Impact of Supplemental Feeding for Northern Bobwhite on Movement Ecology of Eastern Wild Turkeys in South Carolina

Patrick H. Wightman, *School of Renewable Natural Resources, Louisiana State University, Baton Rouge LA 70803*

Jay R. Cantrell, *South Carolina Department of Natural Resources, Columbia, SC 29202*

Charles R. Ruth, *South Carolina Department of Natural Resources, Columbia, SC 29202*

Michael E. Byrne, *School of Natural Resources, University of Missouri, Columbia, MO 65201*

Michael J. Chamberlain, *Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602*

Bret A. Collier, *School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge LA 70803*

Abstract: Management techniques to improve wildlife populations often can affect non-target species indirectly. Supplemental feeding for northern bobwhite (*Colinus virginianus*) has become a popular management technique to improve bobwhite recruitment and survival, but potential impacts on non-target species such as eastern wild turkey (*Meleagris gallopavo silvestris*) are unknown. We deployed 111 global positioning systems on wild turkeys on the South Carolina Department of Natural Resources Webb Wildlife Management Area Complex during 2014–2016 to evaluate if supplemental feeding for quail impacted wild turkey movement ecology. Turkeys which used areas where supplemental feeding had occurred maintained larger ranges before, during, and after hunting season. Ranges of individuals that used the treatment area in 2014 before feeding occurred were larger than individuals' ranges that overlapped the treatment area after feeding began, but differences were minimal (<16 ha). Eighteen individuals maintained ranges that encompassed both treated and non-treated areas. The greatest average percentage of range overlap in the treatment area for any period was 14%. Using logistic regression, we estimated that the probability of turkeys using areas where supplemental feeding occurred was 0.032 for all individuals and 0.116 for individuals whose range included the treatment area. Using first passage time (FPT) analysis, area restricted searching (ARS) occurred at points close to supplemental feed, but we found no influence of distance to supplemental feeding area on ARS as ARS occurred throughout areas of individual turkey ranges. Wild turkeys are generalists that show considerable individualism in behavioral choices, thus we assume that supplemental feeding may affect individuals differently across the landscape.

Key words: Eastern wild turkey, movement ecology, resource selection, northern bobwhite, supplemental feed

Journal of the Southeastern Association of Fish and Wildlife Agencies 5:114–124

Wild turkey (*Meleagris gallopavo*) habitat selection and use have received significant attention in the literature particularly in the southeastern United States. In addition to documenting selection at both the local and landscape scale, research has examined how turkeys distribute themselves temporally in relation to a suite of predictor variables such as vegetative communities (Chamberlain and Leopold 2000, Conley et al. 2015), roost locations (Byrne et al. 2015, Gross et al. 2015), water (Byrne et al. 2014), anthropogenic factors (Miller and Conner 2007, Collier et al. 2017), other birds on the landscape (Holbrook et al. 1987, Hurst et al. 1991), and food availability (Kurzejeski and Lewis 1990, Byrne et al. 2014). Turkeys make numerous temporally-specific behavioral decisions, and the combined behaviors of individuals likely give rise to larger demographic patterns (Badyaev et al. 1996, Chamberlain and Leopold 2000, Thogmartin et al. 2001, Holdstock et al. 2006, Miller and Connor 2007). Therefore, studying habitat selection and movement behavior at the individual level can help managers better understand turkey populations to help inform management decisions (Collier and Chamberlain 2010).

There are a wide variety of stimuli that can impact movement ecology of wildlife species (Nathan et al. 2008, Jacoby et al. 2012) with either positive (Sisson et al. 2000, Buckley et al. 2015) or negative (Cooper and Ginnett 2000, Fahrig 2007) demographic impacts. One of the most widespread anthropogenic stimuli on the landscape in the United States is supplemental feeding of wildlife (Robb et al. 2008, Weidman and Litvaitis 2011, Sorensen et al. 2014). Evaluating the impact of artificial feeding on wildlife has evolved into a complex and controversial area of study (Dunkley and Cattet 2003, The Wildlife Society 2006). In the southeastern United States, supplemental feeding on private lands for northern bobwhite (*Colinus virginianus*, hereafter quail) is common (Townsend et al. 1999, Sisson et al. 2000, Thackston and Whitney 2001, Godbois et al. 2004, Miller 2011). Supplemental feeding has been shown to benefit quail by providing readily available food which improves body condition and, when combined with predator management, can increase reproductive success (Burger et al. 1998, Townsend et al. 1999, Sisson et al. 2000, Miller 2011). Additionally, Buckley et al. (2015) found that range sizes of quail did not decrease in response to supplemental feeding, indicating use, but not focused selection on supplemental feed sites. Although considerable research has investigated response of quail to supplemental feeding, there has been limited evaluation of impacts on non-target species (Sisson et al. 2000, Dewey and Kennedy 2001, Godbois et al. 2004, Turner et al. 2008, Miller 2011).

Most supplemental feeding activities are focused on congregating wildlife for harvest (Geisser and Reyer 2004, Deelen et al. 2006) rather than on increasing or supporting species' health *per se*. Therefore, if wild turkeys were to respond to supplemental feeding for quail, they may congregate at feeding sites during hunting seasons, which conceivably could impact harvest rates. Moreover, as baiting is typically illegal for wild turkey hunting in most states, turkey hunters could be found in violation of regulations when hunting in areas where supplemental feeding occurs. Our research objective was to evaluate if supplemental feeding for quail influences habitat use and movement ecology of wild turkeys in South Carolina before, during, and after the turkey hunting season.

Study Area

We conducted our research on three contiguous Wildlife Management Areas (WMAs) managed by the South Carolina Department of Natural Resources (SCDNR). Webb, Palachacola, and Hamilton Ridge WMAs (hereafter Webb WMA Complex) were located in the Atlantic Coastal Plain of Hampton and Jasper counties which included 10,438 ha and 22 km of frontage along the Savannah River (Figure 1). Webb WMA is 2,373 ha, and approximately 917 ha was dominated by bottomland hardwoods typical of the Southeastern river floodplains. The remaining 1,458 ha was upland habitat typical of the Atlantic Coastal flatwoods, consisting of longleaf (*Pinus palustris*), loblolly (*P. taeda*), and slash pine (*P. elliottii*) with interspersed hardwood stands along riparian drainages. Hamilton Ridge WMA is 5,374 ha and contained 2,664 ha which was mainly bottomland hardwoods with some palustrine, lacustrine, and riverine wetlands. The remaining 2,710 ha of upland habitat was primarily managed pine plantations of various age classes with the predominant species being loblolly, with some slash and longleaf pine present. Palachucola WMA consisted of 2,734 ha and was dominated by 1,618 ha of planted loblolly pine being converted to longleaf pine. The remaining 1,092 ha were bottomland hardwoods with some upland hardwoods found on slopes along riparian corridors. Primary management activities on the Webb WMA Complex included both dormant and growing season prescribed fire, an active timber management program, fallow field management, and maintenance of agricultural food plots. These management techniques were tailored to enhance habitat with an emphasis mainly on white-tailed deer (*Odocoileus virginianus*), eastern wild turkey, and quail.

