SEASONAL MOVEMENTS OF FEMALE WHITE-TAILED DEER

IN A LOW-DENSITY POPULATION

by

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(Under the Direction of Karl V. Miller)

ABSTRACT

I captured, radiocollared, and tracked the daily movements of 13 female white-tailed deer (*Odocoileus virginianus*) relative to parturition, breeding, and managed dog hunts on the Savannah River Site (SRS), Aiken, South Carolina during 2002. I compared measures of spatial mobility, including daily home range size, rate of travel, and distance between extreme daily locations, among the periods of pre- and post parturition and pre-, peak-, and post-rut and relative to controlled dog hunting. Controlled dog hunting had little long-term effect on female movement. From pre-parturition to post-parturition, I observed decreases in female mobility. Diel home range size, distance between extreme diel locations, and diel rate of travel during the pre-rut and rut exceeded those observed during post-rut. Our data suggest that female white-tailed deer reduce mobility following parturition, irrespective of population density. Furthermore, despite a near equal sex ratio, estrous does may be required to actively seek potential mates due to low population density.

INDEX WORDS:Daily movements, Distance between extremes, Dog hunting, Home range,
Parturition, Radio-telemetry, Rate of travel, Rut, White-tailed deer

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DEDICATED TO THE WHITE - TAILED DEER

May the road rise to meet you. May the wind always be at your back. May the sun shine warm upon your face. May the rain fall soft upon your fields. Until we meet again, may God hold you in the palms of his hands.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

The seasonal movements of white-tailed deer (*Odocoileus virginianus*) have been well documented across most regions and habitats within its range (Ivey and Causey 1981, Tierson et al. 1985, Nixon et al. 1992, Lesage et al. 2000, Grund et al. 2002), but few studies have focused on the 24-hour diel movements within seasonal patterns. Investigations of changes in female seasonal home range size and location (Nixon et al. 1992), and the social behavior associated with parturition (Ozoga et al. 1982, Bertrand et al. 1996) have not focused on lactating females in a low-density population.

Labisky and Fritzen (1998) suggested that female white-tailed deer in a low-density population with a disproportionately lower abundance of males may increase daily movements during the breeding season to facilitate mate acquisition. However, no studies to date have examined the behavior of breeding females in a low-density population with even sex ratio.

While it is well established that deer alter their movements in response to hunting pressure (Sweeney et al. 1971, Root et al. 1988, VerCauteren and Hygnstrom 1998, Kilpatrick and Lima 1999), information is limited regarding the movements of white-tailed deer during intensive hunts over broad areas. No studies have examined deer movements during short-term, controlled dog hunting aimed at maximizing deer harvest.

My study objectives were to document the 24-hour diel movements of female whitetailed deer relative to managed dog hunts, parturition, and breeding activity in a low-density population with even sex ratio on the Savannah River Site, South Carolina. Chapter 2 describes the movement responses of female deer to controlled dog hunting, and Chapter 3 assesses female mobility relative to parturition and breeding. Chapters 2 and 3 represent manuscripts that have been or will be submitted to the *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*.

LITERATURE REVIEW

Deer Movements Relative to Parturition

Differences in female white-tailed deer movements relative to parturition have been attributed to population density (Ozoga et al. 1982, Bertrand 1996), mother-young behavior (Ozoga et al. 1982, Nixon et al. 1992, Schwede 1993), and nutritional demands on lactating females (Fritzen 1992). In a supplementally fed captive herd, Ozoga et al. (1982) observed sharp and lasting declines in doe home range size immediately following parturition. Additionally, Ozoga et al. (1982) associated increased fawn mortality with higher population densities. Similarly, Nixon et al. (1992) related reductions in doe home range sizes just prior to and immediately following parturition to the protection of fawns rather than defense of resource territories. Bertrand et al. (1996) observed no difference between the home range areas of lactating and non-lactating females in a high-density captive population. However, following a >50% herd reduction in the same population, Bertrand et al. (1996) reported that lactating females reduced their home range size for at least 18 weeks post-parturition. Conversely, Schwede et al. (1993) found that does in a high-density population socially and spatially isolate

themselves through maternal aggression during the weeks following parturition. In a lowdensity population, Fritzen (1992) speculated that relatively high female mobility postparturition was due to the high energy requirements imposed by lactation and the poor forage quality in the northern Florida pinelands.

Deer Movements During Breeding

Breeding season movements of female white-tailed deer may be dependent on the availability of a suitable mate. Ozoga and Verme (1975) correctly identified estrus in penned does separated from males based on sharp increases in female movements, and proposed that such mobility peaks may be a mechanism aimed at enhancing a female's ability to acquire a mate.

Hölzenbein and Schwede (1989) used observations and radio-telemetry to monitor the breeding activity and behavior of female white-tailed deer at the National Zoo's Conservation and Research Center, Front Royal, Virginia. They found that 7 of 8 females continually decreased activity and mobility from pre-rut until post-rut, presumably to increase the likelihood of being located by a breeding male. The remaining female made a long-distance excursion out of her regular home range immediately prior to mating at the end of rut after most breeding activity had ceased. From these findings, Hölzenbein and Schwede (1989) suggested that reduced breeding success in a population may be identified by excessive movements of a high proportion of adult females during breeding season.

