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Excursive Behaviors by Female White-tailed Deer during Estrus at Two Mid-Atlantic Sites

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Abstract.—Current research suggests that female white-tailed deer (*Odocoileus virginianus*) will adopt sedentary breeding strategies in populations with an abundance of males and a more active mate-searching strategy in low-density or unbalanced herds. We used GPS collars to document the movements of 10 female deer during the breeding season at two Mid-Atlantic study sites that support high-density herds with nearly equal sex ratios. We calculated 95% and 50% seasonal and weekly kernel home ranges and the daily percentage of points located outside of the seasonal home range (SHR). Peaks in weekly home range size and in the percentage of points located outside of the SHR occurred between 7 Nov. and 9 Dec. ($\bar{x}$ = 22 Nov.) for eight deer. Past data from one of the study sites have indicated that most breeding activity occurs from 5–25 Nov. Peaks in the percentage of points outside of the SHR corresponded to brief ($\bar{x}$ = 24.0 h, SD = 18.2 h; range 8–68 h) excursions. On peak days, 46–100% ($\bar{x}$ = 68.3%, SD = 17.1%) of data points were located outside of the SHR. No other excursions were observed during the 17 wk study period. Our results suggest that female deer may travel outside of their home range during the breeding season even when presented with an abundance of potential mates; these data suggest females are engaging in a discrete form of mate selection.

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INTRODUCTION

Conventional knowledge suggests that female white-tailed deer (*Odocoileus virginianus*) likely play a passive role in mate selection. However, Ozoga and Verme (1975) reported increased activity among penned females just prior to conception, providing the first evidence to suggest that females may play a more active role in breeding related activities. Subsequent research has reported increased activity or home range expansion among females during the rut (Labisky and Fritzen, 1998; D'Angelo *et al.*, 2004), including large excursions outside of their home range at the estimated time of conception (Holzenbein and Schwede, 1989; Sawyer *et al.*, 1989; Labisky and Fritzen, 1998; D'Angelo *et al.*, 2004). Presumably, these excursions are efforts by females to find suitable mates. In contrast, other studies have reported decreased activity or constricted home ranges among females during rut (Ivey and Causey, 1981; Holzenbein and Schwede, 1989; Beier and McCullough, 1990).

Changes in activity levels at the time of estrus seem to be related to the presence or absence of suitable mates. Holzenbein and Schwede (1989) hypothesized that in high-density populations with an abundance of mature males, females would use their core areas more frequently during estrus to be predictably found by males. However, in low-density populations or when relatively few mature males are present, females would need to actively search for prospective mates to ensure successful breeding.

Many deer populations have female-biased sex ratios due to greater male mortality rates (Nelson and Mech, 1986). Under these conditions, females may need to invest significant energy in mate-searching behaviors. In contrast, recent deer management efforts to promote more-balanced herds with mature male age structures should result in more energy-efficient, sedentary breeding behaviors among females. However, even with a balanced sex ratio, D'Angelo *et al.* (2004) reported excursive behaviors among females at the purported time of estrus in a South Carolina deer herd, perhaps due to the low deer density (~5 deer/km^2) on the study area.

Although the suggestion that female deer will use the most energy-efficient strategy to breed has support, some studies offer conflicting results. Sawyer *et al.* (1989) documented large excursions by three female deer in an unhunted, high-density Georgia deer population. Holzenbien and Schwede (1989) also observed a large excursion by a single female under high-density conditions on a Virginia study site.

The movements of adult female deer during rut in populations with an abundance of adult males remains unclear. To help better understand the movements of female deer, we designed our study to investigate rut-related movements of adult female deer in two moderate-high density, hunted deer populations with an abundance of adult males.