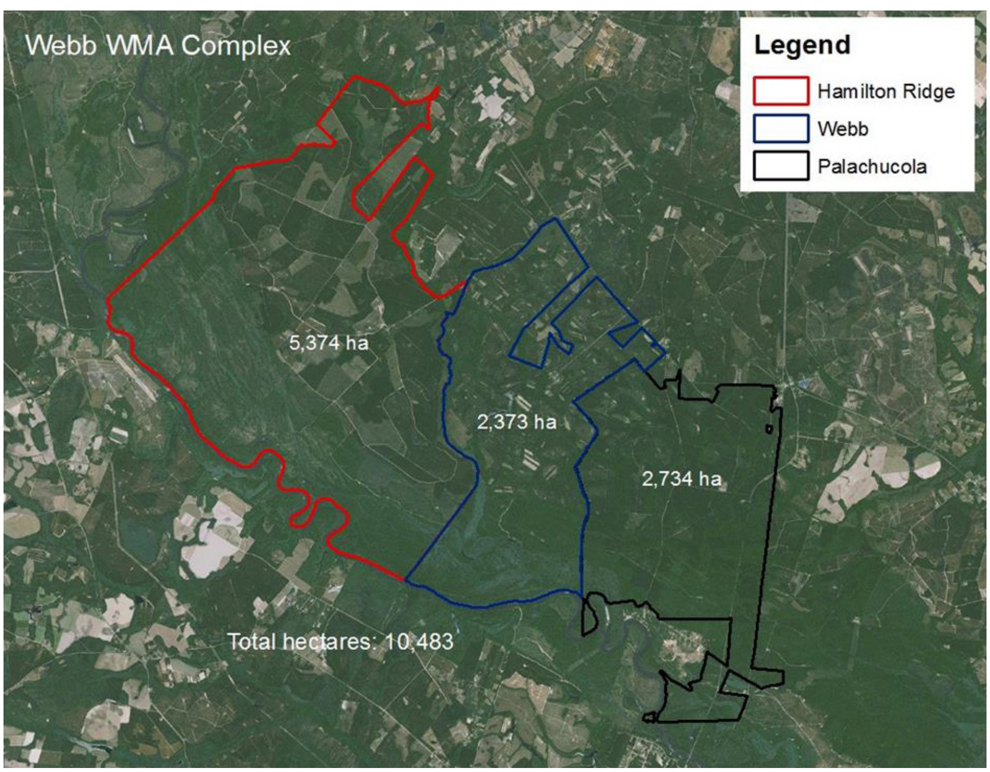

Figure 1. Map of the three contiguous South Carolina Department of Natural Resources Wildlife Management Areas (WMA) known as the Webb WMA Complex, South Carolina. Red border represents Hamilton Ridge WMA, blue border represents Webb WMA, and the black border represents Palachacola WMA between 2014 and 2017.

Methods

We captured turkeys with rocket nets (Bailey et al. 1980) baited with cracked corn during winter (December–February) 2014–2016. Captured individuals were sexed and aged based on presence of barring on the ninth and tenth primary feathers (Pelham and Dickson 1992). We banded each bird with an aluminum rivet leg band (National Band and Tag Company, Newport, Kentucky) and then radio-tagged each individual with a backpack-style GPS-VHF transmitter (Guthrie et al. 2010) produced by Biotrack Ltd. (Wareham, Dorset, UK). We programmed transmitters for males to take one location nightly (23:58:58) with daylight (0500-2000) locations collected hourly from 15 February–14 March, every 30 minutes from 15 March–15 May, and hourly again beginning 16 May until the battery died or the unit was recovered. Transmitters we placed on females were programmed to take one location nightly (23:58:58) and hourly locations between 0500 and 2000 from 15 February until the battery died or the unit was recovered. We collected female locations once hourly in support of additional ongoing research objectives. We immediately released turkeys at the capture location following processing. Our capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permits A2014-013 and A2015-07). Additionally, to monitor general location and survivorship, we located all individuals >4 times weekly using 3-element and 5- element handheld Yagi antennas and R2000 receivers (Advanced Telemetry Systems, Inc., Isanti, Minnesota). We downloaded GPS information weekly from units via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK), to ensure optimal data collection and to minimize data loss.

We treated 364 ha of upland pine located in the northern portion of the Webb WMA Complex with 21 km of feed trails (Figure 2). We

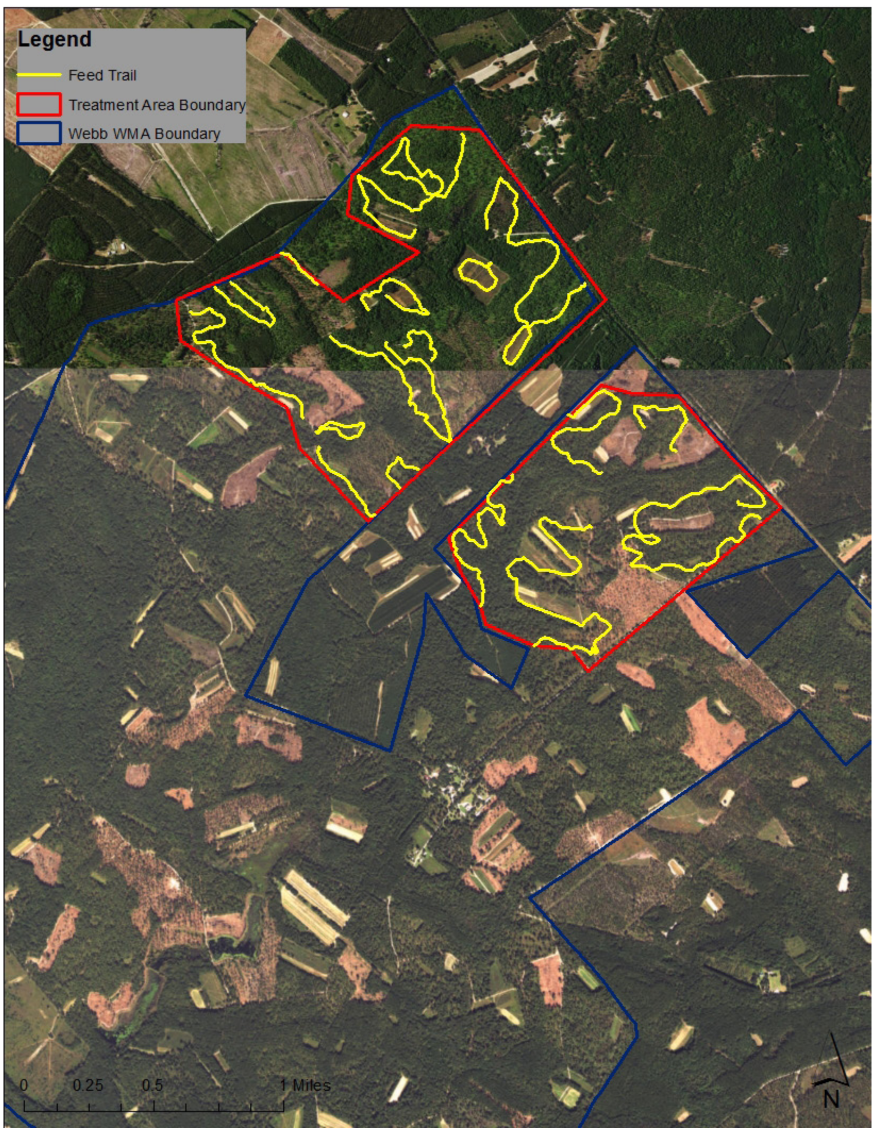

Figure 2. Map of feed trail (21 km; red line) located within 364-ha treatment area (yellow border) of the upland pine woods on the northern portion of Webb WMA (blue border), South Carolina, between 2014 and 2017.

selected this region as our treatment area, as quail management activities are focused within this portion of the Webb WMA Complex. During 2014 we did not treat the area, but beginning 1 February 2015 following protocols outlined by Miller (2011), we distributed milo (*Sorghum bicolor)* uniformly on a biweekly schedule along feed trails using a tractor and a pull behind spreader calibrated at approximately 69.1 kg/km, a rate that would provide roughly 2 bushels of milo per 0.4 ha per year (Robel and Arruda 1986, Whitelaw et al. 2006, Miller 2011, Larson et al. 2012).

