Am. Midl. Nat. (2015) 174:96–104

Spring Excursions of Mature Male White-tailed Deer (Odocoileus virginianus) in North Central Pennsylvania

ANDREW K. OLSON, WILLIAM D. GULSBY[1] AND BRADLEY S. COHEN
D. B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens 30602

MICHAEL E. BYRNE
Savannah River Ecology Lab, University of Georgia, Aiken, South Carolina 29808

AND

DAVID A. OSBORN AND KARL V. MILLER
D. B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens 30602

Abstract.—During the breeding season, male white-tailed deer (*Odocoileus virginianus*) have been reported to take excursions outside of their normal home ranges, likely in search of receptive females. However, we documented additional excursive movements by males during spring in north central Pennsylvania. From December 2011 – April 2012, we equipped 13 mature (≥2.5 y old) male white-tailed deer with global positioning system (GPS) collars programmed to record locations hourly. We defined an excursion as any occasion where a male traveled ≥1.6 km outside of its 95% home range boundaries for ≥12 h. Between 6 April and 6 June 2012, nine males (69.2%) made excursions with six making ≥2 excursions. Mean total path distance and duration of excursions was 4.0 km (range = 1.7-8.0 km) and 22 h (range = 12–40 h), respectively. Although the reason for spring excursions is obscure, hypotheses such as increased doe aggression before parturition, males returning to natal home ranges, or visitation to mineral sites do not appear tenable based on current observations.

Introduction

Understanding how animals utilize landscapes is necessary to identify ecological processes influencing population dynamics, gene flow, and disease transmission. Long and short duration excursive behaviors undoubtedly influence these processes. Previous research has reported both male and female white-tailed deer (*Odocoileus virginianus*) make temporary excursions outside of their normal home range during the breeding season (Tomberlin, 2007; Kolodzinski *et al.*, 2010; Karns *et al.*, 2011; Foley, 2012; Basinger, 2013). Excursions by females at this time have been attributed to harassment by rutting bucks, hunting pressure, or active mate selection (Kolodzinski *et al.*, 2010; Basinger, 2013). Male excursions likely are related to pursuit of receptive females but also may occur as males chase off other competing males or isolate receptive females from male competition (Hirth, 1977; Tomberlin, 2007; Karns *et al.*, 2011; Basinger, 2013).

Despite reports of autumn excursions by white-tailed deer of both sexes, excursions during other portions of the year rarely have been reported. However, during a study of the movement ecology of mature male white-tailed deer in north central Pennsylvania, we observed many of our study animals engaging in infrequent, short duration, long distance movements during the spring. Although Kilgo *et al.* (1996) reported some deer (sex not

[1] Corresponding author: e-mail: gulsbyw@warnell.uga.edu

reported) exhibited long distance, springtime movements in Florida, herein we describe the first reports of spring excursions by mature male white-tailed deer.

Study Area

We captured deer on an approximately 3000 ha tract of privately owned land in Elk County, PA (41° 19' 0" North, 78° 23' 12" West). The study area (~6700 ha) was defined *post-hoc* by creating a minimum convex polygon with a 200 m buffer around all point locations of male deer ≥2.5 y old, excluding short-duration, long-distance excursions. The study area focused on the private land where capture activities occurred but included adjacent state and privately owned lands. The area was located on the Allegheny Plateau and elevations ranged from approximately 430-670 m.

The habitat was primarily contiguous forest, consisting of mostly mature and regenerating northern hardwood forest species including oaks (*Quercus* spp.), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), American basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), sweet birch (*B. lenta*), eastern hemlock (*Tsuga canadensis*), ash (*Fraxinus* spp.), cucumber magnolia (*Magnolia acuminata*), and tulip poplar (*Liriodendron tulipifera*). Small forest openings also were present and contained fescue grass (*Schedonorus arundinaceus*) or agronomic crops planted to supplement native deer forage such as clover (*Trifolium* spp.), forage chicory (*Chicorium intybus*), and brassicas (*Brassica* spp.) but only encompassed approximately 1% of the study area. In addition, supplemental feeding of a processed ration or whole kernel corn occurred throughout the privately owned land during the winter months. Human disturbance on the area consisted of periodic road and food plot maintenance. Hunting pressure consisted of approximately five hunter-days/week during the 6 wk archery season and 18 hunter-days/week during the 2 wk firearms season.

