemetry bearings was 0.87 degrees. To minimize the error polygons associated with triangulation, locations were calculated when the angular distance between outermost stations was 60–120°. We used the computer program, LOCATE II, to convert compass-referenced location data to X-Y coordinates based on the Universal Transverse Mercator system (Nams 2000). We entered georeferenced locations into ArcView 3.2 (Environmental Systems Research Institute, Redlands, California) and overlaid road coverage maps, aerial photographs, and topographic maps. We manually digitized roads not present on maps or photographs.

In June 2004, 34 (6 males, 28 females) of the 41 radiocollared deer remained alive. During June-September, we located each of these deer once every 48 hours. We used the Animal Movements v2 extension (Hooge and Eichenlaub 1997) of ArcView to generate 95% and 50% minimum convex polygon (MCP) home ranges for each deer based on recorded locations. The 95% MCP home range of each deer was plotted against number of locations for that deer to ensure adequate sample size and to remove location outliers (Millspaugh and Marzluff 2001). We analyzed spatial relationships between summer home ranges and proximity of roads by calculating home range centroids (i.e., geometric centers) of 95% and 50% MCP home ranges of each deer. We then compared mean distance of 95% and 50% MCP home range centroids of all deer to nearest roads using paired t-tests, assuming unequal variances and accepting significance at $\alpha \leq 0.05$ (SAS. 2001).

During June-September, we recorded hourly locations of eight females for a series of six-hour intervals to obtain 5–7 diel periods of temporal data (120–168 locations) for each deer. We defined the six-hour intervals as period one (0800–1400 hours), period two (1400–2000 hours), period three (2000–0200 hours), and period four (0200–0800 hours). With these data, we examined diel movements of deer for behavioral responses to changing traffic volume and possible temporal patterns of home range use in relation to proximity of nearest roads. For each deer, we calculated mean rate of travel (i.e., average distance moved per hour during each six-hour interval). We used repeated measures analysis of variance, blocked by deer (SAS. 2001) to test for differences ($P < 0.05$) in mean rates of travel among periods one to four. We used Tukey's LSD test to separate treatment means ($\alpha = 0.05$; SAS. 2001).

Results

We censored data from one male deer because of inadequate samples (adjusted $N = 33$). The remaining radiotelemetered deer survived throughout our monitoring period (June-September 2004). The 95% MCP home range for each deer contained ≥1 road and home range overlap among deer was common. Mean summer home range size (95% MCP) was 36.5 ha (± 4.5 ha, range = 26.2–47.3 ha) for males and 22.5 ha (±1.7 ha, range = 8.3–46.0 ha) for females.

On average, deer remained <100 m from nearest roads even when traffic volume exceeded 45 vehicles per hour. Distance of the mean 95% centroid to a road ($\bar{x} = 53$m ± 9.6) and distance of the mean 50% centroid to a road ($\bar{x}$ = 55m ± 7.6) did not differ (P = 0.89, t_{32} = 1.3), suggesting deer did not use areas selectively within their home ranges based on relative proximity to roads. In addition, we found no temporal differences ($P > 0.05$) in distances of deer to nearest roads during any 24-hour period (Fig. 1). Rate of travel for deer during period one ($\bar{x}$ = 114.2 m/hr, range = 85.0–144.4 m/hr) did not differ ($P \geq 0.05$) from other periods. However, deer were more active ($P < 0.001$, $F_{3, 238} = 6.96$) during period two ($\bar{x}$ = 129.2 m/hr, range = 99.3–166.1 m/hr) than during periods three ($\bar{x}$ = 85.0 m/hr, range = 64.7–119.3 m/hr) and four ($\bar{x}$ = 86.7 m/hr, range = 51.5–129.9 m/hr; Fig. 2).

Discussion

Deer-vehicle collisions are the primary source of deer mortality in suburban and park habitats (Nelson and Mech 1986, Etter et al. 2002, Porter et al. 2004). We assumed RTMSP deer were predisposed to vehicle collisions because we frequently saw them foraging along grassy roadsides during the day as vehicles drove past. Some deer used food "handouts" tossed to them from vehicles when park visitors stopped on road shoulders to view and photograph deer. However, because no radiocollared deer died during our monitoring period (June–September 2004), our above assumption of predisposed risk may be invalid or at least dependent on dynamic variables (i.e., deer density, season, weather pat-