To evaluate if supplemental feeding influenced space use of turkeys, we used the period 25 February–6 June as it included the 35 days before, during, and after (hereafter referred to as periods) the turkey hunting season (1 April–May 5) on the Webb WMA Complex. We used a dynamic Brownian bridge movement model (dBBMM; Kranstauber et al. 2012) to calculate ranges for individuals during each period. We used R (Version 1.0.136, R Development Core Team 2016) and the R package "move" (Kranstauber and Smolla 2016) with a margin size of 5, a window size of 21, and a location error of 15 (Guthrie et al. 2010, Collier et al. 2017). For each period, we derived 50% and 99% utilization distributions that represented core areas and the overall range of each individual (Collier et al. 2017). For those individuals whose range encompassed both treated and non-treated areas, we estimated the percentage of the 99% range that overlapped the treatment area. Furthermore, for birds that were captured in 2014 and then recaptured in any of the following years after supplemental feeding began, we compared ranges in 2014 (control) to 2015–2016 (treatment).

We used logistic regression to estimate the probability of use of the treatment area for all male and female turkeys in our study (Apps et al. 2004). We pooled all GPS locations and classified them as within (use = 1) or outside (non-use = 0) the treatment area. We evaluated use/non-use by year to evaluate if differences occurred between non-treatment (2014) and treatment (2015–2016) years, and we additionally evaluated whether there was evidence of a sex-specific response in use/non-use. We then created a subset of our data that included only those birds whose ranges included the treatment area and used logistic regression to calculate the probability of use/non-use for those individuals which were known to have used the treatment area.

Next, we conducted first passage time (FPT) analysis using daily movement tracks for individuals whose range overlapped the treatment areas during 2015 and 2016 (Fauchald and Tveraa 2003). First passage time is defined as the time required for an animal to cross a circle of a given radius (Johnson et al. 1992). Inferences on movement behavior can be drawn from FPT values calculated at evenly spaced points along a movement trajectory. Higher FPT values indicate slower, more sinuous movements associated with area-restricted searching (ARS) behavior, whereas lower values are associated with faster and more linear movements. We analyzed movement paths only of males from 15 February–15 May, as points collected every 30 minutes allowed for a more accurate assessment of passage time relative to female locations recorded hourly. We interpolated male locations every 10 m along movement paths and calculated FPT values at these locations for circles with radii ranging 10–400 m in 10-m increments (Byrne et al. 2014). The variance of log-transformed first-passage time values for each trajectory and circle radius was calculated to determine at which radius variance peaked, which, in turn, indicated the scale at which individuals concentrated their activities (Fauchald and Tveraa 2003). This scale varied across individual movement trajectories, so we calculated an average scale across all trajectories for comparisons (Frietas et al. 2008, Byrne et al. 2014). We calculated the distance from every interpolated point to the nearest section of feed trail in the treatment area using the near analyst tool in ArcMap 10.2 (ESRI, Redlands, California). Once a mean scale of activity was determined ($r = 80$; see results), we used a Cox proportional hazards model (CPH; Bastille-Rousseau et al. 2010) to assess the relationship between FPT and distance to feed trail for each location along movement paths (Freitas et al. 2008, Byrne et al. 2014). The CPH model estimates the probability (hazard function/risk) of the turkey leaving the area around a point or staying based on the distance of the point to supplemental feed. If turkeys were concentrating movements near supplemental feed, then we would expect a negative relationship between FPT and distance to feed. To further refine our analysis, we also ran a CPH on a subset of the data including only points within 1000 m of the feed. We performed the refined analysis because when qualitatively reviewing results, it became apparent with points ranging from 1 to 5000 m from supplemental feed that the relationship between distance to feed and FPT values may vary depending on scale of analysis used.

Results

We captured and tagged 111 wild turkeys (41 males, 70 females) on the Webb Center Complex during 2014–2016. We obtained 272,706 GPS locations, 9,182 of which were inside the treatment area (Table 1). Of the 111 turkeys captured 18 had ranges that overlapped the treatment area (Table 2.) We excluded 31 (28%) turkeys from estimates of range because full data sets were compromised due to natural mortality, harvest, or tag loss.

Aggregated across 2014–2016, the average range [ha; (SD)] of males whose range did not overlap the treatment area was 520.7 (320.7), 470.2 (281.0), and 472.9 (306.3) for the periods before, during, and after the hunting season. The average range for males whose ranges did overlap the treatment area was 598.7 (364.9), 488.0 (315.2), and 399.2 (382.5) before, during, and after the hunting season. For females with no overlap of the treatment area, average ranges were 384.9 (160.0), 385.4 (242.3), and 314.0 (301.0) during periods before, during, and after the hunting season. Female ranges which overlapped were 794 (195.5), 223.9 (99.4), and 348.5 (183.5) before, during, and after the hunting season (Table 3). Generally, range size varied little across time periods, with the exception of females whose range overlapped the treatment area. However, the large decrease in average female range size (799 to 233) is due to two females that had ranges that overlapped the treatment area, one of which nested within the treatment area resulting in a reduced range size. However, we did not exclude the nesting female, as reductions in range sizes also were occurring for females distributed outside the treatment area as well. Generally, male ranges that overlapped the treatment area were larger, but we found considerable individual variability annually and within periods (Table 3).

During 2014, ranges of 6 males overlapped the treatment area with average range sizes of 601.8 (321.5), 497.4 (145.2), and 406.1 (276.6) during the three periods. After treatment was initiated (2015 and 2016), ranges of 10 males overlapped the treatment area. Average percentages of ranges that overlapped the treatment area for individuals in 2014 that used treatment area were 0.082, 0.127, and 0.142 during the three respective periods. After treatment (feeding) began, average percent range overlaps were 0.110, 0.095, and 0.035 during these same respective periods (Table 2, Figure 3).

One male was followed for the three years of our study. In 2014 before treatment occurred, his range size for the periods before, during, and after hunting season was 561.1, 453.2, and 401.6 ha, with overlap in the treatment area of 81.8, 56.6, and 55.4 ha, respectively. After treatment occurred, in 2015, we saw a slight decrease in his range size but an increase in the amount of range overlapping the treatment area; whereas in 2016 his range decreased with a concomitant decrease in the range overlap of the treatment area (Table 2).