In a low-density population in which males were highly exploited, Labisky and Fritzen (1998) radio-tracked breeding does at 2-hour intervals during 24-hour monitoring sessions. The spatial mobility of females increased as rut progressed, whereas their use of core areas decreased. Labisky and Fritzen (1998) concluded that estrous females made a behavioral shift from

maintaining a predictable location to an active search mode to facilitate fertilization. However, they were unable to exclude the effects of hunting activity on doe movements.

Deer Movements Relative to Hunting

Previous studies of deer exposed to hunting pressure have suggested that deer exhibit a high fidelity to home ranges, but temporarily may make spatial or temporal shifts in activity to avoid disturbance (Sweeney et al. 1971, Pilcher and Wampler 1982, VerCauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). Sweeney et al. (1971) monitored the behavior of 6 deer during repeated experimental chases by hunting dogs. Deer eluded hounds in every chase and exhibited behaviors characterized as: (1) the deer remained bedded; (2) the deer quickly ran a straight, long-distance course, quickly leaving its home range; (3) the deer ran a complicated, circuitous course, crossing its own trail while not leaving its home range; (4) the marked deer separated from other deer; (5) the deer ran through water. Sweeney et al. (1971) observed radio-collared deer to leave their home ranges during 78% of pursuits and all but 1 returned within 1 day. Similarly, Downing and McGinnes (1976) found that most deer chased from their normal home ranges during controlled dog drives returned by the following day within the Radford Army Ammunition Plant enclosure, Virginia.

VerCauteren and Hygnstrom (1998) monitored female movements relative to a 3-day muzzleloader hunt on the DeSoto National Wildlife Refuge, Nebraska. Doe home range sizes did not differ among pre-hunt and post-hunt periods, however home range centers shifted to permanent cover. During the hunt period, 63% of does left their pre-hunt home range, but 12 of 13 returned within 6 days post-hunt. VerCauteren and Hygnstrom (1998) concluded that does were available for harvest in the same areas where they caused crop damage. Likewise, Marshall and Whittington (1969) reported that 5 deer exposed to managed archery and rifle hunts

remained within their home ranges despite heavy hunting pressure. During a 9-week urban archery hunt, Kilpatrick and Lima (1999) found that most deer remained within their home ranges but avoided hunters by increasing nocturnal activity and shifting diurnal core use areas.

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CHAPTER 2

EFFECTS OF CONTROLLED DOG HUNTING ON THE MOVEMENTS OF FEMALE WHITE-TAILED DEER¹

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ABSTRACT

Understanding the responses of white-tailed deer (Odocoileus virginianus) to controlled dog hunting can aid in the effective implementation of canine-assisted population management strategies. We examined the 24-h diel movements of 13 radio-collared female deer exposed to dog hunting on the Savannah River Site (SRS) near Aiken, South Carolina, where regulated dog hunting has occurred since 1965. We compared diel home range size, rate of travel, and distance between extreme diel locations before, during, and after hunts from 14 September-14 December 2002. Diel home range size ($\underline{F}_{2,91} = 7.71, \underline{P} < 0.001$) and distance between extreme diel locations $(\underline{F}_{2,91} = 6.78, \underline{P} = 0.002)$ on hunt day were greater than 10-day pre- and post-hunt periods. There was no difference between pre-and post-hunt diel home range size ($\underline{F}_{2,91} = 7.71, \underline{P} = 1.00$) and distance between extreme diel locations ($\underline{F}_{2,91} = 6.78, \underline{P} = 0.70$). Rate of travel ($\underline{F}_{2,91} = 2.74, \underline{P} = 0.74$). 0.07) did not differ among the pre-, hunt day, and post-hunt periods. In 8 of 15 monitoring periods of individual deer during hunts, deer moved outside the periphery of their fall home range. The mean distance deer moved outside of their fall home range boundary was 0.8 km (SE = 0.2 km) and all returned within 13 hours. Our data suggest short-term, controlled dog hunting has little long-term effect on adult, female white-tailed deer movement on the SRS. Because deer did not leave the hunt area, the effectiveness of such hunts may be increased by extending their duration.

Key words: dog hunting, home range, movements, <u>Odocoileus virginianus</u>, South Carolina, white-tailed deer

INTRODUCTION

The intensity and duration of hunting pressure may have variable effects on white-tailed deer (<u>Odocoileus virginianus</u>) movements (Marshall and Whittington 1969, Sweeney et al. 1971, Root et al. 1988, VerCauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). Because deer alter their movement patterns in response to hunting pressure, hunting-related activities may influence deer vulnerability to harvest and other sources of mortality (Root et al. 1988). Understanding responses of white-tailed deer to controlled hunting may help managers better meet harvest goals.

Many studies have suggested that deer exhibit a high fidelity to home ranges when disturbed, but may make temporary excursions outside of their home range to avoid hunting pressure (Sweeney et al. 1971, Downing and McGinnes 1976, Pilcher and Wampler 1982, VerCauteren and Hygnstrom 1998). Managed hunts often are designed to control deer density to alleviate localized deer-human conflicts. However, few studies have assessed whether normal ranges of deer disturbed by short-term hunting activity are reflected in kill locations (Downing and McGinnes 1976, VerCauteren and Hygnstrom 1998).