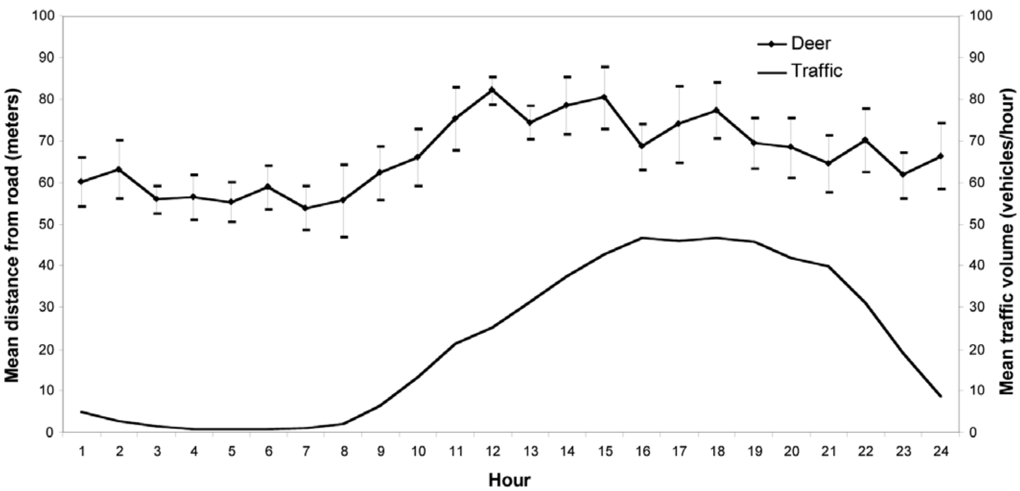

Figure 1. Mean (± SE) hourly distances from primary roads for eight female, radiocollared deer and corresponding traffic volume during June-September 2004 on Red Top Mountain State Park, Cartersville, Georgia.

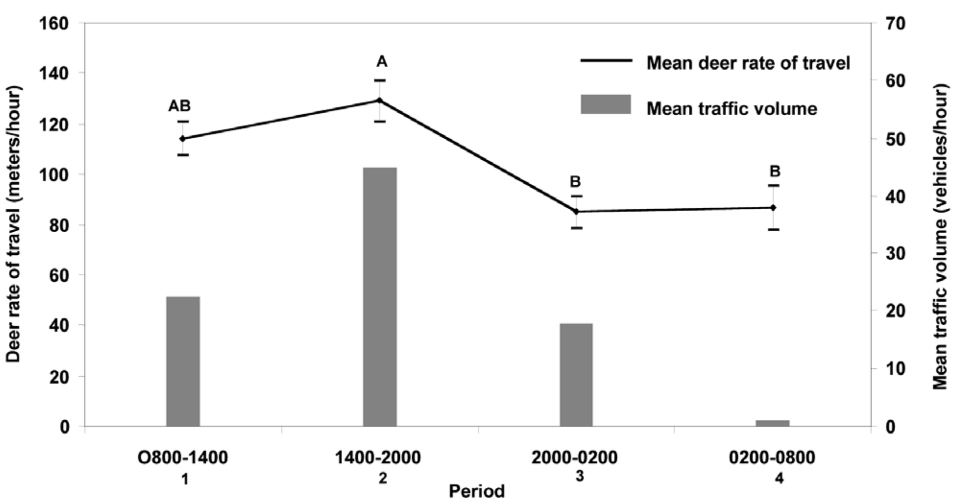

Figure 2. Mean (± SE) rate of travel for eight deer monitored during 5–7 diel periods between June-September 2004 on Red Top Mountain State Park, Cartersville, Georgia, with corresponding traffic volume. Means with the same letter are not different (Tukey's LSD, α = 0.05).

terns, etc.). When considering deaths of seven radiocollared deer that died before our monitoring period, it seems clear that vehicle collisions are an important source of deer mortality at RTMSP. Of these deer, three (43%) were killed by vehicles on park roadways, one (14%) was shot on the park during the herd reduction, two (29%) drowned after being chased into a lake by dogs, and one (14%) died of unknown causes (Killmaster 2005).