Methods

Deer capture and handling

We captured deer from December 2011 to April 2012 using a combination of free darting, rocket nets, and clover traps. When free darting, we used 3 ml transmitter darts (Pneu-dart Inc., Williamsport, PA) to intramuscularly inject a Telazol® (Fort Dodge Animal Health, Fort Dodge, IA)/xylazine hydrochloride (Congaree Veterinary Pharmacy, Cayce, SC) (480mg/315mg) mixture to immobilize deer. We immobilized deer captured in rocket nets and clover traps with an intramuscular Telazol®/xylazine hydrochloride (240mg/180mg) injection. To reduce recovery time in cold temperatures (<-6 C) we changed immobilization for deer captured in rocket nets and clover traps to 2 ml xylazine hydrochloride (100 mg/ml; Lloyd Laboratories, Shenandoah, IA). During handling following immobilization, we monitored vital signs, treated any minor injuries, lubricated eyes, and blindfolded each deer.

While immobilized each deer was equipped with either a Lotek 3300L (Lotek Wireless Inc., Newmarket, Ontario, CA) or a Followit Tellus® 5H1D (Followit AB, Lindesberg, SE) global positioning system (GPS) collar, tightened within 8 cm (approximately 4 fingers width) of the deer's neck to allow for neck swelling associated with the breeding season. We estimated deer age using tooth replacement and wear characteristics (Severinghaus, 1949) and only collared males ≥2.5 y old at time of capture.

Following processing, the effects of the xylazine were reversed using 3 ml of the antagonist Tolazoline HCl (100 mg/ml; Lloyd Laboratories, Shenandoah, IA), administered half intramuscularly and half intravenously, 80 min after injection of the immobilizing agent. All deer were monitored until fully mobile. Animal handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (#A2011-08-025-Y1-A0). Deer capture activities were approved by the PA Game Commission and conducted under Special Use Permit No. 184-2011.

DATA COLLECTION AND MONITORING

All GPS collars were equipped with mortality sensors and programmed to record hourly fixes throughout deployment. We monitored each deer ≥1 time/w using very high frequency (VHF) telemetry equipment to ensure study animals were alive and collars were functioning properly. If a mortality or failure signal was detected, the collar was retrieved as soon as possible. At the end of the study, activation of a remote release mechanism or a timed release mechanism was used for retrieval of the collars from the field.

Upon collar recovery, we imported GPS fixes for each deer into ArcMap 10.0 (Environmental Systems Research Institute, Inc., Redlands, CA) for analysis. Mean telemetry error (18 m) was estimated using data collected following four mortality events. For each of the four collars, we obtained the average x and y values of 100 points collected after the mortality event, but prior to retrieval of the collar by researchers, and considered this as the true location. Mean error then was calculated based on the average distance of points from the collars' estimated true locations.

DATA ANALYSIS

We used a dynamic Brownian-bridge movement model (hereafter, DBBMM; Kranstauber *et al.*, 2012) to estimate utilization distributions (UD) and construct spring home ranges (95% UD isopleth). A UD is a spatial probability distribution that describes the probability of an animal occurring in a specific location during a given time period. Because Brownian-bridge based UD estimation is based on the movement trajectory and behavior of an individual, these methods perform well on high volume GPS datasets that often violate the independence assumptions underlying traditional UD estimation methods (e.g., kernel density method) which are based solely on the spatial pattern of relocations (Horne *et al.*, 2007).