Table 1. Summary of GPS points collected on 111 eastern wild turkeys (*Meleagris gallopavo silvestris*) in areas where supplemental feeding did and did not occur on the Webb WMA Complex, South Carolina, 2014–2016.

	2014	2015	2016
Number of points	51,070	98,728	122,908
Points in treatment area	5,107	2,313	1,762
Birds whose range overlapped treatment	6	8	8
Number of females captured	6	24	40
Number of females whose range overlapped treatment	0	1	1
Number of males captured	14	16	11
Number of males whose range overlapped treatment	6	4	6

Table 2. Utilization distribution (50% and 99%) ranges (ha) calculated by year, period, and sex, as well as estimated area of range overlapping the treatment area for 18 eastern wild turkeys (*Meleagris gallopavo*) whose range included the treatment area on the Webb WMA Complex, South Carolina, 2014–2016.

		Period									
		25 Feb–31 Mar		1 Apr–5 May		6 May–9 Jun			Overlap area		
Year	ID	50%	99%	50%	99%	50%	99%	Sex	25 Feb–31 Mar	1 Apr–5 May	6 May–9 Jun
2014	113	58.7	1266.0	37.0	801.8	16.1	197.7	M	0.0	26.1	0.0
	129	20.5	370.4	39.9	525.7	38.1	363.9	M	66.3	112.1	56.2
	145	42.6	561.1	31.4	453.2	58.4	401.6	M	81.8	56.6	55.4
	147	46.8	573.1	24.9	386.2	2.0	27.0	M	74.2	75.9	0.0
	149	46.7	589.1	39.3	369.5	–	–	M	74.8	105.3	–
	150	24.4	251.2	45.1	448.2	45.3	538.0	M	0.0	1.8	105.4
2015	223	19.5	598.5	46.0	323.4	36.7	531.9	F	15.6	27.35	0.0
	117	18.9	660.8	23.7	313.2	–	–	M	102.3	0.0	–
	121	23.6	481.2	–	–	–	–	M	88.8	–	–
	105	16.2	444.5	66.6	1165.9	53.9	908.8	M	106.9	185.3	114.4
	145	28.7	457.4	23.8	329.8	–	–	M	158.7	73.22	–
2016	651	50.8	989.5	0.4	124.5	6.1	165.0	F	115.7	15.37	0.0
	773	3.3	407.7	11.3	425.2	17.0	153.7	M	0	52.58	0.0
	916	14.5	330.7	12.8	313.7	1.5	19.6	M	66.5	97.81	9.43
	744	25.4	530.1	5.0	198.3	–	–	M	23.8	0.0	–
	145	14.0	324.6	7.3	158.2	10.2	136.1	M	23.4	2.1	0.0
	761	20.9	610.4	24.4	206.9	24.1	313.2	M	8.41	0.0	0.0
	751	38.8	1721.6	32.0	1224.0	38.3	1331.3	M	122.7	0.0	0.0

Table 3. Minimum (Min), mean, standard deviation (SD), and maximum (Max) values of 50% and 99% utilization distribution ranges for male and female eastern wild turkeys (*Meleagris gallopavo silvestris*) who maintained ranges where supplemental feeding for quail occurred (In) and for birds whose ranges did not occur where supplemental feeding for quail was present (Out) on the Webb WMA Complex, South Carolina, 2014–2016.

			25 Feb–31 Mar		1 Apr–5 May		6 May–9 Jun	
Year			**50%**	**99%**	**50%**	**99%**	**50%**	**99%**
2014	Female/In	–	–	–	–	–	–	–
	Female/Out	Min	6.4	130.7	1.7	120.7	0.3	33.6
		Mean	17.5	260.5	29.0	413.0	6.0	148.9
		SD	10.9	115.9	16.6	210.8	8.7	131.0
		Max	40.3	514.3	46.7	748.2	24.4	427.3
	Male/In	Min	20.5	251.2	24.9	369.5	2.0	27.0
		Mean	39.9	601.8	36.2	497.4	32.0	305.6
		SD	13.4	321.5	6.5	145.2	20.3	176.6
		Max	58.7	1266.0	45.1	801.8	58.4	538.0
	Male/Out	Min	6.9	241.5	9.0	102.7	35.9	415.6
		Mean	32.5	549.2	30.5	350.4	50.7	615.2
		SD	16.5	232.9	17.2	152.9	12.9	172.2
		Max	65.5	950.0	49.7	585.5	67.2	835.9
2015	Female/In		19.5	598.5	46.0	323.4	36.7	531.9
	Female/Out	Min	5.7	103.2	0.4	117.6	0.5	85.2
		Mean	21.4	329.6	21.7	316.3	20.3	298.6
		SD	8.7	147.9	13.5	117.4	14.8	173.4
		Max	39.6	599.9	50.8	521.7	49.0	650.1
	Male/In	Min	16.2	444.5	23.7	313.2	53.9	908.8
		Mean	21.8	511.0	38.0	603.0	53.9	908.8
		SD	4.7	87.5	20.2	398.1	0.0	0.0
		Max	28.7	660.8	66.6	1165.9	53.9	908.8
	Male/Out	Min	6.3	193.4	1.5	191.1	18.6	194.1
		Mean	24.1	522.5	39.0	592.2	38.8	510.7
		SD	11.7	402.9	29.9	324.9	16.8	354.8
		Max	40.6	1730.2	105.1	1399.3	69.2	1334.1
2016	Female/In		50.8	989.5	0.4	124.5	6.1	165.0
	Female/Out	Min	8.6	161.4	0.4	93.6	0.3	53.0
		Mean	34.3	448.2	20.8	423.9	17.4	371.4
		SD	15.9	148.1	20.1	289.2	17.6	380.9
		Max	67.1	823.0	84.9	1377.0	63.8	2127.1
	Male/In	Min	3.3	324.6	5.0	158.2	1.5	19.6
		Mean	19.5	654.2	15.5	421.1	18.2	390.8
		SD	11.0	488.3	9.6	369.9	12.5	479.5
		Max	38.8	1721.6	32.0	1224.0	38.3	1331.3
	Male/Out	Min	7.9	208.3	2.5	273.8	10.1	127.1
		Mean	33.7	471.0	18.8	314.2	20.2	242.6
		SD	23.6	185.0	9.6	50.6	7.2	81.6
		Max	67.8	680.4	27.7	399.2	26.0	300.8