In previous reports of deer chased by hunting dogs, deer readily left their home ranges while being pursued, but most returned within one day (Sweeney et al. 1971, Downing and McGinnes 1976). Sweeney et al. (1971) released 1-7 dogs in close proximity to radio-collared deer and observed individual deer movements. No studies have examined deer response to intensive, organized dog hunts involving hundreds of dogs and hunters in a concentrated area.

Our objectives were to assess the effects of controlled dog hunting on movements of white-tailed deer on Savannah River Site (SRS) and to use this information to refine deer population control methods on SRS. Additionally, this information will be helpful to researchers

and managers interested in whether harvested deer lived in the area in which they were harvested.

STUDY AREA

Our study was conducted on the 80,267-ha SRS in Aiken, Barnwell, and Allendale counties, South Carolina. SRS is a U.S. Department of Energy National Environmental Research Park located in the Upper Coastal Plain physiographic province (Imm and McLeod In Press). The topography is gently rolling to flat with elevations ranging from 20-130 m. SRS is 97% forested, with pines being dominant (68%) in the overstory canopy, including longleaf pine (<u>Pinus palustris</u>) and loblolly pine (<u>P. taeda</u>). Other major vegetation types are swamps and riparian bottomlands (22%) and upland hardwoods (7%) (Imm and McLeod In Press).

In 1950, SRS was estimated to contain <24 deer (Johns and Kilgo In Press). By 1965 the population rebounded and controlled dog hunting was instituted to reduce the incidence of deer-vehicle collisions. Controlled dog hunting has provided a safe, efficient means of maximizing hunter effort within areas targeted for deer population control (Novak et al. 1999). The U.S. Forest Service sets annual population reduction goals to maintain a sitewide population of 4,000 deer with even sex ratio. In 2002, the pre-hunt population was estimated at 5,500 deer, of which 1,318 deer were harvested by hunters and 88 deer were killed by vehicles. Each hunt unit (3,458-5,273 ha) was hunted only 1-2 days from 28 September-04 December 2002 for a duration of 3-4 h either in the morning or afternoon. Hunts involved 91-200 stationary standers placed along roadways at >275 m intervals and 67-70 dog packs (3-6 dogs and 1 mobile handler each). Stationary stander and dog pack release sites were pre-determined and geo-referenced. Hunters

used shotguns loaded with buckshot and were instructed to shoot all deer that presented safe shots, regardless of age or sex.

METHODS

We captured deer in rocket nets and by tranquilization with a dart gun (Dan-inject, Børkop, Denmark; Palmer Cap-chur Equipment, Douglasville, Georgia) from January 2001 to July 2002. We targeted adult females during our capture efforts because male white-tailed deer movements during the breeding season are more variable and could have confounded our results (Marchinton and Hirth 1984, Beir and McCullough 1990, Sargent 1992). Rocket nets were placed on established food plots planted in seasonally desirable forage crops and baited with whole kernel corn and trace mineral salts. Deer captured in rocket nets were immobilized with xylazine hydrochloride administered intramuscularly at 1 mg drug/kg estimated body weight. We loaded transmitter darts (Pneu Dart, Williamsport, Pennsylvania) with a 3-cc mixture of Telazol® (500 mg in solution) and xylazine hydrochloride (180 mg). Deer were fitted with radio-collars (Advanced Telemetry Systems, Isanti, Minnesota), eartagged, and assigned an approximate age by tooth wear and replacement criteria (Severinghaus 1949). We reversed immobilization drugs with yohimbine hydrochloride (0.06 mg/kg intramuscularly). Animal handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (#A3437-01).

We used radio receivers (Advanced Telemetry Systems, Isanti, Minnesota; Communication Specialists, Orange, California) and 3-element folding Yagi antennas to take bearings from geo-referenced telemetry stations. We located deer at 1-h intervals by triangulation during 2-5 24-h diel periods for 10 days pre- and post-hunt. Bearings for

triangulation were obtained sequentially, taking <20 min to collect the 3-7 bearings used to estimate the location of an individual deer (Nams and Boutin 1991). On the day of the hunt, we located deer at 20-min intervals just before and during the hunt by biangulation using simultaneous bearings or triangulation. Immediately after hunters left the woods at the conclusion of the hunt, we continued to locate deer by triangulation at 1-h intervals for the remainder of the 24-h diel period encompassing the hunt. The mean angular telemetry error was 8.3° (SE = 0.80) as determined by estimating bearings (N = 50) to 10 test transmitters placed at known locations in the study area. We used LOCATE2 (Nams 1990) to estimate deer locations.

We entered geo-referenced deer locations into a spreadsheet and imported them into ArcView 3.2 (Environmental Systems Research Institute, Redlands, CA) as point themes. We calculated minimum convex polygons (Mohr 1947) with the Animal Movements extension (Hooge and Eichenlaub 1997) in ArcView to estimate fall home range and diel home range. For all 24-h monitoring periods, we calculated diel home range using only one location/1-h interval. We used 50 to 145 locations/deer from 18 April 2001 to 11 April 2003 to define annual home ranges. We derived fall home ranges for each deer from a distribution of 21-27 randomlyselected locations/deer from 14 September to 23 December 2002, not including hunt days. We quantified diel home range (ha) as the area used in a 24-h period. We also used point locations to calculate diel rate of travel and distance between extreme diel locations. Diel rate of travel (m/h) was the sum of successive distances traveled between sequential radio locations divided by the number of hours a deer was monitored. Distance between extreme diel locations (m) was the greatest distance between any 2 radio locations obtained for a deer during a diel monitoring period (Labisky and Fritzen 1998). We performed statistical analyses with Statistical Analysis System software. We used analysis of variance (PROC ANOVA) (SAS Institute 2001) to detect

differences among diel home range size, diel rate of travel, and distance between extreme diel locations for the pre-, post-, and hunt day periods. We used Tukey's HSD to make pairwise comparisons of significant results ($\underline{P} < 0.05$).