STUDY SITES

Our study was conducted at Chesapeake Farms (CF) in Kent County, Maryland and the Great Cypress Swamp (GCS) in Sussex County, Delaware. Chesapeake Farms is a 13.4-km^2 research and demonstration property owned by Dupont Agricultural Enterprise. Tomberlin (2007) characterized CF as 50% forested (primarily oak (*Quercus* spp.)/hardwood), 33% agricultural fields (primarily soybean and corn), 14% managed wildlife habitat and 3% impoundments. The GCS, owned by Delaware Wild Lands Incorporated, is a 44.5-km^2 unfragmented, low-lying, mixed hardwood forest containing sizeable stands of loblolly pine (*Pinus taeda*), surrounded by agricultural lands.

Both study sites supported deer densities between 30–40 deer/km^2 and were intensively managed by selective harvest guidelines to promote deer herds with nearly equal sex ratios and mature male age structures. Shaw (2005) determined the CF preharvest deer density to be 33 deer/km^2. In 2006, the CF deer population had a sex ratio near 1:1.5 (M.C. Conner, Chesapeake Farms, unpublished data). In 2005, the GCS area had one of the highest deer densities in Delaware, approximately 36 deer/km^2 (DNREC, 2006) and a camera survey in 2006 estimated the sex ratio to be near 1:1.

Although liberal, either-sex hunting permits were issued throughout most of the season in both states, CF and GCS allowed hunters to harvest one antlered deer per season. Hunters at GCS had the opportunity to harvest a second male after they harvested two females. Sixty-one deer were harvested at CF during the 2005 hunting season, of which 46 were females (G. R. Karns, unpublished data). Annual harvests at GCS typically ranged between 100–125 deer with a 75% female harvest (R. Haas, Delaware Wildlands Inc., unpublished data). The 2006 hunting season at CF opened on 15 Sept. and concluded on 29 Dec.; however, hunting at the Farm was focused between 24 Nov. and 8 Dec. Hunting seasons at GCS were from 1 Sept.–31 Jan., although shotguns and or muzzleloaders were only permitted 6–30 Oct., 10–18 Nov., 9–16 Dec. and 13–27 Jan.

METHODS

CAPTURE AND DATA COLLECTION

We captured adult female deer (≥1.5 y old) at GCS (n = 3) from Feb.–Apr. 2006 and at CF (n = 5) from Jun.–Aug. 2006 using a combination of free-darting and rocket nets. We used 3-ml transmitter darts (Pneu-dart Inc., Williamsport, Pennsylvania, USA) with a 7.0 mg/kg Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA)/6.5 mg/kg xylazine hydrochloride (Cervizine®, Wildlife Laboratories, Inc., Fort Collins, Colorado, USA) mixture to immobilize animals. Deer captured in rocket nets were immobilized with a 10.7 mg/kg ketamine hydrochloride (Ketaset®, Fort Dodge Animal Health, Fort Dodge, Iowa, USA)/2.2 mg/kg xylazine hydrochloride injection. Dosages were calculated assuming an average weight of 70 kg at GCS and 45 kg at CF., During immobilization, we monitored heart and respiration rates, treated minor injuries, lubricated eyes and blindfolded deer. We estimated deer ages based on dental eruption and wear (Severinghaus, 1949). We fitted deer with activated, Televilt Tellus® Basic, 5H1D GPS collars (Televilt/TVP Positioning AB, Lindesberg, Sweden). After being immobilized for 90 min, all deer captured through darting received a 400 mg injection of tolazoline hydrochloride (Tolazoline®, Lloyd Laboratories, Shenandoah, Iowa, USA) to reverse the effects of the immobilization agent. Deer immobilized with ketamine/xylazine were reversed with a similar injection after 30 min. We monitored all deer until they were fully ambulatory. Animal handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (#A3437-01).

Collars were programmed to collect and store 3D GPS locations in the form of X, Y coordinates on their nonvolatile memory. The collars were programmed to collect 32 locations per day at equal intervals. The GPS collars were equipped with a VHF beacon that allowed for regular mortality checks. At the end of the study period, activation of a remote-release mechanism caused functioning collars to fall from the animals. We used Televilt Tellus® TPM Project Manager software (Televilt/TVP Positioning AB, Lindesberg, Sweden) to download the data.