On an annual basis, deer in fragmented habitats tend to have smaller home ranges than deer in more contiguous forested or agricultural habitats (Christie et al. 1987, Kilpatrick and Spohr 2000). High quality food resources in a relatively small area (e.g., lawns, gardens, ornamental plantings, bird feeders) and high deer numbers contribute to small home ranges (Swihart et al. 1995, Kilpatrick and Spohr 2000, Porter et al. 2004). Mean summer home ranges of males (36.5 ha) and females (22.5 ha) in our study were similar to summer home ranges of 12 females in a 5,101-ha upland hardwood forest in northeastern Georgia ($\bar{x}$ = 34.8 ha, Carlock et al. 1993), but smaller than those of five females in a 2,025-ha bottomland hardwood forest in central Mississippi ($\bar{x}$ = 711.1 ha, Mott et al. 1985). On Shenandoah National Park in Virginia, Scanlon and Vaughan (1985) reported that deer captured and radiocollared near the main road had smaller summer home ranges than deer captured >1 km from the road. They believed females and their young relied heavily on grassy roadsides for food and established core home ranges around them. Most bucks in their study used roadsides infrequently and deer captured >1 km from the road might never have visited it.

Although anthropogenic features, like roads, might limit deer home range expansion and become functional boundaries (Kilpatrick and Spohr 2000), we did not observe this pattern at RTMSP. Nor did we identify deer that established clearly linear home ranges parallel to roads, as reported by Scanlon and Vaughan (1985). Location of roads within home ranges appeared random, but each 95% MCP home range included a road. Because mean distance from centroids of 95% and 50% MCP home ranges to nearest roads at RTMSP was similar, deer clearly used their home ranges without regard for roads. If radiocollared deer were repulsed by roads, the centroid of their 50% MCP home range would be further from roads than the centroid of their 95% MCP home range. The opposite relationship would have occurred if deer were attracted to roads.

Although we recognize clear similarities between deer use of RTMSP and that of Shenandoah National Park (i.e., importance of grassy roadways), as reported by Scanlon and Vaughan (1985), we believe clear differences also exist. At both of their study sites (65 km^2 each), there was only one primary road with remaining habitat completely forested except for a few abandoned home sites. In contrast, RTMSP was smaller and primary roads transected all areas. In some ways, deer at RTMSP are subjected to habitat characteristics similar to deer in residential communities because they frequently interact with humans and must adapt to habitat fragmentation. However, RTMSP also differs from typical suburban habitats because the peninsular shape of the park effectively separates deer from residential developments. When compared to deer in suburban communities, deer at RTMSP have limited access to fertilized plantings or bird feeders. Their nutritional plane is more influenced by natural fluctuations in hardwood mast production (Carlock et al. 1993). Habitat quality and deer nutritional condition were poor on RTMSP during our study (Killmaster 2005).

Because we did not monitor deer movements before February 2004, we did not speculate about effects of the herd reduction on deer home range size and spatial arrangement or deer movements. However, because deer had three months to adjust to a reduction in population density (36 deer/km^2 to 10 deer/km^2) we believed density-related effects on summer home ranges were minimal. We acknowledged that having fewer deer caused a measurable recovery of deer forage plants (Killmaster 2005) and this might have influenced individual home ranges. However, this effect was constant across individuals.

Deer movements, activity patterns, and habitat use are affected by factors such as climate, deer population density, habitat quality, predation, season, and weather (Marchinton and Hirth 1984, Beier and McCullough 1990). Deer budget time spent on normal activities (e.g., foraging, social interactions, movement, rest) to balance energy uptake and expenditure, while minimizing risk of predation. Previous research suggests that without negative reinforcement (e.g., shooting or intentional harassment), wildlife soon adjusts to increases in park visitation and associated traffic volume (Schultz and Bailey 1978, Burson et al. 2000). In general, ungulates are rather resilient to disturbances by even high (300–5,000 vehicles per hour) volumes of traffic (Alexander et al. 2005), but differences in sensitivity to traffic occur among deer species (Wisdom et al. 2004).

When considering deer activity (i.e., mean rate of travel) as influenced by traffic volume, activity was greatest during period two (1400–2000 hours), although it was daylight and traffic volume reached peak levels. These findings differ from reports indicating deer exhibit mostly crepuscular activity during summer (Kammermeyer and Marchinton 1977) and seek refuge and remain relatively inactive during periods of high human activity (Vogel 1989, Storm et al. 1995).

In conclusion, we believe deer activity at RTMSP was disrupted during periods of high traffic volume; however, proximity of roads did not influence establishment and proportional use of deer home ranges. Although attraction or repulsion to roads was not demonstrated, we believed grassy roadsides were important feeding areas within a deer's home range. When park managers develop deer management strategies, it is necessary to consider how deer might affect visitor satisfaction and safety, and the park's ecosystems. Concurrently, managers must consider the park's ability to provide year-round food for deer, and potential effects of park visitation and traffic volume on deer behavior.

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