RESULTS

From 14 September to 14 December 2002, we located 13 female deer 1,938 times during 94 24-h diel monitoring periods (pre-hunt = 35, hunt day = 15, post-hunt = 44). We monitored female deer movements relative to four individual hunts on 28 September, 30 October, 02 November, and 04 December 2002. Mean diel home range size ($\underline{F}_{2,91} = 7.71, \underline{P} < 0.001$) and distance between extreme diel locations ($\underline{F}_{2,91} = 6.78, \underline{P} = 0.002$) during hunt days were greater than pre- and post-hunt monitoring periods (Table 2.1). We detected no differences among pre- and post-hunt periods for diel home range size ($\underline{F}_{2,91} = 7.71, \underline{P} = 0.10$) or diel rate of travel ($\underline{F}_{2,91} = 2.74, \underline{P} = 0.70$) (Table 1). Diel rate of travel ($\underline{F}_{2,91} = 2.74, \underline{P} = 0.070$) did not differ among periods although it was more than 15% greater on the hunt day (Table 2.1).

All radio-collared deer remained within hunt area boundaries during the 15 24-h hunt day monitoring periods. Two radio-collared deer were harvested during hunts and data on their movements were excluded from analyses. Hunters did not report seeing other marked deer. Estimated movement paths of deer during hunts suggested that deer avoided dogs and hunters by backtracking, running long distances, and remaining inactive for extended periods (Figure 2.1). Our telemetry data, along with the fact that few of our research animals were observed by hunters, suggest that deer made use of thick escape habitats such as stream corridors and young pine plantations. In 8 of 15 monitoring periods during hunts, deer were observed outside the periphery of their fall home range. The mean distance deer moved outside of their fall home range boundary during a hunt was 0.8 km (SE = 0.2 km). One doe traveled 2.3 km from her fall home range boundary and did not return to her home range until about 13 h later after the hunt ended (Figure 2.2). This deer remained outside of her home range longer than any other. In 6 of 15 monitoring sessions during hunts, deer were observed outside of their annual home range. The mean distance deer moved from the periphery of their annual home range was 0.8 km (SE = 0.3 km).

DISCUSSION

Despite the release of >200 dogs/hunt, controlled dog hunting had no apparent long-term effect on female deer movements. During the hunts, does displayed a high fidelity to seasonal and annual home ranges. Those deer that did leave their fall or annual home ranges during the hunts generally returned before the hunt was over or soon after disturbance subsided. Deer resumed normal movements within seasonal and annual home ranges during the post-hunt monitoring period.

Our findings are consistent with most previous reports of deer chased by hunting dogs (Schoonmaker 1938, Sweeney et al. 1971, Downing and McGinnes 1976) and deer exposed to human hunting pressure for a more extended period (Pilcher and Wampler 1982, VerCauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). Sweeney et al. (1971) found that deer left their home ranges when pursued in 78% of experimental chases with dogs and 98% of those deer returned to their home ranges within one day. Downing and McGinnes (1976) introduced dogs to an enclosure on 6 weekends during a 2-month period to drive deer from a 245-ha watershed, and although virtually all deer were driven from the area, most returned to their home ranges the following day. VerCauteren and Hygnstrom (1998) reported deer that flushed from their home

ranges during a 3-day muzzleloader hunt returned to pre-hunt home ranges within 6 days posthunt. Conversely, Kilpatrick and Lima (1999) found that most deer responded to disturbance by shifting diurnal core use areas within their home range to avoid hunters during a 9-week urban archery hunt.

Sweeney et al. (1971) observed deer harassed by hunting dogs to exhibit characteristic behaviors to escape pursuit including holding, circuitous movements, and distance running. Similarly, we found as the hunt progressed, deer made presumably deliberate attempts to elude dogs and humans as displayed by periods of inactivity integrated with occasional extensive movements. We also observed deer using backtracking movement patterns. Deer backtracked only during hunts and generally toward the interior of their home range. Deer returning to their home ranges after the hunt used direct routes rather than backtracking.

Downing and McGinnes (1976) found that kill locations of tagged deer during managed dog hunts did not represent the normal ranges of those deer, though they did not quantify differences. Sweeney et al. (1971) found that >90% of marked deer remained within 1 km of their home ranges. Our results also indicated that does exposed to short-term, intensive, dog-hunts remained in close proximity to their established fall and annual home ranges. All radio-collared deer were available for harvest in the hunt areas during the 3-4 h hunts, but only 2 of 13 were sighted. Increasing the duration of hunts in individual units may facilitate a more effective harvest by forcing deer to continue moving and in turn present hunters with more shot opportunities. Also, because of the limited range of buckshot, further concentrating dog packs and increasing the number of standers may increase hunt efficiency. Future research quantifying the habitat characteristics of escape cover may prove beneficial to hunt planners.