DATA ACCURACY

We filtered out all locations with dilution of precision (DOP) values > 6 from each dataset. Because the collars failed to collect the needed satellite information, we were unable to differentially correct the data. However, it is unlikely that differential correction would have had a significant effect (Dussault *et al.*, 2001).

We assessed the accuracy of our data by placing an unused GPS collar at four different locations that were pinpointed on an aerial photograph and picked to represent the various habitats on the two study sites. The test collar collected data for 1–2 d at each location. We filtered the data as described above. We created buffer regions around each of the four locations and determined the percentage of data that fell within each region.

EXCURSIONS

Datasets contained 17 wk of data from 1 Oct. 2006 to 27 Jan. 2007. As a result of collar failure, one dataset contained data from 1 Oct.–11 Dec. 2006. We included two additional datasets from adult females previously collared at CF (Muller *et al.*, 2006) in our analyses. These deer were collared with Lotek GPS-2200 GPS Collars (Lotek Engineering, Ontario, Canada). One dataset spanned from 1 Oct.–22 Nov. 2001 and collected 6 locations per day, whereas the other dataset spanned from 1 Oct.–30 Nov. 2002 and collected 12 locations per day.

We calculated 95% and 50% seasonal and weekly kernel home ranges with the Home Range Tools for ArcGIS extension (Rodgers *et al.*, 2007). We used all dataset locations to calculate seasonal home ranges (SHR). We also calculated the percentage of points located outside of the SHR for each week and day.

We inspected the data to identify obvious excursions outside of the SHR. We defined an excursion as an isolated string of points with ≥50% of the daily points occurring outside of the SHR or as an isolated string of points extending more than 0.75-km outside of the SHR. Because of the less-frequent sampling rate in 2001, points collected during that deer's excursion were not included in SHR analyses.

REPRODUCTIVE DATA

At CF, the peak of the rut occurred between 5 and 25 Nov. (Tomberlin, 2007). To confirm these dates, we harvested five adult female deer in early 2008 at CF and used fetal measurements (Hamilton *et al.*, 1985) to determine the average time of conception.

RESULTS

There was a 92% average fix rate among datasets. Data from the test collar showed that 70% and 92% of the data fell within 30 m and 75 m of the actual locations, respectively.

Nine of the 10 females that we monitored showed discernable peaks in weekly home range and core area size (Fig. 1) that corresponded to peaks in the percentage of weekly points located outside of the SHR (Fig. 2). The peaks in the percentage of points outside of the SHR occurred over a 1–4 d period (Fig. 2). On these days, 46–100% ($\bar{x}$ = 68.3%, SD = 17.1%) of data points were located outside of the SHR. The locations outside of the SHR corresponded with relatively brief ($\bar{x}$ = 24.0 h, SD = 18.2 h; range 8–68 h) excursions. Seven of 10 deer made a single excursion. One deer did not make any notable excursions. The two remaining deer made excursions lasting approximately 14 h, returned to their home ranges and then repeated these excursions the following night to the same area. Eight of the nine peaks occurred between 7 Nov. and 9 Dec. ($\bar{x}$ = 22 Nov.), whereas the peak for the other doe (1.5 y old) occurred on 30 Dec. No other excursions outside of the SHR were observed for any deer over the study period.