Several parameters are needed to estimate a Brownian-bridge UD; a time-indexed series of animal locations, an estimate of mean telemetry error for each location, and an estimate of Brownian motion variance (σ^2_m), which is a measure of the irregularity of an animal's movement path between two locations and is a function of the animal's behavior. We defined telemetry error for each location as 18 m based on estimates described above. Animals are known to transition between behaviors (foraging, resting, migrating, etc.) over time, and the DBBMM accounts for this behavioral variability by estimating a unique σ^2_m value for each time step between GPS locations based on the behavioral state of the animal. This is accomplished by sweeping a moving window (a continuous portion of the movement path encompassing n number of sequential GPS locations) along the trajectory to statistically detect behavioral shifts using a variation of the behavioral change point analysis of Gurarie *et al.* (2009), and assigning σ^2_m values accordingly. The researcher is required to define the size of the moving window, which must encompass an odd number of GPS locations as σ^2_m is estimated via a ''leave-one-out'' method (Horne *et al.*, 2007), as well as a margin of ≥ 3 locations bounding each end of the window in which no behavioral changes can occur (Kranstauber *et al.*, 2012; Byrne *et al.*, 2014). We specified a window size of 21 steps and a margin size of 5 steps for all deer as visual inspection indicated these settings were consistently able to identify relevant changes in behavior. While a detailed description of this process is beyond the scope of this manuscript; we encourage readers to consult Kranstauber *et al.* (2012) for a thorough

TABLE 1.— Date, duration, direction, and distance of excursions made by mature (≥2.5 y old) male white-tailed deer (*Odocoileus virginianus)* during spring 2012 in north central Pennsylvania. Excursions were defined as travel ≥1.6 km outside of 95% home range boundaries for ≥12 h

Animal ID	Start date/time	End date/time	Total time (h)	Direction traveled (degrees)	Distance from 95% UD boundary (km)	Total path distance (km)
1	4/6 06:00	4/7 12:00	30	220	3.2	16.4
1	4/18 05:00	4/18 10:00	29	190	1.8	10.1
1	4/30 06:00	4/30 21:00	15	195	3.5	9.3
1	5/5 06:00	5/5 20:00	14	158	3.0	6.1
1	5/16 06:00	5/16 20:00	14	162	2.8	6.3
1	5/18 06:00	5/18 20:00	14	155	2.7	7.9
1	5/26 04:00	5/27 07:00	27	198	4.2	10.2
5	4/6 06:00	4/7 12:00	30	220	3.2	12.6
5	4/18 05:00	4/18 10:00	29	190	1.7	10.0
5	4/30 06:00	4/30 21:00	15	195	3.5	9.4
5	5/16 06:00	5/16 20:00	14	162	2.4	6.4
5	5/26 04:00	5/27 07:00	27	198	4.2	10.3
7	5/13 08:00	5/14 20:00	12	89	2.1	5.5
9	4/28 05:00	4/28 18:00	13	180	1.9	5.2
9	6/2 05:00	6/2 21:00	16	178	5.6	11.6
17	4/18 06:00	4/19 00:00	18	168	5.0	8.7
17	5/10 05:00	5/12 00:00	19	181	6.9	16.8
18	4/6 05:00	4/8 08:00	38	300	2.4	12.6
24	4/12 06:00	4/13 18:00	36	203	2.3	8.4
24	4/28 04:00	4/29 07:00	27	185	4.9	12.3
28	4/12 06:00	4/12 18:00	12	183	5.1	9.3
28	4/17 08:00	4/18 09:00	25	315	1.8	6.5
28	4/28 05:00	4/29 06:00	25	182	5.4	14.1
28	5/11 05:00	5/12 21:00	40	194	7.6	21.8
28	6/5 06:00	6/6 10:00	28	192	8.0	20.3
38	4/29 06:00	4/29 21:00	15	187	5.5	11.3
Mean	5/2 00:04	5/2 22:57	22	192	4.0	11.0

treatment. The model was implemented using the package move (Kranstauber and Smolla, 2014) in R version 3.0.0 (R Development Core Team 2013).