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Table 2.1. Mean (SE) diel home range size (ha), diel rate of travel (m/h), and distance between extreme diel radio locations (m) for 13 female white-tailed deer during pre-hunt, day of hunt, and post-hunt, Savannah River Site, South Carolina, 14 September-14 December 2002. Mean values in columns followed by the same capital letter did not differ (P > 0.05) according to Tukey's HSD comparisons.

Period	Diel home range	Diel rate of travel	Distance between extreme diel locations
Pre-hunt	43.0 (4.7)A	188.9 (9.5)A	691.5 (57.7)A
Hunt day	85.7 (17.2)B	225.8 (22.1)A	1301.8 (209.4)B
Post-hunt	43.0 (5.0)A	184.2 (8.1)A	758.0 (89.7)A

Figure 2.1. Estimated movements of 1 female white-tailed deer on Savannah River Site, South Carolina during a 24-h period, which included a controlled dog hunt on 28 September 2002. The numbers "1" and "2" indicate distinct backtracking patterns.



Figure 2.2. Estimated movements of 1 female white-tailed deer on the Savannah River Site during a 24-h period, which included a controlled dog hunt on 02 November 2002.



CHAPTER 3

DAILY MOVEMENTS OF FEMALE WHITE-TAILED DEER RELATIVE TO PARTURITION AND BREEDING¹

¹D'Angelo, G.J., C.E. Comer, J.C. Kilgo, C.D. Drennan, D.A. Osborn, and K.V. Miller. To be submitted to *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*.

ABSTRACT

We examined the 24-h diel movements of female white-tailed deer (Odocoileus *virginianus*) relative to parturition and breeding in a low-density population with near even sex ratio at the Savannah River Site (SRS), South Carolina. We conducted a series of intensive, 24-h radio-tracking periods of 13 females by obtaining radio locations at 1-h intervals during spring and fall 2002. We compared daily home range size, rate of travel, and distance between extreme daily locations, among the periods of pre-parturition and post-parturition and pre-, peak-, and post-rut. From pre-parturition to post-parturition, we observed decreases in diel home range size (-38.2%, SE = 18.7, P < 0.001), distance between extreme diel locations (-17.0%, SE = 21.5, P = 1.5, P = 1.0.003), and diel rate of travel (-18.2%, SE = 11.6, $\underline{P} < 0.001$). Diel home range size, distance between extreme diel locations, and diel rate of travel during the pre-rut and rut exceeded (P < 0.05) those observed during post-rut. Using the Dixon outlier detection test, we further identified substantial increases in mobility during 12 24-h diel periods for 8 females, suggesting breeding excursions related to estrous receptivity. Our data suggest that female white-tailed deer reduce mobility following parturition, irrespective of population density. Furthermore, despite a near equal sex ratio, estrous does may be required to actively seek potential mates due to low population density.

Key words: breeding, movements, *Odocoileus virginianus*, parturition, rut, white-tailed deer.

INTRODUCTION

Investigations of changes in seasonal home range size, and the social behavior associated with parturition and breeding have yielded little information on the driving force behind 24-h daily movements of female white-tailed deer (Ozoga et al. 1982, Hölzenbein and Schwede 1989, Nixon et al. 1992, Bertrand et al. 1996). Decreases in the home range size of females immediately prior to and following parturition have been observed in captive herds (Ozoga et al. 1982) and in moderate to high-density, free-ranging populations (Nixon et al. 1992, Schwede et al. 1993). Territory defense and the anti-social behavior associated with fawning have been attributed to the necessary formation of the mother-offspring bond (Lent 1974). Isolation and maternal aggression also may be vital for the protection of fawns from predators (Ozoga et al. 1982). Researchers have associated higher deer densities with small home ranges (Marchinton and Jeter 1967, Ellisor 1969, Marshall and Whittington 1969, Ozoga et al. 1982, Marchinton and Hirth 1984) and increased fawn mortality (Ozoga et al. 1982). In areas with overcrowding and fragmented habitat, doe home range size does not differ among seasons, probably due to a minimum home range size being reached (Bertrand et al. 1996, Kilpatrick and Spohr 2000). Bertrand et al. (1996) reported that parturition home range size increased in fawning seasons following a controlled reduction in deer herd density. In a low-density deer population in Florida, Zultowsky (1992) reported that decreases in home range sizes of lactating females were not evident until the weaning period, but this period coincided with a time of drought and low forage quality in the region.

Female white-tailed deer breeding behavior may be affected by the relative density of males (Ozoga and Verme 1975, Hölzenbein and Schwede 1989, Labisky and Fritzen 1998). In populations with an abundance of males, does entering estrus restrict movements to core-use

areas, perhaps to make their locations more predictable to prospective mates (Downing and McGinnes 1976, Ivey and Causey 1981, Hölzenbein and Schwede 1989, Beier and McCullough 1990). In observations of penned does separated from males, Ozoga and Verme (1975) reported a marked increase in activity the night before females entered estrus. Other research by Hölzenbein and Schwede (1989) suggested that does faced with the onset of estrus without a potential mate will switch from a passive breeding strategy to an active search mode. Correspondingly, Labisky and Fritzen (1998) reported that females in a low-density population with a relative scarcity of males used core areas less and increased movements from pre-rut to peak-rut. No studies to date have examined the behavior of breeding females in a low-density population with an equal proportion of males.