We observed both long and short-distance excursions (Fig. 3) during the 17 wk study period. Four deer made long-distance travels (2.36–4.78 km, $\bar{x}$ = 3.23, SD = 1.11 km). These movements occurred in a straight line over a few hours. Each deer occupied a new area for

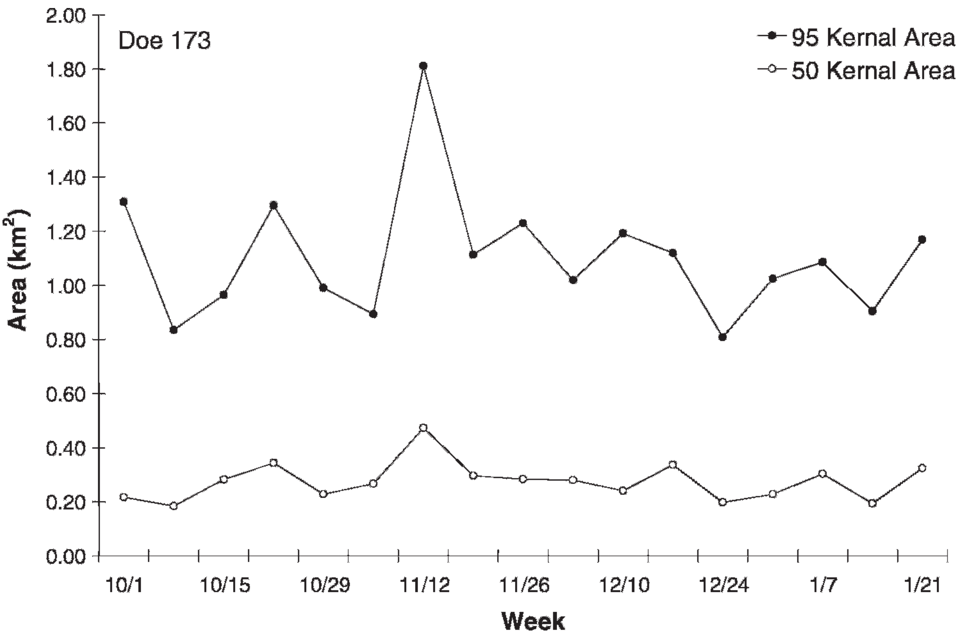

FIG. 1.—Example of weekly home range sizes (95% and 50% kernel) over the 17 wk study period (244 locations/wk) for Doe 173 at the Great Cypress Swamp, Delaware, 2006

several hours and then returned to their normal SHR. Two deer made long-distance excursions that crossed a 100–150 m wide embayment of the Chesapeake Bay. Short-distance travels (0.57–1.05 km, $\bar{x}$ = 0.86 km, SD = 0.20 km) were made by the remaining five individuals. These movements were characterized by travels to areas adjacent to the SHR. Deer also remained in these locations for a few hours and then returned to their normal home range.

Based on fetal measurements, we determined that conception had occurred between 6 and 23 Nov. ($\bar{x}$ = 15 Nov., n = 5).

DISCUSSION

Our data mimic those previously collected from low-density and/or unbalanced herds (Ozoga and Verme, 1975; Ivey and Causey, 1981; Holzenbein and Schwede, 1989; D'Angelo *et al.*, 2004). However, if females used the most energy-efficient strategy to breed, the high densities and balanced sex ratios of our study sites would have suggested that females should have adopted a more sedentary breeding strategy (Ivey and Causey, 1981; Holzenbein and Schwede, 1989; Beier and McCullough, 1990). In contrast to expectations, we observed that most females made a single excursion outside of their home range during a time when conception might have occurred. Eight of the nine excursions occurred in mid- to late Nov. during the time of intense breeding activity. The exception came from the only yearling female in the study, who did not conduct an excursion until late Dec. Delayed conception, and hence late excursions, could be associated with a deer of that age (Ozoga and Verme, 1982).

Accordingly, we posit three hypotheses that may explain these movements: (1) increased harassment by rutting males during tending, (2) movements associated with hunting pressure, (3) mate selection by females.