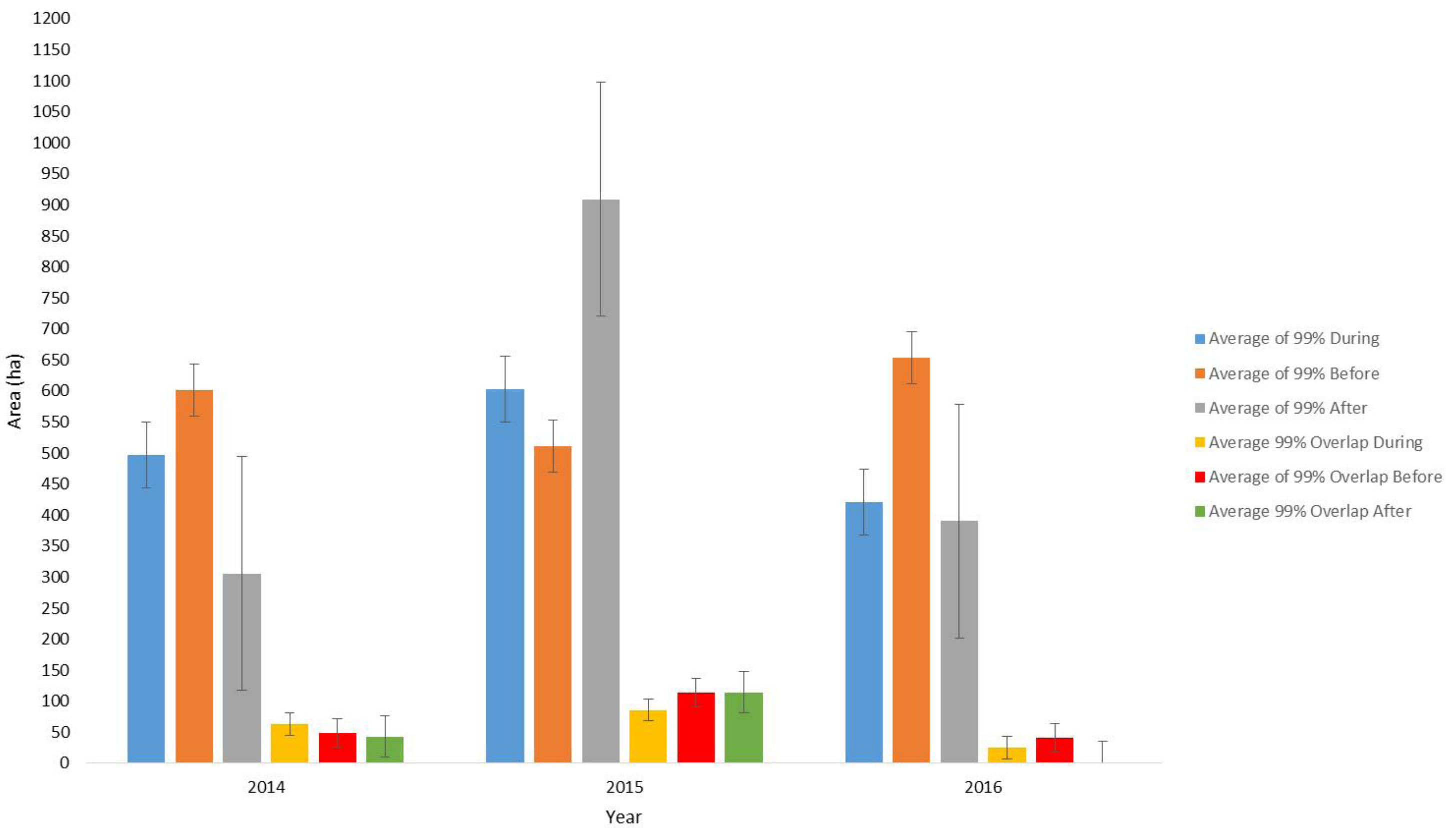

Figure 3. Average area (ha) and standard error of 99% range calculations before (blue), during (orange), and after (gray) hunting season and associated area (ha) of range overlapping the treatment area before (yellow), during (red), and after (green) the hunting season on the Webb WMA Complex, South Carolina, between 2014 and 2016.

Table 4. Logistic regression parameter estimates (β), 95% confidence intervals (CI), standard errors (SE), predicted probability (*P*) of treatment area use for all eastern wild turkeys (*Meleagris gallopavo*) captured 2014– 2016 on the Webb WMA Complex, South Carolina, and 95% confidence intervals (CI) for predicted probability. Each estimate was rounded to the appropriate significant digits.

Model	β	CI(β)	SE	*P*	CI
All birds	−3.42	−3.44 – −3.40	0.01	0.03	0.031 – 0.033
Sex					
Female	4.93	4.72 – 5.15	0.11	0.0005	0.0004 – 0.0006
Male	−7.50	−7.72 – −7.29	0.11	0.07	0.070 – 0.073
Year					
2014	−2.31	−2.34 – −2.28	0.02	0.09	0.088 – 0.093
2015	−1.42	−1.47 – −1.37	0.03	0.02	0.023 – 0.024
2016	−1.92	−1.98 – −1.86	0.03	0.02	0.014 – 0.015
Year*Sex					
Male					
2014	−2.15	−2.18 – −2.12	0.02	0.10	0.102 – 0.108
2015	−0.73	−0.784 – −0.68	0.03	0.05	0.051 – 0.055
2016	−0.77	−0.83 – −0.71	0.03	0.05	0.049 – 0.053
Female					
2014	–	–	–	–	–
2015	−7.57	−7.95 – −7.22	0.19	0.0005	0.0003 – 0.0007
2016	0.17	−0.28 – 0.63	0.23	0.0006	0.0004 – 0.0008

With results from the logistic regression analysis, we noted that the aggregate probability that a turkey (male or female) would use the treatment area was 0.032 (95% CI = 0.031–0.033) and the probability that males or females would use the treatment area was 0.071 (95% CI = 0.070–0.072) and 0.0005 (95% CI = 0.0004–0.0006), respectively (Table 4). For individuals whose range overlapped the treatment area, we estimated the probability of use of the treatment area to be 0.116 (95% CI = 0.114–0.116; Table 5). We estimated males having a higher probability of use [0.15 (95% CI = 0.149–0.155)] compared to females [0.005 (95% CI = 0.004–0.006)]. Probability of use of the treatment area for all birds and birds whose ranges overlapped the treatment area was higher in 2014 (not treated) versus 2015 and 2016 (treated; Tables 4 and 5).

We evaluated 806 daily movement paths from eight adult males who maintained ranges that overlapped the treatment area during 2015–16 when feeding occurred. Based on the variance of log-transformed FPT values, we found that a circle radius of r = 80 m represented the average scale at which individuals were concentrating their movement activities (Figure 4). Mean distance from locations to the nearest portion of the feed trail was 1566 m, and

Table 5. Logistic regression parameter estimates (β), 95% confidence intervals (CI), standard errors (SE), predicted probability (*P*) of treatment area use by eastern wild turkeys (*Meleagris gallopavo*) whose range overlapped treatment area 2014–2016 on the Webb WMA Complex, South Carolina, and 95% confidence intervals (CI) for predicted probability. Each estimate was rounded to the appropriate significant digits

Model	(β)	CI(β)	SE	*P*	CI
All birds	−2.026	−2.049 – −2.004	0.012	0.116	0.114 – 0.119
Sex					
Male	3.630	3.422 – 3.854	0.110	0.152	0.149 – 0.155
Female	−5.348	−5.570 – −5.141	0.109	0.005	0.004 – 0.006
Year					
2014	−1.564	−1.597 – −1.532	0.016	0.173	0.169 – 0.178
2015	−0.607	−0.659 – −0.552	0.027	0.102	0.097 – 0.107
2016	−1.013	−1.071 – −0.955	0.030	0.071	0.067 – 0.074
Year*Sex					
Male					
2014	−1.564	−1.596 – −1.532	0.016	0.173	0.169 – 0.178
2015	0.339	0.282 – 0.395	0.029	0.227	0.219 – 0.234
2016	−0.793	−0.853 – −0.734	0.030	0.087	0.083 – 0.091
Female					
2014	–	–	–	–	–
2015	−6.066	−6.453 – −5.722	0.186	0.002	0.001 – 0.003
2016	1.523	1.081 – 1.986	0.230	0.011	0.008 – 0.014