To provide additional understanding of how demographic features of a herd affect reproductive behaviors, we investigated the 24-h diel movements of female white-tailed deer relative to parturition and breeding in a low-density population with even sex ratio on the Savannah River Site, near Aiken, South Carolina.

STUDY AREA

Our study was conducted on the 80,267-ha SRS in Aiken, Barnwell, and Allendale counties, South Carolina. SRS is a U.S. Department of Energy National Environmental Research Park located in the Upper Coastal Plain physiographic province (Imm and McLeod In Press). The topography is gently rolling to flat with elevations ranging from 20-130 m. SRS is 97% forested, with pines being dominant (68%) in the overstory canopy including longleaf pine (<u>Pinus palustris</u>) and loblolly pine (<u>P. taeda</u>). Other major vegetation types are swamps and riparian bottomlands (22%) and upland hardwoods (7%) (Imm and McLeod In Press).

In 1950, SRS was estimated to contain <24 deer (Johns and Kilgo In Press). By 1965 the population rebounded and controlled dog hunting was instituted to reduce the incidence of deer-vehicle collisions. Controlled dog hunting has provided a safe, efficient means of maximizing hunter effort within areas targeted for deer population control (Novak et al. 1999). The U.S. Forest Service sets annual population reduction goals to maintain a sitewide population of 4,000 deer with even sex ratio.

METHODS

We captured deer in rocket nets and by tranquilization with a dart gun (Dan-inject, Børkop, Denmark; Palmer Cap-chur Equipment, Douglasville, Georgia) from January 2001 to July 2002. Rocket nets were placed on established food plots planted in seasonally desirable forage crops and baited with whole kernel corn and trace mineral salts. Deer captured in rocket nets were immobilized with xylazine hydrochloride administered intramuscularly at 1 mg drug/kg estimated body weight. We loaded transmitter darts (Pneu Dart, Williamsport, Pennsylvania) with a 3-cc mixture of Telazol® (500 mg in solution) and xylazine hydrochloride (180 mg). Deer were fitted with radiocollars (Advanced Telemetry Systems, Isanti, Minnesota), eartagged, and assigned an approximate age by tooth wear and replacement criteria (Severinghaus 1949). We reversed immobilization drugs with yohimbine hydrochloride (0.06 mg/kg intramuscularly). We captured 13 females, including 12 adults and 1 yearling. Animal handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (#A3437-01).

We used radio receivers (Advanced Telemetry Systems, Isanti, Minnesota; Communication Specialists, Orange, California) and 3-element folding Yagi antennas to take

bearings from geo-referenced telemetry stations. We triangulated deer locations using sequential bearings, taking <20 min to collect the 3-7 bearings used to estimate the location of an individual deer (Nams and Boutin 1991). We located deer at 1-h intervals during 6-13 24-h diel monitoring sessions, separated by > 24 hours, during each of the periods of pre-parturition (09 May - 31 May), post-parturition (01 June - 12 July), pre-rut (14 September - 29 October), rut (30 October - 28 November), and post-rut (29 November - 23 December). Monitoring periods were based on conception dates previously described for adult, female white-tailed deer on SRS (Rhodes et al. 1991), and a 200-day gestation length (Haugen 1959, Verme 1965). Rhodes et al. (1991) reported that > 70% of adult and yearling female white-tailed deer on SRS conceive within 13 November \pm 15 days. The mean angular telemetry error was 8.3° (SE = 0.80) as determined by estimating bearings ($\underline{N} = 50$) to 10 test transmitters placed at known locations in the study area. We used LOCATE2 (Nams 1990) to estimate deer locations.

We entered geo-referenced deer locations into a spreadsheet and imported them into ArcView 3.2 (Environmental Systems Research Institute, Redlands, CA) as point themes. We calculated 95% kernel home range with the Animal Movements extension (Hooge and Eichenlaub 1997) in ArcView to estimate diel and period home ranges. We quantified diel home range (ha) as the area used in a 24-h period. We derived monitoring period home ranges for each deer from all locations collected during 24-h monitoring sessions in that period. We also used point locations to calculate diel rate of travel and distance between extreme diel locations. Diel rate of travel (m/h) was the sum of successive distances traveled between sequential radio locations divided by the number of hours a deer was monitored. Distance between extreme diel locations (m) was the greatest distance between any 2 radio locations obtained for a deer during a diel monitoring period (Labisky and Fritzen 1998).

We visually confirmed fawning in 10 of 11 adult does during the post-parturition period, all of which were seen with fawns. We did not observe 1 adult and the yearling. However, we assumed that both fawned because nearly 100% of adult females (Johns and Kilgo In Press) and 40% of fawns (Rhodes et al. 1991) conceive on SRS.

Radiocollared does were subjected to 3-4 h hunts on 28 September, 30 October, 04 December, and 07 December 2002. We excluded the post-rut movements of 2 does harvested during managed hunts on 04 December and 07 December 2002 from analyses. We removed all 24-h monitoring sessions that included a managed hunt, and considered hunting to have negligible effects on female movements during other diel periods (D'Angelo et al. In Press). We used the Dixon outlier detection test (Sokal and Rohlf 1995) to identify and remove deviant 24-h monitoring periods from paired analyses among monitoring periods. We then calculated mean diel home range, mean diel rate of travel, and mean distance between extreme diel locations for each doe during each of the spring and fall monitoring periods. We used the Kolmogorov-Smirnov two-sample test ($\underline{P} < 0.05$) (Sokal and Rohlf 1995) to test for normality among mean measures of mobility for periods paired for comparison including pre-parturition and postparturition, pre-rut and post-rut, pre-rut and rut, and rut and post-rut. We used a paired-sample ttest (P < 0.05) to compare mean measures of mobility for each female among periods that did not differ significantly in frequency distributions. We used the Wilcoxon rank sum test ($\underline{P} < 0.05$) (Sokal and Rohlf 1995) to compare mean measures of mobility among periods with non-normal distributions.