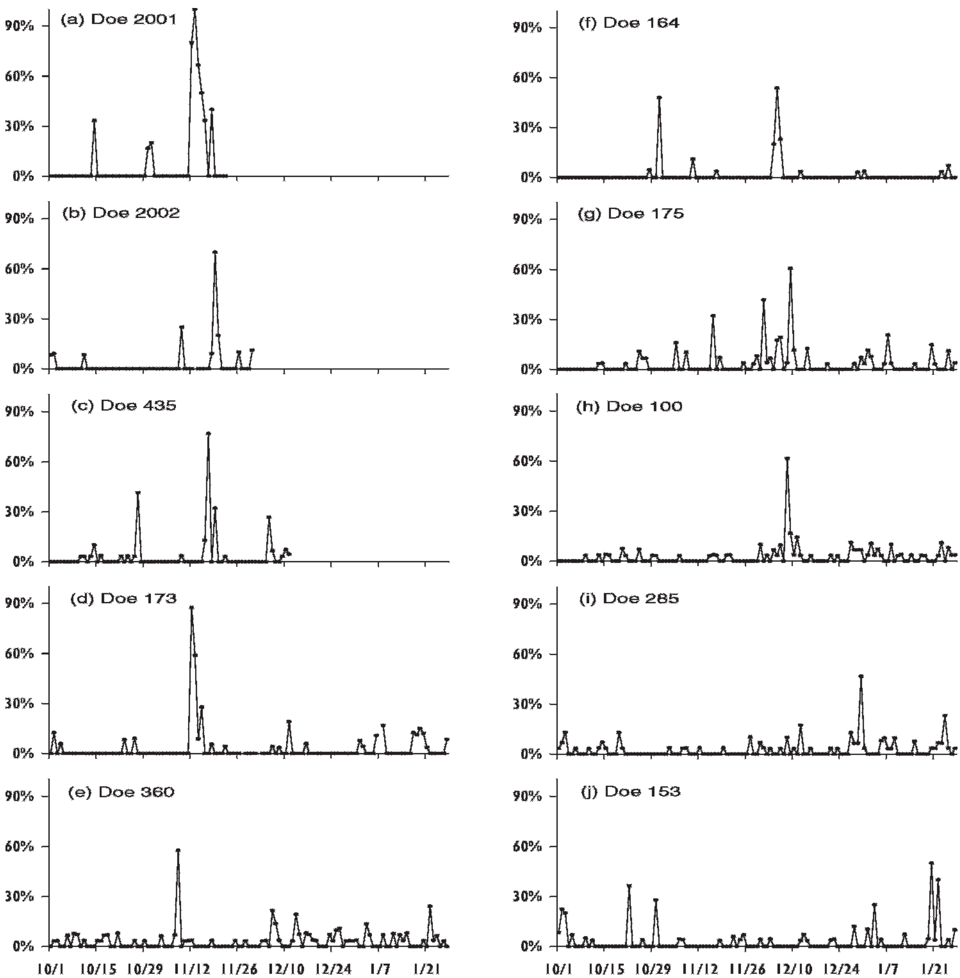

FIG. 2.—Percentage of locations outside of each adult female white-tailed deer's seasonal home range per day at Chesapeake Farms, Kent County, Maryland during 2001 (a), 2002 (b) and 2006 (c, e, g–i) and the Great Cypress Swamp, Sussex County, Delaware during 2006 (d, f, j). No significant excursion was identified for deer 153 (j). Subfigure (i) represents data collected from a yearling doe on Chesapeake Farms

Because these excursions were rare and ubiquitous among the females, we believe that harassment or disturbances associated with hunting pressure is an unlikely cause. Hunting-related excursions might be expected to occur over the entire hunting season. In addition, several of these excursions occurred before any major hunting activity. Sawyer *et al.* (1989) also documented similar excursions in a non-hunted population in Georgia.