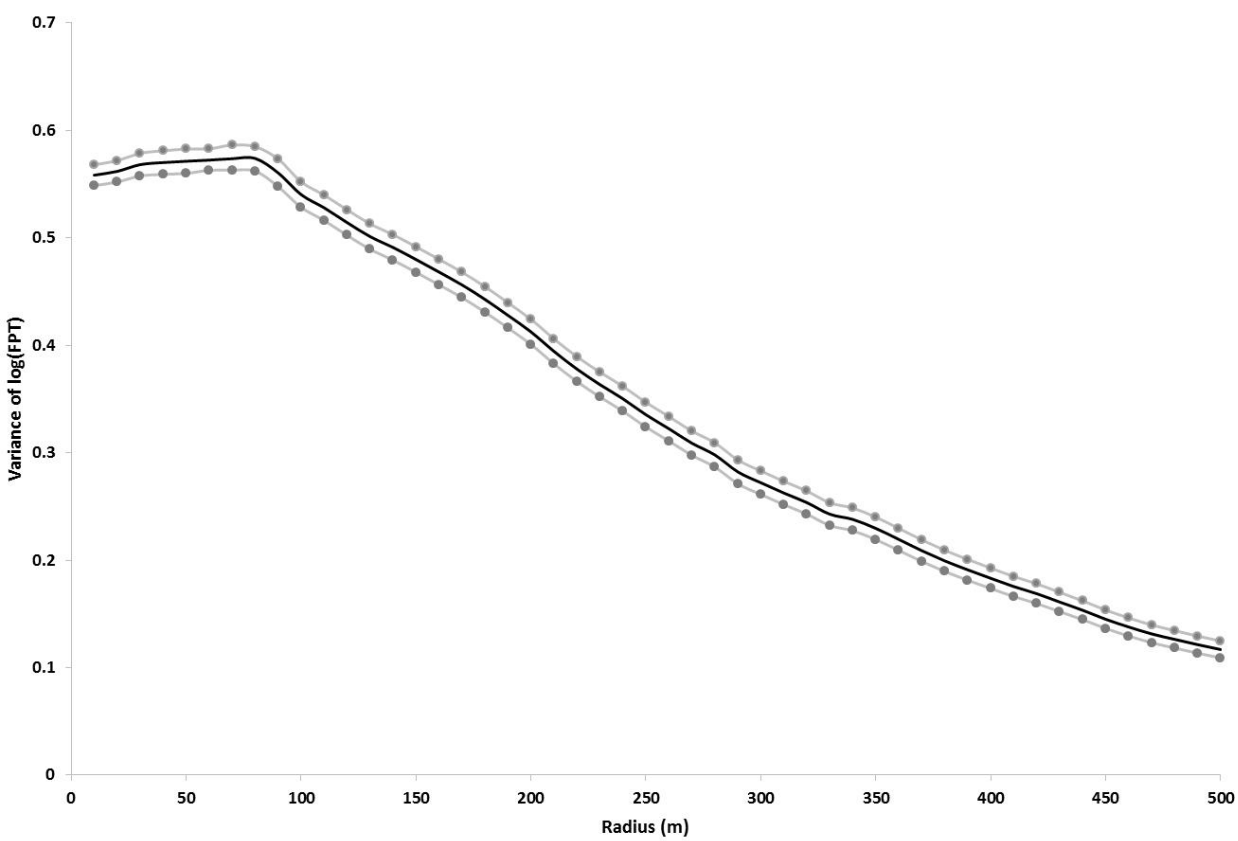

Figure 4. Mean variance (±SE) of log-transformed first-passage time values for 806 daily movement paths as a function of circle (m) for eight adult males whose range included the treatment area on the Webb WMA Complex, South Carolina, between 2015 and 2016.

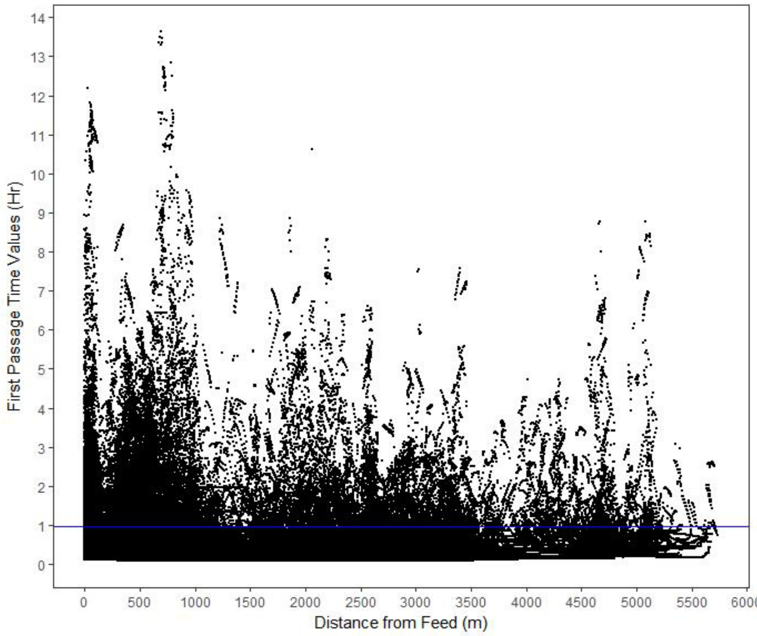

Figure 5. Scatter plot of first passage time values (hours) in relationship to distance of point to feed (m) with blue line representing the average first passage time value from 806 daily movement paths for eight adult males whose range included the treatment area on the Webb WMA Complex, South Carolina, between 2015 and 2016.

Table 6. Estimated coefficients (β), 95% confidence intervals (CI) for (β), hazard ratios (e^{β}), and 95% CI for (e^{β}) for Cox proportional hazard-ratio model fit to first-passage time data for eight eastern wild turkey (*Meleagris gallopavo silvestris*) on the Webb WMA Complex, South Carolina (Model 1), and a subset of data containing points only within 1000 m of supplemental feed (Model 2) in 2015 and 2016. Each estimate was rounded to the appropriate significant digits.

Model	β	CI(β)	e^{β}	CI(e^{β})
1	0.000017	0.000013 – 0.00026	1.000017	1.00001 – 1.00002
2	–0.000498	–0.000526 – –0.00047	0.9995	0.99947 – 0.99953

mean FPT value in minutes was 56.62 (min = 4.47 and max = 819; Figure 5). Calculated hazard ratios for both models were equal to 1, indicating that there was no influence of distance to feed on ARS behavior (Table 6).