RESULTS

We located 11 adult and 1 yearling female white-tailed deer 4,367 times (pre-parturition = 1,355, post-parturition = 3,012) during 221 24-h diel spring monitoring sessions (pre-

parturition = 73, post-parturition = 148). Diel home range generally encompassed one-third to one-half of the period home range (Table 3.1). From pre-parturition to post-parturition, we observed decreases in diel home range size (<u>t</u>-test: <u>t</u>₁₁ = -5.05, <u>P</u> < 0.001), distance between extreme diel locations (<u>t</u>₁₁ = -3.25, <u>P</u> = 0.004), and diel rate of travel (<u>t</u>₁₁ = -5.21, <u>P</u> < 0.001; Table 3.2).

During the fall sampling period, we located 12 adult and 1 yearling female deer 6,141 times (pre-rut = 2,583, rut = 1,930, post-rut = 1,628) during 288 24-h diel periods (pre-rut = 123, rut = 92, post-rut = 73). We detected no difference between the periods of pre-rut and rut for diel home range size ($\underline{t}_{12} = 0.89$, $\underline{P} = 0.20$), distance between extreme diel locations ($\underline{t}_{12} = 0.23$, $\underline{P} =$ 0.410), and diel rate of travel ($\underline{t}_{12} = -0.20$, $\underline{P} = 0.42$). We observed decreases in diel home range size ($\underline{t}_{10} = -2.69$, $\underline{P} = 0.01$), distance between extreme diel locations (Wilcoxon rank sum test: T = 4, $\underline{P} < 0.001$), and diel rate of travel (T = 0, $\underline{P} < 0.001$) from pre-rut to post-rut. Likewise, female movements during rut exceeded those during post-rut for diel home range size ($t_{10} = -2.07$, <u>P</u> = 0.03), distance between extreme diel locations (T = 2, $\underline{P} < 0.001$), and diel rate of travel (T = 0, \underline{P} < 0.001). Those 24-h periods removed as outliers for fall monitoring periods were characteristic of substantial increases in female mobility, suggesting breeding excursions related to estrus (Figure 3.1). We identified 12 such periods for 8 does from 26 September to 6 December 2002. During periods of fall excursion, does averaged a 360% (SE = 231.07, <u>N</u> = 12) increase in diel home range size, a 163% (SE = 124.76, \underline{N} = 12) increase in distance between extreme diel locations, and a 75% (SE = 38.47, \underline{N} = 12) increase in diel rate of travel. Three does exhibited 2 periods of excursion each, separated by 50, 50, and 48 days, respectively.

DISCUSSION

Based on the results of our spring monitoring, it is apparent that lactating female whitetailed deer minimize mobility after fawning in this low-density population, as has been reported for herds with other demographic conditions. Ozoga et al. (1982) found that a sudden, lasting decline in home range size coincided with female parturition date in a crowded, supplementally fed, captive herd. Correspondingly, Bertrand et al. (1996) confirmed that females decreased home range size and frequency of social affiliations relative to parturition in a high-density, captive herd. However, the parturition home range size for does in that herd were greater in a fawning season following a controlled reduction in deer herd density, but were still less than those of non-lactating does. The degree to which parturient females reduce mobility is probably due to intraspecific competition for territory to promote the formation of a mother-offspring bond. Schwede et al. (1993) observed isolation of lactating does from previous offspring and other parturient females through aggression. Nixon et al. (1992) proposed a kinship theory with deer recognizing relatives and behaving toward them within limits dictated by their degree of relatedness.

Our data suggest that despite a near equal sex ratio, estrous does may be required to actively seek potential mates due to low population density. These findings correspond with those of Labisky and Fritzen (1998) for females in a low-density population in which males were limited. Similarly, Hölzenbein and Schwede (1989) observed a <24-h, long-distance excursion by a female immediately prior to her tending by an adult male at the end of rut after most breeding activity had ceased. Beier and McCullough (1990) reported 6 occasions on which radio-tagged does increased daily activity by > 80% during rut on the George Reserve, Michigan, where males were culled in greater numbers than females. Sawyer (1981) determined that the

temporary movements of 3 does to the outside or periphery of their home ranges coincided with conception.

Excluding excursions, indices of female movements remained stable throughout pre-rut and rut. Seasonal variations related to weather or food availability may have caused reduced movements during post-rut (Marchinton and Hirth 1984). Active searching for a mate by females likely explains daily increases in mobility. However, an alternative explanation may be forced movements resulting from harassment by bucks after onset of physiological heat before the doe's peak estrous receptivity (Verme and Ullrey 1984). Hölzenbein and Schwede (1989) found that females maintained predictable locations within their core areas prior to formation of tending bonds and then expanded their range over a period of several days in attempts to avoid the courting male.