We defined the spring season based on the astronomical calendar (20 March – 20 June), which we considered biologically meaningful, as this period roughly coincided with snow melt and vegetative green up at the study site. We defined an excursion as any occasion where a male traveled ≥1.6 km outside of its home range boundaries for ≥12 h. We used Geospatial Modelling Environment version 0.7.2.0 (Beyer, 2012) to obtain metrics of distance and direction traveled during excursions. Because excursion paths were primarily linear, direction of travel was measured from the last point location occurring within the home range to the furthest point recorded during the excursion.

RESULTS

We equipped 13 mature (≥2.5 y old) male deer with GPS collars (three Lotek 3300L and 10 Followit Tellus® 5H1D) from 15 December 2011 to 1 April 2012. Nine of 13 (69.2%)

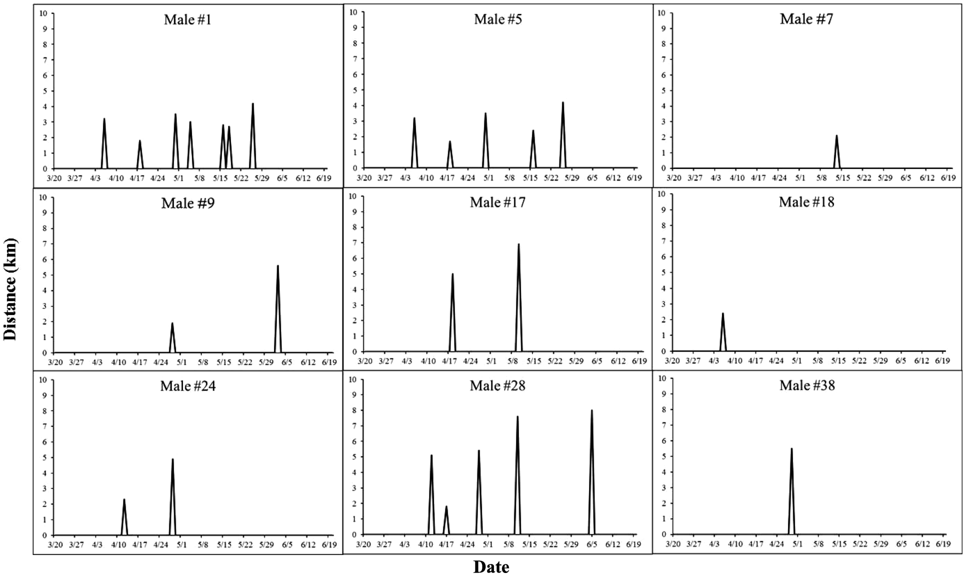

FIG. 1.—Spring excursions of mature (≥2.5 y old) male white-tailed deer deer (*Odocoilous virginanus)* in north central Pennsylvania during 2012. Distance was calculated by determining the distance of the farthest point of the excursion from the nearest boundary of each deer's 95% utilization distribution

males demonstrated excursions from 6 April through 6 June ($\bar{x}$ = 2 May), with six males making multiple excursions (Table 1, Fig. 1). Mean maximum distance from the home range boundary was 4.0 km (range = 1.7–8.0 km). Mean directional bearing of travel away from home range boundaries was 192° (Fig. 2). Mean duration of excursions was 22 h

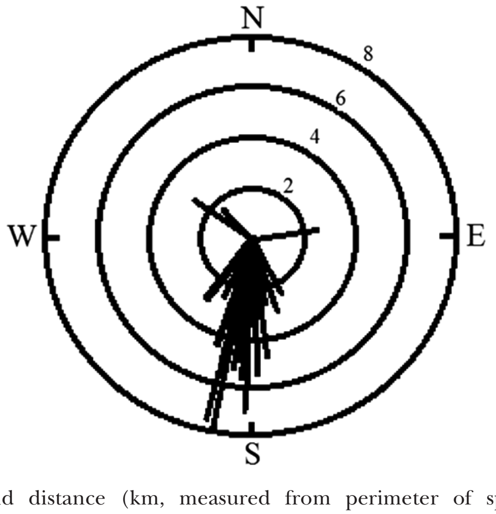

FIG. 2.—Direction and distance (km, measured from perimeter of spring home range) of 26 excursions made by 9 mature (≥2.5 y old) male white-tailed deer (*Odocoileus virginianus)* during spring in north central Pennsylvania. Mean direction was 192° (SE = 8.3°)