Harassment by males outside of the tending phase of courtship would also be expected to occur on multiple occasions and to span most of the breeding season. Rather, these one-time excursions reliably correspond to the peak of the breeding season and the timing of conception. Although we cannot directly tie these events to the formation of tending bonds, it appears likely that conception occurred around the time of these movements. Our data do

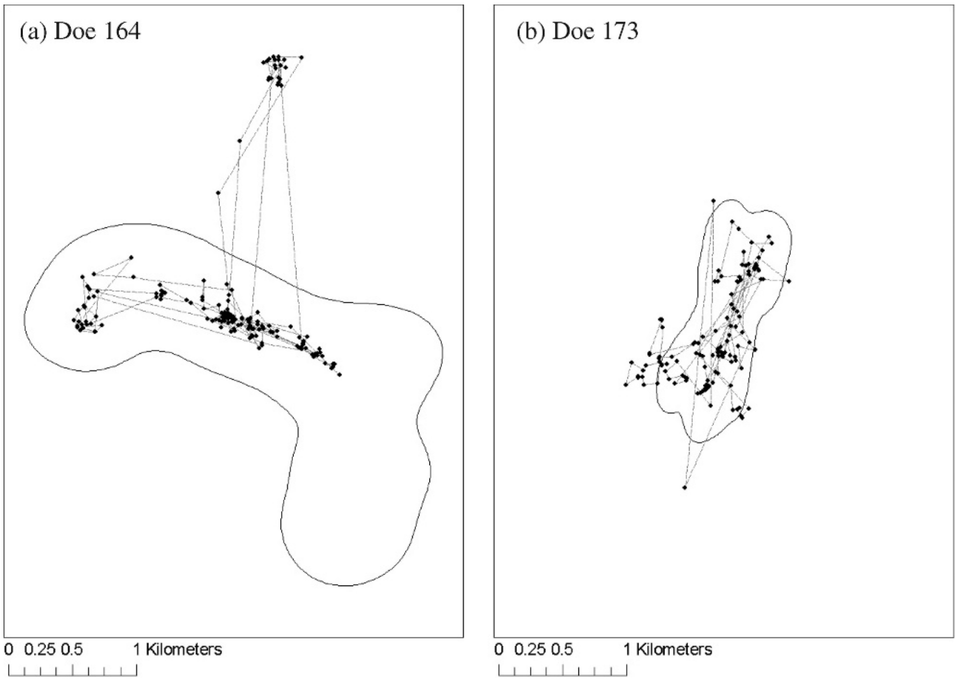

FIG. 3.—Examples of (a) long and (b) short-distance excursions outside of the seasonal 95% kernel area (solid black line) of two adult female white-tailed deer at the Great Cypress Swamp, Sussex County, Delaware during the 2006 breeding season. Individual data points represent observations during the week in which the excursion occurred

not let us evaluate whether the excursions are a result of tending behaviors between the sexes and selection for isolated breeding areas, or active searching for a suitable male by the females. However, the fact that these excursions tend to be relatively straight-line travels up to several kilometers outside of the females' normal home range suggests that active searching by the female is a plausible explanation.

Even in high-density herds with balanced sex-ratios, females might still need to search for prospective mates because the relative abundance of mature males to reproductively mature females may be low. If most males are preoccupied with receptive females, then females entering estrus may be forced to engage in active mate-searching behaviors. However, the fact that nine of the 10 females in our study displayed excursive behavior suggests that females may be engaging in discrete selection for the most reproductively fit breeding partner.

Although some previous studies have not reported similar movements (Ivey and Causey, 1981; Holzenbein and Schwede, 1989; Beier and McCullough, 1990), the relatively infrequent sampling schedules associated with traditional radio-telemetry may have failed to document these relatively brief movements. Our study, conducted with GPS technology, suggests that excursive movements associated with breeding behaviors of female deer may be more common than previously reported. Clearly, female deer in our study traveled outside of their home range around the time of conception. Both male and female deer have a vested interest in finding the best possible mate. While males commonly compete for breeding rights, we suggest that the movements observed in our study could be the result of a more discrete form of mate selection by female deer.

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