Miller et al. (1995) suggested that shorter breeding seasons in deer herds may be related to balanced sex ratios and increased numbers of mature bucks because fewer does remain unbred during their first or subsequent estrous cycles. Such a sex and age structure exists for the SRS deer population (Johns and Kilgo In Press). However, we observed multiple, probable breeding excursions by at least 3 radiocollared does, suggesting repeated estrous cycling. Protracted breeding seasons negatively impact fawn survival, doe productivity (Jacobsen and Guynn 1995), and antler development (Shea et al. 1992) in white-tailed deer. Thus, in the absence of an acceptable male within a female's home range, a doe may alter movements preceding or during estrus to maximize the probability of encountering a male.

Deer herd demographic conditions during breeding season may cause individuals to be more susceptible to mortality during periods of increased mobility. Sargent (1992) attributed excessive stress in breeding males to an extended rut in conjunction with high water, high

temperatures, and high mosquito densities in the Florida Everglades. VerCauteren and Hygnstrom (1998) reported that does with seasonal migratory patterns appeared more vulnerable than non-migrators due to greater exposure to vehicles and hunting pressure. Fritzen (1992) suggested that increased predation of females resulted from increased mobility in unfamiliar territory during rut. On SRS, variation in the annual number of deer-vehicle collisions is weakly correlated with deer population size (Novak et al. 1991, 1999). Most deer-vehicle accidents on SRS occur during fall with a disproportionately lower number in the spring and summer (Novak et al. 1991). These variations are likely due to differences in deer movements relative to breeding activity. Our results demonstrate that changes in deer herd demographics may impact breeding season movements. In contrast, innate maternal behavior directed at ensuring neonatal survival apparently dominates female movements relative to parturition.

MANAGEMENT IMPLICATIONS

Increasingly, deer management programs emphasize greater harvest of does in attempts to balance sex ratios and maintain deer populations at densities well below carrying capacity (Hamilton et al. 1995). Benefits resulting from such harvest regimes typically include greater forage availability and a sustainable harvest of trophy males (McCullough 1984, Jenks et al. 2002). Yet, the interaction between deer demographics and social behavior may be of greater importance to the fitness of individual deer and the maximum expression of desirable physical characteristics (i.e., large antler size and body mass). Maintaining populations at levels promoting the efficient breeding of does during their first estrous cycle by mature bucks, ensures minimal energy loss by breeding males and females. Likewise, a shortened rut requires breeding

deer to move less, thus decreasing their susceptibility to mortality factors outside of the intended management scheme.

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Table 3.1. Mean (<u>SE</u>) diel home range size (ha) and mean (<u>SE</u>) period home range size for female white-tailed deer during pre-parturition (09 May – 31 May), post-parturition (01 June -12 July), pre-rut (14 September – 29 October), rut (30 October – 28 November), and post-rut (29 November – 23 December) on the Savannah River Site, South Carolina, 09 May - 23 December 2002.

	N	Diel home range	Period home range
Pre-parturition	12	98.77 (42.78)	236.83 (241.69)
Post-parturition	12	60.43 (32.69)	206.03 (202.35)
Pre-rut	13	67.78 (30.28)	208.14 (161.04)
Rut	13	79.43 (52.01)	177.89 (130.68)
Post-rut	11	47.47 (16.02)	108.76 (47.26)

Table 3.2. Mean percent change (<u>SE</u>) in diel home range size (%), distance between extreme diel radio locations (%), and diel rate of travel (%), for female white-tailed deer from preparturition (09 May – 31 May) to post-parturition (01 June – 12 July), pre-rut (14 September – 29 October) to post-rut (29 November – 23 December), pre-rut to rut (30 October – 28 November), and rut to post-rut on the Savannah River Site, South Carolina, 09 May - 23 December 2002.

	<u>N</u>	Diel home range	Distance between extreme locations	Diel rate of travel
Pre-parturition to Post-parturition	12	- 38.17 (18.69) ^a	- 17.04 (21.50) ^a	- 18.20 (11.70) ^a
Pre-rut to Post-rut	11	- 24.76 (28.22) ^a	- 20.12 (16.31) ^b	- 21.34 (10.10) ^b
Pre-rut to Rut	13	22.30 (81.81)	2.40 (24.44)	- 0.23 (15.97)
Rut to Post-rut	11	- 28.35 (32.45) ^a	- 20.85 (16.90) ^b	- 20.89 (12.98) ^b

^a Difference significant at $\underline{P} \le 0.05$ according to paired-sample <u>t</u>-test.

^b Difference significant at $\underline{P} \le 0.05$ according to Wilcoxon rank sum test.

Figure 3.1. Estimated movements of 1 female white-tailed deer on Savannah River Site, South Carolina during a 24-h period, which included an excursion on 18 November 2002.



APPENDIX A

Estimated movements of deer # 104 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 28 September 2002



APPENDIX B

Estimated movements of deer # 126 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 28 September 2002



APPENDIX C

Estimated movements of deer # 108 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 28 September 2002



APPENDIX D

Estimated movements of deer # 121 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 30 October 2002



APPENDIX E

Estimated movements of deer # 121 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 04 December 2002



APPENDIX F

Estimated movements of deer # 128 on the Savannah River Site during a 24-h period,

which included a controlled dog hunt on 30 October 2002