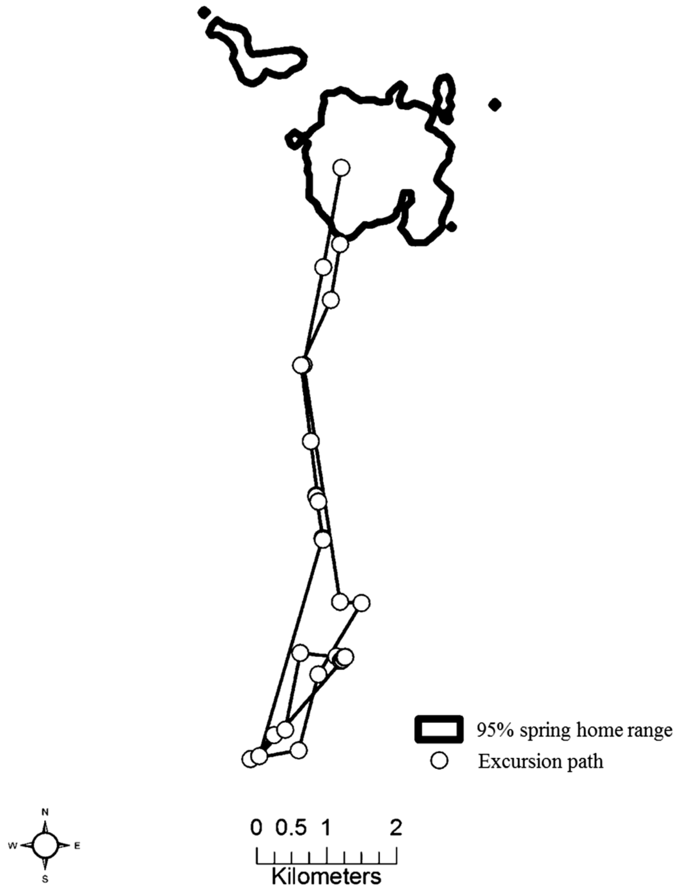

FIG. 3.—Example of a spring excursion by a 3-year old male white-tailed deer (#28; *Odocoileus virginianus*) in north central Pennsylvania. On 11 May 2012 this animal made an excursion outside of its 95% utilization distribution which lasted 40 h and covered a total path distance of 21.8 km

(range = 12–40 h), and total distance traveled averaged 11.0 km (range = 5.2–21.8 km). One male (#1) engaged in seven excursions, the longest of which had a total path distance of 16.4 km and lasted 30 h. This animal was accompanied by another male (#5) on five of these excursions, with the longest lasting 30 h and covering a total path distance of 12.6 km. As a result of the close association between animals #1 and #5, their spring home ranges were similar. Male #7 made one excursion lasting 12 h with a total path distance of 5.5 km, whereas Male #9 made two excursions with the longest covering 11.6 km in 16 h. Male #17 made two excursions, with the longest covering 16.8 km in 19 h. Male #18 made one excursion lasting 38 h and covering a total path distance of 12.6 km. Male #24 made two excursions with the longest lasting 36 h, and the greatest distance traveled 12.3 km. Male #28 made five excursions, with the longest covering 21.8 km in 40 h (Fig. 3). This animal accompanied Male #24 on both of its excursions, and both males had similar spring home ranges. Male #38 made one excursion lasting 15 h and covering 11.3 km. Four males made no excursive movements during spring. However, for bucks that made excursions, the duration, distance, and direction of travel was similar.

Discussion

Although Kilgo *et al.* (1996) provided evidence of springtime excursions by white-tailed deer in Florida, the frequency of spring excursions and the age and sex characteristics of deer engaging in these excursions was not reported. To our knowledge, we are the first to identify and describe the occurrence, timing, and directionality of spring excursions of mature male white-tailed deer. We observed no temporal patterns of excursions among individuals that would suggest a seasonal or climatic cue (Fig. 1). Of the 26 excursions, more than 50% were made within a 1 mo period before parturition ($\bar{x}$ = 6 June, range = 26 April-5 September; PA Game Commission, 2011).