Discussion

In general, our results indicate that the relationships between supplemental feed, turkey movements and range size are positive, but biologically slight. When comparing male ranges that overlapped the treatment area versus those that did not over the three years, we see a small increase in the average range size before and during hunting season periods and range size declines of approximately 40 ha after the hunting season. Our results also indicate that males whose range overlapped the treatment area when supplemental feed was on the ground were smaller than those that overlapped the treatment area before feeding occurred. However, the decline was only 16 ha which likely is not biologically relevant for a species with an average spring range size of 380–780 ha (Grisham et al. 2008, Rauch et al. 2010, Gross et al. 2015, Collier et al. 2017). Furthermore, for males whose range overlapped the treatment area, there was a minimal (3%) increase in the average area of overlap before the hunting season.

Our logistic regression results indicated that the likelihood of a wild turkey using the treatment area was low. We found that the probability of using the treatment area was higher for male (0.07) versus female (<0.01) wild turkeys. We found mixed results for comparing probability of use of the treatment area by males after feeding as the probability increased in 2015 but decreased in 2016. We found no relationship between ARS behavior and the distance to supplemental feed. Area-restricted searching behavior did occur near supplemental feeding areas, but ARS also occurred throughout areas of individual turkey range regardless of distance to feed. Wild turkeys are generalists, whose feeding behavior has been described as moving across the landscape using whatever acceptable plant and animal items are available (Bailey and Rinell 1967, Korchgen 1967, Lewis 1973), and our findings support this description. Studies have found wide varieties of food in crop samples (Korchgen 1973), and observations of poults of the same clutch feeding on different available resources (Healy 1999) supports the idea that, when feeding, turkeys are highly individualistic. With this high individualism it can be assumed that supplemental feeding may affect individuals differently, significantly, or not at all.

Although we found no prevailing relationship between supplemental feeding for quail and wild turkey movements, the potential for individuals to concentrate (i.e., ARS) where feed is present could influence harvest susceptibility and/or predation risk. Supplemental feeding for quail has been shown to increase use of fed areas by bobcats (*Lynx rufus*; Godbois et al. 2004) and red-tailed hawks (*Buteo jamaicensi*; Turner et al. 2008). Thus, for those individuals with overall ranges that overlap the supplemental feeding, risk to predation could potentially be increased if predator communities are shown to focus in regions where supplemental feeding is occurring.

We recognize that turkey movement relative to supplemental feeding may differ across habitat types and be influenced by changes in turkey behavior relative to timing within the annual cycle. We note that based on our study design some birds never encountered a fed site strictly based on where capture operations occurred or where the individual turkey decided to range. Therefore, our study represents a small subset of possible individuals which could have been impacted by supplemental feeding, those that were within the supplemental feeding area, and were radio-tagged. Future research should consider feeding at different rates to determine if a higher density of feed could impact movements. Furthermore, researchers should conduct treatments across the landscape in a way to include focal ranges of individual birds thereby increasing the likelihood that individuals will encounter at least 1 treated area within their range and measure individual response rates accordingly.

Acknowledgments

Our research was funded and supported by the South Carolina Department of Natural Resources. We are thankful for help provided by numerous biologists and technicians at the Webb WMA complex, along with all the field technicians from Louisiana State University during the three-year study period. Furthermore, we are grateful for all the neighboring property owners that allowed us access to their land to assist with data collection. This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, McIntire Stennis project under No. 1005302.

Literature Cited

Apps, C.D., B.N. McClellan, J.G. Woods, and M.F. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management 68:138–152.

Badyaev, A.V., T.E. Martin, and W.J. Etges. 1996. Habitat sampling and habitat selection by female wild turkeys: ecological correlates and reproductive consequences. Auk 113: 636–646.

Bailey, R.W., D. Bennett, H. Gore, J. Pack, R. Simpson, and G. Wright. 1980. Basic considerations and general recommendations for trapping the wild turkey. Proceedings of the National Wild Turkey Symposium 4:10–23.

———__ and K.T. Rinell 1967. Management of the eastern wild turkey in the northern hardwoods. In: O.H. Hewitt (Ed.): The Wild Turkey and Its Management. The Wildlife Society, Washington, DC.

Bastille-Rousseau, G., D. Fortin, and C. Dussault. 2010. Inference from habitat-selection analysis depends on foraging strategies. Journal of Animal Ecology 79:1157–1163.

Buckley, B.R., A.K. Andes, B.A. Grisham, and C.B. Dabbert. 2015. Effects of broadcasting supplemental feed into roadside vegetation on home range and survival of female northern bobwhite. Wildlife Society Bulletin 39:301–309.

Burger Jr., L.W, D.C. Sisson, H.L. Stribling, and D.W. Speake. 1998. Northern bobwhite survival and cause-specific mortality on an intensively managed plantation in Georgia. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 52:174–190.

Byrne, M.E., B.A. Collier, and M.J. Chamberlain. 2015. Roosting behavior of Male Eastern and Rio Grande wild turkeys. Proceedings of the National Wild Turkey Symposium 11:175–185

———__, J.D. Guthrie, J.B. Hardin, B.A. Collier, and M.J. Chamberlain. 2014. Evaluating wild turkey movement ecology: an example using first passage time analysis. Wildlife Society Bulletin 38:407–413.

Chamberlain, M.J. and B.D. Leopold. 2000. Habitat sampling and selection by female wild turkeys during preincubation. Wilson Bulletin 112:326–331.

Collier, B.A. and M.J. Chamberlain. 2010. Redirecting research for wild turkeys using global positioning system transmitters. Proceedings of the National Wild Turkey Symposium 10:81–92.

———, P.H. Wightman, M.J. Chamberlain, J.R. Cantrell, and C.R. Ruth. 2017. Hunting activity and male wild turkey movements in South Carolina. Journal of the Southeastern Association of Fish and Wildlife Agencies 4:85–93.

Conley, M.D., J.G. Oetgen, J. Barrow, M.J. Chamberlain, K.L. Skow, and B.A. Collier. 2015. Habitat selection, incubation, and incubation recess ranges of nesting female Rio Grande wild turkeys in Texas. Proceedings of the National Wild Turkey Symposium 11:117–126

Cooper, S.M. and T.F. Ginnett. 2000. Potential effects of supplemental feeding of deer on nest predation. Wildlife Society Bulletin 28:660–666.

Deelen, T.R.V., B. Dhuey, K.R. McCaffery, and R.E. Rolley. 2006. Relative effects of baiting and supplemental antlerless seasons on Wisconsin's 2003 deer harvest. Wildlife Society Bulletin 34:322–328.

Dewey, S.R. and P.L. Kennedy. 2001. Effects of supplemental food on parental-care strategies and juvenile survival of northern goshawks. The Auk 118:352–365.

Dunkley, L. and M. R .L. Cattet. 2003. A comprehensive review of the ecological and human social effects of artificial feeding and baiting of wildlife. Canadian Cooperative Wildlife Health Center, Saskatchewan, Saskatoon.

Fahrig, L. 2007. Non-optimal animal movement in human-altered landscapes. Functional Ecology 21:1003–1015.

Fauchald, P. and T. Tveraa. 2003. Using first-passage time in the analysis of area-restricted search and habitat selection. Ecology 84:282–288.

Freitas, C., K.M. Kovacs, C. Lydersen, and R.A. Ims. 2008. A novel method for quantifying habitat selection and predicting habitat use. Journal of Applied Ecology 45:1213–1220.

Geisser, H. and H.U. Reyer. 2004. Efficacy of hunting, feeding, and fencing to reduce crop damage by wild boars. Journal of Wildlife Management 68:939–946.

Godbois, I.A., L.M. Conner, and R.J. Warren. 2004. Space-use patterns of bobcats relative to supplemental feeding of northern bobwhites. Journal of Wildlife Management 68:514–518.

Grisham, B.A., M.J. Chamberlain, and F.G. Kimmel. 2008. Spatial ecology and survival of male wild turkeys in a bottomland hardwood forest. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 62:70–76.

Gross, J.T., A.R. Little, B.A. Collier, and M.J. Chamberlain. 2015. Space use, daily movements, and roosting behavior of male wild turkeys during spring in Louisiana and Texas. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:229–234.

Guthrie, J.D., M.E., Byrne, J.B. Hardin, C.O. Kochanny, K.L. Skow, R.T. Snelgrove, M.J. Butler, M.J. Peterson, M.J. Chamberlain, and B.A. Collier. 2010. Evaluation of a GPS backpack transmitter for wild turkey research. Journal of Wildlife Management 75:539–547.

Healy, W.M. and S.M. Powell. 1999. Wild turkey harvest management: biology, strategies, and techniques. U.S. Fish and Wildlife Service, Biological Technical Publication, BTP-R5001-1999.

Holbrook, H.T., M.R. Vaughan, and P.T. Bromley. 1987. Wild turkey habitat preferences and recruitment in intensively managed Piedmont forests. The Journal of Wildlife Management 51:182–187.

Holdstock, D.P., M.C. Wallace, W.B. Ballard, J.H. Brunjes, R.S. Phillips, B.L. Spears, S.J. Demaso, J.D. Jernigan, R.D. Applegate, and P.S. Gipson. 2006. Male Rio Grande turkey survival and movements in the Texas Panhandle and southwestern Kansas. Journal of Wildlife Management 70:904–913.

Hurst, G.A., D.R. Smith. J.D. Burk, and B.D. Leopold. 1991. Wild turkey gobbler habitat use and home range in loblolly pine plantations. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 45:115–123

Jacoby, D.M.P., E.J. Brooks, D.P. Croft, and D.W. Sims. 2012. Developing a deeper understanding of animal movements and spatial dynamics through novel application of network analyses. Methods in Ecology and Evolution 3:574–583.

Johnson, A.R., J.A. Wiens, B.T. Milne, and T.O. Crist. 1992. Animal movements and population dynamics in heterogeneous landscapes. Landscape Ecology 7:63–75.

Korchgen, L.J. 1967. Feeding habits and food. Pages 137–198 *in* O.H. Hewitt, editor. The wild turkey and its management. The Wildlife Society, Washington, DC.

——— 1973. April foods of wild turkeys in Missouri. Pages 143–150 *in* G.C. Sanderson and H.C. Schultz, editors. Wild Turkey Management: current problems and programs. Columbia: The Missouri Chapter of the Wildlife Society and University of Missouri Press.

Kranstauber, B., R. Kays, S.D. LaPoint, M. Wikelski, and K. Safi. 2012. A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous animal movement. Journal of Animal Ecology 81:738–746.

——— and M. Smolla. 2016. Move: visualizing and analyzing animal track data. R package version 2.0.0.

Kurzejeski, E.W. and J.B. Lewis. 1990. Home ranges, movements and habitat use of wild turkey hens in northern Missouri. Proceedings of the National Wild Turkey Symposium 6:67–71.

Larson, J.A., T.E. Fulbright, L.A. Brennan, F. Hernandez, and F.C. Bryant. 2012. Preference and nutrition of Quail Breeder 16TM, common agricultural feeds, and a mix of native seeds as northern bobwhite food. Proceedings of the National Quail Symposium 7:92–100.

Lewis, J.C. 1973. The world of the wild turkey. Lippincott, Philadelphia, Pennsylvania.

Miller, D.A. and L.M. Conner. 2007. Habitat selection of female turkeys in a managed pine landscape in Mississippi. The Journal of Wildlife Management 71:744–751.

Miller, R.S. 2011. Foraging behavior of northern bobwhite in relation to resource availability. Thesis, Mississippi State University, Starkville.

Nathan, R., W.M. Getz, E. Revilla, M. Holyoak, R. Kadmon, D. Saltz, and P.E. Smouse. 2008. A movement ecology paradigm for unifying organismal movement research. Proceedings of the National Academy of Sciences 105:19052–19059.

Pelham, P.H. and J.G. Dickson. 1992. Physical characteristics. Pages 32–45 *in* J.G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Mechanicsburg, Pennsylvania.

R Development Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rauch, S.E., J.T. Anderson, and A.A. Billings. 2010. Spring hunting season home range size of male wild turkeys in north central West Virginia. Proceedings of the National Wild Turkey Symposium 10:157–163.

Robb, G.N., R.A. McDonald, D.E. Chamberlain, and S.A. Bearhop. 2008. Food for thought: supplementary feeding as a driver of ecological change in avian populations. Frontiers in Ecology and the Environment 6:476–484

Robel, R.J. and S.M. Arruda. 1986. Energetics and weight changes of northern bobwhites supplemental feed 6 different foods. Journal of Wildlife Management 50:236–238.

Sisson, D.C., H.L. Stribling, and D.W. Speake. 2000. Effects of supplemental feeding on home range size and survival of northern bobwhites in South Georgia. Proceedings of the National Quail Symposium 4:128–131.

Sorensen, A., F.M. Van Beest, and R.K. Brook. 2014. Impacts of wildlife baiting and supplemental feeding on infectious disease transmission risk: A synthesis of knowledge. Preventive Veterinary Medicine 113:356–363.

Thackston, R. and M. Whitney. 2001. The bobwhite quail in Georgia: history, biology and management. Georgia Department of Natural Resources, Social Circle.

The Wildlife Society. 2006. Baiting and supplemental feeding of game wildlife species. The Wildlife Society, Bethesda, Maryland. http://wildlife.org/wp-content/uploads/2014/05/Baiting06-1.pdf

Thogmartin, W.E. 2001. Home-range size and habitat selection of female wild turkeys (*Meleagris gallopavo*) in Arkansas. American Midland Naturalist 145:247–260.

Townsend, D.E., R.L. Lochmiller, S.J. Demaso, D.M. Leslie, A.D. Peoples, S.A. Cox, and E.S. Parry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginianus*). Wildlife Society Bulletin 27:1074–1081.

Turner, A.S., L.M. Conner, and R.J. Cooper. 2008. Supplemental feeding of northern bobwhite affects red-tailed hawk spatial distribution. Journal of Wildlife Management 72:428–432.

Weidman, T. and J.A. Litvaitis. 2011. Can supplemental food increase winter survival of a threatened cottontail rabbit? Biological Conservation 144: 2054–2058

Whitelaw, R.E., W.E. Palmer, S.D. Wellendorf, and J.P. Carroll. 2006. Effects of supplemental feeding on winter diet and body mass of northern bobwhites. Proceedings of the National Quail Symposium 6:282–289.