Female aggression associated with preparturition and neonatal territoriality might lead bucks to temporarily leave an area (Hirth, 1977; Ozoga *et al.*, 1982; Schwede *et al.*, 1993; Bertrand *et al.*, 1996; D'Angelo *et al.*, 2004). However, all males invariably returned to their typical range within a short time period ($<$40 h). In addition many excursions occurred months before parturition, suggesting a maternal aggression cue is unlikely. Further, no excursions were observed after 5 June, and if maternal aggression was a causative factor, one would expect excursions to last throughout the fawn rearing season.

Kilgo *et al.* (1996) hypothesized spring and autumn excursions by adult deer may represent return trips to natal ranges. However, in the Allegheny Plateau of Pennsylvania, average dispersal distance was 8.0 +/- 0.61 km with a maximum dispersal distance of 40.6 km (Long *et al.*, 2008). In contrast, the excursions by mature males we observed averaged 4.0 km (SE = 0.36 km; range = 1.7-8.0 km) much shorter than reported dispersal distances. Furthermore, 23 of 26 excursions (88.5%) were towards the south or southwest, whereas only two were towards the northwest and one was towards the east. In Pennsylvania and Florida, dispersal movements from natal ranges tended to follow an east or east-west axis (Kilgo *et al.*, 1996; Newberry *et al.*, 2004). Therefore, with the comparatively short distances and southerly orientation of most spring excursions, it appears unlikely that a return to natal range is a proximate factor.

A final hypothesis for the spring excursions we observed is males were visiting mineral sites. To the south of the property is a paved township road where antiskid containing salt is used during the winter months. Salt deposits would be present alongside the road during the spring after snow melt. In West Virgina, Campbell *et al.* (2004) reported 30 of 121 (25%) radiocollared deer traveled a mean distance of 3.0 km (range = 0.9-5.5 km) to a gas-well site to consume water from a ground seep containing a high concentration of sodium. Sodium deficiencies during the spring and summer months often cause deer to seek sodium sources (Weeks and Kirkpatrick, 1976), which may occur outside their home range (Wiles and Weeks, 1986). However, analysis of excursion destinations, where males spent several hours, did not show any mineral attractant. Furthermore, manmade mineral sites are abundant throughout the study site and at least one mineral site was present within the spring home ranges of all males. Thus, it is unlikely mineral lick visitation was a factor influencing the occurrence of excursions.

Similar to dispersal movements, spring and autumn excursions in Florida were highly directional, with most excursions occurring along an east-west axis (Kilgo *et al.*, 1996). In Florida, no landscape features were apparent that had the potential to influence directionality of movements. Similarly, our observations of excursions in this study suggested movements were highly linear and independent of topographic features.

Although spring excursions may be a common occurrence in white-tailed deer populations, they commonly have not been reported in previous studies, perhaps due to the dearth of studies employing GPS technology during this time of year. Alternatively, in the highly fragmented habitats typical of the whitetail's range, excursive behaviors would be risky as deer are exposed to unfamiliar open areas and highways. Future investigations should seek to examine if these excursions occur across white-tailed deer populations and the spatial associations these males make with the landscape as they traverse unfamiliar territories.

Acknowledgments.—We thank Kip J. Fulks for funding this project and for the use of equipment and property. We also thank Dr. Jacob R. Werner, Attending Veterinarian and Senior Research Associate at Penn State University, for his wildlife veterinary support throughout the project. We gratefully acknowledge E. Belser, E. Miller, C. Farrell, C. Evans, E. Cooney, B. Olson, R. Miller, M. Schneider, J. Rupprecht, S. Ruprecht, M. Rupprecht, R. Levinski, A. Straub, and G. Eckert for field assistance in extreme conditions, and T. Goetz for data collection and management.

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SUBMITTED 8 JULY 2014 ACCEPTED 17 MARCH 2015